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D3.5 - Smart Energy Systems in Groningen

WP3, Task 3.4

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Abbreviations and acronyms

Acronym	Description
BIPV	Building integrated Photovoltaics
CHP	Combined Heat and Power
DER	Distributed Energy Resource
PED	Positive Energy District
PV	Photovoltaic
PVT	Photovoltaic Thermal
VPP	Virtual Power Plant

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 D3.5 describes the results of Task 3.4 which is dedicated to the description of useful Smart Energy Systems for the Groningen PEDs. The intermediate version of this document is available as deliverable D3.16.

In the MAKING-CITY project various smart energy systems are implemented in two PEDs. Such systems are either local interventions such as insulation or LED lighting to reduce usage, energy producers such as PV panels, or regionally controlled systems, most notably the heat grid and the sensor systems for monitoring the energy usage.

Demand response systems are described, but there are not many *flexible* energy systems in the PEDs outside of the heat grid. The HeatMatcher system can take advantage of the flexibility of the heating systems in the Mediacentrale, and is currently being used to control a simulated heat grid of the Groningen North PED.

Keywords

Smart devices, smart meters, demand response

1 Introduction

1.1 Purpose and target group

This deliverable aims to give an overview of the different smart energy systems included in the Groningen PEDs. In this context we will discuss the various interventions and discuss what systems actively or passively change the energy balance of the PED. Also, we will discuss the potential of demand response to make optimal use of the smart energy systems.

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	Contribution
3	GRO	Section 2.6 information on the Sport Complex Europahal
4	TNO	Lead of this deliverable – editing and all other chapters and sections
5	GPO	Section 2.2 on the terraced houses
8	NIJ	Section 2.1 on the Nijestee highrise buildings
10	SB	Section 2.7 smart metering systems
11	RUG	Section 2.5 about the Energy Academy Europe

1.3 Relation to other activities in the project

A complete overview of the PED interventions and actions is given in D3.1. In D3.4 a more detailed specification is provided of the Smart Energy Systems in the PED buildings. In D3.3 the modelled city and the resulting energy balance from the following systems are presented using data from simulations.

In D2.5 a parallel description of the smart energy system in the city of Oulu are presented.

1.4 Groningen PEDs

In the MAKING-CITY lighthouse city Groningen, there are two PEDs: one in the north west, which has mostly education and residential buildings, and another in the south east, with offices and industry. An overview of the PEDs is shown in Figure 1.

Figure 1. An overview of the two PEDs in the Groningen Lighthouse city.

2 Smart Energy Systems in Buildings

In this chapter an overview is provided on the different (types of) smart devices that were or will be installed in the PEDs.

2.1 Nijestee high-rise buildings

Two high-rise buildings from Nijestee were included in the project. Each building consists of a common room and 108 residential apartments with a size of around 25 m^2. In 2018 and 2019 both buildings were renovated and the following interventions were implemented:

- **Improved insulation** of the cavity walls and roofs. The **ventilation system** was upgraded, so that it is now controlled based on CO_2 levels. The estimated average savings in heating and hot water use are 21%.
- 56 **PV panels** were installed with a total of 16.52 kWp capacity on each building, located on the roof.
- Both high-rise buildings were **connected to the heat grid** of WarmteStad. Hence, the houses are no longer heated by gas boilers.
- **LED lighting** was installed in the public areas within both buildings.
- In 2020 the **meter boxes** in both flats were renewed because they were too old and cannot be connected to the measuring systems of the monitoring system. Subsequently, the monitoring system was installed and the energy use of the buildings was measured.

Within the project, a topic of research is to investigate whether the connection of the elevator might also be used for an **EV charging station**. Finally, **BIPV (Building Integrated PV)** is another potential candidate that is being researched; this would involve placing vertical solar panels on the south wall of the buildings.

Figure 2. One of the Nijestee high-rise buildings

2.2 Terraced houses in Paddepoel

For the MAKING-CITY project, three different representative households have been selected to implement the smart solutions. Two of the three homes (Household 2 and 3) are constructed after 2000, which implies that these houses are relatively well insulated and require (relatively) less energy to be heated up. The 'older' household (Household 1), built between 1960 and 1975, originally has fewer insulation. To describe all smart systems, the households will be discussed separately.

Household 1

For this household the following interventions were implemented/planned:

- **Retrofitting**, including efficient glazing, floor and roof insulation, with an expected reduction of around 40% in gas consumption.
- On the roof, 26 x 360 Wp (9.36 kWp) **PV panels** were installed in an east-west configuration.
- The implementation of an all-electric solution requires a high level of insulation to be a cost-effective solution. An alternative for heating the household is to connect it to a district heating network, which was also originally planned for this household. Due to unforeseen circumstances, this was no longer possible within the timeframe of the project. Therefore, it was decided to place an **air/water heat pump** in order to simulate **a low-temperature district heating network** (20-30 degrees Celsius).
- To raise the temperature of the of the water from the air/water heat pump, a **water/water heat pump** was installed to provide high-temperature water to the household.

