WP4 – HYPERGRYD Digital Twin Platform as a service

Task 4.5 Workflow management and end-user API development

D4.5 Fully operational HYPERGRYD Platform and API with integrated tools and services

HYPERGRYD. *This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036656*

DISCLAIMER

ACKNOWLEDGEMENT

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Project	
Project Acronym	HYPERGRYD
Project Title	Hybrid coupled networks for thermal-electric integrated Smart Energy Districts
Grant Agreement number	101036656
Call identifier	H2020-LC-GD-2020
Topic identifier	LC-GD-2-1-2020 Innovative land-based and offshore renewable energy technologies and their integration into the energy system
Funding Scheme	Research and Innovation Action
Project duration	42 months (From 1 October 2021)
Coordinator	ARCbcn
Website	http://hypergryd.eu
Deliverable	
Deliverable No.	D4.5
Deliverable title	Fully operational HYPERGRYD Platform and API with integrated tools and services
Description	The objective of this task is to describe the development of the API, which will be based on different HYPERGRYD tools/service requirements regarding data exchange needs, formats, etc.,successfully integrating tools and services developed by the project partners - Gussing Energy Technologies Gmbh (GET), Encoord GmbH (ENCO), Grid Singularity (GSY), and Kungliga Tekniska Hoegskolan (KTH) - into the HYPERGRYD PaaS/SaaS developed by project partner IDP Ingenieria Y Arquitectura Iberia SL (IDP). The API, which underpins HYPERGRYD's PaaS and its integrated services/tools aims to take into account end-user/stakeholder recommendations, usability techniques and methods - used at different stages of the development - which guarantees an end product that meets previous needs and requirements from stakeholders, use cases, roles, ICT architecture, planning platform and data requirements from previous tasks: T4.1, T4.2 and T4.3. This developed API presents a complete control system adapted to energy saving and optimisation driven configuration, including a user-friendly and comfortable interface to users, which will implement solutions for all the known use cases. An interface that helps visualize the gathered and relevant data to discover actionable insights is here presented. This responsive interface can be adapted to meet all users' energy management needs as well as other needs regarding facility and/or asset management, design & construction planning and management, etc. The platform also aids decision making for workflow management in real time, for both the electrical and thermal energy flows set in the coupled energy network complex, as an intuitive dashboard (interface) through gathered information based on different HYPERGRYD tools/services.
WP No.	WP4
Related task	T4.5 – Workflow management and end-user API development
Lead Beneficiary	9 - IDP
Author(s)	Jorge Leao, Luis Ibañez Adrian, Genis Carrillo, Mikel Borras (IDP)
Contributor(s)	-
Type	OTHER
Dissemination	**PU** Public
Language	English – GB
Due	31/03/2025 **Submission date** 31/03/2025

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1 Executive Summary

The goal of HYPERGRYD project is the development of a set of replicable and scalable cost effective technical solutions to allow the integration of Renewable Energy Sources (RES) with different dispatchability and intrinsic variability inside Thermal Grids as well as their link with the Electrical Grids, including the development of innovative key components, in parallel with innovative and integrated ICT services formed by a scalable suite of tools for the proper handling of the increased complexity of the systems from building to Local Energy Community (LEC) levels and beyond, and accelerate the sustainable transformation, planning and modernization of District Heating and Cooling (DHC) towards 4th and 5th generation.

The purpose of this deliverable is to detail the successful integration of tools and services developed by the project partners, Güssing Energy Technologies GmbH (GET), Encoord GmbH (ENCO), Grid Singularity (GSY), and Kungliga Tekniska Hoegskolan (KTH) into the HYPERGRYD PaaS/SaaS developed by project partner IDP Ingenieria Y Arquitectura Iberia SL (IDP). The joint platform, therefore provides access to the following services:

ENCO -> SAInt (Scenario Analysis Interface for Energy Systems) Modelling and simulation software designed to simulate the operation of an integrated energy system that couples heating and electricity networks:

- GET -> Exergoeconomic optimization tool for 4th and 5th generation of DHC: Exergy-based analysis and assessment of energy-conversion systems for district heating and cooling.
- GSY -> Grid Singularity Exchange : Tool stack including advanced local peer-to-peer energy trading simulation tool that supports planning by evaluating the benefits of P2P trading and analysing the most optimal asset configuration, with additional tools to manage operation of energy communities;
- KTH -> IoT-enabled demand response management (DRM) for local energy communities: An open-source software solution that enables cost-effective heating by coordinating energy management among community members.

The report's intended audience encompasses a wide range of stakeholders, including District Heating and Cooling (DHC) operators, Distribution System Operators (DSOs), Energy Service Companies (ESCOs), energy producers, energy suppliers, municipalities, local and national policymakers involved in energy efficiency decision-making, waste heat suppliers, engineering firms, and utility companies. This public report will allow them to review innovative solutions developed in the framework of the HYPERGRYD project and consider their future market application.

On behalf of Authors

Jorge Leão (IDP)

Genis Carrillo (IDP)

2 Introduction

2.1 Scope

This report details the successful integration of tools and services from GET, ENCO, and GSY into the HYPERGRYD PaaS/SaaS developed by IDP. The implementation adheres to the architecture defined in Deliverable 4.2: « *ICT Architecture and data requirements for HYPERGRYD DT PaaS* ».

2.2 Audience

This report is intended for technical stakeholders interested in the application of a Digital Twin-based PaaS for the integration of thermal and electric grids. A fundamental understanding of the subject matter is assumed, which may limit its accessibility to the general public and end-users.

Target groups for the deliverable include:

- ESCOs (Energy Service Companies)
- DSOs (Distribution System Operators)
- DH (District Heating) operators
- Energy producers
- Municipalities and policy makers
- Engineering professionals
- Energy community managers, end-users and the general public.

2.3 Definitions / Glossary

BIM – Building Information Modelling, it is the virtual representation of the physical and functional characteristics of a facility (Tang et al., 2017).

GIS – Geographic Information System, it is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface (GIS (Geographic Information System), n.d.).

Digital Twin – Technology that uses digital representation of real-world assets allowing the users to access these assets and their data such as their dimensions or the cost or energy consumption of an equipment (Overview: What Is Digital Twin Technology?, 2022).

API – Application Programming Interface, it is a software interface that allows different programs to communicate (What Is an API? Application Programming Interface Definition, 2022).

2.4 Abbreviations

API : Application Programming Interface

BIM: Building Information Modelling

DHC: District Heating and Cooling

DSO: Distribution System Operator

ESCO: Energy Service Company

GIS: Geographic Information System

LEM: Local Energy Market

PaaS: Platform as a Service

P2P: Peer-to-Peer

PV : Photovoltaics

SaaS: Software as a Service

2.5 Contributions of partners

The IDP team exclusively authored this deliverable, with other technical partners providing inputs for the solutions they developed and a deliverable review.

2.6 Baseline

This deliverable builds upon the work performed in task 4.5 – « Workflow management and end-user API development » which its objective is to integrate the different tools and services from GET, ENCO, GSY, and KTH specified in D4.2 – « ICT Architecture and data requirements for HYPERGRYD DT PaaS ».

2.7 Relation to other activities

- **Inputs**: D4.2, D4.3, T4.2, T4.3, and T4.5.

2.8 Structure

- **Section 1:** Executive Summary.
- **Section 2:** Introduction.
- **Section 3**: Exergoeconomic optimization tool for 4th and 5th generation of DHC.
- **Section 4**: SAInt - Scenario Analysis Interface for Energy Systems.
- **Section 5**: Grid Singularity Exchange (local energy marketplace tool).
- **Section 6**: ICT-enabled AI tool for the management of a local energy community.
- **Section 7**: Conclusions.

3 Exergoeconomic optimization tool for 4th and 5th generation of DHC

GET provides an exergy-based analysis and assessment of energy-conversion systems for district heating and cooling systems that is integrated in an API service where the platform sends the Exergoeconomicoptimization tool for 4th and 5th generation of DHC the BIM-GIS model of the DH with all the different buildings, energy assets, and piping information and the API returns the results of the simulation to the platform dashboard.

This simulation results data provided by GET can be accessed directly on the platform dashboard as shown in the following figure:

Figure 1. Exergoeconomic simulation dashboard.

The exergoeconomic simulation dashboard allows users to select between district heating network (pipes) and customer consumption data.

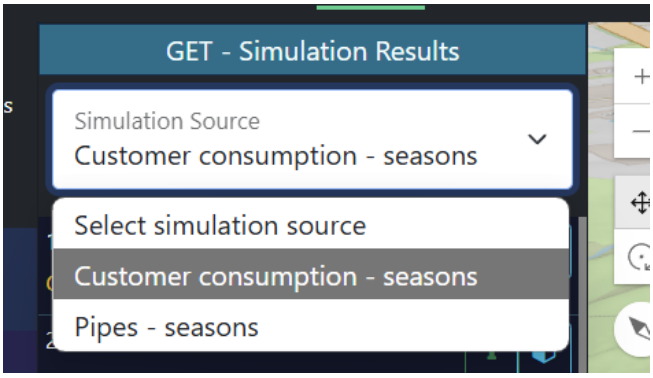


Figure 2. Exergoeconomic simulations.

Selecting customer consumption displays all consumers within the district.

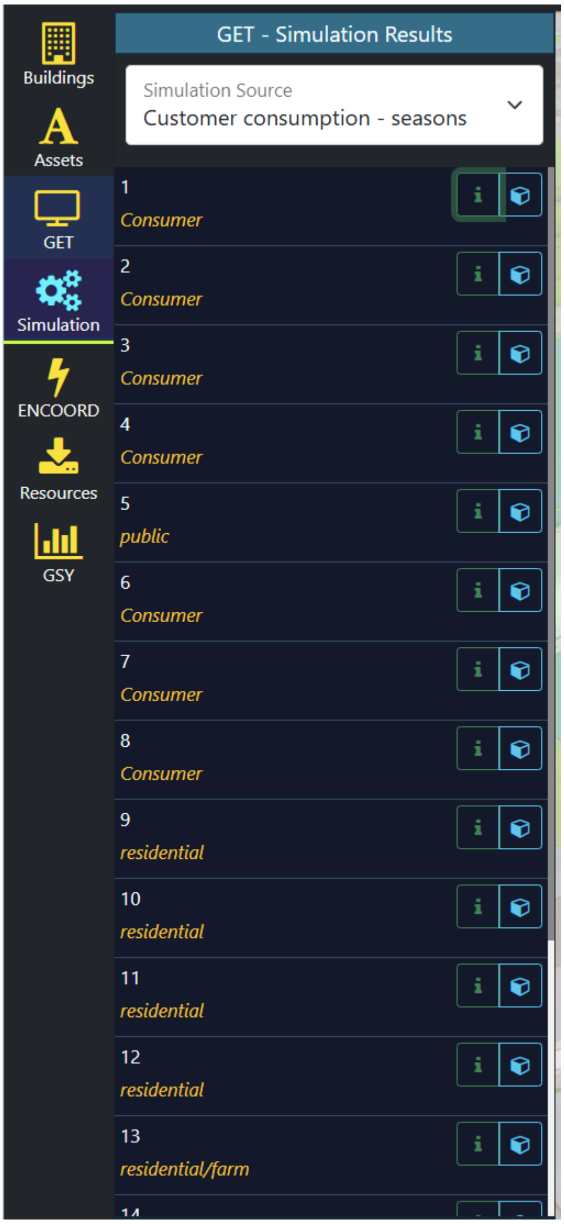


Figure 3. District consumers list.

From this list, users can select individual consumers to view results generated by GET's Exergoeconomic optimization tool for 4th and 5th generation DHC systems. Displayed results include thermal load, flow, flow and return temperatures, flow target temperature at consumer, exergy difference, and heat losses.

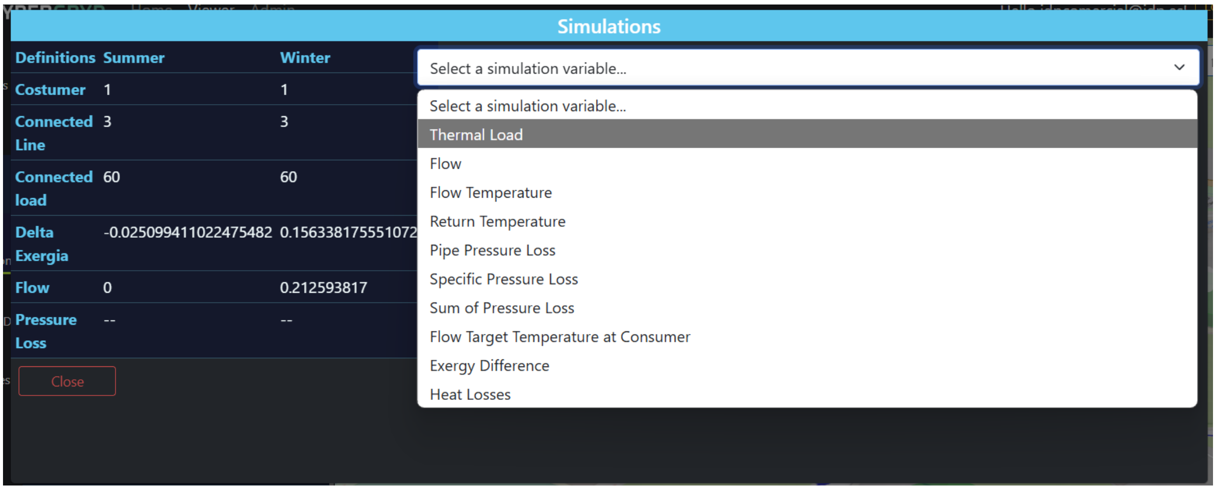


Figure 4. Exergoeconomic District consumers simulation results.

