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D3.3 Simulation models of buildings, energy systems, storage and management of flows algorithms

WP3, Task 3.2

November 2021 [M36]

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Abbreviations and acronyms

Acronym	Description
ATES	Aquifer Thermal Energy Storage
BAG	Basisregistratie Adressen en Gebouwen (Dutch database of buildings)
BSM	Building Stock Model
CBS	Centraal Bureau voor Statistiek (Dutch statistics organization)
DHG	District Heating Grid
EIS	Energy Information System
ESDL	Energy System Description Language
ESSIM	Energy System Simulator
ESM	Energy system model
EAE	Energy Academy Europe
GIS	Geographical Information System
NEDU	Nederlandse Energie Data Uitwisseling (Dutch database containing energy profiles)
PED	Positive Energy District
PESTEL	Political Economic Social Technological Environment Legal

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.

Task 3.2 is dedicated to the baseline of the interventions. A modelling language called ESDL is used to model the Groningen PEDs and can be simulated in a program called ESSIM. This deliverable describes the simulation and modelling results of the Subtask 3.2.1 Simulation models (buildings, energy systems, storage and management of flows algorithms).

Keywords

Energy system simulator, simulation model, intervention model, ESSIM, ESDL

1 Introduction

1.1 Purpose and target group

This Deliverable D3.14 Simulation models (buildings, energy systems, storage and management of flows algorithms) is the main result of the Task 3.2.1 with the same title.

Chapter 2 of this report introduces the modelling tools and methods used, Chapter 3 describes the data gathering process and Chapter 4, 5 respectively the PED model of the two Groningen PEDS North and Southeast.

1.2 Contribution partners

The following Table depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Partner nº and short name	Contribution
02-TEC	Describing section 2.4.1 on Enerkad
03-GRO	Input for data and review
04-TNO	Overall document
12-HUS	Adding section 2.4.2 on the Electric Vehicle Charging Model

1.3 Relation to other activities in the project

The Table 2 below depicts the main relationship of this deliverable to other deliverables developed within the MAKING-CITY Project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable	Relation
D3.1	*Groningen PEDs (North, Southeast) interventions detailed design* specifies the design of the specific Groningen interventions.
D3.2	*Baseline of Groningen PEDs.* The PED Baseline uses the modelling tools to get a good baseline of the PED before the project was started.
D5.8	*Groningen Monitoring Programme.* The monitoring programme is used to store the results of the simulations and compute the KPIs in the same way as the real measurements.

2 Modelling tools and methods

2.1 ESDL

The Energy System Description Language (ESDL) is an open-source modelling language created for modelling the components in an energy system and their relations towards each other. Technically it is an XML schema definition (XSD) for formally describing energy assets in an XML format. This allows ESDL to be used as a formal specification of an energy grid for unambiguous interpretation by experts and tools. The language is machine readable so makers of energy transition calculation tools, simulations and GIS applications can support ESDL in order to enforce the interoperability of their products.

ESDL can express the dynamic behaviour of components in the energy system. For instance, the power consumption of a neighbourhood. ESDL describes components by their basic functionality (Energy Capabilities), these are modelled in 5 abstract categories: Production, Consumption, Storage, Transport and Conversion. Aggregation and composition principles of ESDL enables energy modelers to model a complex energy system in a generic way.

ESDL can be used in various ways, for example:

- By energy transition calculation tools. ESDL acts as a common language for different energy transition calculation tools, specifying the format of the inputs and outputs of such tools. This allows for integration of multiple tools.
- In an Energy Information System. ESDL can be used as a basis for a central energy information system where the energy system of a certain region is registered.
- As a language for (local) governments to model, reason about and share their (local) energy system.
- To monitor the evolution of an energy system: multiple ESDL snapshots of a certain area over time provide insight in the evolution of an energy system.
- As a format to share data relevant to energy systems or the energy transition. Examples:
    - CO2 emissions per energy carrier
    - Technology factsheets for specific components, brands, types (e.g., a heat pump factsheet that describes its typical parameters)
    - Cost information of assets, or expected cost developments in future
    - Standard configurations or templates of typical parts of the energy system (e.g., a house with a heat pump, solar panels and an EV charging station)

A fully detailed description of ESDL, both technical and pragmatic, can be found as an on-line gitbook on https://energytransition.gitbook.io/esdl.

2.2 ESDL MapEditor

The ESDL MapEditor is a map-based energy system editor. With the MapEditor ESDL based energy system descriptions are defined, that can be simulated with a growing number of ESDL capable simulators, among which is ESSIM (section 2.3). The editor allows to define the system on a map, thus placing assets in their real-life location. These assets can be anything from production, consumption, infrastructure (transport), conversion and storage for every imaginable energy carrier. The editor provides features to intuitively construct the system, work with GIS components (WMS layers, shapefiles and more) to assist in visualization of the system. Also, the editor is connected to external data sources (on buildings for example) and to external models (e.g., spatial analysis models). The editor further supports configuring the assets in the system with energy profiles of energy demand, consumption for every applicable asset or any other data that is relevant for further processing/simulating the ESDL energy system. When ESSIM is used for simulation, the results can be visualized in the MapEditor by selecting specific assets and viewing the simulation results in the form of charts and graphs which makes analysis of the system possible.

An open-source version of the ESDL MapEditor can be found here:

https://github.com/ESDLMapEditorESSIM/docker-toolsuite

2.3 ESSIM

ESSIM (Energy System SIMulator) is a tool that simulates network balancing in an ESDL-defined energy system comprising of interconnected multi-commodity energy networks. It takes into account energy system information, data profiles and control strategies configured by the user to simulate dynamics in the energy system over a user-defined time period (in user-defined time steps). ESSIM can also be used as a bridge to a loadflow calculation for the power system using Pandapower [REF]. The simulator generates a dashboard visualising energy mixes in the networks, imbalances and emissions and, if selected, the loadflow calculation results. The Urban Data Platform would act as a source for data profiles to be used in an ESSIM simulation and as a platform to store the relevant KPIs calculated by it.

ESSIM is used in conjunction with the ESDL MapEditor which is a web-based tool used to create and edit ESDL definitions of energy systems. Under the hood, the simulation engine parses the user-fed control strategies to determine the order of solving the networks and then for each network, applies the Fast-LMP (Kok, 2019) principle to aggregate flexibility from energy assets and control dispatch.

An open-source version of ESSIM can be found here:

https://github.com/ESDLMapEditorESSIM/docker-toolsuite

2.4 Other tools

2.4.1 Enerkad

Within the cities, buildings are among the most consuming entities of energy, frequently electricity and natural gas. As individuals live in buildings, as well as for private use, public, or workspace, it seems appropriate to assess the performance of those physical entities in terms of energy consumption (or production).

The modelling of Positive Energy Districts (PEDs) takes place at different levels. Even while it is crucial for the understanding and design of the PED concept, it is not possible to design solutions at the urban scale (where decisions take place mostly, in terms of policies and regulations, as well as plans) without using other modelling tools to contextualise and complement the specific evaluations performed at PED-scale. In that sense, the use of *Building Stock Models (BSM)* seems relevant to characterise the buildings according to their energy nature, thus creating the conditions to understand both the PEDs and the whole city. Besides, other modelling tools must be considered when looking at the long-term behaviour of the city. Thus, the use of *Energy Systems Models (ESM),* a generic nomenclature to refer energy modelling frameworks aimed at creating energy scenarios and assisting in developing energy and climate plans, is frequently used to establish long-term energy and climate narratives.

Regarding BSM, the first modelling strategy deployed is based on Enerkad® developments, a software platform based on Geographical Information Systems (GIS) where extra information related with the energy profiles of the buildings is added. Consequently, the first analysis corresponds to the BSM of the city to deeply understand the way the citizens consume energy in different end-use services (heating, cooling, cooking, water heating, lighting, etc.). This evaluation is performed based on GIS data of the cities plus statistics and data from energy certificates (and real energy consumption data if available).

The main result of BSMs is a picture of the city with energy information very disaggregated (types of technologies, types of buildings, consumption profiles and even emissions). Those results will assist in the identification of areas or buildings where prioritising actions to invest in energy savings or transform consumption patterns, thus supporting to build the PED concept. Moreover, the tool could allow to observe the transformation reversely: to impose interventions in the micro level to reach emissions reductions or energy savings compromised by the city/region in their energy and climate planning targets.

Based on the building-related scheme it is possible to enrich the ESM approach. ESM is a method to evaluate cities, regions, and/or countries, focusing the evaluation on energy balances. In that sense, there are many approaches depending on the interests of the modellers (policymaking, decision-making, technology deployment, sectoral optimisation, etc.). In this case, using statistical data from the cities' energy consumption together with estimates from residential and tertiary sectors coming from Enerkad, ESMs will be created to assist municipalities in the creation of their 2050 Vision. The ESM will serve as basis to develop energy scenarios where the energy profiles of cities are implemented in addition to projections of energy demands according to socioeconomic drivers like GDP, population, etc. Finally, those scenarios -a Business as Usual one plus some alternatives- will be discussed to evaluate the savings achieved and emission cuts when implementing measures.

Besides, the evaluation of the solutions' convenience is a transversal process associated with the decision-making needs. Such qualitative-quantitative evaluation is carried out by means of the *PESTEL* method. PESTEL (Political, Economic, Socio-cultural, Technological, Environmental and Legal) defines an analytical framework of systemic factors used in strategic management. It is part of an external analysis when conducting a strategic assessment and gives an idea of the different issues to be considered.

The last modelling deployment is the evaluation of impacts derived from implementing the PED. To perform such analysis, the Input-Output (I-O) method will be selected. Thanks to the I-O method, a recognised methodology to evaluate the impacts on the economy for a region/country when implementing projects or technologies, it is possible to estimate the economic consequences of such implementations as a variation in GDP (in a monetary basis) and looking at the job creation, among others. Resulting from the value chain characterisation associated to each solution/action implemented, it will be possible to compare the total socioeconomic impact thus allowing to prioritise among PED solutions.

2.4.2 Electric Vehicle Charging Model

The goal of this model is to generate semi-random, but statistically significant electric vehicle charging patterns. Based on measured data, we develop correlations between load patterns and environmental conditions such as time of day, day of week, weather patterns, etc. These patterns will have a given distribution over a given time period.

Assuming normal distributions of these patterns, we can use the average and standard deviation values for given environmental conditions (e.g., time of day) to calculate the inverse cumulative normal distribution of this pattern. By supplying a series of randomly generated values, we obtain a statistically likely load pattern.

For EV charging patterns, we use the above method to determine the probability of a charge cycle's start time, average power level and duration. Once a charge cycle is initiated, it will run for a random (but statistically significant) amount of time at a random (but statistically significant) power level. To more realistically simulate EV charging, the power level will drop off as the battery nears its fully charged state.

In the model, it will be possible to run different scenarios. Key inputs include the number and relative location of charging stations, the adoption rate of EVs, and the option to model the impacts of interventions (e.g., shifting patterns in time and/or flattening power levels by lengthening cycle durations).

The model will run for up to a 1-year period for a given set of criteria, with a timescale of 10 minutes. Based on various inputs, the model will calculate technical data (e.g., load duration curve, overloading minutes) and financial data (e.g., reduced asset lifetime resulting from overloading, etc.). These data can then be analysed and compared between different scenarios.

2.5 Model scenarios

We define the following five scenarios that will be modelled. They represent potential states of the PED under different circumstances.

1. **Baseline scenario**: This is what the PED looked like before the project. This model is also available in the project as an ESDL file.
2. **Implemented interventions:** This is the description of the PEDs at the moment of writing. This is the currently modelled scenario and the one described in this document. When all interventions are modelled in the way that they are actually implemented, the outcome should closely match the reality after five years of monitoring. This scenario can be used to validate the simulation outcomes.
3. **Targeted interventions**: This is the scenario that will be reached at the end of the project when all interventions are finished. In this case a PED should be achieved, and the scenario should resemble the simulation outcomes. This scenario can be used to validate the simulation outcomes at the end of the project.
4. **Original planned interventions**: This scenario describes the PED when all interventions occur as planned during the project proposal. Note that is not necessarily the same scenario that is eventually the end result of the project.
5. **Zero-energy use:** This hypothetical scenario requires development and implementation of data extrapolation methodology. It contains the interventions that would have been required to get to exactly zero-energy use. Depending out the outcome of the implemented interventions, this scenario can give insight in potential places to save money, or in which interventions to put more efforts.

- **Dream scenario**: Another hypothetical scenario that requires development and implementation of data extrapolation methodology. In this scenario all interventions are scaled up to the limit. This option would be very expensive to deploy in real life, but it is an interesting playground to see how far we could get.

3 Data gathering process

To create simulation models of the two districts, appropriate building and energy data of the district has to be collected and modelled. Building data refers to building surface area and the type of the building. Energy data refers to energy demand (both electricity and heat), energy production from local sources, and local energy storage. As the intervention buildings in the projects are of different types, it is important to distinguish between different types of district energy consumers, to be able to see the effect of the individual interventions on the district level and to extrapolate interventions to other buildings at a later stage.

Building data, in combination with energy demand estimations for different building types in The Netherlands, is used to estimate district energy demands. For that purpose, several different data sources are used and combined.

The data sources include:

- Dutch key register of addresses and buildings (Basisregistratie Adressen en Gebouwen - BAG)
- ECN tool that estimates gas and electricity consumption per square meter of floor for Dutch service sector consumers.
- Central Bureau of Statistics (Centraal Bureau voor de Statistiek - CBS)
- Making City technical documentation.
- Discussions and interviews with consortium partners that are the intervention owners.
- Technical documentation and energy performance sheets received from partners.
- Energy Transition Model estimation of building-related consumption percentage.

The requirements and usage of the data sources are also described in Deliverable D5.18.

Due to limited data availability, some data is estimated, and some is modelled as provided in the technical documentation of the project. The latter refers mainly to interventions data. However, even in the case of interventions, data estimations are used due to lack of specifications.

Energy production data is modelled individually for each production source, both on the interventions and the district level, except for district rooftop solar, which is modelled on an aggregate level.

3.1 Building data

The first step in modelling energy demands in the district is data collection on different types of buildings in the district, their number, and surface area.

For that purpose, a service from BAG is used. BAG differentiates between the following building categories:

- Education
- Gathering
- Healthcare
- Hotel
- Industry

- Office
- Other
- Residential
- Shopping
- Sports
- Prison

The service is run both for the North and the South district. The North district includes only the three neighbourhoods included in the project (Zernike Campus, Paddepoel-Noord and Paddepoel-Zuid), while all the neighbourhoods from the South district are included. BAG service returns the number of buildings in each of the categories and their total surface area, for both districts.

The surface area data for buildings with interventions is taken from the project's technical documentation as described in MAKING-CITY deliverable D3.1.

3.2 Energy data

Energy data refers to energy demand and energy production in districts, and in individual buildings with interventions. Energy data is separated per energy commodity, such as: electricity, heat and gas.

In case of interventions, energy data is modelled as specified in the project's technical documentation, when available. When unavailable, data is estimated or derived from other parameters from the specification. Energy demand data is the most challenging to acquire, therefore in most of the cases energy demand is estimated.

