This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957845

LC-SC3-ES-3-2018-2020
Integrated local energy systems (Energy islands)

RENergetic

Community-empowered Sustainable Multi-Vector Energy Islands

Project Nº 957845

D4.1 – Interim evaluation of actions impact on Pilot site 1: Ghent – Nieuwe Dokken

Responsible:	Clean energy innovative projects, Lieven Demolder
Document Reference:	D4.1
Dissemination Level:	Public
Version:	1.0
Date:	13 May 2022

Executive Summary

CEIP and its subsidiary DuCoop have been working on a thorough integration of different technologies and data management systems in the Nieuwe Dokken district in Ghent. During the RENergetic project (see Figure 24), the EMS system was brought to implementation and officially started by the Belgian minister for Energy on June 2nd 2021. A battery charging strategy was implemented first, to optimize the utilization of locally produced PV-power and the cost of grid electricity. During 2021, tools were developed to manage sources in the local district heating network (e.g., heat pump control, forecasting, etc). During the coming year, CEIP/DuCoop want to increase accessibility of its EMS platform to pilot assets for testing of control algorithms, using a dedicated API. This will also allow interaction with third-party applications to interact with the EMS of the Ghent pilot. This is essential to test control algorithms from RENergetic partners. Furthermore, tools will be developed to control electricity consumption, for example by developing smart loading strategies for the pilot's EV charging infrastructure. More information and interactive tools will be made available to the end-users through the existing public and private end-user dashboard.

The effect of the different EMS strategies will be monitored online, using the existing EMS-Grafana platform. Based on different parameters the technical (sustainability), economic (cost) and social KPI's will be measured.

More work was realized by CEIP to assess the possibilities to produce more local renewable energy from building integrated photovoltaics (BIPV), using photovoltaics in the facade system, rooftiles or parapets. CEIP also wants to look into the possibilities to use excess renewable energy from neighbouring sites to increase the share of renewable energy in the district.

Furthermore, CEIP/DuCoop researched the options for the potential of Energy communities to increase the access to renewable energy both within the district as well as in the wider area around the Nieuwe Dokken. Together with the local DSO, DuCoop looked at the options to reduce peak injection/peak load on the local DSO-grid, and in that way create economic value. A technical and legal assessment will demonstrate the most optimal scenarios for the design of the local energy infrastructure.

For the third development phase of the Nieuwe Dokken (Zuidveld), DuCoop/CEIP are exploring different scenarios to optimize the collective energy system costs. Tieing different renewable energy systems and collective loads (heat pumps, EV-chargers, pumps, lighting, etc.) together creates the ability to respond to real-time energy pricing, to save network costs and capacity tariffs.

The objective of RENergetic is to demonstrate the viability of so-called "urban energy islands". Energy islands seek to achieve the highest possible degree of self-sustainability with regards to the supply of its energy demand, be it electricity or heat through local renewable resources. At the same time an urban energy island may offer ancillary services to the public grid surrounding it.

These islands place the consumer at the centre of the energy transition, giving them an active part in energy communities capable of producing their own energy, sharing the surplus with the rest of the public grid and optimizing consumption. RENergetic will demonstrate that Urban Energy Islands increase both the amount of renewables in these areas and the energy efficiency of local energy systems. RENergetic will demonstrate the viability of this energy islands in three site pilots, each of them of a different nature: New Docks, a residential area in Ghent – Belgium, Warta University Campus in Poznan, Poland and San Raffaele Hospital and its investigation and research campus in Segrate-Milan, Italy. The impact of the Urban Energy Islands is assured as technical, socio-economic and legal / regulatory aspects are considered while safeguarding economic viability.

RENergetic will be carried out over the stretch of 42 months involving 14 European partners: Inetum (Spain, France, and Belgium), Clean Energy Innovative Projects and Gent University (Belgium), Poznan University of Technology, Veolia and Poznan Supercomputing and

Networking Center (Poland), Ospedale San Raffaele, Comune di Segrate and University of Pavia (Italy), Energy Kompass GMBH (Austria), the University of Mannheim and the University of Passau (Germany), University of Stuttgart (Germany) and Seeburg Castle University (Austria).

Contributors Table

DOCUMENT SECTION	AUTHOR(S)	CONTRIBUTOR(S) TO RESULTS	REVIEWER(S)
All	Lieven Demolder (CEIP)	Lieven Demolder (CEIP)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
I. Introduction	Lieven Demolder (CEIP)	Lieven Demolder (CEIP)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
II. Pilot Descriptions	Lieven Demolder (CEIP)	Lieven Demolder (CEIP)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
III. Detailed description of the actions	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
IV. Data	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
V. Monitoring of the KPI's	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
VI. Experiments	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Lieven Demolder (CEIP), Chaïm Demulder (DuCoop)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)
VII. Summary and Conclusion	Lieven Demolder (CEIP)	Lieven Demolder (CEIP)	Peter De Smet (CEIP), Eduardo Vendrell (INETUM ES), Sonja Klingert (UNIMA)

Table of Contents

I. INTRODUCTION ... 9
I.1. Purpose and organization of the document ... 9
I.2. Scope and audience ... 9
I.3. Relations to other activities ... 9

II. PILOT DESCRIPTIONS ... 11
II.1. Ghent Nieuwe Dokken ... 11
II.2. Local Settings and Infrastructure ... 12
II.3. Availability of Renewable Energy Sources ... 13
II.4. Local Stakeholders and Roles ... 15
II.5. Alignment with other Research and innovation projects ... 17

III. DETAILED DESCRIPTION OF THE ACTIONS ... 18
III.1. Epic 1: Heat supply optimization ... 19
III.2. Epic 2: Heat demand side response ... 20
III.3. Epic 3: Forecasting ... 21
III.4. Epic 4: Electric supply optimization ... 21
III.5. Epic 5: Electricity demand response ... 22
III.6. Social Engagement ... 23
1. Public dashboard ... 23
2. End-user dashboard ... 24
3. Notifications ... 25

III.7. Development of Energy community schemes ... 25
1. Legal analysis ... 27
2. Impact on local DSO-grid ... 27
3. Electricity system design ... 28

III.8. Feasibility study BIPV ... 28

IV. DATA ... 30
IV.1. Data acquisition systems and EMS ... 30
IV.2. Development of API ... 31

V. MONITORING OF KPI'S ... 33
1. Technical dimension ... 33
2. Economic dimension ... 35
3. Social dimension ... 37

VI. EXPERIMENTS ... 39
VI.1. Experiments Epic 1 - Heat Supply optimization ... 39
VI.2. Experiments Epic 2 - Heat source optimization ... 40

VI.3. Experiments Epic 3 - Forecasting **41**
VI.4. Experiments Epic 4 - Electricity supply optimization **41**
VI.5. Experiments Epic 5 - Electricity demand side management **42**

VII. SUMMARY AND CONCLUSION **44**

VIII. REFERENCES AND INTERNET LINKS **45**

Table of Figures

Figure 1. Overview of the different phasing in the realisation of the Nieuwe Dokken project 12
Figure 2. Status of the Ghent- Nieuwe Dokken district in April 2022. At the end of 2022 the 2nd phase of the project will be finished. 13
Figure 3. In the 3d phase of the Nieuwe Dokken project (Southfield) the possibility to install building integrated photovoltaics (BIPV) panels is being investigated. 13
Figure 4. Using the Energy Communities framework, CEIP/DuCoop hopes to use excess renewable energy that is being produced at neighbouring sites to increase the share of renewable energy in the energy consumption of the district. 14
Figure 5. Electricity scheme Nieuwe Dokken 14
Figure 6. Overview of the heat pump system 15
Figure 7. During the H2020 Run4Life project (GA n°730285) a stakeholder map was constructed for the role CEIP and its subsidiary DuCoop in the Ghent- Nieuwe Dokken project. 16
Figure 8. CEIP used a cooperative financing scheme to finance the investments at the Nieuwe Dokken, together with its other financing partners. In the end, the residents will take over the capital of the local sustainability cooperation 'DuCoop'. 17
Figure 9. Overview of different innovation projects at the Nieuwe Dokken 17
Figure 10. The district heating network of DuCoop in operation (red) and planned (green). 19
Figure 11. Availability of all the sources through the year (per h) 20
Figure 12. Combination of different heat sources in the district heating system of the Nieuwe Dokken 20
Figure 13. Weekly trends (Monday- Friday) in heat consumption for the building 'Faar' (47 apartments) 21
Figure 14. Overview of the EV charging strategy that will be developed together with IMEC-University of Ghent to control the electric load of EV charging in the Nieuwe Dokken district. 22
Figure 15. Overview of the DuCoop public dashboard, giving an overview of the environmental services and performance on DuCoop sustainability goals 24
Figure 16. Overview of the private end-user dashboard 25
Figure 17. Scenario for a design of the local energy infrastructure in the 3rd phase of the 'Nieuwe Dokken' (Zuidveld). These different renewable energy systems and collective loads (heat pumps, EV-chargers, pumps, lighting, etc.) together create the ability to respond to real-time energy pricing, to save network costs and capacity tariffs 28
Figure 18. In the 3d phase of the Nieuwe Dokken project (Southfield) the possibility to install building integrated photovoltaics (BIPV) panels is being investigated. 29
Figure 19. Overview of the structure of the data-collection system. All subsystems of DuCoop are equipped with Siemens S7 PLC connected to a central WinCC platform. From there, timeseries of different process parameters are collected in an online data platform and visualized in a Grafana

dashboard. The EMS system also allows to adapt parameters (e.g., setpoints, I/O-signals, etc.) based on an overarching optimization strategy. 30

Figure 20. The DuCoop EMS system was officially started by the Belgian minister for Energy Tine van der Straeten on June 2nd 2021. 31

Figure 21. The development of an Application Programming Interface (API) is essential to allow third-party applications to interact with the EMS of the Ghent pilote. This is essential to test control algorithms from RENergetic partners. 32

Figure 22. Overview of the development of the KPI's in the social dimension 38

Figure 23. Leaflet that was used to introduce people to the heat DSM trial. Residents participated voluntarily, which meant that they allowed the temperature settings of their smart thermostats to be adapted to a heat demand shifting strategy, set out by the DuCoop EMS. 39

Figure 24. Shift of the morning heat demand peak in the building 'Faar' on Wednesday, before and after the implementation of a heat demand management tool (week 11/12 vs week 6-9). 40

Figure 25. Overview of the control of the heat pump in the contribution to the energy mix of the DH network in W11/2022. 41

Figure 26. Forecasting of heat demand. Blue line: actual data; other colours: forecasts of 48 in the future at different points in time. 41

Figure 27. Extract from Ghent Pilot Grafana Dashboard. The current EMS system controls use of local renewable energy (PV), charging of the local battery system (200kWh) or consumption of grid power based on availability of local RES, consumption prediction and energy market prices (ENDEX). 42

Figure 28. DuCoop operates 20 Powerade EV-charging points (11kW) in the first phase of the Ghent Pilot. In a second phase (2022) 32 extra EV charging points will be added. 43

Figure 29. Overview of RENergetic EMS programming activities in the Ghent Pilot site Nieuwe Dokken (: done, : to do, *: not relevant) 44

List of Tables

Table 1 - Ghent pilot actions 18

Table 2. Overview of the implementation of the European energy community's framework 26

Table of Acronyms and Definitions

Acronym	Definition
COP	Coefficient of Performance
DC	Data Centre
DSO	Distribution system operator
DH	District Heating
EMD	EU Electricity market directive
HP	Heat Pump
ICT	Information and Communication Technologies
PV	Photovoltaics
CEIP	Clean Energy Innovative Projects
EMS	Energy Management System
API	Application Programming Interface
HDR	Heat Demand Response
REDII	(second) EU Renewable energy directive
RES	Renewable Energy Systems

I. INTRODUCTION

I.1. Purpose and organization of the document

This document is the first deliverable of Work Package 4 (WP4) and describes the Ghent Pilot site. The purpose of the document is to present the institutions collaborating within the Pilot, their technical infrastructure and detailed description of the performed and planned actions. These actions refer on one hand to the main epics defined in the project and on the other hand to the pilot-specific work needed to collect required data and enable impact on the pilot. This pilot-specific work includes development and deployment of data acquisition systems as well as experiments performed in the interim period.

The document is structured as follows:

The first chapter introduces the goals of the deliverable and present the scope and relations to other activities of the project. The second chapter contains description of the Ghent Pilot site 1. It describes the local settings and infrastructure, availability of Renewable Energy Sources (RES) and local stakeholders and roles for all partners involved in pilot site. The third chapter is dedicated to the detailed description of the actions. It includes the list of strategies selected for the site, the main tools to be used in actions and the epics involved. The fourth contains the architecture of the data acquisition systems and describe how the data are stored and imported from databases to be used in the implementation of the RENergetic pilot optimization strategies. Starting from this data collection system a dedicated API is described (chapter 5) that will be developed to allow other partners of the RENergetic project to interact with our data management platform and EMS through a dedicated API-tool to extract data or test/implement RENergetic algorithms and EMS-tools. Chapter 6 presents the examples of experiments performed with data and EMS from the Ghent pilot. Chapter 7 gives a summary and conclusion of this report.

