FLEXPOSTS
FLEXIBLE ENERGY
POSITIVITY DISTRICTS

BARRIERS AND POTENTIALS FOR IMPLEMENTING PEDS IN DENMARK

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2025

New Energy Coalition
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Denmark Greenhub
AALBORG UNIVERSITY
Gemeente Leeuwarden
Innovationsfonden
URBAN EUROPE

Project Title	FLEXPOSTS
Project Duration	2022 - 2025
Project Coordinator	Hanze University of Applied Sciences
Report Title	Barriers and Potentials for Implementing PEDs in Denmark
Deliverable N°	D5.2
Work Package N°	WP 5
Dissemination Level	External
Lead Organisation	AAU
Publication Date	19.03.2025
Authors	Kristian Olesen & Rasmus Nedergård Steffansen
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Information to be use for citation of this report	Olesen & Nedergård Steffansen (2025) Barriers and Potentials for implementing PEDs in Denmark
Version 1	Last updated 19.03.2025
Status	Final

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The FLEXPOSTS project has received funding from National Agencies under the JPI URBAN EUROPE- PED Programme Management, with Project number: 43979516.

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Introduction

The aim of FLEXPOSTS (FLEXible energy POSitivity districTS) is to develop effective and replicable strategies to enhance the process of establishing Positive Energy Districts (PEDs). WP5 investigates how a PED can be established in the demo site Aalborg East in Denmark. The aim of this report is to analyse the barriers and potentials for implementing PEDs in Denmark and in Aalborg East (D5.2). First, we discuss the relevance of PEDs in a Danish context and outline our understanding of PEDs. Here, we discuss how the PED concept fits into the Danish context and aligns with the existing (infra)structures in Denmark. Second, we turn our attention to Aalborg East and outline the main characteristics of Aalborg East, and how Aalborg East may develop into a PED. Third, we discuss the barriers and potentials for developing Aalborg East into a PED. In conclusion, we summarise the main barriers and potentials for developing Aalborg East into a PED that needs to be taking into consideration when developing future energy scenarios (D5.4), business models and an implementation strategy for Aalborg East (D5.5).

This report analysing the barriers and potentials for implementing PEDs in Denmark and in Aalborg East is the second report (D5.2) in WP5 on implementing a PED in Aalborg East. An overview of the reports that will be published about turning Aalborg East into a PED is presented below.

Textbox 1: Reports in WP5 – Demo Site Aalborg East

D5.1: Local energy balance assessment

D5.2: Barriers and potentials for implementing PEDs in Denmark

D5.3: Mapping of existing partnerships and networks

D5.4: Future energy scenarios in Aalborg East

D5.5: Business models and implementation strategy in Aalborg East

The relevance of PEDs in a Danish context

Positive Energy Districts (PEDs) is a new policy concept in a Danish context. To our knowledge no Danish policies address specifically PEDs, and no municipalities have yet developed plans to set up PEDs. The interest in PEDs remains largely academic driven by universities engaged in European research projects funded by JPI Urban Europe and Driving Urban Transitions, such as FLEXPOSTS.

Denmark is well-known as pioneer country for promoting renewable energy, especially wind power (Johansen, 2021). In a Danish context, much emphasis has until now been dedicated towards developing policies and models that can support Denmark's transition towards carbon neutrality and a 100% renewable energy system in 2050 on a national scale. One example is the Danish Society of Engineers's (IDA) energy vision 2050 (Mathiesen et al., 2015).

Recently, Danish energy policies have primarily focused on developing large-scale energy production facilities both offshore and on land to support the transition towards renewable energies and develop the capacity to support the ongoing electrifications of several sectors, such as transportation. One example is the recent government initiative to establish large-scale 'energy parks' on land (Planinfo, 2024). With the strong focus on national energy planning in Denmark and large-scale production units, the starting point for approaching PEDs as vehicle for facilitating the transition towards 100% renewable energy may therefore be different in Denmark than in many other European countries. It is therefore also not clear how or whether the PED concept can fit into the current Danish model for how to transition into a 100% renewable energy system in 2050.

Having said this, there are some obvious strengths in the Danish model that the implementation of PEDs could build on. All Danish cities have highly developed integrated district heating networks, that cover entire cities and connect major urban functions of the city and in many cases integrate excess heat from incineration plants and larger industries into the network. In this sense, the city is in many ways already 'joined up', as envisaged in the PED concept. However, the PED concept's framing of the district, as 'urban areas or groups of connected buildings' (cf. textbox 2) does to some extent contradict the well-established scalar logics of energy planning at national and city scale in Denmark.

Textbox 2: Definition of Positive Energy Districts from JPI Urban Europe

'Positive Energy Districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability.' (JPI Urban Europe, 2020)

It can therefore not be assumed that stakeholders automatically will accept the PED concept and acknowledge its potential added value in the Danish context. This is further complicated by the rather technical definition of a PED, which tends to emphasise PEDs as 'isolated islands', which should be optimised to achieve a surplus in the local annual energy balance. There is in other words a need to reconceptualise or rescale the concept of PEDs, if it is to play any meaningful role in a Danish context.

