Seeking a possible Positive Energy Districts (PEDs) location choice from a local context, a case study in Tainan City, Taiwan

Yi Hsuan Shen
Affiliation: Department of Urban Planning, NCKU
Email: P26134032@gs.ncku.edu.tw

Tzuyuan Stessa Chao
Affiliation: Department of Urban Planning, NCKU
Email: tychao@mail.ncku.edu.tw

Abstract
COP28 emphasised the urgent need to accelerate energy transitions and decarbonisation. Cities, as major centres of energy consumption and carbon emissions, have become critical arenas for implementing these transitions. The EU and IEA have actively promoted Positive Energy Districts, shifting the focus from individual buildings to the district scale to enhance energy efficiency. This study focuses on socio-economic indicators and explores key variables influencing residential electricity consumption (REC). Using Tainan City as a case study, it combines rooftop PV generation potential and REC forecasting to evaluate the electricity self-sufficiency rate of each district. The results indicate that only "total household income" shows a significant positive correlation. Future research could utilise more granular data to improve assessment accuracy and provide evidence-based support for urban energy planning.

Keywords: Positive Energy Districts; PEDs potential; Renewable Energy; Spatial Multi-criteria

1 Introduction

The Intergovernmental Panel on Climate Change (IPCC), in its Sixth Assessment Report (AR6) released in 2023, projected that global temperatures are likely to rise by 1.5°C within the next two decades. This increase is expected to intensify climate-related hazards and may further exacerbate challenges related to energy, water resources, and food security.

In response, the 28th Conference of the Parties (COP28) to the United Nations Framework Convention on Climate Change (UNFCCC) emphasised the need for all countries to enhance their Nationally Determined Contributions (NDCs), improve energy efficiency, and adopt new technologies to advance energy transition and decarbonisation efforts. Over 100 countries have now declared net-zero emissions targets, including Taiwan, which has committed to achieving net-zero emissions by 2050. Taiwan's 2050 Net-Zero Emissions Roadmap outlines four major strategies: energy transition, industrial transformation, lifestyle change, and social transition.

According to the International Energy Agency (IEA), cities account for approximately 75% of global energy consumption and 70% of global greenhouse gas emissions. In this context, **cities—being densely populated areas with high energy consumption and concentrated carbon emissions—have emerged as critical arenas for driving energy transitions and realising net-zero goals.** Consequently, institutions such as the European Union and the IEA have initiated a range of urban-centred energy transition policies and pilot programmes. These efforts have evolved from single-building-scale initiatives, such as near-zero energy buildings (NZEBs), to larger, district-scale approaches exemplified by Positive Energy Districts (PEDs).

The European Union, under the Strategic Energy Technology Plan (SET-Plan), has set a goal of establishing at least "100 PEDs" across Europe by 2025. Simultaneously, IEA Annex 83 has been conducting research into the definitions, implementation methods, tools, and technologies associated with PEDs. Projects such as MAKING-CITY have also provided detailed methodologies and procedures for evaluating PEDs, emphasising that such evaluations must consider not only urban form and energy infrastructure, but also the social structures of the target districts.

Nevertheless, most existing studies on PEDs have focused on location suitability assessments based on comprehensive, objective indicators aimed at aiding policymakers in the strategic deployment of PEDs. While these evaluations help identify areas with higher potential for PED implementation, **the Urban Agenda for the EU underscores the critical role of public participation in energy transitions**.

Given the diverse socio-economic conditions across regions, variations in energy use behaviours and public acceptance (Rolf et al., 2007) may significantly influence the feasibility and effectiveness of PED implementation.

However, current studies seldom address the potential influence of local resident characteristics—such as economic status and demographic composition.

This study proposes the following research objectives:

1. To explore the key factors influencing REC from a "socio-economic perspective", with a particular emphasis on how resident structures affect energy behavior. This aims to address the current research gap in PEDs evaluations, which often overlooks the role of residents.
2. To conduct an empirical study in a selected city in Taiwan, integrating REC forecasting and rooftop PV potential analysis to evaluate the "electricity self-sufficiency rate" of each administrative district. The study further assesses the advantages and challenges of administrative districts as potential PEDs units.

