Innovation Action

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D3.6 - Positive District Energy Flows

WP3, Task 3.5

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Abbreviations and acronyms

Acronym	Description
ATES	Aquifer Thermal Energy Storage System
BESS	Battery Energy Storage System
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DSO	Distribution System Operator
PED	Positive Energy District
PV	Photovoltaic
RES	Renewable Energy Source

Executive Summary

Objective of WP3 is describing and delivering Lighthouse demonstration actions in Groningen and the design and validation of two Positive Energy Districts, Groningen North and Groningen Southeast. This deliverable (D3.6) describes the results of Task 3.5 which is dedicated to the description of District Energy Flows for the Groningen PEDs. The intermediate version of this same document is available as deliverable D3.17.

The energy flows in the Groningen PEDs are mostly implemented by the Dutch national electricity grid, the national natural gas grid, and the local heat grid from WarmteStad. During the MAKING-CITY project the Nijestee high rise buildings are connected to the heat grid, providing a more renewable heat source. The electricity grid is unaltered, since the impact of a single PED is not expected to have a large impact on the electricity grid. However, in the semi-long term (about 20 years) there are consequences since the loads are reduced, but care must be taken to avoid congestion.

Keywords

PED concept, PED calculation, heat grid

1 Introduction

1.1 Purpose and target group

This deliverable is part of the Making City project, work package 3 (Demonstration of PED concept in Groningen). This deliverable is main outcome of task 3.2 (District Energy Flows). This document describes the energy flows between the buildings and to wider energy systems (electrical and thermal) and describes the impact of the PED on the involved parties.

Where possible, this document attempts to be as self-contained as possible. However, the reader of this document is assumed to have a basic knowledge of the Making City project including its goals, and the Groningen PED in particular.

1.2 Contribution partners

Partner no.	Partner	
3a	WAR	Section 2 - Groningen PED Heat grids
4	TNO	Editor - All other sections
5	GPO	Section 3.2 - PED impact on an energy supplier
6	SEV	Section 3.1 - PED impact on a DSO

1.3 Relation to other activities in the project

The results in this document are the outcome of shared efforts of work done in many tasks. Hence a close relation to work in other parts of the project can be found. In deliverable D2.6 the district energy flows of the city Oulu are described as the parallel MAKING-CITY lighthouse city. A complete overview of the PED interventions and actions is given in D3.1, and the modelling of the PED and the outcomes thereof in D3.3. Furthermore, the energy balance calculations are defined in D4.2.

Deliverable no.	Relation
D2.6	Positive District Energy Flows for the city of Oulu. This is the corresponding deliverable that describes the same positive energy flows in the other lighthouse city.
D3.1	Describes the overall design of the PED including all interventions.
D3.3	The model of the PED is described as it is used for simulations of different scenarios. The energy flows are an important factor in this simulation.
D3.4	The (smart) energy systems in the PED themselves affect the energy flows. The smart energy systems in the PED are described in this deliverable.
D4.2	The energy balance calculation methods that are defined are used in this document to display the total energy flows.

D5.8	The Groningen Monitoring Programme defines how the data is collected, and thus determine the PED energy flows. Any energy flow mentioned in this deliverable can be measured by the monitoring programme.

2 Groningen PED Heat grids

Two District Heating systems based on RES are located in PED North and PED Southeast and will be the main responsible to supply thermal energy to the buildings located in both PEDs.

2.1 District heating network PED North

The most ambitious, most complex investment project of WarmteStad is the so-called: Warmtenet Noordwest project. Within Warmtenet Noordwest some 10,000 – 12,000 households equivalents will be supplied with sustainable heat via an heating district network. WarmteStad has already started with the construction of the network. In 2017 the first part is realized in the Zernike part.

At the end of the summer in 2017 the national mining authority (SodM) decided to refuse the permit for the use of geothermal energy at a depth of roughly 3 km. The SodM was not 100% sure about the interference risks with the Groningen gas field, which is nearby. This was a major drawback for the City of Groningen, but luckily it was already decided that the district heating network was to be rolled out and contracts were already signed.

In June 2019 the City council and water company decided that the new renewable local energy source will be waste heat from two datacenters (Bytesnet and QTS). In October 2019 WarmteStad, the City council and the water company signed the contract for financing the construction of the whole district heating network including the sustainable heating source.

The two datacenters are both situated in the North PED district just across the original location of the geothermal energy source. WarmteStad receives according to forecasts 1.5 MW waste heat from the datacenters at a temperature of 23°C. WarmteStad extracts 5°C of the waste heat which is used to raise the return water of the district heating from 50 °C up to 75 °C by using heat pumps. If necessary during the winter the temperature can be raised up to 90 °C by using a Combined Heat and Power (CHP) installation and/or gas boilers.