The PED literature recognises this challenge, and attempts have been made to reconceptualise the meaning(s) of PEDs in ways that seek to capture the plurality of contexts that PEDs may operate in. Lindholm et al. (2021) distinguish for example between three types of PEDs:

- PED autonomous: a district with clear geographical boundaries, which is self-sufficient with renewable energy and produces more energy than it uses.
- PED dynamic: a district with clear geographical boundaries, which annually produces more renewable energy than it uses, but is coupled to a wider energy system allowing import and export.
- PED virtual: a district with geographical boundaries, where renewable energy production may take place outside the boundaries of the geographical district. The combined energy production (inside and outside) is larger than energy demand of the district annually.

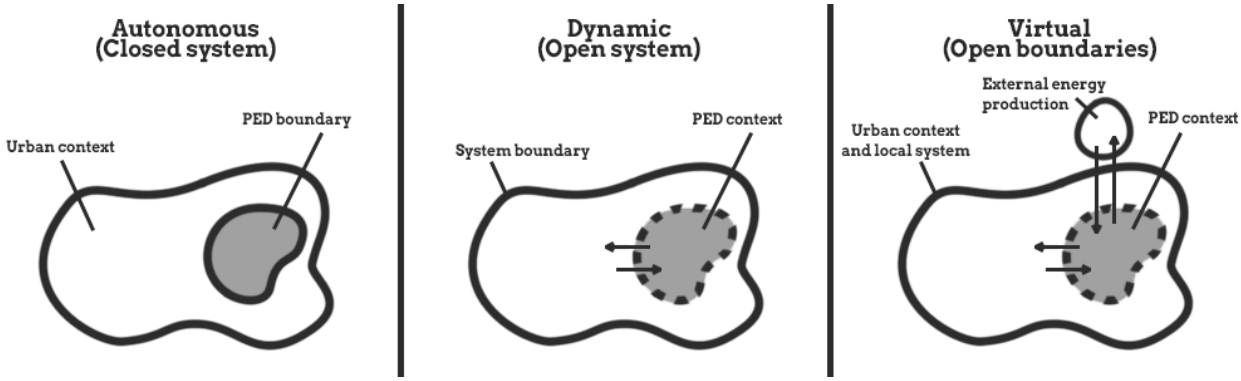

Figure 1: PEDs have been conceptualised as autonomous, dynamic, or virtual.

The aim of reconceptualising PEDs has also been to further the understanding that establishing a PED as a functionally disconnected unit from its surroundings, should not be a goal in itself, as this potentially leads to processes of sub-optimisation (Vandevyvere et al., 2022). PEDs should rather be understood as building blocks for realising carbon neutral cities and transition towards 100% renewable energies. A PED's interactions with neighbouring districts, the city, and larger region remain a question to be explored further in the PED-literature. One obvious contradiction is whether a city district can be considered a PED, if the majority of the energy production takes place outside of the district (maybe even in another city or country), which the PED virtual model allows. These conceptual challenges can potentially hinder the political support and therefore implementation of the concept.

The scalar tensions between national and municipal energy planning (public sector initiatives) and local bottom-up (often private) initiatives are already present in the Danish energy policy debate. In the Danish context some attempts have been made to advance the concept of 'energy communities', which largely resembles the thinking in PED autonomous. The idea of establishing energy communities contradicts, however to some extent, the idea of delivering electricity and heat city-wide as a public sector service, which today remains a dominant approach to energy planning in the Danish context. In Denmark, energy communities are still considered a niche, which in many ways contradicts and potentially threaten to undermine the established common infrastructures of district heating.

If the PED concept is to have any relevance in the Danish context, beyond the idea of energy communities, PEDs must be understood as either dynamic or virtual. In addition, PEDs must be

understood in the larger context of city-wide district heating networks and policy initiatives towards a 100% renewable energy system at national scale. One idea could therefore be to align the boundaries of PEDs with the boundaries of the district heating network. However, this would bring the concept of PEDs to a much larger scale (city-side and sometimes regional) than it was envisioned originally. In any case, it is important that establishing a PED locally does not contradict or impede wider initiatives and policies of transitioning towards renewable energies.

District heating in Denmark

Denmark has more than 100 years of experience in providing district heating, and this constitutes a unique point of departure for establishing PEDs. District heating emerged initially in Denmark as bottom-up grassroot initiatives based on a cooperative model. The first primitive district heating plant was built in Frederiksberg Municipality in 1903, with the aim of solving the municipality's increasing waste problems and lack of landfill sites, whilst also providing nearby municipal institutions with heat (Johansen & Werner, 2022). In the following decades the district heating technology was improved and the model spread throughout the country. After the Second World War the public sector grew, and municipalities became increasingly responsible for providing a stable and affordable energy supply. In the larger cities, the municipalities invested in larger district heating plants to service the growing population. As a result, the district heating network grew.