2 Literature Review

2.1 Positive Energy Districts (PEDs)

2.1.1 Definition of PEDs

According to the European Commission, a Positive Energy District is defined as "an energy-efficient district that produces more renewable energy than it consumes, while enhancing regional energy system flexibility through smart management and local storage". Meanwhile, the SET-Plan defines PEDs as "energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net-zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy." Based on these definitions, **PEDs refer to geographically connected clusters of buildings with internal energy exchanges, aiming to achieve a net-positive energy status through the efficient and flexible use of renewable energy sources.**

The European Energy Research Alliance (EERA) further categorises PEDs into three types based on differences in geographic boundaries and energy balancing approaches: **PED Autonomous**, **PED Dynamic**, and **PED Virtual**. A PED Autonomous has clearly defined geographic boundaries and achieves complete electricity self-sufficiency within the district, allowing energy export but prohibiting external energy input. By contrast, a PED Dynamic allows energy exchange with other PED systems. A PED Virtual enables energy production and storage systems to be located outside the district while still serving energy needs within the area.

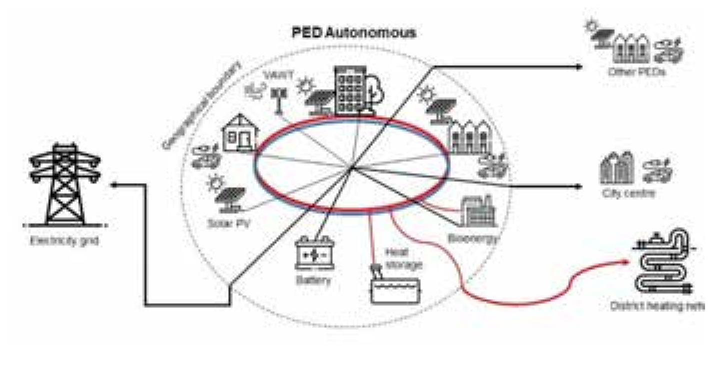

Figure 1. PED autonomous diagram

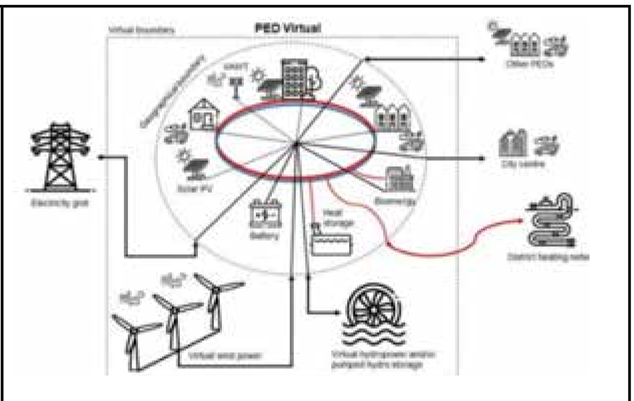

Figure 2. PED virtual diagram

2.1.2 Benefits and Challenges of PEDs

According to the Positive Energy Districts Solution Booklet, compared to achieving zero or positive energy targets at the individual building level, the diverse usage patterns of different building types often make it difficult to reach these goals in isolation, or may lead to energy overproduction and waste. **Therefore, shifting the focus to district- or community-level PEDs allows for more flexible and efficient energy utilisation.**

However, the current definition of PEDs still lacks clarity, particularly concerning "geographic boundaries" (Oscar et al., 2021), which can vary significantly depending on local characteristics. This suggests that a single

PED model may not be applicable across all contexts, and it is essential to consider local conditions during site evaluation. Furthermore, Erkinai et al. (2022) emphasise the importance of accounting for end-users and adopting an area-based policy approach tailored to local conditions, especially regarding fiscal and social dimensions. The study also criticises the idealistic nature of PED Autonomous models, which often overlook urban challenges such as high population density, limited space, and restricted access to renewable energy sources. As a result, the development of "Dynamic and Virtual" PEDs, in conjunction with Virtual Power Plants (VPPs), is regarded as a more viable pathway.

2.1.3 Methods for Evaluating PEDs Locations
Two key uncertainties complicate the definition and planning of PEDs (I. Aparisi-Cerdá et al., 2024). The first is the issue of **geographic boundaries** — the appropriate size and delineation of PEDs may vary depending on city characteristics, which in turn affect the feasibility of renewable energy deployment and local energy consumption. The second is **parameter selection** — identifying suitable PED locations depends on multiple factors across technological, social, economic, and environmental domains, each with a wide array of potential indicators. Therefore, selecting appropriate evaluation indicators is critical in PED planning.