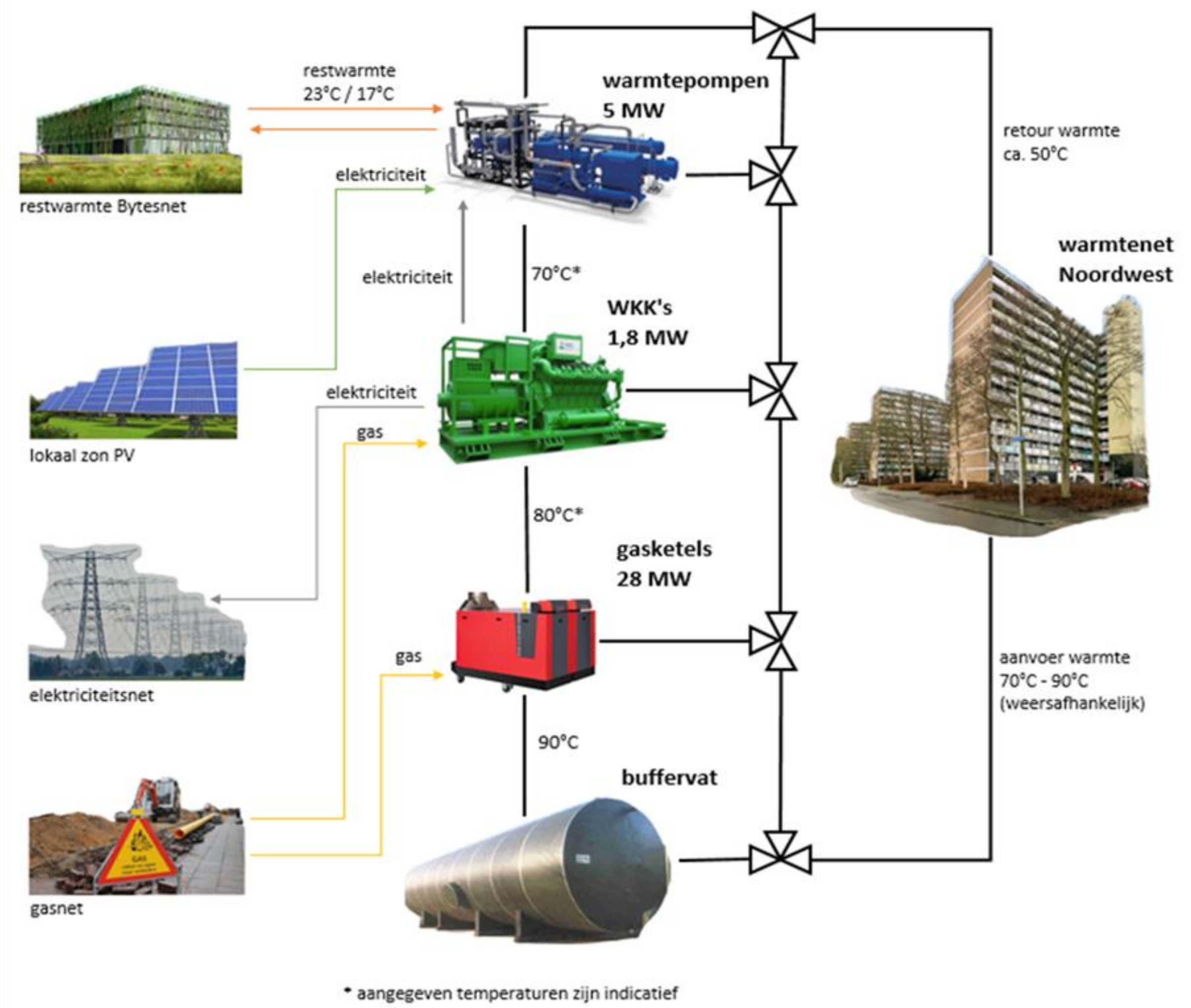

Figure 1. Configuration of the new renewable local energy source

At the start of Making City project (dec 2018) WarmteStad just launched its temporary heat plant based on two CHP installations. This temporary heat plant provided in the end of 2018 heat for the buildings of the Hanze University and the AVEBE innovation center on the Zernike Campus.

Figure 2. Installation of the heat grid pipes near next to the residential flat of Nijestee