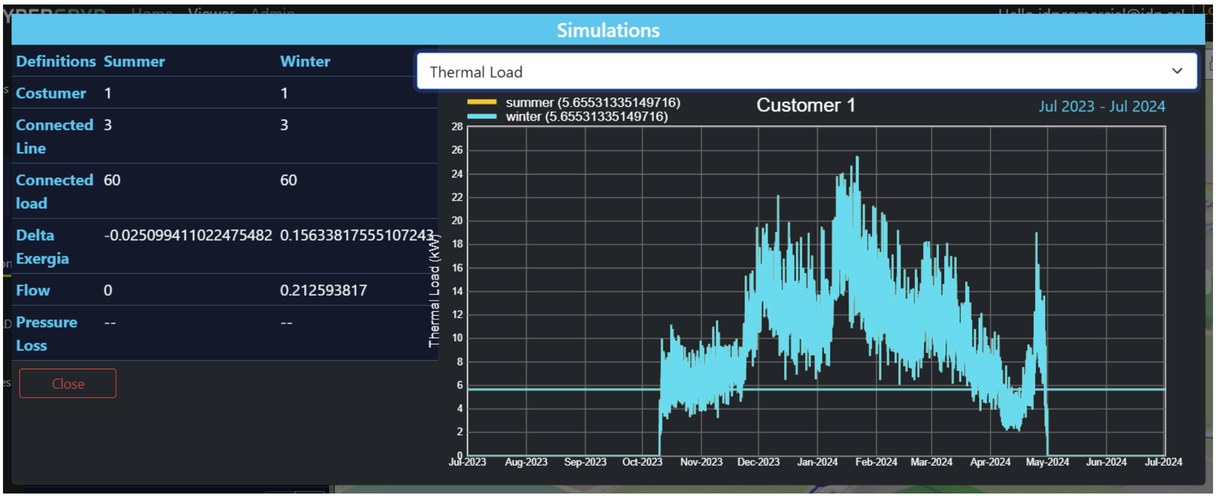


Figure 5. Exergoeconomic District consumers thermal load simulation result.

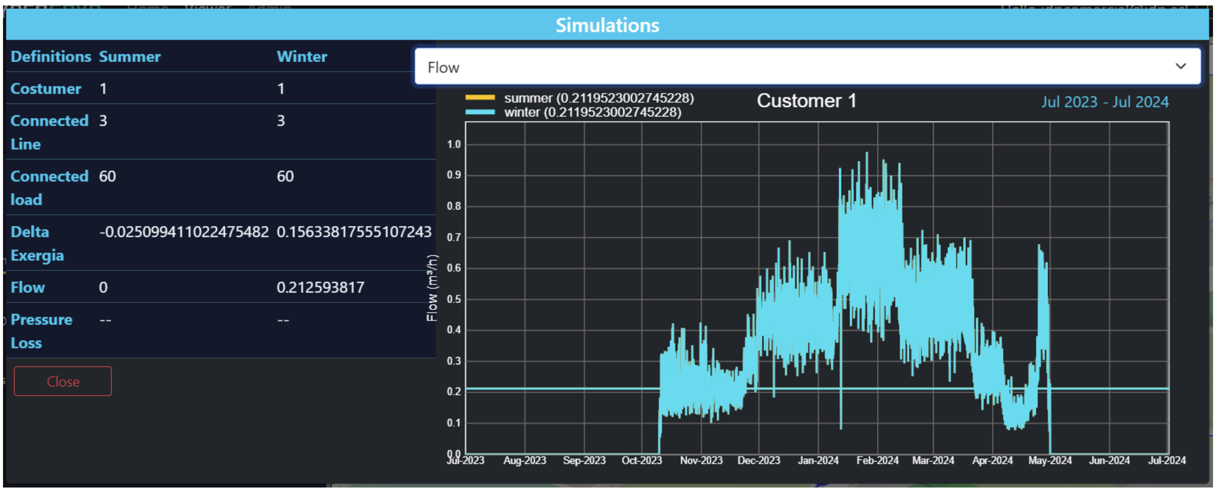


Figure 6. Exergoeconomic District consumers flow simulation result.

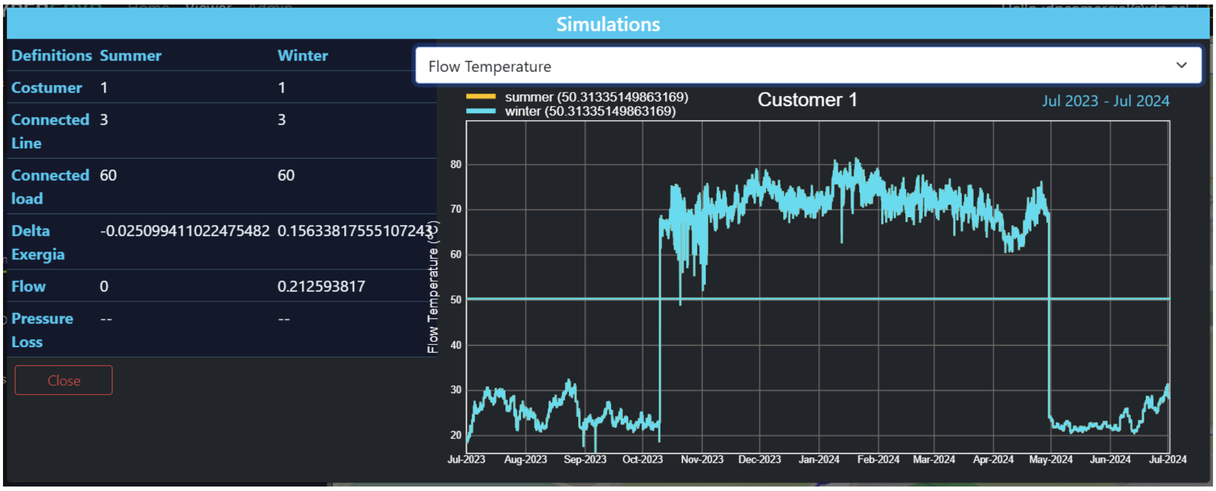


Figure 7. Exergoeconomic District consumers flow temperature simulation result.

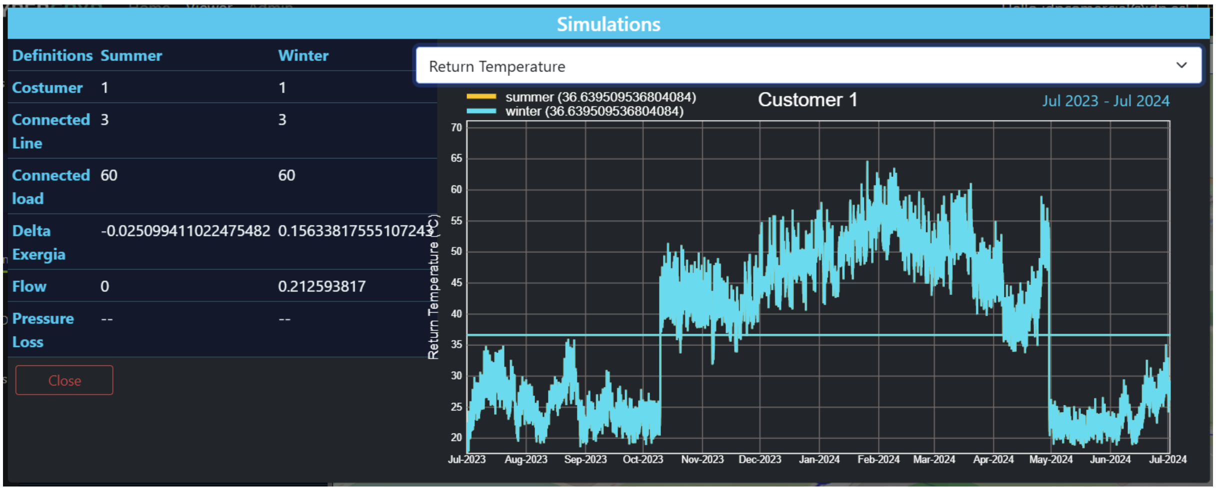


Figure 8. Exergoeconomic District consumers return temperature simulation result.

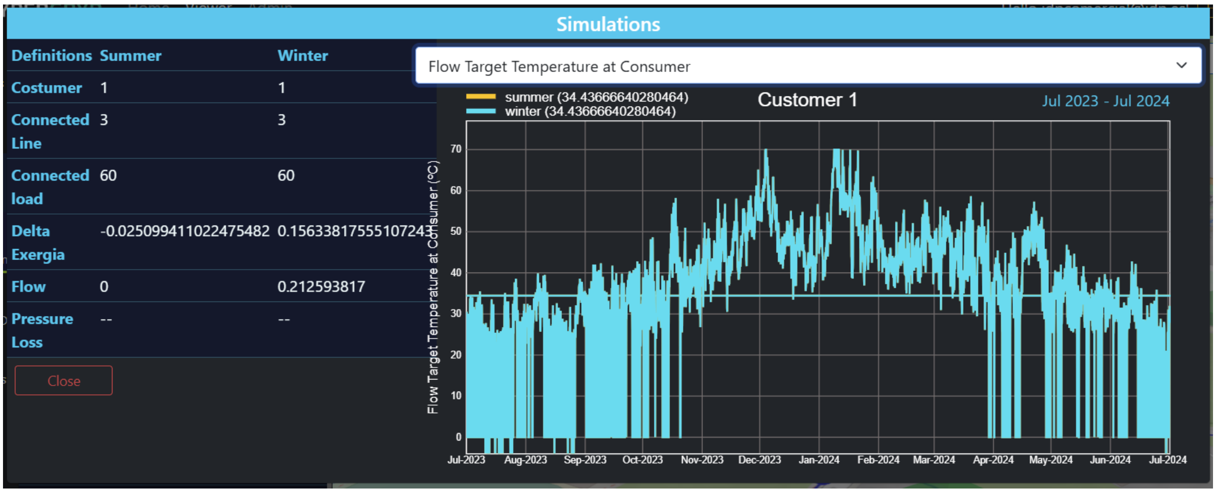


Figure 9. Exergoeconomic District consumers flow target temperature at costumer simulation result.

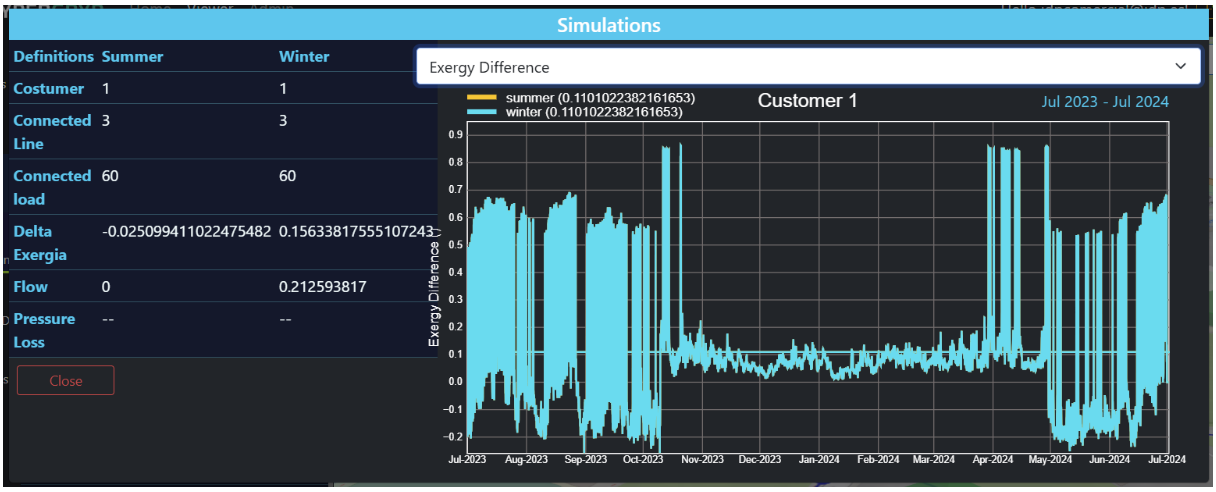


Figure 10. Exergoeconomic District consumers exergy difference simulation result.

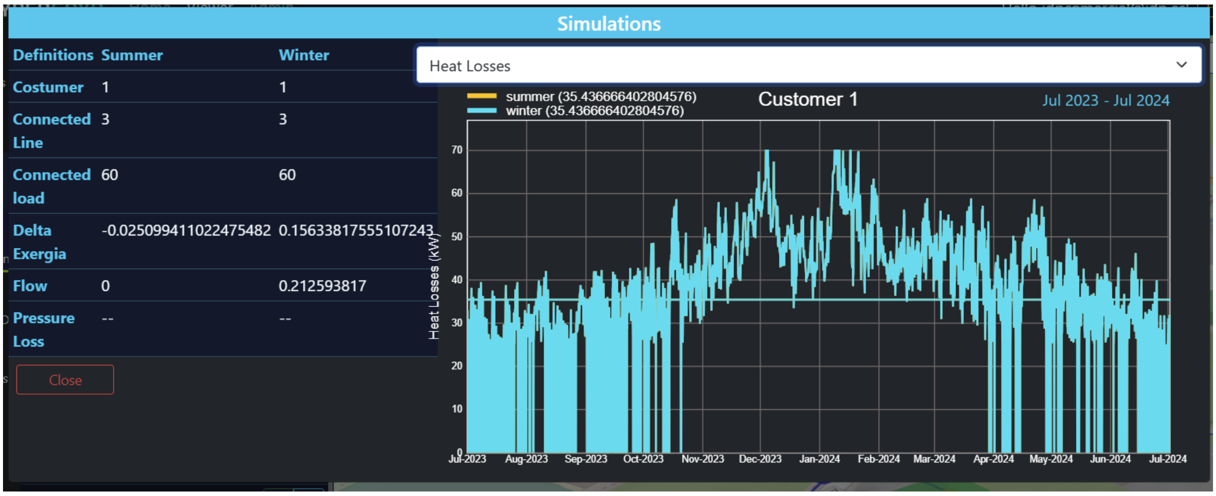


Figure 11. Exergoeconomic optimization tool for 4th and 5th generation of DHC tool simulation results of the heat losses for a consumer.

