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Positive Energy Districts and Energy Poverty

Clemens Mayer, Sebastian Seebauer, Andreas Tuerk, Michael Brenner-Fließer, Mia Ala-Juusela

(Clemens Mayer, MScMSc, Joanneum Research, Waagner-Biro Straße 100, 8010 Graz, clemens.mayer@joanneum.at)
(Dr Sebastian Seebauer, Joanneum Research, Waagner-Biro Straße 100, 8010 Graz, Sebastian.seebauer@joanneum.at)
(Mag Andreas Tuerk, MBA, Joanneum Research, Waagner-Biro Straße 100, 8010 Graz, andreas.tuerk@joanneum.at)
(Dr Michael Brenner-Fließer, Joanneum Research, Waagner-Biro Straße 100, 8010 Graz, michael.brenner-fliesser@joanneum.at)
(D.Sc. (Tech.) Mia Ala-Juusela, VTT, Tekniikantie 21, FI-02044, mia.ala-juusela@vtt.fi)

1 ABSTRACT

Positive Energy Districts (PEDs) are promoted as tools for urban decarbonisation, combining high building efficiency, local renewable energy generation and smart energy management. By definition, they minimise operational energy costs and therefore have a strong structural potential to reduce energy poverty for residents. In Europe, energy poverty is driven by low incomes, high energy costs and inefficient housing, so these PED characteristics directly target core drivers. However, social inclusion and affordability are rarely central in current PED deployment, creating risks that vulnerable households remain excluded or displaced. This paper examines how PEDs can both alleviate and unintentionally exacerbate energy poverty through their impacts on income, energy costs, building efficiency and energy saving behaviour. It argues that PEDs will only contribute meaningfully to a just transition if affordability safeguards, targeted renovation of low efficiency districts and inclusive governance are integrated from the outset. Based on this analysis, the paper formulates policy recommendations to ensure that PEDs benefit low income households and support an equitable energy transition.

Keywords: Positive Energy District, Energy Poverty, Affordability, Social inclusion, Renovation

2 INTRODUCTION

Energy poverty has become a recognised socio economic and health challenge across Europe. It affects households that struggle to secure adequate heating, cooling, lighting and the use of basic appliances at an affordable cost. The issue is driven by a combination of low household incomes, rising energy prices and a large share of inefficient and aging residential buildings, particularly in dense urban areas where renovation backlogs are most pronounced (Bouzarovski, 2014). Energy poverty has important social and spatial dimensions, as it disproportionately affects vulnerable populations and contributes to unequal living conditions, excess winter mortality and a reduced quality of life (Walker, et al., 2016).

In parallel with this development, the concept of PEDs has gained increasing prominence in European research, funding programmes and urban planning strategies (JPI Urban Europe, 2020). PEDs are understood as urban areas that combine highly energy efficient buildings, local renewable energy production and smart control systems in order to achieve a positive annual energy balance (Bossi, et al., 2020). While they are primarily promoted as tools for decarbonisation and energy system innovation, an emerging discussion highlights their relevance for social equity and affordability. Because PEDs directly influence levels of energy demand, energy prices, building quality and the organisation of local energy systems, they are potentially relevant for addressing some of the structural drivers of energy poverty.

This paper examines whether and how PEDs can contribute to reducing energy poverty. It analyses both the mechanisms through which PEDs may alleviate energy poverty and the mechanisms through which they may unintentionally increase it, for example by raising housing costs or limiting access for vulnerable households. By considering these positive and negative pathways side by side, the paper highlights that the social effects of PEDs are not automatic but depend on how they are planned, financed and governed. Building on this analysis, the paper formulates policy recommendations aimed at improving the ability of PEDs to benefit low income households and contribute to a socially just energy transition.

3 METHODOLOGY

The analysis presented in this paper is based on a combination of literature research and expert input gathered within the DUT project RESPED (Ala-Juusela, et al., 2025). The literature research covered scientific articles, policy documents and technical reports on energy poverty and PEDs, with the aim of identifying relevant concepts, impact mechanisms and empirical observations. This provided the conceptual basis for analysing how PEDs may affect the drivers of energy poverty.