Household 2

The first of the newer households is a terraced household that already has some energy saving actions installed. The homeowners have installed several PV-panels (12 x 295 Wp) as well as a solar water heater. For this household the following interventions were implemented/planned:

- Installation of an **air/water heat pump** which will replace the gas boiler. Since the homeowners already decreased the temperature of their gas boiler, such a heat pump would produce sufficient energy to provide enough comfort for the homeowners. The heat pump will be connected to the existing heating system of the house (including underfloor heating).

Household 3

The household has a good insulation rate, as well as the other one described above, but has a disadvantage. The roof of the household is located to the North, which means that PV-panels (or PVT) have a relatively low yield (<50%). With the current prices of the installers, the homeowners do not consider this as an interesting investment.

- For this household **PV panels** will be installed on an extra roof in the back of the garden of the household delivering 5.33 kWp (15 x 410 Wp).
- An all-electric solution was chosen for the heat demand by installing **an air/water heat pump**.
- To determine the energy flows within the households, all three have been equipped with **smart plugs** that communicate with a router. The consortium partner Sustainable Buildings (SB) had developed a **dashboard** on which the homeowners can see their energy use. Together with the coaches from GPO, the energy use will be analyzed, and a plan will be made to help the homeowners save energy and therefore money. All major equipment installed in the households is measured and can be analyzed.

2.3 Powerhouse building

In 2019 the powerhouse building was finished, on the ground floor there is 1500 m^2 of office space, and the other six floors are available for residential purposes consisting of 80 apartments. In the basement a parking garage is available. Since the building is recently built, the **insulation is of high quality**, meaning little energy required for heating and cooling. To get this heat, the powerhouse building is **connected to the district heating network** of WarmteStad which is connected to several local underground storages. On the roof, 164 **PV solar panels** are installed, with a nominal power of 49.2 kWp, yielding an estimated annual production of 42.0 MWh/a.

In order to use the local heat grid, a heat pump is used to provide the central heating and domestic hot water:

- Heating power: 3 x 100 kW
- COP W10/W65: 2.9
- Heating energy demand: 120.7 MWh/a
- Cooling energy demand: 62.7 MWh/a
- DHW energy demand: 62.7 MWh/a

Figure 3. A rear view of the finished powerhouse building in 2020.

2.4 Mediacentrale

With a floor area of 14,400 m^2 distributed across 65 offices, the Mediacentrale is an important office building in the Europapark business area in the city of Groningen, the Netherlands. The building was created in 2005 through a renovation of the Helpman Power Station that was established in 1914 and decommissioned in 1982. A feature interesting for optimisation of heating within the building is a central atrium that spans three floors that possibly allows the area to be used as a heating buffer.

Figure 4. Outside view of the mediacentrale after the 2005 renovation.

The retrofitting of this building consisted of implementing thermal energy storage combined with a geothermal heat pump. Additionally, smart thermostats for temperature control were installed.

The installed geothermal heat pump has the following characteristics:

- Type: Mono source, 45 m^3/h.

- Temperature: 40-50 °C
- Cooling capacity: 665 kW
- Cooling COP: out of storage 40, regeneration: 6.
- Cooling energy demand: 37 MWh/a
- Heating capacity: 713 kW
- Heating COP: 4.2
- Heating energy demand: 298 MWh/a

The heat pump is providing 89% of the heating demand of the building. Therefore, for peak demands the gas installation is still in place. The desire is to add an extra air to air heat pump to cover the last part of the demand.

2.5 Energy Academy Europe

The Energy Academy Europe (EAE) has been designed as a **zero-emission building**. Over the course of 40 years, the positive energy balance, which is achieved by on-site renewable energy production and effect energy use, compensate emissions from building and construction. Below, an overview is given of the energy solutions that are in place to achieve EAE's zero emission goal and how an optimal energy performance is achieved.

The EAE generates its electricity, heat and cooling on-site. Electricity is produced by 1600 **PVP-panels**, which have been installed on its roof with a total capacity of 521 kWp, generating about 470 MWh/a. The PVP panels have been positioned in 133 triangular setups to allow for a natural lighting of the building, see figure below. Heat and cold is regulated by a hybrid ventilation system, seasonal thermal energy storage, an electric heat pump and concrete core activation.

