Cities transformation through Positive Energy Districts: MAKING-CITY project.

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Abstract. This paper presents a MAKING-CITY project overview that is focused to address the cities transformation through positive energy districts. MAKING-CITY is a large-scale demonstration project aiming at the development of new integrated strategies to address the urban energy system transformation towards low carbon cities, with the positive energy district (PED) approach as the core of the urban energy transition pathway. Currently city energy plans are starting to be designed with a 2030 horizon. MAKING-CITY will address methodologies to support cities in their long term (2050 vision) urban planning towards an adequate energy transition, paving the way of the planning, implementation and up-scaling process. Cities of Groningen (Netherlands) and Oulu (Finland) will act as lighthouses. These cities are currently working intensively in ambitious transformation planning. Both have committed to deploy a demonstration of at least one positive energy district. León (Spain), Bassano del Grappa (Italy), Kadiköy (Turkey), Poprad (Slovakia), Vidin (Bulgaria) and Lublin (Poland) are the follower cities. All of them have assumed a huge commitment to develop a solid execution project of Positive Energy District and foster high level of replication of the solutions demonstrated in Groningen and Oulu.

Keywords: Energy efficiency, urban regeneration, positive energy district, sustainability cities, smart cities.

1 Introduction

Cities, whatever their size is, are essential actors in fighting climate change. According to the COP21 Paris Agreement, cities around the world are taking steps to promote renewable energy, support electric vehicles, change streetlights to energy-saving LEDs, slash emissions from buildings and acting as a host of other measures. Just within the more than 80 megacities that make up the C40 cities [1], members have taken more than 10,000 climate actions, as this organization reported in 2015. In 2016, the organization's "Deadline 2020" report [1] indicated that cities alone can reduce 5% of the world's global emissions, contributing to meet the Paris Agreement, and in concert with other tiers of government and the private sector, they can potentially contribute to reduce 46% [2].

UN SGD11 [3] aims by 2030 to enhance inclusive and sustainable urbanization, and capacity for participatory, integrated and sustainable human settlement planning

and management in all countries, besides substantially increase the number of cities adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change.

Therefore, the reference time-horizon is 2030 (12 years ahead), that could be considered as a mid-term planning. On the contrary, longer term energy planning in cities has been normally evaded. Only few incipient studies in big cities, like London with a long-term vision in mobility [4] or the more general Goteborg 2050 [5] plan, have analyzed this long term horizon. There is a clear need to be systematically learning from the past, but planning also the future, updating continuously the cities strategies with a combined vision deployed in three levels: longer-term vision, mid-term strategy and short-term execution plans.

The term energy transition [6] designates a significant change for an energy system at long-term, that could be related to one or a combination of changes related to structure, scale, economics, and energy policy. Usually referred as a change in the state of the whole energy system in opposition to individual changes in energy technologies or fuel sources [6], historical energy transitions can be mentioned. For example the resource depletion triggered by technological innovations that lead to shifting to new energy sources in the 19th Century like kerosene or other petroleum-derived products.

Urban planning has been performed without considering mixed-use districts and buildings have been built individually, irrespective of the surrounding buildings. But, these heterogeneous districts and RES local energy production need to be seen as the key element contribute to sustainable cities, once both are locally interconnected and managed [7]. Therefore, an interdisciplinary design process is needed, in order to not only reduce consumption of those districts but also to allow an interchange of energy flows within the limits or even export energy outside its limits.

A useful approach is to work from the district and building point of view, where this “micro-level” can be analysed, addressing new concepts to foster and support the energy transition, as for instance the idea of Positive Energy Districts (PED), as a fully scalable way to progress in the city transformation in systematic way, consolidating sustainable changes while the way is paved for further advances.

To sum up, MAKING-CITY project aims to achieve evidences about the actual potential of the PED concept, as foundation of a high efficient and sustainable route to progress beyond the current urban transformation roadmaps through two cities demosites and 6 six follower cities.