Four main dimensions of impact of PEDs on energy poverty were defined: household income, energy costs, building energy efficiency and energy related behaviour. These mechanisms reflect established drivers of energy poverty and enable a structured assessment of both positive and negative effects. In this paper, each mechanism is analysed separately in order to clarify how PED characteristics may alleviate or exacerbate energy poverty through these different causal pathways.

Complementing the desk research, insights were collected through workshops organised within the RESPED consortium and with selected external stakeholders, involving experts from research, municipal planning, housing and energy related fields to discuss affordability challenges, accessibility issues and potential social impacts associated with PED deployment.The findings informed the interpretation of the literature and helped identifying practical conditions under which vulnerable households may or may not benefit from PEDs. The combined approach allows the paper to address both theoretical mechanisms and practice oriented considerations relevant for the social implications of PEDs.

4 POSITIVE IMPACTS OF PEDS ON ENERGY POVERTY

The following subsections discuss how PEDs may reduce energy poverty by analysing their influence across four central dimensions of energy poverty: income, energy costs, building efficiency and energy saving behaviour.

4.1 Positive Impact through Income

In terms of income, the direct influence of PEDs on energy poverty is limited as PEDs do not provide additional revenues to households to boost their incomes. In some cases, electricity feed-in from surplus generation can create additional revenue streams, but these are typically modest (often well below €100 per month) and tend to accrue to building owners rather than tenants, who are more often affected by energy poverty. When such revenues do reach households, they function less as direct payment and therefore passive increase in income, but rather as a reduction of the net electricity bill, which makes them more appropriately understood within the impact mechanism through energy costs rather than income.

4.2 PositiveImpact through Energy Costs

The most significant way in which PEDs can mitigate energy poverty is by decreasing household energy costs. By producing more renewable energy than they consume, at significantly lower costs than the energy market or even near-zero costs, PEDs are able to substantially lower, or in some cases even eliminate, energy bills, which are disproportionately high for people experiencing energy poverty (Casamassima, et al., 2022). For energy-poor households, whose expenditures on electricity and heating amount to disproportionately high share of overall costs of living, these reductions can free up resources for other essential needs.

Furthermore, the enhanced capacity of PEDs to self-sufficiently cover energy demand from their own production provides resilience against energy price fluctuations. This might be particularly relevant in response to potentially rising prices for fossil fuels due to carbon pricing and geopolitical factors (Hearn, 2022). Energy poor households tend to have low savings, because they spend most of their available income on covering their everyday living expenses. Thus, energy poor households cannot buffer energy price fluctuations by themselves, but PED self-production may do so.

However, it is important to consider that if the high upfront investment costs of PEDs are passed onto residents through increased rents, the energy cost savings from PED self-production may be partly offset, limiting the overall impact on reducing energy poverty. Therefore it is important to combine the energy efficiency measures of PEDs with measures ensuring affordable housing to ensure that PEDs can considerably mitigate energy poverty.

Overall it can be assumed that in practice, if low-income households manage to take residence in a PED, they are no longer likely to be affected by energy poverty. This is because PEDs, by their very design, keep energy bills low. From this perspective, the impact mechanims of energy costs generally helps to reduce energy poverty inside PEDs. The bigger question, however, is not whether PED residents benefit, but whether people who are already struggling with energy poverty are actually able to find housing in these districts. If low-income households are excluded or pushed out, the positive effects of PEDs on energy poverty remain very limited. This issue will be discussed in Section 5, which focuses on the possible negative effects of PEDs on energy poverty.