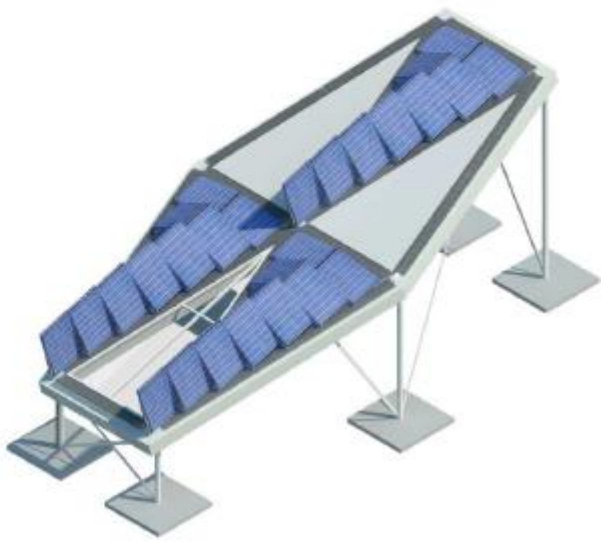


Figure 5. Triangular setup PVP-panels Energy Academy Europe.

The **hybrid ventilation system** that is installed in the EAE primarily uses natural ventilation. A black surfaced thermal chimney at the top of the building warms the air to enhance a natural stack ventilation through the building. The updraft created by the chimney can be used to draw either warm air from the winter garden, or cool air from a 200-meter concrete thermal labyrinth underneath the building. If weather conditions don't allow this natural ventilation, the building can be mechanically ventilated using air handling units. These air handling units are equipped with a thermal wheel that achieve a heat recovery efficiency of 80%.

In addition, the EAE relies on **underground seasonal thermal energy storage**, an electrical **heat pump** and concrete core activation heat and cooling. The underground seasonal thermal energy storage system (STES) (COP=17) consists of two wells near the EAE building at a depth of 100 meters, one containing hot water, the other containing cold water. Two Carrier Aquaforce 30XM heat pumps (COP =6) are connected to the STES for the generation of additional heat. The heat pumps also generate warm water. Heath and cooling are distributed through building by concrete core activation as well as low temperature radiant panels and high temperature cooling panels. An electric boiler is used for heating tap water.

Thermic insulation of the building envelope promotes energy efficiency. Furthermore, LED lighting, motion detectors, and daylight harvesting systems are installed to encourage efficient energy use. A building automation system helps to constantly manage the energy devices that are in place to achieve an optimal energy performance.

2.6 Sports Complex Europahal

This newly built sports complex building from 2018 combines sports-, educational-, office- and meeting room facilities. The sports facilities have a total surface area of 4208 m^2, while the remaining areas occupy 1107 m^2 of space. The local **district heating network** of WarmteStad provides heating and cooling to the building. The 88 **PVT panels** are mainly used for the balance of the hot and cold wells of the **geothermal heat pump** system, but also provide electricity for the building. The **PV panels** on the roof provide enough electricity for the building to become energy positive.

Figure 6. Sportcomplex Europapark

Technical installations:

Heating

- Simaka Heatpump (Simatron WP 201/2 WW-R407C, 200 kW). Source based upon a district geothermal heatpump system.
- 800 L buffer tank
- Low temperature heating between 35-45 °C, depending on the weather conditions.

- COP W10/W35: 6.02, COP W10/W45: 4.61
- Expected energy consumption: 61 MWh/a

Cooling

- Geothermal heatpump system used for cooling
- High temperature cooling (10-16 °C)
- Expected energy consumption: 7.9 MWh/a

Hot Water

- Sports facilities: Central boiler (2000L) with electric flow device (ŋ=1.00). Heat supplied by simaka heatpump (Simatron WP 50/2 WW- R134a, 50 kW). COP W10/W65: 4.0.
- 2000 L buffer tank
- Expected energy consumption: 32.8 MWh/a
- Other facilities: electric boiler with small buffers for on the spot solution. Heat is instantly available and no heat losses for transport.

Ventilation

- Sports facilities: Mechanical in and output combined with heat recovery system (ŋ=0.70) and CO_2 controlled. Capacity: 3800 dm^3/s, minimal recirculation 20%, fan energy 8.8 kW
- Other facilities: Mechanical in and output combined with heat recovery system (ŋ=0.70) and CO_2 controlled. Capacity: 3400 dm^3/s, windows can be opened for ventilation boost, fan energy 8.0 kW

Lighting

- Sports facilities: 8 W/m^2, including detection system and dimming, Dali based, LED based,
- Other facilities: 6 W/m^2. Daylight and presence detection

RES on building

- 88 PVT panels (Solaris) (200 m^2). Expected heat generation: 71.2 MWh hot water (55 °C) and 17.6 MWh electricity (PV=165 Wp/m^2).
- 1040 PV panels, 280 Wp (291 kWp). No optimizers are used, thus the generation will be lower than anticipated. Expected generation: 247 MWh/y.

2.7 Smart metering systems

Most buildings in the Netherlands have installed smart metering systems, with the capability of being read remotely. This is used by energy companies to automatically and remotely collect the electricity and gas consumption data from the grid, which is, for example, used for invoicing. The companies responsible for installing and maintaining these meters generally provide an API, which can be used by third parties to programmatically retrieve the data. Sustainable Buildings will be requesting access to and retrieve the data of such meters wherever they are available, as these meters generally provide a more reliable source of the consumption data.

