oPEN Lab
TARTU PAMPLONA GENK
LEADING THE TRANSITION TO POSITIVE ENERGY NEIGHBOURHOODS

Outline of the oPEN-Lab policy roadmap

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Authors: Victoria Taranu, Emily Bankert, Carolina Koronen (BPIE)
Contributors: Maarten De Groote (VITO), Paulina Rodriguez Fiscal (VITO)
Reviewers: Kaspar Alev (TARTU), Mariangiola Fabbri (BPIE), Zsolt Toth (BPIE), Eva Brardinelli (CAN Europe), Arianna Vitali (The Coalition for Energy Savings)

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BPIE

Abbreviations and acronyms

Acronym	Description
EED	Energy Efficiency Directive
EMD	Energy Market Directive
EPBD	Energy Performance of Buildings Directive
GHG	Greenhouse gas
ICT	Information and communications technology
NZEB	Nearly zero-energy building
RED	Renewable Energy Directive
PEB	Positive energy block
PED	Positive energy district
PEN	Positive energy neighbourhood
ZEB	Zero-emission building
ZED	Zero energy district

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Executive summary

The positive energy neighbourhood (PEN) approach can contribute to scaling up renovations while engaging local communities in the energy transition. A PEN is characterised by a group of buildings and public spaces with connected infrastructure, within a geographical area. A PEN aims for energy-efficient and energy-flexible groups of connected buildings and urban areas which produce net zero greenhouse gas (GHG) emissions from energy use on an annual basis and actively manage an annual local or regional surplus production of renewable energy. This report includes an analysis of the EU policies relevant for underpinning the PEN approach to building renovations.

The Energy Performance of Buildings Directive (EPBD) explicitly mentions the neighbourhood approach, sets minimum energy standards, and addresses energy poverty, all of which are elements of the PEN approach. The Renewable Energy Directive (REDIII) raises renewable energy targets, promotes renewable energy integration in buildings, and streamlines permit procedures, which also supports PEN principles and facilitates the procedures for their creation. The Energy Efficiency Directive (EED) sets energy-saving targets, broadens the energy efficiency first principle, and prioritises addressing energy poverty. Effective national implementation is pivotal for PENs to leverage the opportunities presented by these directives.

Harmonised definitions and frameworks for PENs are necessary for assessing progress and ensuring consistency across Member States. More tailored financing solutions are required to protect vulnerable households and mitigate energy poverty, aligning with the directives' focus on social equity. Assessing the social and environmental co-benefits of PENs is critical for maximising their impact. By addressing these challenges and leveraging the opportunities presented by the EPBD, REDIII and EED, PENs can emerge as a cornerstone of sustainable urban development within the EU, contributing significantly to energy efficiency, renewable energy deployment, and social goals.

Key insights from the EU-level policy framework for EU-level and national policymakers and the financial sector include:

- A harmonised definition and framework for PENs is needed to enable assessment of progress towards policy goals.
- During implementation, tailored actions and policies are needed to protect vulnerable households and mitigate energy poverty, including supporting access to renovation and renewable energy systems.
- Financing solutions must be better designed to benefit the income groups that need them.
- Assessment methods of social and environmental co-benefits of PENs are needed to enable access to public and private environmental, social and governance (ESG) finance.

Introduction

The decarbonisation of the EU building stock requires renovation at scale. The Renovation Wave aims to at least double renovation rates across EU Member States by 2030 in order to achieve a decarbonised building stock by 2050.

> 'The necessary decarbonisation of the Union building stock requires energy renovation at a large scale: almost 75% of that building stock is inefficient according to current building standards, and 85-95% of the buildings that exist today will still be standing in 2050. However, the weighted annual energy renovation rate is persistently low at around 1%. At the current pace, the decarbonisation of the building sector would require centuries.'
>
> **2024 EPBD recast**

The neighbourhood/district approach is recognised in the 2024 EPBD recast as a cost-efficient way to scale up renovations while taking into account social and environmental aspects.

Within the oPEN Lab project, a positive energy neighbourhood (PEN) is an approach which aims to decarbonise a neighbourhood, while the Living Lab is a network of stakeholders which enables co-creation with the local community for testing of technological, process and social innovations in a real-life environment (see Figure 1). A PEN includes a cluster of buildings together with public space and shared services and facilities, and it includes specific technological and financial solutions, adapted to the local context. A PEN aims for energy-efficient and energy-flexible groups of connected buildings and urban areas which produce net zero greenhouse gas (GHG) emissions from energy use on an annual basis and actively manage an annual local or regional surplus production of renewable energy. The PEN project is enabled by a Living Lab which gathers groups of local stakeholders from the public, NGO and private sectors who will scale up PEN projects and other initiatives in the district/city. oPEN Lab Living Labs have a strong focus on engagement, consultation and co-creation processes, and trusting relations with local stakeholders and communities.

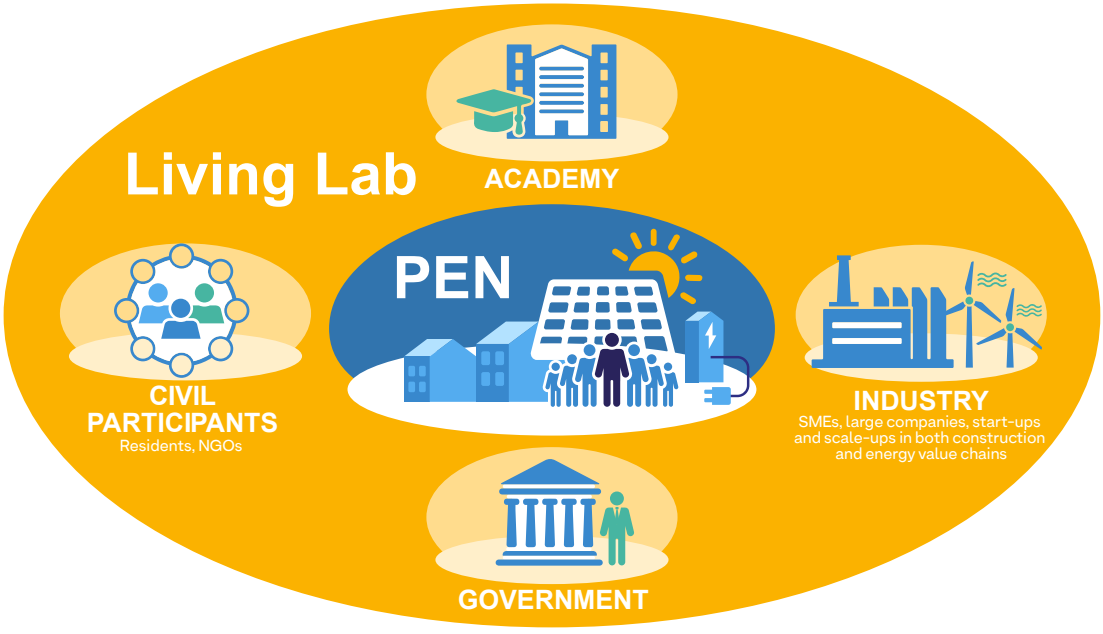

Figure 1 Conceptual difference between PEN and Living Lab

The Fit for 55 Package increased the Union's target to a 55% reduction in GHG emissions by 2030. The EPBD, EED and RED were revised/recast to align their measures and targets to the increased targets for 2030. This report aims to map the latest developments in the EU directives relevant for PENs, providing a first analysis of the key policy areas to be further developed in subsequent stages of the project. PENs are the right scale for municipalities to renovate in an inclusive way, engaging the communities and key local stakeholders to adjust the technical and financial solutions to the local context. With a series of PENs plus individual building and urban regeneration, municipalities can achieve renovation and climate targets more efficiently.

The 2024 EPBD recast for the first time considers the neighbourhood/district approach to renovations, shifting from an individual building approach to a building embedded in the urban infrastructure. Even though other directives and national, regional and local policies do not yet incorporate the neighbourhood approach, they relate to other relevant aspects for PENs, such as:

- Energy performance
- Collective production, sharing and selling of energy
- Demand-side flexibility
- Whole-life carbon and circularity
- Fuel poverty and affordability of renovation
- Finance and incentives

The present report is organised as follows: first, a literature review of the evolution of concepts related to PEN is presented, with a comparison of definitions within EU initiatives. Next, the oPEN Lab definition of PEN is illustrated in relation to policy relevance. Section 4 dives into the EU directives of the Fit for 55 package: the 2024 EPBD recast, EED and REDIII. The goal of 'Outline' – the oPEN-Lab policy roadmap – is to map the main policies and barriers as a basis for discussion with key stakeholders in a collective effort to build the 'Final' policy roadmap. This first analysis will be used for stakeholder engagement sessions to co-create non-technical solutions packages to overcome PEN barriers. The goal of the 'Final' policy roadmap (due in 2026) is to embed the PEN approach into policies at all levels to work towards achieving local energy, environmental, housing and social goals; along with EU goals such as doubling renovation rates, digitalisation, circular economy etc.

2. The positive energy neighbourhood concept

2.1 Added value of neighbourhood approaches in building policies

Positive energy neighbourhoods (PENs) are at the pinnacle of the energy transition in urban environments. PENs can contribute to the decarbonisation of the building stock, while providing additional benefits for residents both at the building and neighbourhood level, enhancing wellbeing and social cohesion. Besides the deep renovation of individual buildings, PENs can encompass a range of shared spaces, services and facilities, such as shared heat pumps, photovoltaic panels, electric vehicles (EVs), EV charging stations, bicycles, and common spaces with greenery, water and biodiversity. Neighbourhood approaches provide additional benefits to demand-side flexibility compared to single apartments or buildings through the aggregation of energy assets and stacking of revenue streams – and thus generate greater energy savings and economic benefits for homeowners. **PENs go beyond the mere combination of individual positive energy buildings. They are the integration of buildings and neighbourhood infrastructure, creating a dynamic interaction with energy, mobility and industry.** This approach aligns seamlessly with the Renovation Wave's call for an integrated, participatory and neighbourhood-centred approach.

Renovations are a key requirement for the successful decarbonisation of the European building sector.[1] As recognised in the Renovation Wave,[2] deep renovations currently only occur in 0.2% of the building stock per year. The advantages of neighbourhood approaches to renovations as opposed to individual building approaches are acknowledged in the 2024 EPBD recast, and Member States are required to implement and report on the 'district and neighbourhood approaches' in their national building renovation plans.

> (j) the promotion of district and neighbourhood approaches and integrated renovation programmes at the district level, which may address issues such as energy, mobility, green infrastructure, waste and water treatment and other aspects of urban planning and may take into account local and regional resources, circularity and sufficiency;
>
> **2024 EPBD recast**

2.2 Evolution of the positive energy neighbourhood concept in the EU

Over the last two decades, the concept and definition of nearly zero-energy building (NZEB) and positive energy building have evolved in parallel to those of PEN. At the building level, there is a common EU definition and guidelines for the calculation of energy performance of NZEBs, even if it is implemented differently by the Member States. For the PEN concept there is currently a lack of consistency in the terminology, definition and KPIs in the various policy initiatives and projects.