In case of district energy demand and production, demand-related data is estimated, while production data is modelled according to information acquired from Groningen partners and online sources. District residential solar production is estimated from available CBS data on residential PV installations. However, this data is potentially incomplete as PV owners in the Netherlands are not obliged to register their PV installations (however, most people will do it).

To estimate yearly energy demand, two data sources are used: CBS data on residential energy demand and ECN tool that estimates service sector demand per square meter, for different service sector consumers. As service sector consumers type list, as defined in ECN tool, is more extensive than that of BAG, a mapping from ECN tool to BAG categories is first performed, and the average energy demand per category is calculated.

Table 3 shows the estimated yearly gas and electricity demand of Dutch service sector consumers, divided into BAG categories.

Building type	Gas [m3/m2]	Electricity [kWh/m2]
Education	14.33	38.33
Gathering	16	84
Healthcare	20	54.75
Hotel	28	120

Industry	12.8	456
Office	17	60
Other	19.22	135.55
Shopping	18	177
Sports	27.67	94.33

Table 3: Estimated yearly gas and electricity demand of Dutch service sector consumers

Total gas and electricity demand is calculated using the numbers from Table 3 in combination with BAG data on the total surface area per category, for each of the districts. Heating demand is then calculated from gas demand.

Residential energy demand is taken from CBS, which publishes data on average energy demand per household, for Dutch neighbourhoods and districts. These numbers are also used for intervention buildings when energy demand data is unavailable. Combining CBS data with BAG data on the number of residential buildings in the district, aggregate residential energy demand is calculated.

Aggregate yearly demand is modelled on an hourly basis using average electricity and heat profiles for different consumers from NEDU1, the Dutch energy data exchange.

In simulation models, energy demand data is modelled at different levels, namely: building level for buildings with interventions, and aggregate level for the rest of the district. Due to the definition of positive energy districts, only building-related consumption is estimated form the total energy demand. Building-related consumption includes:

- Heating (heat demand)
- Domestic hot water (heat demand)
- Cooling/ventilation (electricity demand)
- Lighting (electricity demand)
- Other (electricity demand)

For more detailed information on estimation of building-related consumption, please refer to Deliverable 3.2, section 3.

The following is a summarized procedure used for energy data modelling:

For each district:

1. Run a BAG service to get the number of different building categories and their total surface area
2. Map the BAG categories to ECN tool categories. ECN tool is for service sector buildings only.
3. Calculate the total energy demand per service sector category using the ECN estimations per surface area

[1] NEDU Verbruiksprofielen nedu.nl/documenten/verbruiksprofielen/

4. Use CBS residential energy demand data per household to estimate the total residential energy demand (BAG service returns the number of residential buildings in the district).
5. Use ETM estimations of building-related consumption to separate the total energy demand into building-related consumption categories.

Then, for each intervention individually:

1. Separate building from district-level interventions
2. Model energy demand and production as specified in the technical documentation or though discussions (other partner documents)
3. When data is unavailable or missing, use the district energy estimation methodology (see above)

4 Groningen North PED

The North location is composed of more than 100 buildings of different typologies. The district is basically split into three areas, the Zernike Science park (source of the district heating system and home to the Energy Academy Europe building, EAE), Paddepoel North and Paddepoel South. Paddepoel North is a residential area composed of terraced houses (approximately 2,000) and some high-rise flats. Most of the current buildings are supplied with natural gas for heating and have been built in the 1960s. The goal is to transform this part into a complete district heating area. Paddepoel South is also a residential area with terraced houses and some high rises, but its building typology is different, a part is poorly constructed and undergoes a transformation of rebuild and new built. Another part of the area is relatively new built, after the 2000s. The main solution for these buildings is an all-electric variant.

A sample of reproducible buildings (6) has been taken to start the process of becoming fully positive in this area. The city council is committed to scale up the results after the project following the same principles, so the approach affecting MAKING-CITY will address a limited number of buildings of different typologies (3 residential individual, 2 high-rises and 1 tertiary) with very low consumption regarding the national regulation codes. The energy performance will be based on an extensive use of RES on-site. District heating is the key to the thermal energy supply system, that allows to avoid energy input from outside the district. A very small part of the energy demand is will most likely be covered from the natural gas network, so it is taken from outside. Some PV facilities compensate the electricity consumption, in particular a big facility in the tertiary building allows to supply an excess of energy and provide an energy surplus reaching a positive yearly balance.

4.1 Overall PED model

Based on the gathered data, a simulation model of the energy system is developed using MapEditor (see section 2.2). Table 4 shows a legend of icons used to model PEDs and energy assets they represent. Green icons represent energy producers (e.g., electricity and gas import, PV parks and installations, residual heat source), blue icons for consumers (e.g., electricity and heat consumers), red icons for storage (e.g., WKO), yellow icons for transport (e.g., electricity, heat and gas networks and connections from intervention buildings), while purple icons represent conversion (e.g., heat pumps and gas heaters). The grey icon represents a building, which is used to represent each of the intervention buildings.

Asset	Asset type	Icon
Import	Producer	
PVPark	Producer	
PVInstallation	Producer	

ResidualHeatSource	Producer	
GenericProducer	Producer	
Export	Consumer	
ElectricityDemand	Consumer	
HeatingDemand	Consumer	
CoolingDemand	Consumer	
GasHeater	Conversion	
HeatPump	Conversion	
CHP	Conversion	
ATES	Storage	
ElectricityNetwork	Transport	

HeatNetwork	Transport	
GasNetwork	Transport	
GConnection HConnection EConnection	Transport	
Building		

Table 4: ESDL assets and icons

Figure 1 shows the PED model of Groningen North district. The blue area indicates the district borders, as defined by the standard definitions of CBS. With respect to energy, everything within these borders is referred to as local district energy production and demand, whereas everything outside the borders is referred to as imported and exported energy (electricity and gas import are indicated by green icons with a P, outside the district area, while exports are indicated by blue icons with a C). Note that a part of the district included in the blue area is excluded in the project proposal. However, due to lack of specifications which data to exclude, this area is included in the current model, and will be updates when more specific data is obtained.

In both district PED models, each intervention building is modelled individually (indicated by grey icons in Figure 1: Groningen North PED model (for icon legend, refer to Table 4: ESDL assets and icons)), in detail, while the rest of the district is modelled on an aggregate level. The buildings with interventions in PED North are:

- Energy Academy Europe
- Nijestee
- Three Terraced Houses

The intervention models are discussed in the next section 4.2 Detailed intervention models.

Energy demand

As this model should later be used to extrapolate interventions to other buildings, aggregate energy demand is separated into three categories corresponding to those of the intervention buildings. In case of the North district, the categories are the following:

- Education (Energy Academy Europe)
- Residential (Nijestee and Three Terraced Houses)
- Other (All the other)

The total energy demand is calculated using estimations from the section Energy data and is separated into electricity and heat demand.

Energy production

In PED North, electricity and gas are imported from the national grid into the district via electricity and gas network, respectively. The grid topology is not modelled, but assumed to be a copper plate. Imported gas is converted into heat using gas heaters (purple icons). In addition, the district has a local district heating grid (DHG, indicated by red lines representing pipes), which is supplied by a residual heat source (green icon with RHS) from data centres and two CHPs (purple icon with a CHP).

In terms of local electricity production, the PV park Sungrazer located in Zernike campus is modelled (green icon with PVP), as well as estimated aggregate rooftop PV production in the district.

Any excess production is exported to the national grid, outside the district.

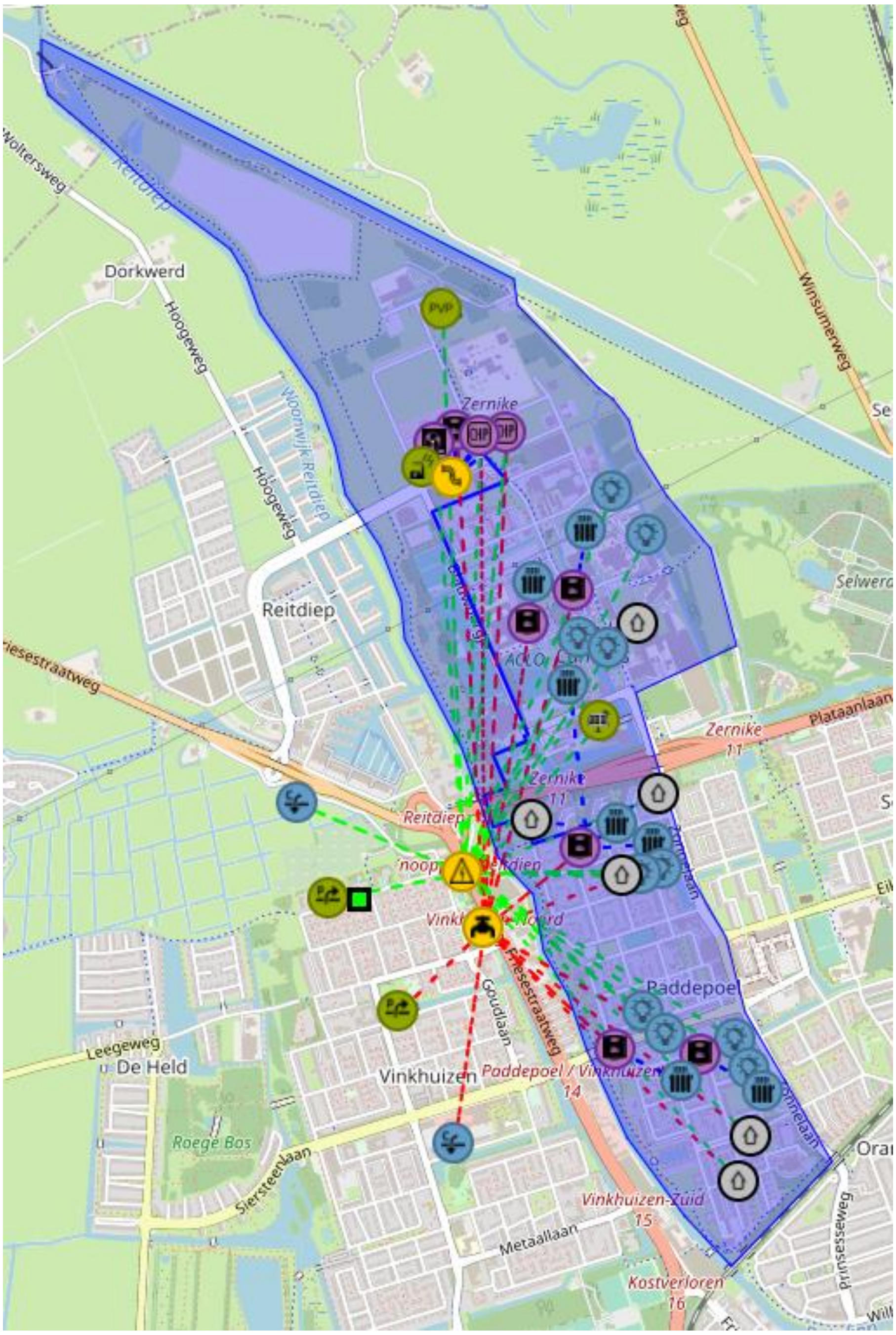


Figure 1: Groningen North PED model (for icon legend, refer to Table 4: ESDL assets and icons)

4.2 Detailed intervention models

4.2.1 Energy Academy Europe

Energy Academy Europe (EAE) is a tertiary building which houses both lecture rooms and offices with a surface of 9,636 m2 and was completed in 2016. It is the most sustainable teaching building in the Netherlands due to a BREEAM Rating Outstanding score of 89.62%. This building contains a geothermal heat pump and has 1,600 solar panels on the roof. The panels are arranged in various angles to allow more panels on the roof and thus increase energy performance. EAE is a unique building and as such is an intervention in itself.

EAE energy demand data is modelled using technical data sheets on energy performance provided by partners.

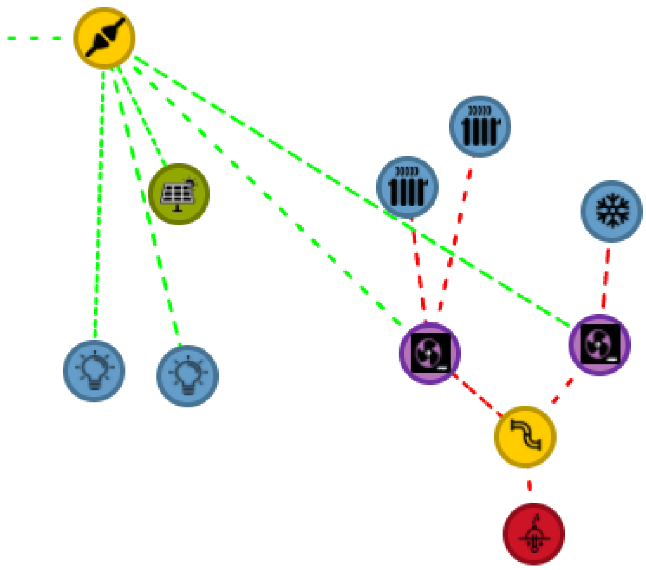


Figure 2: Energy Academy Europe energy system model

Figure 2 shows the ESDL model of EAE. EAE has an electricity connection to the electricity grid (yellow icon in the upper-left corner), and an internal heat network (yellow icon with a pipe) connecting its ground source ATES (red icon at the bottom) with the heat pump (purple icons).

This heat pump is used both for heating and cooling. To be able to simulate this functionality using ESSIM, the same heat pump is modelled twice. The heat pumps are connected to a ground source. The heating heat pump delivers heat to heating demand and domestic hot water demand (blue icons with a heater). Cooling demand (blue icon with a snowflake) functions as a heat producer, as it extracts heat from the air and delivers it back to the ground source. Electricity demand (blue icon with a lightbulb) is supplied from the national grid, and the local PV installation (green icon with a solar panel). PV production is estimated based on an average peak panel production.

Energy profiles used are the following:

- Heat demand: Heating households (G1A), a heat demand profile of Dutch households, with hourly values

- Domestic hot water demand: Electricity shops, office, education (E3A), an assumption that hot water is used in the same pattern as electricity (this is due to lack of more representative profiles).
- Electricity demand lighting: Electricity shops, office, education (E3A)
- Electricity demand cooling/ventilation: Solar, an assumption that cooling/ventilation systems are used more in the summer, due to lack of a better profile.
-

4.2.2 Nijestee high-rise Flat 1 and Flat 2

Two Nijestee buildings are multi-owner Highrise residential buildings in PED North. They are modelled separately, but their models are the same, in terms of energy assets. The yearly demands differ, which is reflected in the simulation outcomes.