The following smart metering systems are installed in all of the intervention buildings, in order to feed data into the MAKING-CITY monitoring system developed by CGI, which is further described in D5.21.

2.7.1 CEMMs

The CEMM is a small device, developed by the Dutch company Cedel (www.cemm.nl), which can be connected to the electricity and gas meter of a building in order to make remote reading of the meter values possible. It is capable of recording the meter values at a high frequency (more than one update per minute) and in real time.

The recorded meter values are sent roughly every 10 seconds using an internet connection provided by a LAN-cable or via the cellular network (using a 3G sim card).

Figure 7. A CEMM gateway and corresponing app on a smartphone.

2.7.2 Plugwise Plugs

Plugwise Plugs are used for measuring the electricity consumption of different device groups in the three terraced houses in the Paddepoel neighbourhood. The Plugwise is a small plug that can be fitted between the power plug of a device and the wall socket and it is capable of measuring the electricity consumption of the device that is plugged in.

The Plugwise Plug is developed by Plugwise (www.plugwise.com), a Dutch manufacturer of smart home devices. It uses the Zigbee wireless communication protocol, which is a low-power communication protocol that is widely used for wireless communication between smart home devices.

Figure 8. A set of plugwise plugs.

2.7.3 Homey

For the collection of the consumption data from the Plugs, an additional device called the Homey is used. The Homey is a smart home hub made by the Dutch company Athom. It is a device that collects data from and interacts with a large spectrum of different smart home devices using different wireless communication protocols. The Homey device is deployed in all of the terrace houses in order to collect the data from all the installed Plugs, which is then forwarded to the Sustainable Buildings platform.

Figure 9. The Athom homey home automation hub.

2.7.4 Smart meters

Additionally, to the installation of CEMM devices for the measurement of real time electricity and gas consumption, data of the smart meters in the buildings is collected. To this end, the smart meters following the DSMR 4 protocol, that have been placed by the energy measurement company are also interfaced with.

3 Smart Energy Systems in PEDs

Apart from the smart energy systems that are directly related to any of the intervention buildings, there are the following systems in the PED. They are connected to the same electricity grid and/or to the heat grid of WarmteStad.

3.1 PV parks in PED

3.1.1 Woldjerspoor

Woldjerspoor is a former landfill in the southern part of Groningen, which has been repurposed as a PV solar park. A total of 43,000 solar panels of 280 Wp each, have been placed in order to generate renewable electricity, as well as hydrogen. With a combined power of 12 MWp, they are projected to generate about 10.2 GWh per year.

3.1.2 Roodehaan

Another PV park to the south of Groningen is the Roodehaan solar field. The first solar panels are already in place, with 81,444 panels of 140 Wp each. This means that currently the total power is 11.4 MWp, which should generate approximately 9.7 GWh/a. Eventually the complete park is dimensioned at 67 MWp, which should generate around 57 GWh/a.

Figure 10. An aerial view of what the Roodehaan solar field will look like when finished.

3.1.3 SunGrazer

In the North PED, a smaller solar park is installed, which is meant to power the particle accelerator research facility at the Zernike campus. A total of 1,700 solar panels of 252 Wp each lead to a total of 429 kWp, and a solar yield of 365 MWh/a.

3.1.4 Solar road

A new bicycle lane and footpath is planned in the South PED near the Europahal Sports Complex. It is not installed yet, but is planned to provide a peak power of 112 kWp, which would lead to a yearly energy production of 90 MWh/a.

3.1.5 Floating PV

Finally, near the Sport Complex building floating solar pontoons are planned. The innovative doubled-sized floating panels will make full use of the reflecting properties of the water allowing the usage of two-sided solar panels increasing the yield of solar power. However, the original planned location was not approved because of interference with shipping lanes. The alternative location that will be used was found in a local site near the Roodehaan PV park.

3.1.6 Parking lot PV

Above the parking lot of the sports complex a large PV installation will be implemented. Currently, the plan is to implement a total of 131 kWp worth of PV panels, possibly more in the future. This means that at least 111 MWh/a is expected to be produced, and likely much more.

3.2 Heat Grid

3.2.1 Underground heat storage

In the south PED, two double aquifer thermal energy storage wells have been realized. These are used in the winter for extraction by using heat pumps, which is fed in the south heat grid. In the summer, the connected buildings are passively cooled, which leads to the harvested heat being stored in the ground, regenerating the storage.

3.2.2 Waste heat from server parks QTS / Bytesnet

The datacenters of Bytesnet and QTS are both situated in the North PED district just across the original location of the geothermal energy source. According to forecasts, the local heat grid receives 3.3 MW and 2.5 MW respectively, of waste heat from these sources with a temperature of 23°C. WarmteStad extracts the waste heat which is used to raise the return water of the district heating up to 75°C by using three heat pumps with a combined nominal power of 25.2 MWth and a COP of 2.9. If necessary, during the winter the temperature can be raised up to 90°C by using a CHP and/or additional gas boilers.