Current methods for identifying promising PED locations often employ Geographic Information System (GIS) overlay analysis (Shnapp et al., 2020; Alpagut et al., 2020). Given the multidimensional nature of these indicators, many studies adopt Multi-Criteria Decision-Making (MCDM) or Multi-Criteria Decision Analysis (MCDA) approaches (Sassenou et al., 2024; I. Aparisi-Cerdá et al., 2024), which combine expert judgement to determine key indicators and their relative weights, followed by quantification and statistical analysis of candidate areas.

2.1.4 Why Taiwan's Urban Context is Suitable for PEDs
Taiwan is heavily reliant on energy imports, and most power plants are located far from the areas where energy is consumed. This spatial separation between energy generation and demand leads to greater transmission losses and, consequently, energy waste. **Given Taiwan's high level of urbanisation and population density, urban areas offer promising opportunities for implementing PEDs that flexibly utilise energy at the district scale.** Additionally, Taiwan faces land scarcity, and the deployment of renewable energy infrastructure often leads to land-use conflicts — particularly with agricultural land — an issue that has drawn strong opposition from environmental groups. Strategically deploying renewable energy in suitable urban areas and managing its distribution efficiently could ease pressure on valuable farmland while helping to safeguard food security.

Among Taiwanese cities, **Tainan stands out for having one of the highest installed capacities of solar photovoltaic systems and considerable solar energy potential.** The local government has taken proactive steps towards urban decarbonisation, including the development of Taiwan's first low-carbon community. However, most solar panels are currently ground-mounted and located in rural areas, far from the urban centres where energy demand is greatest. This spatial mismatch has raised concerns over land use and environmental justice. Consequently, this study selects **Tainan City** as a case area for evaluating potential PED locations. By integrating GIS-based spatial analysis with assessments of renewable energy potential, this research explores the feasibility of implementing PEDs in urban contexts and aims to provide insights for future planning and policymaking in Taiwan.

2.2 Socio-economic Indicators Influencing Residential Electricity Consumption
Residential electricity consumption (REC) is closely linked to household characteristics. Identifying the key factors that significantly influence residential electricity use not only helps to reduce consumption, but can also support forecasting future electricity demand.

Zhifeng et al. (2018) reviewed previous studies on the psychosocial factors influencing residential electricity behaviour. Commonly cited indicators include **household size, presence of children, age of household members, education level, social status, household income, and housing type.** These indicators may have either a positive (i.e. increasing) or negative (i.e. decreasing) effect on electricity use. However, the results vary across regions, indicating that the same indicator may exhibit different effects depending on the local context. This highlights the importance of identifying region-specific influencing factors and exploring the underlying reasons for such variations.

Najeeb et al. (2024) conducted a systematic review of the determinants of REC across South Asia, East Asia, and Southeast Asia, encompassing socio-economic, building-related, locational, and environmental-climatic dimensions. Within the socio-economic domain, several frequently studied indicators were identified. The review found that household income, household expenditure, household size, age of the head of household, and educational attainment of the household head were significantly correlated with electricity consumption. Conversely, indicators such as household size, age of the head, number of children, social class, household occupation, and unit electricity price showed weak or non-significant effects in certain contexts.

In addition, **within the context of the urban energy transition, public perception, acceptance, and willingness to adopt renewable energy are critical social factors. Stakeholders may hold differing attitudes towards renewable energy depending on their roles and interests.** Masoud et al. (2015) found that the acceptance of and willingness to use renewable energy are positively influenced by moral norms, attitudes, and perceived behavioural control (PBC). These factors may be useful in predicting regional willingness to adopt renewable energy technologies.

3 Methodology

3.1 Introduction to the Case Study Area

This empirical case study focuses on the former urban area of Tainan City, encompassing six administrative districts: East District, South District, North District, Annan District, Anping District, and West Central District. The total area of the study region is approximately 176.3 km², with Annan District accounting for the largest share, comprising 60.8% of the total area. As of the end of 2024, the total population of the study area is estimated at around 779,000, with Annan District having the highest population, approximately 203,000. The average population density is around 4,419 people per km².

In terms of building characteristics, the average building age across the area is approximately 33 years. West Central District has the oldest building stock, with an average age of 41 years, while Anping District has the newest, with an average building age of 25 years.