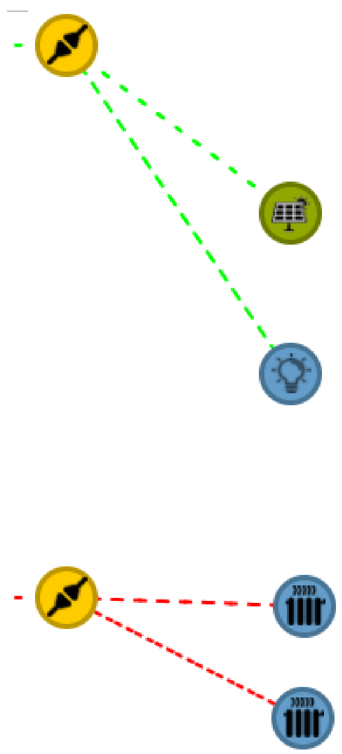


Figure 3: Nijestee high-rise energy system model (Flat 1 and Flat 2 have the same model)

The list of executed interventions is the following:

- Retrofitting (isolate façades, floor and roof)
- Geothermal district heating connection
- 50 kWp of PV panels

As seen in Figure 3, Nijestee energy model has a heat connection to the district heating grid, used to meet its heating demand. Electricity demand and PV panels are connected to the electricity network via an electricity connection. In this model, interventions related to retrofitting are not modelled, these should be indicated by heating demand. However, due to lack of data, heating demand is estimated as described in section Energy data, while electricity demand is modelled according to numbers provided by Nijestee partners. These still must be validated.

As this is a residential building, energy profiles used to model the demand are:

- Heat demand: Heating households (G1A), a heat demand profile of Dutch households, with hourly values
- Electricity demand lighting: Electricity households (E1A), an electricity demand profile of Dutch households, with hourly values
- Domestic hot water demand: Electricity demand: Electricity households (E1A)

4.2.3 Terraced houses Paddepoel

In PED North, three terraced houses are planned to be retrofitted. The three terraced houses are modelled using the numbers from the technical documentation provided by partners.

As these are residential households, energy profiles used to model the demand are based on NEDU profiles for:

- Heat demand: Heating households (G1A)
- Electricity demand lighting: Electricity households (E1A)
- Electricity demand other: Electricity households (E1A)
- Domestic hot water demand: Electricity demand: Electricity households (E1A)
- Electricity demand cooling/ventilation: Solar

4.2.3.1 Neptunusstraat

This terraced house has a gas connection to the Dutch national gas network and a gas heater used for meeting the heating and domestic hot water demand. Furthermore, there is an electricity connection to the Dutch electricity grid, supplying the electricity demand of the house. There are no local production sources.

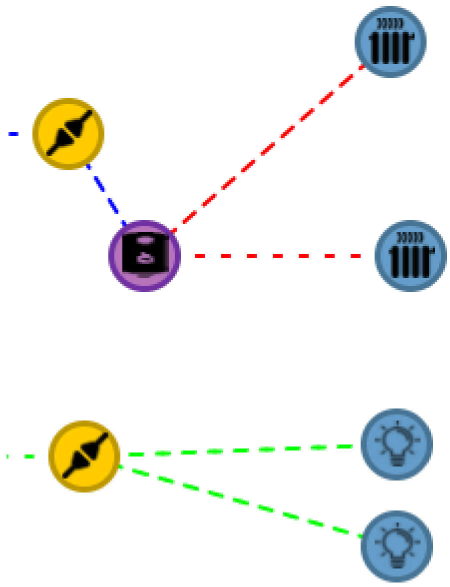


Figure 4: Neptunusstraat energy system model

4.2.3.2 Zuiderkruislaan

This terraced house has a gas connection to the Dutch national gas network and a gas heater used for meeting the heating and domestic hot water demand. Furthermore, there is an electricity connection to the Dutch electricity grid, supplying the electricity demand of the house. There are no local production sources.

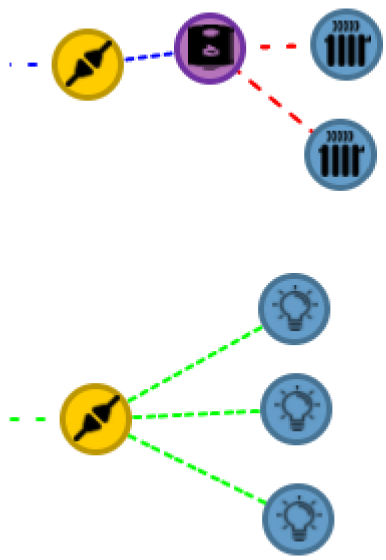


Figure 5: Zuiderkruislaan energy system model

4.2.3.3 Grote Beerstraat

This terraced house has a gas connection to the Dutch national gas network and a gas heater used for meeting the heating and domestic hot water demand. Furthermore, there is an electricity connection to the Dutch electricity grid, supplying the electricity demand of the house. However, unlike the two previous houses, this house has solar panels that are connected to its electricity connection and used to meet the local demand, but also to export electricity, if there is surplus.

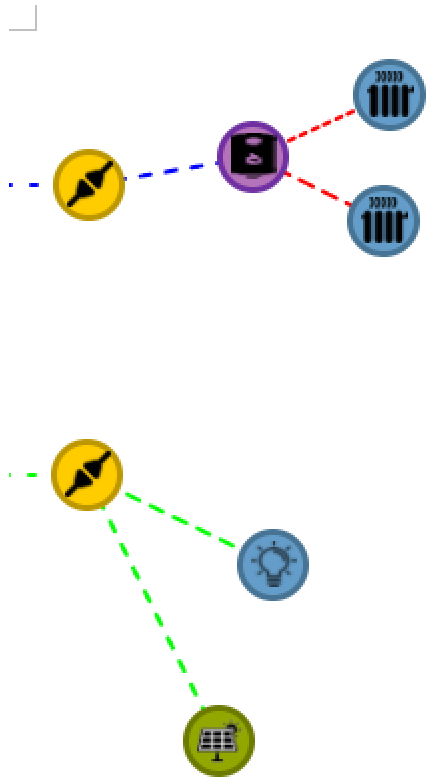


Figure 6: Grote Beerstraat energy system model

4.3 Simulation outcomes

This section presents ESSIM simulation outcomes for PED North. These outcomes show network balances for each of the energy carriers (electricity, heat and gas), on an hourly basis, for a period of one year. Energy assets and their aggregate yearly production or demand are shown on the right-hand of the dashboard, while the graphs visualize hourly values. Energy production is indicated by a negative sign, while energy demand is indicated by a positive sign.

First, district-level balances are discussed, followed by those of the individual intervention buildings.

4.3.1 PED North gas network

PED North imports gas from the Dutch national gas network. Figure 7 shows gas network balances. *SourceProducer* indicates gas import into the district, and *SinkConsumer* indicates export from the district. In the district, gas is supplied to the CHPs of the district heating grid and to the rest of the district, not connected to district heating. Figure 8 shows the hourly gas import into the district. As there are no local gas sources, all the gas is imported from outside the district.

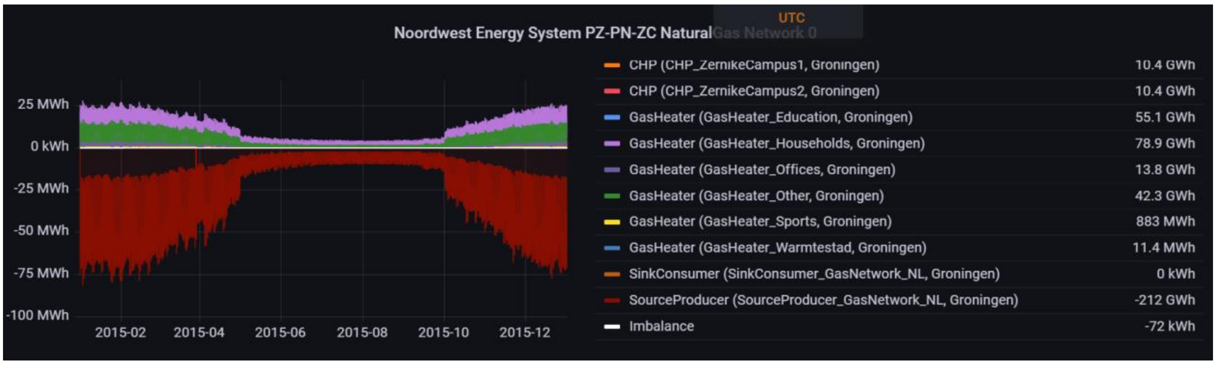


Figure 7: PED North gas network balances

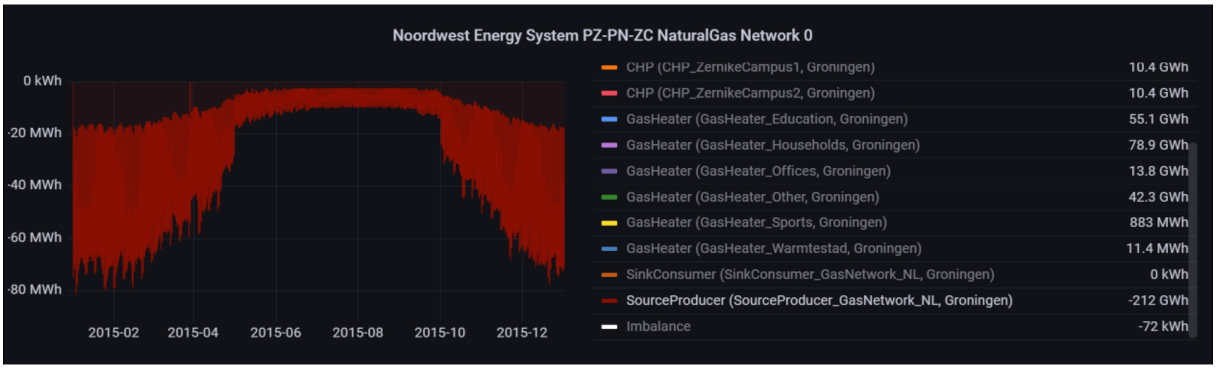


Figure 8: Gas import into PED North

4.3.2 PED North heat network

Figure 9 shows PED North district heating grid network balances. As a main source, DHG is supplied by RHS from data centres, and two CHPs. As information on only one of the CHPs was available, the other CHP was modelled with the same specifications. The assumption was that the two CHPs, combined with heat from RHS, are be able to provide enough heat during winter months. The figure shows that during summer months RHS alone is enough to meet the heating demand (see Figure 10).

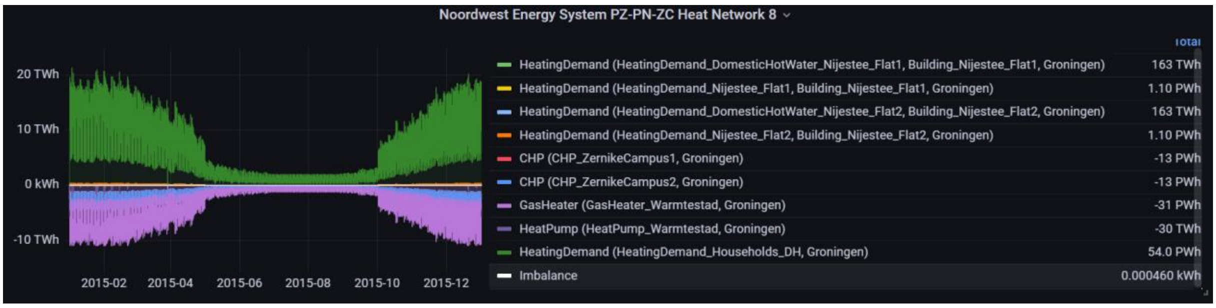


Figure 9: PED North district heating grid network balances

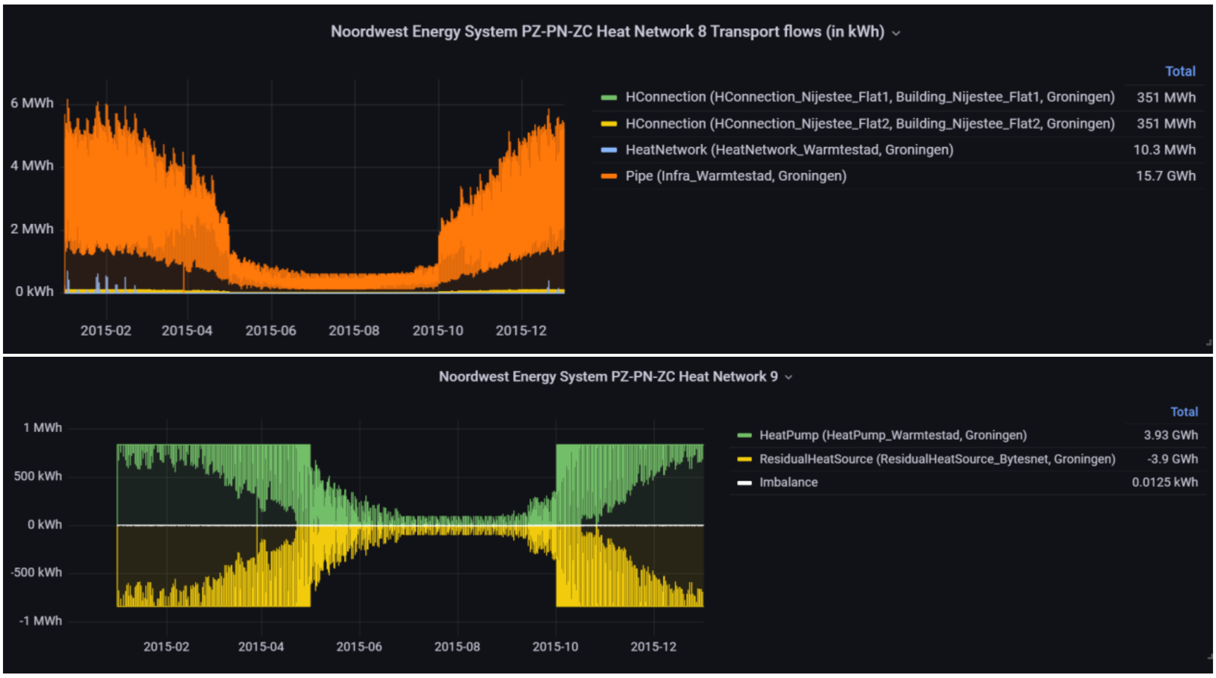


Figure 10: PED North district heating grid transport flows

4.3.3 Ped North Electricity network

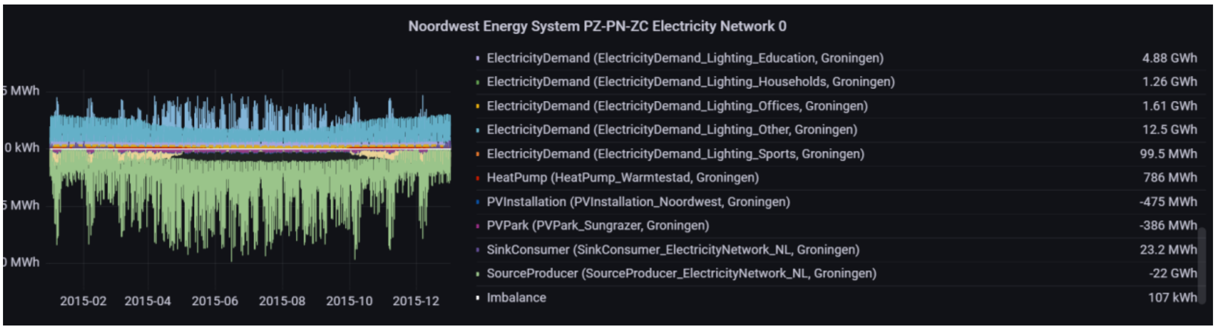


Figure 11: PED North electricity grid network balances

Figure 11 shows detailed electricity network balances of PED North, while Figure 12 shows electricity import into PED North. Despite several local resources such as PV park Sungrazer, local rooftop PV installations and PV installations on intervention buildings and the two CHPs, most of the electricity must be imported from the national grid.