4 Smart grid technologies

4.1 Demand response

Smart grid technologies represent an immense saving potential over traditional grid solutions, but initial investments are significant. Ideally, a high degree of electrification is coupled with a high penetration of smart devices. Control algorithms can plan, for instance, the charge period of electric vehicles, pre-heat rooms using CHPs or heat pumps, or even change the activation time of washing machines. Any such interventions help flatten demand peaks of the electricity power profile.

A user can provide flexibility to a smart grid, e.g. by specifying that the room temperature needs to stay within certain boundaries instead of a fixed single setpoint, or require only some final time for a dishwasher to be ready. This provides an increased amount of degrees of freedom for the algorithm to control. Because of the demand side operation of flexible devices, demand response constitutes a shift from “generation-follows-demand” to “demand-follows-generation”. To enable such a shift, sizable investments are required in smart devices, monitoring hardware, and control software.

Efforts to control the demand profile are often denoted by demand response (DR) or demand side management (DSM). These terms reflect that not only supply, but also demand has an important role to play in the energy transition. In the context of PEDs, demand response describes the process and methods that enable the coordination of different demands. By proper leveraging of DR techniques, the impact on the electrical grid is minimized, and high penetrations of RES is more possible. It is mainly this potential that motivates the growing volume of smart grid related research and applications.

4.2 Potential technologies

4.2.1 Smart charging stations

In the MAKING-CITY project, 14 smart charging stations will be installed in the PEDs. More information on this intervention can be found in D3.6.

4.2.2 PowerMatcher

To balance the load and fluctuations, TNO developed PowerMatcher, a solution that combines IT and technology innovations to balance the grid and offer reliable, efficient energy at all times of the day and night (see http://flexiblepower.github.io/). PowerMatcher turns ordinary power grids into smart grids that efficiently integrate green energy resources, and manage the loads with more precision and efficiency. By partnering with energy suppliers, grid operators, municipalities, manufacturers and IT experts, TNO is helping to balance the supply and demand of alternative energy sources in electricity grids, and enable the most advanced uses for alternative energy. The fluctuating availability of wind and solar energy, combined with the increased demand for electricity to power heat pumps, vehicles and appliances will cause significant strain on existing power grids. Active Demand allows end-users to have more influence on the grid than ever before.

4.2.3 ReFlex

ReFlex is a software solution, developed by TNO, that empowers aggregators to create a powerful Virtual Power Plant (VPP). In contrast to a real, centralized power plant, a VPP utilizes the energy flexibility of large quantities of (small) assets. The VPP occurs to the energy system as being a large source of power generation or demand, while in fact it represents many Distributed Energy Resource (DER) assets, such as: electric cars, batteries and solar panels. The VPP can use the flexibility in both energy markets and ancillary services markets. In this way, the value of flexibility can be stacked. ReFlex is compatible with multiple open smart grid standards such as: EFI, USEF and OCPI, allowing to deploy it easily in the operational process of an aggregator. See https://flexible-energy.eu/portfolio/software-for-a-virtual-power-plant/

4.2.3.1 ReFlex concepts

ReFlex consists of the following three concepts.

Flexibility Engine

The beating heart of ReFlex is its Flexibility Engine. The Flexibility Engine is a mathematic module that provides detailed insight and control over the available flexibility in a cluster of connected DERs. Secondly, it provides insight into the consequence of dispatch choices, such as 'how much flexibility is left in the portfolio after a (hypothetical) dispatch? With this functionality an aggregator gets grip on the available flexibility in its cluster and can utilize it with the highest impact.

Interoperability

The application of open communication standards is a key feature of ReFlex. DERs can easily be connected and controlled because ReFlex is compatible with the Energy Flexibility Interface (EFI) protocol, an initiative of the Flexible Power Alliance Network. ReFlex is ready for congestion management at distribution grid level because it is compatible with USEF.

Adaptability

An Aggregator has a commercial role in the energy system and to be competitive, it needs to develop smart trade strategies to utilize the flexibility in its portfolio. These trade strategies form the identity of the Aggregator. To facilitate this, ReFlex supports configurable trade strategies (business rules), with which the Aggregator is always in full control of the flexibility in its portfolio. The business rules can be targeted at optimization for self-consumption, maximize the

4.2.3.2 Using ReFlex

ReFlex has proven its value in a pilot project in Eindhoven (https://www.interflexstrijp.nl/), in which it has optimized the flexibility of a large battery, electric vehicles, and a curtailable PV system. To test the algorithms and enrich the scenarios, simulated devices have been developed too. Hence, compatible models for batteries, electric vehicles and PV come for free with ReFlex. The modular architecture allows for easily adding new models too.