[1] https://www.european-calculator.eu/wp-content/uploads/2020/04/EUCalc_PB_no3_Buildings.pdf
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

There are more than 35 terms to define similar concepts to PEN (Brozovsky et al., 2021) such as positive energy districts (PEDs), net-zero energy districts, green building neighbourhoods, positive energy blocks (PEBs), climate positive circular communities, sustainable plus energy neighbourhoods (SPENs), and many others. Some of them focus exclusively on the operational phase, while others also take into account embodied emissions, resource efficiency and sustainable material use. However, they all go beyond calculating the energy balance, and include social, economic and environmental aspects. There are significant conceptual differences within the categories and calculation methods of the KPIs. Some frameworks apply to all the existing buildings within a district, while others include only a selected set of interconnected buildings which are part of a new development or renovation project.

This section provides a literature review of the different concepts and methods within the EU. The European Strategic Energy Technology (SET) Plan (SET Plan Action 3.2) has set the target of deployment and replication of 100 PENs by 2025 through the programme 'Positive Energy Districts and Neighbourhoods for Sustainable Urban Development'. The 2024 EPBD recast foresees Member States reporting on their progress on 'district and neighbourhood approaches' within the template for the national building renovation plans (ANNEX II). If policy goals are set up to scale up PENs, a harmonised approach to the concept and methodology for KPIs on energy, flexibility, social, environmental and economic aspects should be agreed upon. Only a common methodology shared between Member States will allow the tracking of progress on policy goals and make it possible to compare projects for many purposes, including investments. A framework on the core and optional KPIs can provide a harmonised framework for municipalities to assess and implement PEN projects. The thresholds and ambition on the energy balance can be flexible and can be adjusted by the municipality for each district, based on heritage constraints or renewable energy potential, and in line with municipal climate, environmental and fuel poverty reduction targets.

Nearly zero-energy building

The definition and calculation method of nearly zero-energy building (NZEB) was first introduced in the 2010 EPBD.[3]

> '"Nearly zero-energy building" means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.'
>
> **Article 2, 2010 EPBD**

The national calculation methods follow the ISO 52000-1, 52003-1, 52010-1, 52016-1 and 52018-1 standards, developed under mandate M/480 given to the European Committee for Standardisation (CEN).

[3] DIRECTIVE 2010/31/EU

The end objective of the energy performance calculation is to determine the annual overall energy use in net primary energy in kWh/m^2.year, which corresponds to energy use for space heating, space cooling, domestic hot water, ventilation, built-in lighting and other technical building systems. The methodology applied by the Member States for the determination of the energy performance of a building should be transparent and open to innovation.

While in Annex I of the 2010 EPBD the energy performance of a building was to be determined based on calculated energy use, the 2018 EPBD[4] introduced metered energy consumption and typical energy use which reflects user behaviour:

> 'Member States shall ensure that the typical energy use is representative of actual operating conditions for each relevant typology and reflects the typical user behaviour. Where possible, typical energy use and typical user behaviour shall be based on available national statistics, building codes and metered data. Member States may use metered energy consumption under typical operating conditions to verify the correctness of the calculated energy use and enable comparison between calculated and actual performance.'
>
> **Annex I, 2018 EPBD**

Net-zero energy districts

The European Commission's Joint Research Centre (JRC) developed a framework for net-zero energy districts or zero energy districts (ZEDs) as the next step in scaling up NZEB and accelerating the energy transition in cities (Saheb et al., 2019). However, the shift in the methodology of calculating the energy balance of NZEB and ZED is not only in the scale, from a building to a district-scale energy balance, but there is a paradigm shift from it being merely energy-related, to introducing social and environmental aspects. The framework includes the following targets and indicator categories:

- Triple net zero (energy/carbon, water and waste)
- Empowering local actors and citizens
- Functional and social mixing
- Cost-effectiveness of the project
- Resource preservation
- Environmentally friendly quality of life

Thus, while tackling the energy transition, municipalities can use the district approach to address other socioeconomic and environmental issues. Engaging the local community in governance is also considered a key aspect of ZED. The case studies analysed are large-scale, such as an island, and include all the existing buildings, not only a selected cluster of them.

Positive energy blocks

The first shift from the individual building approach to a cluster of buildings within the urban infrastructure was the concept of positive energy blocks (PEBs), introduced by The Energy Efficient Building Committee of the European Construction, Built Environment and Energy Efficient Building Technology Platform (ECTP).[5] The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) contributed to promoting the PEB concept, by establishing guidelines and setting the goal of scaling up 100 PEBs across the EU by 2020.

According to Blumberga et al. (2020), the potential energy savings in the transition to PEB can be divided into three main groups: building-related; smart energy systems including waste heat utilisation and renewable energy systems; and energy savings via energy communities and behavioural change (Blumberga et al., 2020).

Positive energy districts

The European Commission established the European Strategic Energy Technology Plan (SET Plan Action 3.2) in 2018. The Plan stated that a PEB can be considered as the smallest component of a PED, and proposed the following definition:

> 'Positive Energy Districts are 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.'
>
> **Urban Europe and European Strategic Energy Technology Plan (SET Plan Action 3.2)**

The main strategies to achieve a positive energy balance are renewable energy only (energy production function), to best utilise renewable energy (the energy efficiency function), and finally, the energy flexibility function. PED, similarly to ZED, is conceptualised as being at the ideal scale to address the economic, cultural and climate-related diversity of cities, and aims to go beyond being a mere 'algorithm for calculating the input and output of energy'. The SET Programme 'Positive Energy Districts and Neighbourhoods for Sustainable Urban Development' supports the replication of 100 PEDs in Europe by 2025.

[4] Directive (EU) 2018/844

[5] ECTP Energy Efficient Buildings Committee FP9 2021-2027 position paper, 2016 https://ectp.org/fileadmin/user_upload/documents/E2B/ECTP_E2B_Committee_Position_Paper.pdf https://ectp.org/fileadmin/user_upload/documents/E2B/ECTP_E2B_Committee_Position_Paper.pdf

Comparison of definitions within EU initiatives

The EU has supported several projects and initiatives focused on reducing energy consumption at district, block and neighbourhood scale, as well as sustainability and GHG emissions reduction. These include the following:

European Commission: Horizon 2020 work programme 2	European Strategic Energy Technology (SET) Plan (SET Plan Action 3.2), conducted by Joint Programming Initiative (JPI) Urban Europe	COST Action Positive Energy Districts European Network (PED-EU-NET)	EERA Joint Programme Smart Cities (EERA JPSC)
Positive Energy Blocks (PEBs)/Districts (PEDs) PEBs/PEDs consist of several buildings (new, retro-fitted or a combination of both) that actively manage their energy consumption and the energy flow between them and the wider energy system. PEBs/PEDs have an annual positive energy balance. They make optimal use of elements such as advanced materials (e.g. bio-based materials), local renewable energy sources, local storage, smart energy grids, demand-response, cutting-edge energy management (electricity, heating and cooling), user interaction/involvement and ICT. PEDs are designed to be an integral part of the district/city energy system and have a positive impact on it (also from the circular economy point of view). Their design is intrinsically scalable, and they are well embedded in the spatial, economic, technical, environmental and social context of the project site.	**Positive Energy Districts (PEDs)** PEDs are 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.	**Positive Energy Districts (PEDs)** PEDs require interaction and integration between buildings, the users and the regional energy, mobility and ICT systems, as well as an integrative approach including technology, spatial, regulatory, financial, legal, social and economic perspectives. Ideally, PEDs will be developed in an **open innovation framework**, driven by cities in cooperation with industry and investors, research and citizen organisations.	**Smart and Liveable Neighbourhoods and Communities** Mixed-use energy-efficient districts that have net-zero CO_2 emissions and actively manage an annual local surplus production of renewable energy. They require interaction and integration between buildings, the users and the regional energy, mobility and ICT system, while ensuring social, economic and environmental sustainability for current and future generations.

A series of European projects are advancing these concepts by testing them on the ground in real-life projects, with different frameworks and goals. Figure 2 compares the key concepts, calculation methods and boundaries of PEN-type concepts within EU initiatives and projects. For the comparison of the boundaries, Hedman et al. (2021) used the framework elaborated by the EERA Joint Programme Smart Cities (EERA JPSC) (Vandevyvere et al., 2022):

- PED-autonomous: Net positive yearly energy balance within the geographical boundaries of the PED and internal energy balance at any moment in time (no imports), or even helping to balance the wider grid.

- PED-dynamic: Net positive yearly energy balance within the geographical boundaries of the PED, but dynamic exchanges with the grid to compensate for momentary surpluses and shortages.
- PED-virtual: Net positive yearly energy balance within the virtual boundaries of the PED, but dynamic exchanges with the grid to compensate for momentary surpluses and shortages.
- Pre-PED: No net positive yearly energy balance within the geographical boundaries of the PED, but energy difference acquired on the market by importing certified green energy (i.e. achieving a zero-carbon district).

Comparison of existing PED Definitions

		Calculation of balance				Scale	Boundary	Key energy concepts					
		Positive Energy	CO^2 emission (Net zero)	Yearly-Time frame	Method			Renew. supply	Energy Effic.	Energy Storage	Building	Tran-sport	ICT
EU Organisations and Programmes	SET-Plan Action 3.2	✓	✓	✓		District		✓	✓				
	Horizon 202	✓		✓		Several buildings		✓	✓	✓	✓		✓
	JCR	✓		✓			Defined borders	✓	✓		✓		
	JPI EU	✓	✓	✓		Connected buildings		✓	✓		✓	✓	✓
	EERA JPSC	✓	✓	✓		District	4types	✓	✓		✓	✓	✓
Revelant projects	ATELIER	✓	✓	✓				✓	✓	✓	✓	✓	✓
	+CityXchange	✓	✓	✓		District		✓	✓	✓	✓	✓	✓
	MAKING-CITY	✓		✓	✓	District	Geographical	✓	✓	✓	✓	✓	✓
	POCITYF	✓		✓	✓	District	Geo. & virtual	✓	✓	✓	✓	✓	✓
	SPARCS	✓	✓	✓	✓	District	3types	✓	✓	✓	✓	✓	✓
	SYN.ikia	✓	✓	✓	✓	Connected buildings		✓	✓	✓	✓		
	Zukunfsquartier	✓	✓	✓	✓	District	3types	✓	✓	✓	✓	✓	
	PHVision	✓	✓	✓	✓	District	Geo. & virtual	✓	✓	✓	✓	✓	✓
	ZEN Centre	✓	✓	✓	✓	NBRHD	Geo. & virtual	✓	✓	✓	✓	✓	✓

Comparison of existing PED Definitions

		Non-energy considerations			Other considerations
		Social	Economic	Environ-mental	
EU Organisations and Programmes	SET-Plan Action 3.2	✓			Urban/regional Integration, affordable living
	Horizon 202	✓	✓	✓	Urban integration
	JCR	✓	✓	✓	Renewable insite/nearby, NZEB, citizen participation
	JPI EU	✓	✓	✓	Regional integration, mixed-use areas
	EERA JPSC	✓	✓	✓	Regional integration, mixed-use areas
Revelant projects	ATELIER	✓	✓	✓	Energy flexibility, energy autonomy, electro-mobility, citizen engagement, life-cycle assessment
	+CityXchange	✓	✓	✓	Build up from PEBs
	MAKING-CITY	✓	✓	✓	PEBs, renewable onsite, non-renewable primary energy, energy community
	POCITYF	✓	✓	✓	Heritage districts
	SPARCS	✓	✓	✓	Energy flexibility, electro-mobility, citizen engagement
	SYN.ikia	✓	✓	✓	NZEB, energy flexibility, life-cycle assessment, indoor environment, inclusiveness, affordable living
	Zukunfsquartier	✓	✓	✓	Primary energy balance, embodied energy, density-based adjustment
	PHVision	✓	✓	✓	Passive house, self-sufficiency, embodied energy, regional integration
	ZEN Centre	✓	✓		Energy flexibility, life cycle assessment (LCA) for buildings 60 years and infrastructure 100 years

Figure 2 Comparison of PED definitions. Retrieved from Vandevyvere et al. (2022)

IEA EBC Annex 83 – towards a harmonised definition

Besides the European projects and initiatives, the International Energy Agency (IEA) is also contributing to establishing and testing a PED concept within the Implementing Agreement on Energy in Buildings and Communities (EBC), Annex 83.