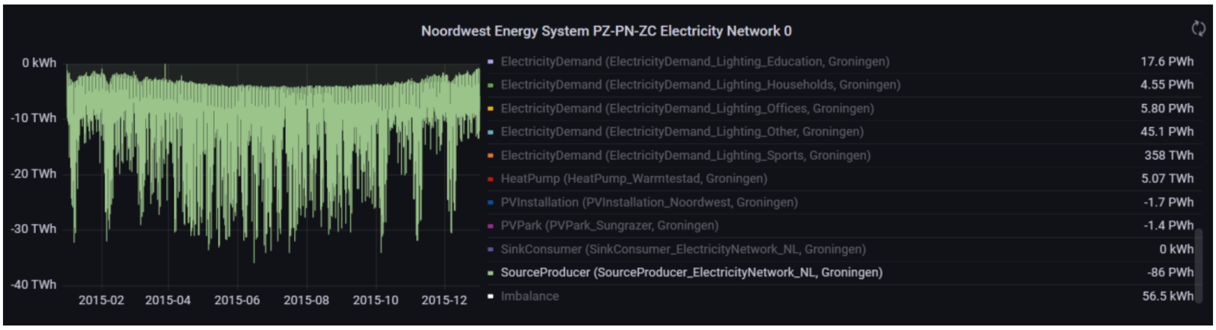


Figure 12: Electricity import into PED North

Figure 13 shows transport flows of PED North electricity network. This graph shows that Energy Academy Europe and Grote Beerstraat intervention buildings have an aggregate negative energy flow through their electricity connection, which means that, on a yearly basis, they export more electricity than they consume. The other intervention buildings still consume more than they locally produce.

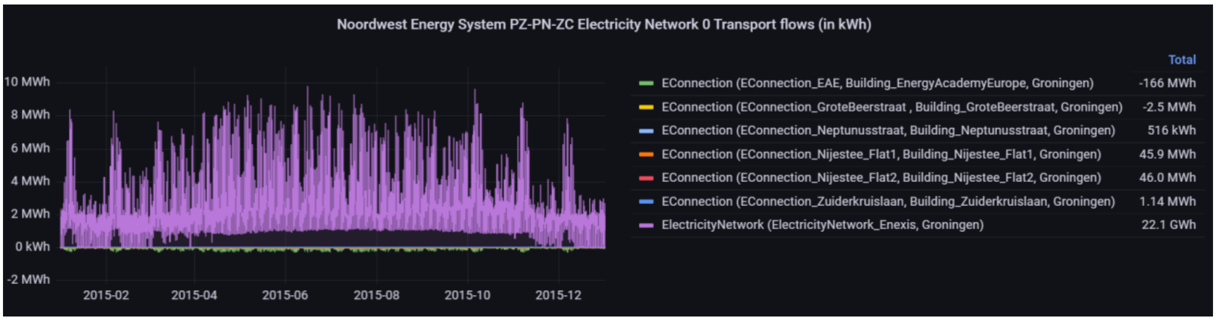


Figure 13: PED North electricity network transport flows

4.3.4 Energy Academy Europe - simulation outcomes

As seen in

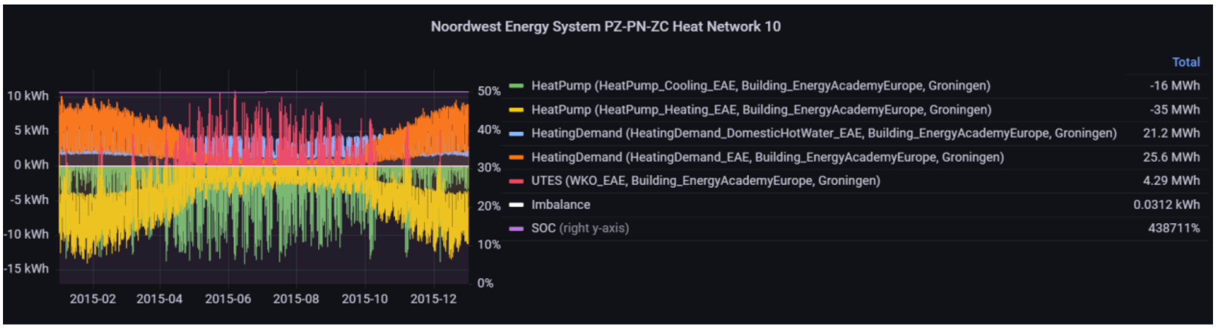


Figure 14, EAE heat network includes heating and domestic hot water demand supplied by a heat pump, cooling demand extracting heat to the underground geothermal source, and the heat pumps connected to an internal heating network. This network consists of the two heat pumps (one extracting from and the other one pumping heat in the network), and a local geothermal source (UTES). The figures show that EAE heat network is in balance, using its own heat sources. However, as noted before, the specifications for all the production and demand in this network are not the real values, therefore, these results should be taken with caution.

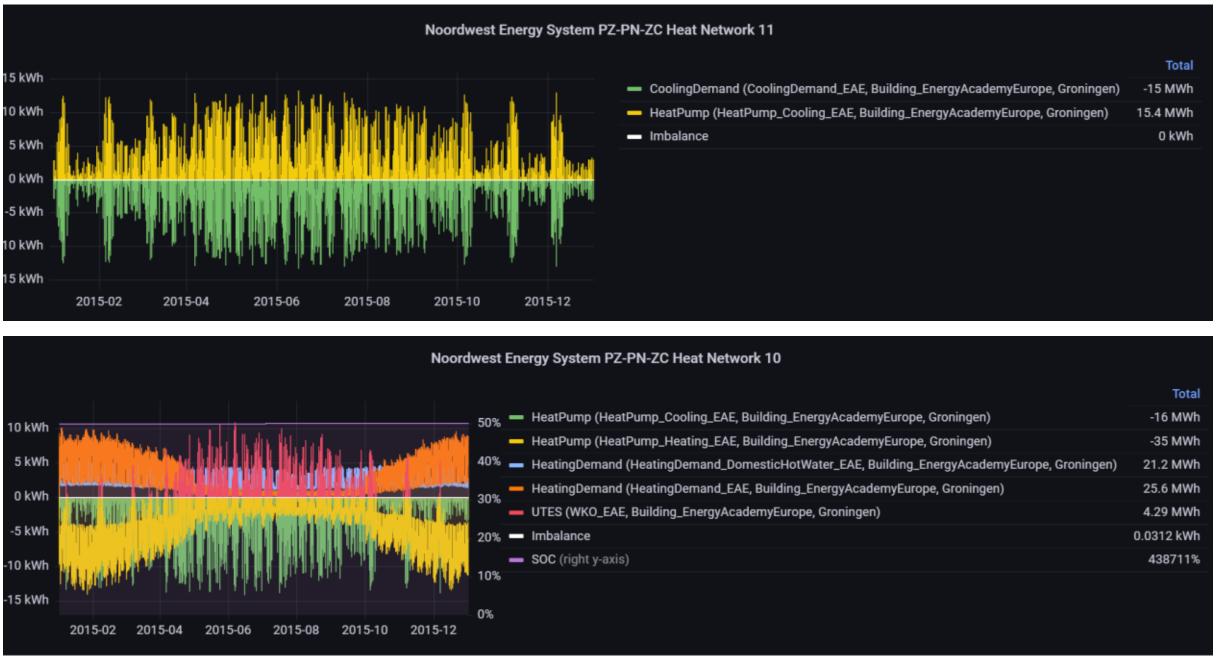


Figure 14: Energy Academy Europe heat network balances

Figure 15 shows network balances of EAE electricity grid. Estimated production of EAE PV installation, aggregated over a year, is enough to meet the electricity demands of the house, including those of the heat pumps. PV panels overproduce, so there is almost 166 MWh yearly export to the electricity grid (see also Figure 13).

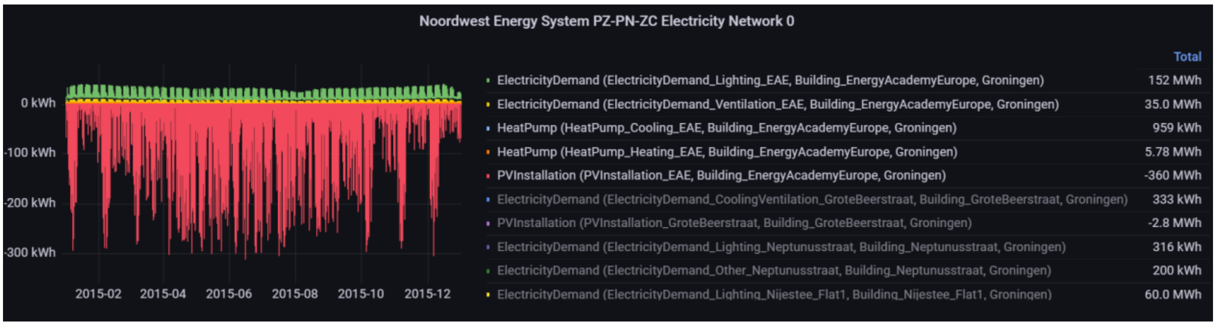


Figure 15: Energy Academy Europe electricity network balances

4.3.5 Nijestee flats - simulation outcomes

Figure 16 shows heat network balances of the two Nijestee buildings. Nijestee buildings are connected to PED North DHG and have no connection to the gas network.

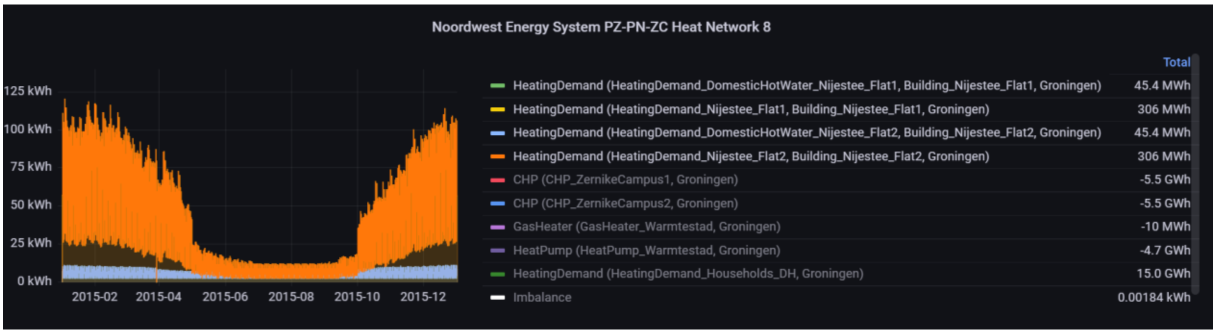


Figure 16: Nijestee heat network balances

Figure 17 shows electricity network balances of the two Nijestee buildings. It can be seen that PV installations significantly contribute to meeting the electricity demand, with its peaks surpassing the demand at several intervals, therefore contributing to the district electricity grid. However, on a yearly aggregate level, Nijestee's demand is higher than its production.

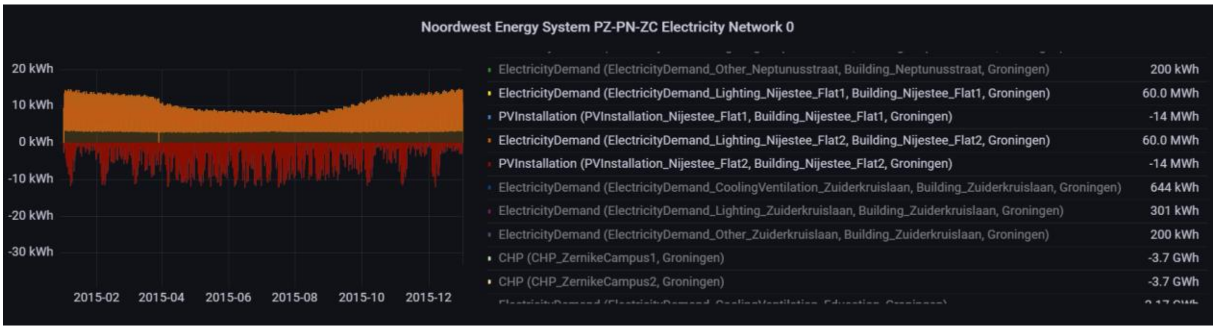


Figure 17: Nijestee electricity network balances

4.3.6 Three terraced houses - simulation outcomes

4.3.6.1 Neptunusstraat - simulation outcomes

Figure 18 shows heat network balances of the first terraced house. This house has a gas heater connected to the gas grid to meet its heating demands. There are no local heating sources.

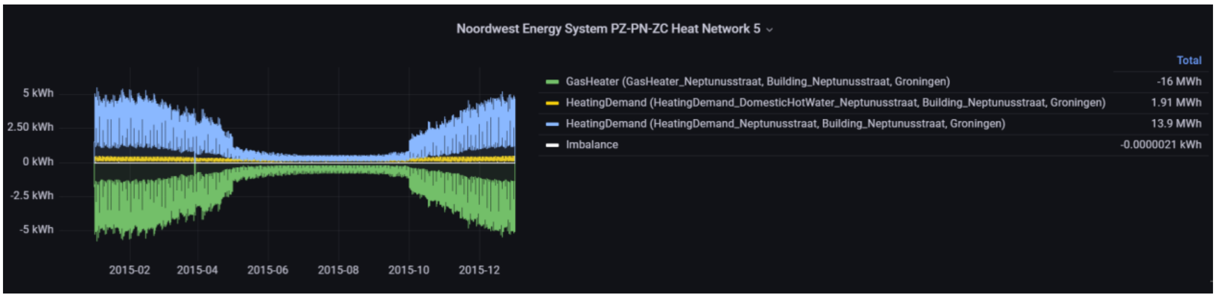


Figure 18: Neptunusstraat heat network balances

Figure 19 shows electricity network balances of the first house. This house has no local production sources; therefore, it imports all its electricity from the Dutch national grid.

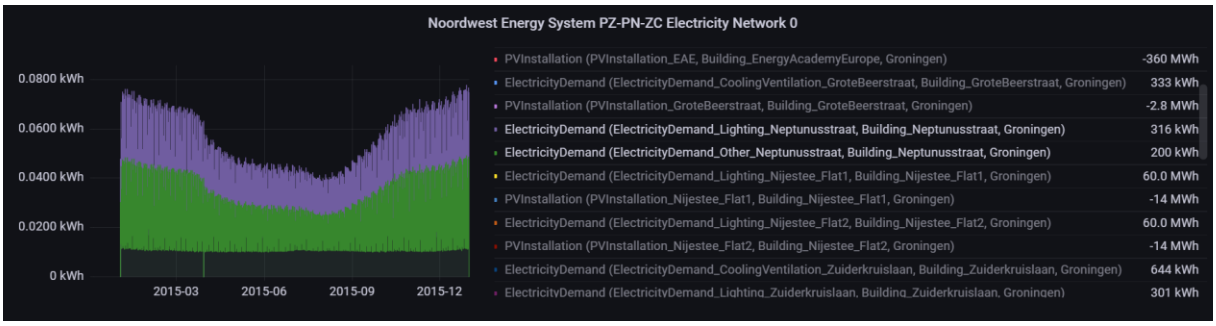


Figure 19: Neptunusstraat electricity network balances

4.3.6.2 Grote Beerstraat - simulation outcomes

Figure 20 shows heat network balances of the second terraced house. This house has a gas heater connected to the gas grid to meet its heating demands. There are no local heating sources.