I.2. Scope and audience

Deliverable 4.1 relates to Interim evaluation of actions impact on Pilot site 3: Ghent- Nieuwe Dokken Pilot. Since this deliverable is the first one released for Work Package 4, the context of the pilot and the lead partner, CEIP and its subsidiary DuCoop will be explained. This deliverable will constitute a presentation of partners within Pilot, their technical infrastructure and detailed description of the actions. Interim analysis of the data and further actions to be taken were also indicated in the document. In addition, description of the data acquisition system and initial data analysis are presented. The pilot-related experiments are also collected at the end of the document. In the initial stage of this project, we have focussed on the construction of the data platform, the EMS and some initial tools for heat source optimization and heat demand response in the local district heating system. Generally, the audience include partners of the project involved in the design and development of the RENergetic platform and all other readers interested in energy islands and topics such as local waste heat re-use, use of renewable energy and energy management in buildings.

I.3. Relations to other activities

The Ghent Nieuwe Dokken site representing Work Package 4 is one of the three pilots in the RENergetic project. It is worth noting that the pilots in the project are very different from each other, both in terms of infrastructure, the work profile, stakeholders, activities or the main actions and epics carried out within the project. The essential relations between individual pilots focus particularly on the level of cross functional epics such as the interactive platform as well as forecasting. Additionally, the Ghent pilot puts a lot of effort into heat optimization. Also, scenarios for electric vehicle charging stations are considered for development. Chapter III gives an overview of the different epics that are discussed.

The project's ICT tools for these epics should be applicable and useful to each of these different pilots. ICT tools are developed under WP3 - ICT for energy island communities where CEIP, as a unit with extensive experience in the field of ICT, also puts a lot of effort.

In addition, WP2 presents issues related to social science for energy island communities. Furthermore, WP7 implements the proposal for evaluation, exploitation, and impact where IMEC- University of Ghent is also strongly involved as a global reach company in terms of research, infrastructure, and projects as well. WP8 is responsible for replicability within the RENergetic project, for which the Ghent Nieuwe Dokken site pilot is a reference.

II. PILOT DESCRIPTIONS

II.1. Ghent Nieuwe Dokken

CEIP (Clean Energy Innovative Projects) has started the Nieuwe Dokken-project in 2012, when a feasibility study was initiated which wanted to integrate decentral wastewater treatment with other sustainable technologies, like 4th generation district heating based on aquathermics (water-water heat pump) and low-temperature industrial waste heat, resource- and water recovery and smart renewable energy systems.

These concepts were integrated in 'De Nieuwe Dokken' site, which is considered as an important showcase on a first phase of buildings for how a sustainable, liveable environment can be created in a densely populated area. The main purpose of the project is to demonstrate economically viable business models for more sustainable newly built living environments.

At full deployment, the district will be an example of circular economy, with yearly re-use of over 30.000m³ of freshwater (>90% of the total consumption), recovery of over 750MWh of waste heat and the production of 1.500kg of phosphate- and nitrogen rich crystals (struvite), which could be used as a renewable fertilizer in a local urban agriculture project. This water treatment system will combine novel technologies like vacuum sewer systems, digestion of black water, struvite recovery, recovery of waste heat from the effluent of the water treatment plant with a heat pump and an aerobic membrane bioreactor.

To finance all these activities, a legal structure was brought to live, as the local cooperation DuCoop [1]; who realized the investments for a local district heating network providing the 400 apartments in the 'Nieuwe Dokken' district with central heating and sanitary hot water, supplied with sustainable waste heat that is produced from biogas and a heat pump. This will cover up to 1/3 of the district's heat demand (1.500 MWh). The remaining heat will be provided by low-temperature (55°C) waste heat from nearby industry. Peak boilers (natural gas) should be able to provide the peak demand of the heating system at any time; but their application is minimized to avoid greenhouse gas emissions . Next to this, DuCoop will develop solar PV-panels on the rooftops of the apartment buildings, offer EV-charging points for sustainable (shared) mobility and try to optimize the energy consumption through storage, information networks and data monitoring, and the use of intelligent energy management system (EMS) algorithms.

People are involved, informed and aware of the sustainable values of the project, and we are enjoying a huge degree of participation in our board meetings, information sessions, etc. Also, other stakeholders (universities, knowledge institutions, project developers, policy makers) want to come and see the project during site visits, colloquia and events.

In 2019, a first building phase was realized and connected to the utility services of DuCoop. In the underground premises of the Central field all crucial sustainable systems (water treatment plant, vacuum station grid, district heating network & pumping station, buffers) were installed to operate the sustainability system for the whole neighbourhood.

II.2. Local Settings and Infrastructure

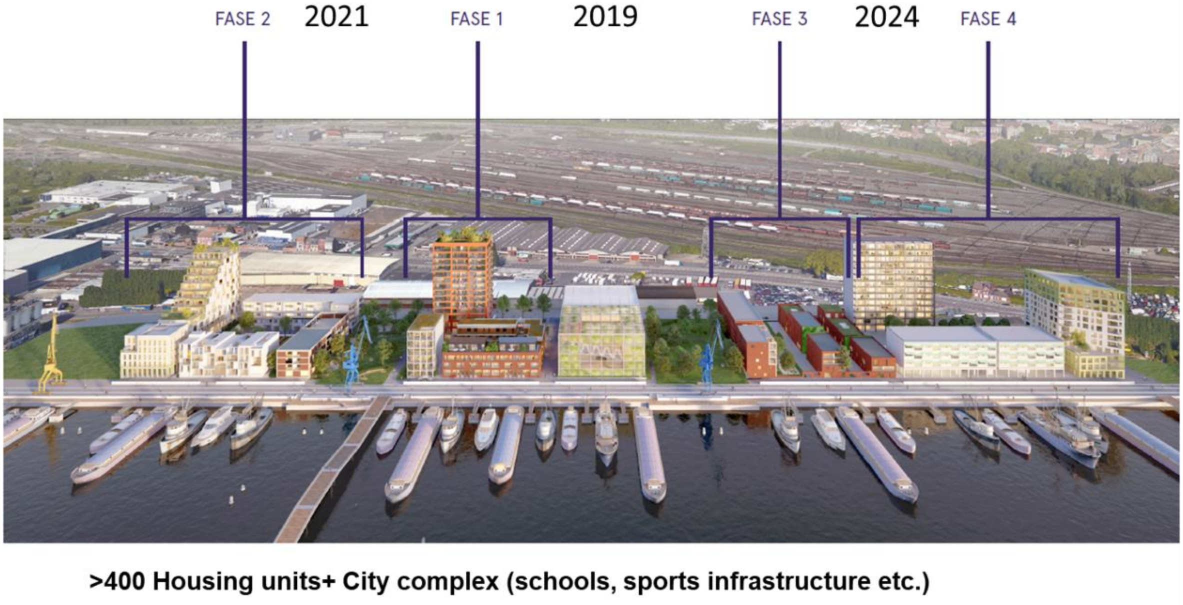

Figure 1. Overview of the different phasing in the realisation of the Nieuwe Dokken project

Pilot infrastructure and assets include:

- 90 dwellings, 6 office spaces, 8 commercial venues and a city building (public school, sports facility) equipped with solar rooftop PVs as distributed RES generation (+120 housing units in 2nd phase of the development in 2022)
- 4th generation low temperature district heating network (1,5 MWh)
- District heat pump (125 kWh) + waste heat exchanger (700 kW)
- More than 20x AC 22 kWh intelligent recharging station
- 30 kW biogas boiler
- 88 kW rooftop PV District battery storage system 200 kW
- Smart metering in 100 venues (+120 housing units in 2nd phase of the development (2022)
- SCADA system for monitoring & control of collective environmental services and end-user data platform.

Figure 2. Status of the Ghent- Nieuwe Dokken district in April 2022. At the end of 2022 the 2nd phase of the project will be finished.

II.3. Availability of Renewable Energy Sources

In the central housing area, some 80kWp of solar PV is installed. A direct line will connect 120kWp on the roofs of the buildings in Northfield. CEIP is also reviewing the possibility to produce more renewable energy from building integrated photovoltaics (BIPV), using photovoltaics in the façade system, rooftiles or parapets. CEIP also wants to look into the possibilities to use excess renewable energy from neighbouring sites to increase the share of renewable energy in the district.

CEIP/DuCoop has developed a community design for the collective energy systems in the Nieuwe Dokken district (see Figure 5) to bundle renewable energy production and collective loads (EV-chargers, heat pump, water treatment, etc.).

Figure 3. In the 3d phase of the Nieuwe Dokken project (Southfield) the possibility to install building integrated photovoltaics (BIPV) panels is being investigated.

Figure 4. Using the Energy Communities framework, CEIP/DuCoop hopes to use excess renewable energy that is being produced at neighbouring sites to increase the share of renewable energy in the energy consumption of the district.

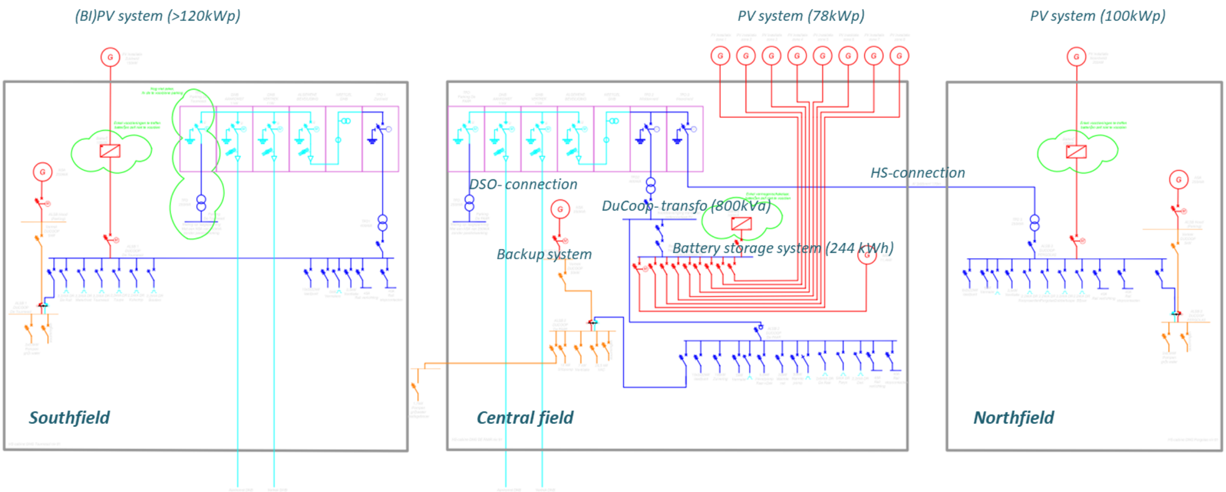

Figure 5. Electricity scheme Nieuwe Dokken

A heat pump (125kW$_{th}$) generates heat which is recovered from a decentralized wastewater treatment plant, that has been operating since the summer of 2020 and is treating the wastewater of the residents and buildings in the Nieuwe Dokken district. Due to the local treatment of wastewater, effluent temperatures of 22-27°C are achieved, allowing heat recovery at high COPs (>4).

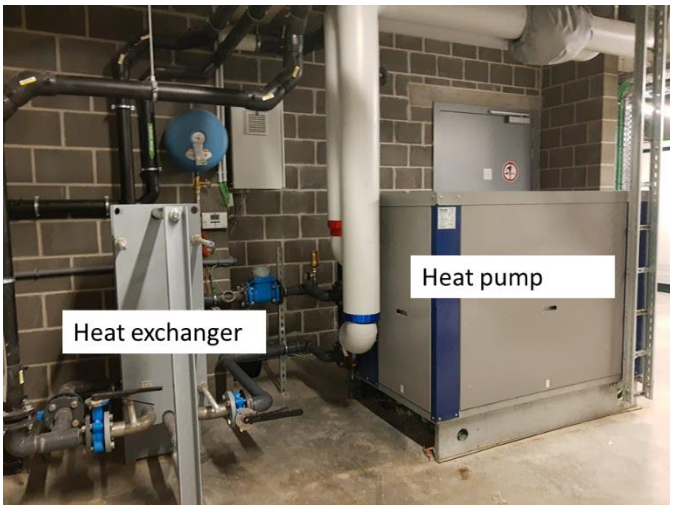

Figure 6. Overview of the heat pump system

II.4. Local Stakeholders and Roles

Stakeholders in the Nieuwe Dokken project are:

1) Technical energy manager - people responsible mainly for reliability and quality of service (CEIP- DuCoop).
2) Business manager - people responsible for economic feasibility – CEO of DuCoop (Peter De Smet- also the CEO of CEIP).
3) Investors – organizations like Farys (local water utility company), EnerGent (local energy cooperation), Trividend, Oya seed capital, SKD (Schipperskaai Development, company which is the real estate company developing the buildings at the Nieuwe Dokken), banks (Triodos), financial institutions that provide the funds for the technology investments and check the economic viability of the project.
4) Project developers - organisations that plan and construct newly built residential and commercial buildings. They also promote and sell appartements to the end-users.
5) Resident - mainly families living in the houses and appartements at the Nieuwe Dokken. They affect the temperature settings in the rooms, window opening and the consumption of domestic hot water.
6) End User (Not Resident) - teachers, students at the primary school 'Melopee', users of the daycare center, sports complex… Employees and staff of the different office units, shops, catering and their customers.
7) Passers-by - guests visiting the people that live in the district, the public spaces, companies, use the sports facilities or the catering facilities. They are not permanently associated with the Nieuwe Dokken-site.
8) Sustainability Evangelist - person responsible for PR concerning sustainability of the energy island. At the Nieuwe Dokken, DuCoop is organizing the communication (events, newsletters, etc.). with the end-users about the sustainability goals of the district/community.
9) Energy suppliers providing (waste)heat (e.g., Christeyns), gas and electricity (energy suppliers, neighboring PV-sites that could share excess renewable energy through an energy community framework) and distribution system operator (DSO, Fluvius), regulator (VREG, setting the tariffs and the conditions of the energy system and community design).