2 Project Overview

Coordinated by CARTIF, MAKING-CITY is a large-scale H2020 Smart Cities and Communities demonstration project aiming at the development of new integrated strategies to address the urban energy system transformation towards low carbon cities, with the Positive Energy District (PED) approach as the core of the urban energy transition pathway. The MAKING-CITY consortium brings together expertise from 34 partners of across Europe (see **¡Error! No se encuentra el origen de la referencia.**): 9 city councils, 5 universities, 4 research centres, 4 clusters and foundations, 4

rental housing administrators, 4 SMEs, 3 energy companies, and one construction firm. The insights of Groningen (Netherlands) and Oulu (Finland), as "lighthouse cities", will be adopted by the six follower cities of Bassano del Grappa (Italy), Kadiköy (Turkey), León (Spain), Lublin (Poland), Poprad (Slovakia) and Vidin (Bulgaria).

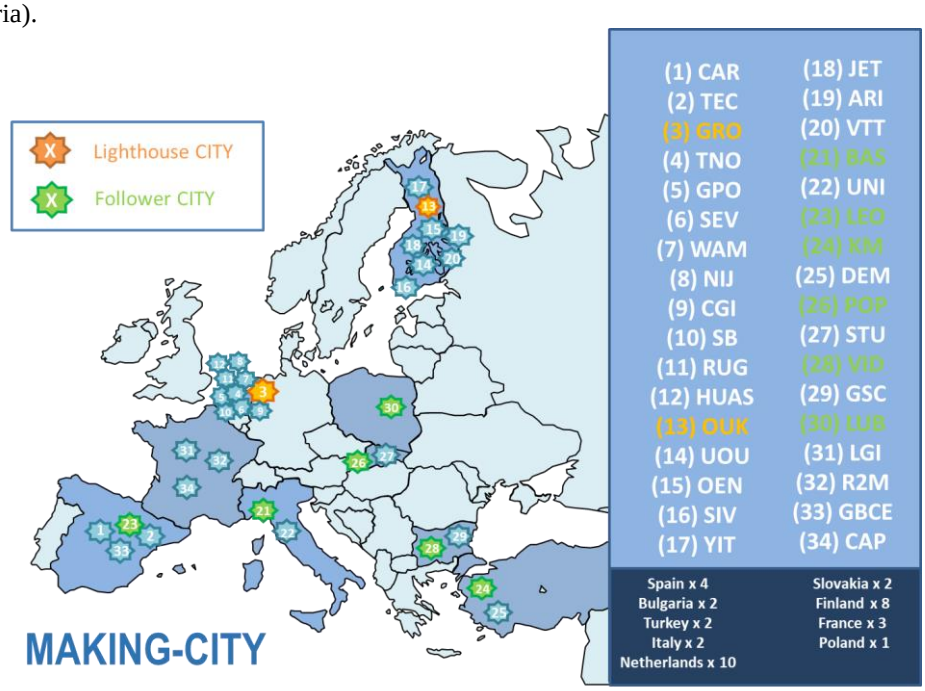


Fig. 1. Origin of the consortium members.

As the main goal, MAKING-CITY wants to apply the PED approach as the core of the urban energy transition, with the districts producing more energy than what they consume. The project's set of solutions includes positive energy buildings, renewable energy systems, energy sharing, electric mobility and smart IT. Furthermore, MAKING-CITY focuses on non-technical solutions such as effective policy innovation, business models, new regulations and standards, or actions to increase energy awareness among citizens. One of the key elements of MAKING-CITY is a strong collaboration and knowledge transfer between the cities, triggering public and private investments in the developed energy solutions. The project will also foster the growth of new sustainable start-ups and small businesses, creating up to 4000 new jobs. Therewith MAKING-CITY will not just contribute to mitigating climate change but also improve quality of life of the local citizens and stimulate the economy.

In other words, the project is intensively focused on achieving evidences about the actual potential of the PED concept, as foundation of a high efficient and sustainable route to progress beyond the current urban transformation roadmaps.