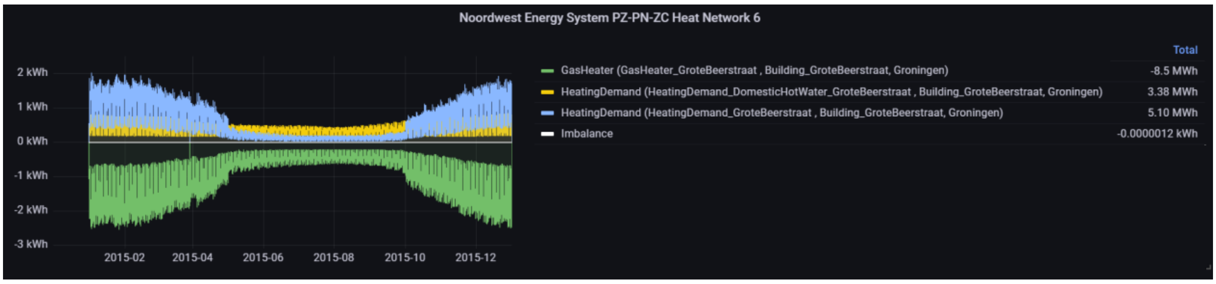


Figure 20: Grote Beerstraat heat network balances

Figure 21 shows electricity network balances of the second terraced house. This house has PV panels which overproduce during the year, compared to the electricity demand of the house. The house has 2.8 MWh yearly export to the electricity grid (see also Figure 13). However, here, only information of electricity demand was that of cooling/ventilation, and none of lighting or other building-related consumption. This could be the cause of apparent electricity overproduction of this house.

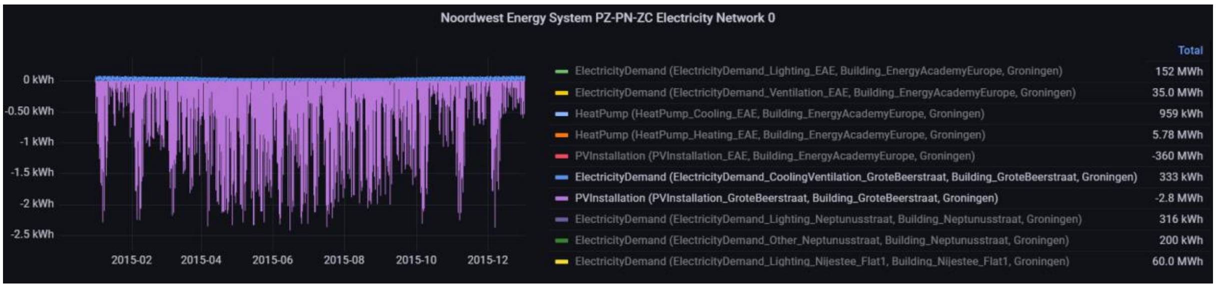


Figure 21: Grote Beerstraat electricity network balances

4.3.6.3 Zuiderkruislaan - simulation outcomes

Figure 22 shows heat network balances of the first terraced house. This house has a gas heater connected to the gas grid to meet its heating demands. There are no local heating sources. Figure 23 shows electricity network balances of the third terraced house. This house has no local production sources; therefore, it imports all its electricity from the Dutch national grid.

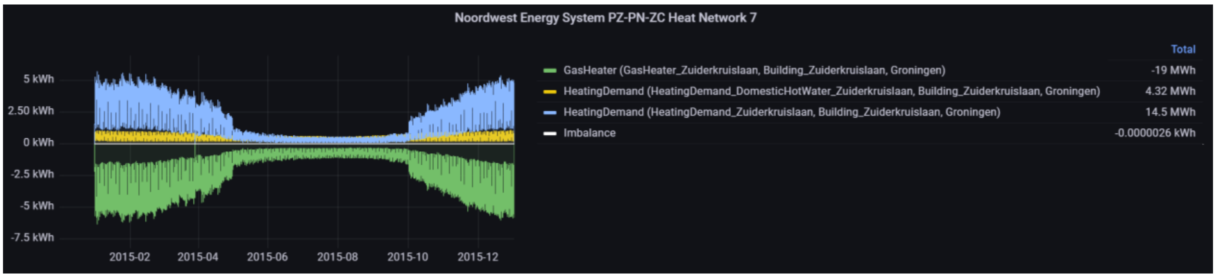


Figure 22: Zuiderkruislaan heat network balances

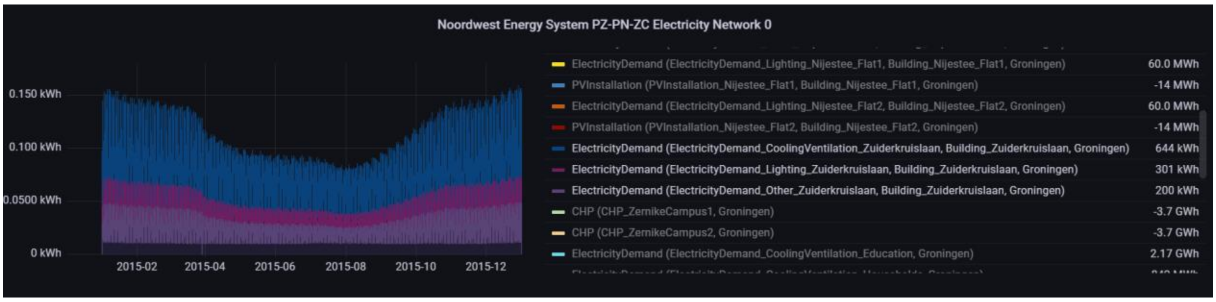


Figure 23: Zuiderkruislaan electricity network balances

4.4 Simulation totals

Intervention building	Electricity [kWh]		Heat [kWh]		Gas [kWh]	
	Demand	Production	Demand	Production	Demand	Production
Energy Academy Europe	194 200	-360 000	46 725	0	0	0
Nijestee	120 000	-28 000	702 800	0	0	0
Neptunusstraat	516	0	0	0	15 810	0
Grote Beerstraat	333	-2 800	0	0	8 500	0
Zuiderkruislaan	1 145	0	18 820	0	19 000	0
Residual Heat	0	0	0	-702 800	0	0
SunGrazer PV	0	-38 600	0	0	0	0
Total	**316 194**	**- 429 400**	**768 345**	**- 702 800**	**43 310**	**0**

Table 5 shows the total simulated energy demand and production per intervention building in PED North. In case of EAE, electricity demand comes from the building, and the heat pumps, whereas its production is from the installed PV panels. In terms of heat, heat demand of EAE comes from its heating heat pump (which supplies the heating demand), while heat production comes from both the ATES and the cooling heat pump. On an aggregate level, EAE is self-sufficient, and overproduces electricity. Nijestee produces roughly a fourth of its electricity consumption using its PV panels, and the rest is supplied from the national electricity grid. Nijestee does not have any local heat production, but is fully supplied by the DHG of PED North. Neither of the buildings is connected to the gas network. The heat of the three terraced houses is delivered through gas heaters, connected to the gas grid. There is no local gas production. Electricity of Neptunusstraat and Zuiderkruislaan is met from the national grid, while Grote Beerstraat produces more throughout the year (through its PV panels) than it consumes.

It should be noted that these numbers are on an aggregate yearly level, which means that at times when there is no local electricity production, the buildings get their electricity from the national electricity grid, while at times when there is overproduction, it is exported to the grid (see also the results of the simulations in the previous sections).

Intervention building	Electricity [kWh]		Heat [kWh]		Gas [kWh]	
	Demand	Production	Demand	Production	Demand	Production
Energy Academy Europe	194 200	-360 000	46 725	0	0	0
Nijestee	120 000	-28 000	702 800	0	0	0
Neptunusstraat	516	0	0	0	15 810	0
Grote Beerstraat	333	-2 800	0	0	8 500	0
Zuiderkruislaan	1 145	0	18 820	0	19 000	0
Residual Heat	0	0	0	-702 800	0	0
SunGrazer PV	0	-38 600	0	0	0	0
Total	316 194	- 429 400	768 345	- 702 800	43 310	0

Table 5: Total simulated energy demand and production per intervention building in PED North

5 Groningen Southeast PED

The second PED district covers a large area in the southeast of the City and is completely different compared to the North PED. This area is mainly characterized by industrial, tertiary buildings and a few residential buildings. Also, the FC Groningen soccer stadium is situated in the area. The district is a mix of older and new buildings. The selected buildings are a representative of this topology, the old energy intensive Mediacentrale with its offices, the new Powerhouse that is a combination of offices and apartments and the new sports complex Europahal that has an energy positive configuration already. In addition, in the Southeast PED two solar parks are situated that provided power to the district. The district heating grid is already in place, but will extend during the project period and connect for instance the Powerhouse building.

5.1 Overall PED model

Figure 24 shows the PED model of Groningen South district. Note that a part of the district included in the blue area is excluded in the project proposal.

As previously mentioned, each intervention building is modelled individually, in detail, while the rest of the district is modelled on an aggregate level. The buildings with interventions in PED South are:

- Mediacentrale
- Powerhouse
- Sport complex Europahal
- Harm Buiterplein

The intervention models are discussed in the following section.

Energy demand

As this model should later be used to extrapolate interventions to other buildings, aggregate energy demand is separated into three categories corresponding to those of the intervention buildings. In case of the South district, the categories are the following:

- Offices (Mediacentrale, Powerhouse and Harm Buiterplein)
- Residential (Powerhouse)
- Sports (Europahal)
- Other (All the other)

The total energy demand is calculated using estimations from the section Energy data and is separated into building-related electricity and heat demand.

Energy production

In PED South, electricity and gas are imported from the national grid into the district via electricity and gas network, respectively. Imported gas is converted into heat using gas heaters. In addition, the district has a local district heating grid (indicated by red lines representing pipes), which is supplied by two local geothermal sources (Aquifer thermal energy storages).

In terms of local electricity production, the PV park Woldjerspoor is modelled, as well as estimated aggregate rooftop PV production in the district.

Any excess production is exported to the national grid, outside the district borders.

PED South has a district heating grid, which uses two ATES systems for heating and cooling.

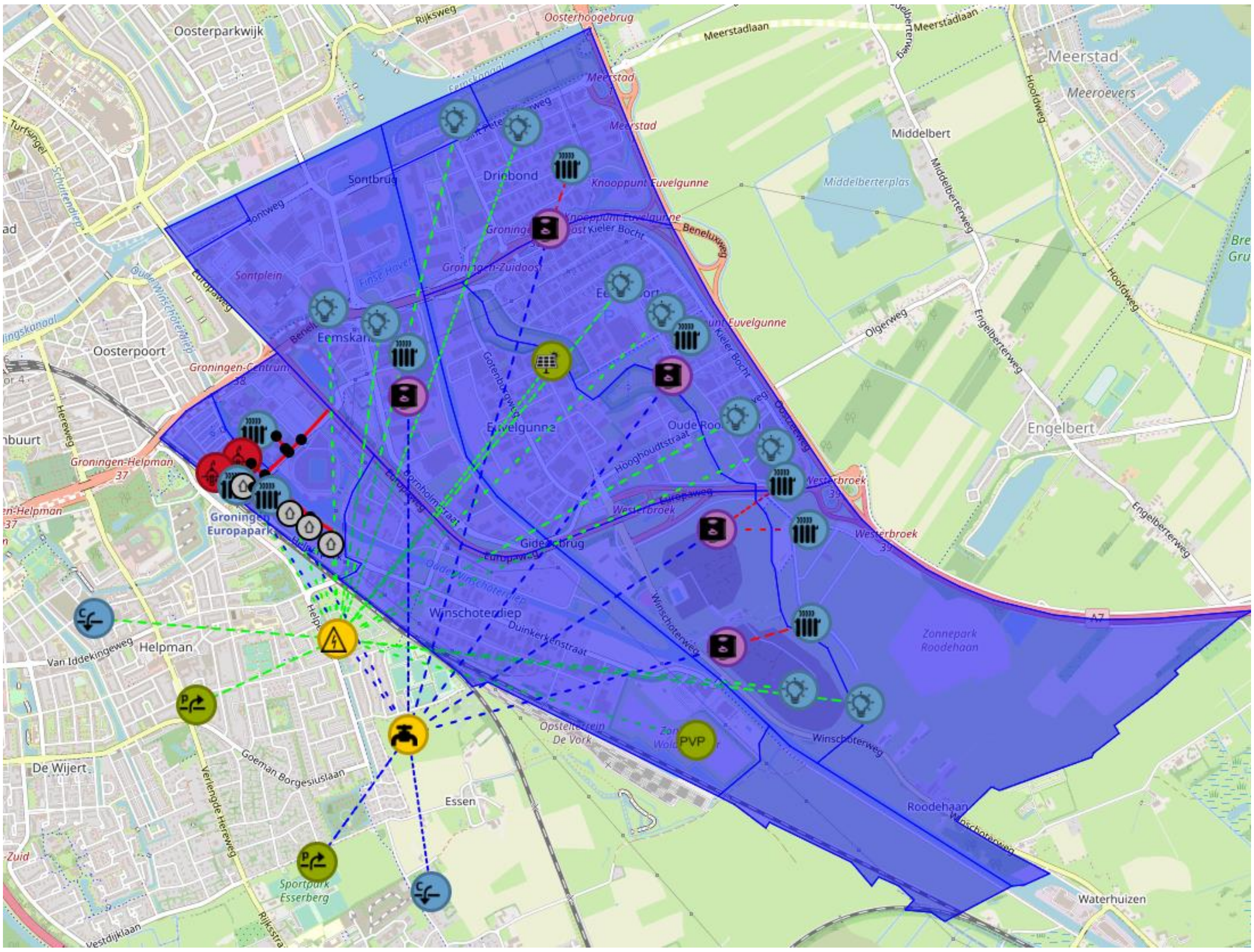


Figure 24: Groningen South PED model

5.2 Detailed intervention models

5.2.1 Mediacentrale

Mediacentrale was built in the 1930s as an energy plant and was repurposed as office building in 2005. As an energy-intensive building, it is chosen to be retrofitted by realizing its own geothermal heat pump connection with its own independent ground source. However, as the heat pump provides 89% of heating demand of the building, the gas installation is still in place. Heat pump is also used for cooling.