When the energy crisis hit Denmark in the 1970s, Denmark was almost 100% reliant on energy import (Arler & Sperling, 2020; Johansen & Werner, 2022). The increasing energy costs created the momentum for the Danish government to change its energy policy and become increasingly self-sufficient. The Danish Heat Supply Act (*Lov om Varmeforsyning*) was passed in 1979, which provided the legal foundation for the planning of large-scale infrastructures for district heating (Johansen & Werner, 2022). During the 1980s and 1990s increasing environmental awareness led to the Danish Government to publish the world's first low carbon energy transition strategy, the Energy 2000 Action Plan in 1990 (Johansen & Werner, 2022). With the strategy followed an increasing support for renewable energies, especially wind-power.

Today, district heating constitutes one of the cornerstones in the Danish energy system. The district heating network is divided into six larger central heating areas around the largest cities and 400 smaller decentralised district heating networks. Approximately 68% of all private households are connected to the district heating network (Danish Energy Agency, 2024). In Denmark, district

heating is operated by non-profit district heating corporations (*fjernvarmeselskaber*), which ensures that the prices of heating do not exceed the production costs. Most district heating corporations (82%) are organised as cooperations owned by the consumers. 15% are owned by municipalities, whilst the remaining 3% have other ownership structures (Danish District Heating Association, 2024). In the last couple of decades, the share of renewable energies in district heating has increased significantly. In 2022 76% of the heat production from district heating came from renewable energies (Danish District Heating Association, 2024). From a district heating perspective, Denmark therefore has a strong potential for implementing PEDs.

The Danish Electricity Network

Whilst the district heating network in Denmark is operating on a non-profit basis, the electricity network has been liberalised in accordance with EU legislation. The Danish electricity market was liberalised in 1999, and the production and distribution of electricity is today sold/bought on market terms (Arler & Sperling, 2020).

The Danish Electricity Network consists of three parts: electricity production, the transmission network, and the distribution network. The transmission network (infrastructures above 100 kV) is operated by the independent public enterprise Energinet, which is owned by the Ministry of Climate, Energy and Utilities. The distribution network (infrastructures below 100 kV) is operated by distribution companies, which are private companies subject to financial regulation (Danish Ministry of Climate, Energy and Utilities, 2024a). Denmark is divided into 37 distribution areas, each operated by a distribution company. Energinet and the distribution companies are responsible for the maintenance of the network. Consumers buy their electricity from electricity trading companies, which are also private companies. There are around 45 electricity trading companies in Denmark, and consumers can decide which company to buy their electricity from.

The share of renewable energy has increased significantly in Denmark since the beginning of the 2000s. In 2022 81.4% of the electricity production came from renewable energy sources (Danish Energy Agency, 2023). In the Energy Agreement passed in 2018, the Danish Government set the goal of becoming a low emission society in 2050 (Danish Government, 2018). A cornerstone in the agreement is that all electricity production should rely on renewable energy sources in 2050 and that the electricity should be produced on marked terms. In order to achieve this ambition, the Danish Government is currently planning large-scale offshore windfarms and so-called 'energy

parks', where electricity is produced from multiple sources of renewable energies (Planinfo, 2024). Despite the high percentage of renewable energy sources, the security of supply on electricity in Denmark was around 99,99%, equal to around 20 minutes shortage per year for a consumer in average (Danish Ministry of Climate, Energy and Utilities, 2024b).

Figure 2: The risk of congestion on the transmission network in 2040 (Energinet, 2022: 10).

Energinet expects that the increase in electricity production and consumption will lead to problems with congestion on the transmission network in the future. In Energinet's *Long-term Development Plan 2022* for the energy network, Energinet has analysed the risks of congestion in 2040 (Energinet, 2022). Energinet concludes in the report that significant investments and upgrades are needed, if

the energy network is to handle the increase in electricity production from renewable energy envisioned by the Danish Government.

Municipal planning in Denmark

Denmark has large and fairly autonomous municipalities, which could play an important role in promoting PED initiatives. In 2007 a structural reform on public administration was implemented in Denmark, which increased the power of municipalities and reduced their number to 98. Today, Denmark is one of the most centralised countries in Europe, looking at the number of inhabitants per municipality. In Denmark, urban and energy planning is carried out at the municipal level. Every four years, Danish municipalities publish a municipal planning strategy, which outlines the overall strategy across different sectors, including urban and energy planning. The priorities outlined in the strategy forms the starting point for a revision of the overall comprehensive spatial plan for the municipality, the municipal plan, which designates land uses for a 12-year period.

In addition to the municipal plan, municipalities may have several sector specific strategies or plans. Many municipalities have for example prepared 'heat plans', outlining the energy sources that can be used in the municipality. Recently, many Danish municipalities have prepared 'climate plans', which outline how reductions in greenhouse gas emissions can be achieved in the municipality across different sectors. The climate plans are part of a larger agenda called DK2020, which aims to promote climate neutral cities by 2050. There is thus potentially strong links between the Danish climate plans and the long-term objectives of PEDs.

In addition to the municipal-wide plans and policies, Danish municipalities also prepare other types of formal and informal plans. However, these plans do often not correspond to the neighbourhood scale of PEDs. Local plans are for example prepared in connection to specific urban development or energy infrastructure projects, with the aim of specifying the conditions under which the area in question may be used in the future. The challenge is therefore that PEDs operate at district or neighbourhood scale, which, although these can be defined in different ways, typically would be a scale that lies in-between the municipal and local level. The district scale is typically a scale that Danish municipalities from an urban and energy planning perspective have limited experiences with. The PED focus on the district or neighbourhood scale may therefore constitute a barrier in the sense that it represents a different spatial logic than the existing municipal – local logic around which planning traditionally has been done.

