Smart-BEEjS

Human-Centric Energy Districts: Smart Value Generation by Building Efficiency and Energy Justice for Sustainable Living

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DELIVERABLE 5.3

Report on "must-read" factors in policy design to tackle energy poverty through PED creation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Actions, Innovative Training Networks, Grant Agreement No 812730.

Document Information	
Grant Agreement:	8120
Project Title:	Human-Centric Energy Districts: Smart Value Generation by Building Efficiency and Energy Justice for Sustainable Living
Project Acronym:	Smart-BEEjS
Project Start Date:	01 April 2019
Related Work Package:	WP 5. Evidence-based policy propositions to tackle energy poverty through PEDs
Related Task(s):	Task 5.2. Influencing the regulatory framework for tackling energy poverty through PEDs
Lead Organisation(s):	RWI, University of Basel, University of Nottingham Trent
Submission Date:	31 July 2021
Dissemination Level:	Public

Modification History

Date	Submitted by	Reviewed by	Version (Notes)
31 July 2021	Kostas Galanakis	The Editors & Annika Sohre	Original

Author contribution statement:

Hearn Adam, Marggraf Clemens and Lamonaca Luca (in alphabetical order) conceived and wrote the first draft based on initial literature review and analysis of case studies;
Hearn Adam and Marggraf Clemens (in alphabetical order) reconceived and wrote the final draft based on editors' and reviewers' comments and added further literature and case studies analysis;
Galanakis, Kostas and Ackrill, Robert analysis of material, conceptualisation, review and editorial supervision of the final draft.

Document Editors:

Galanakis, Kostas: Nottingham Business School, Nottingham Trent University.
Ackrill, Robert: Nottingham Business School, Nottingham Trent University.

With acknowledgement:
Luigi Bottecchia, EURAC and Nicolas Caballero, EURAC for the useful discussion regarding the conceptualisation of the must-read factors.
Maria Lujan, Nottingham Trent University, for information regarding the section on energy advice, suggestions of case studies and reviewing the relevant sections of the document.
Pietro Zambelli, EURAC for supporting the organisation of the work.
Annika Sohre, University of Basel, for final review of the draft.

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Graphical Abstract

Must-read Factors to Reduce Energy Poverty with Positive Energy Districts (PEDs)

Definitions

Energy Poverty *is defined as a household's inability to meet its energy needs.*

- ***Positive Energy Districts:***
- *Aim to produce more energy than they consume.*
- *Are powered by renewable energy*
- *Offer affordable living.*
- *Can help to reduce Energy Poverty*

Positive impact redevelopment versus Gentrification

This can be achieved through introducing rent caps, establishing generous quotas for social housing and reflecting local needs and demographics.

Energy Advice

Impartial advice prior to, during and after the installation of ICT, provided by local advisors who are best able to recognise those suffering from energy poverty.

Fair and inclusive financing for deep renovation of districts

Achievable through legislating to make certain minimum standards of retrofitting necessary, incentivisation of "neutral" third party intermediaries, provision of a low-cost repayment mechanism.

Support a shift in the individuals energy consumption behaviour.

Incentivisation of behaviour change coupled with financial assistance when those in energy poverty are adversely affected.

Encourage and empower Renewable Energy Communities

Improved by tasking local authorities with the creation of RECs, ceding of municipal roof spaces for PV, encouraging community involvement, and the provision of an appropriate local governance framework.

Further information and full document:

Inclusive Mobility

Achieved through affordable and accessible public transport, introducing comprehensive soft mobility plans, and reducing the need for private personal mobility

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Actions, Innovative Training Networks, Grant Agreement No 812730

Executive Summary

The main aim of this brief is to encourage policy makers and key stakeholders working on the creation of Positive Energy Districts (PEDs) and similar low carbon initiatives to incorporate energy poverty reduction within their district design.

Energy poverty mitigation and policies that reduce the impact of climate change are closely linked but have remained relatively separate in terms of policy planning[1] despite their intersections. Ensuring that reducing energy poverty does not, in turn, increase emissions is possible through synergistic policies. On the other hand, disjointed thinking within the policy design and implementation cycle could undermine attempts to reduce energy poverty.

The PED programme in the EU Strategic Energy Technology Plan (Set-Plan) aims to reduce GHG emissions from urban areas, as part of the broader energy and climate strategies of the EU[2]. Urban areas are acknowledged as major sources of GHG emissions, and PEDs have a target of optimising energy efficiency, flexibility and production aiming towards both climate neutrality and an energy surplus. One of the guiding principles of PEDs is a focus on affordability, and the prevention of energy poverty. Owing to the synergy in goals between reducing energy poverty and creating PEDs, planning and developing PEDs with energy poverty in mind assists in integrating policies that make PEDs more attractive for cities and citizens.

In order to develop and situate our insights we use an energy justice framework and rely on the policy design cycle to identify necessary must-read factors, drawing from scientific papers and grey literature on different PED projects.

Our research reveals that energy poverty is not considered in a uniform way across the EU. In order to ensure that energy poverty and PED creation are approached synergistically we have identified a number of must-read factors that can play a significant role either at the stage of policy design or policy implementation. Considering each of these factors will assist policymakers in establishing PEDs that are fully inclusive and have a long-term positive effect on energy poverty mitigation. In summary:

1. **Positive impact redevelopment versus Gentrification.**

This can be achieved through introducing rent caps, establishing generous quotas for social housing and reflecting local needs and demographics.

[1] D. Ürge-Vorsatz, S.T. Herrero, Building synergies between climate change mitigation and energy poverty alleviation, Energy Policy. 49 (2012) 83–90.

[2] White-Paper-PED-Framework-Definition-2020323-final.pdf, (n.d.). https://jpi-urbaneurope.eu/wp-content/uploads/2020/04/White Paper-PED-Framework-Definition-2020323-final.pdf (accessed April 9, 2021).

2. **Fair and inclusive financing for deep renovation of existing districts**

Achievable through legislating to require certain minimum standards of retrofitting, incentivisation of “neutral” third party intermediaries, provision of a low-cost repayment mechanism.

3. **Encouragement and empowerment of energy communities.**

Improved by tasking local authorities with the creation of Renewable Energy Communities (RECs), ceding municipal roof spaces to PV, encouraging community involvement, and providing an appropriate local governance framework.

4. **Avoid, shift and improve transportation.**

Achieved through affordable and accessible public transport, introducing comprehensive soft mobility plans, and reduce the need for private personal mobility.

5. **Energy advice on the doorstep**

Impartial advice prior, during and after the installation of Information and Communications Technology (ICT), provided by local advisors who are best able to recognise those experiencing energy poverty.

6. **Support a shift in the individuals energy consumption behaviour.**

Incentivisation of behaviour change coupled with financial assistance when those in energy poverty are adversely affected.

These factors may mean that initial set-up costs for PEDs are higher than expected, but this is offset by the numerous long-term benefits that flourishing, inclusive communities are able to offer, in line with UN 2030 Agenda for Sustainable Development notion of “Leave No One Behind”.

Keywords:
Energy poverty, energy justice, Positive Energy Districts (PEDs), policy design, retrofitting, energy efficiency, gentrification, inclusive finance, Energy Communities, mobility, energy advice, energy consumption behaviour change

A. Defining the concepts of PEDs and energy poverty

Positive Energy Districts (PEDs) were conceived as part of the Smart-Cities concept, as part of the need of decarbonisation of urban areas in Europe. However, the potential effect that such initiatives might have on energy poverty has been noted and is debated internationally [1]. The initial aim, outlined in the European Strategic Energy Technology Plan (SET-Plan), Action 3.2 "Smart Cities and Communities"[2], is to create 100 PEDs by the year 2025, with an emphasis on replicability in order to significantly assist the EU in meeting its carbon reduction goals. JPI Urban Europe defines Positive Energy Districts (PEDs) as

> "*Energy-efficient and energy flexible urban areas or groups of connected buildings which produce net-zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require the integration of different systems, infrastructure and interaction between buildings, users and 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*" [3]p4

The creation of a PED has been linked to six specific building blocks [2]:

1. A PED is embedded in an urban and regional energy system, preferably driven by renewable energy, in order to provide optimised security and flexibility of supply.
2. A PED is based on a high level of energy efficiency, in order to keep annual local energy consumption lower than the amount of locally produced renewable energy.
3. Within the regional energy system, a PED enables the use of renewable energy by offering optimised flexibility and in managing consumption and storage capacities on demand. Active management will allow for balancing and optimisation, peak shaving, load shifting, demand response and reduced curtailment of RES, and district-level self-consumption of electricity and thermal energy.
4. A PED combines 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. E.g., PEDs facilitate increased EV charging capability within the district and ensure that the impact of EVs on distribution will be minimised by using local generation where possible.
5. A PED makes optimal use of elements such as advanced materials, local RES and other low carbon energy sources (e.g., waste heat from industry and service sectors, such as data centres), local storage, smart energy grids, demand-response, cutting edge energy management (electricity, heating and cooling), user interaction/involvement and ICT.
6. A PED should offer affordable living for the inhabitants.

Hence, a PED is defined as a district with annual net zero energy imports, and net zero CO_2 emissions, working towards an annual local surplus production of renewable energy. The district must also be characterised by energy efficiency measures and should offer affordable and good living standards to its inhabitants.

POLICY DESIGN AND IMPLEMENTATION CHALLENGE

Would designing for PEDs exclude energy poor, or alleviate energy poverty?

This last point is significant in the context of energy poverty. On the one hand PED creation could be designed to exclude the energy poor, lead to gentrification of districts that see the energy poor marginalised in districts yet to be modernised. On the other hand, there is the potential for the transformation of districts to significantly alleviate energy poverty. The latter would mean creating districts in which energy efficiency measures reduce energy demand, energy supply is managed by community owned renewable sources, serving as a source of wealth to further counter vulnerability. The JPI Urban Europe White Paper [3] specifically mentions in its guiding principles for PEDs the fundamentals to make them more attractive to citizens and cities: quality of life; inclusiveness (with special focus on affordability and the prevention of energy poverty); sustainability; resilience and security of energy supply for all.

Therefore, the purpose of this paper is to detail the most important factors to consider during policy design and implementation for PED creation, in order to simultaneously reduce energy poverty and achieve GHG emission targets. The aim is to encourage policy makers who are creating PEDs or PED-like areas and key stakeholders to integrate energy poverty mitigation fully within their design.

This dual target policy design enforces a need to understand the added value of PED development beyond decarbonising the energy system. These facets of value leverage attention on the local energy generation and participation consideration, the scale of intervention, the level of return and improved wellbeing of residents, increased job creation, increased community engagement and, crucially, the potential eradication of energy poverty. The research team recognises that the decarbonisation of urban areas as a target alone, probably could be achieved in a cost-effective way by creating large scale developments of renewable energy production such as PV farms, on- or off-shore wind, and maintaining the central nature of distribution of the energy system. However, multiple studies have shown the benefits from local, decentralised, energy generation. For example, placing PV panels on every suitable roof in Catalonia, Spain, would provide around 50% of the energy required to power urban areas ([4]:p10). Therefore, there is scope for different thinking and radical policy value prioritisation.