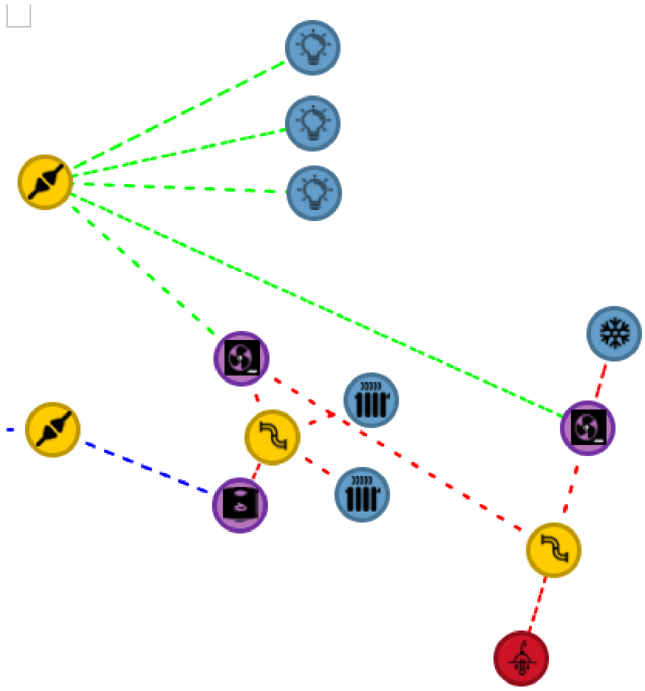


Figure 25: Mediacentrale energy system model

The list of executed interventions is the following:

- Realizing an own geothermal heat pump
- Connecting the heat pump to its individual ground source

Figure 25 shows the energy model of Mediacentrale. Mediacentrale has an electricity and a gas connection to the national grid. Electricity connection is used to meet electricity demand of the building, and electricity demand of the heat pump (modelled separately). The gas connection is connected to a gas heater, that delivers a small percentage of heat. Most of the heating demand is met using a heat pump. This heat pump is used both for heating and cooling.

Energy data for Mediacentrale is modelled as specified in the project's technical documentation. Electricity demand, however, is estimated using the approach described in section Energy data.

As this is an office building, energy profiles used to model building-related energy demand are:

- Heat demand: Heating households (G1A) – due to lack of office building profiles for heating, the standard households' profile is used
- Electricity demand lighting: Electricity shops, office, education (E3A)
- Electricity demand other: Electricity shops, office, education (E3A)
- Domestic hot water demand: Electricity shops, office, education (E3A)
- Electricity demand ventilation: Solar

Energy profiles used to model energy production are:

- Cooling demand: Since Mediacentrale is an office building, cooling demand comes from cooling servers. As this must be cooled throughout the year, constant profile is used.

5.2.2 Sport complex Europahal

The sports complex building combines sports-, educational-, office- and meeting room facilities. The sports facilities have a total surface area of 4208 m2, while the remaining occupies 1107 m2 of space. The construction of this energy positive building was finished by the end of 2018. WarmteStad provided heating and cooling to the building. The 88 PVT panels are mainly used to balance 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.

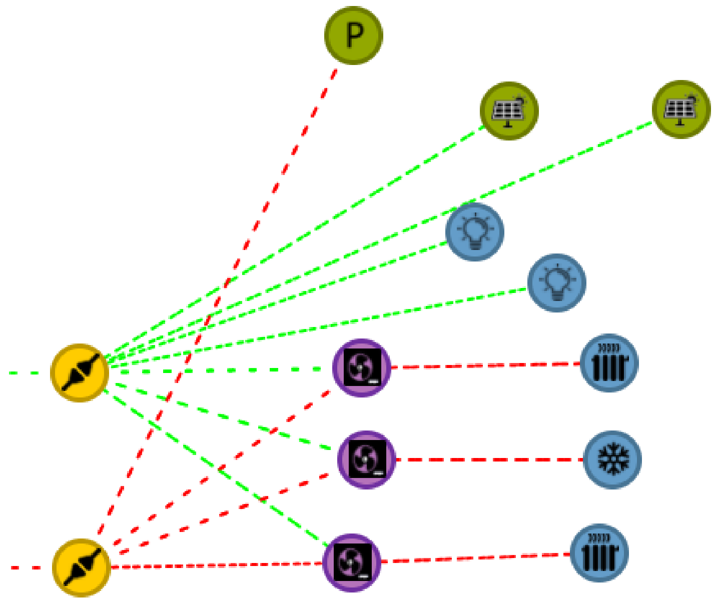


Figure 26: Sports complex Europahal energy system model

The list of executed interventions is the following:

- Connection to the district heating grid via heat pumps (a heat pump for heating and cooling and a heat pump for hot water)
- PV panels on the rooftop
- PVT panels on the rooftop (electricity and heat back to the district heating grid)

Europahal has a heat connection to the district heating system and an electricity connection to the Dutch electricity grid. The heat connection is used to deliver heat to the building and to export heat from the building's PVT thermal production and cooling demand to the district heating grid.

Energy data for Europahal is modelled as specified in the project's technical documentation. Electricity demand, however, is estimated using the approach described in section Energy data.

Energy profiles used to model building-related energy demand are:

- Heat demand: Heating households (G1A). Due to lack of sports building profiles for heating, the standard households' profile is used

- Electricity demand lighting: Electricity shops, office, education (E3A). As Europahal also hosts office and education facilities and due to lack of sports building profiles, E3A profile is used
- Electricity demand ventilation: Solar
- Domestic hot water: Electricity shops, office, education (E3A). Due to lack of domestic hot water profile, electricity profile is used as it most resembles behaviour of hot water usage. This should further be explored, and a decision made on whether to model hot water separately or aggregate it with heating demand (current heating demand profiles used include both heating and hot water usage in the Netherlands).

As seen in Figure 26, PVT panel production is separated into electricity (green icon with a solar panel) and thermal production (green icon with a powerplant, denoting a *GenericProducer*), to be able to simulate it using ESSIM. Electricity production of PVT is connected to electricity connection, while thermal production is connected to heat connection and exported to the district heat grid.

Energy profiles used to model energy production are:

- Cooling demand: Due to lack of a cooling profile, solar production profile is used to simulate cooling behaviour. The total cooling demand is modelled as specified in the technical documentation.
- PV and PVT production: Solar production profile.

5.2.3 Powerhouse apartments

Powerhouse is a newly built apartment complex with 79 apartments and 1,500 m2 of office space. The complex has a heating system based on a heat pump and geothermal energy, connected to district heating.

The list of executed interventions is the following:

- Connection to the district heating grid via a heat pump (the heat pump is used for heating, cooling and hot water)

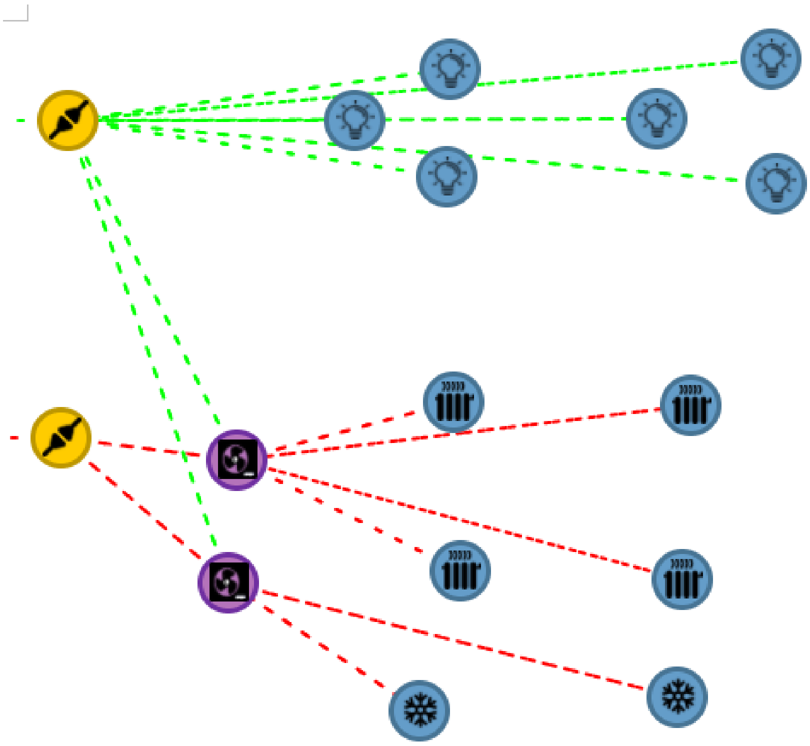


Figure 27: Sports complex Powerhouse energy system model

Figure 27 shows the energy model of Powerhouse. It has a heat connection to the district heating grid and an electricity connection to the electricity grid. Electricity connection is used to deliver electricity to meet the electricity demand, and to power the heat pumps. The heat connection is used to deliver heat for hot water and heating, and to export it back to the district heating when extracted from the cooling demand.

Energy data for Powerhouse is modelled as specified in the project's technical documentation. Building-related energy demand, however, is estimated using the approach described in section Energy data. Since this is a building with both offices and residential area, energy demand is further separated into office and residential demand.

NEDU Energy profiles used to model building-relate energy demand are:

- Heat demand - households: Heating households (G1A).
- Electricity demand lighting - households: Electricity households (E1A).
- Electricity demand other - households: Electricity households (E1A).
- Electricity demand ventilation - households: Solar
- Domestic hot water - households: Electricity households (E1A).
- Heat demand - offices: Heating households (G1A).
- Electricity demand lighting - offices: Electricity shops, office, education (E3A).
- Electricity demand other - offices: Electricity shops, office, education (E3A).
- Electricity demand ventilation - offices: Solar
- Domestic hot water - offices: Electricity shops, office, education (E3A).

Energy profiles used to model energy production of both offices and residential area are:

- Cooling demand: Due to lack of a cooling profile, solar production profile is used to simulate cooling behaviour of the households. For offices, constant profile is used.

5.2.4 Harm Buiterplein

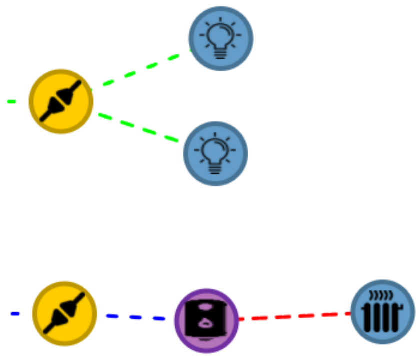


Figure 28: Harm Buiterplein energy system model

As there were no new interventions implemented for Harm Buiterplein at the moment of writing the deliverable, this building's energy model is the same as its baseline (see deliverable D3.2). Figure 28 shows the ESDL energy model of Harm Buiterplein. This building has a gas connection to the Dutch gas network and uses a gas heater for space heating. Furthermore, it has an electricity connection to the Dutch electricity grid, to meet the electricity demand.

As this is an office building, energy profiles used to model building-related energy demand are:

- Heat demand: Heating households (G1A).
- Electricity demand lighting: Electricity shops, office, education (E3A).
- Electricity demand cooling/ventilation: Solar

5.3 Simulation outcomes

5.3.1 PED South Gas network

PED South imports gas from the Dutch national gas network. Figure 8 shows gas network balances. *SourceProducer* indicates gas import into the district, and *SinkConsumer* indicates export from the district. In the district, gas is supplied (via gas heaters) to the part of the district not connected to district heating grid. Figure 30 shows the hourly gas import into the district. As there are no local gas sources, all the gas is imported from outside the district.

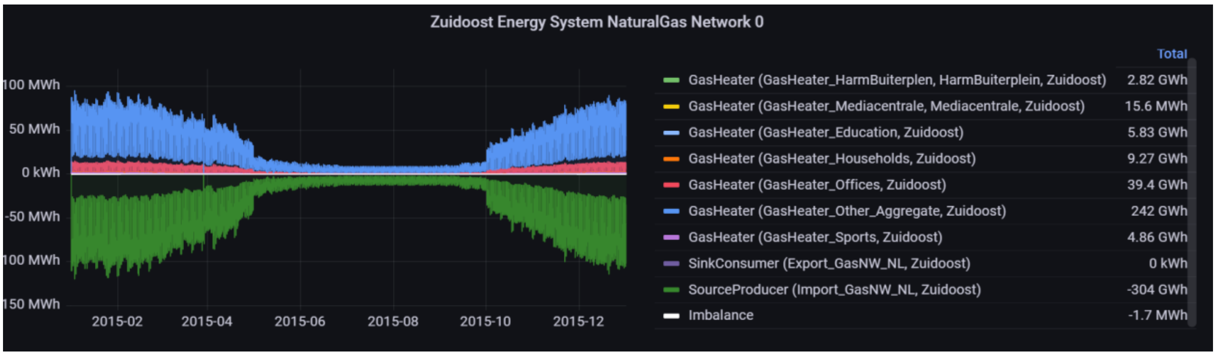


Figure 29: PED South gas network balances

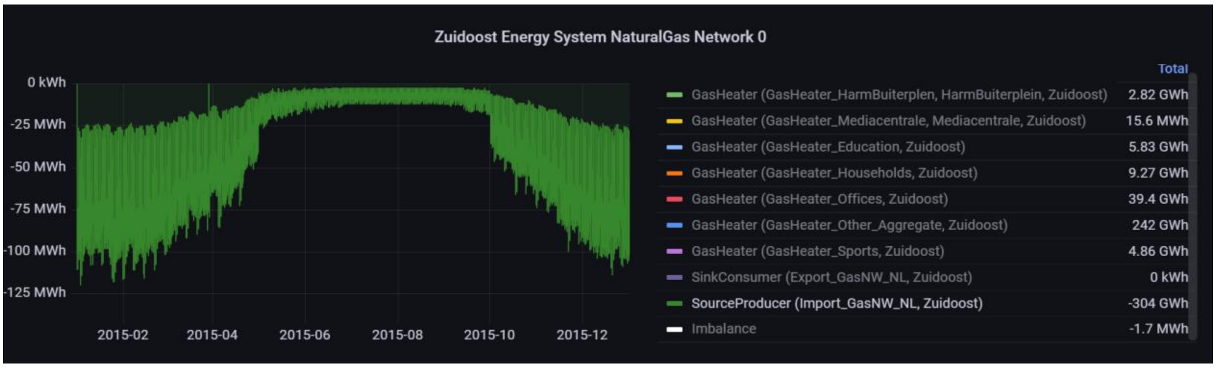
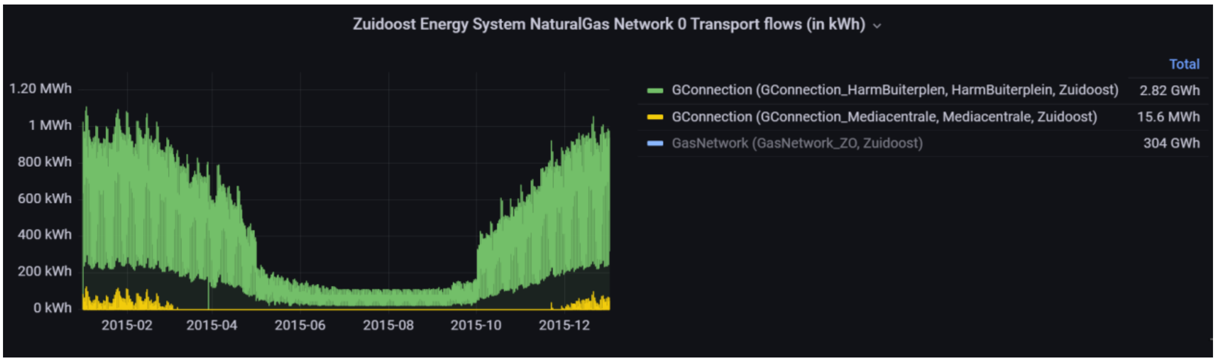


Figure 30: Gas import into PED South



5.3.2 PED south heat network

Figure 31 shows district heating grid balances. DHG is supplied by two ATES units (as the main heat sources), heat extracted by cooling (from Europahal and Powerhouse) and thermal PVT production from Europahal. As discussed, no specifications of the two ATESs are available. It is our assumption that, combined, these units do provide enough heat to meet the heating demand of the connected consumers. Therefore, ATESs are modelled with very large capacities.