Energy Communities

As previously mentioned, the idea of establishing energy communities is still fairly new in Denmark, but the concept is gaining increasing traction. A few smaller islands already have considerable experiences with establishing energy communities (Heaslip et al., 2016). Up until now the idea of establishing energy communities have mainly resonated with eco-villages or similar off-grid experimental villages. However, non-profit housing associations have increasingly become interested in the model. At the moment, the legal and financial barriers for implementing energy communities seem, however, to outweigh the potential benefits. One of the main barriers is that households or industries, who produce energy for own consumption, e.g. via solar panels, are considered 'energy producers', if they are to transfer excess electricity to the neighbouring buildings via the distribution network. For some entities, like industries, this constitutes a legal barrier. Whilst housing associations are allowed to establish a separate cooperation for redistributing locally produced electricity internally in the housing area, the residents would still have to pay the standard fee for the transmission, which in many cases represent an economic barrier for establishing an energy community.

Bridging Urban and Energy Planning

The Danish Government's energy policies seek primarily to transition the energy sector into renewable energies and increase the production of renewable energies to accommodate the implementation of large-scale PtX facilities and support the electrification of other sectors. What has received less political attention is how to reduce energy consumption, which constitutes an important dimension in the PED framework.

In many countries urban planning and energy planning remain separate sectors with limited interaction between the two sectors. Denmark is no exception. One of the core ideas in the PED framework is therefore to break the existing 'silo thinking' and bridge urban and energy planning. Whilst this silo thinking constitute one of the most important barriers for the implementation of PEDs, it has so far only received limited attention in the PED literature.

In urban planning literature and planning practice there are however a long tradition for taking sustainability measures into consideration in the planning of urban areas. Whilst these principles

for sustainable urban planning have not been conceived with the aim of reducing energy consumption per say, they constitute a helpful framework for thinking about how strengthening the link between urban and energy planning is essential for the implementation of PEDs.

One of the core principles of sustainable urban planning is to integrate the planning of urban development and transport infrastructures to promote the use of public transport. Here, the Finger Plan for the Greater Copenhagen Area, originally published in 1947, constitute a well-renowned example of how a few basic principles for urban development can contribute to reduce the energy use from transportation (Olesen & Elle, 2025). The core idea of the Finger Plan was to conceptualise the spatial structure of Copenhagen as a hand with spread fingers, where urban development was concentrated in the palm of the hand and along the fingers as urban corridors, supported by public transport (S-trains) (Olesen, 2022). The web between the fingers would be reserved for recreational green spaces and agriculture. Although the ideas of the Finger Plan are more than 75 years old, they still form the foundation for the overall spatial planning in the Greater Copenhagen Area today, and the ideas have in many ways become an integrated part of the Danish planning culture (Olesen, 2022).

Based on the experiences of the Finger Plan and the urban planning literature in general, a few key principles for sustainable urban planning can be identified:

1. Urban density

Dense urban developments, either as brownfield development or urban infills, can reduce the increase in energy demand that typically follows from urban growth, compared to outward urban expansions, typically referred to as urban sprawl.

2. Promote public transport

A dense urban structure will typically also promote the use of public transport and active forms of transportation like walking and biking, and thereby reduce the car-dependency and energy use from transportation.

3. Dense living

A dense urban structure will typically also lead to the construction of denser housing typologies, like apartment blocks. Apartments blocks consume in general less energy for heating than single family housing and terrace housing. People living in apartment blocks live in general on fewer m^2

than people in other housing typologies. A denser and more compact urban structure can thus also reduce the total land allocation needed for urban development.

4. Mixed urban development

Mixed use developments that place various urban functions in close proximity tend to reduce the need for transport, whilst creating more lively urban neighbourhoods throughout the day.

5. Multifunctionality

Many buildings and public spaces have been constructed with only one function in mind. By thinking multifunctionality into the (re)development of buildings and public spaces, more functions can be added on less space, reducing the need to expand the urban areas.