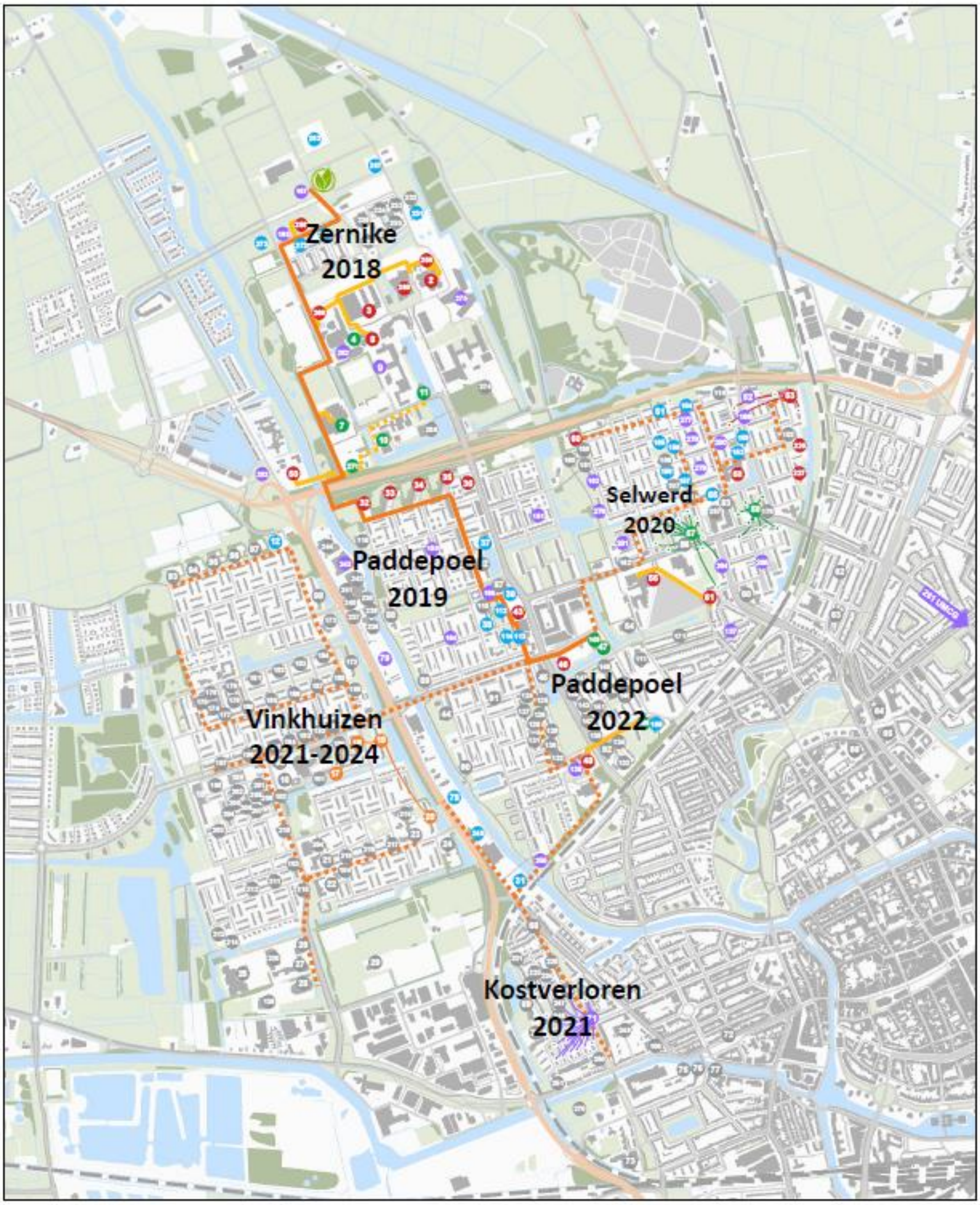

Figure 3: Planning of the construction of the heat grid 2018-2024

The district heating network is extended in 2019 to the Paddepoel neighborhood. The residential flats of Nijestee have also been connected to the heat grid in this period. In 2020 the heat grid was be extended to the Selwerd neighborhood in the eastern part of the project area. According to our planning the heat grid will cover the neighborhoods Paddepoel, Selwerd, Kostverloren and the first part of Vinkhuizen.

2.2 ATES network PED Southeast

Another project within WarmteStad's portfolio that has been realized is an aquifer thermal energy storage system (ATES) at the business park Europapark. The project was started in 2014 with one 200 m^3/h geothermal doublet. The network distributing the groundwater has been expanded each year since. Via a collective system for the entire business park, excess heat in the summer is stored in the groundwater for beneficial use in the winter. During the winter the process is reversed and the stored heat is used to heat the buildings while the excess cold is stored for use in the summer. In 2018 WarmteStad decided to drill an additional geothermal doublet in order to connect more buildings to the collective system.

Figure 3. The starting ceremony for drilling the second geothermal doublet for the ATES Europapark

At the start of the MAKING-CITY project (December 2018) WarmteStad provided heat and cold for four major buildings (see the building numbers 501, 502, 503 and 522 on the map on the following page). At this moment the number of buildings is increased to eight major building (numbers 501, 502, 503, 504, 505, 519, 521 and 522). It is expected to connect several more buildings to the ATES system in the next three years.

One the most important aspects for exploiting an ATES is to keep a heat and cold balance in the ground. In order to maintain this balance we need to accumulate sufficient heat in the summer and cold in the winter into the warm and cold source. At this moment several new buildings are connected to the ATES system. This makes it difficult to foresee if we can keep the heat and cold in balance. The quantity of stored heat/cold is also very dependent of the kind of building. Office buildings demand in general more cold and generate therefore during the summer heat for the winter. Residential buildings demand in general more heat and provide therefore more cold in the winter. So for keeping the ATES system in balance a mix of different buildings is most favorable.

The heat and cold demands of the connected buildings could generate an imbalance in the ATES future. In order to balance the ATES system WarmteStad could provide in this case additional balancing equipment. This could be more solar thermal panels or an heat exchanger connected to the surrounding surface water. The heat exchanger connected to the surface water could accumulate heat from the water in the groundwater.