Selecting the district heating network (pipes) displays a list of all pipe segments in the district, along with simulation results including flow, flow and return temperatures, pipe pressure loss, specific pressure loss, consumer flow target temperature, and heat losses for each segment.

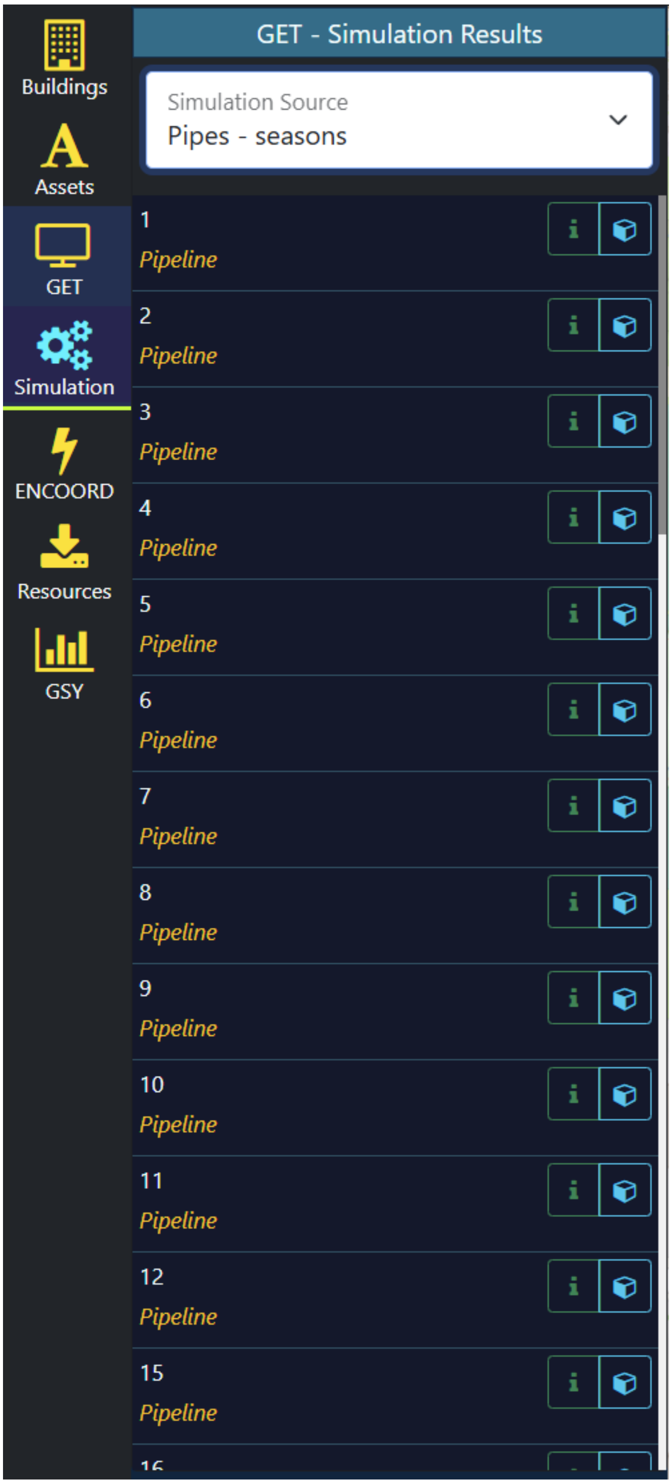
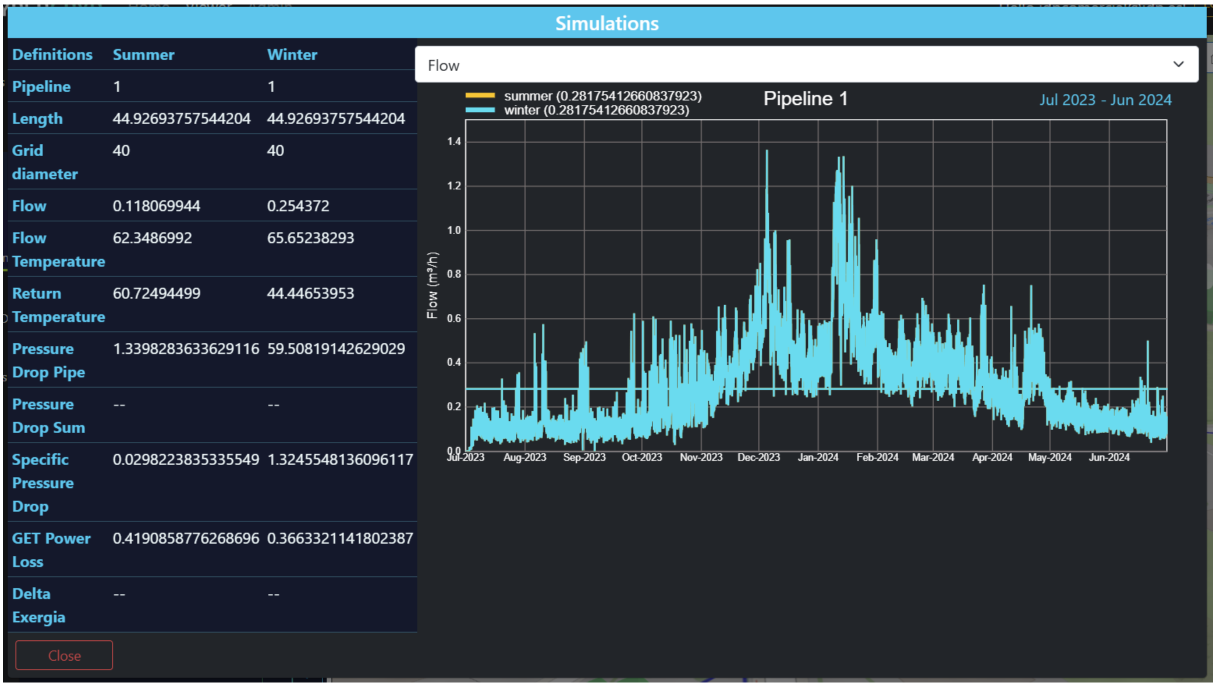
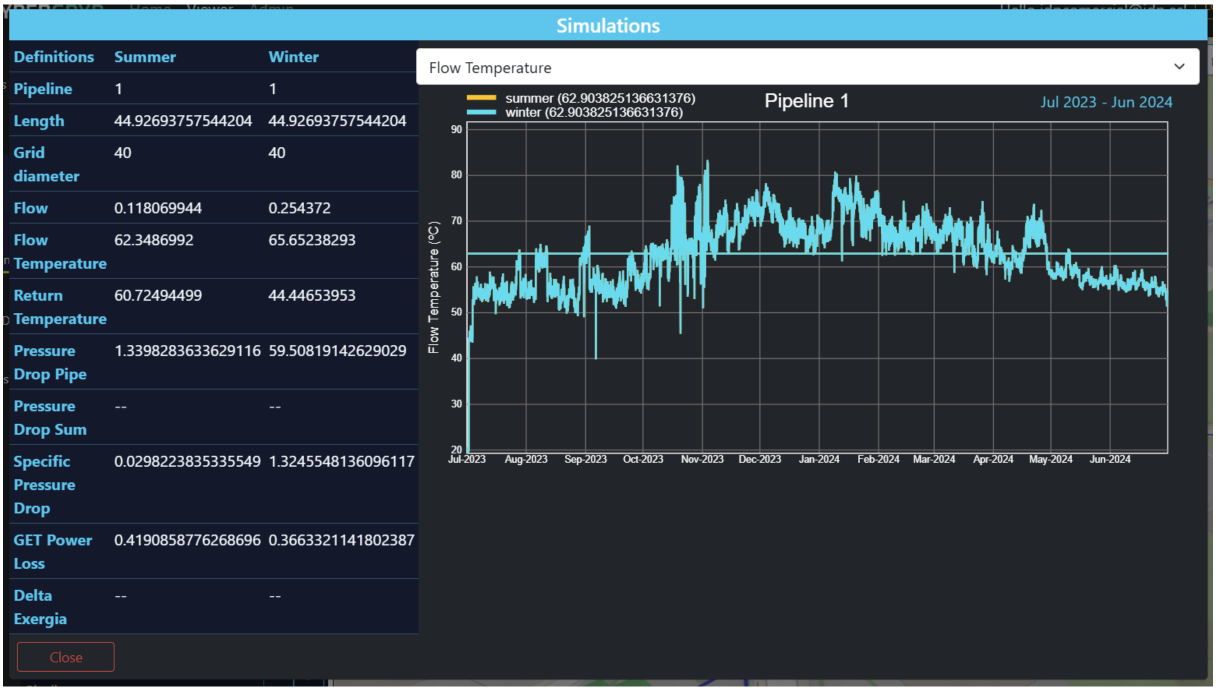


Figure 12. District pipelines list.



Definitions	Summer	Winter
Pipeline	1	1
Length	44.92693757544204	44.92693757544204
Grid diameter	40	40
Flow	0.118069944	0.254372
Flow Temperature	62.3486992	65.65238293
Return Temperature	60.72494499	44.44653953
Pressure Drop Pipe	1.3398283633629116	59.50819142629029
Pressure Drop Sum	--	--
Specific Pressure Drop	0.0298223835335549	1.3245548136096117
GET Power Loss	0.4190858776268696	0.3663321141802387
Delta Exergia	--	--

Figure 13. District pipes flow simulation result.



Definitions	Summer	Winter
Pipeline	1	1
Length	44.92693757544204	44.92693757544204
Grid diameter	40	40
Flow	0.118069944	0.254372
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Pressure Drop Pipe	1.3398283633629116	59.50819142629029
Pressure Drop Sum	--	--
Specific Pressure Drop	0.0298223835335549	1.3245548136096117
GET Power Loss	0.4190858776268696	0.3663321141802387
Delta Exergia	--	--

Figure 14. District pipes flow temperature simulation result.

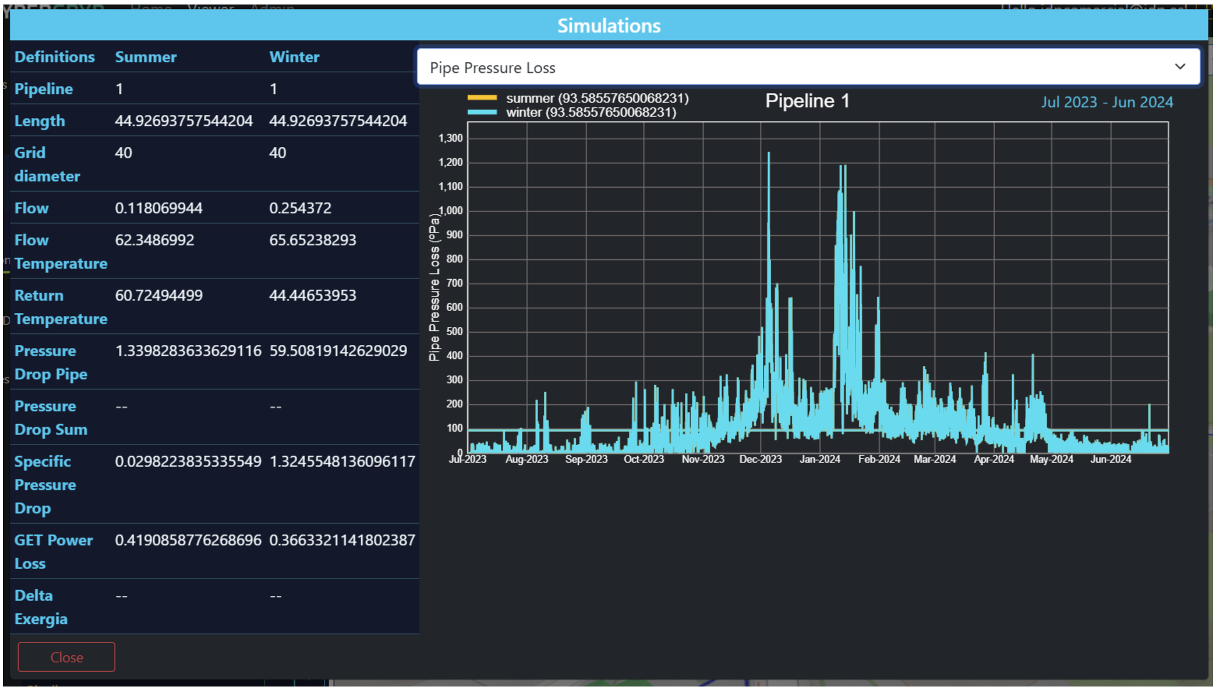


Figure 15. District pipes pipe pressure loss simulation result.