4.3 Positive Impact through Building Energy Efficiency

Enhancing building energy efficiency is a key way in which PEDs can help alleviate energy poverty. By integrating highly efficient building envelopes, advanced insulation, and smart energy management systems, PEDs drastically reduce the amount of energy required for heating, cooling, lighting, and appliances (Bossi, et al., 2020). This inherent high efficiency minimises energy waste and lowers total energy demand, leading to substantial reductions in household energy consumption. Even if these efficiency gains are partially offset by larger floor areas (rebound effect), or because energy poor households no longer need to cut back on heating expenses and can now afford to heat to normal temperatures, the substantial reduction in energy demand still accrues to lasting benefits. For people affected by energy poverty, this means that even if energy prices rise, their efficient homes require significantly less energy to maintain comfortable living conditions, thereby buffering the impacts of increasing energy prices. However, while improved energy efficiency reduces operational costs, the high initial investment required for such advanced building standards may still pose barriers if not mitigated by targeted subsidies or financing schemes. PEDs also improve indoor environmental quality by providing more stable indoor temperatures, better humidity control, reduced noise, the absence of indoor air pollution from burning improvised fuels, and enhanced natural light. These factors directly support the health and well being of residents. Energy poor households often live in buildings with low indoor environmental quality, so moving into a Positive Energy District can significantly improve their living conditions.

PEDs are typically either new constructions or thoroughly renovated buildings built to the highest standards, their efficiency and comfort benefits are ensured by design. In summary, the high levels of building energy efficiency embedded in the PED concept naturally reduce energy demand and therefore contribute to lowering the risk of energy poverty. However, as with the energy cost mechanism, the main challenge is not whether PEDs are efficient, but whether energy-poor households are able to benefit from these efficiencies, either by affording to live in new PED developments or by having their existing, less efficient homes renovated to PED standards. Without addressing this accessibility issue, the efficiency gains of PEDs risk bypassing those who need them the most.

4.4 Positive Impact through Energy-Saving Behaviour

PEDs can influence energy poverty by fostering energy saving behaviour among residents. Through integrated smart systems, real-time energy monitoring, and user-friendly feedback technologies, PEDs raise awareness of personal energy consumption patterns and encourage behavioural changes to reduce unnecessary usage (Hearn, et al., 2021). This behavioural shift can lead to further energy savings beyond the building's inherent efficiency, empowering low-income households to learn about the main reasons for their energy consumption in order to actively manage and reduce their energy expenses. Educational programmes and community engagement initiatives often embedded within PED projects can further strengthen these behavioural impacts by enhancing knowledge and skills for long-term energy-aware living or by introducing social feedback among neighbours. However, it is important to recognise that behavioural change depends on user motivation, comprehension, and time availability, which may vary, limiting its effectiveness without adequate support.

5 NEGATIVE IMPACTS OF PEDS ON ENERGY POVERTY

PEDs may also exacerbate energy poverty through high investment costs and low accessibility of energy poor households. So, PEDs face several concerns that could hinder their role in alleviating energy poverty. The most pressing concern are the cost for constructing or renovating buildings and for installing the energy technologies that are characteristic for PEDs (Bouzarovski, 2014). The high initial investment required for PED implementation, particularly in economically disadvantaged areas, risks excluding energy vulnerable people and thereby increasing energy poverty (Bouzarovski, 2014; Hearn et al., 2021). The following subsections outline possible negative impact mechanisms of PEDs via the four dimensions of energy poverty. The issues regarding affordability and gentrification are discussed in the impact mechanism regarding energy efficiency (section 5.3).

5.1 Negative Impactthrough Income

PEDs have no meaningful direct impact on household income, as they neither raise wages nor provide additional earnings to residents. In this sense, no negative income effects are expected and the income dimension does not constitute a relevant impact mechanism for PEDs in relation to energy poverty.

5.2 Negative Impact through Energy Cost

Basically, PEDs reduce energy costs as outlined in the previous section. However, in some cases theseeffects could be rather limited as the advanced technologies and integrated systems of PEDs could leadto complex pricing structures and high maintenance costs, especially if PEDs are pilot projects whereunforeseen costs may emerge because of experimental technologies that require ongoing technicalsupport. These costs may be transferred to residents through elevated service charges or energy tariffswithin the district (Hearn, et al., 2021). Additionally, if the PED business model prioritises cost recovery or private returnson investment, locally produced renewable energy might be sold on the market, leading toconventional energy prices for all PED residents, including energy poor households.