A challenge that new energy resources cause is that they could potentially overload the electricity grid. Congestion management is concerned with the tasks to make sure that this grid overloading is prevented, and ReFlex contains algorithms to realize this. It is needed that energy resources are provided with a link to a so-called congestion point, which is point in the electricity grid in which grid overloading is expected to occur. With that information, ReFlex optimizes the device behavior in such a way that grid overloading is prevented. In the InterFlex project ReFlex negatioated Congestion Management services with the systems of the DSO Enexis using the USEF Flex Trading Protocol (UFTP).

To give the user (the aggregator) insight in the state of the flexibility of his cluster, ReFlex comes with a user web interface. In this interface, the user can view the optimized schedules for the devices, the load per congestion point, and it enables the user to experiment with optimization targets and start new optimizations manually.

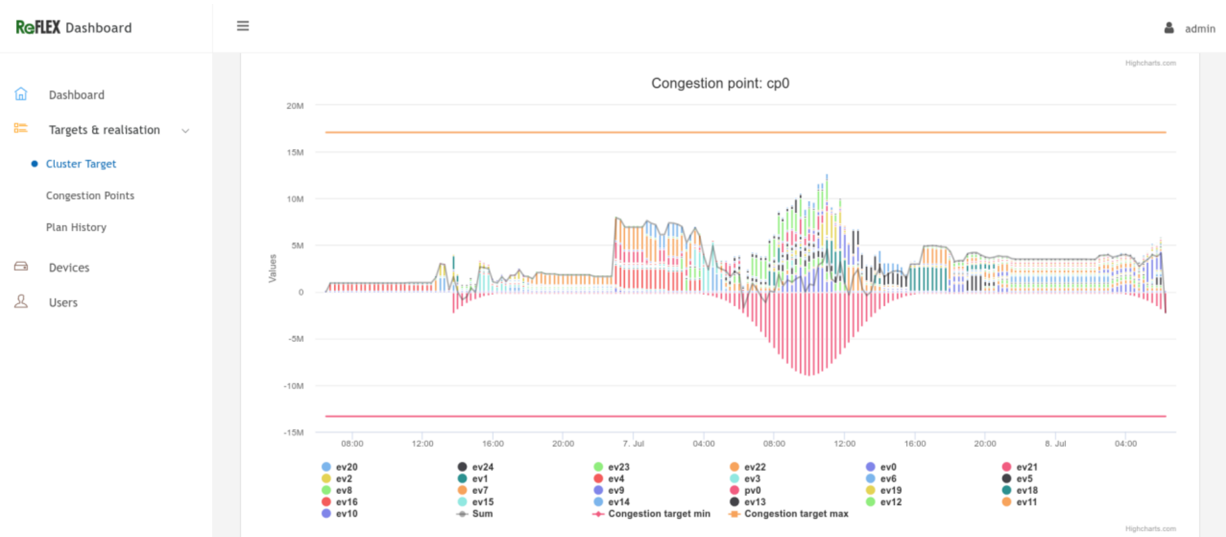
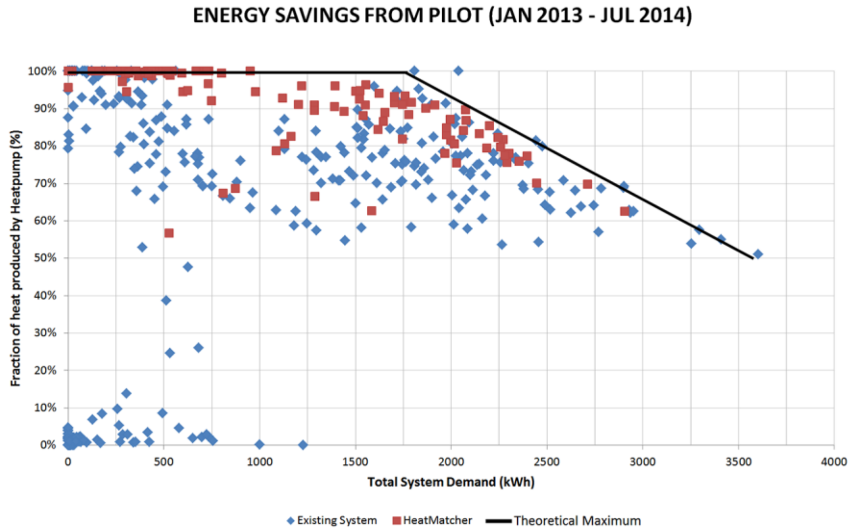


Figure 11. An example of te ReFlex dashboard, mitigating congestion in an EV charging park.