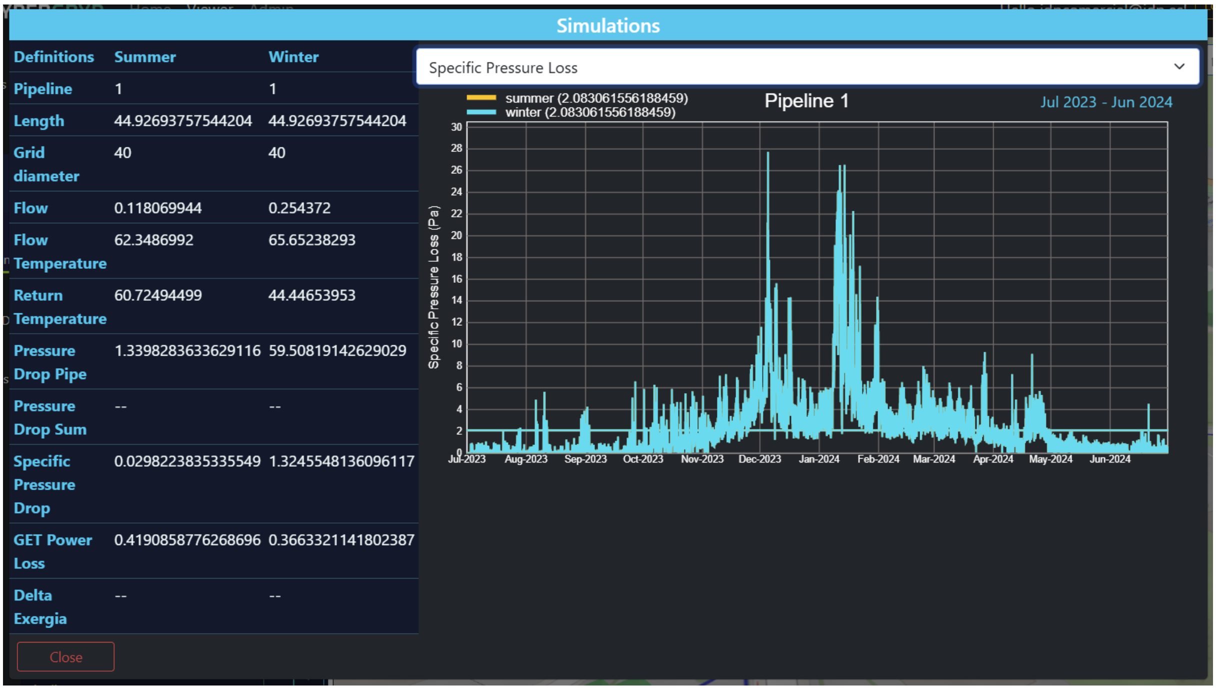


Figure 16. District pipes specific pressure loss simulation result.

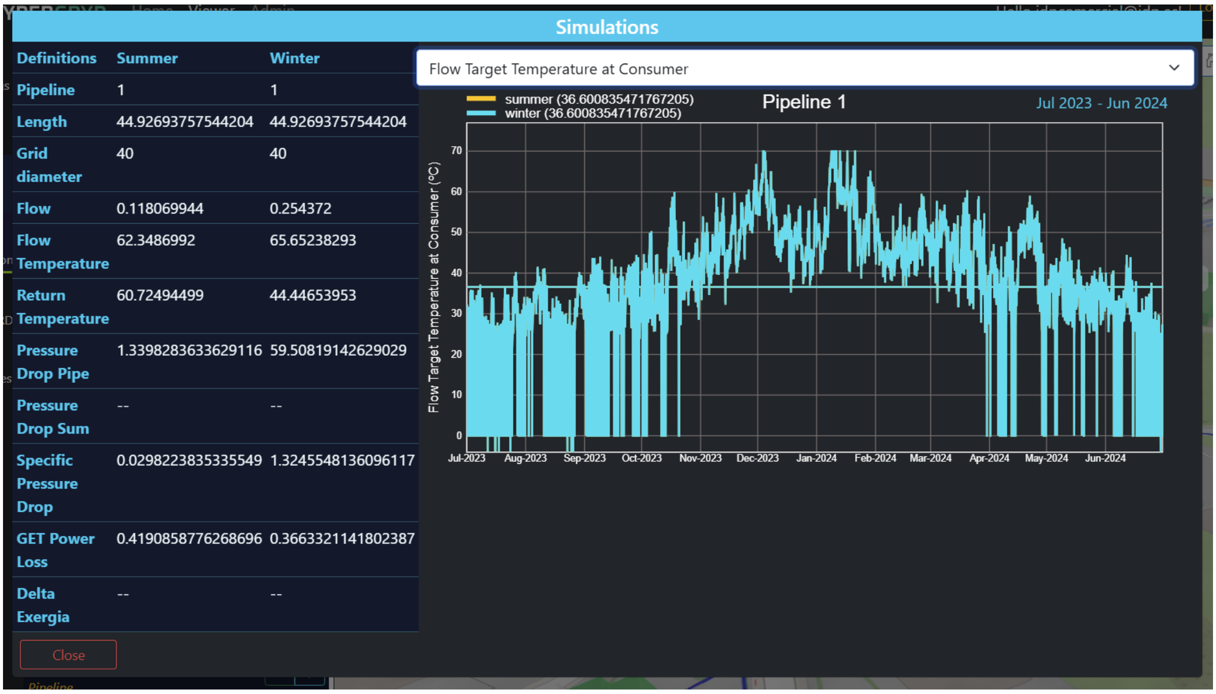


Figure 17. District pipes flow target temperature at consumer simulation result.

Figure 18. Exergoeconomic optimization tool for 4th and 5th generation of DHC tool simulation results for heat losses.

4 SAInt - Scenario Analysis Interface for Energy Systems

The "Scenario Analysis Interface for Energy Systems" (SAInt) is modelling and simulation software designed to simulate the operation of an integrated energy system that couples heating and electricity networks. This service is integrated directly into the HYPERGRYD Platform back end, and to run it, we had to install the license provided by SAInt directly on the platform virtual server.

This service is a core service of the HYPERGRYD platform and integrates seemingly with the BIM-GIS toolkit. With the toolkit, the user draws thermal and electric networks, including the buildings that will consume energy, the energy provider assets of the grid (e.g., PV plans), the nodes of the network, the connection to the buildings, and the points where the network will connect outside the grid. The objects making up a network have specific properties which the user can modify, like the diameter of a pipeline or the rated current capacity of an electric line.

After a district heating or an electrical grid is modelled using the BIM-GIS toolkit, a scenario needs to be created on the « Simulation module » of the SAInt tool in order to run the simulation. To create a scenario, it is necessary to specify the start and end dates of the simulation and the time step. The scenario data consists of the dates and timestep mentioned before, the scenario type (for example « SteadyThermal » for a steady state thermal simulation for thermal networks or « SteadyACFP » for a steady state alternating current power flow simulation for an electrical network), the network data, the profiles (i.e., how properties should be changing in a quasi-dynamic simulation) or events data (i.e., constraints for properties set-points) and the scenario name. This data is registered into a database and then used to create a json model, which is sent and consumed by the SAInt's API.

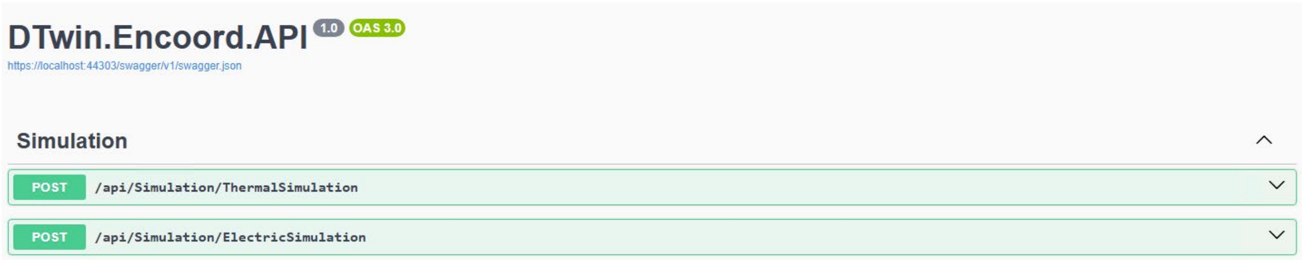


Figure 19. DTwin Encoord API endpoints.

The API is hosted next to the SAInt licence manager on a virtual machine. The service runs, executes a simulation, and returns the results to the HYPERGRYD platform, which makes them available to the user through the HYPERGRYD platform dashboard. The SAInt dashboard allows the user to see the results of thermal or electrical stimulation.

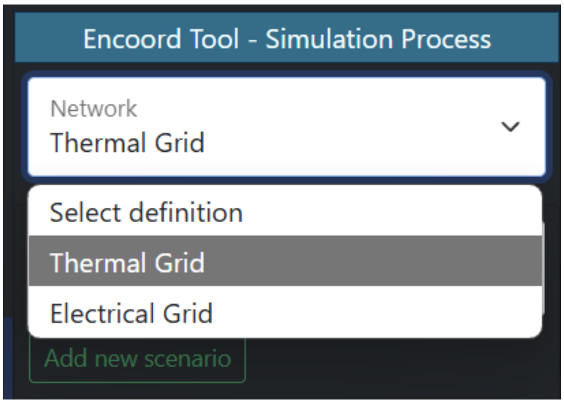


Figure 20. Menu for selecting the type of network for running a SAInt simulation.

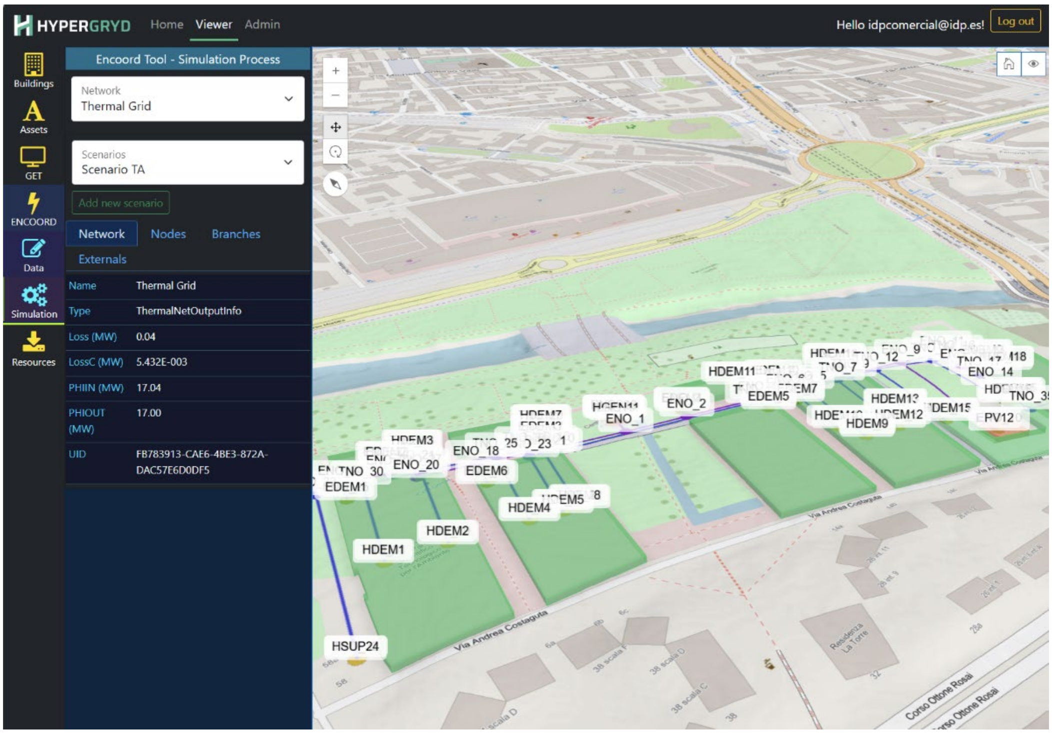


Figure 21. Example of a SAInt thermal grid simulation in the HYPERGRYD platform.

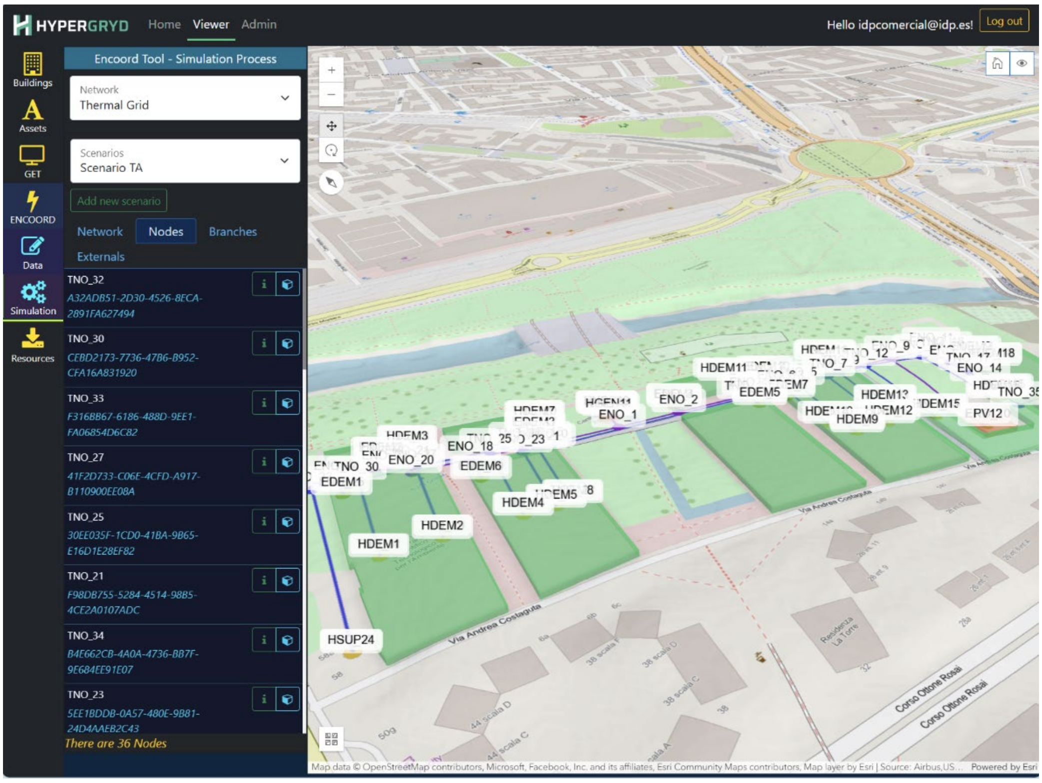


Figure 22. Example of the list of nodes in a SAInt thermal grid network.