The Positive Energy Block concept is already integrated in the Action 3.2 Smart Cities and communities of the Energy Union and Set Plan, that aims at net–zero-

energy/emission districts (ZEED) that will strongly contribute to COP21 targets. A further step to this ZEED concept is the consideration of "positive energy districts (PED) [8]". These districts consist on delimited areas of buildings and public spaces where the total annual energy balance is positive, therefore the area will deliver, in average, an energy surplus to be shared with other urban or peri-urban zones. The total annual energy balance is the energy taken from outside the district against the energy delivered on-site (whatever the energy carrier). Achieving positive energy balance means that the energy delivered by the district must be higher that the energy supplied from outside. Since all energy carriers must be considered as potential energy inputs or outputs, just primary energy units can be used in the calculations to merge all of them. Therefore, in PED's the balance of primary energy consumed and delivered by the district must be positive. This consideration requires an intensive energy generation on-site, playing renewables (e.g. solar, geothermal…) a key role together with very efficient generation equipment (e.g. heat pumps, CHP...). Besides, a very low consumption is critical, so retrofitting actions for old buildings or ambitious designs of new ones to achieve high performance buildings are essential, integrating advanced materials, control systems, energy storage, etc. Both aspects, renewables on site and low consumption properly combined can led energy performance beyond the buildings codes and attractive business cases, thus fostering a faster energy transition. A schematic diagram to sum up the PED concept is shown in Fig. 2

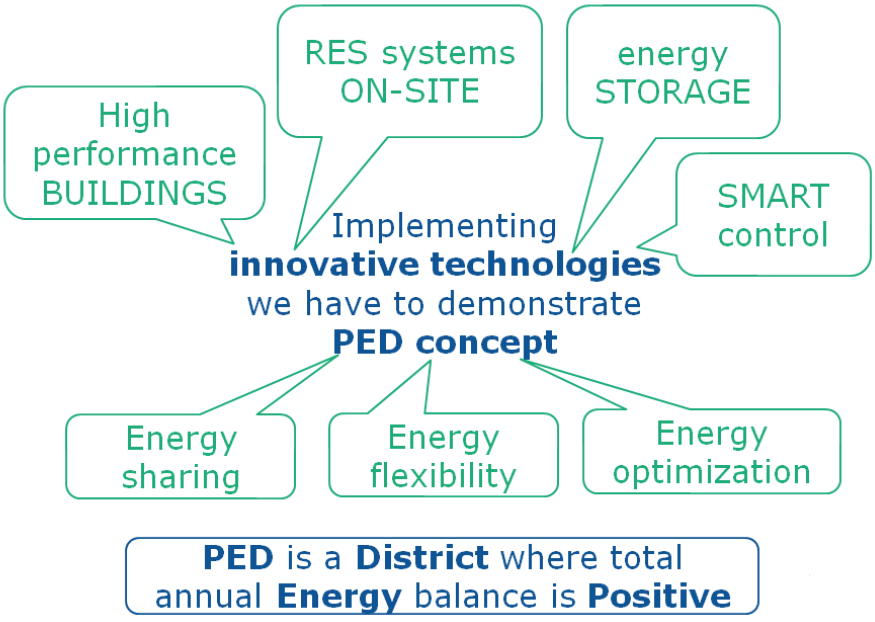


Fig. 2. Positive Energy District concept.