Table 1. List of basic information of the study area

District	Area (km²)	Area proportion	Population	Density (people/km²)	Building average age
East District	13.4	7.6%	181,854	13,556	33
South District	28.0	15.9%	120,151	4,285	36
North District	10.4	5.9%	125,801	12,057	33
Annan District	107.2	60.8%	203,882	1,902	28
Anping District	11.1	6.3%	70,435	6,365	25
West Central District	6.2	3.5%	77,212	12,478	41
Total	176.3	100.0%	779,335	4,419	33

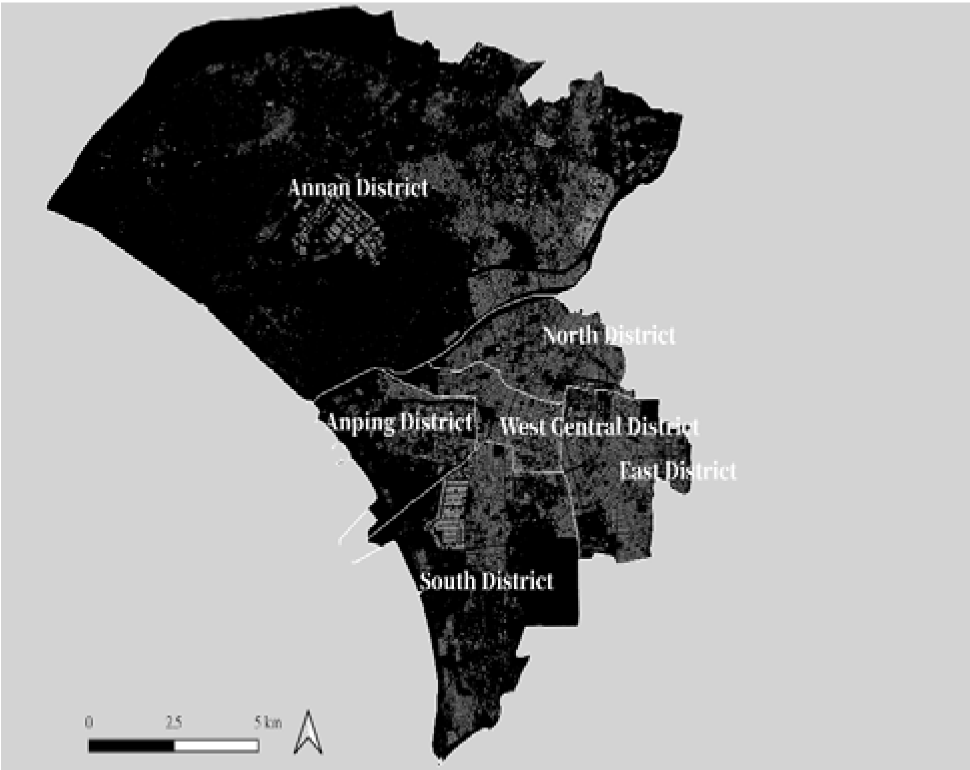

Figure 3. Case Study Area

3.2 Forecasting Trends in REC
Trends in REC are analysed using historical electricity sales data provided by Taiwan Power Company (Taipower). Based on Taipower's statistics, this study calculates annual growth rates from the historical data and applies them to project future electricity demand.

Due to a revision in the statistical reporting format in September 2020, data prior to that date differ substantially in classification and structure, and are therefore excluded from the growth rate calculation. **The study uses the average annual growth rate between 2021 and 2024 for each administrative district to estimate future trends. An exponential growth model is employed to forecast REC from 2025 to 2030.**

3.3 Correlation Analysis Between REC and Socio-economic Indicators
Assuming that Taipower's electricity sales data accurately reflect actual electricity consumption, this study adopts residential electricity sales as the dependent variable to assess the impact of socio-economic indicators on REC. The 2024 residential non-commercial electricity sales figures from Taipower serve as the dependent variable.

Socio-economic indicators are used as independent variables, selected through a review of relevant literature and contextualised for the Taiwanese setting. **Five key dimensions are considered: children, age of household, household size, educational level, and household income.** Each dimension comprises specific evaluation indicators, as illustrated in Figure 5 below.