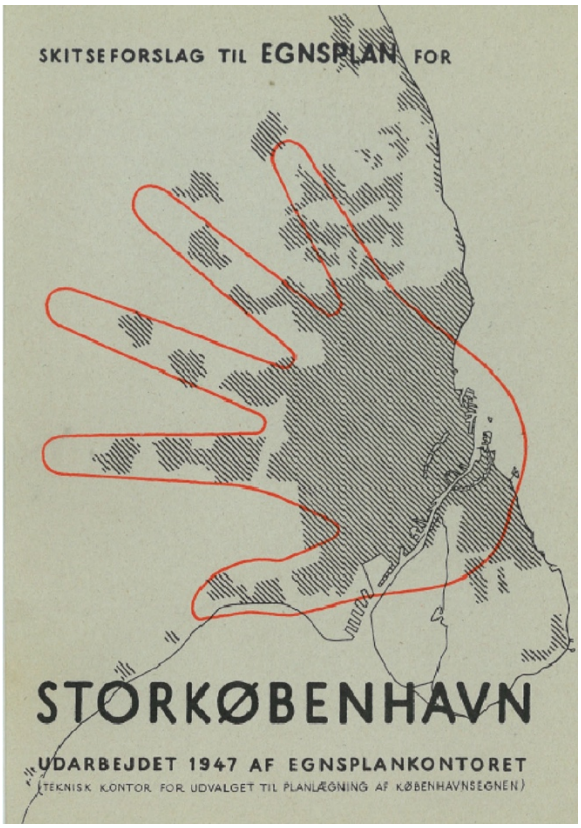

Figure 3: The Finger Plan for Greater Copenhagen Area envisioned with spatial structure of Copenhagen as a hand with spread fingers (Regional Planning Office, 1947).

Aalborg East as a PED

Aalborg East is a suburban mixed-use neighbourhood consisting of approximately 25,000 households and 25,000 workplaces. Housing is predominantly concentrated in the western part of the area and is characterised by a large proportion of non-profit housing managed by housing associations. The businesses and industry are mainly located in the eastern part of the area, with a large concentration of businesses in the wind power sector located near the Port of Aalborg in the north-eastern part of the area. The area also includes the incineration plant Nordværk and the cement factory Aalborg Portland. In addition, the Aalborg East is also home to several larger educational and cultural facilities, including Aalborg University's main campus and the sport complex Gigantium. A new university hospital is also currently under construction in the area.

Figure 4: Outline of Aalborg East including major urban functions

Aalborg East is also characterised by several prominent stakeholders, including the 9220 Business Network, who actively work to promote the sustainability agenda. There is thus an existing foundation that the development of Aalborg East into a PED could built on. We will elaborate on the most important stakeholders in Aalborg East in the report Mapping of Existing Partnerships and Networks in Aalborg East (D5.3).

When assessing the potentials for implementing PEDs, it is important to take the spatial characteristics of the area into consideration (Stoeglehner et al., 2011). Aalborg East is a suburban area, and the area has grown significantly in the last couple decades, as farmland has been converted into new urban areas for housing and industry. As Aalborg East lies at the fringes of the urban area of Aalborg, the area has been developed with low density and based on planning principles of segregated functions that were developed in the late 1960s. This means that low density housing is often separated from the other functions in the area, while being connected with a hierarchical road network and a separate cycling infrastructure. In recent years however, the municipality has had a planning strategy focused around a "growth axis" that extends across the city of Aalborg towards Aalborg East and the harbour. In this axis urban development were to be densified and businesses should prioritise the urban development opportunities here. It has also been a political prioritise to upgrade the public transportation services in the growth axis with the implementation of a bus rapid transit system. Though the original layout of Aalborg East does not support the sustainability principles from planning literature, contemporary urban and transport development in the area can be seen to support many of the principles.

Still, the area contains a considerable amount of farmland in the eastern part of the area, which potentially could be utilised for energy production in the future. Furthermore, as demonstrated in the report Local Energy Balance Assessment in Aalborg East (D5.1), Aalborg East heavily relies on electricity import to meet the current demand, whilst the area currently has a surplus heat production and is fully covered by the district heating network of Aalborg.

In addition, Aalborg Municipality and the largest housing association in Aalborg East, Himmerland Housing Association have considerable experience with working at the neighbourhood level. In the period 2010-2020, the municipality and the housing association carried out several urban transformation projects, with the aim of improving the overall attractiveness and reputation of the housing areas Kildeparken and Tornhøj. In addition, a large proportion of Himmerland Housing Association's dwellings in the areas were renovated to improve the energy efficiency. Himmerland Housing Association has also installed low temperature district heating in one of their housing

areas. There is thus considerable experience with planning at the neighbourhood scale in Aalborg East that the future development of a PED could built on.

Barriers and Potentials for implementing a PED in Aalborg East

In this section we analyse the barriers and potentials for implementing a PED in Aalborg East. The PED literature discusses a range of barriers and success factors for implementing PEDs such as economic, legal, technical, stakeholder involvement, and a cross-sectoral approach (see for example Bossi et al., 2020). In this analysis, we divide the barriers and potentials for developing PEDs into the three categories: regulatory, structural, and technical. An overview of the main barriers and potentials are presented in table 1. In our analysis, we draw on insights from the initial analysis of the barriers and potentials for implementing PEDs in Denmark, as well as context specific matters that either constitute a barrier or potential for implementing a PED in Aalborg East specifically.

Regulatory barriers and potentials

The Danish district heating model constitutes a solid foundation for establishing PEDs. District heating corporations in Denmark are typically organised as non-profit cooperatives owned by the consumers, which in many ways is in alignment with the PED concept. In Aalborg Municipality the district heating provider Aalborg Varme A/S is owned by Aalborg Municipality, and the incineration plant Nordværk I/S is owned by Aalborg Municipality together with four other municipalities in the region. These ownership structures provide a unique opportunity for offering district heating as a public service on a non-profit basis.