The basic principle of PED within Annex 83 initiative is similar to the previous European initiatives to analyse the interaction of the building with the urban infrastructure. The goal of PED goes beyond achieving an annual surplus of net energy, and rather minimises the impact on the connected centralised energy networks and provides flexibility services by increasing onsite renewable energy generation and storage, and maximises load-matching and self-consumption with smart systems.

Annex 83 PED is planned to be finished by 2025. The ongoing efforts are towards providing harmonised definitions and key concepts for PEDs, and methods, tools and technologies for realising them, as well as governance principles, and impact assessments through case studies.

A harmonised definition is necessary for mainstreaming the PEN approach into local, national and European policies, and oPEN Lab is contributing, among other projects to gather information from demo projects in support of this policy goal. A working definition is available:

> Positive Energy Districts are energy-efficient districts with net zero greenhouse gas emissions and an annual positive energy balance. They prioritise the use of local renewable energy and resources. They seek to optimise the interaction and integration between buildings, the users, mobility, energy and ICT systems. Positive Energy Districts strive to bring positive impacts to the wider energy system as well as social, economic and environmental benefits to the communities.
>
> The assessment of the annual energy balance is open to any methods that are well defined and grounded on sound principles.

2.3 The PEN concept in relation to policy

PEN as an enabler to achieve policy goals at local level

This section will detail the oPEN Lab concept and definition of PEN, in relation to decarbonisation policies for the building stock. PENs can contribute to achieving the following policy goals:

- Climate mitigation: reduce GHG emissions
- Climate adaptation
- Increase renovation rates
- Increase share of renewable energy
- Smart electricity grid, demand-side flexibility
- Reduce fuel poverty
- Sufficiency policies at city, neighbourhood and building scale
- Improve social cohesion and community engagement

Within the oPEN Lab project, a PEN is a project which aims to decarbonise a neighbourhood. The project regards a cluster of buildings, together with the public space and shared services and facilities, and it includes particular technological and financial solutions adapted to the local context. The PEN project is enabled by a group of local stakeholders, in the Living Lab setting. oPEN Lab Living Labs are based on the quadruple helix model, comprising local partnerships with strong experience in engagement, consultation and co-creation processes, and trusting relations with local stakeholders and communities. The main goal of the Living Lab is to work together to co-create and drive structural changes far beyond the scope of what any organisation or person could do alone. The quadruple helix model consists of the following stakeholder groups:

- Industry (SMEs, large companies, start-ups and scale-ups in both construction and energy value chains)
- Government (local public administration)
- Academia
- Civil participants (residents, NGOs)

Figure 3 Difference between PEN (yellow dotted areas) and district (red dotted area) within Pamplona Living Lab

The goal of PEN projects is to put into practice the climate and environmental policies and targets which are defined at the national and municipal levels. oPEN Lab PEN projects will enable the renovation and urban regeneration of a cluster of buildings, such as the San Pedro social housing and IWER commercial buildings of the Pamplona PEN (image Figure 3).

The collective contributions in energy and GHG reduction made by PENs and individual renovation projects will sum up a balance at the district level and contribute to achieving policy targets at the municipal level. For example, the Pamplona municipality set targets for 2030 and is monitoring progress in the main categories of indicators – climate mitigation, climate adaptation and fuel poverty[6] (Figures 3 and 4) – to which the Pamplona PEN project will contribute.

Figure 4 Indicator categories of the Energy Transition and Climate Change Strategy 2030, Pamplona municipality

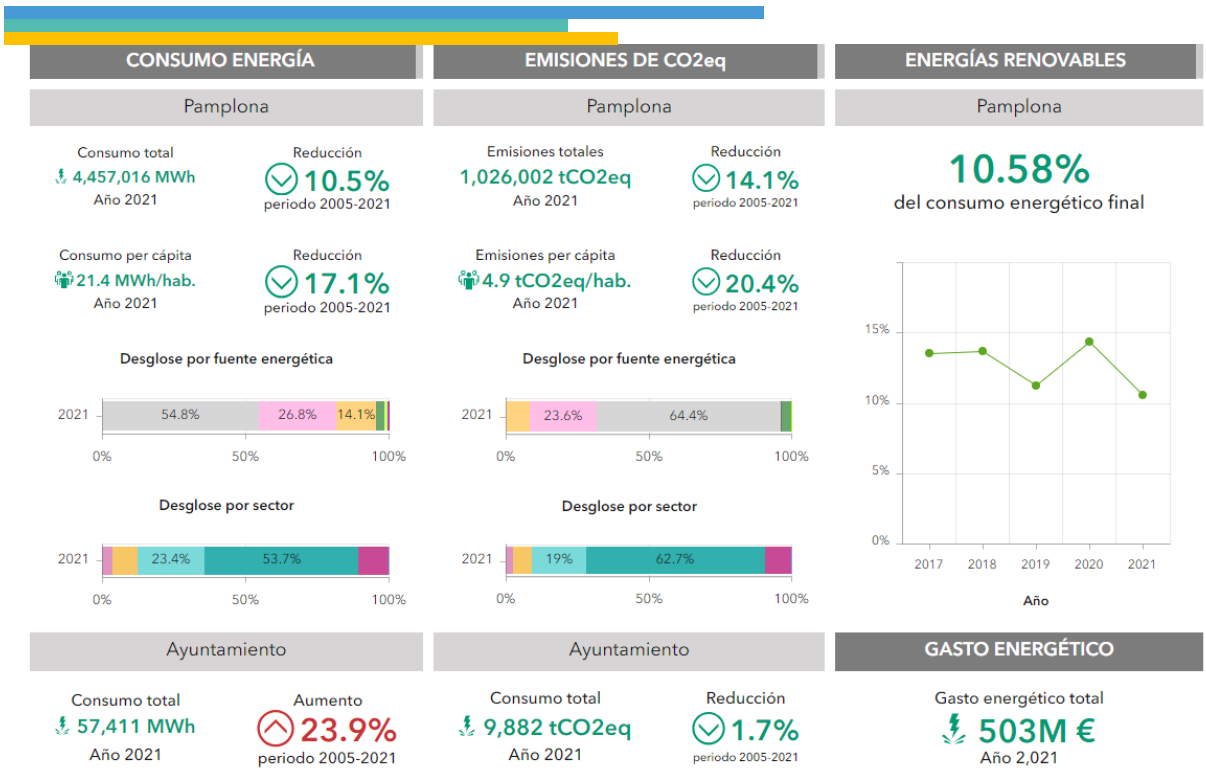

Figure 5 Indicators of climate mitigation, part of the Energy Transition and Climate Change Strategy 2030, Pamplona municipality

[6] Estrategia de Transición Energética y Cambio Climático 2030 https://estrategiaclima.pamplona.es/pages/seguimiento

The right scale to adapt to the local context

In summary, PENs are projects which implement renovations enabled by the Living Lab network of stakeholders to achieve social, climate and environmental policy goals, by adapting the array of available technical, process and financial solutions to the local context. The Dutch government has used a similar neighbourhood-level approach to implement the phase-out of fossil fuel heating systems in residential buildings (OECD, 2023). It used a multi-level approach for vertical and horizontal policy co-ordination:

- Plan a Heat Transition Vision and implementation
- Lead natural gas-free pilot projects
- Engage a broad array of stakeholders, citizens and local businesses to take action.

The neighbourhood is the right scale for public authorities to engage with local communities to collectively find technical solutions for renewable energy heating systems, depending on the renewable energy production and storage potential. For example, if there is a lake in the neighbourhood 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.

Integration with urban infrastructure

PENs consider the interaction of the building with the electrical and district heating and cooling grid. Smart systems, heat and electricity storage maximise self-consumption within PENs, allowing an excess of renewable energy which can be shared with the wider district or renewable energy community. The sharing of energy between a PEN and a renewable energy community can contribute to a sense of community, energy security and sufficiency, as well as empower citizens for active participation in the energy market and energy transition. This can contribute to getting citizens on board and leaving no one behind, and can contribute to the acceptance of climate policies.

Implementing sufficiency principles

Finally, PENs can contribute to the incorporation of the sufficiency principle in energy and environmental policies. Sufficiency is one of the key pillars in building policies to deliver decarbonisation while tackling inequalities in accessing energy services (Figure 5). According to the 6th Assessment Report of Working Group III of the IPCC, 'sufficiency policies are a set of policy measures and daily practices that avoid demand for energy, materials, land and water while delivering human well-being-for-all within planetary boundaries' (Shukla et al., 2022). The main goal is to meet human needs and provide services required for human well-being (e.g. housing including thermal comfort, nutrition and mobility), which implies an economy that stays within planetary boundaries. The PEN approach can untap a series of sufficiency design strategies, with shared spaces, services, renewable energy systems and heating systems which can provide added community well-being while reducing material and land use. For example, this could be as simple as having one heat pump 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 would cut down on parking lots and pollution alike.