The most recent data available from official statistical sources are utilised in the analysis. The data are then processed using SPSS statistical software to conduct a **correlation analysis**, examining both the **statistical significance** and the **direction** (positive or negative) of the relationship between each indicator and residential electricity consumption

Table 2. List of socioeconomic indicators in this study

Dimension	Indicators (Year)
Children	• Proportion of population aged 0~15 (2024) • Average number of children per household (aged 0~15 population / number of households) (2024)
Age of household	• Proportion of population aged under 50 (2024) • Proportion of population aged 51~64 (2024) • Proportion of population aged 65 and above (2024)
Household size	• Average number of persons per household (2024)
Education level	• Proportion of permanent residents with higher education (college and above) (2010)
Household income	• Total household income (NTD) (2021)

3.4 Estimation of rooftop PV Generation and Self-Sufficiency Rate

This study utilises government-provided 3D spatial data to estimate the rooftop area of buildings within each administrative district. Based on these estimations, relevant parameters are applied to calculate the potential annual electricity generation from rooftop photovoltaic (PV) systems in each district.

By comparing the estimated rooftop PV generation with REC, the self-sufficiency rate for each district is derived. Furthermore, the study conducts a series of scenario simulations to explore how variations in electricity generation and REC may influence the self-sufficiency rate.

Table 3. Summary of scenario assumptions

Scenario		Electricity generation	REC
Baseline		10% of the rooftop PV area of existing buildings	Actual REC in 2024
Scenario 1 (Pessimistic)	Generation unchanged REC increased	10% of the rooftop PV area of existing buildings	Estimated REC in 2030
Scenario 2	Generation increased REC increased	25% of the rooftop PV area of existing buildings	Estimated REC in 2030
Scenario 3 (Optimistic)	Generation increased REC unchanged	25% of the rooftop PV area of existing buildings	Actual REC in 2024

4 Results

4.1 Forecasting Trends in REC

An analysis of residential electricity sales from 2021 to 2024 across the six districts (Figure 8) reveals that Annan District consistently recorded the highest consumption, followed by East District, with Anping District having the lowest. Regarding growth rates, East and North Districts exhibited negative growth between 2021 and 2023, whereas Annan, Anping, and West Central Districts showed increases. However, all six districts experienced growth between 2023 and 2024.

Based on these trends, the average growth rate over the past three years was calculated for each district (Figure 7). Annan District recorded the highest average growth rate at 2.58%, while East District had the lowest at 0.27%. **These findings indicate that Annan District not only has the highest consumption but also the fastest growth, whereas East District, despite high consumption, shows signs of a declining trend.**
Future REC from 2025 to 2030 is projected using an exponential growth model based on the calculated average growth rates (Figure 9).

Table 4. Average REC growth rate of each district from 2021 to 2024

District	2021-2022	2022-2023	2023-2024	Average
East District	-1.5%	-0.5%	2.85%	**0.27%**
South District	-1.7%	0.3%	2.83%	**0.47%**
North District	-1.3%	-0.5%	2.67%	**0.29%**
Annan District	1.2%	1.7%	4.91%	**2.58%**
Anping District	0.4%	0.3%	4.96%	**1.89%**
West Central District	0.4%	0.1%	2.83%	**1.11%**