In Aalborg, district heating relies both on waste incineration (which in Denmark is considered a CO_2 neutral energy source), coal (a plan for out phasing is in place), as well as excess heat from the cement factory Aalborg Portland. In addition, a district cooling network is being planned that relies on existing industrial production in the area (chalk pit) and will supply new demands such as the new hospital and datacentres. Thus, the idea of sharing resources within a given district through

established infrastructure has a long tradition in Denmark and Aalborg East. Especially, when it comes to heating and in the future also cooling.

Electricity supply is, as of now, however not built and regulated in similar ways, and more knowledge is needed for understanding how the concept of PEDs can facilitate the transition of the energy network towards 100% renewable and self-sufficient supply. Likewise, more knowledge about how the district energy network (heating and cooling), that in effect work as existing PEDs, interrelates with new technologies, the electricity network and new demands, is needed.

Table 1: Overview of the main barriers and potentials for implementing a PED in Aalborg East

	Barriers	Potentials
Regulatory	No legal option to demand that new housing areas are connected to the district heating network. Barriers for establishing energy communities. Barriers for sharing locally produced renewable energy across households and buildings.	District heating as non-profit.
Structural	Neighbourhood scale not aligned with district heating or political-administrative boundaries. Focus on centralised production in district heating networks. Neighbourhood scale produces ambiguities about who should lead the development of PEDs. National energy policy favours big scale solutions	Adopting sustainable urban planning principles can reduce energy demand. Experiences with planning at neighbourhood scale in Aalborg East.
Technical	Risk of sub-optimisation.	Possibilities for local energy production, flexibility, and security. Possibilities for increasing local renewable energy production.

With the implementation of the Danish Heat Supply Act in 1979, Danish municipalities could stipulate in the local plan that new housing areas must be connected to the district heating

network. The aim of the legislation was to ensure a sufficient customer base for the district heating corporation to keep heat prices down. In 2019 the Danish Heat Supply Act was changed, in order to provide households with the opportunity to choose individual heating sources. This means that the municipalities no longer can demand that new housing areas are connected to the district heating network. Municipalities can, however, demand that households already connected to the district heating network stay connected or pay an annual fee to the district heating corporation, even if they may opt for other heating sources (Retsinformation, 2018; Energy Supply, 2022).

As described above, the opportunities for establishing energy communities in Denmark is limited. As an example, electricity from solar panels can only be shared within a housing block with separate electricity metres. If electricity is to be transferred to the neighbouring housing block the standard transmission fee must be paid, as if the electricity came from the central network. On the other hand, it is also worth highlighting that the limited opportunities for establishing energy communities in some ways contribute to support that households remain connected to the district heating network, rather than opting for more local energy solutions.

Structural barriers and potentials

PEDs focus on the district or neighbourhood scale constitutes the main structural barrier for implementation of PEDs in Denmark. The neighbourhood scale is not well-aligned with the boundaries of most district heating networks or the political-administrative boundaries of municipalities. Furthermore, district heating networks have usually centralised the heat and electricity production in a few places, which contradicts the logic of decentralised production. Furthermore, it is not clear who should lead the process of developing PEDs. In Denmark municipalities are responsible for urban and energy planning, however, as the district or neighbourhood scale fall outside the municipality's traditional scalar focus, it is not obvious for the municipality, why it should endorse the concept. However, Aalborg Municipality has some experience with planning at the scale of Aalborg East and collaboration with many of the key stakeholders in the area. This will be a clear advantage for the implementation of a PED in Aalborg East. We will return to this issue in report D5.3: Mapping of existing partnerships and networks.

At the moment, national energy policies are primarily targeting the development of large energy infrastructures in a few strategic locations. One example is the Danish Government's ambition of developing 32 'energy parks' nationally, combining wind power, solar power and power-to-X

facilities. The Danish government seems thus to favour large-scale energy production units over small-scale local production. This is also the case at municipal level, where some municipalities designate 'areas for energy production' in their municipal plan. This is for example the case in Aalborg Municipality.

On the other hand, it can be argued that PEDs provide an opportunity for rethinking the structures around which the existing energy system is built. One could argue that focusing on developing PEDs at neighbourhood level may present new opportunities for developing unexplored synergies between urban and energy planning, which at municipal level often remain silo-activities with little interaction and opportunities for cross-collaboration.

Technical barriers and potentials

As Danish cities already have well-functioning district heating networks in place, it is not clear what the immediate benefits of implementing PEDs will be from a technical perspective. As previously discussed, it could make sense to conceive PEDs as dynamic or virtual districts, which interact (import/export of energy) with the surrounding areas. However, it is not clear what added value this perspective will bring to the existing structures and technologies. On the other hand, there is a risk that the focus on developing PEDs and optimising the energy balance at the local level may lead to sub-optimisation at a larger scale. In the Danish context, there is essentially no need to scale-up solutions from the neighbourhood level, as city-wide and potentially country-wide solutions are already in place or are being planned.