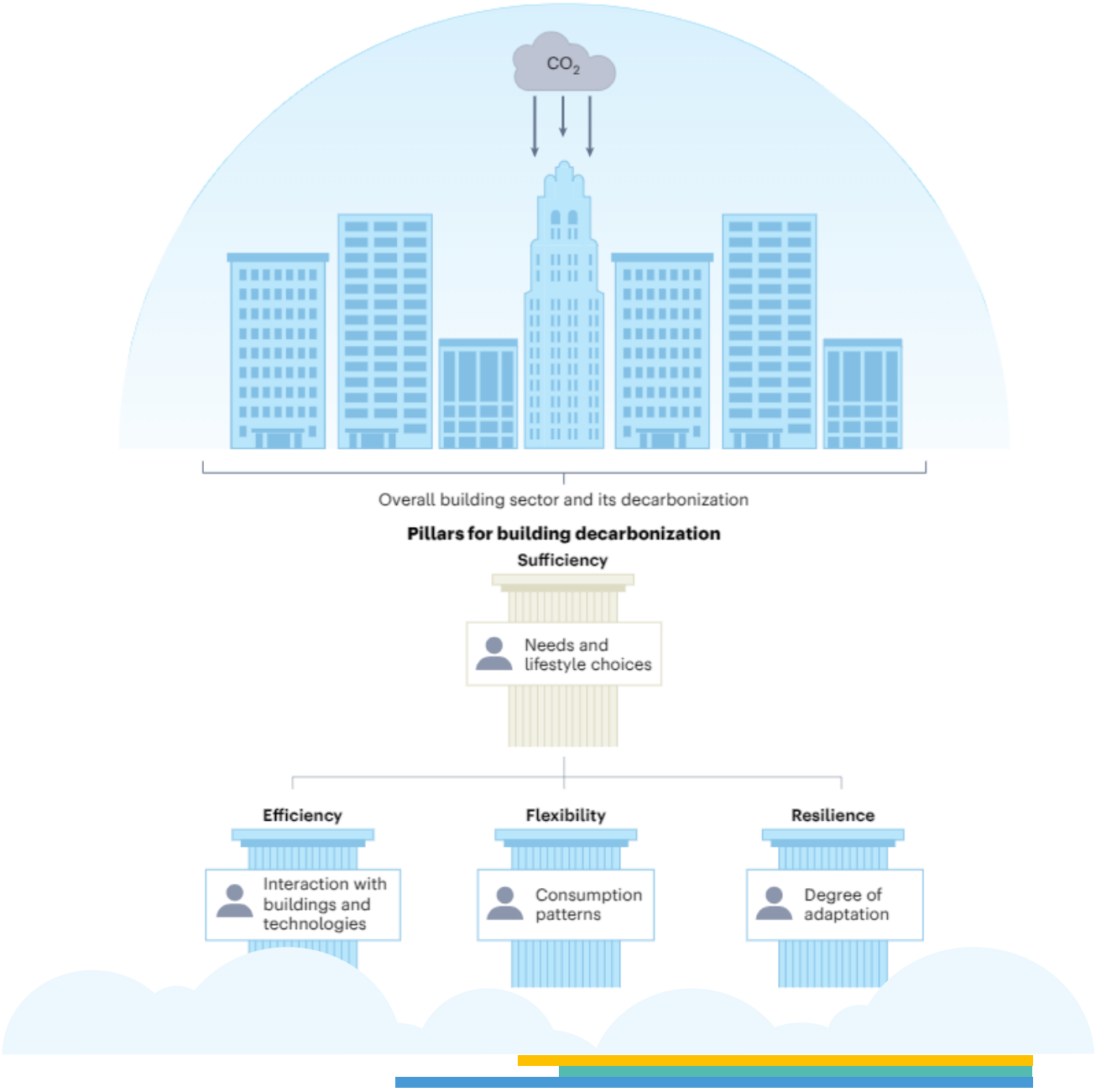

Figure 6 Sufficiency as a key pillar of building decarbonisation policies. Retrieved from Malik et al. (2023)

oPEN Lab PEN definition

Districts and neighbourhoods are frequently differentiated according to their scale and social connotations. The term 'district' is usually related to large-scale urban areas, while 'neighbourhood' typically refers to smaller interconnected urban zones. There are several reasons why a neighbourhood approach is important for developing urban renovation projects. First, a sense of community identity will enhance renovation efforts towards a better urban environment that will improve the welfare of the inhabitants: PENs aim for community wellbeing, supported by instruments for economic, social and environmental development.

oPEN Lab definition of PEN

According to the oPEN Lab project, a positive energy neighbourhood (PEN) is characterised by a group of buildings and public spaces with connected infrastructure, within a geographical area. A PEN aims for energy-efficient and energy-flexible groups of connected buildings and urban areas which 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.

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 energy system and it is driven by renewable energies, which provide optimised and flexible supply.
- Buildings within a PEN environment are energy efficient, and their reduced heat requirements allow for low-temperature and decarbonised heating systems like heat pumps and novel generation from district heating.
- A PEN facilitates increased utilisation of renewable energy within the local energy system by providing optimal flexibility and by managing consumption and storage capacities according to demand.
- A PEN features the sufficiency principle of energy, environmental and social strategies.
- A PEN supports the circular economy and residual value, by embracing lifecycle analysis of embodied energy and embodied carbon considerations.

3. Policy mapping framework

PENs represent 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 dedicated policy initiative that regulates and supports them.

For the purpose of mapping PEN-relevant policy, the central sub-themes and PEN aspects are presented below. Each theme is listed and described in the following subsections. The results of the mapping of EU policy and the Fit for 55 package are presented in Section 4.

3.1 Energy performance

At the EU level, the previously implemented versions of the EPBD introduced minimum performance requirements for new constructions and major renovations. These also included minimum shares of renewable energy produced on-site. The minimum requirements for major renovations have been transposed into national building regulations with different levels of ambition, considering also climate differences.

For neighbourhoods to achieve a yearly net positive energy balance, policies need to encourage individual buildings or whole districts to go beyond minimum energy performance requirements and generate a surplus of renewable energy where possible. This needs to be coupled with the financial and non-financial incentives to do so, such as subsidies to renovate and facilitation services.

3.2 Collective production, sharing and selling of renewable energy

At EU level, REDII[7] and EMD[8] contain important provisions and definitions for a legal framework enabling the production, storage, sharing and selling of energy. REDIII, approved in November 2023, keeps the same definitions for collective self-consumption and renewable energy communities (Table 1).

Renewables self-consumers	**Article 21, REDII**	'A final customer […] who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity.'
Jointly acting renewables self-consumers (collective self-consumption)	**Article 21, REDII**	A group of at least two cooperating 'renewables self-consumers […] who are located in the same building or multi-apartment block' or, where permitted by a Member State, within other premises.
Renewable energy community	**Article 2 (16), REDII**	A **legal entity**, based on open and voluntary participation, autonomously controlled by shareholders or members in proximity to renewable energy projects, **consisting of natural persons, SMEs, or local authorities**, with the primary goal of delivering environmental, economic, or social community benefits rather than financial profits. They are limited to renewable energy systems (heat and electricity) and rooted in the local community.
Citizen energy community	**Article 2 (11), EMD**	A **legal entity**, also based on open and voluntary participation that is value-driven rather than by financial profits. **There is no geographical limitation and electricity only is being produced and shared.**

Table 1 Overview of different energy-sharing possibilities in EU directives.

[7] Directive (EU) 2018/2001
[8] Directive (EU) 2019/944

PENs rely on an enabling framework for sharing energy among individuals and groups – sharing and thus reaching a net balance is at the core of the PEN concept. Thus, for this section, the degree to which regulations encourage or inhibit energy production, sharing and trading and the functioning of renewable energy communities or collective self-consumption is explored.

3.3 Demand-side flexibility

With the electrification of heating and mobility, electricity will become the core of the energy system in the next few decades – and the IEA[9] emphasises the huge role that flexibility will play. The EPBD recast, REDIII and EED include important provisions to encourage energy storage, smart heating, integration with sustainable mobility, and energy management systems. Demand-side flexibility is a key service of PENs which aims to maximise self-consumption at neighbourhood level and provide flexibility services to the grid. To exploit this potential it is key that regulations promote demand-side flexibility and smart technologies.

3.4 Whole-life carbon and circularity

Previous EU legislation did not mandate Member States to implement regulations that promote the use of secondary construction materials, their circularity, or life-cycle assessment methodologies. Thus, for this section any relevant national policies that have emerged on the initiative of a Member State will be listed. Going forward, the Council Conclusions on the Circular Economy in the Construction Sector from 28 November 2019 urged the Commission to facilitate the circularity of construction products when revising the Construction Products Regulation (EU) No 305/2011. The Commission's proposal for the construction products regulation currently under revision includes clarity on reused pre-fabricated houses. Several provisions of the 2024 EPBD recast make the shift from operational GHG to embodied carbon, among them the introduction of global warming potential over a building's whole life cycle. However, at this stage, no minimum requirements regarding the whole life-cycle emissions are being introduced.

With the PEN approach, renovations are a key measure to improve energy performance and make the most of collective renewable energy assets. Ideally, sustainable material choices (e.g. also secondary construction materials) are facilitated by a coherent whole-life carbon perspective and methodology.

3.5 Fuel poverty and affordability of renovation

Tackling fuel poverty and engaging vulnerable households in the energy transition are key goals of the EPBD recast, EED and REDIII. As Member States move towards the renovation of their worst-performing building stock under the 2024 EPBD recast with the introduction of minimum energy performance standards (MEPS), the affordability of the renovations as well as the affordability of housing become key issues. Often, public subsidies encouraging renovation such as tax rebates end up mostly benefiting higher-income groups – this is known as the Matthew Effect.[10] Appropriate funding programmes and incentives need to ensure that vulnerable households are also targeted.

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[9] https://www.iea.org/reports/net-zero-by-2050

[10] The Matthew Effect refers to a pattern in which those who begin with advantage accumulate more advantage over time and those who begin with disadvantage become more disadvantaged over time (Linda K. George et al., 2016).

Efforts to renovate social housing need to be supported, since it is often exempted from the obligation (for example, in the obligation of public authorities to renovate 3% of the buildings under the EED). At the same time, PEN can play a key role in including low-income households in the energy transition, because it foresees the engagement of the local community in the co-design and tailoring of financing solutions for the needs of each homeowner.

4. Policies at the EU level

4.1 Policy context

During the 2019-2024 policy cycle, energy and climate have been high on the agenda for the European Commission, and several communications and strategies have set the scene for subsequent efforts to align European regulations and directives with policy ambitions.

4.1.1 Fit for 55

The Fit for 55 package was presented in 2021. It is the EU's strategic legislative framework that sets out to achieve the Union's target of a 55% reduction in GHG emissions by 2030. Renewable energy integration, energy efficiency, flexible and resilient energy systems, and a just transition are all central themes in Fit for 55. The package spans a long list of directives that had to be revised to bring the EU in line with the new ambitions set for 2030. This list includes the EED, REDIII and EPBD, which have been deemed the most relevant for PENs.

4.1.2 Renovation Wave

Renovations have been identified as a key enabler of the EU's efforts to conserve energy and deliver on its energy and climate commitments. In 2020, the European Commission presented the Renovation Wave strategy along with an action plan, in a targeted effort to double energy renovation rates by 2030, all while reducing carbon emissions and growing the green job market.