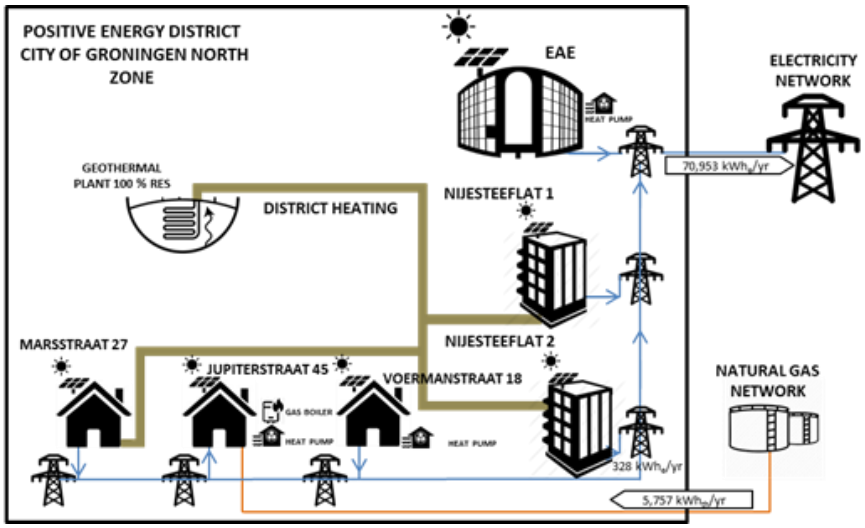
Positive Energy Districts of various sizes are expected to be used as innovation-pushing "seeding points" to showcase in highly concentrated form the integration of all the aspects that are needed for net–zero- energy/emission districts. Although many references about the individual concept of positive-energy building or positive home concept can be found in the state of the art (even others such as the smart energy zones approach, that is the general strategy of the city of Groningen) a small number of evidences about the actual performance and benefits of this new global PED concept can be found, like the Hikari district in Lyon [9]. According to this, PED claims for an extensive demonstration and validation action to consider this innovative concept as a reference to guide the energy transition in cities.

3 Demosites

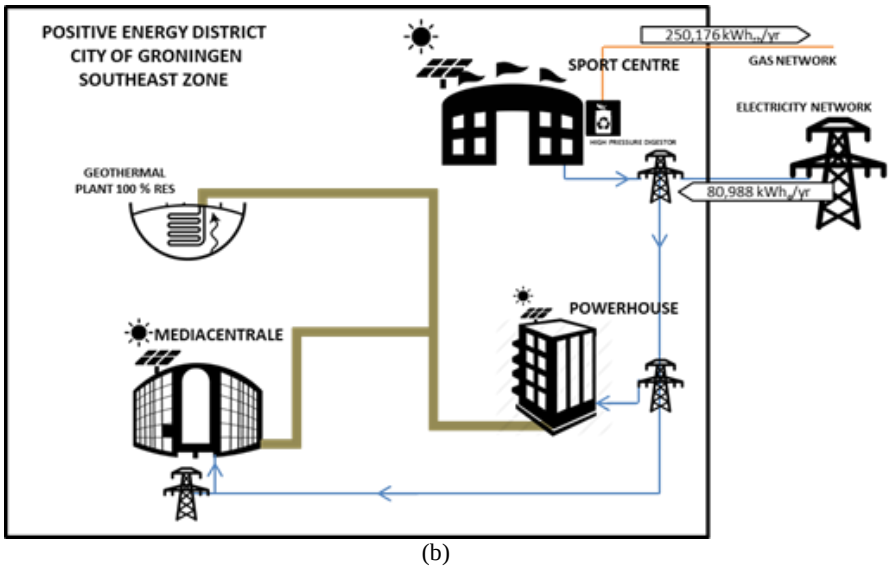
3.1 Demonstration of Positive Energy Districts in lighthouse cities

Cities of Groningen (Netherlands) and Oulu (Finland) are the lighthouses. These cities are front-runners in the urban energy system transformation and provide a powerful added value to the project objectives addressing a set of demonstrations of technologies and solutions in representative areas of the cities that become Positive Energy Districts.

Groningen
Groningen will address the transformation of two districts in PEDs, one in North and other one in Southeast (see Fig. 3 a, b).