PEDs typically have a positive net energy balance. This means that they generate more energy thanthey consume within a timespan of one year which should lead to low energy costs and therefore apositive effect on energy poverty. However, this presumes that feed in revenues are received byresidents and not only by investors or building owners.

Another negative impact mechanism that could undermine the positive effects could be a deliberately high energy price in PEDs. The PED project Hunziker Areal in Zurich has deliberately set high energyprices in order to avoid rebound effects, that is low energy costs, as they are typical in PEDs, incentivizinghigher energy use (Hearn, et al., 2021). While this is counter balanced by the highly energy efficient infrastructure, it maybe perceived as an energy injustice for lower income groups (Hearn et al., 2021).

In summary it can be said that all in all it is not expected that PEDs will increase energy costs forresidents due to their high energy efficiency and low energy consumption. However, the positive effectson energy costs could be limited in some cases by high service fees, maintenance costs or othercharges.

5.3 Negative Impact through Building Energy Efficiency

Households experiencing energy poverty typically live in dwellings with inadequate insulation, outdated heating systems and generally low energy performance. By definition, however, PEDs consist of highly efficient and well insulated buildings, which means that the negative effects of low energy efficiency do not apply within PEDs themselves. In this sense, PEDs do not directly exacerbate energy poverty through the efficiency mechanism. The central challenge instead lies in ensuring that energy poor households can access these highly efficient dwellings. This raises critical questions about affordability, the inclusion of existing low income housing in PED frameworks and how risks of gentrification and displacement can be minimised. Consequently, this subsection focuses on the interrelated issues of affordability, gentrification and accessibility of PEDs for energy poor households.

High energy efficiency comes with high upfront construction or retrofit costs. These costs may be passed on to tenants or owners through higher rents, service charges or purchase prices, potentially excluding lower income groups from accessing the benefits of energy efficient living (Walker, et al., 2016) (Hatz, 2021). Investments in renovating existing buildings to PED standard could even trigger the displacement of previous low-income residents who cannot afford an increased rent, a phenomenon sometimes referred to as renoviction, especially in areas where housing markets are already under pressure (Hatz, 2021). This affordability challenge is exacerbated by the heavy reliance on private sector investment in PED development. Unless regulatory frameworks enforce inclusivity, this dependence on investment from the private sector may prioritise profit over social equity (Hearn, et al., 2021). Studies have shown that retrofit policies relying on market-based mechanisms tend to have regressive effects, reproducing or even deepening existing energy inequalities (Rosenow, 2012) (Rosenow, et al., 2013). These considerations on affordability and social equity within financing are particularly relevant in the context of PEDs, as the European SET Plan for PEDs estimates that public investment of 0.74 billion euro will need to be matched by at least 100 billion euro from private investment and cities (JPI Urban Europe, 2020), highlighting the scale of private influence on implementation.

Beyond implementation costs, the post upgrade affordability of housing within PEDs also matters. As energy efficiency and renewable technologies raise property values, living spaces within PEDs may become unaffordable for lower income households. Without regulatory frameworks, PEDs are at risk of becoming exclusive domains for wealthier populations, resulting in gentrification and the potential displacement of energy poor households as they are pushed out to cheaper and less efficient housing (Hearn, et al., 2021).

Finally, energy poor households and their buildings may face structural exclusion from PED projects altogether. PEDs are often new private sector developments that target high efficiency standards in newly constructed buildings. As a result, existing buildings with poor energy performance, such as aging public or social housing stock where energy poverty is most prevalent, are less likely to be included. This exclusion reinforces spatial and social divides, as those who would benefit most from reduced energy demand and improved comfort lack access to highly efficient PEDs. Furthermore, energy efficiency upgrades in existing buildings, especially in older municipal housing, are often costly and complex, making them less attractive to private investors or PED planners. Integrating low performing affordable housing into PED frameworks must therefore be a priority if PEDs are to support rather than hinder a just energy transition.