10) Municipality of Ghent: local authorities aiming to achieve to ambitious targets of their climate action plans. They are pushing to build more sustainable in newly built areas, and they stimulate energy and climate innovation.
11) Research institutions (e.g., University of Ghent) and technology companies: CEIP and DuCoop are working together with different academic and private partners to develop and implement new technologies at the Nieuwe Dokken.
12) Architects, Construction company (THV Nieuwe Dokken) who is constructing the buildings at the Nieuwe Dokken and the subcontractors of CEIP/DuCoop that implement the different technologies at the Nieuwe Dokken (district heating network, PV-infrastructure, data-infrastructure.

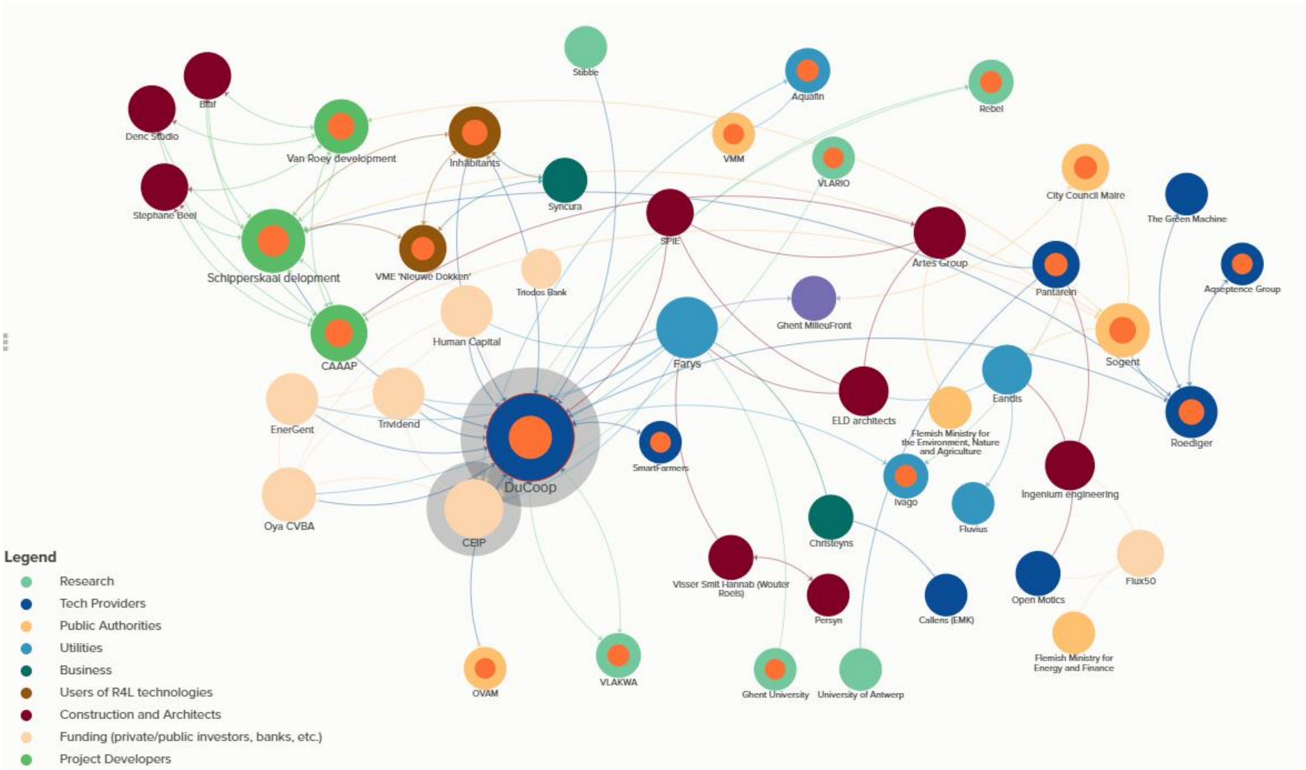

Figure 7. During the H2020 Run4Life project (GA n°730285) a stakeholder map was constructed for the role CEIP and its subsidiary DuCoop in the Ghent- Nieuwe Dokken project.

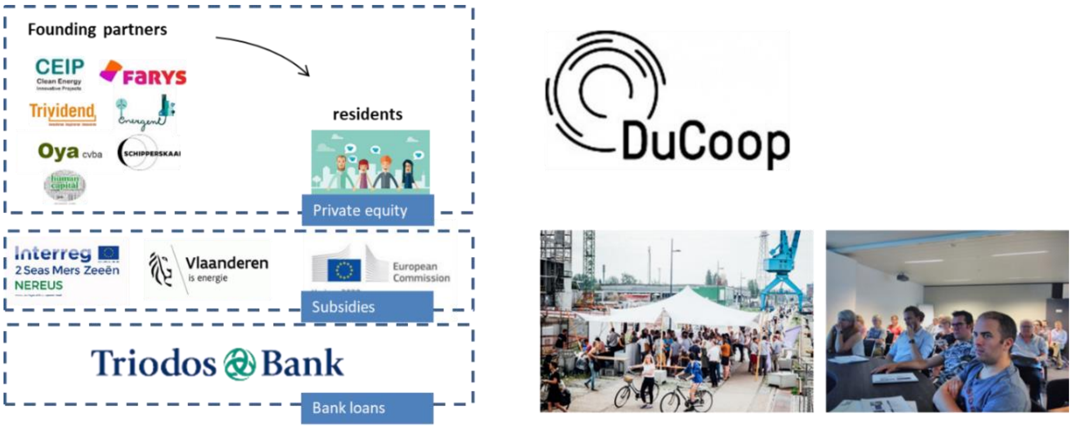

Figure 8. CEIP used a cooperative financing scheme to finance the investments at the Nieuwe Dokken, together with its other financing partners. In the end, the residents will take over the capital of the local sustainability cooperation 'DuCoop'.

II.5. Alignment with other Research and innovation projects

The work done within the RENergetic project is also aligned with other innovations which were implemented during different other European and regional research and innovation projects: Run4Life (H2020 GA no 730285) [2], NEREUS (Interreg) [3], H2020 Interconnect (H2020 GA no 857237) [4], BRIGHT (H2020 GA no 957816) [5], Rolecs (Vlaio-ICON) [6]

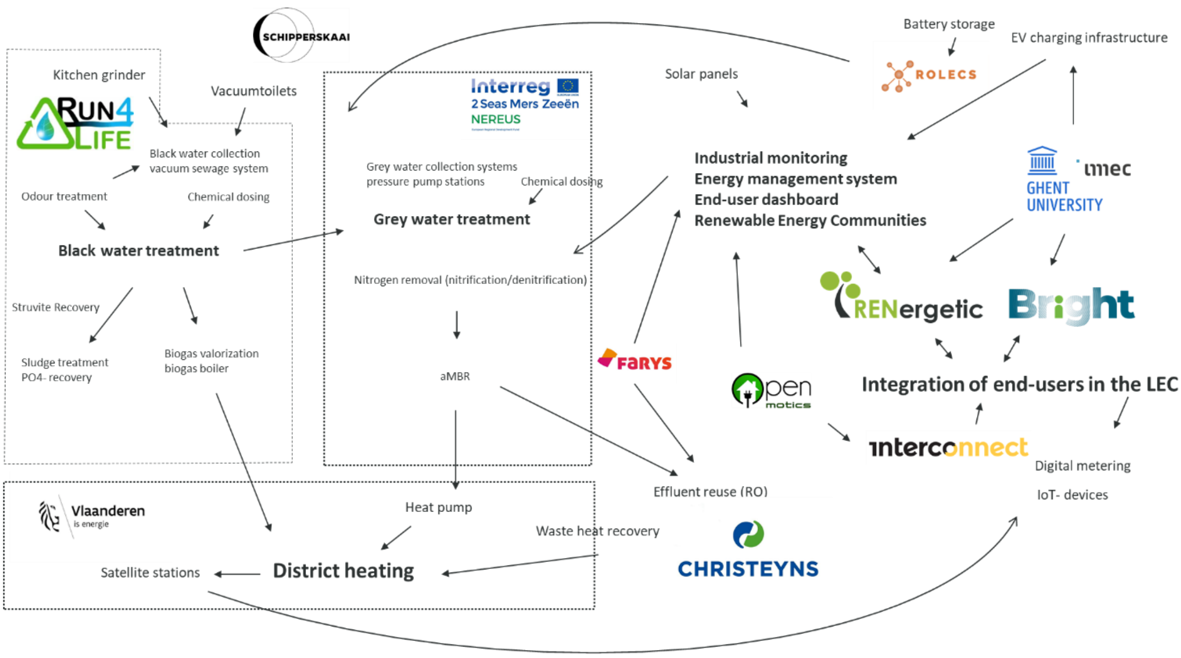

Figure 9. Overview of different innovation projects at the Nieuwe Dokken

III. Detailed description of the actions

Table 1 presents a summary of the most important selected strategies, tools and epics within the Ghent pilot.

Table 1 - Ghent pilot actions

Strategies selected	Main tools	Epics
DH load management	simulations, data acquisition, digital twin	Heat Supply optimization
DH hydraulic optimization	full-scale experiment, data acquisition	Heat Supply optimization
Heat Demand Response HDR	data acquisition, IT solutions, full-scale experiment	Heat Demand Response
Prediction and anomaly detection	data acquisition, machine learning, simulations	Heat & electricity Supply Opt. & Forecasting
Engaging community	IT solutions, data acquisition	Heat Supply Opt., Heat Demand Response
Smart control of EV charging stations	IT solutions, data acquisition, full-scale experiment	Electricity Supply Opt./ DR
Bidirectional charging EV	IT solutions, data acquisition	Electricity Supply Opt./DR
Development of energy community strategies	Technical design/ Legal review/ economic assessment	Energy communities
Feasibility study BIPV	Technical and Economic assessment	BIPV

As can be seen in Table 1, the most important epics within the Ghent pilot are:

- heat supply optimization,
- heat demand response,
- forecasting and anomaly detection
- electricity supply optimization and demand response (mostly focused on (bidirectional) EV-charging and local battery storage).
- Community engagement
- Development of Energy community schemes
- Feasibility study of Building integrated photovoltaics (BIPV)

III.1. Epic 1: Heat supply optimization

The DuCoop district heating network has been exclusively designed for the Nieuwe Dokken project, based on the availability of industrial wasteheat at a nearby industry site, Christeyns [7], a factory that produces soapproducts, desinfectants, and surfactants. Apart from this, DuCoop is also valorizing wasteheat from residential wastewater, using a aquathermic heatpump in combination with a very innovative watertreatment system in the basement of the buildings in central area (Middenveld).

Using a 4th generation district heating system, DuCoop aims at creating the ability to provide space heating (SH) and sanitary hot water (SHW) from a DH network operating at minimal temperatures (about 55°C) to be able to reutilize wasteheat that is usually discharged (convector cooling) in industry, or dissipating in the sewer network (in the case of residential wastewater).

In 2018, a district heating connection was created between Christeyns and the central area of the Nieuwe Dokken (approximately 1000m). From there, the heat is distributed to the buildings of the central building area ('Middenveld') and the other developments ('Noordveld', and in the future (2025) also 'Zuidveld'). Since 2019, the system was activated and is supplying heat to the public building 'Melopee' (School and sportcomplex) and the residents of the 'Middenveld' (spring 2020).

Figure 10. The district heating network of DuCoop in operation (red) and planned (green).

At first, heat was provided using wasteheat from cooling chemical reactors (esterification process). Due to the limited supply of residential wastewater (delayed delivery of the construction works, COVID-19 pandemic, operation below design capacity, etc.) the contribution of the wastewater heatpump was very limited. In a second phase (end 2022), coolant water of a CHP-system at Christeyns will be available at 60°C to increase the share of wasteheat in the energymix, and reduce the activity of the backup-gasboilers. Optimally, the wastewater heatpump could fullfill the total heat demand for DHW in the summer season.

A prediction of the available heatsources, and a prediction of the yearly energymix was made for the district heating network at the Nieuwe Dokken at full development (by 2027) and the coming years. It is the goal of CEIP/DuCoop to have at least 80% of sustainable heatsources (industrial wasteheat or heatpump) in the yearly supply of heat to the district.