4.1.3 REPowerEU

REPowerEU was presented in May 2022 in response to Russia's invasion of Ukraine, and has the goal of boosting Europe's energy independence. It presented a set of actions to quickly reduce Europe's dependence on Russian gas by diversifying the energy supply and saving energy, building on the previously presented Fit for 55 package. In it, the Commission set out further ambitions for some of the key targets in Fit for 55, e.g. raising the energy efficiency target in the EED to 13% and the renewables target in the RED from 40% to 45%.

4.2 PEN-relevant policy

The PEN approach is designed to deliver on several policy objectives that are addressed at EU level. The objective of this mapping is to analyse the relevant EU-level policy provisions for PENs, with a focus on those resulting from the recast or revisions of major directives as part of the Fit for 55 package.

Using the framework described in the previous chapter, the most relevant provisions are identified. Their strengths and shortcomings in relation to mainstreaming the PEN approach are discussed. The main principles and objectives of a PEN are defined in Section 2.3., 'The PEN concept in relation to policy'.

The directives included in this policy mapping are:

- EED
- REDIII
- EPBD

4.3 Energy Performance of Buildings Directive

The Energy Performance of Buildings Directive (EPBD) is the most important piece of EU legislation for PENs, since it directly concerns the building stock and how to bring it to climate neutrality by 2050. As part of the Fit for 55 package, the European Commission presented its recast proposal in 2021, and a political agreement was reached between co-legislators in trilogue in December 2023.

Overall, one of the main political challenges in the EPBD is to strike a balance between a sufficiently stringent and harmonised European approach to building decarbonisation, while allowing enough flexibility and leeway to accommodate for national differences in the building stock and the social, economic and cultural conditions surrounding it in individual Member States. As a result, it is not yet entirely clear how the provisions from the EPBD will ultimately impact the feasibility of the PEN approach. This will be largely decided in national implementation.

Nonetheless, this mapping highlights some of the key provisions for PENs (Table 2) and discusses them by theme in the following sections.

4.3.1 Introducing the neighbourhood approach

A novelty of the recast EPBD, which is of notable importance for mainstreaming PENs, is the explicit mention of a neighbourhood and district approach, e.g. in Article 17 on financing, Article 18 on one-stop shops, and Article 28 on review. Moving from a single-building perspective to seeing buildings as components in a bigger system will unleash potential for further energy efficiency gains, renewable integration, social cohesion, economies of scale etc. This is what the PEN approach builds on. Though a complete switch of approach is still far away, the explicit mention of the neighbourhood approach is a step in this direction.

4.3.2 Minimum energy performance standards as drivers for PENs

The overall objective of the EPBD is to achieve the goal that by 2050 the whole building stock should be decarbonised and converted into zero-emission buildings (ZEBs). One way to achieve this is by implementing minimum energy performance standards (MEPS) for residential as well as non-residential buildings. Member States are tasked with developing national trajectories to renovate the worst-performing buildings. Several intermediate targets for reducing the average primary energy use of the residential sector must be met: a reduction of at least 16% by 2030, of 20-22% by 2035, and by 2040 a reduction ‘equivalent to, or lower than nationally determined value derived from a progressive decrease of the average primary energy use from 2030 to 2050 in line with the transformation of the residential building stock into a zero-emission building stock’ (Article 9.2). These reduction targets all use 2020 as a baseline.

In general, the measures to ensure building stock decarbonisation are all potential drivers of PENs, as the approach can allow the scaling-up of renovations and on-site renewable energy technology installation. After mapping the worst-performing buildings, municipalities can scale up the renovation of these in clusters by making use of the PEN approach, while taking the individual building approach to the rest.

An important aspect of the envisioned route to decarbonisation, and one that is also significant for PENs, is that 55% of the decrease in energy use in the residential sector must be the result of renovating the worst-performing buildings. PENs are a suitable approach to achieve a large volume of renovated dwellings from the worst-performing part of the stock, such as big housing blocks. A weakness of this provision, however, is that it is expressed in terms of percentage decrease in primary energy use. Expressing this only in terms of primary energy use reduction could leave the way open to address only the supply side, without performing sufficient interventions to reduce energy demand. Percentage of primary energy use is also a rather abstract indicator. A more easily communicated way could be to set a target based on EPCs.

4.3.3 Zero-emission buildings' significance for PENs

Another central concept for PENs from the new EPBD is that of the zero-emission building (ZEB), and the criteria by which this building standard will be defined. As laid out in Article 11, a ZEB is a building with very high energy performance both in the sense that its energy demand is low and that the small amount of energy it still needs is sourced from renewables, district heating or cooling, or carbon-free sources. It is however up to each Member State to set the precise energy demand thresholds that will define the ZEB standard. Though there are no requirements to meet ZEB for renovations, ZEB represents the long-term vision for the entire EU building stock. The ambition driving its implementation will also directly impact PENs.

The approved energy supply sources have some implications for PENs: including district heating and cooling among the approved energy sources is positive, and so in general is the inclusion of renewable energy. However, the current definition of efficient sources for district heating and cooling (in EED Art. 24) allows up to 50% fossil fuel sources until 2040, which is not aligned with the PEN concept.

Furthermore, renewable energy community energy does not necessarily encourage local production and self-consumption, which are integral to the PEN concept. Similarly, 'energy from carbon-free sources' does not encourage local energy generation and sharing, and thus misses related benefits such as avoided grid upgrades.

Although the preamble of the directive describes how ZEB should contribute to demand-side flexibility, the description of ZEB in the article does not fully promote utilising its smartness and flexibility: this is a shortcoming in the context of supporting the PEN approach.

4.3.4 Mandatory installation of solar energy, charging infrastructure and control systems

Another theme in the EPBD that has notable impact for PENs is the mandatory installation of solar energy and smart technology.

Article 13 will ensure that residential buildings undergoing major renovations (and new buildings) will be equipped with systems to monitor and control energy flows, and will thus prepare the ground for smart integration with surrounding buildings and the wider energy system. This smartness aspect is a necessity for the operation of PENs, so the obligation to have this equipment installed will support their deployment.

In a similar way, Article 14 mandates the installation of e-mobility charging infrastructure in residential buildings undergoing major renovations (and new ones). Integration with an electric vehicle fleet for energy storage and flexibility is another important component of the PEN concept, therefore this provision is also supportive of PENs.

Article 10 mandates the installation of solar energy systems on certain categories of buildings, based on their floor area. Renewable energy from such installations is a potential component of PENs, and this provision could therefore be a driver. However, the article abandons the principle of technology neutrality. The PEN approach, by contrast, allows communities to collectively decide on the optimal renewable energy technology based on their neighbourhood's potential for generation and storage.

4.3.5 Addressing financial barriers and energy poverty

The EPBD aimed to address the problem of upfront cost for renovations and their potential economic burden on vulnerable households by obliging Member States to take this into consideration in various policy measures. The national building and renovation plans (Article 3) must include indicators that monitor impact on energy poverty, and due consideration and support must be given to the implementation of MEPS (Article 9).

Article 17 is dedicated to ensuring that the barrier of financing is addressed by Member States through a combination of numerous policy tools.

The success of PENs will likely also depend on adequate public and private financing, and support mechanisms are therefore necessary. When designing the support, it is important to ensure that it is enough to get low- and middle-income households on board with a PEN project, and avoid a situation where public incentives only benefit the already well-off.

4.3.6 Information tools guiding towards PENs

Finally, the EPBD recast includes more emphasis on various types of information tools to support the necessary renovations. From the perspective of supporting PENs, it is important that all these tools include the option of applying the PEN approach when they develop their recommendations and advice.

The voluntary scheme for renovation passports in Article 12 will for instance give homeowners advice on how to bring their property to NZEB (before 2030) or ZEB (after 2030) through step-wise renovations. It would be detrimental to the PEN approach if different homeowners in a potential PEN area receive individual and uncoordinated renovation advice.

Article 18 obliges Member States to establish one-stop shops (OSSs) that will provide independent technical advice to citizens on renovations. OSSs may be established in areas to provide integrated district renovation programmes, and in these cases there are synergies with PENs. However, if these centres for technical advice do not consider and promote PENs in cases where they present a feasible option, this measure could have a negative impact on PENs.

Table 2 Provisions in EPBD

ARTICLE	ENERGY PERFORMANCE	DEMAND-SIDE FLEXIBILITY	COLLECTIVE PRODUCTION AND SHARING OF ENERGY	WHOLE-LIFE CARBON AND CIRCULARITY	FUEL POVERTY AND AFFORDABILITY RENOVATION	FINANCE AND INCENTIVES	COMMENT
ARTICLE 2 DEFINITIONS *On-site and nearby renewable energy sources* • 'On-site' is defined as on the premises of and on the building itself. • Defines 'energy from renewable sources produced nearby' for a building as energy from renewable sources 'within a local or district level perimeter', fulfilling certain listed criteria including that connections are made at the low-voltage grid level. *Zero-emission buildings* • A 'zero-emission building' is defined as a building with very high energy performance. The criteria for ZEB are further elaborated in Article 9b and Annex 1. *Worst-performing buildings* • 'Worst-performing buildings' is defined as the bottom 43% of the national building stock in terms of energy performance. *Renovation passports and building logbooks* • The 'renovation passport' is defined as a 'tailored roadmap for the deep renovation of a specific building in a maximum number of steps that will significantly improve its energy performance.' • The concept of 'digital building logbook' is introduced and defined as a common repository for building data.	✓		✓			✓	*Nearby and on-site* The definitions of on-site and nearby are very similar concepts to PEN in terms of physical boundary and of being limited to a low voltage grid, which encourages demand-side flexibility. *Zero-emission buildings* For a positive energy balance at neighbourhood level, PEN buildings should meet ZEB or A+ standard. Worst-performing buildings It is important to focus on the worst-performing buildings, and PEN can be a solution to renovate them at a faster pace. *Renovation passports and building logbooks* Renovation passports can guide households to renovate, and thus be a driver for PENs – but staged renovation may be difficult to combine with the PEN approach, since each homeowner would receive a different renovation roadmap, while some investments have to be made collectively. The logbooks are a potential source of information for stakeholders involved in PENs. Out of the potential logbook contents listed, district-level information is not included – however, information regarding the grid capacity, flooding risk, and renewable energy potential are relevant for building and PEN design and maintenance.