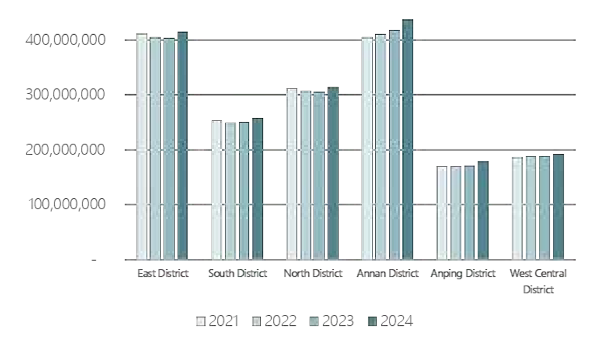

Figure 4. Residential electricity sales from 2021 to 2024

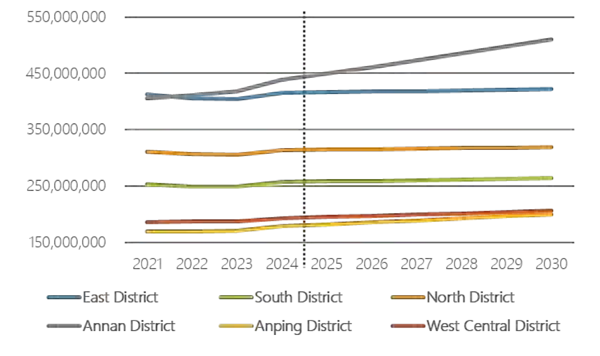

Figure 5. Estimated REC from 2025 to 2030

4.2 Correlation Analysis Between REC and Socio-economic Indicators

Using Pearson's correlation analysis, the relationships between eight indicators across five dimensions and residential electricity consumption were examined. The results show that only the variable *Total Household Income* had a significant positive correlation with REC (Pearson r = 0.814, p = 0.049 < 0.05), consistent with findings from previous literature. All other indicators did not show statistically significant correlations.

Table 5. Pearson correlation results

Dimension	Indicators (Year)	Pearson correlation	Significance (two.sided)
Children	Proportion of population aged 0-15 (2024)	0.214	0.683
	Average number of children per household (aged 0-15 population / number of households) (2024)	0.418	0.410
Age of household	Proportion of population aged under 50 (2024)	0.507	0.305
	Proportion of population aged 51-64 (2024)	-0.520	0.290
	Proportion of population aged 65 and above (2024)	-0.273	0.601
Household size	Average number of persons per household (2024)	0.671	0.145
Education level	Proportion of permanent residents with higher education (college and above) (2010)	-0.046	0.930
Household income	Total household income (NTD) (2021)	0.814	0.049*

* Significance (two.sided) <0.05 was significant

4.3 Estimation of Rooftop PV Generation and Self-Sufficiency Rate Analysis

4.3.1 Estimation of Rooftop PV Generation

The potential rooftop PV generation for each district was estimated by first calculating the available rooftop area using government-provided spatial data, then applying the following formulas:

Estimated Rooftop PV Installation Capacity (kW)= Rooftop area × 0.5 / 10
(0.5: proportion of usable rooftop area; 10 m²/kW: area-to-capacity conversion factor)

Estimated Annual Electricity Generation (kWh)= Installation Capacity (kW) × Average Annual Output per kW
(Average Annual Output = 1,246 kWh/kW)

4.3.2 Electricity Self-Sufficiency Rate Analysis

Three simulation scenarios were conducted to evaluate changes in self-sufficiency rates. In the most optimistic scenario (Scenario 3), Annan District reached a self-sufficiency rate of 40%, while Anping District reached only 17%. **The improvement in self-sufficiency ranged from 26.8% in Annan to 10.9% in Anping, highlighting significant regional disparities in the potential for electricity self-sufficiency.**

Table 6. Electricity Self-sufficiency rate results under different scenarios

District	Area (km^2)	Baseline	Scenario 1	Scenario 2	Scenario 3
East District	13.4	**7.82%**	7.69%	19.24%	19.55%
South District	28.0	**12.92%**	12.56%	31.40%	32.30%
North District	10.4	**8.00%**	7.86%	19.66%	20.00%
Annan District	107.2	**16.38%**	14.05%	35.13%	40.94%
Anping District	11.1	**6.81%**	6.09%	15.22%	17.03%
West Central District	6.2	**9.01%**	8.43%	21.07%	22.52%

5 Discussion & Conclusion

This study focuses on two key analyses:
(1) The correlation between REC and socio-economic indicators; and
(2) the assessment of electricity self-sufficiency rates under varying rooftop PV generation and REC scenarios across administrative districts.

The first analysis reveals a generally weak correlation between REC and socio-economic indicators at the administrative district level, except for a significant positive correlation between "total household income" and REC. This suggests that households with higher income levels tend to consume more electricity, likely due to their greater ability to afford electricity costs. Conversely, lower-income groups may exhibit higher sensitivity to electricity pricing, indicating disparities in energy affordability. Furthermore, **the lack of significant associations across most indicators implies that the administrative district scale may be too general to identify the key social-economic factors behind PEDs.** Future research could develop and utilize sub-district level data to improve the accuracy and contextual appropriateness of PEDs.