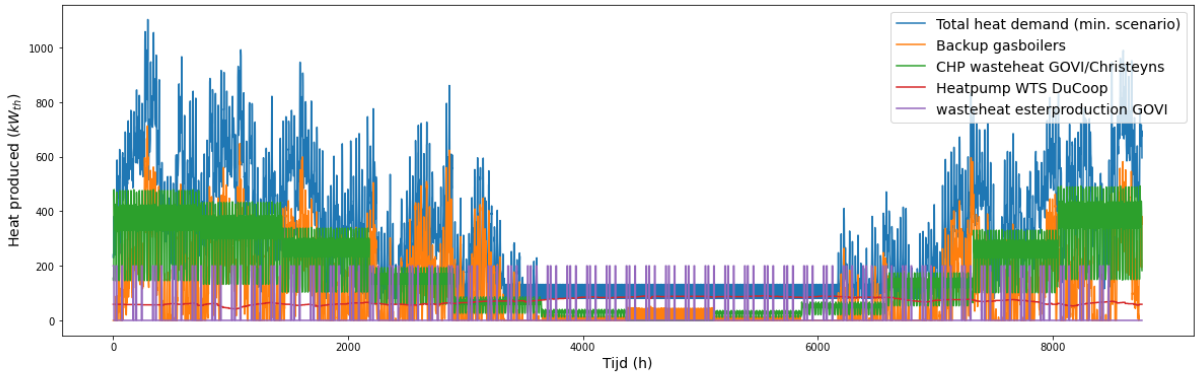

Figure 11. Availability of all the sources through the year (per h)

CEIP/DuCoop do not (always) have the option to control the availability of these heat sources. This gives cause to mismatches between heat supply and demand and the potential loss of some of the available waste heat. One of the strategies is to adapt demand to the supply of heat (discussed in the next Epic 2: Heat demand side response). Another strategy could be to shift heat sources in time to optimize their use. The red bar in Figure 12 shows that approximately 10% of extra waste heat could be more effectively utilized using a combination of heat supply- and demand strategies.

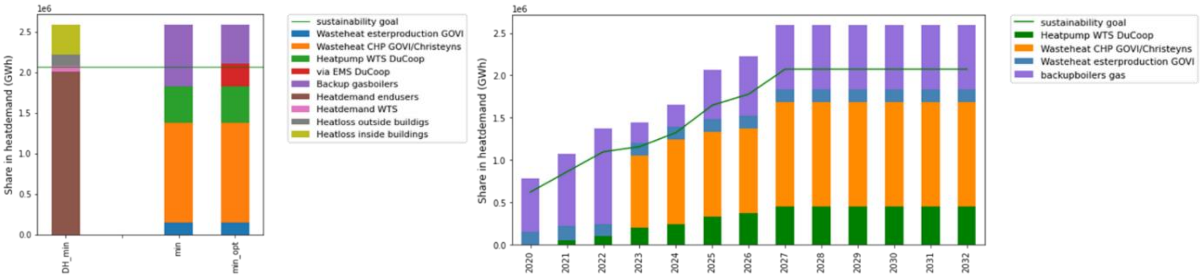

Figure 12. Combination of different heat sources in the district heating system of the Nieuwe Dokken

One of the first strategies that were developed at the Nieuwe Dokken was an optimized control of the heatpump working on the effluent of the watertreatment plant. Before, the heatpump started producing heat whenever there was enough effluent available. Using the buffer capacity of the watertreatment system, the Energy management system of DuCoop now carefully decides when it is activating the heatpump, avoiding collissions with other heat sources, or timeframes without any significant demand for heat.

III.2. Epic 2: Heat demand side response

Another strategy would be to adapt demand to the supply of heat. From data-analysis we could notice daily peaks in the energy consumption, mostly attributed to heat consumption due to simultaneous heating and hot water demand (morning routine) (see Figure 13).

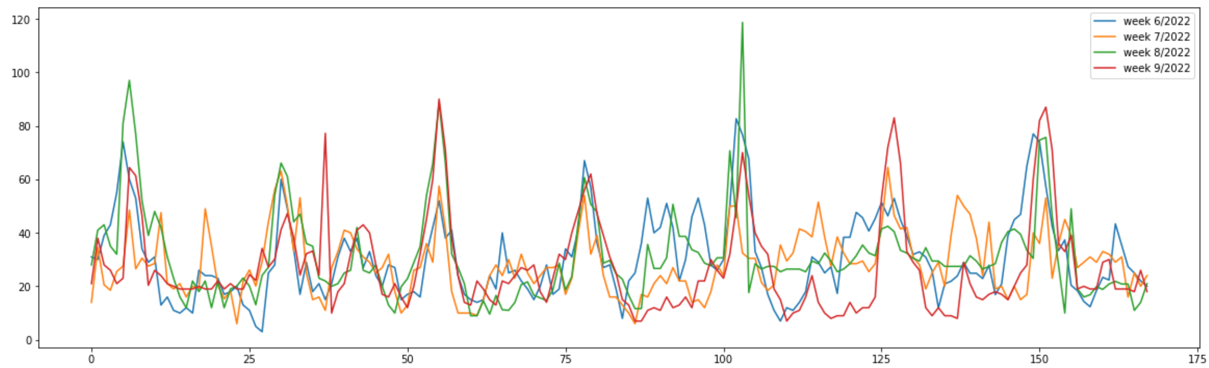

Figure 13. Weekly trends (Monday- Friday) in heat consumption for the building 'Faar' (47 apartments)

The peaks in heat demand rarely fit the production of wasteheat at the Christeyns factory. Strategies to align production and demand could be to use the buildings as a heating buffer or to push the heat demand when excess wasteheat is available and reduce demand when wasteheat production is shut down.

III.3. Epic 3: Forecasting

To continue developing the alignment of heat production and consumption as discussed in Epics 1 and 2, the forecasting of the heat demand is an important element which is dealt with in the transversal epic "forecasting". Although forecasting of the heat production can be considered equally important, the challenge there is twofold in the case of the Belgian pilot. Firstly, the production of industrial waste heat is unpredictable, as this entirely depends on operational schemes of the Christeyns factory, which are not available in an online fashion. Secondly, to get a forecast of the heat available in the treated wastewater, extensive hydraulic modelling of the decentralised water treatment plant would be required, an effort that is out of scope for the RENergetic project and will become redundant in a couple of years' time, when the treatment facility is running at full capacity.

Forecasting efforts for the heat demand have started using a statistical approach of which the result is shown in Figure 15. Using historical data and a linear regression with the hour of the day, the day of the week and the outside temperature as explaining variables, the heat demand forecasts already reach quite an accurate level. The morning peaks can clearly be distinguished, which will probably be the most important feature to continue optimizing the district heating network with. Depending on further needs for more detailed forecasts, additional efforts will be done to improve the prediction quality.

III.4. Epic 4: Electric supply optimization

Forecasting will also be used to optimize electricity consumption. Although DuCoop doesn't sell any electricity to the residents of the Nieuwe Dokken district directly, it manages quite a large portfolio of electric loads in the neighbourhood, e.g., to operate its sustainable systems (hydraulic pumps, heat pump, water treatment plant, EV-charging infrastructure). DuCoop also manages the PV-infrastructure on the rooftops of the buildings in the district and enjoys variable tariffing as a midvoltage electricity consumer.

Using the EMS system to control electric consumption in all the subsystems of the pilot, CEIP/DuCoop can adapt its consumption to the supply of sustainable or cheaper electricity that becomes available both locally (PV) as well as on the grid. Using a local battery system (200kWh) DuCoop can also shift the supply of more sustainable and cheaper electricity during the day, to avoid consuming grid electricity during peak hours later in the day when the grid electricity system would also be relying on less sustainable resources. At the end of the RENergetic project CEIP/DuCoop also hopes to use bidirectional EV-charging to optimize the local storage, consumption, and supply of renewable power the Nieuwe Dokken pilot.

III.5. Epic 5: Electricity demand response

Together with University of Ghent/IMEC

- General interest: research on demand response control algorithms for the charging of EVs with focus on Reinforcement Learning techniques.
- Recent research focuses on the improvement of the Markov decision process formulation in terms of state-action representation and cost function. This leads to a lower computational complexity reducing training time with 30%, but with a similar performance as before:
  - 40%- 50% improvement in load flattening compared to BAU (= charging at full power upon arrival)
  - 20%-30% compared to simple heuristic control policy (= spreading out charging of each individual EV over its full connection time)
- Next steps
  - Integration of the current algorithm in the RENergetic architecture
  - Investigation of other objective functions (e.g., maximizing self-consumption instead of load flattening)
  - Validation with pilot data (Ghent, Segrate) & demonstration in pilots
  - Investigation of a multi-agent reinforcement learning solution for the RENergetic multi-vector optimizer

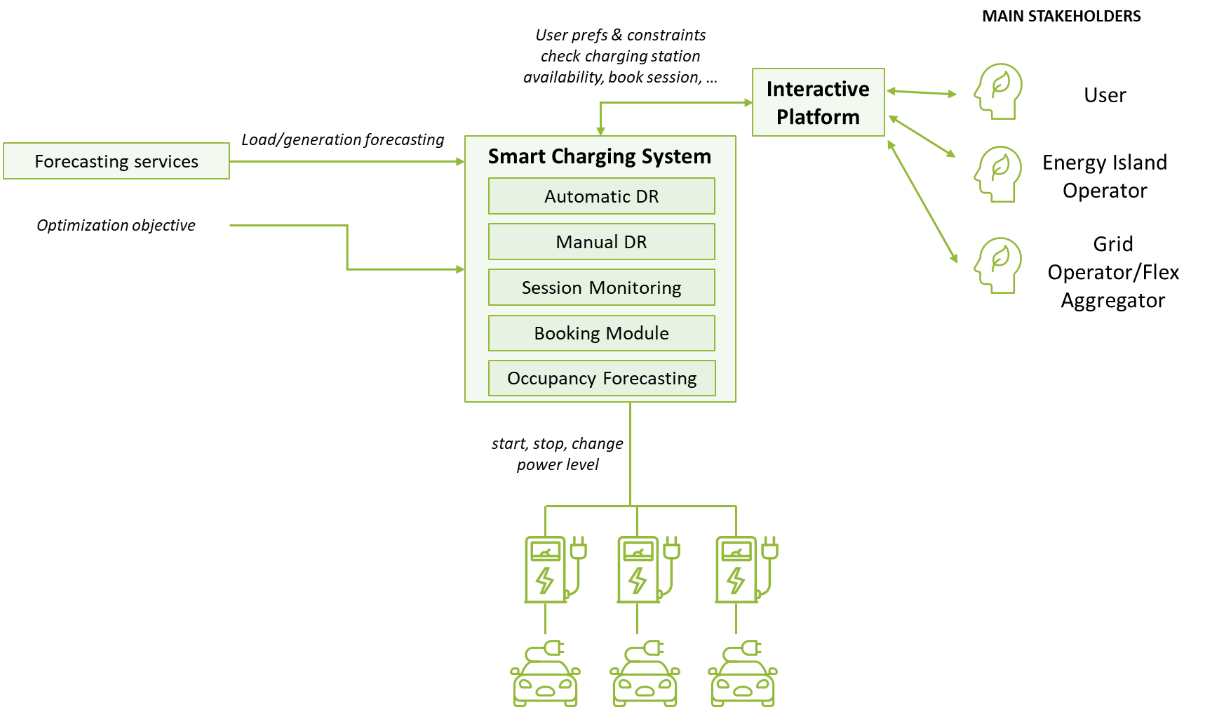

Figure 14. Overview of the EV charging strategy that will be developed together with IMEC-University of Ghent to control the electric load of EV charging in the Nieuwe Dokken district.

III.6. Social Engagement

DuCoop will manage a portfolio of 4-5 million EURs of investments in sustainable infrastructure with a maximized IRR of 6% over 30 years. Future homeowners and tenants will be involved through a citizen cooperation: They can financially participate in company's capital and/or they can be involved in the cooperative's governance. This encourages end-users to be more engaged, better understand what the goals and mission of DuCoop as a service company mean for them, and thus, use the system more appropriately. As part of the agreement with the City of Ghent, DuCoop adopted the BATNEEC (Best Available Technology, not Entangling Excessive Extra Costs)-principle in its tariffing structure. In this way, the cost structure is transparent, and socially vulnerable users are not impacted by higher costs of innovative technologies.

We are reaching our end-users and customers through our sustainability cooperation 'DuCoop'. People are involved, informed and aware of the sustainable values of the project, and we are enjoying a huge degree of participation in our board meetings, information sessions, etc.

1. Public dashboard

Since 2021, real time data from DuCoop's EMS are broadcasted on the DuCoop-website. This dashboard gives an overview of operational figures like supplied heat and electricity, production of renewable energy and avoided carbon emissions. A large screen will be installed in the local coffeebar at the Nieuwe Dokken, explaining the importance of the different technologies and projects that are being implemented at the Nieuwe Dokken. In that way, not only residents but also accidental passers-by are informed about the goals and ambitions of the Nieuwe Dokken and projects like RENergetic.