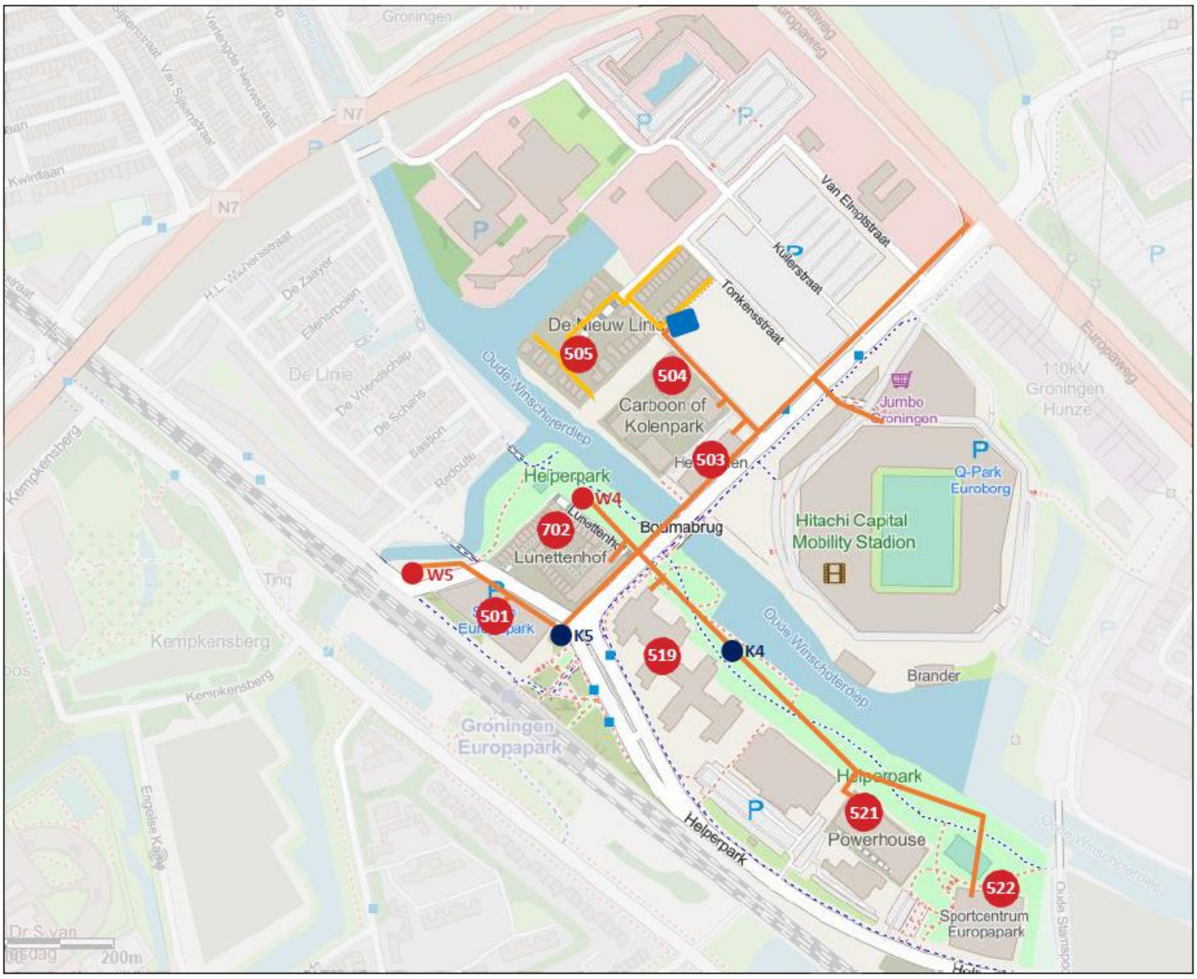

Figure 4. Map of the ATES Europapark

3 Groningen PED Electricity grid

The Groningen electricity grid is part of the Dutch national grid and is installed and maintained by the Distribution System Operator (DSO) called Enexis. Enexis distributes electricity (and gas) from the national grid to over 3 million households in the Netherlands.

Local RES (such as PV) already has a significant impact on the electricity grid, and positive energy districts will have an even larger impact. In this chapter we will discuss that impact, and to a lesser extent, the impact on energy suppliers.

3.1 Impact for a DSO

The main objective of MAKING-CITY is 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. Aligned with this aim, a harmonized energy and urban planning methodology is developed for PED design in cities. This section will focus on the short- and long-term impact of PEDs for Distribution System Operators (DSOs). Since a PED is still a conceptual idea, this section will look at the impact the PEDs in the Groningen Lighthouse city can have on the regional DSO. First, the more commonly known Regional Energy Strategy will be discussed. Thereafter, this strategy will be compared to the PED concept. The reason why a PED is compared to the regional energy strategy is because its goals and methods are similar, but the impact of the regional energy strategy can have on a DSO is currently better known.

3.1.1 Regional Energy Strategy and Grid Congestion

Thirty regions in the Netherlands have the task to generate 35 TWh of energy (gas, electricity, and heat) together on a yearly basis from 2030 onwards from renewable sources[1]. Each region is obligated to develop a so-called Regional Energy Strategy where they describe how they will contribute to this goal. These strategies contribute to the national climate goals which state that 70% of all the electricity in the Netherlands and a minimum of 27% of all the energy (gas, electricity, and heat) need to be generated by renewable sources in 2030. The implementation of the regional energy strategy in the North of the Netherlands has already led to the generation of a relatively large amount of renewable electricity by the increase in installed wind- and solar fields. The overproduction of wind- and solar energy during peak moments puts a lot of pressure on the existing electricity grid and causes congestion issues for the DSOs. Enexis, which is the DSO in the North-Eastern region of the Netherlands, is responsible for the management of the electricity grid on a regional level. Enexis is experiencing increasing difficulties to distribute all the generate electricity with the existing electricity grid. On top of that, according to the Dutch electricity law of 1998[2], a DSO is obligated to connect all electricity consumers or producers to the electricity grid. Hence, an increase in grid congestion.

3.1.2 PED Concept

The PED concept is based on the Trias Energetica. A PED is an urban area with clear boundaries, consisting on buildings of different typologies that actively manage the energy flow between them and the larger energy system to reach an annual positive energy balance. An annual positive energy balance can be achieved by increasing: (1) energy efficiency, (2) regional/local supply of renewable energy, and (3) flexibility for energy consumption within districts.

[1] https://www.regionale-energiestrategie.nl/res+regio+groningen/default.aspx

[2] https://wetten.overheid.nl/BWBR0009755/2019-01-01

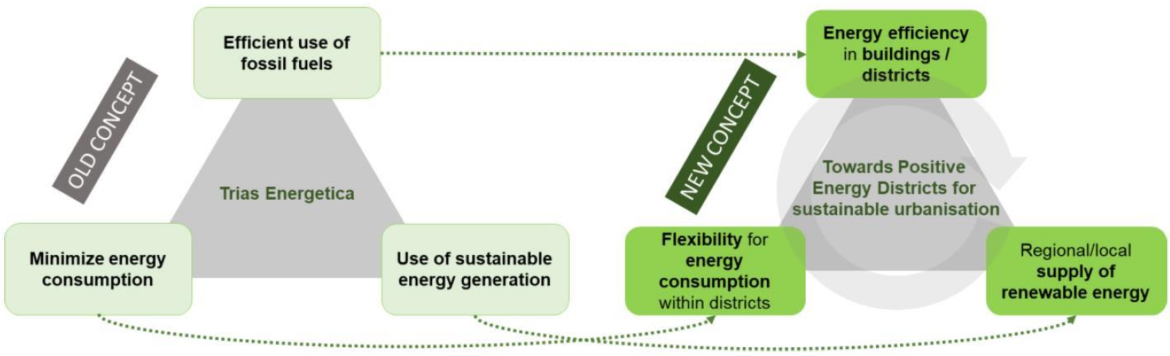

Figure 5. Trias Energetica versus positive energy district methodology.