Energy poverty[3], together with climate change and security of energy supply, has been identified as one of the major transformation challenges that need to be faced simultaneously within the climate and energy nexus [5]. It is a term which often encompasses fuel poverty and energy vulnerability and is generally used to refer to households that are unable to afford adequate levels of energy needs [6]. Since the 1980s there has been growing awareness of energy poverty within developed nations and a significant body of research into energy poverty in EU countries. Within the EU, energy poverty is believed to affect at least 9.8% of households in the EU27 [7]. The Observatoire Nationale de la Precarité Energetique [8] statistics office in France estimates 3.6 million households are energy poor in France alone. The EU Energy Poverty Observatory [9], which is part of the Energy Poverty Advisory Hub (EPAH), proposes a set of indicators[4] to identify energy-poor households, which are applicable on a European-wide basis and which allow for national variations in standards and definitions based on their own context [11]:

- Households where the share of energy expenditure to income is double or more the national median;
- Households where energy expenditure, in absolute terms, is less than half the national median;
- Share of the population that is not able to warm their home adequately (Self-reported levels of thermal discomfort);
- Share of population that experience arrears on utility bills over the past 12 months. (Self-reported areas on utility bills over the past 12 months).

So far, very few member states have a national definition of energy poverty (notably Ireland, France, and Slovakia, plus the UK), but there are multiple and varied attempts to reduce energy poverty across the continent.

Energy poverty is seen as a series of interrelated problems driven by general poverty and inequality, poor-quality and inefficient housing [12], ownership of the property (tenants are more vulnerable), composition of household, health conditions and professional status of the residents [22-25]. Day, Walker and Simcock [13] and Middlemiss et al. [14] examine energy poverty using the capabilities framework approach, and define it as being the **lack of access to sufficient energy services.** They also make a clear link between energy poverty and its consequences, seeing energy poverty as resulting in individuals and households being unable

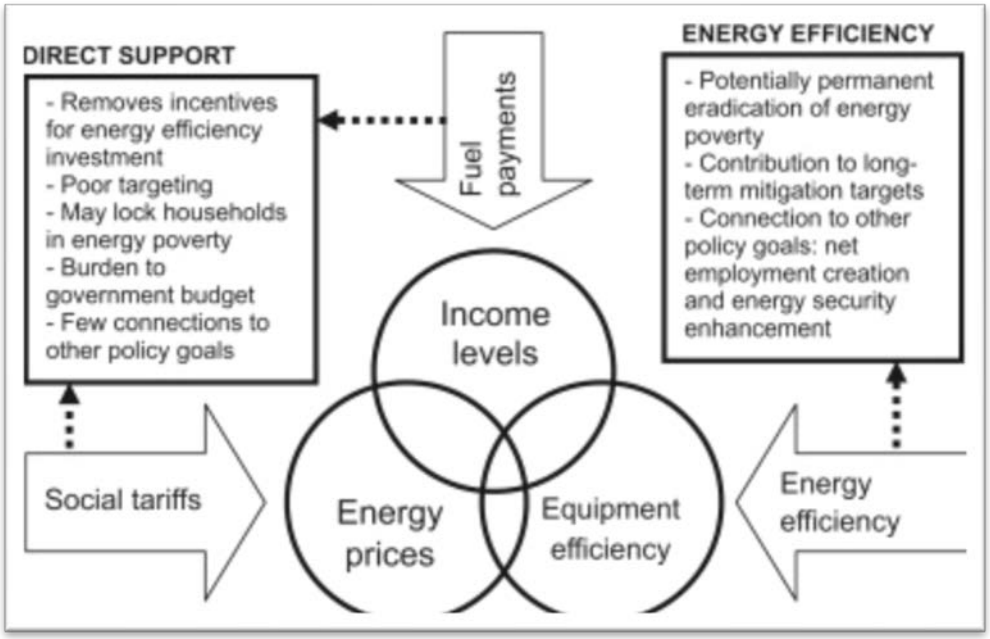
[3] Often known as fuel poverty.

[4] However, EPOV suggests a further 24 secondary indicators. EPOV makes it clear that energy poverty is a multidimensional concept and is often measured using multiple indicators. EPOV recommends examining expenditure, self-reported assessments of comfort, and direct observations if possible [10].

to "*realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services*" [13]:p260]. Furthermore, it is crucial to recognise that energy poverty is often hidden [15–17] because individuals might not self-identify as energy poor. Kearns et al. [18] examine the role of occupant behaviour as a driver for energy poverty. They focus on energy efficiency, support networks and mental health issues as worthy of examination, but also identify **behaviour** as a fourth major driver of energy poverty [18–20]. However, behaviour alone cannot explain energy poverty, and in the light of hidden energy poverty where those affected already under-consume (often in what is referred to as the "heat-or-eat dilemma" [21]), expecting those in energy poverty to adapt their behaviour is not likely to be a successful approach.

Research into the connection between energy poverty and climate change mitigation [22] makes clear that aspects of PED creation, such as energy efficiency, are significant drivers of potential energy poverty mitigation as well as contributing to long term climate change mitigation (Figure 1, below). It can be argued that although energy poverty is connected to income levels, energy prices and efficiency, by improving energy efficiency sufficiently the need for direct support can be diminished, freeing funds for further energy efficiency improvements.

Figure 1 Contributing factors and policy entry points to fuel poverty and their relation to climate change mitigation from Ürge-Vorsatz, Tirado-Herrero [22]



B. Methodology

In order to identify suitable factors to consider, we drew on observations of practice together with a literature review, in which we identified research based on searches using the term "Positive Energy District" or "PED", as well as a number of related terms from preceding low carbon urban developments such as eco-quartier, and 2000 watts. This was coupled with a review of literature on energy poverty and energy justice, as well as policy design. From an energy justice perspective [23] we examined potential issues that could arise through the unfair distribution of benefits and burdens, lack of recognition and misrecognition, and procedural justice issues [24,25]. However, in the context of PEDs we also considered intragenerational and intergenerational justice as well as restorative justice [23], but we excluded issues of global justice as these have a very limited impact on energy poverty within the PED.

The observations of practice were based in part on the individual EU member state National Energy and Climate Plans (NECPs [26]), which were produced for the European Commission and outline energy policies. 13 different member states did not provide objectives or targets for energy poverty mitigation, with a further 10 member states having no specific policies for energy poverty outside of existing social policies (Czechia, Denmark, Finland, Germany, Latvia, Malta, Netherlands, Romania, Slovakia and Sweden). In addition, Poland and Hungary did not recognise energy poverty to the extent of detailing any specific approach, social or otherwise. This may lead to further misrecognition and stigmatisation of those suffering from energy poverty [27]. In many cases, the countries that use social welfare policies to reduce energy poverty are those that suffer from low levels of this. Nevertheless, reducing the issue of energy poverty to one of social welfare may mean that reductions in the numbers of those affected may occur at a slower pace than if addressed as part of energy transition policy. Member States that do incorporate energy poverty inside energy transition plans have specific targets and measures that attempt to directly address energy poverty, including (e.g. in the case of Spain [28]) the potential to pre-empt emerging forms of energy poverty that relate to summer vulnerability (which refers to extreme heat) [29]. Changing the focus of the energy poverty conversation from social welfare to energy transition policy, may enable a more holistic approach.

The areas of interest we identified are the mitigation of gentrification, inclusive financing, novel forms of energy ownership, inclusive mobility, energy advice, and energy behaviour change. These are grouped and presented under the policy design cycle (Table 1, Appendix).

The policy design cycle [30] is an idealised process that explains how a policy should be designed. It can be divided into four phases: Agenda setting, Policy Formulation, Implementation and Evaluation [31,32]. The areas of interest, incorporating energy poverty and decarbonisation aspects, raised a set of specific problem settings. From the review of studies, project reports etc. we identify strategies and actions to deal with these issues and the interrelations between them.

We examine each of these aspects and determine potential methods to mitigate negative impacts in the agenda setting, formulation and implementation stages. Following this, in the evaluative aspect of the policy cycle, we would recommend that the district and the town be evaluated using energy poverty measures such as those recommended by Energy Poverty Advisory Hub (EPAH, formerly EPOV), and that the impact of the PED is also evaluated based on the recommendations made in Deliverable 5.2.

For the planning/design stage of the PED before the district is created, we identify the following key must-read factors to consider:

1. Positive impact redevelopment vs. Gentrification

2. Ensure Inclusive Retrofitting

3. Consider novel ownership models of RET

4. Inclusive and sustainable Mobility

During the implementation phase of the PED, the following must-read factors merit consideration:

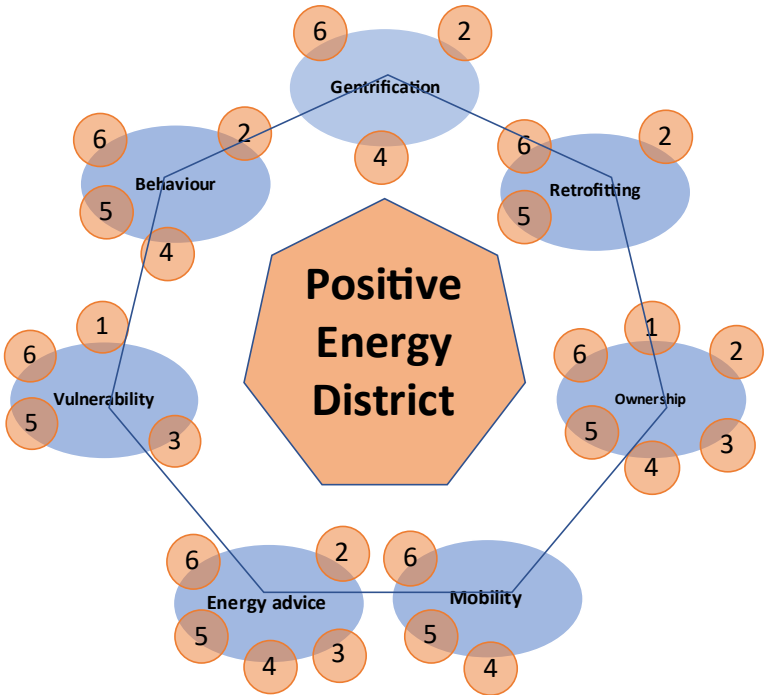
5. Energy advice and Vulnerability to energy flexibility

6. Behaviour change

In Figure 2 (below), we connect the six must-read factors on energy poverty mitigation with the six building blocks. It is immediately apparently that all of these connect to building block #6 (affordable living), as this ties in directly to energy poverty mitigation. However, most of the must-read factors are also connected to building block #4 (creating added value and incentives), which can have an effect on reducing energy poverty,

as well as #5 (optimal use of different elements), as increasing overall efficiency may lead to reduced costs and thus also reduce energy poverty. Furthermore, building block #1 (embedding PEDs in the regional energy system) connects very clearly to the establishment of community energy initiatives, #2 (high energy efficiency) connects firmly with retrofit finance, and #3(energy flexibility) connects to reducing vulnerability and energy behaviour change. Ensuring that the factors we consider are connected to PED building blocks allows us to focus on issues that are directly relevant to PED development and energy poverty.