4.2.4 HeatMatcher

HeatMatcher, developed by TNO, is an agent-based demand and supply matching algorithm that optimises dispatch among sources of heat in a building heating installation according to objectives set by the user. Typical objectives include reducing reliance on non-renewable sources and thus cutting emissions as well reducing cost of maintenance of the installation. Within five field trials across four different locations in the Netherlands where HeatMatcher was installed, gas consumption was reduced by 28% and cost of maintenance was cut by 18%, without any changes to the physical installations themselves. HeatMatcher proves its worth in installations with multiple sources of heat such as gas heaters, heat pumps, solar collectors, etc. and manipulates the flexibility offered by heating buffers. See



https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/sustainable-energy/smart-energy-

Figure 12. Result from an earlier HeatMatcher (red) pilot indicating optimal use of heat pump (a source driven by renewable energy) compared to the existing control system (blue)

system-solutions/heatmatcher-innovation-in-control-for-heating-and-cooling-systems-and-networks/

4.2.4.1 The HeatMatcher concept

In HeatMatcher the heat produced or consumed is sold or bought respectively by an agent on an electronic energy exchange market by the means of bid functions. Every bid defines what amount of heat is consumed or produced at a range of prices for the upcoming period, and must be defined as a monotonically decreasing curve in which production is defined as negative demand. This property of the curve helps best represent the rationale of participating agents, i.e. producers want to produce more when the price is high, whereas consumers will reduce their demand in this case. As a corollary, consumers want to consume more when the energy is cheap while producers minimise their production for low prices.

A market in HeatMatcher is a logical grouping of agents based on operational or physical constraints. An installation may have many markets and an agent may be present in multiple markets and in each market have a different role (producer or consumer, flexible or inflexible).

For each market all the bids for a certain period are gathered and combined by adding them up (production is defined as negative consumption). This renders an aggregated bid for the market for that period. Then the market is cleared – a process where the market equilibrium is determined by finding the price on the aggregated bid curve where the heat transferred is zero. Subsequently HeatMatcher uses this price to identify in each bid function the amount of energy an agent must produce or consume in the upcoming period. A contract is created to make sure the heat is delivered on time and the agent is informed of this contract. With this information an agent knows how to control the physical heat component it represents for the duration of the contract. This process is then repeated for the next time period.

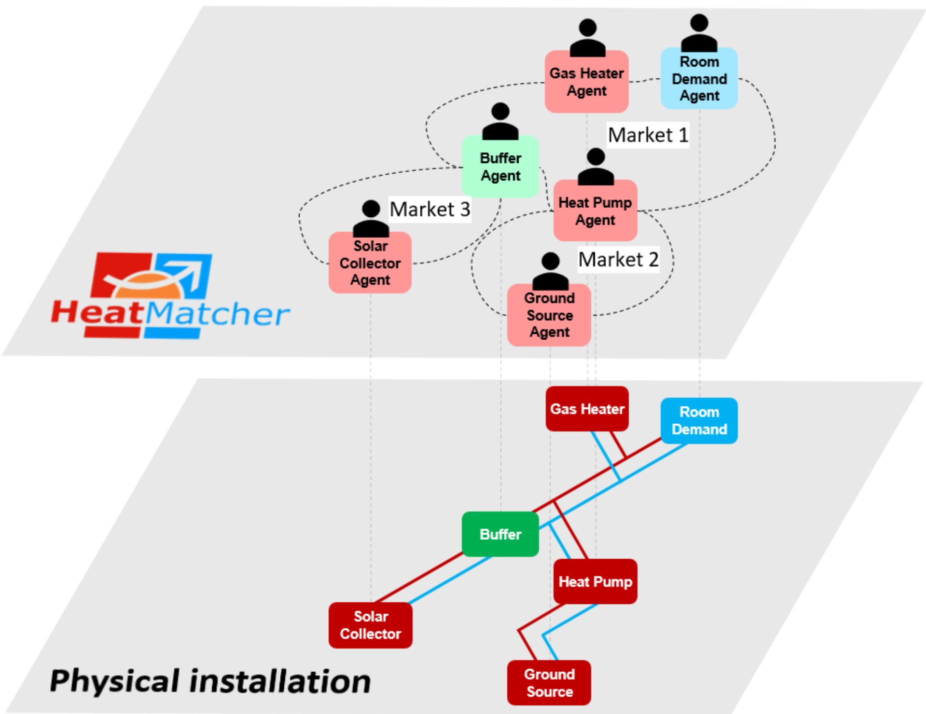


Figure 13. Representation of devices as agents in markets in HeatMatcher

4.3 Implementation in Groningen PEDs

There is a large potential benefit of demand response, and in the MAKING-CITY project, the different possibilities to implement any of the above mentioned technologies were investigated. HeatMatcher was initially planned to be installed at two locations: the Nijestee high-rise buildings (A1) and the

Mediacentrale (A4). However during the project we came to conclude that for the Nijestee buildings, there is only one source of heating, and no buffering. Without any room for control HeatMatcher cannot improve on the efficiency or cost of the energy usage, since there are no degrees of freedom.

As an alternative location, the Sports Complex Europahal was considered as well. Initially the Sport Complex Europahal seems like an interesting option for HeatMatcher. However, the room for optimizing is still limited since the heating system is very straightforward. Heat is mainly provided by WarmteStad's district heating network, and excess heat of the PVT panels is fed back to the heat grid. Finally, the Powerhouse building was also considered, which is connected to the heat grid, and thus the situation is almost the same as for the sports complex, albeit even simpler due to the lack of PVT panels.