Based on the modified Trias Energetica illustrated in Figure 5, we can differentiate four different strategies that contribute to the regional/national climate goals:

- Strategy A focusses on increasing the regional and local supply of renewable energy (which is in line with the approach of the Regional Energy Strategy)
- Strategy B focusses on increasing energy efficiency in buildings and districts
- Strategy C focusses on flexibility for energy consumption within districts to avoid the use of fossil fuels
- Strategy A+B+C focusses on the combination of energy efficiency, renewable energy production, and energy consumption flexibility (which is the focus of MAKING-CITY)

It is expected that a PED can be achieved when a district increases its energy efficiency by approximately 1/3 which means they need 1/3 less energy than before. The other 2/3 of the renewable energy demand will be generated within the PED itself as much as possible. The renewable energy that cannot be generated in the PED itself, due to the lack of space to generate all the necessary renewable energy in a city district for instance, will be imported from outside the PED. This is expected to be the case in PED-North in Groningen. Where the Regional Energy Strategy mainly looks at increasing the regional generation of renewable energy a PED focusses on a more small scale energy system that can be controlled on a more local level by the combination of: energy efficiency, energy generation, and energy management, such as energy storage systems and demand response. Instead of burdening an entire part of the regional electricity grid and risk grid congestion, a PED is focussed building an energy system on a more local level.

Compared to the Regional Energy Strategy the PED concept is:

- more ambitious in terms renewable energy share (100% renewable)
- focused on the generation and consumption of energy on a district level by incorporating energy management systems and storage
- focused on maximizing the energy efficiency of its buildings

3.1.3 Possible impact for a DSO when implementing the PED concept

Contrary to the Regional Energy Strategy of Groningen region the PED concept focusses on reaching an annual positive energy balance on a district level by incorporating an energy management system and storage on a building/district level instead of on a regional level. Reducing the distance between the generation and consumption of energy carriers (mainly electricity, but also the case for heat and gaseous carriers) not only helps to reduce energy distribution and thus grid congestion, but also prevents energy losses and therefore contributes to a PED's energy efficiency. When a PED generates more energy than it is able to consume there is an overproduction which either needs to be stored or distributed elsewhere. In the first case the electricity can be stored by using neighbourhood Battery Energy Storage System (BESS).

However, in the case these BESS' are full or when there is no storage system in place, the overproduction needs to be distributed through the existing electricity grid to other consumers outside the PED. It is expected that the DSO is able to cope with the distribution of some overproduction, but only until a certain point. Specifically for any PED this may or may not lead to a problem since the existing power grid infrastructure has different characteristics in different PED locations.

The impact a PED can have on the DSO is further discussed below and explained in four phases based on the Groningen situation, all with their own relevant period in time. Each phase takes the same three steps but on a different scale. First, the buildings will be insulated to increase the energy efficiency. These adjustments reduce the annual energy consumption by approximately 30%. Secondly, the buildings will be equipped with renewable energy sources, such as roof-top solar panels and heat pumps. Thirdly, energy management systems, such as energy storage and demand response, will be installed to increase its self-sufficiency and reduce the load on the electricity grid.

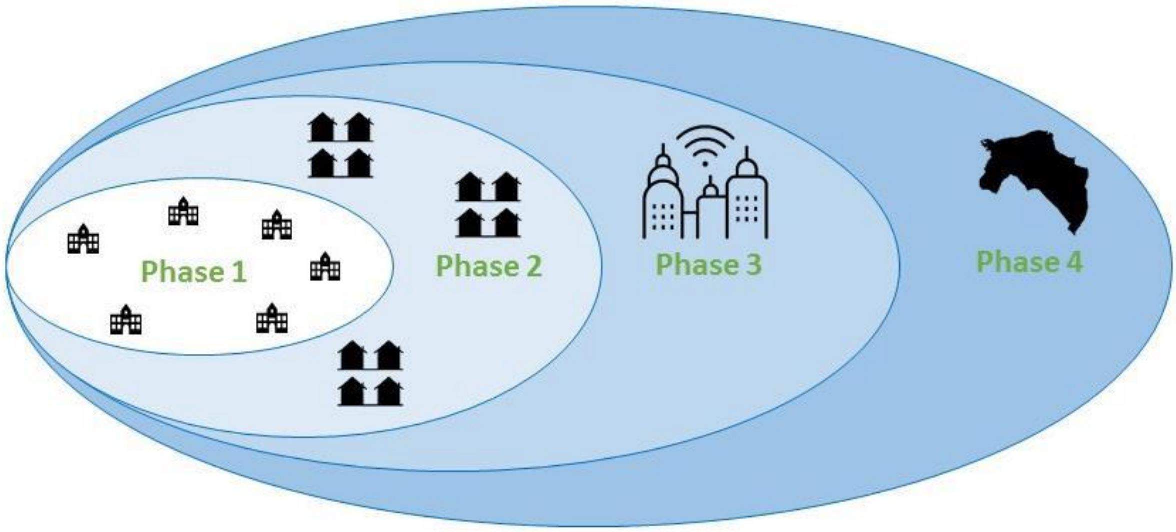

Figure 6. Four different phases of the PED concept.

Figure 6 illustrates the four different phases on which the PED concept is based. MAKING-CITY focusses on phase 1 by demonstrating the PED concept and investigating its replicability and scalability potential in order to execute the other three phases. Each phase is further described below:

Phase 1: MAKING-CITY - Annual energy balance is less negative – (5-10 years)

In this phase, several buildings that follow the concept of a PED will be realized in a city' district to reduce its annual energy balance. These buildings will generate their own electricity and consume the bulk of it themselves. A PED can only become energy positive when there are enough Positive Energy Blocks (PEBs) installed within the district to compensate for the consumption of other non-PEBs.

Phase 2: PED - Annual energy balance is positive for some PEDs – (10-20 years)

In this phase the PEB concept demonstrated in phase 1 is scaled up in order to realize a PED. In phase 2 a PED generates enough electricity by itself to become net energy neutral. Similarly to phase 1, phase 2 uses energy management systems to control the in- and outflow of renewable energy to increase the self-consumption which reduces the use of the regional energy grid significantly. By developing more small-scale energy systems, who are able to manage their own energy system, it is expected that a PED can contribute to both achieving the regional and national climate goals and simultaneously lower the workload for the DSO.

Phase 3: Smart City Groningen- Annual energy balance is positive for the whole city– (20-30 years)

If enough PEDs are installed in phase 2 it can contribute to the cities long-term vision of becoming carbon neutral in 2035. Installing enough PEDs throughout a city will help to increase renewable energy generation, energy efficiency, and energy flexibility. When more districts become independent from the exists electricity grid by becoming more self-regulating the PED concept can have positive consequences for a DSO since it reduced the load significantly.