Figure 2 Connecting the must-read factors with the main PED building blocks



Our approach takes into account the nexus of all six of the must-read factors we consider and the interrelations between these factors often make them mutually reinforcing and beneficial. Thus, for example, increasing community ownership of RET can help to reduce the negative aspects of gentrification.

In the following section we first present each area of interest, identify the specific problem setting and then demonstrate strategies and actions that offer means of mitigation.

C. Must-read factors for coupling the mitigation of energy poverty and decarbonisation

In this section we detail each significant must-read factor, explaining which PED building blocks it is connected to. Once we have presented the area of interest, we identify the specific problem setting. We then demonstrate strategies and actions that provide potential solutions connected to case studies where these issues have been successfully mitigated. Further, we refer to how each of the areas of interest interconnect between each other.

The first four must-read factors are related to the planning phase of the PED. This does not mean that they should not be referred to during the implementation stage, but that they need to be given consideration prior to the creation of the PED itself. The final two must-read factors are best considered during the implementation phase of the PED. All of the must-read factors need to be re-considered during the evaluation phase in order to make any necessary changes to further mitigate energy poverty.

C.1 Positive Impact Redevelopment versus Gentrification

District redevelopment has many benefits in terms of urban revitalisation, stabilisation and reversal of urban decay, energy efficiency improvements, improved green and communal spaces, improved mobility services and is often associated with a reduction in crime rates. However, it can also lead to gentrification, resulting in community conflict, displacement of lower income or rental populations, increased property prices and rents and a reduction in available affordable housing [33]. Gentrification can have a significant impact on energy poverty, displacing vulnerable residents often to districts with poorer quality housing, that might be further away, exaggerating both energy poverty and transport poverty.

GENTRIFICATION

"The process whereby the character of a poor urban area is changed by wealthier people moving in, improving housing, and attracting new businesses, typically displacing current inhabitants in the process."

Lexico.com, powered by Oxford Dictionaries

Offering affordable living to inhabitants, which is the sixth PED building block, is a major issue when redeveloping a district. The definition of affordability, however, varies significantly between European States[5], and is often coupled with quotas for minimum levels of social housing within a district, rent caps and controls, and tenant and ownership protection regulations at national level. The effects of a vague notion of affordability can include the exacerbation of the displacement of lower income households. Eco-districts tend to see concentrations of high-income residents [35], which could be seen as "green" gentrification [41], arising from the creation of added value eco-services such as bike paths, green spaces, and attractive housing stock. In cases such as Letnica, Gdansk in Poland, the lack of engagement with residents, contributed to waves of displacement. The first wave was a forced displacement, as some buildings were demolished, with ordered relocation. In a second wave, some residents were displaced when their buildings were renovated and new financial barriers created against former residents, such as the requirement for a sizeable deposit in order to be granted the right to a home in the newly developed area [36]. These effects are often coupled with 'touristification' (e.g. Barcelona, Lisbon) [37,38], as these cities become more attractive to visitors and tourism. Data shows that most listings on Airbnb are for entire homes which are rented throughout the year, exacerbating housing access issues and disrupting communities [39].

[5] For example, price/income ration, tenure-related interpretations, market-led or cost-led definitions [34]

In general, across Europe we observe a variety of mitigating policies that set minimum levels of social housing within a district, rent caps and controls, protection for tenants and caps on buy-to-let mortgages for homes within a district [40]. One of the main success stories where gentrification has largely been avoided is the city of Vienna. This is partly because approximately 50% of the building stock in the city is social or municipal housing, with cost-led rental policies and with policies of social sustainability embedded in the urban planning and development regulations [41–43]. The success of the city is reflected in lower mortality rates for Vienna residents compared to other European cities, and the city being ranked as the most liveable city worldwide for 2018 and 2019 [35,44].

The Hunziker district in Zurich, Switzerland [45,46], was created by the "Mehr Als Wohnen" collective [23], formed out of members of 30 housing cooperatives in Zurich. The cooperative decided to ensure that negative gentrification aspects were minimised from the beginning. This was achieved because they were able to:

1. Ensure rents remain approximately 20% lower than other areas of Zurich, hence living in the district remains relatively affordable;
1. Provide an additional 20% of social housing, which is managed and distributed through charities separately to the rest of the district;
2. Reflect the wider demographic of Zurich within the district population. This has been a somewhat contentious move as it also means there are some very wealthy residents. New residents are screened, with priority is given to those that fit the demographic "need" for the district[6].

In the case of the Stimuleringsregeling energieprestatie huursector (STEP) [47] in the Netherlands, financial assistance has been provided directly to improve the energy efficiency of social housing, but crucially, the total costs for the tenants (rent, service and energy costs) has not increased after the renovation.

In cities like Madrid, Rome and Athens community activism, such as the "Yonomevoy" ("I will not leave") group in Madrid [48], fill the regulatory gap, initiating local action for tenancy protection or opening the discussion around new schemes of community energy ownership initiatives [49]. "Yonomevoy" engaged in direct action in order to ensure that about 200 vulnerable residents (mainly elderly) were still able to continue paying rent under their previous contracts, despite the sale of their social housing [50].

Consultation with residents, communities and community-based associations during the planning phases and providing local energy advice with information on consumer and tenant protection rights can reduce negative gentrification effects. These actions (e.g., surgeries and open days to stimulate active engagement) act as a point for informing tenants of their rights and options in the complex net of national and EU regulations and legislation and pro-active engagement for creating positive impact.

To conclude, leaving the effects of PED development to the market forces of supply and demand is likely to result in displacement and exacerbation of energy poverty. Policy design requires a proactive action plan for encouraging positive impacts of PED developments, whilst avoiding the negative effects of gentrification.

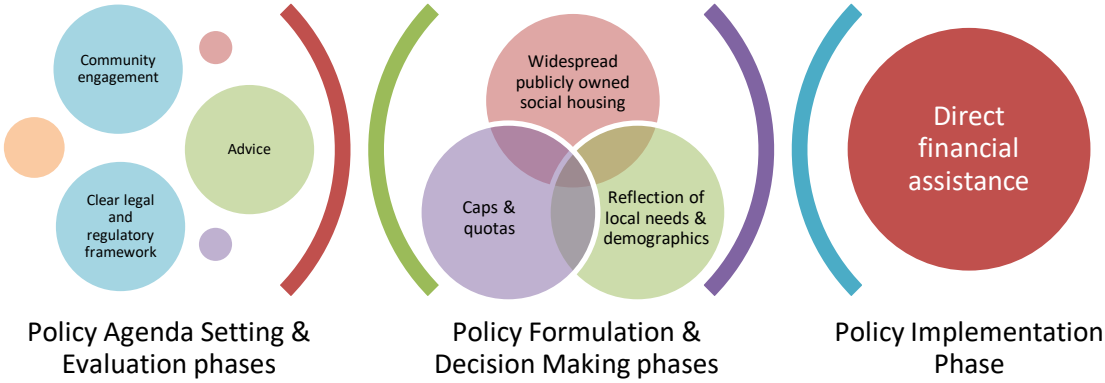
Proposition for Policymakers

In terms of the policy cycle, during the policy agenda setting and evaluation phases, we would encourage the creation of a clear legal and regulatory framework, with clear advice provided to an actively engaged community (Figure 3, below). Engaging the community can best be achieved through numerous different avenues simultaneously, combining face-to-face contact with newsletters and an online presence for example. During the decision-making phases, caps and quotas can be set, and decisions on district demographics could be made to reflect local needs, based on engagement with the community. Establishing

[6] Initially there were issues with attracting sufficient older residents as this was an entirely new district (it was not built on an area where a previous district had existed or in a retrofitted district).

baseline rents which are lower than those in surrounding districts may greatly assist in reducing the risk of gentrification. Finally in the policy implementation phase, direct financial assistance can be considered for those at risk of energy poverty.

Figure 3 Positive Impact Redevelopment Principles



C.2 Fair and inclusive financing for the deep energy renovation of existing districts

Although PEDs are mainly planned as new districts, there is a strong case for creating PEDs in existing districts. This may mean that they are built or undergo deep energy renovation to meet high standards such as PassivHaus [51–53] or Minergie [54,55]. This can include the installation of renewable energy sources (RES) such as PVs, reducing energy cost and providing potential income generation (e.g., from feed-in tariffs). The buildings will, by necessity, be highly energy efficient and more economical to run, as required by the second PED building block. In order for PEDs to become a mainstream concept, there is a clear need to address the retrofitting of existing and historical buildings and installation of such technologies to the existing building stock [56]. Older buildings[7] in existing districts, particularly historical ones (over 100 years old) are often poorly insulated, or in states of degradation, that make retrofitting more costly and difficult to retrofit due to cultural significance, protection regulations and the continuous use from residents and businesses. Historical buildings are often excluded from retrofit actions because of such barriers (e.g. in Italy almost all retrofits occur on post World War II buildings, and an estimated 1,200,000 residential buildings are deemed to be historical [59]). Retrofitting also needs to be of sufficient quality to avoid locking-in properties with less-than-optimal energy performance, and ensure that deep energy renovation is conducted [60].

DEEP ENERGY RENOVATION

"A term for a renovation that captures the full economic energy efficiency potential of improvement works, with a main focus on the building shell, of existing buildings that leads to a very high-energy performance."

Global Buildings Performance Network

[7] This varies significantly within Europe. E.g., in the case of Portugal, 17% of all buildings are classified as old (predating reinforced concrete), often meaning that they are overlooked in favour of easier and more affordable retrofits [57]. In the UK as of 2019, more than 3.12 million owner occupied houses were built before 1919. In contrast, approximately 1.5 million owner occupied houses were built from 2003 onwards [58].

Furthermore, owner-engagement has been identified as one of the key barriers to increased retrofitting [61], with the split incentive meaning that landlords see little benefit in ensuring their properties are retrofitted.

Ensuring inclusive finance, enabling poorer households and those who live in energy poverty to be included in this transformation, most likely living in poorer quality accommodation with reduced energy efficiency, and with the biggest need for renovation [62], is a crucial challenge for retrofitting policies. This measure links directly to the sixth building block of PEDs, to offer affordable living for inhabitants.

The issue of inclusive and fair financing of retrofitting actions – which require high up-front costs to be covered and deal with multiple forms of ownership that is a source of potential conflict – opens a discussion of 'who is to pay for what and how'. Awareness of which financial options are available for residents and institutions is essential in this discussion. Brown et al [63] have codified different forms of financing for residential retrofits in a variety of countries (Table 1).