5.4 Negative Impact through Energy-Saving Behaviour

PEDs may unintentionally deepen energy poverty through the impact mechanism of energy saving behaviour. Making effective use of dynamic pricing schemes and flexibility options, which are often key revenue streams within PEDs, requires a certain level of smart household devices, energy literacy, digital access and time availability that energy poor households may lack, preventing them from benefiting fully and potentially exposing them to higher costs during peak price periods (Hearn, 2022). Consequently, instead of lowering energy expenditures for vulnerable groups, PEDs could risk increasing them, thereby worsening energy poverty for residents already struggling to afford their basic energy needs.

Another relevant effect in this context is the so called rebound effect. This refers to situations where low energy costs in highly efficient buildings lead households to use more energy for comfort instead of saving it. In PEDs this may reduce the motivation for careful energy use and weaken behavioural measures aimed at lowering consumption. While this can improve indoor comfort for households that previously had to limit heating or cooling, it also limits the expected energy savings and can make behavioural interventions less effective for reducing energy costs.

6 POLICY IMPLICATIONS AND RECOMMENDATIONS

Drawing on the mechanisms identified in the previous sections, which highlight both the mitigating and exacerbating effects of PEDs on energy poverty, this chapter presents policy recommendations to ensure that PEDs support affordability and social inclusion and thereby contribute to reducing energy poverty over time.

6.1 Prioritise social housing and energy poor districts for PED retrofits

To ensure that energy poor households benefit from PEDs, renovation programmes should explicitly target social housing and low efficiency districts where energy poverty is most concentrated. Housing stock owned by the public or by non-profit housing cooperatives is often easier to retrofit systematically than mixed ownership buildings, making it a strategic entry point (Hearn, 2022). Large scale publicly funded deep renovations to PED standards in these areas would not only reduce energy bills and improve living conditions but also prevent the exclusion of the most vulnerable households from the energy transition.

6.2 Inclusion of low-income households in PEDs

Public authorities should require PED projects to meet clear social inclusion criteria, such as allocating a share of housing units to low income households or integrating energy poor buildings into the district's scope. Without binding inclusion mechanisms, PEDs risk becoming exclusive developments for wealthier populations. Planning regulations should link public funding or zoning approvals to measurable equity outcomes, ensuring that PED benefits extend to those most vulnerable to energy poverty.

6.3 Public financing for social housing

Public investments in PEDs should come with binding social conditions. Access to EU or national subsidies could be tied to inclusion criteria, such as allocating a fixed share of housing units for low-income

households, rent caps or anti eviction clauses. This ensures that the efficiency and comfort benefits of PEDs are not offset by rising rents or displacement. Long term affordability covenants should be required to maintain inclusivity over decades, not just at the point of construction or renovation.

This means that a portion of public PED funding should be ring fenced for retrofitting and integrating older, energy inefficient social and affordable housing within PED boundaries. Energy poor households are often concentrated in under maintained municipal housing, which is typically left out of high-tech PED projects. Targeted financial support is essential to overcome the technical and economic challenges of upgrading this stock and ensuring these residents are not structurally excluded from the energy transition. (Willand, et al., 2020) even find that a non targeted subsidy approach may be regressive and reproduce energy inequalities. Instead, interest free loans and full grants could improve participation and ensure that retrofitting initiatives reach vulnerable population segments (Willand, et al., 2020) (Hearn, 2022).

6.4 Protecthousingaffordability after renovation

Renovation driven gentrification poses one of the biggest risks to energy poor households. To counter this, policymakers should guarantee existing tenants the right to return after renovations at affordable rents. Legal mechanisms such as rent stabilisation, affordability guarantees or targeted tax incentives for landlords can help balance investment costs with tenant protection (Hatz, 2021). One such example is the Affito Condizionato in Milan which was implemented to avoid gentrification risk after retrofitting projects (Hearn, 2022). These safeguards are critical to ensure that deep renovations raise living standards without forcing low income residents out of their homes and pushing them to cheaper but low quality housing.