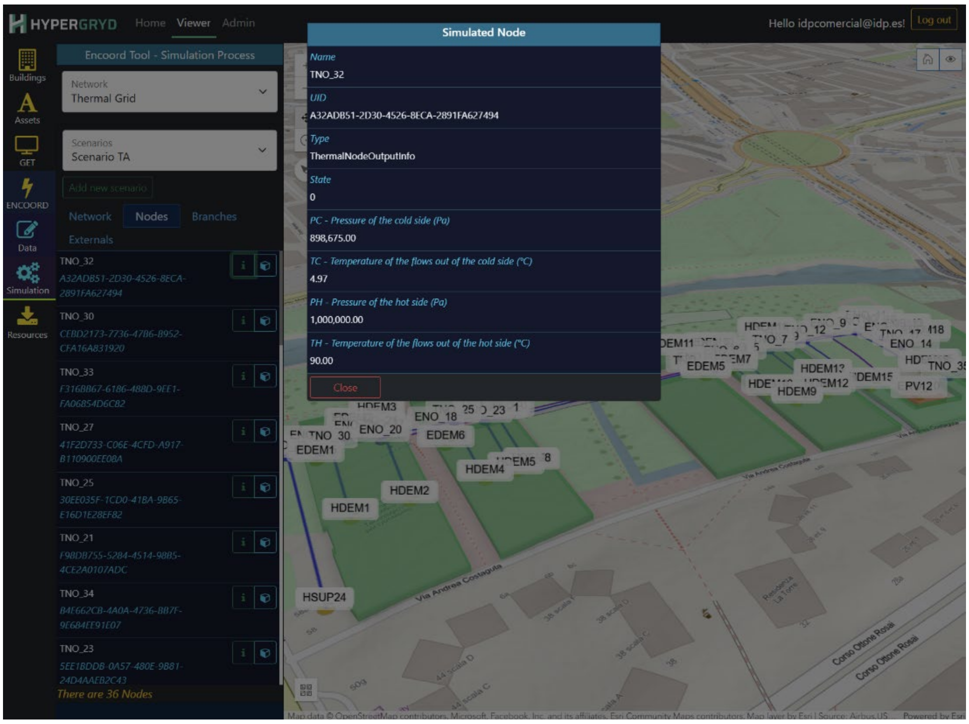


Figure 23. Example of the SAInt thermal grid simulation node results.

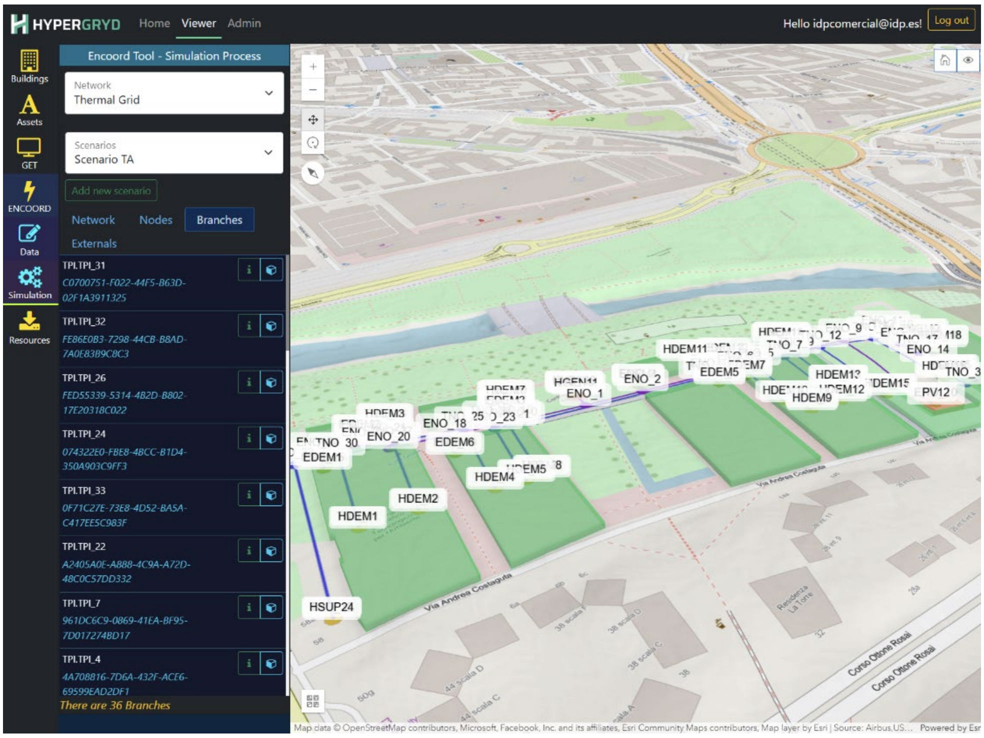


Figure 24. Example of the list of branches (i.e., pipelines) in a SAInt thermal grid network.

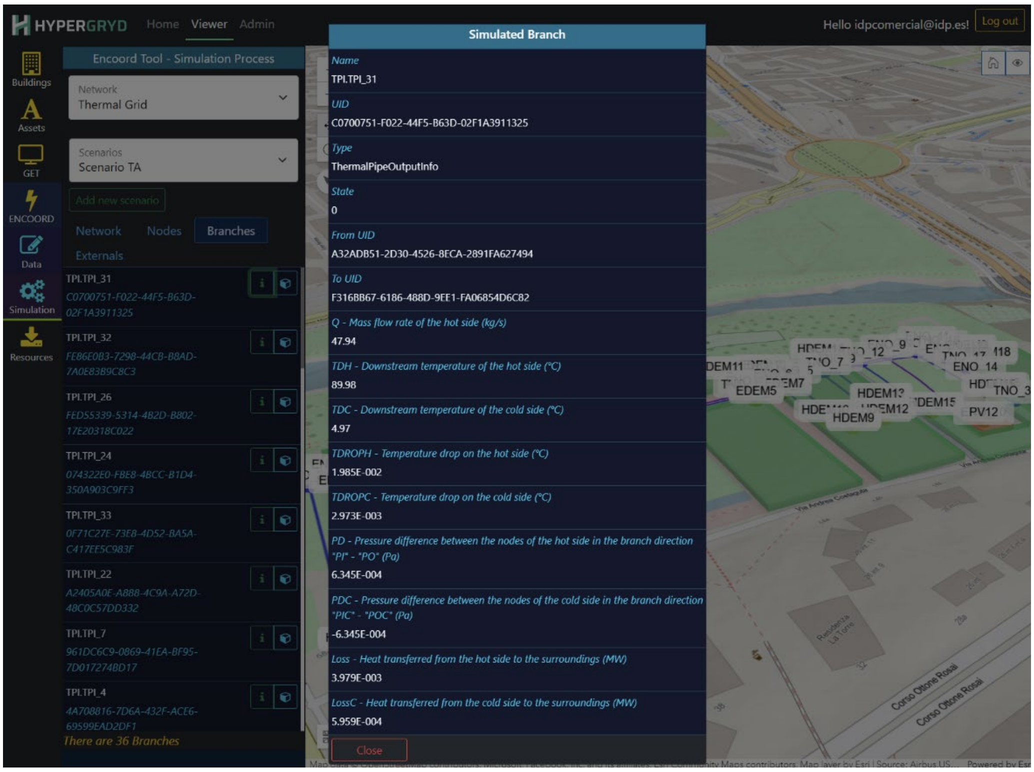


Figure 25. SAInt thermal grid simulation branch results.

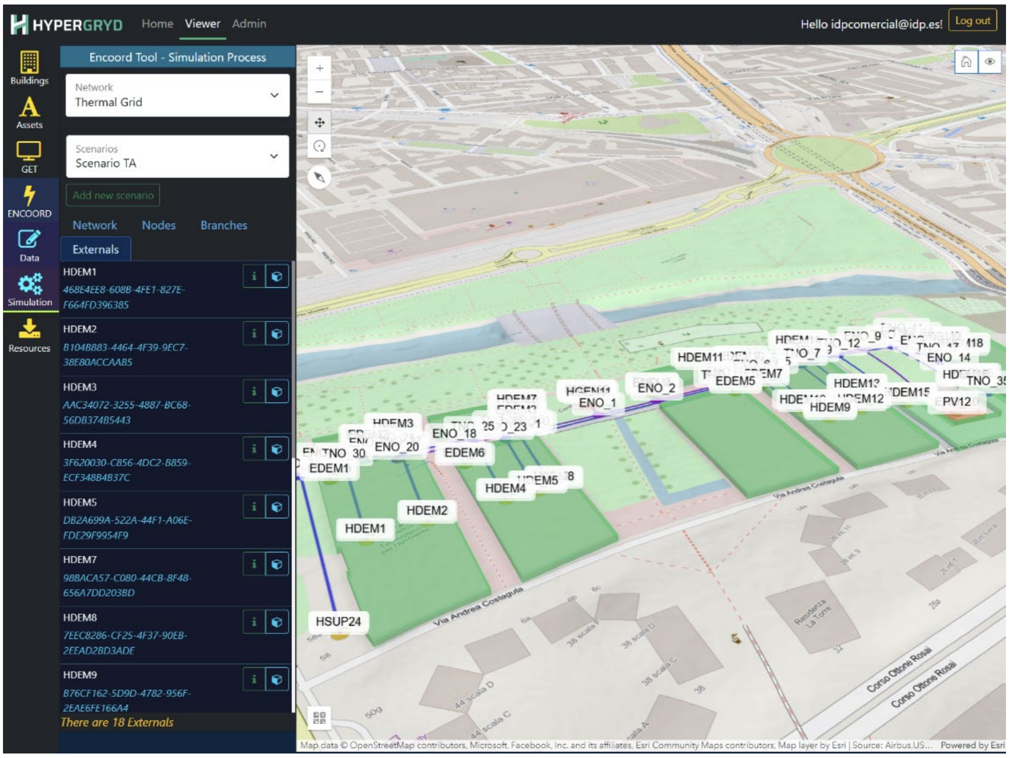


Figure 26. Example of the list of externals (i.e., heat demand and heat supply points) in a SAInt thermal network.

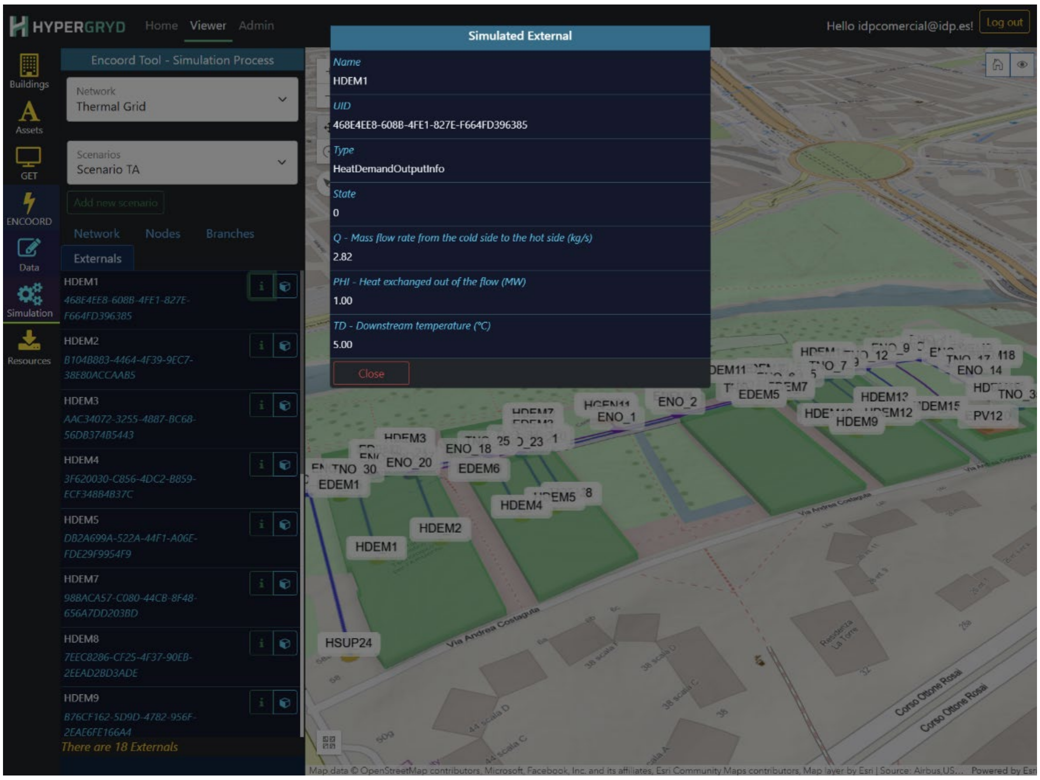


Figure 27. SAInt thermal grid simulation external results.