Having said this, Aalborg East represent in a Danish context an interesting case of how a PED may be established. The central power plant in Aalborg Municipality, Nordjyllandsværket, is in the process of phasing out its coal-fired power plants, which leads to the interesting question of whether energy production should remain centrally produced, or whether it can be supplemented by local production units in the future. To our knowledge, this is however not something that is being discussed at the moment.

As demonstrated in the assessment of the current energy balance in Aalborg East (D5.1), the area can already be considered a PED, if we only look at heat production/consumption. From an electricity perspective, Aalborg East is however far from realising its PED potential. This leads to interesting reflections on how much electricity should be produced in Aalborg East in the future, and whether some of the farmland in the area should be converted to electricity production, or whether electricity

production potentially could take place in the existing built-up area, such as solar panels on larger industrial buildings or smaller wind farms. The focus on local energy production could increase the flexibility of the system, and to a greater extent allow energy to be produced where it is consumed. This may also be preferable from an energy security perspective.

Locally perceived barriers and potentials

To better understand how the local stakeholders perceive the barriers and potentials for implementing a PED in Aalborg East, two workshops were organised with the business community: an explorative workshop with the 9220 Business Network and a more focused workshop with the Sustainability Forum. The Sustainability Forum consists of 12 businesses primarily (but not exclusive) located in the business park near the Port of Aalborg. The Port of Aalborg facilitates the forum, and the forum consists of businesses interested in promoting a sustainable transition. At the workshop 10 businesses were present.

Textbox 2 presents the main findings from the workshop. The workshop demonstrated that the businesses (who generally are interested in sustainability issues) already have considerable experiences with implementing various kinds of energy measures to either reduce energy consumption or produce renewable energies for own consumption. For example, 80% of the businesses had already implemented energy renovations on their buildings and 50% had invested in some form of green energy. When asked about the experienced barriers for implementing measures to reduce energy consumption or produce renewable energy, the businesses highlighted economy and finance as the biggest barrier, whilst spatial limitations also played an important factor. In the workshop, it became evident that the businesses were interested and willing to implement measures that could further the PED agenda, if the investments would make sense from an economic perspective. It is thus mainly an economic rationality that underpins the decision-making on whether to invest in energy measures in the businesses. Having said this, the businesses highlighted that they are interested in doing more and generally are sympathetic towards the PED concept. The Port of Aalborg have already started to investigate the possibility of establishing an energy community in the business park but are currently facing legal challenges on how this could be done.

Textbox 3: Local businesses perceived barriers and potentials for implementing PEDs

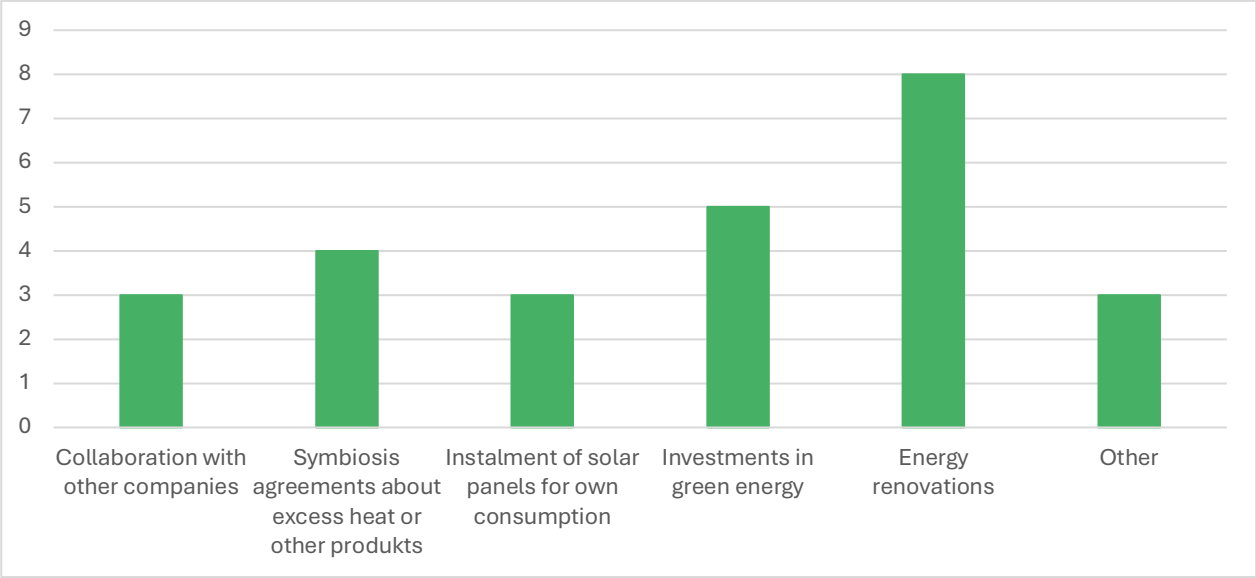

Figure 5: Number of businesses with experiences in implementing energy measures. N=10.