Phase 4: Regional Energy Strategy 2.0 - Annual energy balance is positive for the whole province – (30+ years)

The last phase of the PED concept is where Groningen becomes a so-called 'Smart City' which contributes to the regional energy goals. This phase refers to strategy A+B+C where all three components of the PED methodology (Figure 5) are installed on a large scale. Phase 4 contributes to the strategy goals and reduces the load on the electricity grid for the DSO by managing the energy systems on building/district level instead of on a regional level.

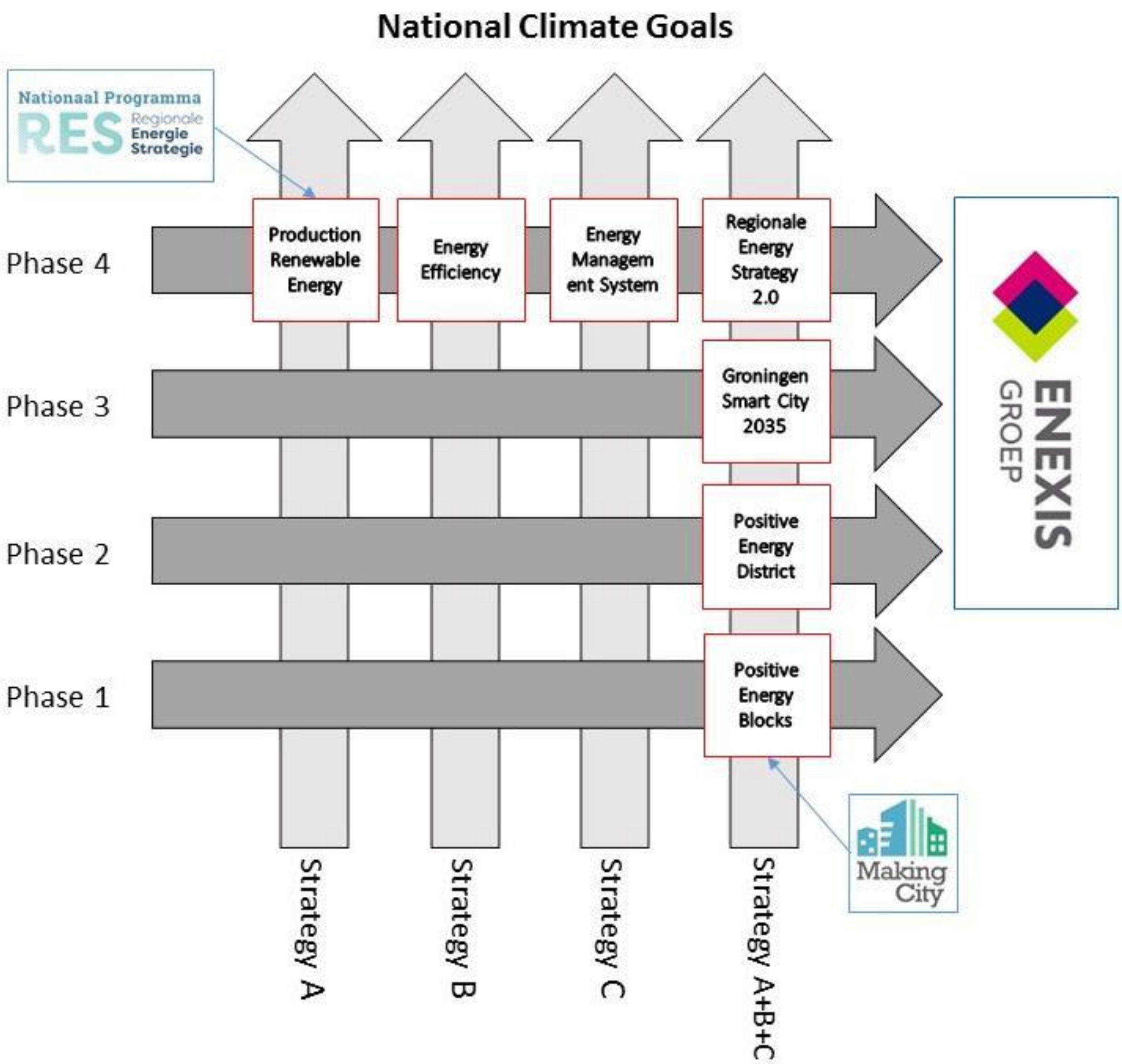

Figure 7. Comparing the Regional Energy Strategy to the PED Concept

Figure 7 compares the Regional Energy Strategy to the PED concept by illustrating the different strategies and phases. Both contribute to the regional/national climate goals. The local DSO (Enexis) will mainly play a role in phase 2-4 of strategy A+B+C since most of the energy management in phase 1 is done on building level.

3.2 Impact for an energy supplier, both technical and societal

As stated above, the most obvious stakeholder for creating PED's in Groningen would be the network operator, Enexis. As the energy flows between districts/PED's, the durability of the network could be extended. A less obvious stakeholder, but maybe even a more interesting one is the inhabitant of a PED. If the PED philosophy works, the inhabitants of the area will have to be both consumer and prosumer. The generated energy within the district has to be divided amongst the ones in need for energy. In the design of a system like this, all inhabitants need to be given the chance to participate.

The first challenge that arises is a legal one. Excess energy that is produced, for example on the roof of a household by solar panels, is currently fed to the electricity network. The homeowner receives a fee, which is a lot lower compared to the fee that has to be paid when wanting to buy electricity from the network. If a neighbour, who does not have any PV-panels, is in need of energy, that energy can be bought directly from the network. In a PED, this supply and demand needs to be balanced. Under Dutch law, this is however not possible yet. Every party that produces and sells energy, needs to have all documentation required to be an official energy supplier, like the big industrial organizations. Of course, this is not feasible. Experiments of such nature are currently ongoing in other parts of the Netherlands.