ARTICLE 3 NATIONAL BUILDING AND RENOVATION PLAN • Member States should create a roadmap with targets and indicators towards the 2050 climate neutrality goals. • It should also include an indicator on the progress of reducing energy poverty. • The template includes reporting on 'neighbourhood and district approaches to renovation'	✓				✓	✓	A progress indicator for energy poverty potentially supports PENs, as this aspect is addressed by the approach.
ARTICLE 5 SETTING MINIMUM ENERGY PERFORMANCE REQUIREMENTS • Member States shall set minimum energy performance requirements that at least achieve cost-optimal levels. • Member States are invited to set 'where relevant, more stringent' minimum energy performance requirements.	✓						More stringent minimum energy performance requirements for renovations contribute to more ambitious PENs. Much like Article 3, the nationally determined minimum energy performance requirements may create barriers to harmonisation and differences in ambition.
ARTICLE 9 MINIMUM ENERGY PERFORMANCE STANDARDS FOR NON-RESIDENTIAL BUILDINGS AND TRAJECTORIES FOR PROGRESSIVE RENOVATION OF THE RESIDENTIAL BUILDING STOCK • This article lays out how Member States shall establish a trajectory for renovations to ensure a reduction of primary energy use. The reduction should be at least 16% by 2030, and 20-22% by 2035. By 2040 the reduction should be 'equivalent to, or lower than nationally determined value derived from a progressive decrease of the average primary energy use from 2030 to 2050 in line with the transformation of the residential building stock into a zero-emission building stock.' • 55% of the decrease must specifically be achieved through renovation of the worst-performing buildings. Buildings that undergo renovations following a natural disaster may be counted towards this target. • Member States must provide financial and technical support to comply with the MEPS as well as remove split incentives, and monitor the impact on vulnerable households.	✓						The PEN approach can be an effective way of implementing the scale-up of renovations, including in the worst-performing part of the building stock. However, defining ambition level for renovation of the worst-performing buildings using a percentage of the energy demand decrease rather than EPC labels may be more difficult to implement and communicate. The attention to vulnerable households in this context is important and can contribute to the deployment of PENs. The provision however lacks concrete measures addressing the affordability aspect.

ARTICLE 10 SOLAR ENERGY IN BUILDINGS • Member States are tasked with ensuring that solar energy is installed on an increasing share of new as well as existing buildings, based on their useful floor area.	✓						Mandatory installation of solar may have a supportive impact on the roll-out of some PENs, but the lack of technology neutrality in this provision could also have adverse effects in cases where solar energy is not the optimal technology choice for a project.
ARTICLE 11 ZERO-EMISSION BUILDINGS • Member States are tasked with ensuring the introduction of a maximum energy demand threshold for ZEB. In addition, the primary energy use of ZEB must be covered by nearby or community renewable energy, from district heating or cooling, or from 'carbon-free sources'. • An exception exists for when fulfilling the requirements is not deemed technically and economically feasible. • ZEB also considers embodied carbon with the calculation of Global Warming Potential; however, no thresholds are set. • All new buildings should be ZEB by 2030, and existing buildings should be transformed into ZEBs by 2050.	✓	✓	✓				It is positive for PENs that integration with efficient district heating and cooling is considered in the energy supply for ZEB – but only if the supply is renewable, which may not always be the case. It is also positive that community energy is included as an eligible source. However, renewable energy community energy does not necessarily encourage local production and self-consumption, which are integral to the PEN concept. 'Energy from carbon-free sources' only focuses on decarbonising supply; it does not encourage the benefits of renewable energy systems at building level, such as avoided grid upgrades. Finally, the requirements for ZEB in this article do not promote full utilisation of its smartness and flexibility.
ARTICLE 12 RENOVATION PASSPORTS • Member States are tasked with introducing a voluntary renovation passport scheme. They must also ensure that the passports are affordable, and consider financial support for renovations for vulnerable households.	✓					✓	Renovation passports can guide households to renovate, and thus be a driver for PENs, but staged renovation may be difficult to combine with the PEN approach since each homeowner would receive a different renovation roadmap, while some investments have to be made collectively. Financing support is important.

ARTICLE 13 TECHNICAL BUILDING SYSTEMS • Existing residential buildings undergoing major renovations (as well as new buildings) will need to have equipment installed that can control and monitor energy flows and consumption.		✓					Building monitoring, automation and control systems are necessary for PENs to function well; the obligation to install them in new and renovated buildings is positive for the PEN approach.
ARTICLE 14 INFRASTRUCTURE FOR SUSTAINABLE MOBILITY • In residential buildings undergoing major renovation, installation of pre-cabling and recharging points must be ensured.		✓					Integration with e-mobility is important for storage and balancing of the system, and the neighbourhood/district scale is the right one for adjusting the planning and design. This is positive for PENs.
ARTICLE 17 FINANCIAL INCENTIVES, SKILLS AND MARKET BARRIERS • This article details a list of measures that shall be taken by Member States to address the barrier of financing renovations. • The measures include to assess and address the up-front cost barriers to renovations, promote funding and financing tools, guide energy efficiency investment into the public building stock, promote public-private partnerships and promote energy efficiency lending products, all while protecting vulnerable households. • Notably, 'Member States shall incentivise sizeable programmes that address a high number of buildings, in particular the worst-performing buildings, such as through integrated district renovation programmes'.						✓	Financing mechanisms listed in the article may reduce the upfront cost of PEN, but may not be sufficient to bring middle and low-income households on board. There is a risk that support is utilised primarily by the already well-off. Public-private partnerships and guarantee funds may be highly relevant for PEN projects, which require high investments and regard both public and private spaces/assets. Integrated district renovation is a similar concept to PEN and may thus have a supportive effect. The ambition for such programmes is in line with the Eu Taxonomy but should be set higher than the directive proposes (30% reduction of primary energy demand).
ARTICLE 18 ONE-STOP SHOPS FOR ENERGY PERFORMANCE OF BUILDINGS • Member States shall establish OSSs, centres of independent advice on the energy performance of buildings. Areas where Member States plan integrated district renovation programmes are listed as one of the types of locations where OSSs may be established.							Integrated district renovation is a similar concept to PEN, so there are potential synergies. It is important that OSSs give adequate advice and consider PENs as an option for renovation.

ARTICLE 19 ENERGY PERFORMANCE CERTIFICATES • Member States have the option of defining an A+ energy performance class for buildings that have 20% lower energy demand than a ZEB and whose renewable energy generation exceeds its own demand.	✓		✓				A+ buildings may be necessary to achieve PEN levels; it is positive to highlight them in EPCs.
ARTICLE 28 REVIEW • In the next revision of the Directive, the European Commission is tasked with examining how Member States 'could apply integrated district or neighbourhood approaches in Union building and energy efficiency policy', and to assess if alternative indicators like final energy use or energy needs should be used.	✓	✓	✓				This is positive in the long term for PENs, provided that this assessment is actually carried out in the next review.

4.4 Renewable Energy Directive

The revised Renewable Energy Directive (REDIII)[11] is the main policy for promoting renewable energy technologies. It sets the collective EU target in terms of renewables as a share of final energy, and obliges Member States to take action to facilitate the installation and integration of technology that can deliver this energy, with due consideration notably to protection of natural habitats. The revised REDIII entered into force on 20 November 2023 and will be transposed over the following 18 months, with shorter deadlines for several of its provisions. Key articles regarding collective production of renewable energy, which are highly relevant for PEN, remained unchanged from REDII.[12] The main issues with provisions for 'jointly acting renewables self-consumers' and 'renewable energy communities' lie in the implementation. Thus, the next round of transposition will allow for lessons to be learned from best practices, and there will be a more harmonised approach to the implementation of these frameworks between Member States.

PENs are a solution that can help tackle the problem of balance between increased renewable energy shares and conflicting environmental targets related to land use and biodiversity preservation, since PENs optimise the deployment of renewables in built environments where this conflict is rare.

Some of the main new or revised provisions with great relevance for PENs are:

4.4.1 Renewable energy target raised

The collective target for renewable energy was raised to 42.5% by 2030 from the previous REDII target of 32%. This will keep the pressure on for Member States to find suitable areas and deploy new (combinations of) renewable energy technologies. While this is an economy-wide effort, it could raise interest in PENs as a solution, since the neighbourhood is the right scale to untap the full potential of renewable energy generation and storage while adjusting to local conditions.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413&qid=1699364355105
[10] Directive (EU) 2018/2001

4.4.2 Mainstreaming renewable energy in buildings and in heating and cooling

Article 15a on mainstreaming renewables in buildings is a potential driver for a wider deployment of PENs. It brings together renewables integration and energy efficiency interventions (renovations) in the building sector, which are also at the core of the PEN concept. This closely relates to Article 23 on mainstreaming renewable energy in heating and cooling, which promotes an annual increase of renewables in the heating and cooling sector.

However, in its description of the origins of the renewable energy for buildings that will be subject to minimum requirements, this provision opens up the possibility for renewable energy from the grid as well as renewables with 'on-site' or 'near-by' origins. This goes somewhat against the PEN concept, which strives to increase renewable energy capacity specifically on or in the direct vicinity of the buildings involved. Local production and maximising self-consumption reduce pressure on the grid, and thus avoid the need for additional costly investments in grid upgrades.

4.4.3 Renewable acceleration areas, and planning of other areas

The introduction of the concept of 'renewable acceleration areas' in Article 15c together with the mainstreaming of renewables in buildings in Article 15a are the main policy drivers for PENs in REDIII. The plans for designation of renewable acceleration areas should prioritise (among other types of land) the built environment, and they should build on renewable energy potential as well as energy demand and its flexibility. There is a considerable overlap between areas suitable for PENs and those described in Article 15c.

4.4.4 Permit-granting procedures

Several new and revised provisions in REDIII also aim at streamlining, facilitating and speeding up permit-granting procedures related to the installation of renewable energy technologies. As PENs build on a combination of numerous interventions and technologies, the administrative burden from permitting applications may still be heavy; however, these provisions are an important step towards improving the process.

4.4.5 Facilitating system integration

Part of REDIII also touches on the issue of facilitating system integration of decentralised energy assets, and promoting sector coupling between power and heat systems. Participation in energy markets has long been a key barrier for small and decentralised actors, and efforts towards removing this barrier will have a positive effect on the PEN business case. REDIII mainly supports small actors, like natural persons and SMEs within renewable energy communities, to participate more in and contribute to the decarbonisation of district heating and cooling networks. This article has synergies with the EPBD recast, which lists renewable district heating and cooling as a source of renewable energy for ZEB (which was not the case for NZEB), and with EED Article 26 which aims at decarbonising district heating and cooling systems. The PEN approach is ideal to unlock potential synergies between renewable energy produced onsite and nearby with district heating and cooling, which could be either the main source of energy, or the backup source of energy for other HVAC systems at PEN level.

Key provisions are presented in Table 4.