Although the current dashboard is quite extensive, input from and discussions with RENergetic partners have already and will surely still lead to even more engaging ways of representing our data, for example trying to apply gamification strategies or other community-wide engagement methods.

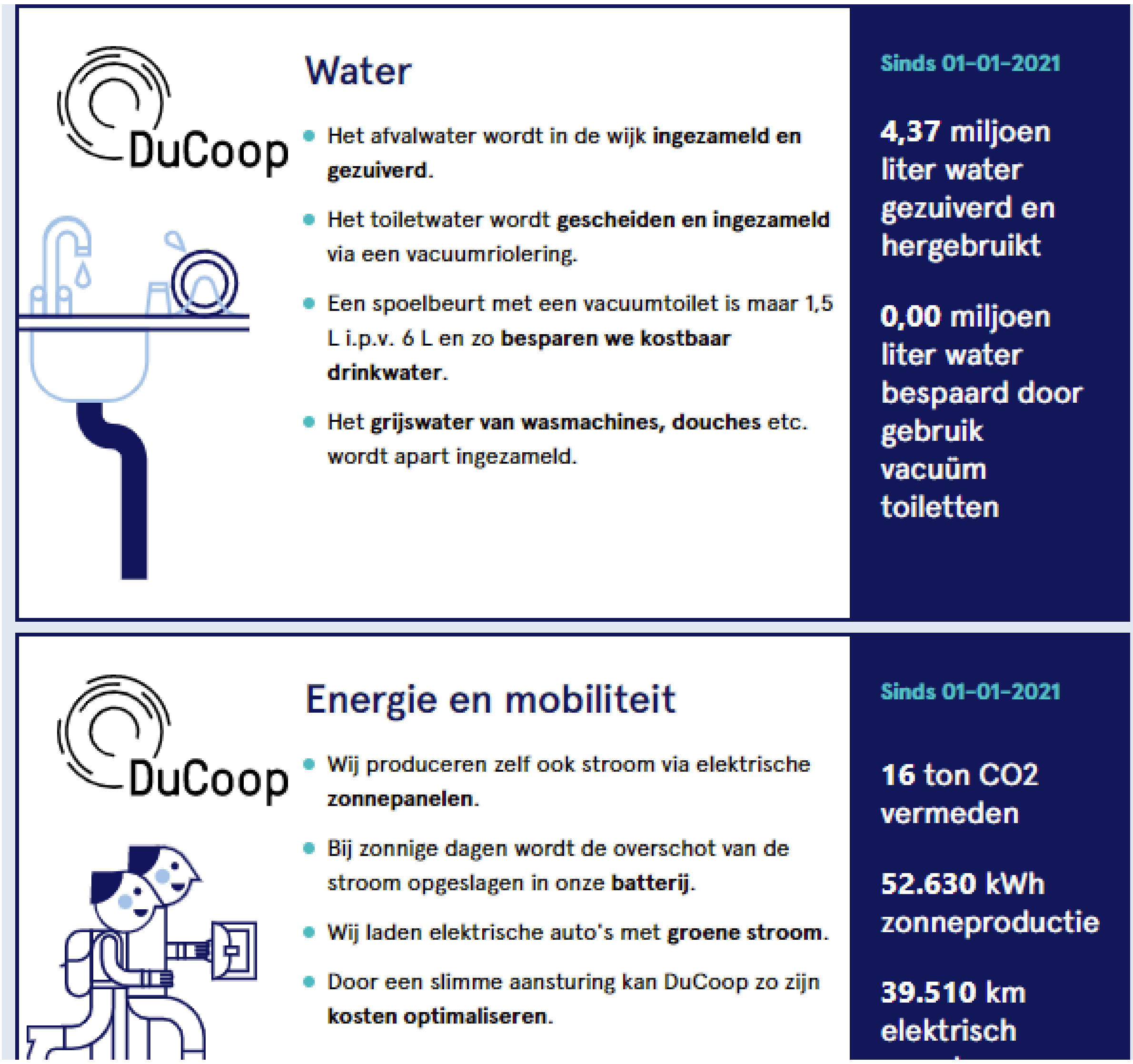

Figure 15. Overview of the DuCoop public dashboard, giving an overview of the environmental services and performance on DuCoop sustainability goals

2. End-user dashboard

Every end-user in the smart district can obtain historic and actual consumption data for water, district heating and electricity from digital metering devices that are installed throughout the buildings. For this purpose, a data-platform and private end-user dashboard was developed by DuCoop in collaboration with the home automation technology supplier OpenMotics (2020) [8].

Homeowners and tenants must agree to share their private consumption data through a GDPR-compliancy agreement and get a personal login to their personal data platform on DuCoop's website www.ducoop.be.

Just like the public dashboard, also here discussions with RENergetic partners are expected to enrich the user experience DuCoop can offer as well as engage district inhabitants.

Figure 16. Overview of the private end-user dashboard

3. Notifications

The coming months, DuCoop will extend the private dashboard with more information on the state of sustainability of the district heating network and the electricity system at the Nieuwe Dokken. People can voluntarily respond to this, for example by increasing there heat or electricity consumption (starting their (hotfill) washing machine, showering, charging their EVs, etc.)

III.7. Development of Energy community schemes

One of the research topics for the Ghent pilot was to investigate the potential of Energy communities to increase the access to renewable energy both within the district as well as in the wider area around the Nieuwe Dokken.

The Flemish energy regulator VREG puts specific limitations to the ability to share collectively produced electricity within a community of end-users. When the European framework for Energy communities was announced in 2016 there was some anticipation for new opportunities for sharing locally produced renewable energy in between prosumers.

Table 2. Overview of the implementation of the European energy community's framework

<table>
<tr><th></th><th>"Active consumer"
(EMD [9])
+ "self-consumer of RE" (REDII [10])</th><th>"Jointly acting active consumers & self-consumers of RE"
(EMD + REDII)</th><th>"Citizen Energy Community" (EMD [9])</th><th>"Renewable Energy Community"
(REDII [10])</th></tr>
<tr><td>Proposed Flemish implementation</td><td>"Actieve afnemer"</td><td>"Gezamenlijk actieve afnemers"</td><td>"Energiegemeenschap"</td><td>"Hernieuwbare energiegemeenschap"</td></tr>
<tr><td rowspan="2">Rights</td><td colspan="2">•Participation in energy services
•Participation in flexibility and aggregation services
•Storage of energy</td><td>Within the community:
•Organisation of and participating in energy services
•Organisation of and participating in flexibility and aggregation services
•Storage of energy
•Sale of self-generated RE
•Organisation of EV charging services
To members of the community:
•Self-consumption of generated RE</td><td>Within the community: identical to CEC except for:
•No organisation of EV charging services
•Possible benefits due to "facilitating framework"
•Possible operation of closed distribution system
To members of the community:
•Self-consumption of generated RE</td></tr>
<tr><td>•Self-consumption of self-generated RE as individual active consumer
•Sharing of self-generated RE surplus with other active consumers (P2P)
•Sale of self-generated RE surplus to other party (energy supplier)</td><td>•Self-consumption of RE as collective of jointly acting active consumers
•Sharing of RE generated within the collective of jointly acting active consumers with active consumer outside the collective
•Sale of RE generated within the collective of jointly acting active consumers to other party (energy supplier)</td><td></td><td></td></tr>
<tr><td rowspan="2">Duties</td><td colspan="2"></td><td colspan="2">Establishment of collective enitity
Notification to regulator</td></tr>
<tr><td colspan="4">Metering Contract with energy supplier</td></tr>
<tr><td>Local criterium</td><td>Place of residence</td><td>Same building or multi-tenant building</td><td>None</td><td>Local</td></tr>
<tr><td>Shareholders</td><td>NA</td><td>NA</td><td>Natural persons, small enterprises, local government</td><td>Natural persons, SMEs, local government</td></tr>
</table>

1. Legal analysis

Most of the legal hurdles in the Ghent project concern the question of energy sharing in closed distribution network instead of the classic distribution network. Possibilities of the local energy communities framework were investigated by Unversity of Ghent:

- Are there legal options for installing building-integrated PV panels on residential towers by means of a system of third-party financing whereby the project developer can also use the PV panels to achieve the intended share of renewable energy (EPB obligation), as well as the residents?
- If the PV panels of 'Zuidveld' will be connected to the distribution network via a separate transformer, would it be possible for the residents as well as DuCoop to purchase this flow within a structure of 'jointly active customers'?
- In the case of the North Field, there is a direct line to the Central Field, over the public domain. Can we set up a system in which DuCoop/the residents of the northern field buy the power from the PV panels on Koopvaarders (e.g., as 'jointly active customers')?
- What are the options for DuCoop to offer its own or external local green energy to the residents through a group purchase or through a 'Renewable energy community' structure?

2. Impact on local DSO-grid

One of the ideas that were developed in the RENergetic proposal was to reduce peak injection/peak load on the local DSO-grid, and in that way create economic value. The underlying purpose is that reducing peak load on the local DSO-grid can induce potential savings on grid investments, and in that way reduce societal costs.

Today, there is no existing compensation system or market mechanism for curbing impact on the distribution system. Together with University of Ghent- IMEC, CEIP had some initial discussions with the Flemish DSO Fluvius about what the potential savings on reducing peak injection/peak load might be. A study of the existing electricity network around the Nieuwe Dokken showed clearly that there is an existing overcapacity of the network; and there were no problems should be expected with an extensive increase of injection (e.g., large photovoltaic systems on industrial sites) or electric load (e.g., additional EV-charging infrastructure).

This was also the result from another study on 4 demo sites for energy communities in Flanders during the ROLECs-project [6] (from which also Nieuwe Dokken was selected): in neither of the 4 pilots, any societal benefit could be determined from potential savings on grid infrastructure.

Under capacity seems to be only a risk in some rural areas with old infrastructure. If the tension on the grid is increasing (e.g., due to simultaneous injection of multiple PV-systems on the same electricity system), the DSO will switch-off the invertors which will immediately solve capacity issues.

As there is no further interest from the DSO to work on the grid-impact of renewable energy- or EV infrastructure this activity has been halted. On the other hand, the Flemish Electricity and Gas Market Regulator (VREG) has recently implemented a 'capacity tariff' which aims at encouraging people to spread their consumption. Until now, the Flemish minister for Energy has postponed the implementation of this new system, due to fear that this new tariff could increase the electricity costs for some households which have already been confronted with spiralling energy prices. If the capacity tariff would come into force eventually, it could incentivize injection/load management strategies.

3. Electricity system design

Contradictory to the assumption that there is little impact of peak injection- or load management on the technical and economical sustainability of the distribution system, there is a planned roll-out of a capacity grid tariff in the Flemish region. Currently, network tariffs make up around 40% of an average household's bills and are mainly based on kWh consumption. For consumers with a digital meter, this capacity tariff, which aims to encourage people to spread their consumption, is determined on the basis of their average monthly peak capacity term. Households with a conventional meter will pay a fixed rate.

For collective energy service providers like DuCoop who have a single connection with the DSO-grid, optimizing peak injection and peak load could make a large difference in costs once capacity tariffs are applied. Already in the existing framework of network tariffs, there is a clear incentive to bundle energy consumption to one common grid access point. As a medium-voltage client you have the ability to respond to real-time electricity prices, creating a cost optimisation problem that has to minimise costs based on the avoidance of peak demand as well as an optimised self-consumption when electricity prices are high.

For the third development phase of the Nieuwe Dokken (Zuidveld), DuCoop/CEIP are exploring different scenarios to optimize the collective energy system costs. Tieing different renewable energy systems and collective loads (heat pumps, EV-chargers, pumps, lighting, etc.) together creates the ability to respond to real-time energy pricing, to save network costs and capacity tariffs (see **Error! Reference source not found.**).

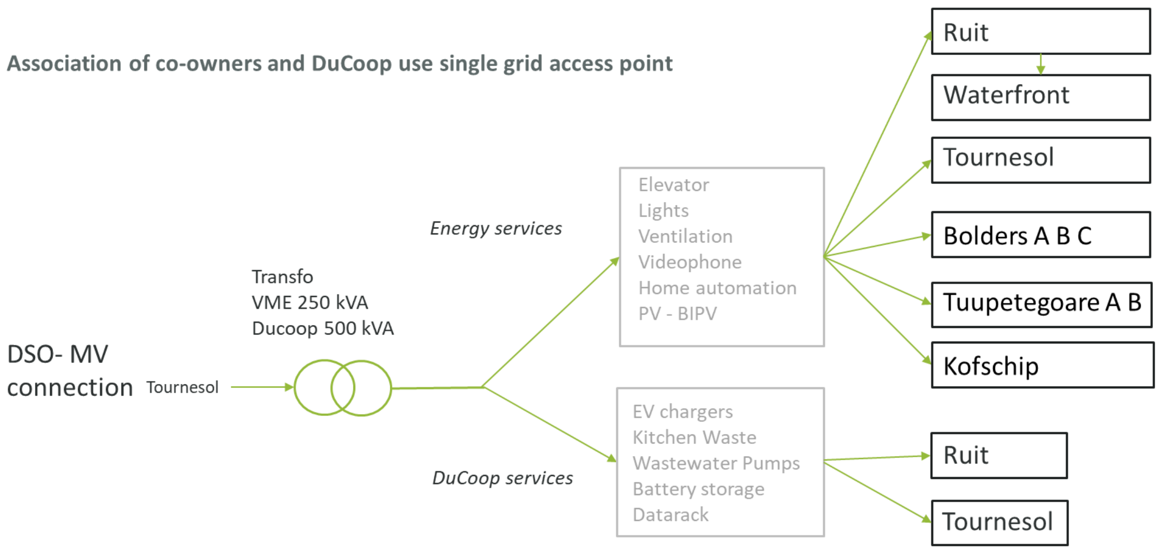

Figure 17. Scenario for a design of the local energy infrastructure in the 3rd phase of the 'Nieuwe Dokken' (Zuidveld). These different renewable energy systems and collective loads (heat pumps, EV-chargers, pumps, lighting, etc.) together create the ability to respond to real-time energy pricing, to save network costs and capacity tariffs

III.8. Feasibility study BIPV

In densely populated urban areas, photovoltaïcs (PV) are the only means to produce renewable energy (DuCoop also plans to produce electricity from biogas using a CHP-system. However, DuCoop does not expect that the biogas that will be produced from the vacuum collected black water and kitchenwaste will significantly contribute to the energy balance, even at full capacity (1.200 PE).