Besides the equal distribution of energy amongst the PED, the question will arise who will determine which parts of the PED can use what amounts of energy at what times. GPO sees a role for a district energy community, that represents all interests of all stakeholders within the district. There is a great opportunity in balancing the districts' energy production and usage by informing all inhabitants and providing them the opportunity to contribute to the discussion of the energy management within the PED. Social structures can be used to decrease the overall energy use, but also creating a social district system where not only the producers of energy benefit from, but also the local inhabitants that do not. If the local inhabitants are organized within a representative group, this group can make deals with the (local) government and other third parties, on behalf of the PED.

4 PED calculation guidelines

The PED calculation guidelines are described in full in Deliverable 4.2 Guidelines to calculate annual energy balance. In this chapter a brief overview of this method is given, as well as a worked-out calculation for the Groningen PEDs.

4.1 Method overview

The European Directive Guidelines 2012/C 115/01 are used within the Making City to determine the energy balance within a PED. In Figure 8 below, the different steps are shown that are required for the energy calculations.

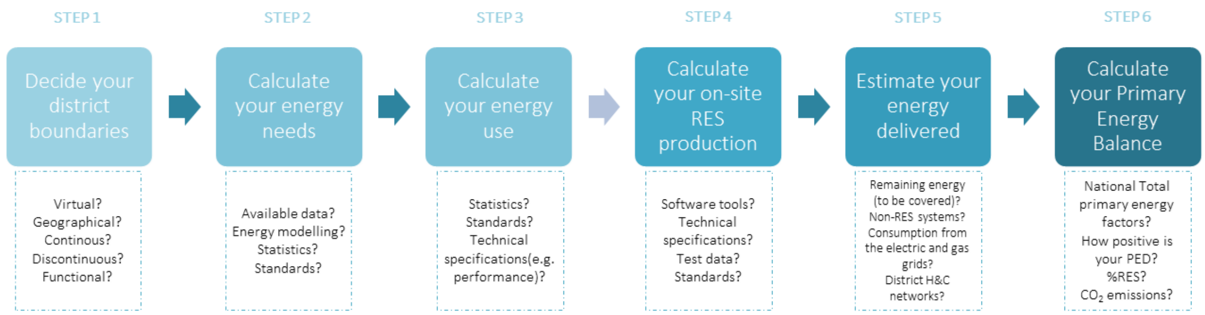

Figure 8. Steps for calculating the PED energy balance.

1. **Determine the district boundaries.** This is important because it defines what is in and what is out of the scope. Note that the boundaries of a PED can be geographical, functional or virtual.

2. **Calculating energy needs.** Estimating the required energy needs of the PED, in all different energy demands, is the next step to determine the PED balance. The energy needs include heating, ventilation, cooling, domestic hot water and electric needs for lighting. Note that any other applications such as TVs, PCs, but also laundry machines, dryers, dishwashers and other non-building related appliances are out of scope.

3. **Calculating energy use.** The energy use is based on the energy needs and the efficiency of the underlying distribution system. Any transport or conversion losses are considered to calculate the total PED energy use.

4. **Calculate on-site RES production.** How much energy can be produced on-site greatly affects the amount or energy for import of export. Energy produced locally can come from: PV, PVT, solar thermal, biomass, geothermal, heat pumps using ambient heat or other local sources.

5. **Estimating energy delivered.** With the energy use and the on-site production, the net energy delivered can be determined. This delivered energy can be supplied by the national electricity grid, gas networks or other methods.

6. **Calculating primary energy balance.** Finally, when the net imported or exported energy is known, the primary energy balance can be calculated by taking into account the primary energy factor. This factor is determined by the national energy mix, as different sources will have different primary energy factors.

4.2 PED Calculations for Groningen

Following these steps for the Groningen North PED, we get the following projected numbers for the final PED balance:

1. In the Groningen PEDs the district boundaries are virtual.
2. The energy needs for the Groningen North PED are: 627.1 MWh_{th}/a, 325.1MWh_e/a
    2.1. Energy Academy Europe: 46.7 MWh_{th}/a, 202.8 MWh_e/a
    2.2. Nijestee: 569.1 MWh_{th}/a, 120.0 MWh_e/a
    2.3. Paddepoel: 11.3 MWh_{th}/a, 2.3 MWh_e/a
3. The energy use for the Groningen North PED are: 658.4 MWh_{th}/a, 328.4 MWh_e/a, taking into account 5% and 1% losses, respectively.
4. On-site production is: 569.1 MWh_{th}/a, 400.6 MWh_e/a
    4.1. Energy Academy PV: 367.2 MWh_e/a
    4.2. Nijestee PV: 28 MWh_e/a
    4.3. Sungrazer PV: 5.4 MWh_e/a (proportionally to geographical district)
    4.4. Waste heat recovery: 569.1 MWh_{th}/a (proportionally to PED buildings to rest of heat grid)
5. Energy delivered: 89.3 MWh_{th}/a, -72.2 MWh_e/a
6. Primary energy balance: -50.8 MWh/a (PEF_{th}:1.08, PEF_e: 2.04)

The calculation yields a total of -50.8 MWh/a, which means that in total the PED delivers some energy to the grid. The results are visually shown in the Sankey diagram below. Note that this does depicts only the final energy use, and not the primary energy required (I.e., it shows the intermediate results after step 5).