6.5 Empower municipalities and communities as PED developers

Municipalities should be supported to act as champions for PEDs in disadvantaged areas, ensuring that local needs and affordability remain central. Public ownership or cooperative models for PED energy systems can allow residents to share the financial benefits of surplus energy generation. By reinvesting revenues locally, for example into community services or further building renovations, municipal and community led PEDs can create a virtuous cycle of inclusivity and affordability that private market led developments often overlook. Municipalities may enter public private partnerships with private developers and energy providers to develop inclusive PEDs with guaranteed affordability measures (Hatz, 2021).

6.6 Develop tailored financing tools for low-income households

Energy poor households often lack the resources to invest in energy efficiency upgrades even when the long term return on investment is obvious. Financing tools such as zero interest loans, pay as you save schemes or on bill financing models with public guarantees can lower these barriers. State backed financing models and guaranteed returns on energy efficiency investments can mitigate this barrier (Hearn, 2022). By aligning repayments with actual energy savings and shielding households from upfront costs, these mechanisms ensure that vulnerable groups can access high efficiency living without additional financial burden. However, these financing tools must consider renter fluctuation and include rules for fair loan transfer if renters do not stay in the flat long enough for the entire payback period of loans.

6.7 Balance upscaling of PEDs with social policy

PEDs raise the overall efficiency standard of the building stock and therefore make an important contribution to reducing long term energy demand and costs. From this perspective, any measure that accelerates renovation rates or promotes new PED developments indirectly helps to reduce energy poverty in total, as other buildings must be renovated as well in order to be able to compete on the housing market.

However, it is neither realistic nor desirable to expect private investors and developers alone to shoulder the responsibility of solving energy poverty. Overregulation of the housing sector could reduce incentives to build or renovate, slowing down the overall transition. Instead, an Efficiency Plus Approach is needed (Hearn, et al., 2021). Policies should prioritise the most cost-effective structural efficiency gains while addressing affordability and energy poverty through parallel social measures such as targeted subsidies, income support or housing allowances. This combined strategy ensures that the benefits of PEDs are maximised without constraining investment or slowing down renovation momentum.

7 CONCLUSION

PEDs have a structurally high potential to mitigate energy poverty because they combine highly efficient buildings with local renewable energy production. By design this reduces or even removes operational energy costs and therefore effectively eliminates the energy spending behaviour that forces low income households to restrict heating, cooling or appliance use. Residents living in such districts are therefore unlikely to experience energy poverty, provided that housing costs remain affordable. However, the central question is not whether residents inside a PED are protected from energy poverty, but to what extent households who are currently affected by, or at risk of, energy poverty are able to access these buildings in the first place.

This challenge becomes even more urgent in light of Europe's renovation needs. The majority of buildings that will exist in 2050 are already built today, and a large share of them perform poorly from an energy perspective. If PEDs are intended to contribute meaningfully to the reduction of energy poverty, they must not remain limited to new, high end developments but need to be applied as a renovation strategy in those areas where energy poverty is actually present. Targeting social housing, municipal stock and low efficiency neighbourhoods is essential to ensure that the benefits of high efficiency and low energy costs reach vulnerable groups rather than bypass them.

The analysis has shown that PEDs do not automatically generate positive social outcomes. Without safeguards, they can increase rents, displace vulnerable households or become exclusive redevelopment projects. For this reason, complementary policy measures are required. Key priorities include linking public PED funding to affordability and inclusion criteria, protecting housing affordability during and after renovation, empowering municipalities and community actors as PED developers, and creating tailored financing tools that enable low income households to participate without upfront costs. These elements are consistent with the broader recommendation that upscaling PEDs must be balanced with social policy rather than driven by efficiency targets alone.

Under these conditions, PEDs can evolve from isolated technical demonstrators into a systemic instrument of the energy transition that improves living conditions, reduces energy expenditure, and ensures that vulnerable households are not left behind. Without such conditions, PED deployment risks reinforcing existing inequalities. Ensuring that PEDs contribute to a just transition therefore hinges on two simultaneous commitments: renovating where energy poverty exists, and creating access pathways so that those most in need can actually benefit.

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