Although DuCoop holds a buildings lease on the installation of solar panels on the different rooftops in the Nieuwe Dokken the development of PV-systems is obstructed by numerous technical installations (ventilation, HVAC, etc.), safety harnesses, access for maintenance works, concerns with wind stability on heigher buildings (>50m).

Buildings integrated Photovoltaics (BIPV) open new opportunities to produce solar energy in all kinds of structural materials e.g. walkable floors, (semi)transparent windows or parapets, facade structures, etc. In this way, more effective surface can be attributed to renewable energy production and a higher degree of energy autonomy can be achieved.

CEIP has been in contact with BIPV suppliers Onyx Solar and Pixasolar.

For the 'Tournesol'-building there is a 400m² south-oriented facade which could allow a BIPV-installation of 75kWp. Total investment would be about 200.000 € (approximately 2x more expensive than a traditional facade) with a paybacktime of 7-8 years (including investment subsidies and a PPA- tariff of 20ctEUR/kWh).

Unfortunately an additional hurdle came up on fire resistance. Since the Grendfell tower fire in 2017, additional fire restrictions were implemented by the Belgian authoraties with respect to facade materials in highrise buildings (>25m). Facade materials in these buildings should comply to a A2 fire reaction class. BIPV-materials only comply to a Bs1d0 fire reaction class.

During the coming year extra fire safety tests will have to determine if the BIPV material could achieve the right fire reaction class certification; or if it could be used as façade material in the lower buildings of the district (Bolders I, II, III and Tuupetegoare). Construction of these buildings will commence in 2023-2024. No investments are planned during the activities of the RENergetic project.

Figure 18. In the 3d phase of the Nieuwe Dokken project (Southfield) the possibility to install building integrated photovoltaics (BIPV) panels is being investigated.

IV. DATA

IV.1. Data acquisition systems and EMS

The central element of the data acquisition system at the Belgian pilot is a Siemens PLC, to which most of the installed assets are connected. In its turn, measurements gathered on the PLC-level are all passed on to the OpenMotics Influx DB database through plugins on the central OpenMotics gateway (see figure 19). The PV installations, the battery, the EV charging stations and of course the assets in the individual living units have separate plugins and send their data to the database over a different connection.

The data acquired is processed and used to populate the district level and individual user dashboards in support of Epic 4 (Community Engagement). Data relevant for the Energy Management System is queried directly from the database by the EMS itself. From there, timeseries of different process parameters are collected in an online data platform and visualized in a Grafana dashboard. The EMS system also allows to adapt parameters (e.g., setpoints, I/O-signals, etc.) based on an overarching optimization strategy. This DuCoop EMS platform was developed during 2020-2021 and officially started by the Belgian minister for Energy, Tine Van der Straeten on June 2nd 2021 [1]. It will be continuously improved with new dashboards and optimization algorithms.

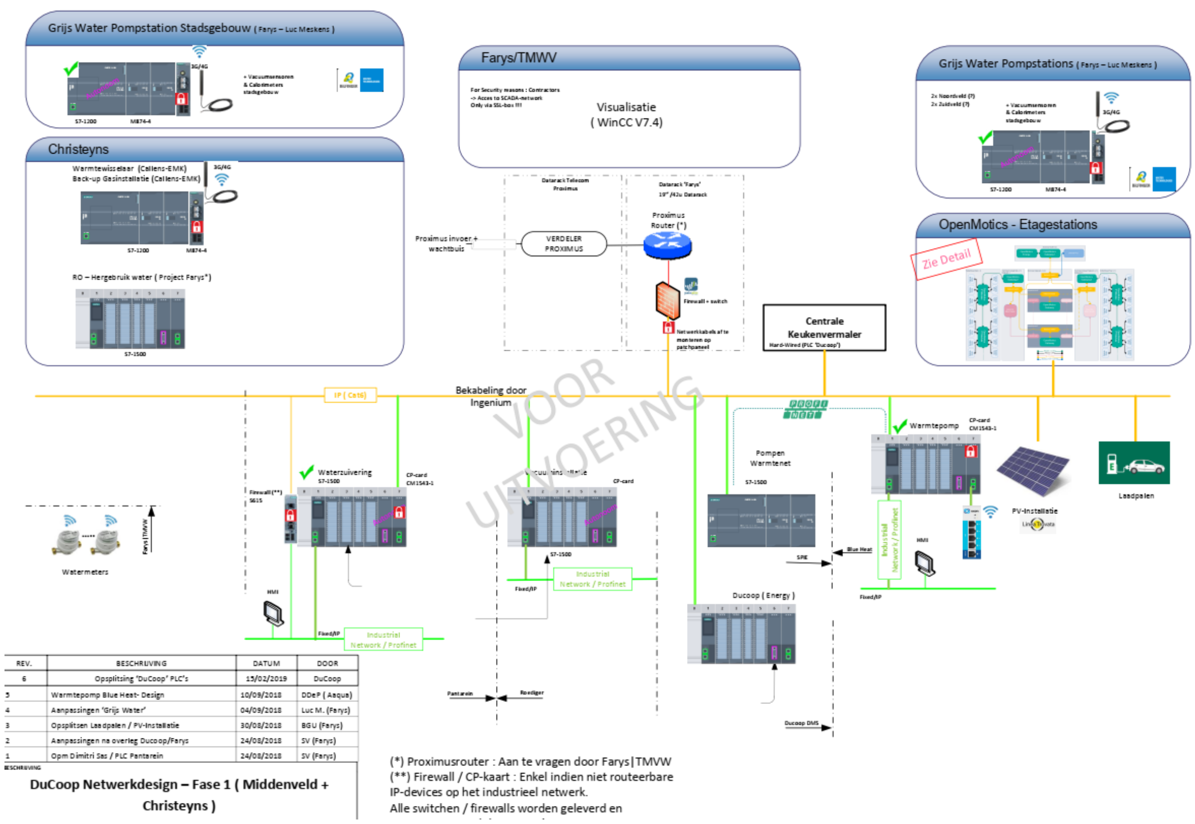

Figure 19. Overview of the structure of the data-collection system.

All subsystems of DuCoop are equipped with Siemens S7 PLC connected to a central WinCC platform. From there, timeseries of different process parameters are collected in an online data platform and visualized in a Grafana dashboard. The EMS system also allows to adapt parameters (e.g., setpoints, I/O-signals, etc.) based on an overarching optimization strategy.

Figure 20. The DuCoop EMS system was officially started by the Belgian minister for Energy Tine van der Straeten on June 2nd 2021.

IV.2. Development of API

To provide RENergetic partners with access to pilot assets for testing of control algorithms, the development of an Application Programming Interface (API) was started. The below figure shows the 'ecosystem' of the smart living and EMS hard- and software, including the place a 3rd party (i.e., a RENergetic partner) can take, in orange. For complete third-party control, access to both the Influx DB database containing the most recent measurements and to the part of the Energy Management System that sends control signals to the different assets is required. The exact way in which this will happen is still being discussed, because such third-party access bears with its security implications that need to be fully understood before implementing it. Also, the way in which a third-party application would interact with the EMS is subject of current discussions. In particular, the way to track what actions are taken, which application (the EMS itself or an external application) sent the control signal and how to do the evaluation afterwards are important points.

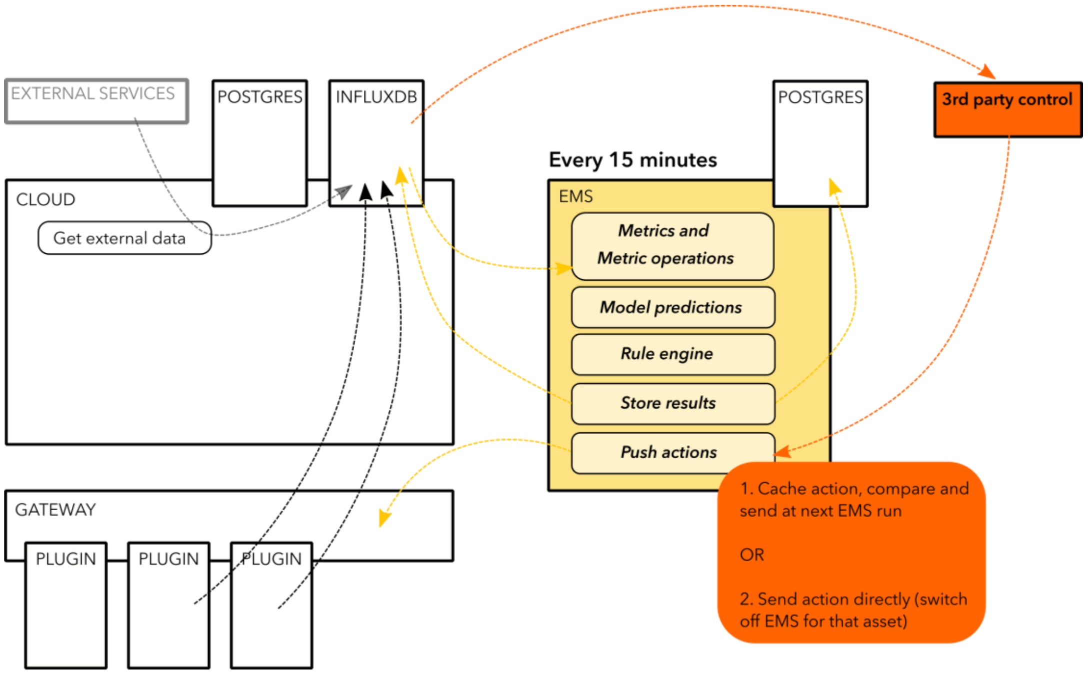

Figure 21. The development of an Application Programming Interface (API) is essential to allow third-party applications to interact with the EMS of the Ghent pilote. This is essential to test control algorithms from RENergetic partners.

V. MONITORING OF KPI'S

Aiming to assess the different dimensions within an energy island, numerous key performance indicators (KPIs) were proposed, validated, and thereafter computed for two of the energy islands under consideration of the RENergetic project. These KPIs were dispatched into three different categories or dimensions to distinguish the multiple aspects of an island from one side and to be able to draw a line towards the achievement of the project goals through time progress.

Defining and alignment of KPI's happened in collaboration in Imec- University of Ghent. They will be implemented on historic and real-time data from the Ghent Pilot. In the coming months, CEIP/DuCoop will extend the existing Grafana platform with automatic calculations and time series of the proposed KPI-parameters.