(a)



(b)

Fig. 3. Energy flows among buildings in Groningen PEDs. North (a) and Southeast (b), respectively

Groningen North and Groningen South are the two districts selected to implement the PED concept developed in the MAKING-CITY project. Several infrastructure typologies are represented in both urban areas: residential buildings bordering a university campus, industrial and tertiary blocks, public facilities. Part of the residential area in Groningen North was built in the 1960's while the vast majority of Groningen South is relatively new, constructed around the 1980's.

Overall, the PED implementation in Groningen North and Groningen South involves the retrofitting of residential buildings to reduce building energy consumption (as for instance high performance insulation, efficient windows, heat recovery facilities smart thermostats and sensors to real-time measuring of energy consumption and advanced energy management systems) in order to maximise infrastructure performance. On the other hand, the main foundation of the achievement of the PEDs is an intensive use of RES, mainly a district heating 100 % based on geothermal energy, a biogas plan in one of the buildings (high pressure digester) and an extensive installation of PV facilities for distributed electricity generation on site. Solar panels will be installed on the roofs of some buildings and car parks. In addition, solar thermal panels will support geothermal heat pumps which are directly connected to the geothermal district heating system. The surplus of thermal energy produced by some residential buildings will be stored and used during energy demand peaks. Finally, biogas technology will be used to collect and "digest" -under high pressure and thanks to bacteria-, waste and waste water produced by public sport and catering facilities. A special focus will be made on cycling and electric mobility. For instance, an existing cycling lane will be converted into a "SolaRoad" by the integration of solar panels in its surface able to produce around 60,000 kWh yearly. Moreover, smart charging

stations for electric vehicles will be installed and directly connected to the current grid and impact in the grid will be analysed in order to demonstrate that a potential roll up of these vehicles will be properly assumed by the existing grid infrastructure if PED concept is properly validated

The boundaries of the districts involve many buildings. Only a limited number of them will be part of the definition of the PED, creating the seed of a further scaling up on the basis of this first approach. Several building typologies have been selected, individual residential, high-rises and tertiary buildings (6 in North and 3 in Southeast) that ensure an easy upscaling.

The positive annual energy balance will be achieved due to the high ratio of PV panels installed and the almost zero demand of thermal energy from outside in the North area and the thermal energy surplus in the Southeast delivered through the district heating and gas network. Groningen North PED will export outside the district 70 MWhe/yr of electricity and will import 5.5 MWhth/yr of thermal energy (natural gas), for a total balance in primary energy units of 170 MWhp/yr exported outside the district. Groningen Southeast PED will export 250 MWhth/yr of thermal energy and will import 80 MWhe/yr of electricity for a total balance in primary energy of 97 MWhp/yr exported outside the district. So both districts have been designed to have a positive annual energy balance.

Oulu

Oulu plans to develop a PED in the area of Kaukovainio on the basis of the very high efficiency geothermal heat pumps and PV panels. Located 3 km away from the city center, this urban area gathers nearly 4,700 inhabitants and is mainly dominated by high-rise buildings and individual houses. The PED approach aims at revitalising the district by attracting more residents and families, fostering a community spirit, advancing equality between population groups, and promoting sustainability.

The main facility is a centralized heat pump that supplies energy to a low temperature district heating and integrates a PV plant to supply part of the electricity to operate the system (see Fig. 4). All buildings (4 residential and one shopping mall) will be connected to the district heating, and particularly the shopping mall will host a high performance heat pump, based on CO_2 tech, hybrid solar panels, PV panels and geothermal for seasonal storage (on summer, the extra energy produced will be redistributed into the district network (heating and hot water), or stored for winter energy demand peaks), that due to the high COP (6) is able to supply energy to the district heating network and reach positive annual energy balance. EV will be also considered. Some charging points will be installed in the shopping mall to analyse the charging impact on the grid and plan the necessary measures to support this new consumption. The annual positive energy balance will be reached by means a high energy surplus on the energy production of high performance heat pumps, distributed through the district heating outside the district. Oulu PED will export 1,020 MWhth/yr of thermal energy through the district heating and will import 518 MWhe/yr of electricity, for a total balance in primary units of 80 MWhp/yr exported to outside the district, so, has been designed to have a positive annual energy balance.