Table 1 Key features of six archetypes of finance mechanism for residential retrofit adapted from Brown et al [63]

	Feature of Finance Mechanism						
Sort of Finance Mechanism	**Example Schemes**	**Source of Capital**	**Financial Means**	**Project Performance**	**Point of Sale**	**Safety and Underwriting**	**Repayment Channel**
Public Loan/Credit Enhancement	HES and HEEPS equity loan (Scotland)	Government spending	Debt	Minimum CO_2 reduction	Third party finance provider	No security – credit check	Unsecure Loan/ equity release
	KfW CBRP (Germany)	Public Bank	Debt (bonds)		Retail bank	No security-basic credit check	Unsecured Loan
	JESSICA → LEEF (EU→London,UK)	Hybrid – EIB, LEEF & Private lender	Debt		Housing provider	Varies	Resolving phase then full repayment
On Bill Financing/On Bill Repayment	UK(OBR) Green Deal	Third party private sector	Debt	Bill neutrality (Golden rule) Third party finance provider	Third party finance provider	Energy meter & bill history	Energy bills
Property Assessed Clean Energy (EuroPACE)	RE:NEW Financial (EU)	Municipal bond → private capital	Debt (bonds)	None – approved contractor schemes	Contractor	Lien on property & tax bill-based underwriting	Property taxes
Green Mortgage	EMF Green mortgage project (EU)	Covered bond market	Mortgage (equity & debt)	EPC improvement	Mortgage provider	Detailed credit check	Mortgage payments
	Ecology Building society (UK)	Member deposits	Equity				
Energy Services Agreement	RENESCO (Latvia)	ESCO → Public bank	Debt & Equity	Energy performance guarantee	Contractor	Based on ESCO	Energy performance contract
	SEA (Italy)	ESCO → Institutional investor				Based on ESCO & bill payment history	
Community Financing	BHESCo (Brighton,UK)	Member share issue	Equity	None	Contractor	Credit check	Hire Purchase agreement → dividends

Although some of these are clearly only applicable for homeowners (Green mortgage, HEEPS), or those with a sufficient rating (community financing / energy services agreement), there is no reason to assume that residents in these groups are not vulnerable to or suffering from energy poverty, and these could be considered as part of a selection of different options made available to the residents of a district. Those financial mechanisms that do not require property ownership or some form of security/credit check are also those which may be best suited for reaching vulnerable residents who may be suffering from energy poverty.

EuroPACE, [64] offers an interesting potential solution for increasing the uptake of retrofitting, proposing that repayments of financing occur via property taxes which are paid by the resident of the property (not necessarily the owner) [65]. This is based on the USA based PACE programme, which is characterised by voluntary participation, coverage of all costs, long-term financial assistance, and the affixation to the property of the loan [66]. Loan repayments are meant always to be less per year than the savings made through the renovation itself. Further benefits to this programme would be that making these loans available are calculated to increase jobs by an average of 18 new jobs per €million invested. In total for the whole of Europe this could lead to the creation of 3.3 million jobs if the renovation gap of € 185 billion per year were met, a significant win-win solution to reducing energy poverty and combatting climate change.

Currently there are no property taxes that could be used for this purpose in Croatia Cyprus and Malta, and EuroPACE notes that applying this sort of financing in member states that are highly centralised in terms of property taxation such as Estonia, Greece or Latvia, may require significant legislative changes to make this viable. Additionally, in member states where this is viable, there may still be a requirement for legislative changes. This can be seen in the case of Austria which was identified as very adequate but where attempts to pilot this form of financing were deemed unconstitutional. For this form of financing to function there also needs to be robust enforcement procedures in the event of payment delinquency [67].

In the UK, private rented accommodation accounts for 20% of the housing stock and is the most likely not to meet the Decent Homes Standards [68]. In a survey of landlords in the UK only 15% were planning on retrofitting properties and 38% were not compliant with EPC regulations. Research by Miu and Hawkes [68] suggests that landlords would respond most favourably towards retrofits if these were associated with grants, tax exemptions and cashback schemes.

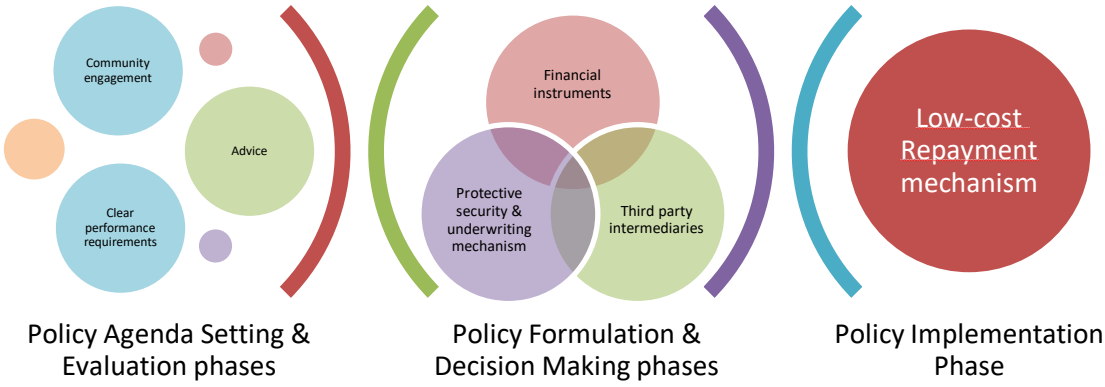
However, there is some evidence to suggest that providing tax deductions for retrofitting is not effective in promoting deep renovation; and that, furthermore, a system whereby intermediaries are incentivised to conduct retrofitting of buildings may be more effective. In the Netherlands, trusted intermediaries [69] focused on ensuring that the best possible longer term low carbon strategy for retrofit was taken, putting forwards different potential suppliers and technologies and establishing mutual agreements. This overcomes issues of trust and complexity which can be barriers to uptake. The Energiesprong government funded programme in the Netherlands [70] is now also being used in France and the UK.

Proposition for Policymakers

There is a clear need for alternative financial models to provide the capital necessary to allow and encourage deep energy renovations [71]. Access to financing needs to be improved, coupled with legislation granting those that live in rental property the authority to embark on retrofitting unless there are good grounds for the owners to veto this. Potential methods to do this could include legislating to make certain minimum standards of retrofitting necessary, but this would need to be coupled with some form of compliance enforcement. Furthermore, an approach that gives the authority to and incentivises "neutral" third party intermediaries may be more successful in the decision-making phase, with a low-cost repayment mechanism for the policy implementation phase (Figure 4).

For those in social housing, the use of direct government spending may be appropriate, whereas for those in private rental properties the issue remains - there is a need to retrofit these buildings despite potential objections from landlords and residents.

Figure 4 Source of capital policy principles



C.3 Encouragement and empowerment of energy communities

The ownership of RET connected to a PED may have a significant effect on energy poverty and is connected to aspects of each of the main building blocks. Community ownership models may help to reduce costs and allow for affordable living, embedding RET locally [72,73].

ENERGY COMMUNITIES

"Empowering renewable energy communities to produce, consume, store and sell renewable energy will also help advance energy efficiency in households, support the use of renewable energy and at the same time contribute to fighting poverty through reduced energy consumption and lower supply tariffs."

European Commission

Under EU directive 2019/944, part of the Clean Energy for all Europeans Package, energy markets have been made to accommodate new forms of energy ownership, including individual prosumers, peer-to-peer energy sharing, Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) [74,75]. PEDs may encompass multiple different forms of energy ownership, from individual through cooperative or utility owned, and the decisions made regarding this could have a long-term impact on energy poverty. The role of Energy Communities in reducing energy poverty has been recognised in the revised Renewable Energy Directive [76]. Tasking local authorities at a municipal level with the creation of these communities would enable greater participation of those that are most vulnerable as these are already identified by the local authorities. Energy production could take place on municipal buildings, and measures could be introduced so that grass-root energy communities incorporate a percentage of disadvantaged families in order to reduce energy poverty.

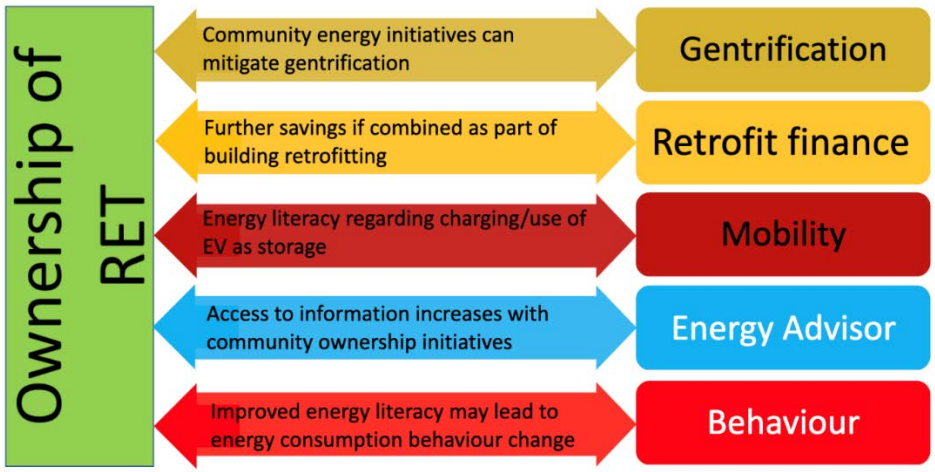
A series of interviews with energy stakeholders conducted in Spain [77] indicates a degree of consensus amongst experts that the creation of Energy Communities could primarily be used as a tool for tackling energy poverty, with local authorities at a municipal level providing a key role in funding, placing of PV (using municipal buildings for example) and deciding to what degree those in energy poverty are included. There is much debate on the ownership of renewable energy sources for PEDs, with some debate on which form of ownership is best [78]. CECS and RECS could provide a significant boost to both PED creation and energy poverty mitigation. Supporting the grassroots creation of CECs could provide a reduction in energy costs to

vulnerable residents, and could even go further and provide a potential income stream, further reducing energy poverty. Additionally, engagement in RECs and CECs is normally accompanied with a significant increase in energy literacy, enabling residents to better manage their own energy consumption.

Under a Business as Usual (BAU) model of energy production, the current mix of utilities will continue to dominate, and it is likely that energy poverty levels will continue to drop as they have been, unevenly throughout the EU. However, the fact that energy poverty increased during the COVID19 pandemic in 2020[8] [80] indicates that a BAU model will not deliver a long-term solution. Indeed, it could be argued that many of the reductions are evidence of EU policy activities that direct national governance on energy poverty [81].

Creating novel forms of energy ownership is not only entirely possible within the context of PEDs but indeed desirable in terms of being in line with the guiding principles of PED creation. Giving the energy poor membership to CECs and RECs could significantly reduce energy poverty. Forms of community energy ownership also connect directly to the other must-read factors. Engaging in these forms of ownership may help to reduce the likelihood of negative aspects of gentrification and could be incorporated into district retrofitting potentially saving time, money and future disruption from later installation (Figure 5, below).

Figure 5 Interconnectivity between new ownership models for RET and the other must-read factors



Some PED-like areas opt for cooperatively owned and run RES (e.g., the Hunziker Areal, Zurich, Switzerland). Others could incorporate private ownership, utility ownership or the creation of energy communities. In the case of the Hunziker Areal, Zurich, this enables the cooperative to set the prices for electricity, and to ensure that energy poverty is addressed locally.