The second analysis estimates the electricity self-sufficiency rates of each district under different rooftop PV generation and consumption scenarios. The results reveal substantial disparities among districts, likely stemming from differences in historical urban development, and zoning regulations that have led to varied urban forms. Consequently, building types and resident demographics differ significantly across districts. These findings underscore that territorial characteristics play a crucial role in shaping PEDs outcomes, particularly in electricity self-sufficiency. **Moreover, the analysis shows that in urbanized areas of Taiwan, electricity consumption cannot be met solely through rooftop PV generation within administrative boundaries. This highlights the necessity of integrating additional renewable energy sources and electricity-saving measures to achieve positive energy targets.**

In summary, this research uses the administrative district as the unit for evaluating PEDs feasibility, aiming to assess whether such spatial units can serve as the operational basis for implementing PEDs. Aparisi-Cerdá et al. (2024) also suggest that using administrative boundaries is practical due to the availability of statistical data and familiarity among experts, which simplifies the research process. The study further finds that smaller spatial units do not necessarily yield higher self-sufficiency rates. For instance, Annan District—the largest in area among the six studied districts—achieved the highest electricity self-sufficiency rate. However, from an operational standpoint, larger districts may contain more variables, such as higher population diversity and more complex stakeholder dynamics, potentially increasing implementation challenges. Figure 12 summarises the advantages and challenges of using administrative districts as the evaluation unit for PEDs, as well as potential improvements needed to better achieve PED objectives in the future.

Table 7. Summary of Advantages and Challenges of Using Administrative Districts as Statistical Units for PEDs Assessment

Aspect	Advantages	Challenges and Suggestions
Policy Alignment	Using administrative districts for local energy planning enables strong alignment with existing urban planning frameworks. This compatibility facilitates the direct integration of policy objectives and enhances the effectiveness of implementation and oversight.	The delineation of administrative boundaries does not necessarily align with the actual boundaries of energy systems, which may lead to ambiguity in planning, management. Future assessments of PEDs may need to establish formalized, cross-regional energy governance frameworks, including legal agreements and decision-making platforms.
Accessibility of Data	As administrative districts are standard statistical units used by Taiwanese government agencies, data related to them are readily accessible, stable over time, and diverse in scope. This supports systematic analysis of energy demand and socio-economic conditions relevant to PEDs, while also enabling effective policy tracking and impact evaluation.	Due to the differences of administrative districts in terms of size and characteristics, aggregated data at the district level may mask high-potential or high-vulnerability areas, thus reducing the precision of strategic planning. It is therefore essential to develop and utilize sub-district level data—such as neighborhoods, communities, or urban renewal units—to improve the accuracy and contextual appropriateness of PEDs' energy demand and management strategies.
Spatial Scope	Administrative districts typically encompass diverse land-use types such as residential, commercial, and industrial districts, which is beneficial for modelling and implementing PEDs that require energy integration, and distribution across heterogeneous areas. The district-scale spatial boundary also provides the spaces for deploying renewable energy infrastructure, such as solar PV systems, and energy storage.	Large spatial scopes and high land-use diversity make implementing PEDs more difficult due to the variety of energy needs and increased technical challenges. Future efforts should identify sub-areas within administrative districts that demonstrate relative strengths or vulnerabilities and incorporate microgrid development to gradually enhance energy resilience and increase the overall self-sufficiency rate within districts.
Cross-District Coordination and Stakeholder Engagement	Since energy is a transboundary resource, infrastructures such as electricity grids, and thermal networks, often extend beyond administrative boundaries. However, administrative districts possess well-defined local governance structures, allowing them to better coordinate and negotiate in different districts. They can also act as intermediaries for establishing cooperation frameworks with higher levels of government.	When renewable energy infrastructure is across administrative boundaries, challenges often arise related to cost and benefit allocation, and the high coordination costs associated with diverse stakeholders. Future strategies should include the formulation of cooperation agreements, transparent mechanisms for revenue and responsibility sharing, and stakeholder engagement frameworks to reduce resistance and foster PEDs deployment.

6 Limitations and Future Research

Although international definitions of PEDs currently distinguish between three types, there is still no unified standard regarding the appropriate spatial scale or delineation method. Xingxing et al. (2021) reviewed 60 PEDs projects in Europe and found that more than half of them occupy less than 1 km², with only five exceeding 5 km² in size. By contrast, even the smallest administrative district in this case study spans over 6 km²—significantly larger than most European cases. The variation in district size is also reflected in the differences in electricity self-sufficiency, reinforcing the critical role of "urban context" in PEDs planning. This study suggests that although administrative districts provide a practical initial scale for PEDs assessment, further refinement into smaller sub-units may be necessary to improve the precision and contextual relevance of PED strategies.