Table 4 Key provisions of REDIII

ARTICLE	ENERGY PERFORMANCE	DEMAND-SIDE FLEXIBILITY	COLLECTIVE PRODUCTION AND SHARING OF ENERGY	WHOLE-LIFE CARBON AND CIRCULARITY	FUEL POVERTY AND AFFORDABILITY RENOVATION	FINANCE AND INCENTIVES	COMMENT
ARTICLE 2 DEFINITIONS • 'Renewables acceleration area' means a specific location or area, whether on land, sea or inland waters, which a Member State designated as particularly suitable for the installation of renewable energy plants.	✓	✓	✓				The introduction of this concept is an opportunity for PENs.
ARTICLE 3 BINDING OVERALL UNION TARGET FOR 2030 • The Union's collective target for renewable energy share in 2030 is set at 42.5%. In addition, it should 'endeavour to increase' this share to 45%.	✓						The raising of the EU renewable energy target puts pressure on Member States to explore all means of integrating more renewable sources. PENs are one of many solutions to deliver this, because they unlock renewable energy production and storage potential while adjusting to local needs.
ARTICLE 15A MAINSTREAMING RENEWABLE ENERGY IN BUILDINGS • Member States shall set an 'indicative national share of renewable energy produced on-site or nearby as well as renewable energy taken from the grid in final energy consumption in their building sector'. • To reach this share they should take measures to support renewable energy integration in combination with energy efficiency improvements that result in an increased number of 'nearly zero energy buildings and buildings that go beyond minimum energy performance requirements'. • They shall also set minimum requirements regarding renewable energy 'produced on-site or nearby as well as renewable energy taken from the grid' for new and renovated buildings, and promote renewable heating and cooling and smart energy management.	✓	✓	✓				The raising of the EU renewable energy target puts pressure on Member States to explore all means of integrating more renewable sources. PENs are one of many solutions to deliver this, because they unlock renewable energy production and storage potential while adjusting to local needs.

• They shall ensure that the public sector leads by example in this regard, by 'providing for the roofs of public or mixed private-public buildings to be used by third parties for installations that produce energy from renewable sources.'							
ARTICLE 15B MAPPING OF AREAS NECESSARY FOR NATIONAL CONTRIBUTIONS TOWARDS THE OVERALL UNION RENEWABLE ENERGY TARGET FOR 2030 • Member States to map and identify areas in which the necessary capacity for renewable energy technology to meet targets can be installed.	✓	✓					These areas could be PENs.
ARTICLE 15C RENEWABLES ACCELERATION AREAS • A subset of the areas in Article 15b to be designated as renewables acceleration areas 'giving priority to artificial and built surfaces, such as rooftops and facades of buildings, transport infrastructure and their direct surroundings'.	✓						These areas are potentially ideal for PENs. Renewable energy projects in the designated areas can be fast-tracked (Art. 16a).
ARTICLE 16 ORGANISATION AND MAIN PRINCIPLES OF THE PERMIT-GRANTING PROCEDURE • Several provisions to facilitate application process, i.e. setting time limits for the acknowledgement of receipt of the application, ensuring that it can be submitted digitally, and that application can be made through a single point of contact.	✓					✓	PENs are projects involving numerous permit-requiring interventions – renovations, renewable energy systems, energy storage, heating systems… Ideally these would also be streamlined into one process.
ARTICLE 16A PERMIT-GRANTING PROCEDURE IN RENEWABLES ACCELERATION AREAS • 'Member States shall ensure that the permit-granting procedure referred to in Article 16(1) shall not exceed 12 months for renewable energy projects in renewables acceleration areas.'	✓					✓	Since PENs would ideally be established in renewables acceleration areas, a fast-track process for permits is positive.
ARTICLE 18 INFORMATION AND TRAINING • Ensure training programmes for installers and designers cover 'renewable heating and cooling technology, solar photovoltaic systems, including energy storage, recharging points enabling demand response, and the latest innovative solutions thereof'.	✓	✓	✓			✓	It is important that such training involves the deployment of these technologies at neighbourhood level.

ARTICLE 20 ACCESS TO GRIDS • Development of efficient district heating and cooling 'where possible in combination with thermal energy storage, demand-response systems and power to heat installations'.	✓	✓					PENs could be key nodes for such sector coupling.
ARTICLE 20A FACILITATING SYSTEM INTEGRATION OF RENEWABLE ELECTRICITY • Ensuring a 'level playing field and non-discriminatory participation in the electricity markets for small decentralised energy assets'.		✓				✓	Entering the electricity market has long been a barrier for decentralised energy assets. Removing such barriers would be beneficial for PENs. However, there is no concrete provision on how to implement it.
ARTICLE 23 MAINSTREAMING RENEWABLE ENERGY IN HEATING AND COOLING • 'Member States shall endeavour to implement at least two of the following measures: […] e) the creation of risk mitigation frameworks to reduce the cost of capital […] k) the promotion of renewable based district heating and cooling networks, in particular by renewable energy communities, including through regulatory measures, financing arrangements and support.'	✓				✓	✓	Reducing the risk of capital is a key challenge for PENs, thus it is positive that it is brought up in the directive. However, this provision is weak in its formulation, so it is up to Member States to take appropriate action.
ARTICLE 24 DISTRICT HEATING AND COOLING • Distribution system operators should assess 'the potential for district heating and cooling systems to provide balancing and other system services, including demand response and thermal storage of excess electricity from renewable sources'.	✓	✓					PENs are well positioned to be these points of interaction between power and heat.

4.4.6 Unchanged provisions from REDII, part of REDIII

Several key provisions have been unchanged since REDII and are still in force with the revised REDIII.

The two concepts of 'jointly acting renewables self-consumers' and 'renewable energy communities' are defined in Article 2 and are very central to PENs. While the creation of these frameworks for collective production and sharing of renewable energy is positive for PENs, the definition of 'jointly acting renewables self-consumers' is unnecessarily narrow in that it is limited to consumers in the same building.

The benefits of collective self-consumption can be better valorised in PENs when this strategy can be applied to more than one building, as long as these are located in the relatively direct vicinity of each other. While most countries have transposed this definition within one building, Spain has extended it to a range of initially 500m and eventually 2km, which allows PENs to untap fully the renewable energy potential and benefit key stakeholders.

A renewable energy community, on the other hand, requires the setting-up of a legal entity, which is not necessary for collective self-consumption. This is an additional barrier for bottom-up initiatives such as PEN, since registering a legal entity with various governance requirements is an administrative burden, and usually this process is facilitated by municipalities within PEN projects. Another limitation of both collective self-consumption and renewable energy communities is the inability to sell energy or flexibility services, without being registered as a utility, which impedes the exploration of additional PEN business models and financing opportunities. However, collective ownership of renewable energy sources and storage can contribute to a sense of community and empowerment, with business models based on energy sharing rather than energy selling.

These provisions from REDII are listed in Table 5.

Figure 5 Unchanged provisions from REDII, part of REDIII

ARTICLE	ENERGY PERFORMANCE	DEMAND-SIDE FLEXIBILITY	COLLECTIVE PRODUCTION AND SHARING OF ENERGY	WHOLE-LIFE CARBON AND CIRCULARITY	FUEL POVERTY AND AFFORDABILITY	FINANCE AND INCENTIVES	COMMENT
ARTICLE 2 DEFINITIONS • 'Renewables self-consumer' means a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non- household renewables self-consumer, those activities do not constitute its primary commercial or professional activity.	✓	✓	✓				*Renewables self-consumer* This definition remained unchanged. *Jointly acting self-consumer* This definition remained unchanged. Notably, the definition of jointly acting renewables self-consumers is limited to consumers in the same building. This is restricting for PENs. *Renewable energy community* This definition remained unchanged.

• ‘Jointly acting renewables self-consumers’ means a group of at least two jointly acting renewables self-consumers […] who are located in the same building or multi-apartment block. • ‘Renewable energy community’ means a legal entity: (a) which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; (b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities; (c) the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits;	✓	✓	✓				*Renewables self-consumer* This definition remained unchanged. *Jointly acting self-consumer* This definition remained unchanged. Notably, the definition of jointly acting renewables self-consumers is limited to consumers in the same building. This is restricting for PENs. *Renewable energy community* This definition remained unchanged.

[13] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

4.5 Energy Efficiency Directive

The revised Energy Efficiency Directive (EED)[13] was adopted in September 2023. The EED is another central part of the Fit for 55 package, and reflects the EU's ambition to increase energy efficiency in response to the energy crisis.

The key new or revised provisions that are relevant to PENs are listed in Table 6.

4.5.1 Energy saving target

A legally binding target to reduce the EU's final energy consumption by 11.7% by 2030, as compared to a 2020 reference scenario, has been established. The EED also sets energy savings obligations for Member States, to gradually increase their annual energy savings starting at 1.3% (2024-2025), then 1.5% (2026-2027), and finally 1.9% from 2028 onwards.

This increased level of required energy savings raises the general pressure on Member States to find ways to conserve energy, and PENs are one of many innovations that can potentially contribute.

4.5.2 Energy efficiency first principle broadened

The energy efficiency first principle is broadened to also include considerations of demand-side resources and system flexibilities. This can potentially facilitate the uptake of the PEN concept, by increasing the attractiveness of PENs as an energy efficiency solution. However, it only applies to planning, policy and projects worth over €100 million (or €175 million for transport infrastructure projects).

4.5.3 Increased attention to energy poverty and vulnerable households

The protection of energy-poor, vulnerable and low-income households is one of the main themes of the energy transition in general and of the EED in particular. Throughout the new EED, Member States are obliged to pay increased attention to energy poverty, and to protect vulnerable households in the design and implementation of energy saving measures. In Article 2 a revised definition of energy poverty is established, and the need to give consideration to energy poverty is already explicit in the energy efficiency principle in Article 3, as well as in several subsequent articles.

This obligation could also potentially underpin a broader uptake of PENs. PENs are a way to bring down upfront costs for renovations, and to lower energy bills. They are a concept for an inclusive and just energy transition.

4.5.4 Public sector leading

The public sector is expected to take a leading role in the energy efficiency improvements and energy savings. A difference from previous versions of the directive is that this leadership applies to all public buildings (owned or occupied) and all levels of governance, as opposed to only state level.

As laid down in Articles 5 and 6 respectively, the public sector must reduce its total final energy consumption by at least 1.9% each year, and ensure that 3% of its buildings (by floor area) are renovated each year to meet the definition of NZEB or ZEB. These targets shall be met without there being negative impacts on energy-poor, low-income or vulnerable households.
bring down upfront costs for renovations, and to lower energy bills. They are a concept for an inclusive and just energy transition.

[13] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

Table 6 Key provisions from the revised EED

ARTICLE	ENERGY PERFORMANCE	DEMAND-SIDE FLEXIBILITY	COLLECTIVE PRODUCTION AND SHARING OF ENERGY	EMBODIED CARBON AND CIRCULARITY	FUEL POVERTY AND AFFORDABILITY	FINANCE AND BUSINESS MODELS	COMMENT
ARTICLE 2 DEFINITIONS • Definitions for 'energy poverty' and 'system efficiency'.		✓			✓		Definitions for energy poverty and system efficiency have been revised and added. These are central concepts for PENs.
ARTICLE 3 ENERGY EFFICIENCY FIRST PRINCIPLE • Energy efficiency first principle broadened to include 'demand-side resources and system flexibilities', for projects worth over €100 million.	✓	✓					This broadened definition of the energy efficiency first principle is fundamental for the transition towards the smart deployment of renewable energy, with storage and maximising self-consumption with demand-side flexibility. This is a key principle of PEN.
ARTICLE 4 ENERGY EFFICIENCY TARGETS • The EU's energy efficiency target is raised to a 'reduction of energy consumption of at least 11.7% in 2030 compared to the projections of the 2020 Reference Scenario'.	✓						The tightening of the EU target puts pressure on Member States to explore all sources of energy efficiencies. PENs are one of many solutions to deliver this.
ARTICLE 5 PUBLIC SECTOR LEADING ON ENERGY EFFICIENCY • The energy saving target for the public sector is that 'total final energy consumption of all public bodies combined is reduced by at least 1.9% each year', while mitigating the impact on 'energy-poor, low-income households or vulnerable groups'.	✓				✓		PENs are a promising solution for balancing energy efficiency measures and for targeting energy poverty in the public sector.
ARTICLE 6 EXEMPLARY ROLE OF PUBLIC BODIES' BUILDINGS • 3% of publicly owned buildings should be renovated each year, to meet the definition of NZEB or ZEB. Social housing may however be exempted if renovation cannot be made cost-neutral for tenants.	✓				✓		PENs can be a way to achieve NZEB and ZEB-level renovations while ensuring cost-neutrality for tenants. However, the exemption of social housing contradicts the previously mentioned focus on 'energy-poor, low-income households or vulnerable groups' in Article 5.