A recent study [78] used a choice experiment to identify ownership preferences of renewable energy technology in PED-like communities in Switzerland, allowing for a number of choices; individual, housing association, cooperative or utility-owned. The results indicated that although there was significant support for utility-owned PV, cooperatively owned renewable energy technologies was preferred by younger segments. Furthermore, the issue of property ownership is recognised as having an effect on decisions regarding energy production technology ownership.

[8] Data from Spain shows nearly 50% increase in those reporting arrears on household bills, and inability to keep the home adequately warm. [79]

The 2018 Greek law N4513/2018[82] on energy communities emphasises a solidarity economy and the reduction of energy poverty that is possible through CECs. Although Greece is so far the only country to do so in the EU, both Bulgaria and Hungary have planned to do so in upcoming legislation and the public consultation on energy communities in Spain in December 2020 may lead to a similar development.

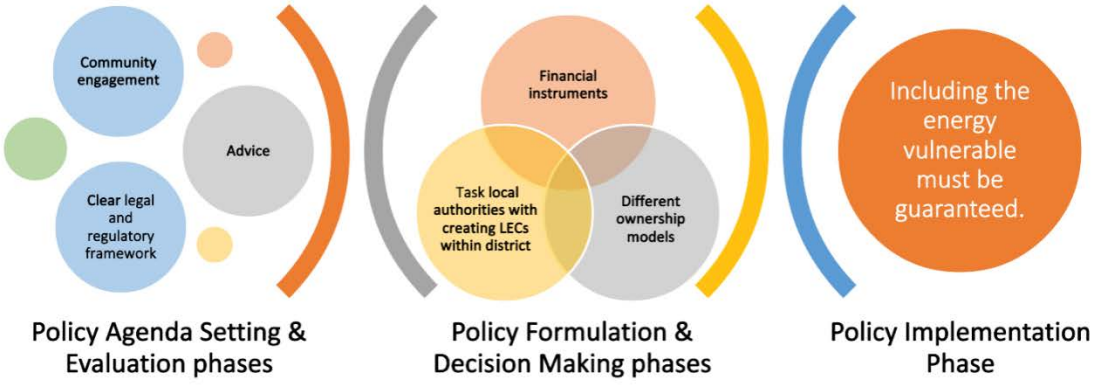
In the case of Viladecans, Spain, the Vilawatt programme [83] now aims to create a series of Citizen Energy Communities in the areas where energy poverty is greatest, using municipal buildings (sports halls, schools etc) as well as apartment blocks, for the placing of an initial 1MW of PV panels. Energy will be provided first and foremost to those identified as suffering from energy poverty.

Similarly, the Barrio La Pinada PED, Valencia, Spain [77] has created participatory groups of potential future residents who are discussing the possibility of creating an Energy Community within the district to help meet their energy needs.

Proposition for Policymakers

The role of Energy Communities in reducing energy poverty has been recognised in the revised Renewable Energy Directive [76]. Tasking local authorities on a municipal level with the creation of these communities would enable greater participation of those that are most vulnerable as these are already identified by the local authorities. Energy production could take place on municipal buildings, and measures are already in place to ensure that energy communities in the forms of both RECs and CECs allow access to vulnerable and low-income households [84] (although the extent of this varies in each member state). In order to make full use of RET in a PED, the community must be involved, an appropriate framework must be in place and guidance on how to use RET is essential, especially for people who are not tech-savvy (e.g., older people). The inclusion of energy-vulnerable persons is ensured by considering a range of measures, e.g., financial instruments or offering different ownership models (Figure 6).

Figure 6 Policy cycle synthesis of local energy initiatives with PEDs



C.4 Avoid, Shift, Improve Transportation

SUSTAINABLE TRANSPORTATION

A shift to sustainable transport plans is essential to significantly improve the overall quality of life for residents, by focusing on inclusiveness, environmental protection and new mobility options.

The "Avoid, Shift and Improve Transportation" concept is an important component of a PED in order to reduce emissions. Avoidance refers to measures that reduce the need for transportation, while shift deals with interventions that shift either to public means, active modes or e-micromobility (e.g., e-bikes and e-scooters). Improvement indicates "green" vehicles (e.g., electric and hydrogen vehicles) or services for shared mobility. However, this holistic conception is often neglected in transportation planning decisions.

Transportation planning decisions involve trade-offs between increased mobility (how fast and far someone can travel) versus local accessibility. For instance, interventions aiming to increase mobility, such as expanding roads and providing generous parking, create a more sprawled land use pattern that is less accessible, and redesigning streets to prioritise speed can create disagreeable conditions for walking and cycling ("barrier effect" [85]).

Designing PEDs so that there is less of a requirement for transportation in the first place, offers the potential to avoid related emissions and costs [86]. This may mean designing districts so that buildings have shared residential/commercial use such as in the Hunziker Areal [23] and providing local space for businesses.

Currently, transit-oriented development (TOD) is considered by many urban planners as a solution to a variety of urban problems, e.g., traffic congestion and air pollution [88]. This concept deals with the development of urban areas in order to design them in such a way that they allow as much residential, commercial and recreational space as possible within walking distance of public transport. However, increased accessibility due to proximity to transit is often capitalised in land and housing prices, which might lead to the displacement of the low-income population that would benefit most from transit connectivity [89].

Further examples regarding the shifting to sustainable motility are the electrifying of train-lines in Baden Wurttemberg, Germany, as well as the introduction of hydrogen fuelled buses e.g., in Bolzano, Italy or the 10mins cycles of active mobility in Torres Vedras, Portugal, all of which help to create higher living standards for the general community. Other PED-like areas such as Alkmaar in the Netherlands and Lviv in the Ukraine are also investing in environmentally friendly mobility infrastructure. The former city built a cycle path that is equipped with integrated solar panels, which light their surroundings at night, while the latter city built 15 km of new cycling infrastructure, which includes bike lanes and bike parking [97].

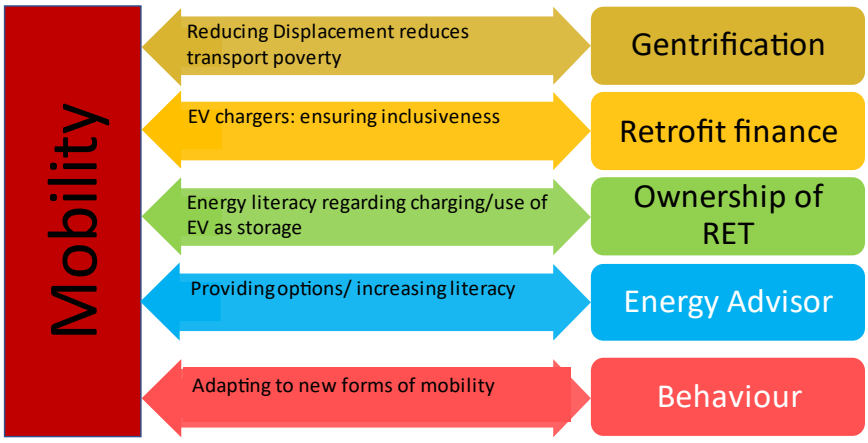
Additionally, electrification of transportation is becoming more and more common and most PEDs have some form of mobility plan that includes providing charging points for electric vehicles (EVs), as well as testing of innovative forms of transportation such as autonomous (driverless) vehicles (AVs). However, although these actions have a high profile and attract publicity, they often reach only the wealthiest segments of the population and require significant investment. For example, a study by Reaños and Sommerfeld [112] found that only 10% of people in the lowest income group would consider buying an electric car, compared with nearly a quarter of those in the four highest income groups. According to the authors, one explanation is that low-income drivers living in rural areas feel particularly disconnected from the new electric car era, as a large majority think they cannot afford an electric vehicle and rely on public transportation. Those that can afford it, on the other hand, face a lack of charging stations.

Both of these issues are related to multiple PED building blocks (#4, #5 and #6). When planning a PED, it is essential that mobility also be taken into account to enable a sustainable life. This means, among other things, that citizens have optimal access to low-energy and, as far as possible, emission-free means of transport at all times and without great effort. For example, enabling the proximity of public transport stops or guaranteeing an infrastructure regarding active means of transport. In addition, the inclusion of all people should also be considered in terms of financial aspects.

Regarding the potential problem of lack of inclusion and accessibility, one solution might be the implementation of a new planning paradigm, which also considers a comprehensive accessibility analysis in order to quantify accessibility impacts [91]. This makes it much easier for decision-makers to identify which mode of transport guarantees speed, inclusivity and sustainability.

Some PED-like areas have implemented interventions which consider the "Avoid, Shift and Improve Transportation" concept. For example, the cabildo of El Hierro (Canaries, Spain [71]) created a sustainable mobility plan that includes amongst other things a subsidised public transport (93% of costs are subsidised), a car share programme for public servants and a taxi share programme. Reininghaus [93], a district of Graz, implemented car free areas and promotes public transportation as an option for car owners by providing residents with an improved mass transit connection to other districts and a 90% subsidy of the costs for a transferable public transit ticket for the first five years of residency. The Hunziker Areal, Zurich, is even stricter with a ban on car ownership (exceptions are made for shift workers and those with disabilities) [87].

Figure 7 Interconnections between Mobility and other must-read factors



Improving sustainable public transportation can be connected to the other identified must-read factors.

Retrofitting homes, for example, often includes the installation of charging points for electric vehicles at home. Therefore, e-vehicle owners have easier access to charging stations and a greater incentive to use this sustainable mode of transport. Furthermore, citizens living in rural areas, where public transport is often not available, can benefit from the use of e-charging stations to be more flexible and independent in their daily lives. Thus, e-charging stations also contribute to inclusion.

Vehicle to Grid (V2G) describes the system of feeding electrical energy from the traction batteries of plug-in electric vehicles (PEV), such as battery electric vehicles (BEV), plug-in hybrids (PHEV) or hydrogen fuel cell electric vehicles (FCEV), back into the public electricity grid. This has been trialled in the UK by the energy

company OVO in conjunction with Nissan [90]. Furthermore, the concept includes smart communication with the electricity network regarding curtailing charging when In this way, the sector coupling provides relief in times of high grid load and reduces the risk of a power outage [91]. In Europe there have been some trials already. Furthermore, electric vehicle batteries can be given a second life. This involves recycling the batteries that no longer meet the requirements of automotive applications such as in Évora, Portugal [92] , but which could still be used for less demanding grid-based energy storage applications [93]. This can also reduce energy vulnerability.