Finally, future research directions should include more granular consideration of rooftop PV generation potential. This includes data on building age, historical building constraints, structural types, and differences in adoption willingness among residents living in different building forms (Shnapp et al., 2020). On the consumption side, future studies could incorporate projected policy targets, resident behavioral patterns, and socio-economic indicators at the village or neighborhood level to more accurately forecast electricity demand variations across different districts.

Reference

European Commission (2018) Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of Positive Energy Districts. *SET-Plan ACTION n°3.2 Implementation Plan*.

EU Smart Cities Information System (2020) *POSITIVE ENERGY DISTRICTS SOLUTION BOOKLET*.

Shnapp, S. Paci, D. Bertoldi, P (2020) Enabling Positive Energy Districts across Europe: energy efficiency couples renewable energy. *JRC technical report*.

Alpagut, B., Gabaldón, A (2020) Guidelines for Positive Energy District Design. *Making City*.

Shnapp, S., Paci, D., & Bertoldi, P. (2020). Enabling positive energy districts across Europe: energy efficiency couples renewable energy. *Publication Office of the European Union: Luxembourg*.

James C. Cramer, Nancy Miller, Paul Craig, Bruce M. Hackett, Thomas M. Dietz, Edward L. Vine, Mark D. Levine, Dan J. Kowalczyk (1985) Social and engineering determinants and their equity implications in residential electricity use. *Energy*, 10 (12), December 1985, 1283-1291.

Bartiaux, Francoise, Gram-Hanssen, Kirsten (2005) Socio-political factors influencing household consumption of electricity: a comparison between Denmark and Belgium. In: Eceee summer study proceedings energy savings what works & who delivers. Conference: eceee 2005 Summer Study, 1547.

Rolf Wüstenhagen [a], Maarten Wolsink [b], Mary Jean Bürer (2007) Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), 2683-2691.

Yigzaw G. Yohanis Jayanta D. Mondol, Alan Wright, Brian Norton (2008) Real-life energy use in the UK: how occupancy and dwelling characteristics affect domestic electricity use. *Energy and Buildings*, 40 (6), 1053-1059.

Eimear Leahy, Sean Lyons (2010) Energy use and appliance ownership in Ireland. *Energy Policy*, 38 (8), 4265-4279.

Fintan McLoughlin, Aidan Duffy, Michael Conlon (2012) Characterising domestic consumption of electricity patterns by dwelling and occupant socio-economic variables: an Irish case study. *Energy and Buildings*,48, 240-248.

Masoud Yazdanpanah, Nadejda Komendantova, Roshanak Shafiei Ardestani (2015) Governance of energy transition in Iran: Investigating public acceptance and willingness to use renewable energy sources through socio-psychological model. *Renewable and Sustainable Energy Reviews*, 45, 565-573.

Zhifeng Guo, Kaile Zhou, Chi Zhang, Xinhui Lu, Wen Chen, Shanlin Yang (2018) Residential electricity consumption behavior: Influencing factors, related theories and intervention strategies. *Renewable and Sustainable Energy Reviews*, 81, 399-412.

Oscar Lindholm, Hassam ur Rehman, Francesco Reda (2021) Positioning Positive Energy Districts in European Cities. *Buildings*, 11(1), 19.

Positioning Positive Energy Districts in European Cities

Derkenbaeva, E., Vega, S. H., Hofstede, G. J., & Van Leeuwen, E. (2022) Positive energy districts: Mainstreaming energy transition in urban areas. *Renewable and Sustainable Energy Reviews*, 153, 111782.

Luca Casamassima, Luigi Bottecchia, Axel Bruck, Lukas Kranzl, Reinhard Haas (2022) Economic, social, and environmental aspects of Positive Energy Districts—A review. *WIREs Energy and Environment*, 11(6), e45.

I. Aparisi-Cerdá, D. Ribó-Pérez, T. Gómez-Navarro, M. García-Melón, J. Peris-Blanes (2024) Prioritising Positive Energy Districts to achieve carbon neutral cities: Delphi-DANP approach. *Renewable and Sustainable Energy Reviews*, 203, 114764.

Louise-Nour Sassenou, Francesca Olivieri, Paolo Civiero, Lorenzo Olivieri (2024) Methodologies for the design of positive energy districts: A scoping literature review and a proposal for a new approach (PlanPED). *Building and Environment*, 260, 111667.