ARTICLE 21 INFORMATION AND AWARENESS RAISING • Member States must create a supportive framework for market actors, including 'one-stop shops […] for the provision of technical, administrative and financial advice' and 'cooperation with private actors that provide services such as […] financing solutions and execution of energy renovations'. • They must also 'remove regulatory and non-regulatory barriers to energy efficiency' that cause split incentives around energy efficiency improvements.						✓	To realise the potential benefits of PENs as a solution, it will be important for supportive frameworks such as OSSs to have the neighbourhood perspective as an option when they provide advice. Measures to tackle split incentives must also support PEN cases.
ARTICLE 22 EMPOWERING AND PROTECTING VULNERABLE CUSTOMERS AND ALLEVIATING ENERGY POVERTY • Member States must 'empower and protect people affected by energy poverty, vulnerable customers, low-income households and, where applicable, people living in social housing'. To this end, they should for example 'ensure access to finance, grants or subsidies bound to minimum energy gains and thus facilitate access to affordable bank loans or dedicated credit lines'.					✓	✓	The alleviation of energy poverty is a theme that is present throughout the EED, and most explicitly through this article. PENs offer a promising solution to manage this, however, many public incentives fail to reach the most vulnerable groups. Member States should increase their efforts to enable private and public finance, including for social housing and vulnerable households. Targeted financial solutions such as green loans should acknowledge the multiple benefits of sustainable projects such as PENs.
ARTICLE 23 HEATING AND COOLING ASSESSMENT AND PLANNING • Municipal heating and cooling plans should be prepared, that consider the needs of local communities and the area-specific potential for energy efficiency measures. The role of energy communities in the implementation of heating and cooling projects should also be assessed in these plans.	✓	✓	✓			✓	The creation of municipal heating and cooling plans presents an opportunity for greater deployment of the PEN concept, provided that this is considered in the development of the plans. Conversely, if PENs are not considered as part of these plans, they will become a barrier.

4.6 Conclusions

PEN is a promising approach for achieving EU energy objectives, but its success depends on national governments' inclusion of the approach in their own policies and programmes.

The explicit mention of neighbourhood and district approaches for renovations and the requirement to report on progress within national building renovation plans in the new EPBD is an important milestone for the PEN approach. To further foster the uptake of PENs there is a need for a common definition and framework. The definition must leave enough flexibility to enable local adjustments, depending on limitations such as heritage regulations, renewable energy potential and electricity grid capacity. However, the concept, approach and calculation method should be harmonised to allow for comparison between projects. In addition, such a definition is critical to enable meaningful follow-up on the policy goals related to the progress of district and neighbourhood approaches in the national building renovation plans.

Defining energy from 'on-site and nearby' renewable energy sources with a combination of a geographical perimeter and the need to remain in the low and medium voltage grid, as is the case in the EPBD, supports local demand-side flexibility within a PEN.

Planning and early identification of spaces within the built environment to be used for renewable energy production is key for PENs. Examples of this are provisions concerning renewables acceleration areas (Article 15c, REDIII) and heating and cooling assessment and planning (Article 23, EED). Both provisions could greatly enhance the PEN approach by identifying and dedicating suitable areas within cities. Conversely, they also risk creating lock-in effects if they are developed with a single-building perspective.

There is a lot of attention paid to low-income households, energy poverty and affordability in the EED, but much less so in REDIII. In other words, energy poverty is considered closely when it comes to reducing energy demand, but much less so when it comes to accessing a renewable energy supply. PENs – and the energy transition in general – rely on both reducing energy demand and increasing renewable energy supply. EU policy support for an inclusive energy transition is thus somewhat asymmetric between the demand and supply sides. PENs can help overcome this gap, as they are a way to make decarbonised energy more accessible for low-income households.

Despite the many mentions of the need to protect vulnerable households and consider energy poverty, there are few concrete obligations to this end. Social housing is often exempted from renovations (e.g. in the 3% renovation target for public buildings in EED).

Financing solutions are a key issue to solve, in order to make the interventions in the EU climate and energy policies a reality. The EPBD, REDIII and EED explicitly mention a range of measures – such as tax incentives, green loans, energy performance contracting, public guarantees etc. – that should be put in place to enable the necessary investments. Historically, many public incentives have failed to reach the lowest-income groups, who are arguably in greatest need. Member States must design their financing instruments and incentives so that they are accessible and better targeted at those who need the support, e.g. by applying income-based schemes.

PENs bring benefits beyond energy performance. The directives analysed naturally focus their benchmarks on energy-related indicators, but to appreciate the full range of benefits that PENs bring, building policy at national level should look into and valorise other – notably social – aspects, which would strengthen holistic approaches like PENs.

Due to the timing of the revision, the Electricity Market Directive has been left out of the scope of this mapping, but it will inevitably also have a great impact on the possibilities of electricity trading for PENs, which will affect the energy sharing aspects as well as the business case. This should also be analysed in due course.

4.7 Key messages

The key stakeholders for a successful mainstreaming of PENs in the implementation of EU buildings and energy policies are national and EU policymakers along with representatives from private financial institutions.

The main takeaways for these actors are:

- A harmonised definition and framework for PEN is needed to enable assessment of progress towards policy goals.
- In the implementation, tailored actions and policies are needed to protect vulnerable households and mitigate energy poverty, including supporting access to renovation and renewable energy supply.
- Financing solutions must be better designed to benefit the income groups that need them.
- Methods for assessing the social and environmental co-benefits of PENs are needed to enable access to public and private ESG finance.

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6. Annex 1 Comparison table of PED definitions within Horizon 2020 projects

Year	2012-2015	2019-2024	2018-2023	2018-2023	2019-2024	2019-2024	2020-2024	2021-2026
Project	COOPERATE	ATELIER	+CityxChange (Positive City Exchange)	MAKING CITY	POCITYF	SPARCS	Syn.ikia	oPEN Lab
Name	EPN	PED	PED	PED	PEB/PED	PED	SPEN (Sustainable Plus Energy Neighbourhood)	PEN
Definition	An 'Energy Positive Neighbourhood' (EPN) is defined as a neighbourhood which can maximise usage of local and renewable energy resources while positively contributing to the optimisation and security of the wider electricity grid. More definitions available on page 9 here.	District that produces more renewable energy than it consumes on an annual basis. Concepts such as energy efficiency and flexibility, energy autonomy and zero direct emissions of non-biogenic CO2 are also considered.	For PEDs, the project adopted the definition from SET-Plan Action 3.2. (This corresponds to the definition of 'Joint programming Initiative Urban Europe'). This definition is also provided at the project's website, here.	A district with annual net zero energy import and net zero carbon emissions, working towards an annual local surplus production of renewable energy. It also follows the SET-Plan Action 3.2 definition, as stated here.	The project adopted the PED definition from the Horizon 2020 Framework Programme.	SPARCS largely adopted the PED definition framework developed by EERA JPSC with three types of PEDs, namely, PED-autonomous, PED-dynamic and PED-virtual.	SPEN aims to achieve more than 100% energy savings, 90% renewable energy generation triggered, and 10% life-cycle costs reduction, compared to the level of 2020 nearly zero-energy buildings (nZEBs). Full definition available on page 2 here.	Positive energy neighbourhoods are energy-efficient and energy-flexible groups of connected buildings or urban areas which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. PENs seek an integrated, participatory, neighbourhood-based approach to maximise the benefits of innovative energy systems.

Boundary	Neighbourhood: group of households, business and public services localised geographically and used by a community on a daily basis.	The PED demonstrations are composed of areas connected geographically as well as virtually through smart grids.	Compact area comprising at least three mixed use buildings (>15,000 m^2).	Urban area with clear boundaries comprising buildings of different typologies.	Several buildings (new, retrofitted or a combination of both).	Two types: geographical or virtual depending on the type of PED (there are three types of PEDs according to SPARCS).	A group of interconnected buildings with associated infrastructure, located within both a confined geographical area and a virtual boundary.	Efficient and energy-flexible groups of connected buildings or urban areas…
Active mgmt. (of their load and local/ regional surplus production of renewable energy)	Contributing to the optimisation and security of the wider electricity grid.	Produces more renewable energy than it consumes on an annual basis.	Produces more energy than it consumes over a year by including local renewable energy production.	Yes – to reach a positive energy balance.	Yes – have an annual positive energy balance.	Actively manage an annual local surplus production of renewable energy.	Marked as an objective of PEDs: 'Active management of annual local or regional surplus production of renewable energy and power performance (self-consumption, peak shaving, flexibility)'.	…which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy.
CO_2/GHG emissions	Reduction in CO_2 emissions.	Zero direct emissions of non-biogenic CO_2.	Net zero CO_2 emissions.	Net zero CO_2 emissions.	Not directly mentioned (implicitly understood to be minimised).	Net zero CO_2 emissions.	Net zero greenhouse gas emissions and carbon footprint reduction.	Net zero greenhouse gas emissions.
Renewable energy, flexibility, demand response, energy efficiency	Energy efficiency and flexibility.	Energy efficiency and flexibility, energy autonomy.	Measures to reduce energy demand.	On-site renewable energy systems, flexibility.		Energy exchange with outside area considered for two of the three PED types defined, allowing for flexibility. The other (Autonomous PED) regards it as optional ('possible connection').	'Increased use and production of renewable energy according to a normalization factor' and '(self-consumption, peak shaving, flexibility)'.	

Social aspects	Not mentioned explicitly.	Not mentioned explicitly.	PED couples built environment, sustainable production and consumption, and mobility to reduce energy use and greenhouse gas emissions and to create added value and incentives for the consumer. 'PEDs should offer affordable living for the inhabitants.'	Affordable, high standard of living, user-added value.	Have a positive impact on it (also from the circular economy point of view). Their design is intrinsically scalable, and they are well embedded in the spatial, economic, technical, environmental and social context of the project site.	'…while ensuring social, economic and environmental sustainability for current and future generations.'	Social inclusiveness and affordable living.	PENs seek an integrated, participatory, neighbourhood-based approach to maximise the benefits of innovative energy systems.

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