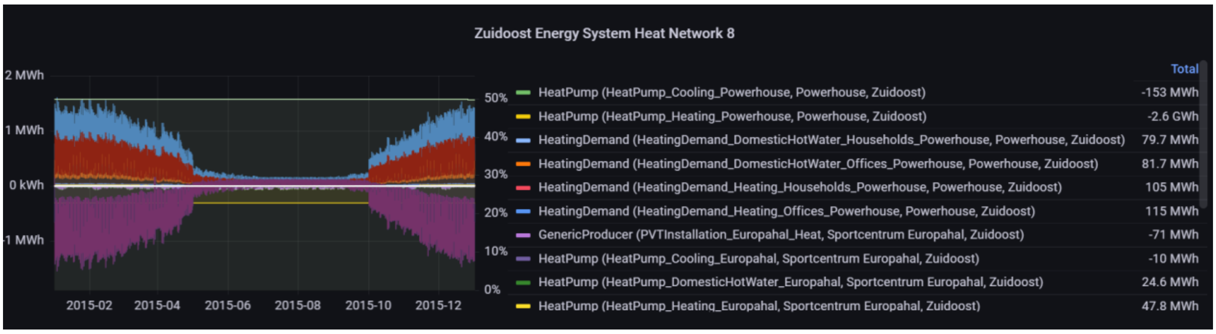


Figure 31: PED South district heating grid

5.3.3 PED South electricity network

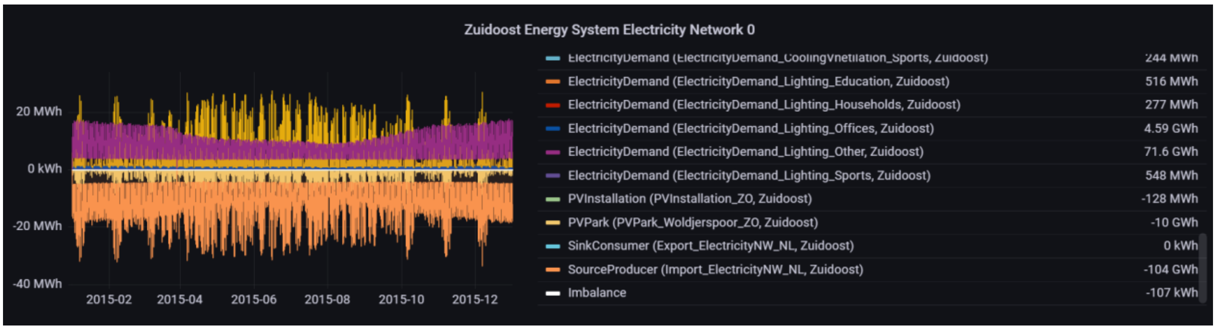


Figure 32: PED South electricity network balances

Figure 33 shows electricity import in PED South from the national grid. Despite several local resources such as PV park Woldjerspoor, local rooftop PV installations and PV installations on intervention buildings, most of the electricity must be imported from the national grid. Local electricity production can be seen in Figure 34.

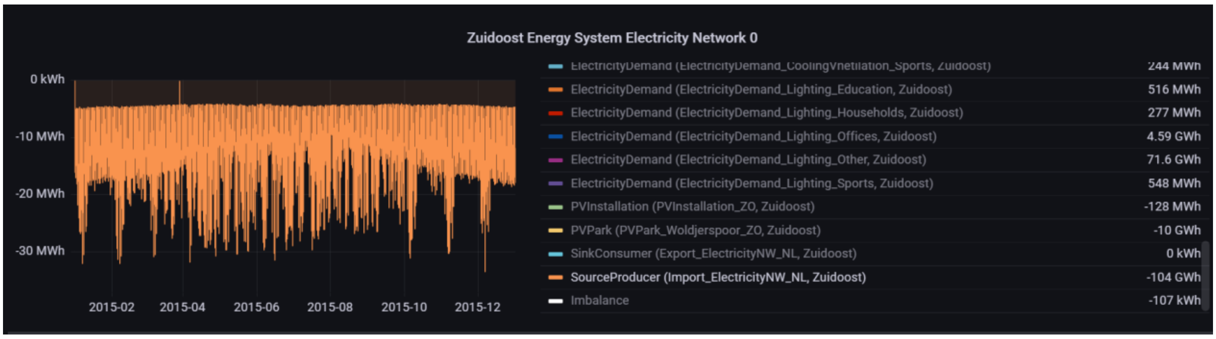


Figure 33: Electricity import in PED South

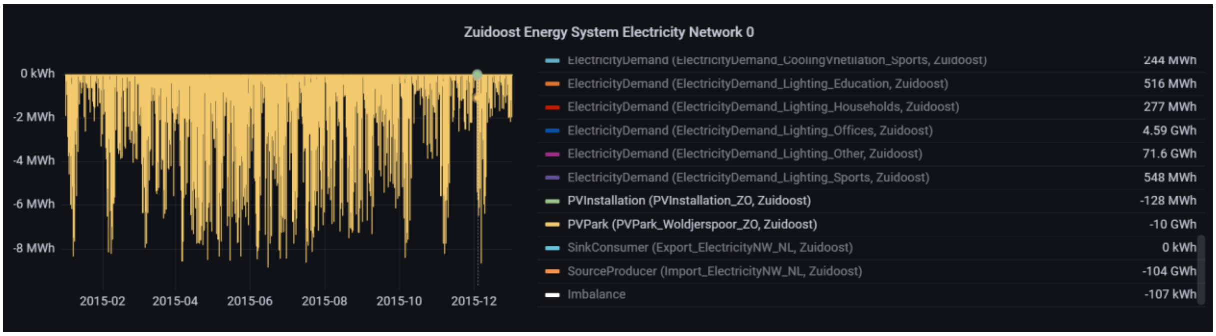
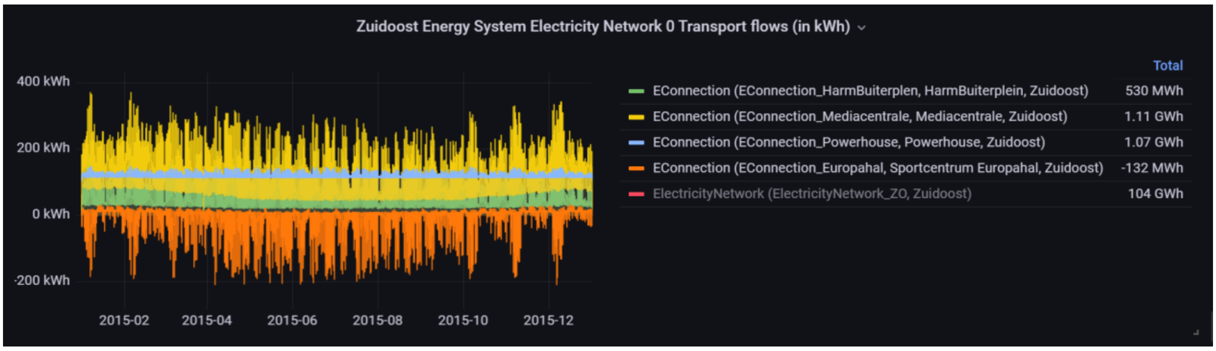


Figure 34: Local electricity production of PED South



5.3.4 Mediacentrale – simulation outcomes

Mediacentrale has a gas connection to the national gas network and an individual geothermal source, as a heat provider. According to the technical specification, the geothermal source is enough to provide 89% of heating demand. This is reflected in balances shown in Figure 35.

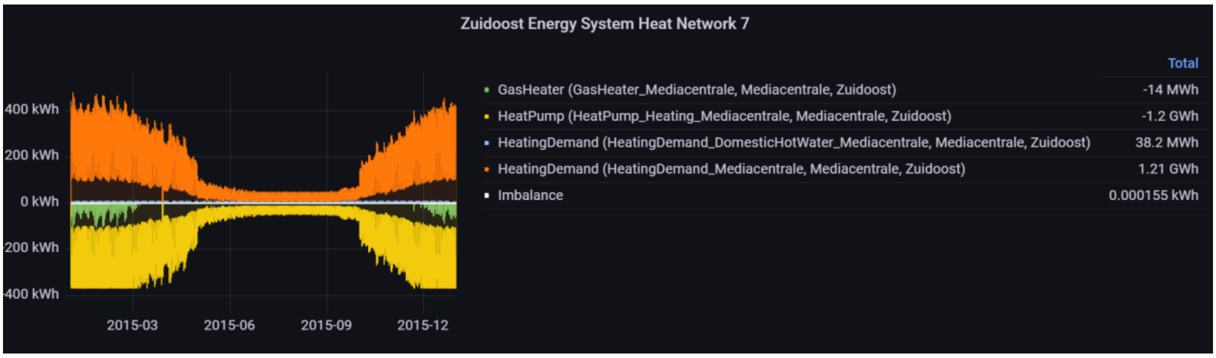


Figure 35: Heating demand of Mediacentrale with gas and heat pump production

Figure 36 shows heat network balances in Mediacentrale. Heat from cooling demand and the geothermal source are enough to meet the heating demand, whereas the geothermal source is also charged at times when there is low heating demand and high cooling demand.

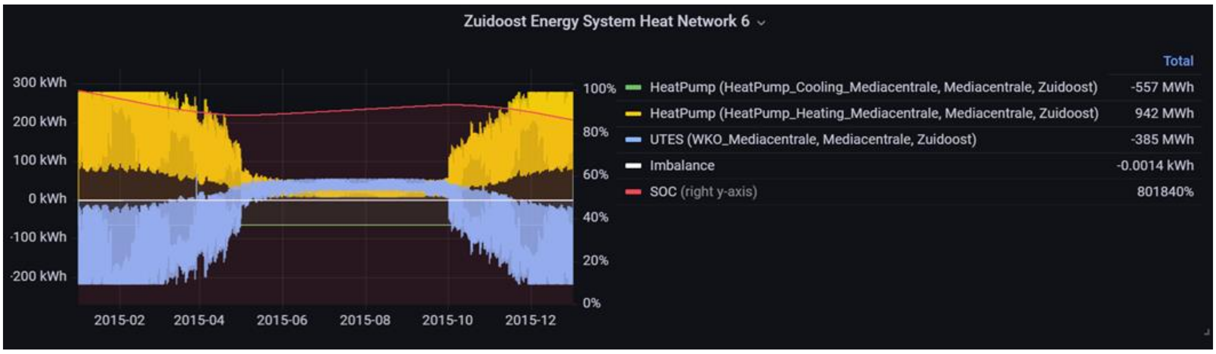


Figure 36: Heat network balances in Mediacentrale

As Mediacentrale does not have any local electricity production sources, Figure 37 shows electricity demand profiles.

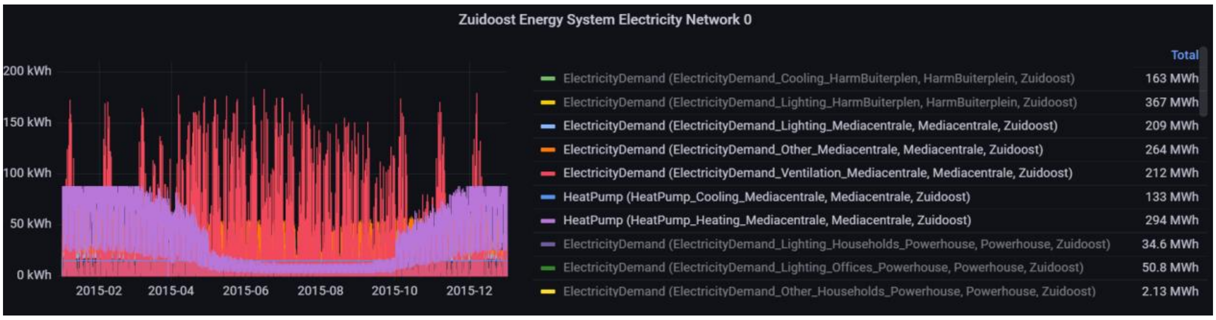


Figure 37: Electricity network balances in Mediacentrale

5.3.5 Sport complex Europahal – simulation outcomes

Europahal is connected to PED South DHG. Figure 38 shows heat network balances of Europahal, within the DHG. During sunny days, Europahal contributes significantly with thermal production from its PVT panels to DHG, which is directly used for heating during winter, and stored into ATES wells during summer.

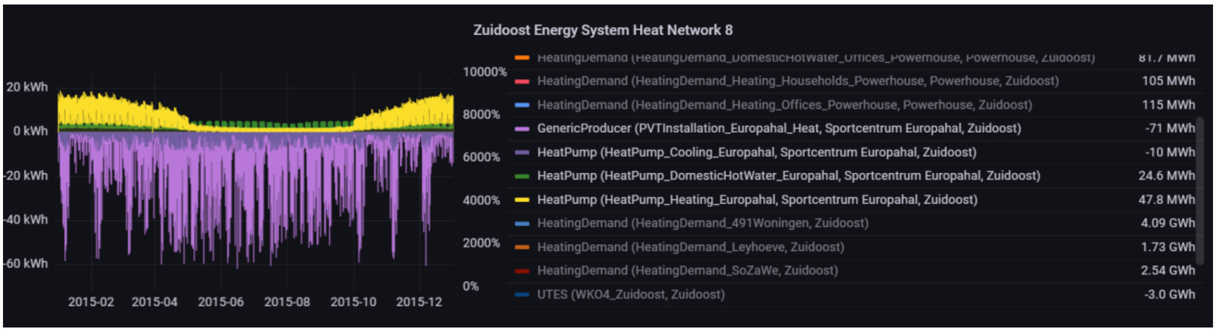
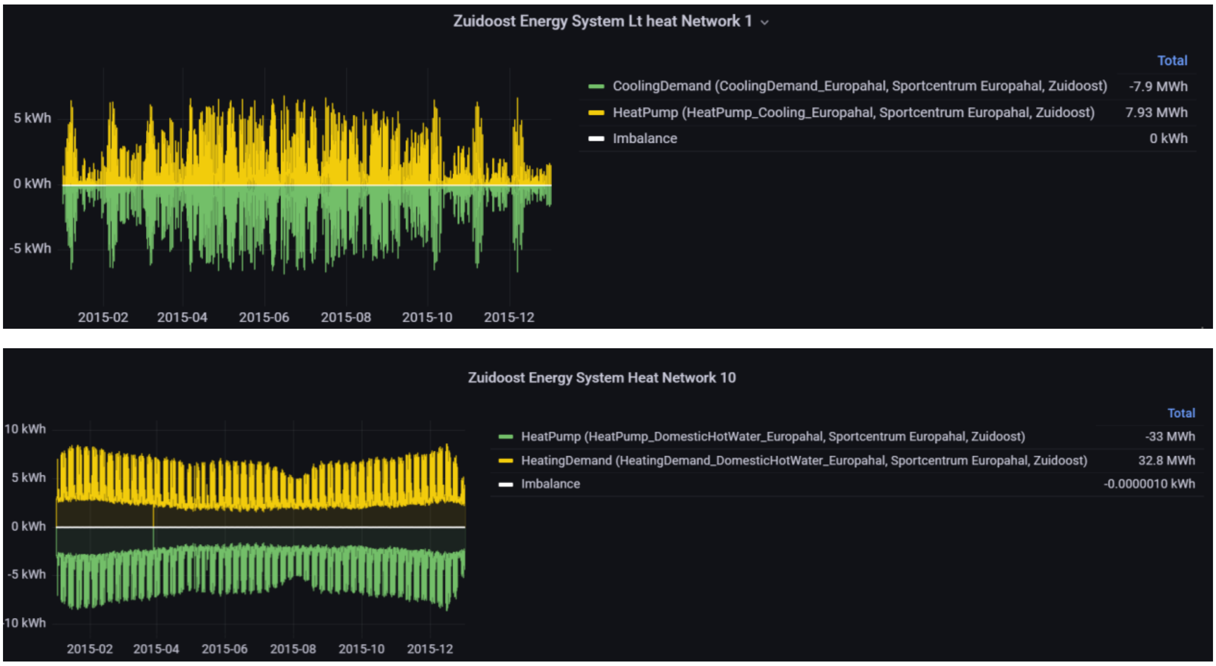


Figure 38: Europahal heat network balances

Figure 39 shows the balances of heat pumps and heating demand.