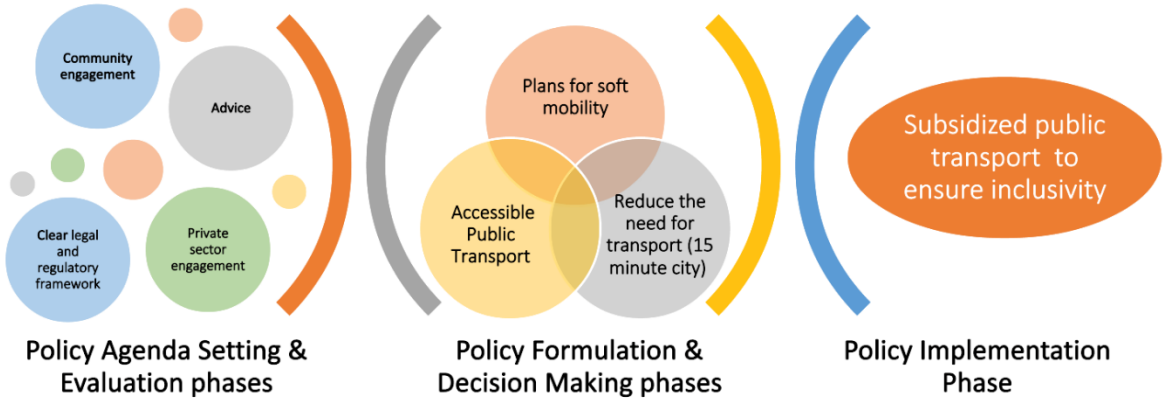
Energy advisors can also help to educate citizens regarding energy literacy and sustainable mode of transport. Thus, owners might be more interested in understanding energy flows, how much energy they use and where the energy comes from. Furthermore, energy advisors can also provide information about the benefits of owning sustainable energy technologies and the current state of the art regarding sustainable energy systems which might be overwhelming and off-putting for some citizens. For example, if consumers think that they do not have a better understanding of electric vehicles than other people, they might prefer a vehicle with a different technology for purchase[94].

Additionally, behaviour also plays a crucial role in terms of using sustainable transportation. There are various factors influencing travel behaviour. For example, socioeconomics, attitudes and motivation [95]. Therefore, policy makers have to be aware of them when creating policies.

Proposition for Policymakers

In order to follow the concept and make transport more environmentally friendly, several conditions need to be met, such as cooperation between different stakeholders and the legal framework. Based on this, policies can be created, including residential urban concepts aiming to mitigate traffic (e.g. 15 minute city [86]), to finally ensure the implementation of an inclusive intervention (Figure 8).

Figure 8 Mobility policy principles



Conventional transport planning evaluates transport system performance based primarily on automobile travel conditions, using indicators such as average traffic speed and congestion, but neglect the "Avoid, Shift and Improve Transportation" concept. However, this conception is essential in order to reduce emissions. A PED supports this approach by creating the conditions to underpin it.

C.5 Energy advice at the doorstep

ENERGY ADVICE

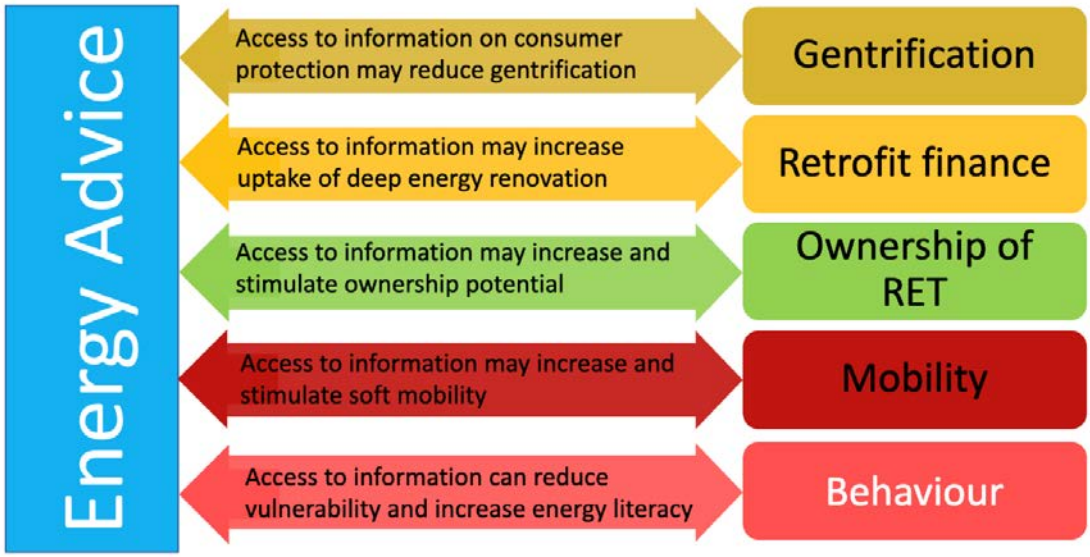
"Local and Regional Authorities should work with partners to ensure a single point of contact is in place for those in energy poverty to access support."

STEP-IN White Paper for Energy Policy Makers

One of the characteristics of PEDs and PED-like areas is increased digitalisation and use of the IoT (Internet of Things[9]). This is of particular interest for reducing energy poverty as the IoT allows for efficiency measures such as easily programmable features (e.g., timers, reducing heating based on weather predictions) that also enable cost reductions for the end user. Smart meters have been treated with suspicion by some consumer groups, but have also been shown to have an effect on energy consumption behaviour which could potentially mitigate aspects of energy poverty [96]. A recent UK survey of 2000 people in vulnerable circumstances with smart meters found that 61% claimed it made managing their energy consumption easier [97]. Poor information or poor access to information is recognised as a barrier to improved energy efficiency in many European countries such as Sweden[98] France [99], and Austria [100].

The increasing digitalisation of energy and spread of the Internet of Things (IoT) [101] may well result in improvements in energy efficient usage of devices as consumers are more able to monitor their energy consumption. However, this also comes with increased risks, often associated with cybersecurity [102]. In order to benefit from any potential energy poverty mitigation effects, ICT can be combined with energy advice, that can help consumers to better use resources in order to ensure comfort is not compromised [103].

Figure 9 Interconnectivity between energy advice and other must-read factors



[9] **IoT,** the networking capability that allows information to be sent to and received from objects and devices (such as fixtures and kitchen appliances) using the Internet https://www.merriam-webster.com/dictionary/Internet%20of%20Things

Energy advice connects to the other must-read factors (Figure 9, above) in that it can increase energy behaviour change, reduce vulnerability and allow new mobility forms to be better taken advantage of, by increasing energy literacy. Furthermore, access to information and advice may help to increase the uptake and participation in community energy and retrofitting initiatives, as well as potentially provide a community hub for information which could have an impact on gentrification.

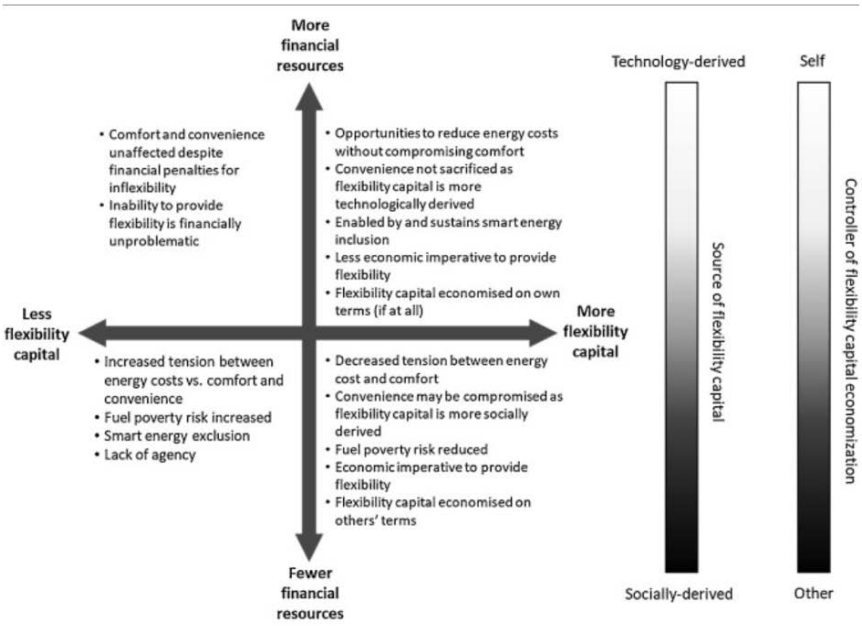
Energy poverty advice is often able to achieve a high positive impact, but there is an issue in that often, vulnerable residents may be hard to reach [104], for example, elderly members of society who do not have easy access to, or are unfamiliar with, technology, or residents who do not self-identify as energy poor, or who even when doing so choose not to seek help owing to fear of stigmatisation. When energy advisors reach out to the vulnerable population and communities directly, e.g., visit properties or community organisations such as religious assemblies, often demonstrate a significantly higher impact. However, it must also be noted that without these interventions, the use of ICT such as smart meters may provide consumers with information on their energy use, but do not necessarily change patterns of consumption behaviour.

The Horizon2020 STEP-IN project [105] included living labs in Greece, Hungary and the UK and reported the EPOV statistic of 15.1% of Europeans living in hidden energy poverty in 2010, referring to those that were considerably under-consuming energy but may not necessarily identify themselves as energy poor. The STEP-IN living labs relied on local experts to help identify those that may need energy advice and assistance but who were at times not necessarily considering this. This included reconnecting homes to utilities that had spent a number of years disconnected and for whom living without access to energy had become the norm [106].

Energy advice given in Spain by energy communities is reported to have a significant effect in reducing energy poverty, largely because this advice often centres on informing consumers about different energy tariffs and companies in order to provide a fuller and more impartial picture [77]. (This is also the case with energy advice given via energy cooperatives such as GoiEner in Spain [107]. This is in line with research from the UK where energy advice given via local and community organisations was shown to be effective [108]. A human-centric perspective in which residents are given the information (and potentially training) that is necessary to make the best choices is likely to have an effect on reducing energy poverty. One of the added benefits of a local community approach is that those suffering from hidden energy poverty may be better recognised and afforded the assistance they need. This advice could be provided by a state-funded energy advice centre, or in conjunction with NGOs in order to ensure that consumer trust is high and impartiality is guaranteed.

There has been research to indicate that energy flexibility may mean vulnerable people suffer more financial and non-financial impacts [109]. Flexibility justice [110] refers mainly to the need for demand to be influenced in order to match supply rather than vice versa, and has existed in the form of variable price structures for over a century. However, increasing the share of renewable energy technology in the energy mix may necessitate an increase in energy flexibility which may result in potential difficulties for those with less financial resources (Figure 10 below).

Figure 10 Generalized representation of the interaction between flexibility capital and financial resources (affluence) from Powell and Fell [110]



In terms of active energy management via pricing, one of the key elements is to ensure that it is inclusive, and that the community has a say in the shaping of this energy management. It is not just about comfort and convenience; there is a very real risk that energy poverty will increase and citizens will be disempowered. On the left-hand side of Figure 10 are people who are unable to be flexible and who are therefore exposed to additional costs, or are unable to take advantage of any benefits afforded by energy flexibility.

In the case of Spain, active energy management in terms of a new time-based variable price structure commenced on June 1st 2021 [112]. This reduces the fixed payment part of electricity bills by 25% but is coupled by a 3-zone system, where charges will differ drastically between what is referred to as the "valley" times, mid-times and peak times (roughly 3 times the price of valley times per kwh). The decision to adopt this new system is intended mainly to change energy consumption behaviour and ensure that demand modulates to follow a more renewably based energy supply. However, the impact on those living in energy poverty has yet to be determined, and it is estimated that it will increase payments by over 15% for at least 10 million households [113]. Active energy management via pricing has also been trialled in the UK where the Octopus energy company has paid Agileoctopus [114] customers to consume energy at times when RET would otherwise have to be curtailed due to overproduction.