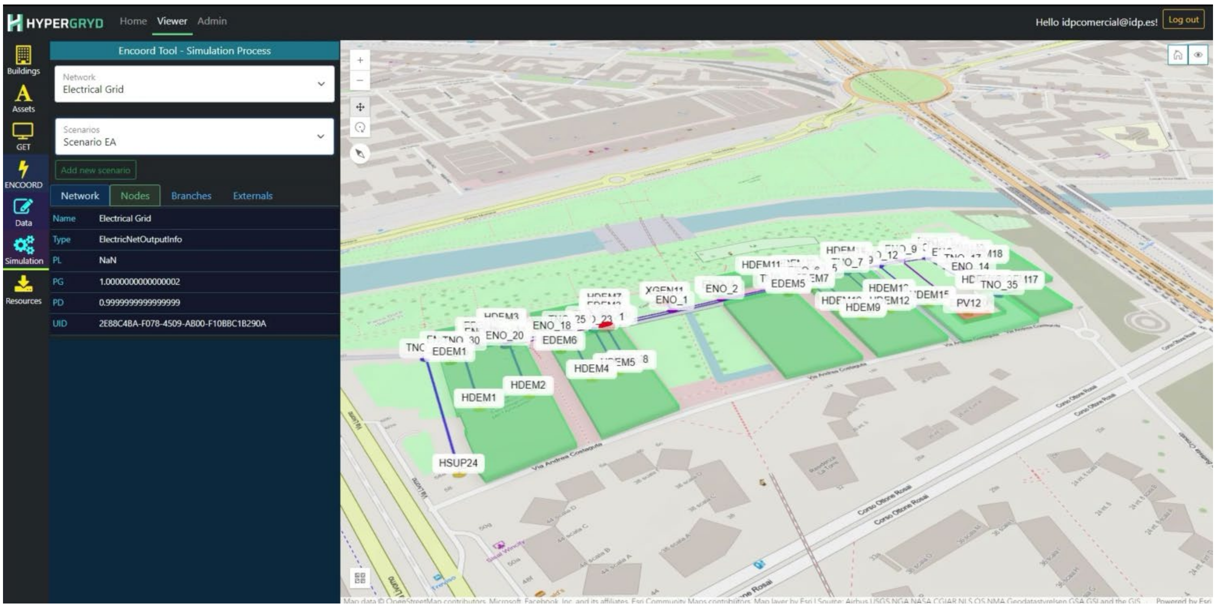


Figure 28. Example of a SAInt electric grid simulation in the HYPERGRYD platform.

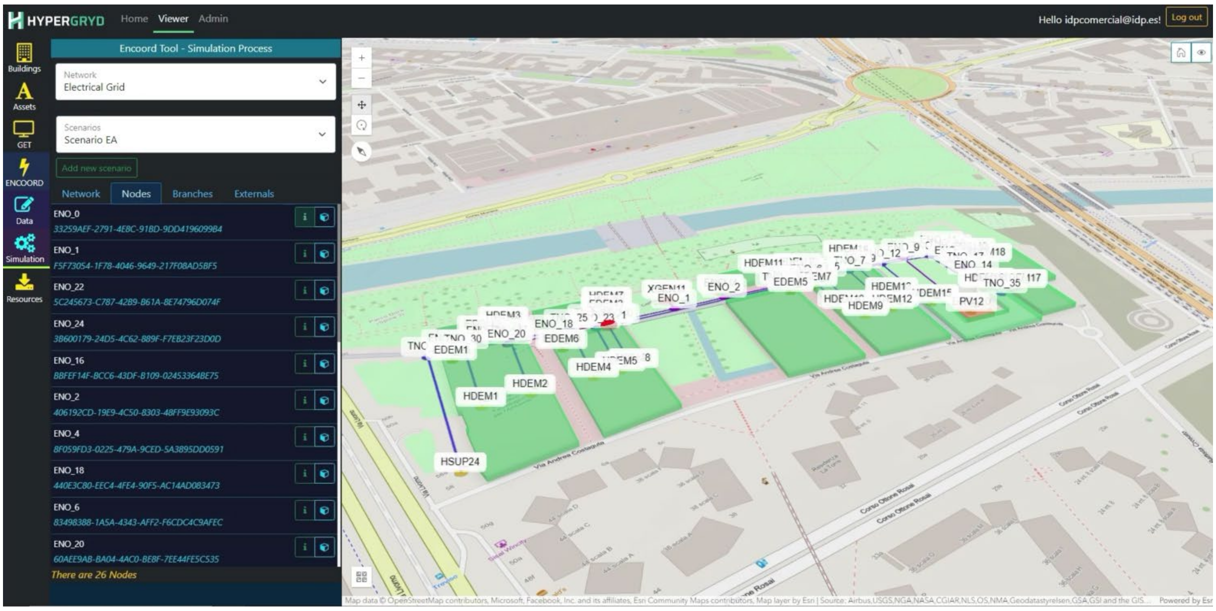


Figure 29. Example of the list of nodes in a SAInt electric grid network.

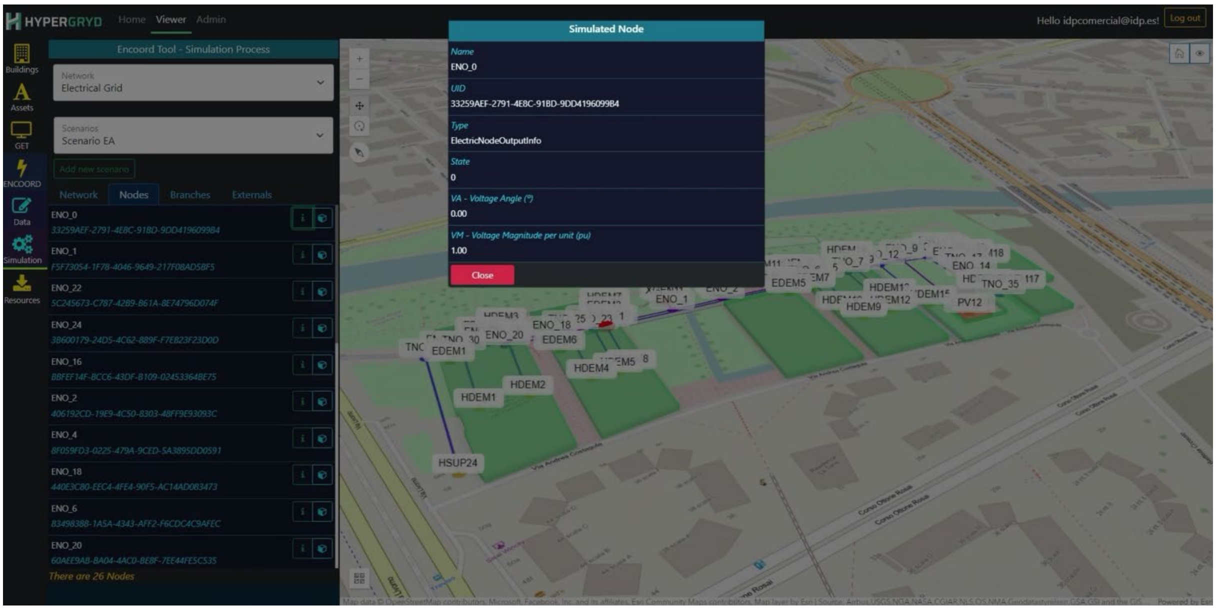


Figure 30. Example of the SAInt electric grid simulation node results.

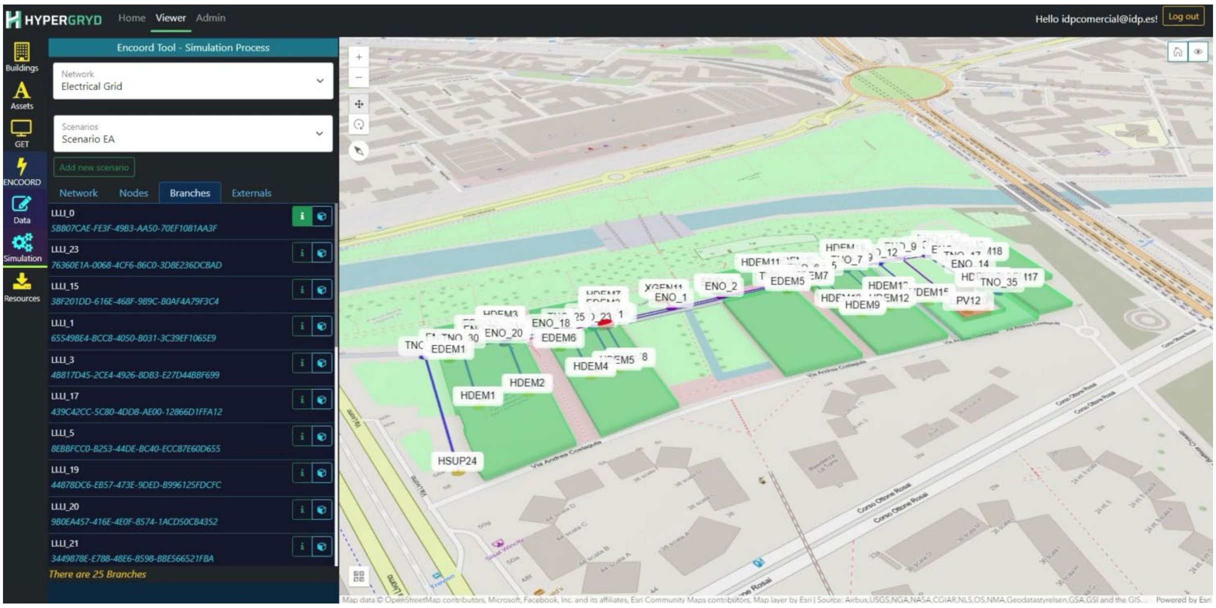


Figure 31. Example of the list of branches (i.e., pipelines) in a SAInt electric grid network.

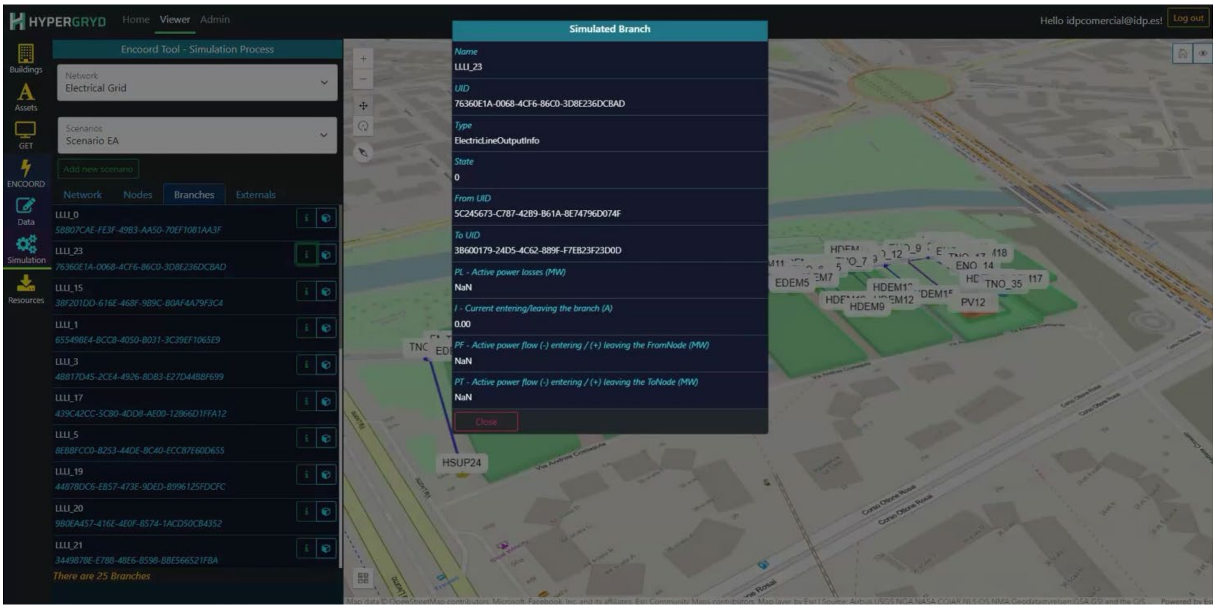


Figure 32. SAInt electrical grid simulation branch results.

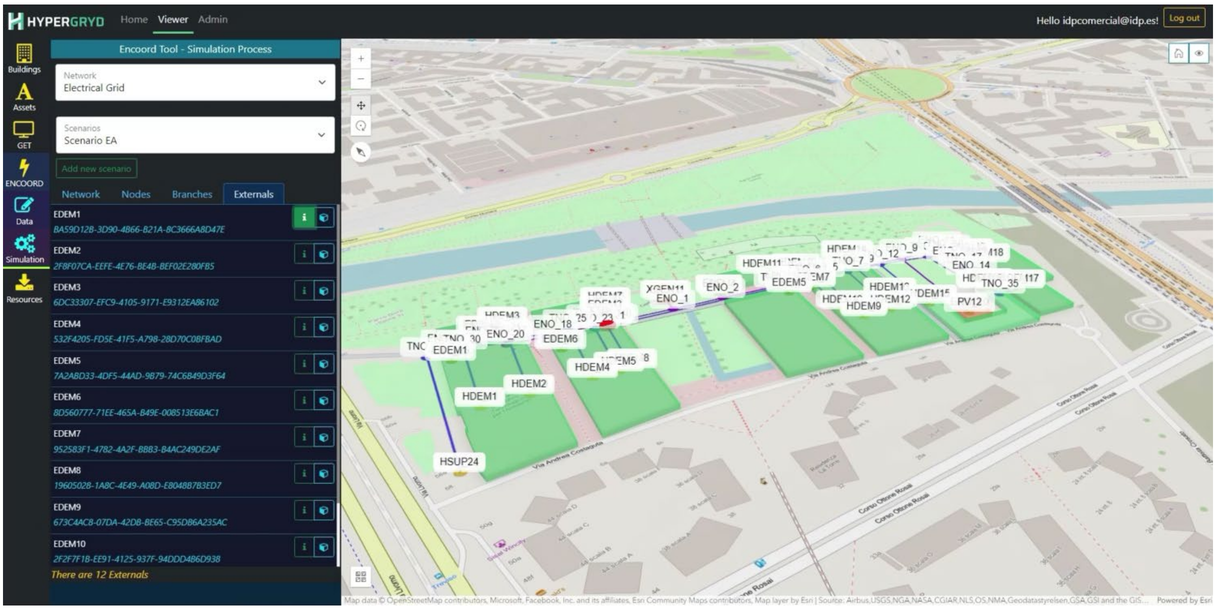


Figure 33. Example of the list of externals (i.e., electric demand and electric supply points) in a SAInt electric network.