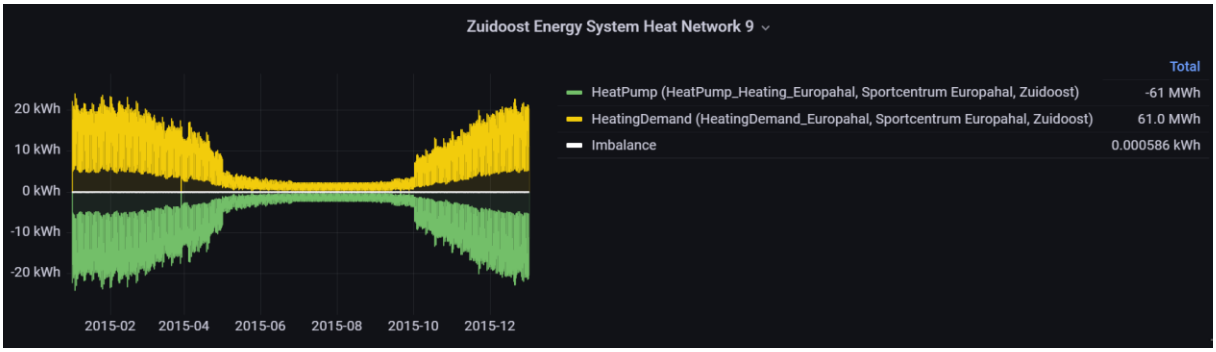


Figure 39: Heat pump, cooling and heating balances in Europahal

Finally, as seen in Figure 40 Europahal's local electricity production comes from PV and PVT installations and, at times when there is solar production, significantly contributes to Europahal's, but also district's balances.

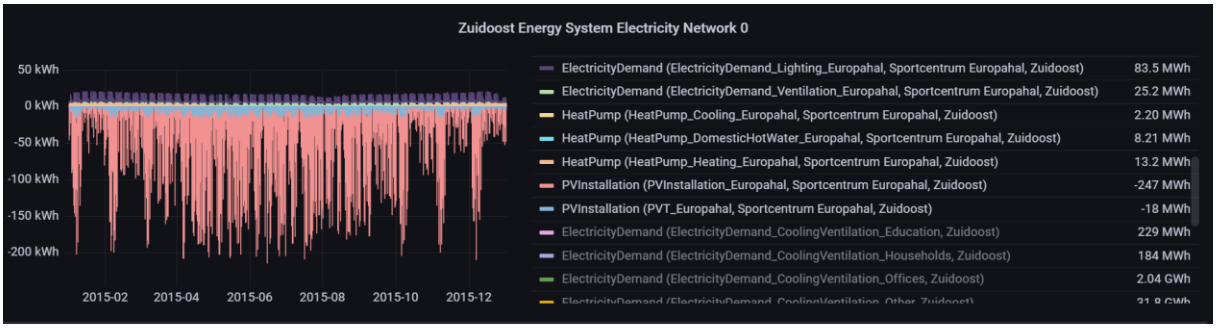


Figure 40: Electricity network balances in Europahal

5.3.6 Powerhouse apartments – simulation outcomes

Figure 41 shows heat network balances of Powerhouse. Powerhouse is connected to DHG and delivers heat to it via its cooling demand heat pumps.

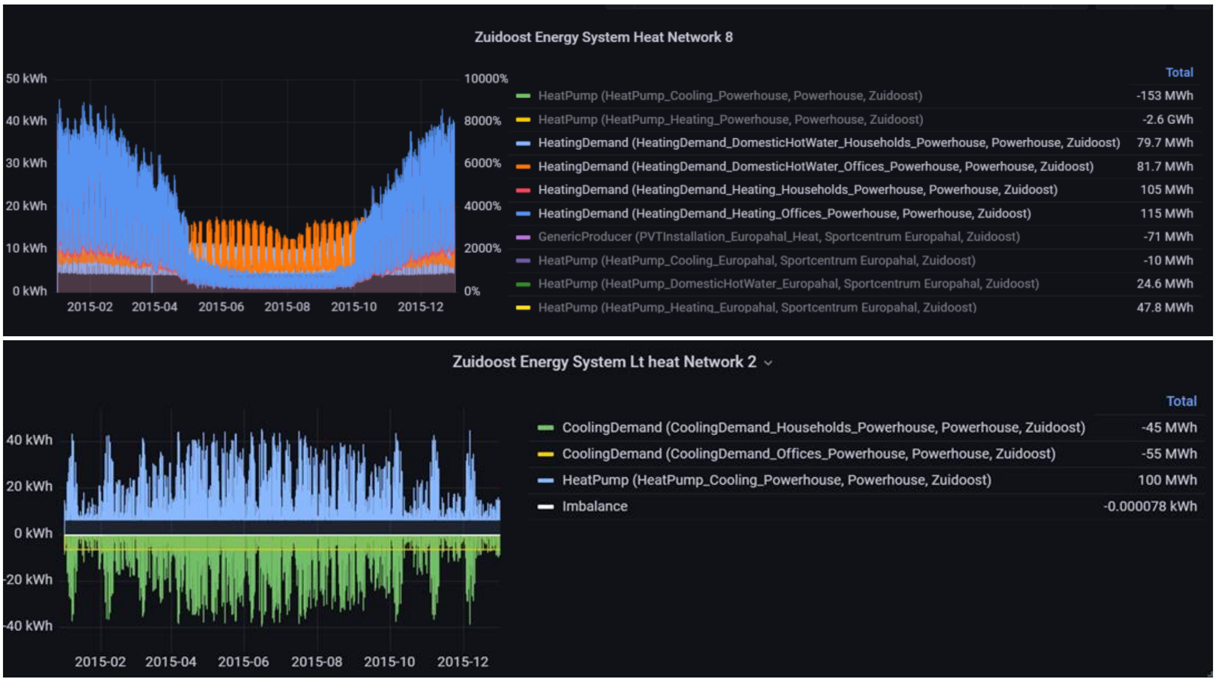


Figure 41: Powerhouse heat network balances

Figure 42 shows electricity network balances of Powerhouse. Powerhouse is connected to the national electricity grid and has no local generation sources. Therefore, only its demand profiles are shown. It can be seen that most of its electrical demand comes from the heat pump use.

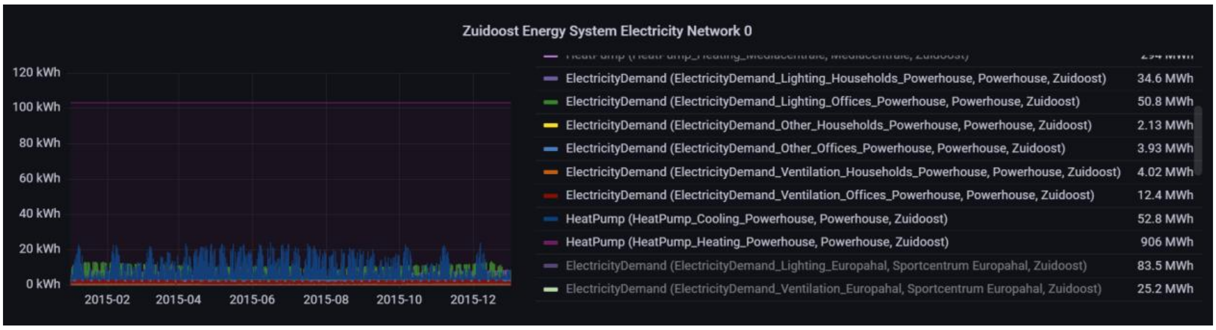


Figure 42: Powerhouse electricity network balances

5.3.7 Harm Buiterplein – simulation outcomes

Harm Buiterplein is connected to the Dutch gas grid and gets its heat through gas heaters. Figure 43 shows heat network balances of this building. Figure 44 shows electricity network balances of Harm Buiterplein. This building has no local production and gets all its electricity from the backbone grid.

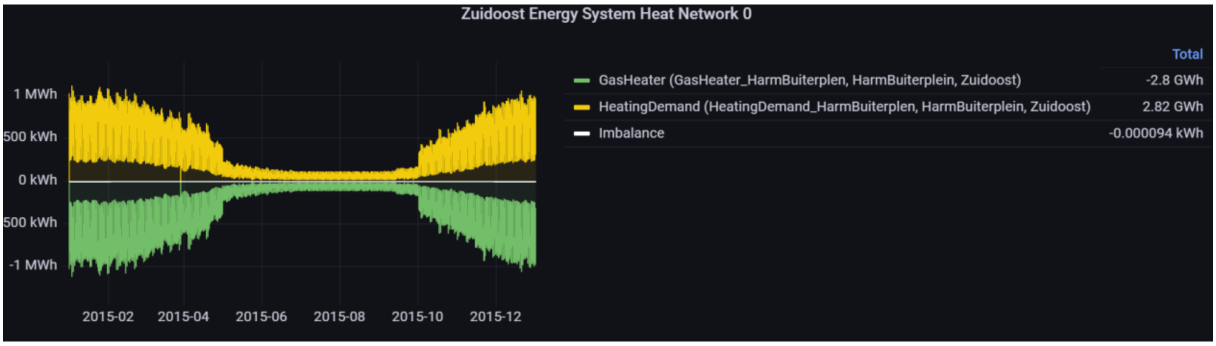


Figure 43: Heat network balances of Harm Buiterplein

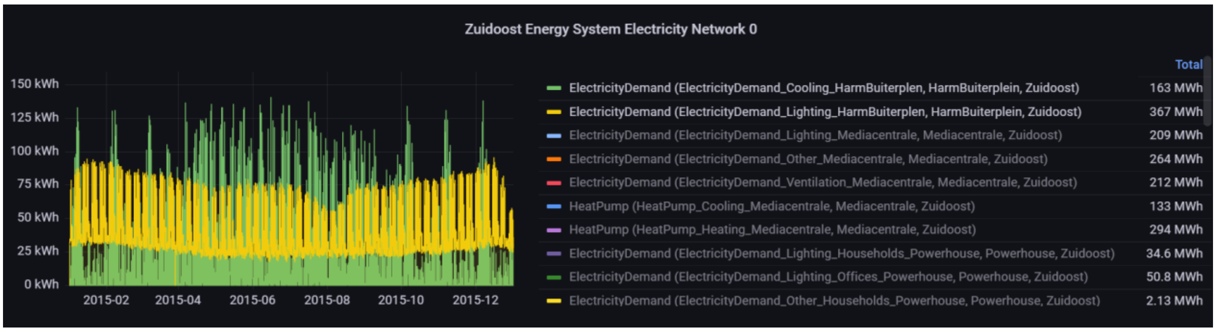


Figure 44: Electricity network balances of Harm Buiterplein

5.4 Simulation totals

Table 6 shows the total simulated energy demand and production per intervention building in PED South. The production comes from local energy sources only. Electricity demands include total electricity demand of the building and that of the heat pumps (for heating and cooling). Heat production includes heat extracted by cooling heat pumps and thermal production from PVT panels (in case of Europahal). Mediacentrale does not have any local electricity production and imports it from the national electricity grid. Most of its heat is supplied by its local heat sources (ATES and cooling heat pump), but at times it imports gas to fully meet the demand (during winter months). Europahal electricity demand is lower than its local production (on an aggregate, annual level), while around 86% of the heating demand is met by its cooling pump and the thermal production from its PVT panels (note that this thermal production is exported to the DHG of PED South). Powerhouse does not have any local electricity production and imports all the electricity from the national electricity grid. Slightly more than 26% of its heat demand is met by the cooling heat pump, while the rest of the heat is met by DHG of PED South. Neither Europahal nor Powerhouse is connected to the gas network. Harm Buiterplein has no local electricity or heat/gas sources. All its heat demand is met using gas heater connected to the main grid, while all electricity demand is met by the national electricity grid.

Intervention building	Electricity [kWh]		Heat [kWh]		Gas [kWh]	
	Demand	Production	Demand	Production	Demand	Production
Mediacentrale	1 112 000	0	1 248 200	-1 200 000	14 000	0
Europahal	132 310	-265 000	93800	-81 000	0	0
Powerhouse	1 064 680	0	381 400	-100 000	0	0
Harm Buiterplein	530 000	0	0	0	2 820 000	0
PV Woldjerspoor	0	-10 000	0	0	0	0
Total	2838 990	-275 000	1 723 400	-1 381 000	2 834 000	0

Table 6: Total simulated energy demand and production per intervention building in PED South

6 Conclusions

In this document we described the process of modelling and simulation of the Groningen PEDs using ESDL and ESSIM. The full process of data gathering, model definition and simulation results are discussed, and the eventual outcome was shown both as the full annual profiles, as well as the total. The tools used in this document to model and simulate the PEDs are available as open source software from https://energytransition.gitbook.io/esdl and https://github.com/ESDLMapEditorESSIM/docker-toolsuite.

We show that using a graphical modelling tool, we can show the PED, and make it possible for the user to define the infrastructure and add consumption or production profiles. Using the simulation tool, this enables nearly immediate insight in the energy flows, energy imported and exported, as well any imbalances.

In the simulations that were done, the whole PED was taken into account, which means that the "general" population was included as well as the intervention buildings. Taking that in account the simulations were far from energy positive. However, according to the current models the PED north should be energy positive already when only considering the intervention buildings, whereas the PED south is not just yet. This is mostly because some PV parks are not yet realized, and therefore not included in this model – although the PV installation at Roodehaan is technical already operational, it is not finished.