Potential policies which could assist in mitigating any negative effects of active energy management in the energy poor involve policies which direct financial assistance to those suffering from energy poverty, both directly as well as through offering energy efficiency improvements within the home, as in the examples detailed below, which could also be managed through an energy advice centre.

A good example of this can be seen in the case of El Hierro, Spain, where financial support measures are available for those most vulnerable to energy poverty. This is determined based on a number of measures such as total household income, number of vulnerable (elderly, disabled and children) in the home, and number of unemployed people in the home. Support is given in a three-tiered system of financial assistance for electricity bills. Those in tier I are eligible to receive up to €495 per year in assistance, those in Tier II can receive up to €330, and those in Tier III can receive up to €165 [115]. Support is determined on a points-based system, with those placed in Tier I needing to be allocated 60 points, tier II: 45, tier II 30 points.

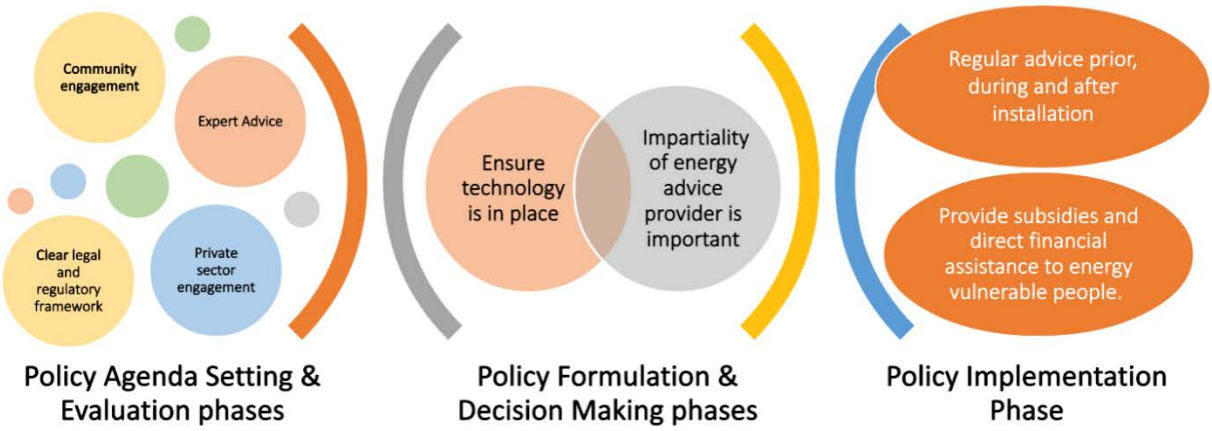
A second approach adopted in El Hierro id to offer significant price reductions to energy vulnerable families in order for them to replace household devices with more efficient ones [115]. This includes fridge, freezer, dishwasher, hob, electric oven, water heater, microwave, hairdryer, and LED bulbs. If districts are transitioning into PEDs, they can adopt similar approaches to that of El Hierro in order to simultaneously reduce energy consumption whilst informing consumers and affecting change in consumer energy behaviour, leading to significant reductions in GHG emissions and energy poverty.

An alternative approach is that put forward by the Papillon project in Flanders, Belgium [116], whereby vulnerable citizens are able to lease energy efficient devices for a small monthly sum which includes warranty and servicing. This enables vulnerable citizens to access devices that would be otherwise unaffordable to them and in turn also make what could amount to significant savings [117]. The added benefit of this approach is that it encourages a circular economy, in which appliances may be used by several customers during their lifetime before being recycled. Making this kind of approach available in districts that are transitioning to become PEDs further reduces energy poverty, whilst also engages consumers in their own energy use, leading to possible behaviour changes.

Proposition for Policymakers

Ensuring that those who are most vulnerable to energy poverty are protected from the potential downsides of energy flexibility is essential, and policy makers should consider increasing citizen participation in decision making processes together with targeted financial support and assistance in energy efficiency measures.

Figure 11 Energy advice policy principles



Policymakers can consider creating an energy advice hub within the PED which actively engages residents through energy advice days, home visits and workshops. This could be state-run or managed by an NGO. In order to harness the benefits of ICT, it is important to actively engage with the community to identify those that are most vulnerable to energy poverty and offer tailored solutions which include information and advice on how to use technology, to ensure optimal energy consumption patterns (Figure 11, above). One of the ways this can be achieved is by providing impartial energy advice that is embedded in the community, ensuring that timely advice is given, including through home visits, as well as direct financial assistance which may help to increase energy poverty mitigation. This can also help to reduce any negative effects brought about through energy flexibility requirements. Whilst this may be mitigated to some extent through the use of energy storage, this is still in its infancy [118, 119], and there will likely be a need for energy information

and advice within the PED setting given the expected deployment of RET that consumers may not be fully familiar with.

C.6 Support a shift in the individuals energy consumption behaviour

Technological improvements are often seen as the solution to reducing energy needs and certainly form part of a powerful set of tools in dealing with energy poverty. However, research shows that this is not enough without a significant element of behaviour change [45]. Improving energy efficiency alone can also lead to a rebound effect in which potential savings are undercut through an increase in demand, and this also needs to be addressed.

One of the biggest issues with measures designed to reduce energy consumption is that this is an aim which could be perceived as directly opposing the aim of energy poverty reduction, as there is a strong tendency to under-consume energy amongst those in energy poverty (underconsumption is indeed taken as a metric for measuring energy poverty [9]). Despite this, Energy Consumption Behaviour Change (henceforth ECBC) can help to reduce overall consumption by between 5 and 20% depending on the intervention [120], and can also be used to directly address behavioural drivers of energy poverty.

ENERGY CONSUMPTION BEHAVIOUR CHANGE (ECBC)

"Most energy efficiency measures implemented (or yet to be implemented) in Europe involve technological interventions, but will equally have to rely on people adjusting their energy consumption behaviour"

EEA Technical report

This could offer a buffer for vulnerable consumers to avoid falling deeper in the poverty cycle, although we reiterate that many of those living in energy poverty already underuse energy, and behavioural interventions should seek to complement other policy actions that we outline in this document. There are multiple approaches to energy consumption behaviour which can be divided into action-specific energy use (e.g., boiling water, cooking), or material specific/embodied, such as purchasing a new boiler or appliance [121, 122]. Most ECBC measures are directed at those not in energy poverty and it is important to distinguish carefully between these two groups of consumers, and to consider and support those that are vulnerable when implementing such measures. ECBC connects directly to the other must-read factors in that by means-testing any kind of behaviour intervention, vulnerability and gentrification can be reduced, and energy literacy can increase engagement in positive energy behaviour change.

An example can be found in the SPARCS project, an initiative to support European cities transform into Sustainable Energy Positive & Zero Carbon Communities. In Leipzig West, a district of Leipzig, Germany, new smart technology will be applied in apartments in order to optimize heat consumption. Newly developed applications should monitor and visualise the heat consumption per unit and should also contain comparison mechanisms for an easier and more transparent understanding of consumption for the resident [123]. In the case of PED-like areas, ECBC strategies have been implemented in Bolzano [124], as part of the Sinfonia project, where residents have been given smart meters which enable them to track their own energy usage.

ECBC has been implemented in Milton Keynes, UK, by the EMPOWER project [125] through schemes for cycling and electric bus use, directed towards changes in travel behaviour. Citizens obtained vouchers for local shops by using sustainable travel, and 70 organisations were engaged in order to extract traffic information and statistics, on the basis of incentive schemes per kilometre for charity. This also helped users to reduce the extent to which they travelled using conventional fuel vehicles. For that purpose, several applications were tested in different locations providing information and allowing residents to gain points, discounts, rewards and engage in community support actions and games.

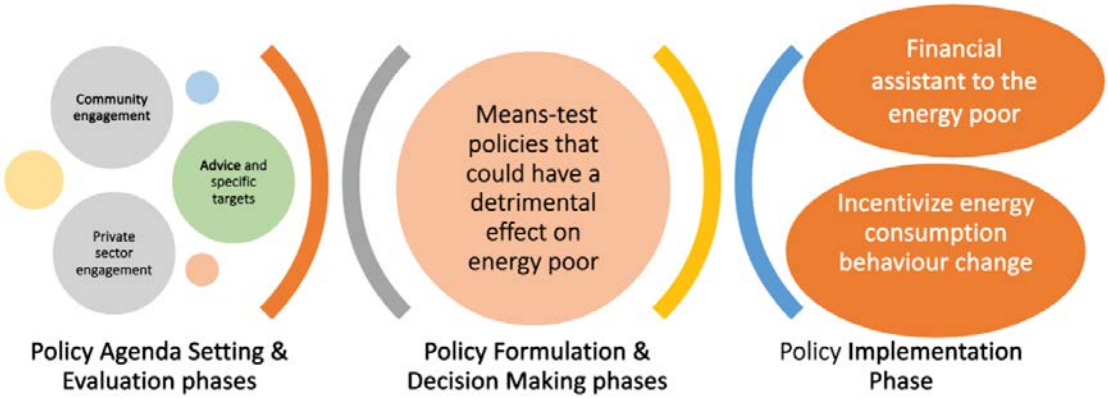
In some PED-like areas such as the Hunziker Areal, Switzerland, utility costs are calculated as a flat rate of 10% of the rental costs. Because rental costs are dependent on property size (price is per m^2) as well as

whether the home is social housing (20% of the available property is social housing), the most vulnerable pay less, even if their needs are greater. Furthermore, this allows an element of planning when it comes to paying for utilities and also gives the district a small surplus to use for social projects (utility costs are significantly lower as the properties are all highly energy efficient). Energy prices are purposely set at the highest in Zurich in order to encourage better energy use. However, those in social housing in the district are also able to get financial support which mitigates any negative effects this could have on those who are most vulnerable [23].

Proposition for Policymakers

Where possible, policymakers should ensure that vulnerable residents are directly targeted through ECBC measures that protect and improve quality of life. ECBC measures should be introduced district-wide, but consideration needs to be given to how these will affect those suffering from energy poverty; and potential mitigation of this through direct financial support, in the case of policies which have a negative impact on the energy poor, or incentives for policies which target those living in energy poverty (Figure 12). This is likely to have an added benefit of increasing community engagement in such policies, which could be disseminated through the use of the energy advice centres recommended in C5.

Figure 12 Energy behaviour change policy principles



D. Discussion and conclusions

There are multiple ways of addressing energy poverty, which is recognised as a multi-faceted problem with a variety of different drivers, barriers as well as regional and national differences. Methods of dealing with energy poverty involve identifying and targeting specific elements of the population that are seen as being vulnerable. An example of this is the Saves2 project [126] which specifically targets students as a method of energy poverty eradication. Similar targeted projects focus on vulnerable groups such as the elderly, minority groups, and women [127]. Likewise, there are multiple pathways to decarbonisation. However, these alternative pathways for mitigating energy poverty and decarbonisation can be delivered simultaneously through PED development.