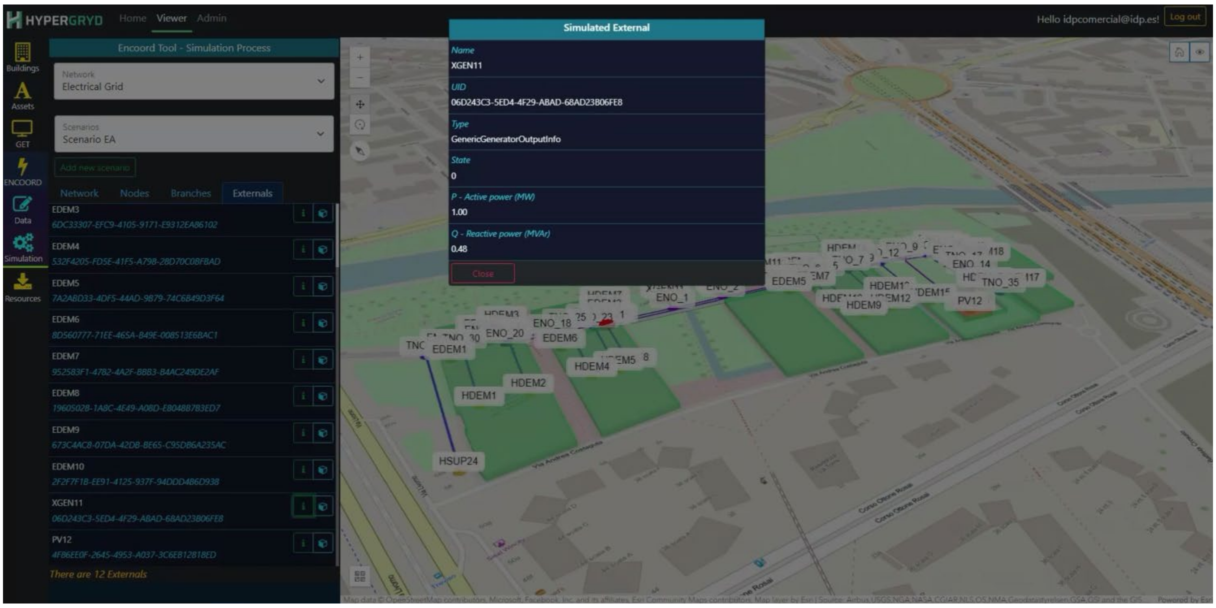


Figure 34. SAInt electrical grid simulation result external.

5 Grid Singularity Exchange (local energy marketplace tools)

The Grid Singularity (GSY) local energy market (LEM) simulation tool (also termed Singularity Map), a core component of the HYPERGRYD project, is based on the Grid Singularity Exchange tool stack (open source GPL v.3 code base and copyright protected user interfaces) that facilitates bottom-up energy markets through advanced simulation and implementation of peer-to-peer (P2P) and other trading mechanisms. The GSY LEM simulation tool enables modelling and analysis of energy community scenarios, supporting prosumers, community organisers, and energy researchers to assess the benefits of local energy trading and plan for an optimal energy asset configuration (type and size of distributed energy resources) at their location. More information on the GSY tool is available in the

Grid Singularity wiki: https://gridsingularity.github.io/gsy-e/documentation/ and the tool can be accessed both via HYPERGRYD platform and directly via Grid Singularity web portal: https://gridsingularity.com/singularity-map .

This service was integrated into the HYPERGRYD PaaS/SaaS through a direct link in the portal as shown in the following image, which in respect of GDPR, provides a visualization of only a limited, anonymised simulation conducted using data from the Sonnenplatz pilot community for just three homes with heat pumps engaging in P2P energy trading. In the commercial, public version of the IDP platform this data will not be shown but only a description of the tool functionalities with the link for interested users. Currently this is a free service provided to any user upon registration.

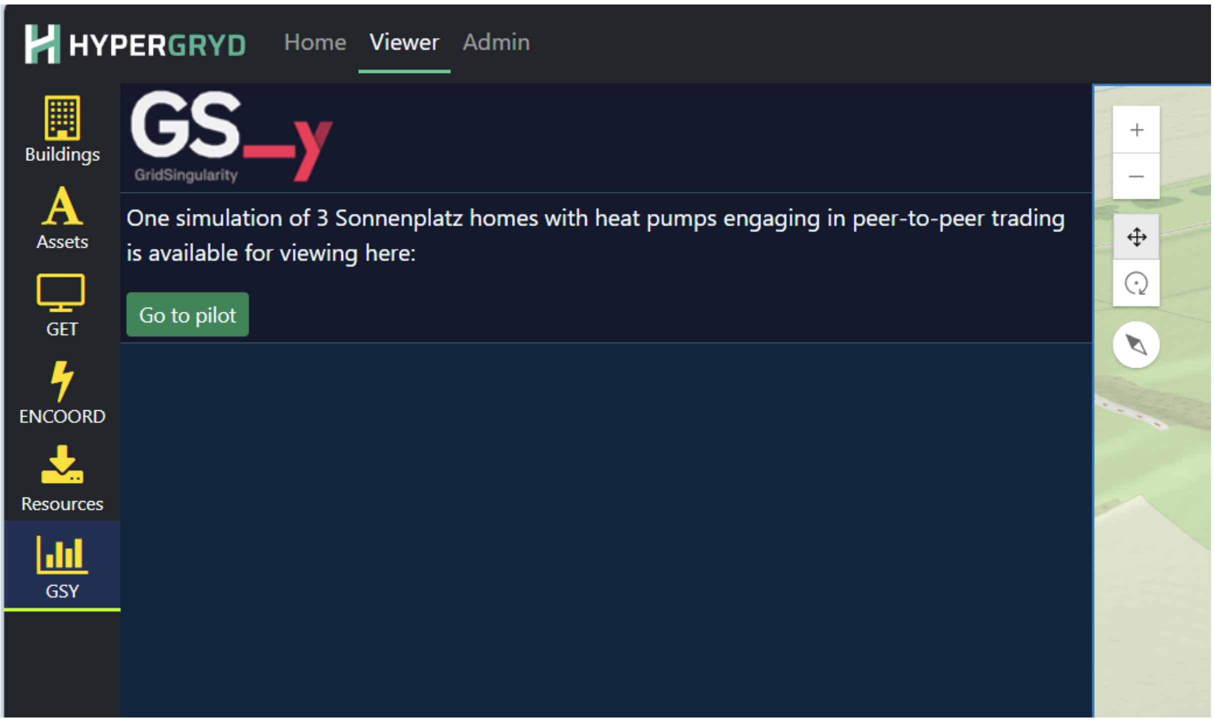


Figure 35. Direct access to the GSY LEM Simulation Tool results of an example simulation through the HYPERGRYD Platform dashboard.

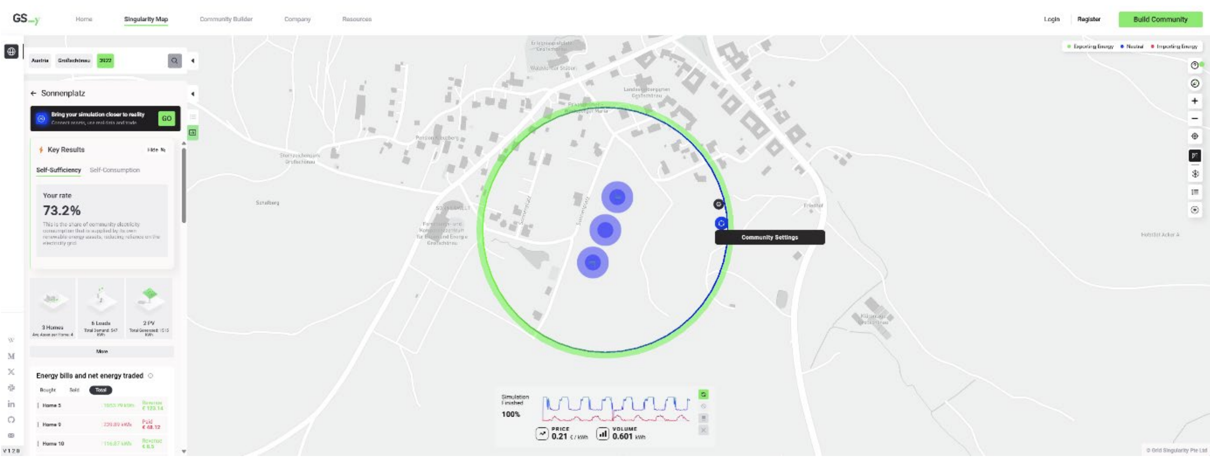
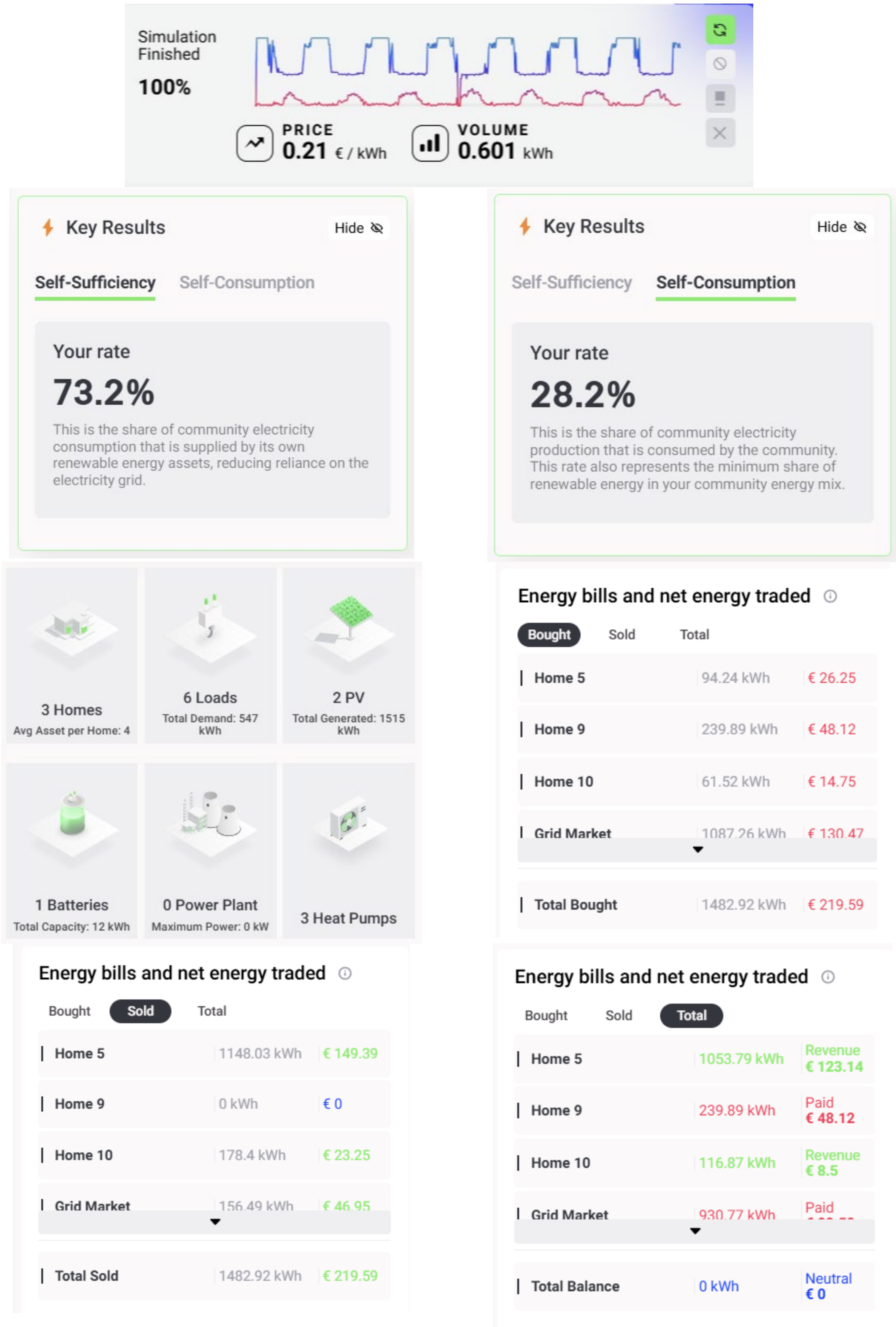


Figure 36. GSY LEM Simulation Tool: dashboard visualisation results of an example simulation.