1. Technical dimension

The first dimension concerns a technical assessment of the island's performance. In this dimension, five KPIs were deemed paramount to embody the actual status of the island and its aptitude to align with the technical related purposes. The list includes the following KPIs:

1. Energy Self-Sufficiency which represents the percentage of energy being consumed from non-sustainable resources (imported energy from the grid). The formula to calculate it is in the following and is specific to the gent case:

$$E_{SS} = \frac{E^T_{Consumed} - E^T_{missing}}{E^T_{Consumed}}$$

$E^T_{Consumed}$	Total of energy consumed by the district = Water Purification + overall district consumption (Far + Desk + Central) over time horizon T
$E^T_{missing}$	Total of energy imported by the district = heat by gasboiler over a time horizon T

2. Energy Potency where it represents the potential of having no losses, no excess, and no import of energy. The way to compute this value is shown below for the specific case of Gent.

$$E_{Pot} = \frac{E^T_{missing} + E^T_{excess} + E^T_{losses}}{E^T_{Consumed}}$$

E^T_{excess}	Total of energy available at a certain time horizon T to the end users but couldn't be used or stored (here it is assumed to be 0) must be further
E^T_{losses}	The energy lost during the transmission in the pipes, in transformation, etc over a time horizon T

3. Share of renewable energy resources where it represents the portion of the renewable energy being injected to the energy community originating from renewable energy sources in relation to the entire energy provision over a period. Its formula is given by the formula below and is calculated for the Gent case.

$$Share_{RES} = \frac{E^{T}{}_{RES}}{E^{T}_{Consumed}}$$

$E^{T}{}_{RES}$	Total of energy consumed from renewable energy sources (heat recovery, geothermal, indirectly solar energy, etc) by the end users during a certain time horizon T

4. Share of fossil fuel energy where it represents the portion of the non-renewable energy being injected to the energy community originating from essentially fossil fuel energy sources in relation to the entire energy provision over a period. Similarly, its formula is given in the following and is computed for the case of Gent energy island.

$$Share_{fossil} = \frac{E^{T}{}_{fossil}}{E^{T}_{Consumed}}$$

$E^{T}{}_{fossil}$	Total of energy consumed from non-renewable energy sources natural gas, oil, nuclear) by the end users during a certain time horizon T

5. $\boldsymbol{CO_2\ Intensity}$ which represents the amount of CO2 emissions released by production and consumption divided by the overall consumed energy. This KPI can be calculated through the following formula and is computed for the specific case of Gent Energy Island.

$$CO_{2intensity} = \frac{CO_{2prod} + CO_{2missing}}{E^{T}_{Consumed}}$$

CO_{2prod}	Amount of $\boldsymbol{CO_2}$ produced while creating the end-users' needs in energy (heat pump electricity consumption to provide heat in our case) over a time horizon T.
$CO_{2missing}$	Amount of $\boldsymbol{CO_2}$ released out of consuming the energy from the imported resources (natural gas, oil, etc.). In our case, this amount is accounted as the $\boldsymbol{CO_2}$ emissions incurred by burning the gas imported by the gas boiler over a time horizon T. (Assumption: 1 m^3 =1 Nm³)

2. Economic dimension

The economic level is structured in a similar way as the technical level. However, the environment is disregarded in this dimension, investors have been added, and the technical components are now considered from a financial point of view. For consumers and investors, the economic KPIs are of particular interest. Consumers have costs for electricity and heating according to their consumption. Investors invest money in energy islands to make a profit. The external grid is now the source of costs and revenues through imports and exports of an energy island and energy sources are considered in the context of their production or import costs. The economic perspective on an energy island depends on its observer. Thus, the interests and priorities regarding the economic KPIs differ depending on whether the energy island is viewed as a whole or by individual consumers and producers.

In the same spirit, the economic KPIs are in number of six. The selected ones are listed in the following section:

Levelized Cost of Energy consumed (LCOE)

- According to the Energy Information Administration in the US: “Levelized Cost of Energy (LCOE) is often cited as a convenient summary measure of the overall competitiveness of different generating technologies”.
- It represents the per-KWh cost of building and operating a generating plant over an assumed financial life and duty cycle.
- This value does not capture the cost of energy at a specific moment rather levelized (averaged) over the overall lifetime of the power project. Thus, it allows a certain comparison between different types of power projects in terms of power generation and overall costs according to the production technologies and the ongoing numerous expenses.
- “LCOE is defined as the ratio of the net present value of total capital and operating costs of a generic plant to the net present value of the net electricity generated by that plant over its operating life.” (UK Government)
- The levelized Cost of Energy consumed is given by the following formula, which is general, applicable, and extensible regarding the elements within which could be inserted for every Energy Island or Energy Project that want to appraise the viability of implementing certain technologies to provide energy in general (heating, electricity). The individual terms of the formula are input and could be disparate from one project to the other where they are function of the infrastructure and the financial structure of the technologies’ portfolio existing or expected to implement.
- The LCOE formula is as follows:

$$LCOE^T_{consumed} = \frac{\sum_{l=1}^{L}\left(C_{Il} \cdot CRF_{Il} \cdot \frac{T}{T_y} + C^T_{Fl} + C^T_{OM\,l}\right) + C^T_{missing}}{E^T_{consumed}}$$

Where:

- ➢ C_{Il} are investment costs in each technology *l*, $l \in \{1,2,\cdots,L\}$
- ➢ CRF_{Il} (Capital Recovery Factor) = $\frac{(1+k)^{T_{Il}} \cdot k}{(1+k)^{T_{Il}}-1}$

Such that,

- T_{Il} : $lifetime\ of\ the\ investment\ in\ technology\ \boldsymbol{l}$

- k: *the weighted average cost of capital*
- $\frac{T}{T_y}$: *the ratio of the observed time horizon T and horizon of one year*
- C_{Fl}^{T}:*fuel cost over the observed time horizon* T
- $C_{OM\,l}^{T}$: *operation & maintenance costsover the observed time horizon* T
- $C_{missing}^{T}$: *represents the cost of energy that is imported from the grid*

Calculation details

- In order to compute the levelized cost of energy (LCOE) for a certain power plant, a detailed description and evaluation of the main variables need to be carried out.
- It is assumed that a power plant (PV plant, gas power plant, etc) output is generated through different production units each with a certain downtime of x weeks/days.
- The availability of the OTEC system can be calculated after considering the downtime periods.
- The annual average capacity factor must be calculated (100% if the resource is always available)

Annual energy production (AEP) = Power Plant output rating * system availability * average capacity factor * 365 * 24 (KWh)

- An input data for the LCOE is the capital cost per kW of energy generation (how much of capital is required to produce 1 Kilowatt? Therefore, the total installed cost would be derived.

Total installed cost = Power Plant output rating * system availability * average capacity factor * Capital Cost

- Interest rate and amortization period must be input to calculate the Capital Recovery Factor (CRF)

$$CRF_{i,n} = \frac{A}{P} = \frac{i(1+i)^n}{(1+i)^n - 1}$$

- At this stage, we can calculate the Levelized Cost of Investment (LCI):

$$\mathbf{LCI} = CRF_{i,n} * \mathit{Total\ installed\ Cost}$$

- Accordingly, we can also calculate the cost of energy for a unit of KWh produced as follows:

$$\mathbf{Unit}\ \mathit{Cost}_{invest} = \frac{\text{LCI (\$)}}{\text{AEP(KWh)}}$$

- The energy cost is affected by operation, maintenance, repair, and replacement (OMR&R) across the lifetime of the power plant and this needs to be accounted.
- **OMR&R** cost per year would be the **sum of operation and maintenance costs and repairs and replacements costs** which is an input from the different pilot sites.
- The present worth factor (**PWF**) for the plant based on the **amortization period**, the **inflation rate** (IF) and **interest rate** (i) would be calculated
- $PWF = \frac{1+IF}{i-IF} * \left(1 - \left(\frac{1+IF}{1+i}\right)^n\right)$ è **Returns the number of years** (n is the amortization period)

- The next step is to calculate the Expenses Levelling Factor (ELF) calculated as follows:

$$ELF = PWF * CRF$$

- The Levelized Expenses Cost (LEC) would be the product of the OMR&R costs per year and the ELF:

$$LEC = \text{OMR\&R costs} * PWF$$

- The cost of energy as a result of the OMR&R cost would be obtained by dividing the LEC by the AEP:

$$Unit\ Cost_{OMR\&R} = \frac{\text{LCI (\$)}}{\text{AEP(KWh)}}$$

- The sum of the cost of electricity from the capital cost and that from the OMR&R cost would give the total levelized cost of energy (LCOE):

$$\text{LCOE} = Unit\ Cost_{invest} + Unit\ Cost_{OMR\&R}$$

- This value gives us an idea about the overall cost per unit of production and enables us to compare the technologies of energy generation

3. Social dimension

The social KPI's are under development in collaboration in University of Mannheim and University of Ghent/IMEC.

- Share of local ownership in energy infrastructure equipment
- Share of local participation in energy-system related orders
- High acceptance of the community hubs -> positive attitudes
- Self-identification
- Share of different types of consumers versus total
- Information opportunities
- Social cohesion
- Lifetime
- Island's unemployment rate
- Thermal comfort

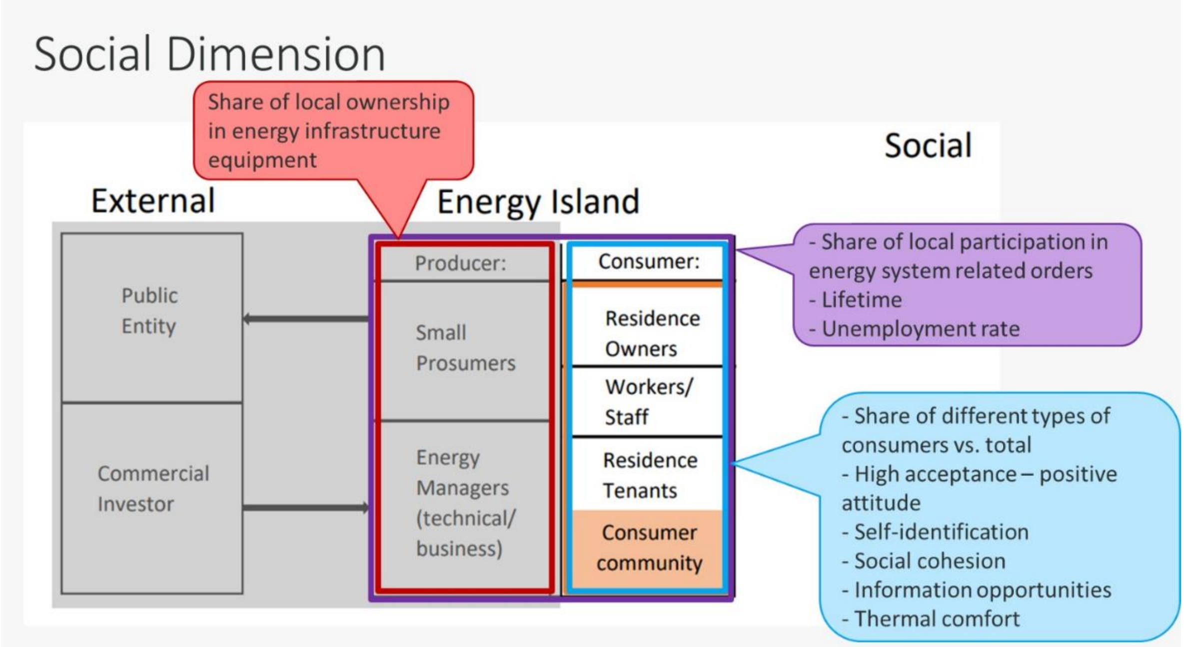

Figure 22. Overview of the development of the KPI's in the social dimension

VI. Experiments

VI.1. Experiments Epic 1 - Heat Supply optimization

A first Heat demand side management trial was started in Q1 2022 using active control of smart thermostats. Figure 24 shows a clear effect of heat demand shifting from 8-10 AM to 6-8 AM. The downside of this heat demand side management methodology is that it requires active participation of the residents. Participation is also restricted to appartements that have smart thermostats that can be remote-controlled, using the OpenMotics home automation system (approximately 60% of the residential units in the first phase of the Nieuwe Dokken project).

CEIP/DuCoop asked people to participate voluntarily in this 'heat innovation trial' that was set out in collaboration with University of Seeburg and University of Mannheim in the heating season of january-march 2022 (see Figure 23). 36 out of 48 apartements in the first construction phase of the Ghent Pilot accepted to participate in the trial. As the temperature shift on the home thermostats was very limited, DuCoop received almost no comfort complaints, apart from pre-trial concerns or a small number of technical issues.

Figure 23. Leaflet that was used to introduce people to the heat DSM trial.

Residents participated voluntarily, which meant that they allowed the temperature settings of their smart thermostats to be adapted to a heat demand shifting strategy, set out by the DuCoop EMS.

Initially, the heat demand side management trial met with some unforeseen technical challenges, but resulted in a peakshifting effect in week 11/12 for the building Faar, where at least 50% of the residential apartements participated in the trial (see Figure 24).

In the coming year this demand side management function will be further developed to respond to forecasting, actual wasteheat supply events, etc. In this way, the heat demand supply optimization algorithm will contribute to a higher take-up of wasteheat and a lower reliance on fossil fueled heat sources of the community. Also more general strategies of temperature control (e.g. by adapting the settings of the primary district heating circuit, or controlling the heating curves of apartements both with and without smart thermostats).

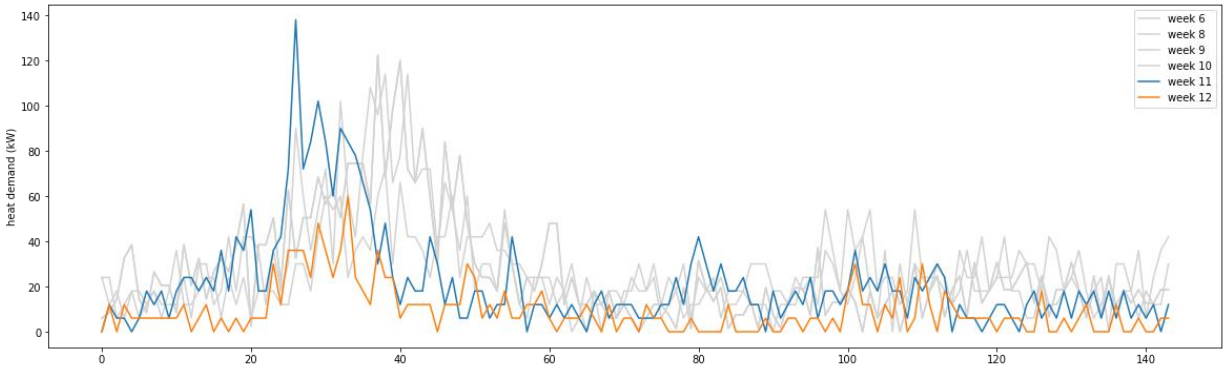

Figure 24. Shift of the morning heat demand peak in the building 'Faar' on Wednesday, before and after the implementation of a heat demand management tool (week 11/12 vs week 6-9).