Reducing Harm; producing Justice-informed PEDs

The PED creation process is still in its infancy, and it is not yet clear which conditions need to be satisfied for PED development to work to reduce energy poverty. This is one of the main reasons why it is important to embed this in at the point of PED development. If PEDs are created according to their guiding principles, in

ways which ensure the energy poor are not excluded, they could work as excellent tools for energy poverty mitigation as illustrated in some of the examples above. Returning to some of the principles of policy design earlier, the issue of energy poverty mitigation is political and the extent to which PEDs can assist in reducing energy poverty will also be determined by decisions made during the planning phases. PEDs are able to bring together a policy mix that may reduce energy poverty within the district as well as help to future-proof generations of residents in the district against energy poverty by ensuring that buildings are as energy efficient as possible, devices within are as energy efficient as possible, and energy saving behaviour is encouraged and adopted by residents. Furthermore, ensuring multiple soft mobility options within the district and increasing financial resilience through measures such as community energy ownership, can also ensure that energy poverty in minimised.

There is, however, a danger that new districts will be priced above the means of the energy poor, and that retrofitting older districts may result in a process of gentrification with landlords increasing prices to reflect energy efficiency improvements, displacing existing residents. The fact that most of the PEDs are currently in the development phase makes it both hard to envisage what the end result will be in terms of energy poverty alleviation, but is also an opportunity for policy makers to ensure that the creation of these districts mitigates energy poverty whilst decarbonising urban areas.

Ensuring that vulnerable citizens are not excluded from participatory processes of PED creation, development and living, will be an important factor when considering energy poverty mitigation. In the case of La Pinada, Valencia, Spain [128] participation requires a €600 deposit on a future property, which may exclude many of the more vulnerable residents. However, assigning a certain number of properties for social housing could mean that even though participation in the planning and development phases is not fully inclusive, energy poverty can still be directly reduced, as in the case of La Fleuraye in Nantes, France [129] where 68 homes have been designated social housing (around 10%).

When considering energy efficiency retrofitting, older buildings are often more expensive and harder to adapt. Historical buildings are estimated to constitute between 10% and 40% of building stock depending on region [130, 131] and may also be more complex to retrofit due to physical characteristics (e.g. irregular geometry) and pre-existing conservation principles.

A significant consideration with implementing energy saving measures in the home is the potential for this to lead to a rebound effect [132, 133]. Given the stated EU goal of reducing GHG emissions, increasing consumption through reducing energy poverty could distort and negatively affect this. Indeed, behaviour change could lead to both increases in energy use in certain areas and decreases in others, and would need to be carefully monitored and evaluated in order to assure overall reductions. In the Hunziker Areal, Zurich, for example, this is achieved overtly by requiring residents to sign a car waiver as a condition of tenancy, as well as through novel space distribution, such as having a communal freezer room and a ban on household freezers [134].

Information and advice policies may provide potential reductions in energy demand and help to improve the general situation of those vulnerable to energy poverty, but attention should be given to the quality of the information and how this is diffused. There is evidence to suggest significant differences in savings can be achieved depending on whether the information is opportunistic (e.g., when residents first move in), energy-efficiency led (e.g., through the media, and energy advice centres), research-led or based on a local project [135]. Furthermore, there is evidence to suggest that tailored advice strategies outperform a one-size-fits-all approach [136].

Impact of COVID19 and Climate Change

At the time of writing, the world has been engulfed in a serious health pandemic, which has undoubtedly had an impact on energy poverty. Although measures such as disconnection protection have been put in place by different member states, there are warnings of as tsunami of debt accumulation for those that have not been disconnected but where there has not been sufficient financial support [137]. This can already been

seen in statistics emerging from Spain, for example, where the number of people living in severe poverty increased form 4.7% in 2019 to 7% in 2020 [79].

The increased risk posed by the effects of climate change may also create conflict between trying to reduce energy consumption to mitigate this, whilst tackling energy poverty (which may increase consumption [138]).

Evaluating energy poverty and PEDs.
We initially identified the must-read factors within the policy design cycle. However, we then situate these within the context of the full policy cycle with an interrelationship between the planning, implementation and evaluation phases which feed into each other. In the PED planning phase, policy makers need to consider the first four must read factors, as a means of ensuring that reducing energy poverty is incorporated from the very beginning. This then allows the other two factors to be considered once the PED has been created, during the implementation phase. Further to this, all of the energy poverty mitigation policies need to be evaluated, at the district level, but also in conjunction with the entire town/city where the PED is located. Means of doing this can involve the use of surveys, combined with hard data, in accordance with EPAH recommendations. In addition, the impact of the district may be evaluated using some of the proposals in project Deliverable 5.2.

Conclusions
Whilst PED creation may originally have been designed in order to assist in meeting EU GHG emissions targets, by their very nature they provide an ideal tool for reducing long-term energy poverty and vulnerability. PED developments aim at an inclusive energy transition. This will undoubtedly require tackling existing inequities in access and affordability of energy, which could lead to the reduction of energy poverty. Therefore, PED actions should increasingly be understood by policymakers not only as a tool to combat climate change, but also as a means to address social disparities in the domain of energy.

One of the significant issues with energy poverty is the potential impact of attempting to resolve it. Increasing the income to energy poor families or reducing energy prices may well result in increased energy consumption, and therefore greater emissions, rendering less likely the meeting of agreed climate change emissions targets. Increasing energy prices may result in emission reductions, but is also likely to increase energy poverty, with more families falling into the vulnerable category. Thus, potentially an appropriate response to energy poverty when taking into account climate emissions, is to significantly increase energy efficiency in order to reduce required energy and therefore emissions [22, 139].

It is clear that energy poverty is a problem and that some policies only provide short term solutions rather than tackling the root causes（e.g., financial assistance to help pay energy bills, which provide relief to those affected but do not address the deeper issues). However, there are also measures which not only reduce energy poverty long-term, they also serve to buffer other inhabitants from becoming vulnerable to energy poverty. The potential use of Positive Energy Districts as a means of dealing with energy poverty long-term is significant and PEDs provide an opportunity for major change.

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F. Abbreviations

CEC: Citizen Energy Community

EPAH: Energy Poverty Advisory Hub (Replaced EPOV, 2021)

EPOV: Energy Poverty Observatory

EV: Electric Vehicle

GHG: Greenhouse Gases

MS: Member State

PED: Positive Energy District

REC: Renewable Energy Community

RET: Renewable Energy Technology

G. Appendix

Table 2 Potential aspects to consider in PED development with regards to the policy design process and energy poverty.

Must-read factor	**Broader setting for policy design with Energy Poverty in mind**	**Specific Problem setting**	**Strategies and actions to deal with this issue**	**Connected PED building blocks**
1 Avoid Gentrification	Different districts will face differing levels of energy poverty	Potential Issue of gentrification of existing districts. How do we avoid gentrification?	Allocate % of homes for social housing in new districts Rental controls, tenant protection (eg anti-eviction ordinances, property tax rebates)	2,4,6
2. Fair and inclusive finance for retrofitting	Those living in energy poverty are in homes that are worst in terms of energy efficiency	Who pays for Retrofitting of complicated older districts? How to avoid "locking in" to substandard retrofits? How to avoid cherry-picking districts for PEDs?	Community financing- and alternatives that are linked to property and not person. Better access to financing,	2,5,6
3 Improving sustainable transportation and prioritising inclusive mobility over high tech mobility	Those in energy poverty often struggle with accessibility to transport, AND there is a sector of the population that is in transport poverty	How can we ensure that transportation is evaluated- based on accessibility over speed of mobility?	Applying accessibility metrics in planning [140] decisions, such as transportation project selection and land use suitability analysis	4,5,6

		How to prioritise inclusive mobility over high tech mobility?	Increased public transportation, and greening the public transportation system.	
4 Novel forms of RET ownership to reduce energy poverty	Including the energy poor in CECs (Citizen Energy Communities, or ensuring access to CECs could significantly reduce energy poverty	How do we ensure ownership of RET within the PED is equitable? Where is the RET located?	Use of public buildings for placement of RET, inclusive policies for ensuring those in energy poverty are part of CECs Community energy storage, Multiple means of production could also mean multiple income streams and redundancies- eg for when the sun is not shining- need to remain connected to grid.	1,2,3,4,5,6
5 Connecting local people with energy advice in order to take advantage of increased digitalisation Energy flexibility needs to take into consideration energy poverty	ICT by itself does not have an effect on energy poverty Flexibility may mean vulnerable people suffer more- financial and non-financial impacts [109]	How to ensure the technology is of use to the consumer? How to connect local people suffering from energy poverty with advice on energy poverty? How can we make sure energy flexibility does not have a negative impact on those in energy poverty?	Bringing in the human centric perspective- ensuring training/information prior to, during installation and afterwards. Creating energy advice centres, holding energy advice days Financial support measures for those most vulnerable	1, 2,3,4,5,6
6 Means testing behaviour change potential and designing policy accordingly	Reducing energy consumption behaviour often has a greater impact on those in EP	How to ensure that those in energy poverty are not adversely affected by policies that focus on Energy Consumption Behaviour Change	Means-testing behaviour change potential and designing policy accordingly	2,4,5,6

About the Smart-BEEjS Project

*The **overarching aim of Smart-BEEjS** is to provide, through a multilevel, multidisciplinary and interdisciplinary research and training, a programme to produce the technology, policy making and business oriented **transformative and influential champions of tomorrow.***
Educated in the personal, behavioural and societal concepts needed to deliver the success of any technological proposition or intervention under a human-centric perspective.

The Smart-BEEjS presents a balanced consortium of beneficiaries and partners from different knowledge disciplines and different agents of the energy eco-system, **to train at PhD level** an initial generation of **transformative and influential champions** in policy design, techno-economic planning and Business Model Innovation in the energy sector, **mindful of the individual and social dimensions,** as well as the **nexus of interrelations between stakeholders** in energy generation, technology transition, efficiency and management. Our aim is to boost knowledge **sharing across stakeholders, exploiting a human-centric and systemic approach to design Positive Energy Districts** (PEDs) for sustainable living for all.
The Smart-BEEjS project recognises that the new level of decentralisation in the energy system requires the systemic synergy of the different stakeholders, balancing attention towards technological and policy-oriented drivers from a series of perspectives:

- **Citizens and Society**, as final users and beneficiaries of the PEDs;
- **Decision Makers and Policy Frameworks**, in a multilevel governance setting, which need to balance different interests and context-specific facets;
- **Providers of Integrated Technologies, Infrastructure and Processes of Transition**, as innovative technologies and approaches, available now or in the near future; and,
- **Value generation providers and Business Model Innovation (BMI)** for PEDs and networks of districts, namely businesses, institutional and community-initiated schemes that exploit business models (BMs) to provide and extract value from the system.

The stakeholders of this ecosystem are **inseparable** and interrelate continuously to provide feasible and sustainable solutions in the area of energy generation and energy efficiency.

This report is part of the (3-4 phrases about the particular element of the deliverable/task)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Actions, Innovative Training Networks, Grant Agreement No 812730.