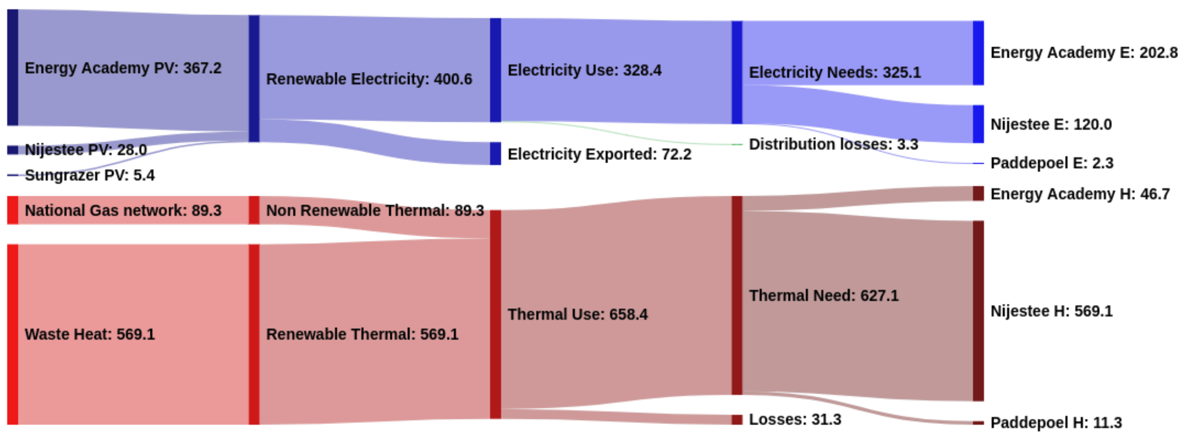

Figure 9. A Sankey diagram for the PED North energy flows in MWh/a.

For the South PED the method provides the following results:

1. Again, the district boundaries are virtual.
2. The energy needs for the Groningen South PED are: 911.8 MWh_{th}/a, 1344.4 MWh_e/a
    2.1. Mediacentrale: 297.7 MWh_{th}/a, 695.4 MWh_e/a
    2.2. Sport complex Europahal: 93.9 MWh_{th}/a, 116.7 MWh_e/a
    2.3. Powerhouse buildings: 381.1 MWh_{th}/a, 208.3 MWh_e/a
    2.4. Harm Buiterplein: 139.1 MWh_{th}/a, 324.0 MWh_e/a

3. The energy use for the South PED are: 957.4 MWh_{th}/a, 1357.8 MWh_e/a, taking into account 5% and 1% losses, respectively.
4. On-site production is: 475.0 MWh_{th}/a, 1709.9 MWh_e/a
    4.1. Sport complex Europahal PV: 346.8 MWh_e/a
    4.2. Harm Buiterplain PV: 36.6 MWh_e/a
    4.3. Powerhouse PV: 114.8 MWh_e/a
    4.4. Solarpark Woldjerspoor: 175.0 MWh_e/a (proportionally to geographical district)
    4.5. Solarpark Roodehaan: 977.1 MWh_e/a (proportionally to geographical district)
    4.6. Solaroad PV: 61.2 MWh_e/a
    4.7. Parking top PV: 111.4 MWh_e/a
    4.8. Heat grid heatpump: 475.0 MWh_{th}/a, -113.1 MWh_e/a
5. Energy delivered: 482.4 MWh_{th}/a, -352.1 MWh_e/a
6. Primary energy balance: -192.3 MWh/a (PEF_{th}:1.08, PEF_e: 2.04)

The calculation yields a total of -192.3 MWh/a, which means that also the South PED delivers energy to the grid. Also, the south PED energy flows are depicted as a Sankey diagram below.

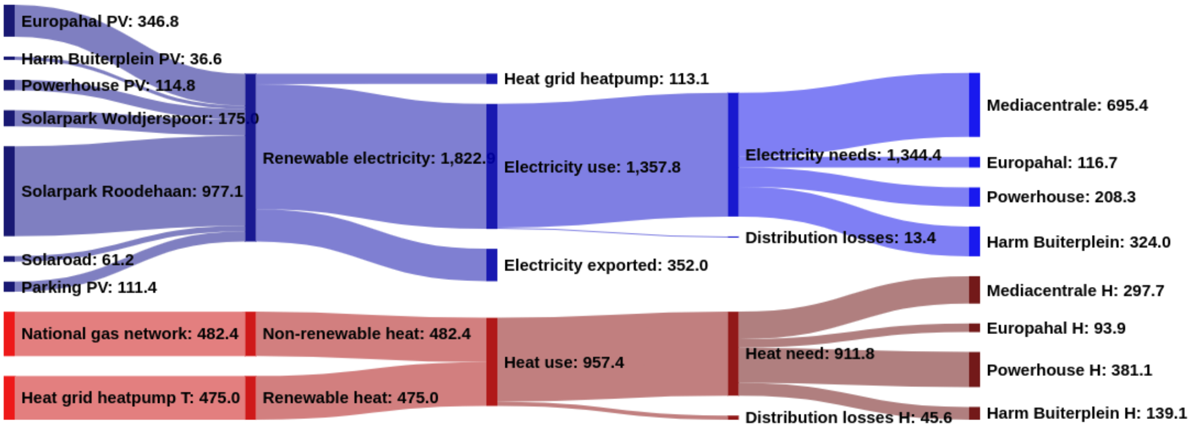

Figure 10. The Sankey diagram for the PED South energy flows in MWh/a.

Conclusions

This document describes the electrical and thermal energy flows between the buildings in the MAKING-CITY lighthouse city Groningen, and to the flows to the national energy grid. Furthermore, the impact of the PED on the involved parties are considered in the short and medium-long term.

It can be concluded that the Groningen heat grid is well on its way to become a modern and reliable heat grid, which allows for a durable an green heating alternative for fossil fuels. There are future interventions planned that will make sure that the heat sources are renewable in both the North and the South district.

The electricity grid in Groningen is the pre-existing network maintained by the local DSO Enexis, and will be able to keep up with the PED in the near future. In the medium-long term however, local storage will need to be used in order to store overproduced energy. In the long term, other parties such as the energy producer, but also the end-consumer will play an important role in order to maintain a stable and balanced energy grid.

Finally, we have shown that given the planned interventions of the MAKING-CITY project allows the two PEDs are indeed expected to become energy positive. This takes into account both the locally generated electricity and residual heat, as well as all the energy reduction interventions.