VI.2. Experiments Epic 2 - Heat source optimization

One of the first heat source optimization strategies that became implemented during the heat source optimization epic was a control strategy for the heat pump in the district heating network:

The storage capacity of the water treatment system is used to avoid activity of the heat pump during times of reduced heat demand or when other waste heat sources (e.g., industrial waste heat) are available:

The heat pump is switched on (O/I), but decides for itself what compression stage to use:

- There is a residual heat demand on the district heating network heat provided by the heat pump is the cheapest source of heat energy. Calculation goes as follows:
  - Calculate the COP for each operable stage, currently based on historical data
  - Calculate the heat price for each operable stage, using the electricity price, the COP and the electric power consumed/stage.

When there is solar or stored energy available, take this into account and recalculate the price of the stages that can (partly) be powered with 'free' energy

- The set point of the heat sink (in this case buffer tank 3) is not reached.
- There is sufficient heat available in the buffer containing the water that heat is extracted from. (buffer flow and T) the EMS is active (communication with EMS or default) (see Figure 25).

In the coming months, DuCoop will also integrate other heat assets in the heat source optimization strategy. In a second phase (end 2022), coolant water of a CHP-system at Christeyns will be available at 60°C to increase the share of wasteheat in the energymix, and reduce the activity of the backup-gasboilers.

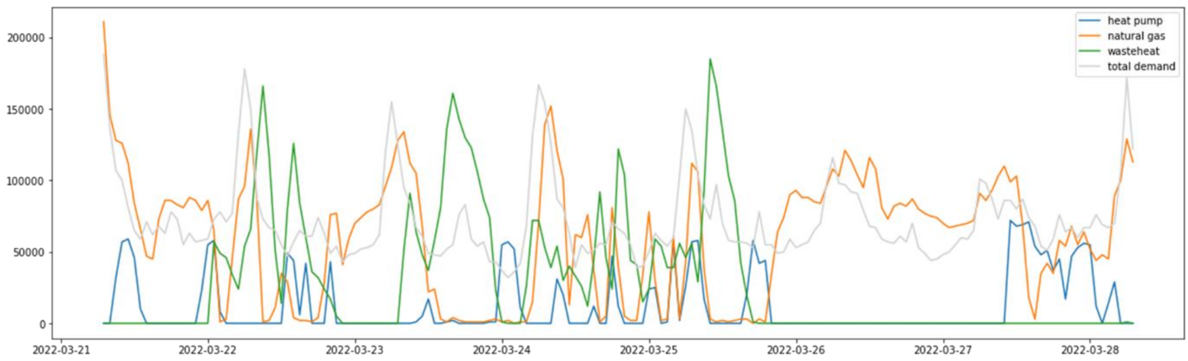

Figure 25. Overview of the control of the heat pump in the contribution to the energy mix of the DH network in W11/2022.

VI.3. Experiments Epic 3 - Forecasting

Using historical data and a linear regression with the hour of the day, the day of the week and the outside temperature as explaining variables, the heat demand forecasts already reach quite an accurate level. The morning peaks can clearly be distinguished, which will probably be the most important feature to continue optimizing the district heating network with. Depending on further needs for more detailed forecasts, additional efforts will be done to improve the prediction quality (see Figure 26).

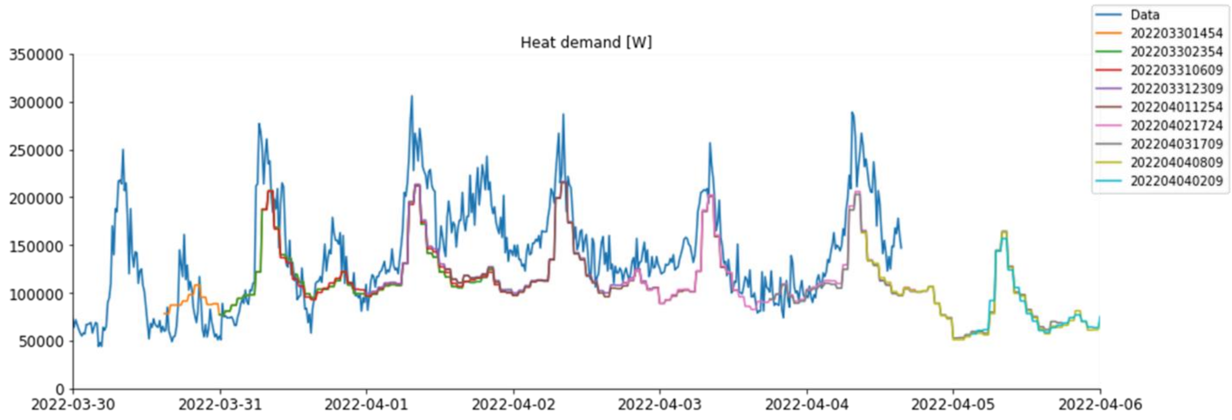

Figure 26. Forecasting of heat demand. Blue line: actual data; other colours: forecasts of 48 in the future at different points in time.

VI.4. Experiments Epic 4 - Electricity supply optimization

One of the first applications that became developed to optimize electricity consumption in the Nieuwe Dokken pilot, was a management for the battery system in the Nieuwe Dokken district.

Based on the predicted PV-production and grid electricity prices, CEIP/DuCoop optimizes the state of charge of the district battery system. This is aimed at increasing the consumption of the locally produced PV-power and reducing the cost of electricity that is taken from the grid (see Figure 27). Certainly, during winter-evenings energy prices tend to increase drastically. If the battery can shift grid consumption in time, this could create an opportunity for cost reduction and a higher reliance on sustainable sources within the community.

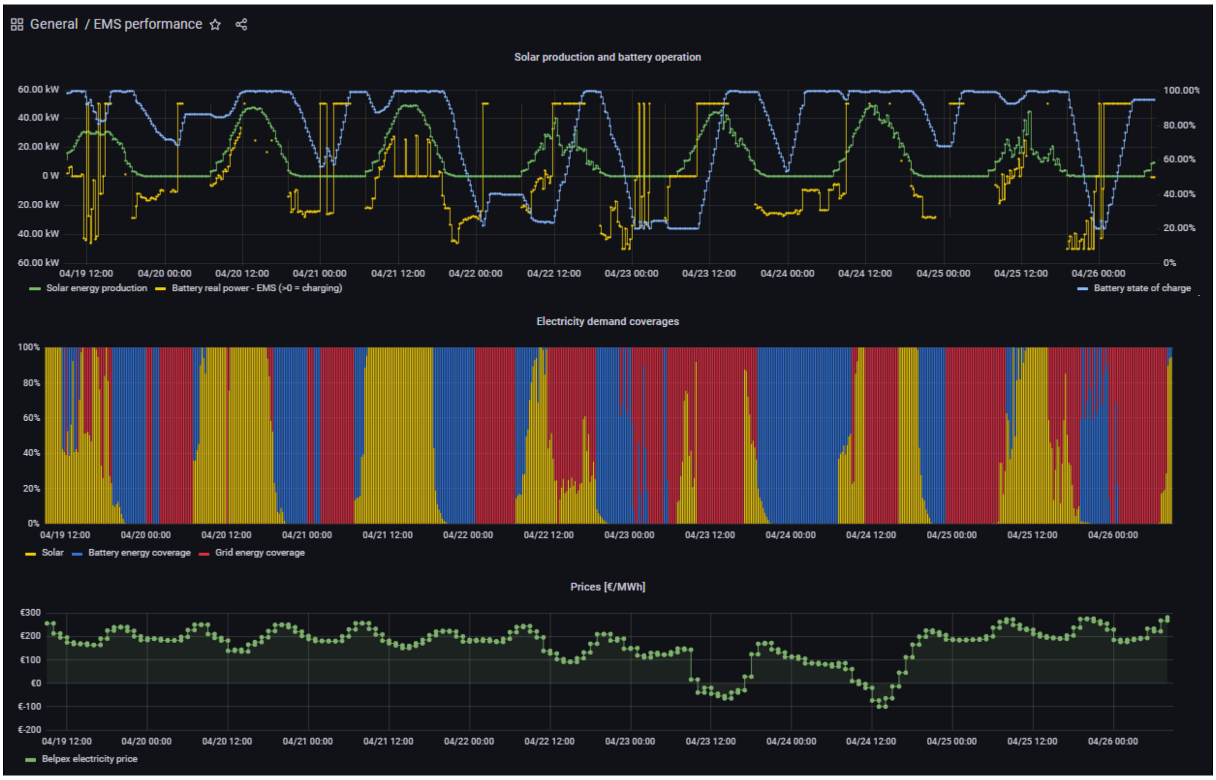

Figure 27. Extract from Ghent Pilot Grafana Dashboard.

The current EMS system controls use of local renewable energy (PV), charging of the local battery system (200kWh) or consumption of grid power based on availability of local RES, consumption prediction and energy market prices (ENDEX).

VI.5. Experiments Epic 5 - Electricity demand side management

Experiments for the Epic 5- Electricity demand side management are under construction. Together with other RENergetic partners (IMEC- University of Ghent) CEIP/DuCoop will develop EV charging strategies to optimize the electricity consumption and electric load in the energy system of the Ghent Pilot (see Figure 28).

In a second phase, also bidirectional EV-charging will be tested in collaboration with the provider of the EV-charging infrastructure.

Figure 28. DuCoop operates 20 Powerade EV-charging points (11kW) in the first phase of the Ghent Pilot. In a second phase (2022) 32 extra EV charging points will be added.

VII. Summary and Conclusion

CEIP and its subsidiary DuCoop have been working on a thorough integration of different technologies and data management systems in the Nieuwe Dokken district in Ghent. During the RENergetic project (see Figure 24), the EMS system was brought to implementation and officially started by the Belgian minister for Energy on June 2nd 2021. A battery charging strategy was implemented first, to optimize the utilization of locally produced PV-power and the cost of grid electricity. During 2021, tools were developed to manage sources in the local district heating network (e.g., heat pump control, forecasting, etc). During the coming year, CEIP/DuCoop want to increase accessibility of its EMS platform to pilot assets for testing of control algorithms, using a dedicated API. Furthermore, tools will be developed to control electricity consumption, for example by developing smart loading strategies for the pilot's EV charging infrastructure. More information and interactive tools will be made available to the end-users.

The effect of the different EMS strategies will be monitored online, using the existing EMS-Grafana platform. Based on different parameters the technical (sustainability), economic (cost) and social KPI's will be measured.

Domain	Current data	Predictions	Control actions
PV installation	◆	✓	*
Battery	✓	*	✓
DH- forecasting	✓	✓	*
DH- heat source optimization	✓	*	◆
DH- demand management	✓	✓	✓
Electricity	✓	✓	*
Energy price (grid)	✓	✓	✓
CO2-intensity	◆	◆	◆
Heat pump	✓	*	✓
EV chargers	✓	◆	◆

Figure 29. Overview of RENergetic EMS programming activities in the Ghent Pilot site Nieuwe Dokken (: done, : to do, *: not relevant)

VIII. REFERENCES AND INTERNET LINKS

[1] "DuCoop," [Online]. Available: www.ducoop.be.

[2] "RUN4LIFE: RECOVERY AND UTILIZATION OF NUTRIENTS 4 LOW IMPACT FERTILIZER," H2020 No 730285, 2017-2021. [Online]. Available: https://run4life-project.eu/ .

[3] "NEREUS: New energy and resources from urban sanitation," Interreg 2seas, 2018-2021. [Online]. Available: https://www.nereus-project.eu/.

[4] "Interconnect: Interoperable solutions connecting smart homes, buildings and grids," H2020 No 857237, 2019-2023. [Online]. Available: https://interconnectproject.eu/.

[5] "BRIGHT: Boosting DR through increased communIty-level consumer engaGement by combining Data-driven and blockcHain technology Tools with social science approaches and multivalue service design," H2020 No 957816, 2020-2023. [Online]. Available: https://www.brightproject.eu/.

[6] "ROLECS: rolling out of energy communities: Flemish regional cooperative innovation project," VLAIO, 2019-2021. [Online].

[7] "Christeyns," [Online]. Available: https://www.christeyns.com/.

[8] "OpenMotics: Home-automation," [Online]. Available: https://www.openmotics.com/.

[9] EMD, "Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU," [Online]. Available: https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/electricity-market-design_en.

[10] "Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources," [Online]. Available: https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en.

[11] "Belgian minister for Energy officially opens DuCoop virtual power plant at the Nieuwe Dokken," 02 06 2021. [Online]. Available: https://ducoop.be/en/news/virtuele-energiecentrale-in-de-nieuwe-dokken-in-gent-vormt-schakel-in-de-overgang-naar-100-hernieuwbare-energie.