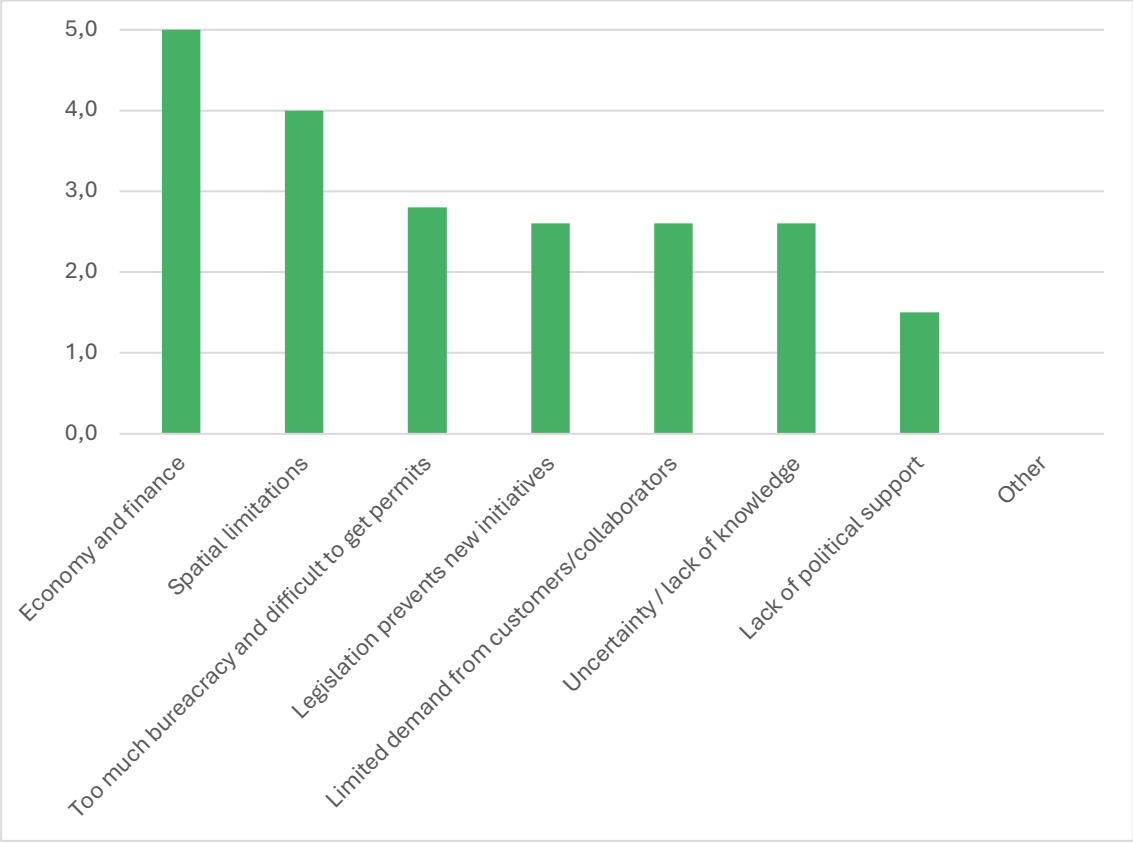

Figure 6: Perceived barriers for implementing energy measures (ranked 1-5). N=10.

FLEXPOSTS
FLEXIBLE ENERGY POSITIVITY DISTRICTS

Conclusions

This report has discussed the barriers and potentials for implementing PEDs in Denmark and in Aalborg East. The main barrier for implementing PEDs in Denmark is that the concept is not well-aligned with existing organisational structures and practices and that it is currently not clear who should champion the implementation. This is a discussion we return to in the report Mapping of Existing Partnerships and Networks in Aalborg East (D5.3).

On the one hand, the current Danish setup of well-developed district heating networks operated by non-profit cooperatives or municipalities provides a solid foundation for the implementation of PEDs. Some of the logics behind PEDs is thus already built into the Danish district heating model, for example the idea of shared ownership. In addition, Denmark has a large percentage of renewable energies in the existing energy system, and the Danish government has adopted policies to drastically expand the production of renewable energies towards 2030.

On the other hand, PED's focus on the district or neighbourhood scale represents an important structural barrier for the implementation of PEDs in Denmark. Although some municipalities, such as Aalborg Municipality, may have some experiences of planning at neighbourhood scale, such experiences are limited and not widely supported by the existing political-administrative structures, which tend to prioritise the planning of city-wide solutions. Still, there is potential to align sustainable urban planning principles with the focus on energy reductions in the layout of the city and energy planning optimisation and performance in the grid.

From a legal perspective, the limited possibilities for implementing energy communities or other governance frameworks for sharing locally produced energy seriously impedes the potentials for implementing PEDs in Denmark. If one, however, conceptualise PEDs on a larger district or neighbourhood scale (large neighbourhoods), such as Aalborg East, these legal limitations become perhaps less important. One important lesson learned from this study is therefore that the barriers for implementing PEDs may be overcome by adjusting the geographical boundaries of the PED and reconceptualising the understanding of what a PEDs is. In a Danish context, the latter would lead to a conceptualisation of PEDs as dynamic or virtual large neighbourhood units. It is therefore important that the PED concept is translated into the national and local context in a meaningful way that supports the renewable energy transition, rather than narrow-minded processes that leads to positive energy balances at the local level at the expense of sub-optimisation at a large scale.

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