Simulation Finished
100%
PRICE
0.21 € / kWh
VOLUME
0.601 kWh
Key Results
Hide
Self-Sufficiency
Self-Consumption
Your rate
73.2%
This is the share of community electricity consumption that is supplied by its own renewable energy assets, reducing reliance on the electricity grid.
Key Results
Hide
Self-Sufficiency
Self-Consumption
Your rate
28.2%
This is the share of community electricity production that is consumed by the community. This rate also represents the minimum share of renewable energy in your community energy mix.
3 Homes
Avg Asset per Home: 4
6 Loads
Total Demand: 547 kWh
2 PV
Total Generated: 1515 kWh
1 Batteries
Total Capacity: 12 kWh
0 Power Plant
Maximum Power: 0 kW
3 Heat Pumps
Energy bills and net energy traded
Bought
Sold
Total
Home 5 94.24 kWh € 26.25
Home 9 239.89 kWh € 48.12
Home 10 61.52 kWh € 14.75
Grid Market 1087.26 kWh € 130.47
Total Bought 1482.92 kWh € 219.59
Energy bills and net energy traded
Bought
Sold
Total
Home 5 1148.03 kWh € 149.39
Home 9 0 kWh € 0
Home 10 178.4 kWh € 23.25
Grid Market 156.49 kWh € 46.95
Total Sold 1482.92 kWh € 219.59
Energy bills and net energy traded
Bought
Sold
Total
Home 5 1053.79 kWh Revenue € 123.14
Home 9 239.89 kWh Paid € 48.12
Home 10 116.87 kWh Revenue € 8.5
Grid Market 930.77 kWh Paid
Total Balance 0 kWh Neutral € 0

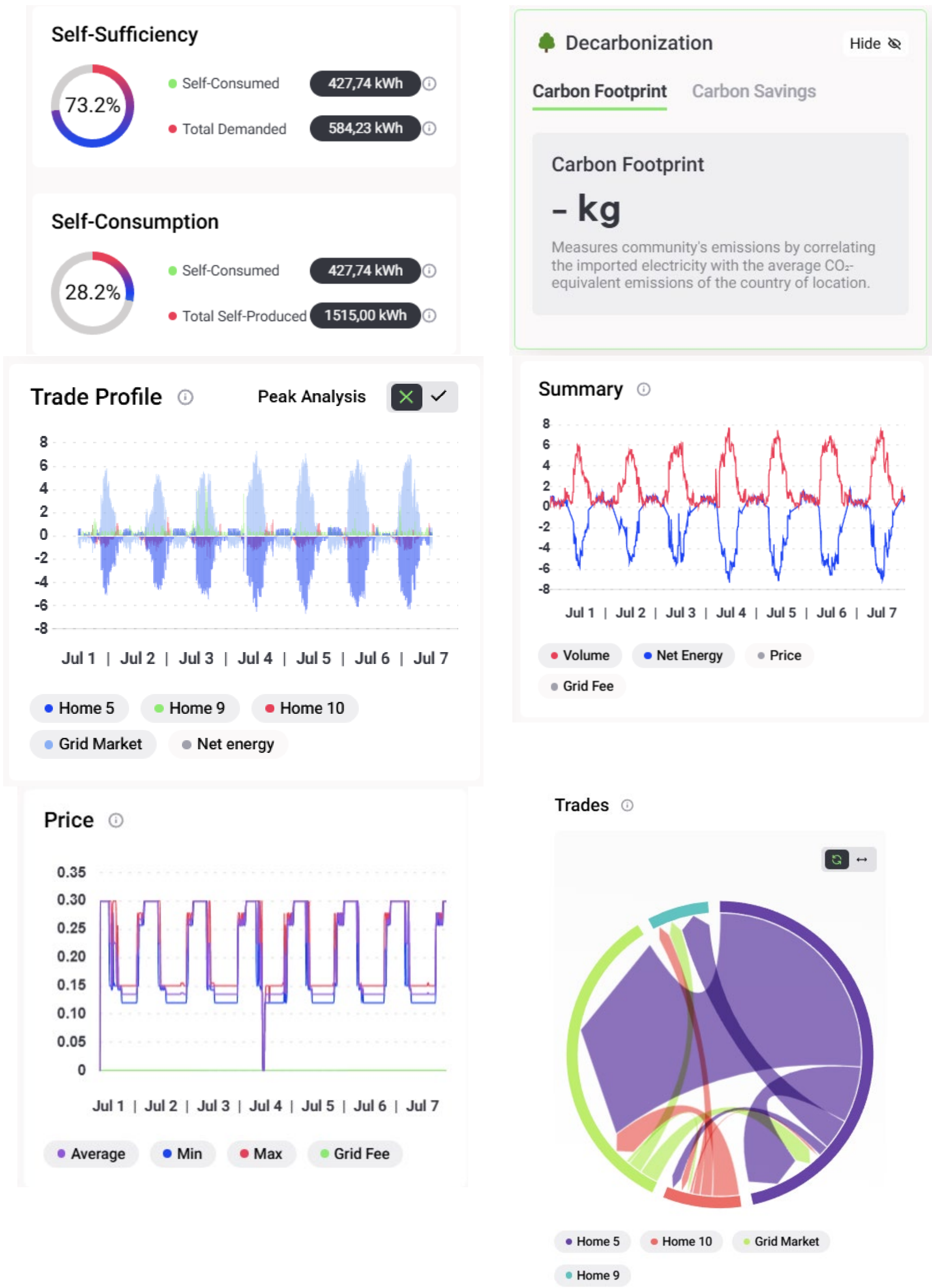


Figure 37. GSY results.

6 ICT-enabled AI tool for heating management of a local energy community

This solution consists of an open-source software tool that enables real-time data collection and enables cost-effective heating by coordinating energy management among community members. This service was integrated through an API that allows the user of the HYPERGRYD platform to visualize the data coming from the smart meters installed in the living lab, as well as its historic data.

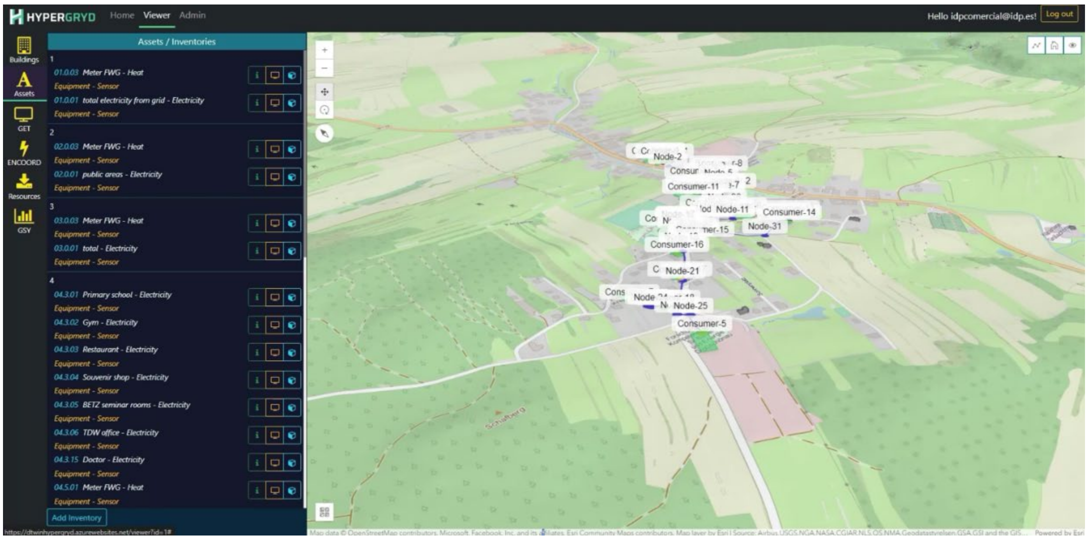


Figure 38. HYPERGRYD platform assets inventory.

Figure 39. HYPERGRYD platform smart meter data visualization.

Based on an edge computing architecture, this tool enables real-time data collection from sensors and meters installed on the SONNE district heating substations. As an optional feature, it can also include some online services from the cloud such as weather forecast. Thanks to their IoT-enabled communication, such sensors and meters can send data remotely to the KTH server, via internet, for storage and later for further analysis through the MQTT protocol. Data communication, security, storage and processing are all handled locally on the KTH server. The server backend is meant to provide some advanced AI-enabled services such as predictions and control recommendation. This later was performed as a demand side management (DSM) algorithm, which explains why the KTH server was called DSM server in Figures 41 and 42.

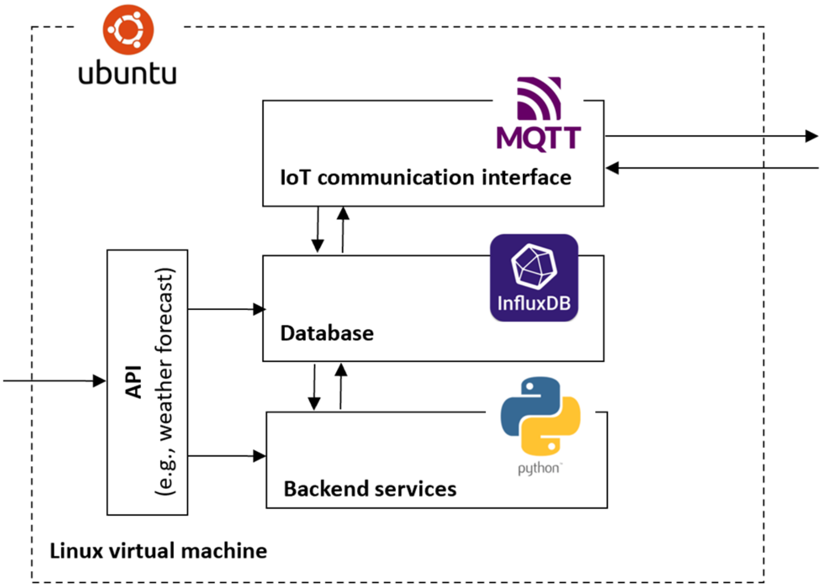


Figure 40. Software solution of the KTH ICT tool for SONNE.

As shown in the figure below, data is being fetched in real time from the electric and heat meters, as well as the water temperature and flow sensors. This data goes to the MQTT broker in the KTH server via internet in JSON format, where it was decoded, processed and stored locally in a time series database using a high programming language.

Starting from the ICT database, real-time and historical data can be made accessible for any third-party exploiter via HTTP API or SQL as described in Figure 42. In the framework of DSM, control recommendation for any existing heat pump with a storage system in the DH heated buildings is possible, here the DSM server sends the right condenser temperature setpoints associated with the heat pump IDs via JSON format. More details about the DSM principle developed by KTH aregiven in D3.4.

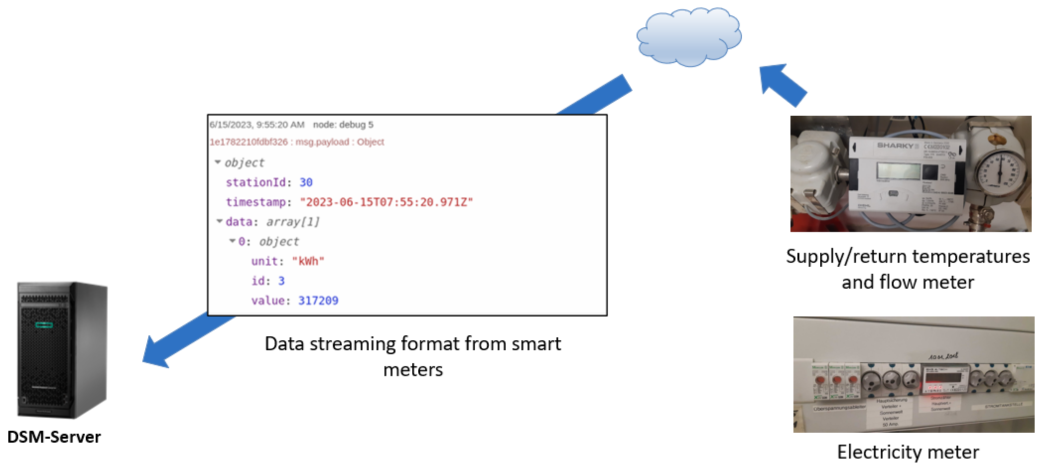


Figure 41. Data flow from smart meters to the KTH server.

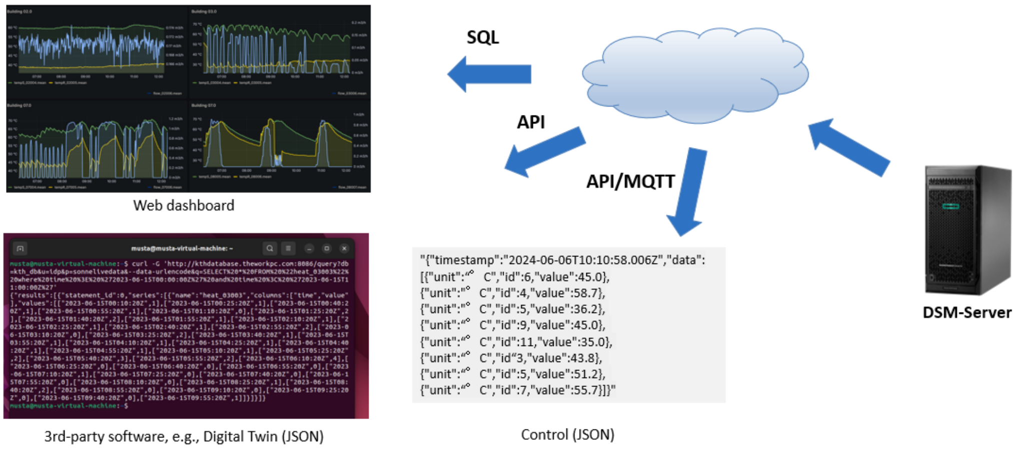


Figure 42. Data flow from the KTH server to the different service users.

7 Conclusions

This report detailed the successful integration of tools and services developed by project partners GET, ENCO, and GSY into the HYPERGRYD PaaS/SaaS developed by IDP. The implementation adhered to the architecture defined in Deliverable 4.2: “ICT Architecture and data requirements for HYPERGRYD DT PaaS”.

8 References

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