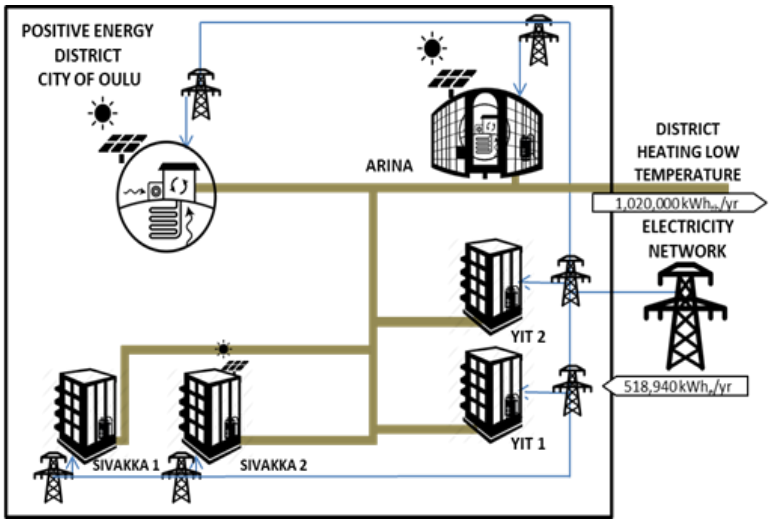


Fig. 4. Energy flows among buildings in Oulu.

3.2 Replication of Positive Energy Districts in follower cities

Six cities will act as followers, León (Spain), Bassano del Grappa (Italy), Kadiköy (Turkey), Poprad (Slovakia), Vidin (Bulgaria) and Lublin (Poland). They compose a geographical, socio-economic and cultural well-balance regarding the lighthouses. MAKING-CITY will address replication goals by means of two main actions:

- Designing a positive energy district in each follower until the level of execution project, defining the general approach of the PED (boundaries and goals), engaging citizens and stakeholders, selecting suitable technologies for increase energy efficiency and local energy production, and finally designing the link among buildings to share energy and supply outside.
- Developing a replication plan oriented to upscale and replicate the solutions demonstrated in the lighthouse and lesson learnt in the above-mentioned designing process.

Follower cities description are:

Bassano del Grappa
In Bassano del Grappa, three districts have been selected to replicate the PED concept developed in MAKING-CITY: Sant'Eusebio, Merlo and San Vito**.** Energy management using smart building energy controllers and the exploitation of existing renewables installations (mostly solar energy) will be part of the core actions undertaken.

León
Entrevias is a group of 5 separated neighbourhoods located at the north of León representing 21,2% of the city's population: La Inmaculada, Cantamilanos, Asuncion, San

Esteban, Las Ventas and San Mamés. With a high density, these districts were built during the 1940's and 1950's to house industrial workers.

A poor isolation of buildings makes today the PED replication applicable in these neighbourhoods through the retrofitting of buildings and the use of biomass and geothermal technology as sources of energy, among others. The final objective is to improve energy efficiency of public facilities located in the 5 districts selected plus to improve and reduce energy consumption for many dwellers.

Vidin

Two neighbourhoods have been selected to replicate the PED concept developed in the MAKING-CITY project. The first one is made of a variety of facilities (public schools and kindergartens, a train station, residential buildings…) while the second one (located closed to the city centre), is mostly dominated by residential housing.

As one of the 6 "Followers cities" part of MAKING-CITY, Vidin aims at replicating the PED approach mainly by the retrofitting of residential buildings (windows, better heating systems…). This will maximise infrastructure performance and reduce energy consumption. Another key objective is the integration of renewable energy sources (solar panels and thermal solar panels) into the current grid in order to achieve self-sufficient energy production.