4.3.1 HeatMatcher for heat grids

Another possibility is to use HeatMatcher to optimize the heat flow of a heat grid itself. Especially in the North PED, the heat grid is a very complex system with multiple heat sources being: residual heat from two server parks, several CHPs, a large heat buffer, and solar heat collectors. Currently the heat grid only utilizes the CHPs for providing heat and a gas heater for peak production; starting next year the server parks' residual heat sources will be added. The solar collectors are planned for the upcoming years. Combined with the fact that there are many different heat sources, there are many optimization constraints, e.g. contracts for heat intake and delivery, balancing of ATES's, and here are also different and goals that are to be optimized: operational costs, fraction renewable energy used, greenhouse gas emissions etc.

TNO is currently investigating the potential of applying HeatMatcher to heat grids in a simultaneous project. In the current context, especially in the North PED, HeatMatcher could be utilized to control an operational heat grid. A particularly interesting challenge is that it should take into account actual fluctuating energy prices, which is currently not taken into account in HeatMatcher. In addition to the actual heating grid, HeatMatcher can also be connected to a digital twin of the grid, modelled in TNO's heat flow simulator engine – CHESS. Together, these tools can be used to analyse future grid expansion scenarios and what source and/or storage options are viable to make the grid more sustainable.

WarmteStad is working on implementing the heat grid, and recognize that heating dispatch is a serious issue, that the problem can be very complex and that mismanagement can be very expensive. Since the heat grid plays a major role in both PEDs, there is a lot of room for potential energy saved.

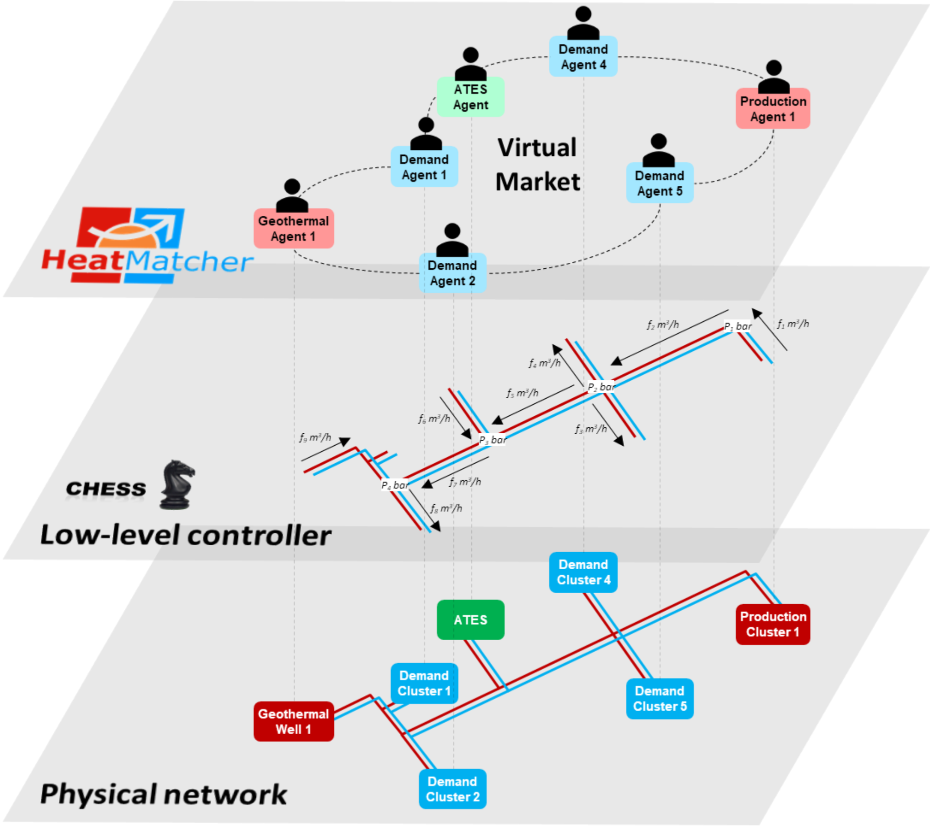


Figure 14. HeatMatcher with CHESS representing the digital twin of the heat grid.

Conclusions

In this document we presented the smart energy systems in the MAKING-CITY lighthouse city of Groningen. An overview was presented of all building related energy systems, as well as the non-building related ones. In doing so we can conclude that there is plenty of potential to achieve the PED result.

Considering the Smart grid technologies in the PED, there is some lack of place to implement the presented technologies (e.g. ReFlex, HeatMatcher). This is mostly due to the lack of flexible resources that can be used as alternatives for heat sources. However, a promising potential use of the HeatMatcher could be provided by using HeatMatcher for the district heating grid.