Poprad

In Poprad, the PED replication will be carried out in 6 different districts (Zapad I & II, Juh I, III, IV & VI, and Centrum). Diversity of infrastructure defined these neighbourhoods: housing blocks, public schools, and central heating stations built at different times.

Main actions to replicate the PED concept developed by MAKING-CITY are:

- the retrofitting of buildings (high efficient insulation, new windows…)
- the installation of smart building energy controllers to better anticipate energy demand and consumption
- the implementation of solutions to connect buildings together and share renewables facilities extra energy production

Kadikoy

Kadıköy aims at reducing its carbon gas emissions by 20% in 2020, and by 40% in 2030 (2015 Paris Agreement). Two highly urbanised neighbourhoods have been selected to replicate the PED concept developed in the MAKING-CITY project: Hasanpaşa and Caferağa.

Main actions to replicate the PED concept carried out in the MAKING-CITY project are:

- the retrofitting of buildings (windows, high efficient insulation…)
- the installation of solar panels on the roofs of some buildings and car parks
- the use of solar thermal panels to produce hot water

Lublin

Located in the Wieniawa district, the two areas selected to replicate the PED concept elaborated in MAKING-CITY are both a mix between public and residential buildings: schools, universities, cultural centre, municipal offices…

In Poland, Lublin was the first city to introduce a "green civic budget". The city committed to reduce by 23% its gas emissions and by 9,5% its energy consumption in the 2008 Low Carbon Economy Plan.

The PED replication developed by the MAKING-CITY partners will mainly include:

- the retrofitting of buildings (windows, high efficient insulation…)
- the installation of more renewables power stations and their connection to the entire district
- the implementation of an intelligent urban lighting management system

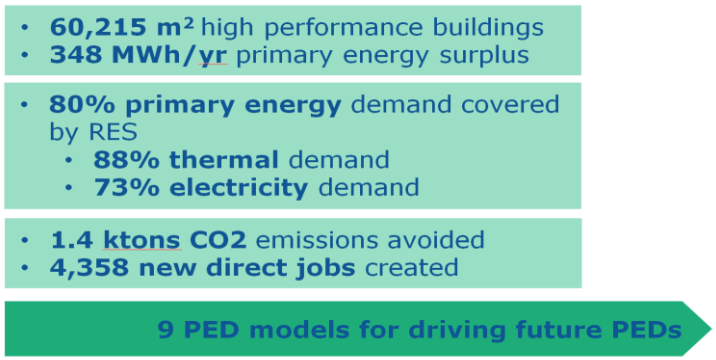
4 Expect results

Three PED full monitored and six PED near to be implemented: As main results during the duration of the project (five years), three PEDs (two in Groningen and one in Oulu) will be operated in real conditions, and the launch of another 6 in the cities that "follow" the project. Each of the eight cities involved in the project will have designed their city plans by including the PED concept in them and encouraging them to the fullest to meet the environmental commitments.

A surplus of 348 MWh/year is expected to be obtained in the PED of the lighthouse cities of the MAKING-CITY project. After two years of monitoring that will be carried out in its final stage, it will be possible to confirm the final surplus obtained, as well as analyze usage patterns that facilitate replicability in the districts identified as potential PEDs in the cities that follow the project.

Guidelines to design and calculate PED: Likewise, a methodology for the design and evaluation of PEDs will be developed, which will be compiled as a guide for easy monitoring by cities outside the project, which will maximize its impact, as well as its replicability contributing to the transformation of cities in more sustainable environments.

In general terms, the results expected with the project are:



5 Conclusions

The MAKING-CITY project sets the guidelines to be followed to include the concept of positive energy districts in the development of city planning, contributing to reach 100 framed PEDs as the objective of the SETPlan by 2025 [8]. PEDs require flexibility in energy consumption patterns that users will implement based on the web services that cities offer them. The business models that will arise around this energy flexibility must satisfy all the agents involved in the exchange, and this will be possible thanks to the real-time monitoring that will allow the combination of a complete measurement system and a versatile data platform.

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