HYPERGRYD

WP5 – TRL5 demonstration in living labs and virtual labs in LEC

Task 5.2 - Digital Twins of components and demonstrators

D5.3 - Digital Twins of components and Living Labs development, final version

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

DISCLAIMER

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Deliverable title	Digital Twins of components and Living Labs development, final version.		
Description	This deliverable highlights the successful integration of the BIM-GIS toolkit with the Gussing Energy Technologies Gmbh (GET) & Encoord GmbH (ENCO) tools into the HYPERGRYD platform for DHC network piping and configuration planning, demonstrating its application in both SONNE and ENVI living labs. The BIM-GIS toolkit provides essential model inputs for the GET and ENCO tools, enabling streamlined design and analysis of energy networks.		
WP No.	WP5		
Related task	Task 5.2 - Digital Twins of components and demonstrators		
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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 and Electrical Grids. The project includes 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.

This report focuses on the successful implementation of a BIM-GIS toolkit within the HYPERGRYD platform. This toolkit is for planning the piping and layout of district heating and cooling networks. It has been used in two real-world settings: the Sonnenplatz Grosschonau GMBH (SONNE) and Parco Scientifico Tecnologico Per Lambiente Environment Park Torino SPA (ENVI) living labs. The experiences in SONNE and ENVI living labs validate the toolkit's effectiveness in real-world scenarios.

In both SONNE and ENVI living labs, the BIM-GIS toolkit developed by IDP Ingenieria Y Arquitectura Iberia SL (IDP) works in conjunction with the tools developed by Gussing Energy Technologies Gmbh (GET) and Encoord GmbH (ENCO). The BIM-GIS toolkit provides the models which are essential inputs for the GET and ENCO tools, enabling them to perform their specific calculations and simulations. This collaboration demonstrates a streamlined workflow for designing and analysing energy networks.

- 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.

This report is primarily aimed at professionals such as district heating operators, energy suppliers, and policymakers. It provides an overview of how the BIM-GIS toolkit can support decision-making and optimise the design of future district heating networks.

On behalf of Authors

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2 Introduction

2.1 Scope

This deliverable presents an in-depth overview of IDP's implementation of the BIM-GIS toolkit within the HYPERGRYD platform, specifically tailored for DHC network piping and configuration planning as part of Work Package 4. As a result of T5.2 – "Digital Twins of components and demonstrators," it details the implementation of the Digital Twin Platform as a service developed within WP4 in the HYPERGRYD Living Lab, based on the BIM-GIS parametric model and planning toolbox. The BIM-GIS toolkit provides essential model inputs for the GET and ENCO tools, enabling them to perform their specific calculations and simulations.

2.2 Audience

This report targets the professional parties having interest on the application of a BIM-GIS toolkit for DHC network piping and configuration planning providing a decision support and generate optimized network layouts and dimensioning parameters for the planning of future-generation district heating networks. Since the text demands baseline understanding for the context, there may be limitations in understanding for certain interest groups such as 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.).

2.4 Abbreviations

BIM: Building Information Modelling

GIS: Geographic Information System

DHC: District Heating and Cooling

DSO: Distribution System Operator

ESCO: Energy Service Company

ICT: Information and Communications Technology

PaaS: Platform as a Service

SaaS: Software as a Service

2.5 Contributions of partners

The IDP team exclusively authored this deliverable.

2.6 Baseline

This deliverable focuses on IDP's implementation of the BIM-GIS toolkit within the HYPERGRYD platform for DHC network piping and configuration planning. A key aspect is demonstrating the toolkit's effective communication and data exchange with the GET and ENCO tools in the SONNE and ENVIPARK living labs. This implementation is built upon the work detailed in D4.5 – "Fully operational HYPERGRYD Platform and API with integrated tools and services," and is a result of Task T4.5 – "Workflow management and end-user API development". T4.5 was specifically concerned with integrating the different tools and services (including GET, ENCO) within the HYPERGRYD platform, providing the necessary framework for the BIM-GIS toolkit to operate in conjunction with them.

2.7 Relation to other activities

Explain relations to other activities in the HYPERGRYD project:

- **Inputs:** Both SONNE and ENVI partners utilized the BIM-GIS toolkit user manual presented in D4.3 as their primary guide for modelling their respective buildings and thermal-electric piping networks within the HYPERGRYD platform.
- **Outputs:** The BIM-GIS toolkit facilitates the creation of models that serve as essential inputs for the GET and ENCO tools, enabling their specific calculations and simulations. This showcases the practical implementation of the workflow management and tool integration goals of Task T4.5. The successful interaction of these tools also contributes to the realization of the HYPERGRYD Platform and API as described in D4.5.

2.8 Structure

- **Section 1:** Executive Summary.
- **Section 2:** LiLs BIM/GIS models.
- **Section 3**: Conclusions.

3 LiLs BIM-GIS models

This chapter will provide a detailed account of the modelling and development process carried out for both the Sonnenplatz and Envipark living labs within the HYPERGRYD project.

Before entering in detail with these living labs, it is crucial to understand that both ENCO (SAInt - Scenario Analysis Interface for Energy Systems) and GET (Exergoeconomic optimization tool for 4th and 5th generation of DHC) have different network models:

- GET defines the different lines and polylines that constitute the network as "connections" when they connect a consumer with the network or as "pipelines" in othercases. The points where a pipeline connects with a supplier building and the points where two or more pipelines and/or connections join are defined as "nodes", while the points where a connection connects with a consumer building are defined as "consumers". It is up to the user drawing the network to define whether the pipeline they are drawing is a pipeline or a connection. The ICT tool automatically defines the nodes in the start and ending points of the created lines and polylines when drawing a pipeline and in the points where two or more of them join. For the connections, the ICT tool automatically creates a consumer at the start point of the line or polyline and a node at the point where the connection joins with a pipeline.
- ENCO defines each line that constitutes the network as "branches", it does not work with polylines, meaning that each polyline defined as "pipeline" by GET will be interpreted as multiple branches by ENCO. Each point where a branch starts or ends, including the points where 2 or more branches join, is defined as a node. Among all nodes, there are nodes that correspond to the points where a consumer or supplier connects to the network. In the same coordinates of these nodes, ENCO defines another point known as "external" which will have information related to the contribution or consumption of energy from the network that the supplier or consumer, respectively, has on that network.

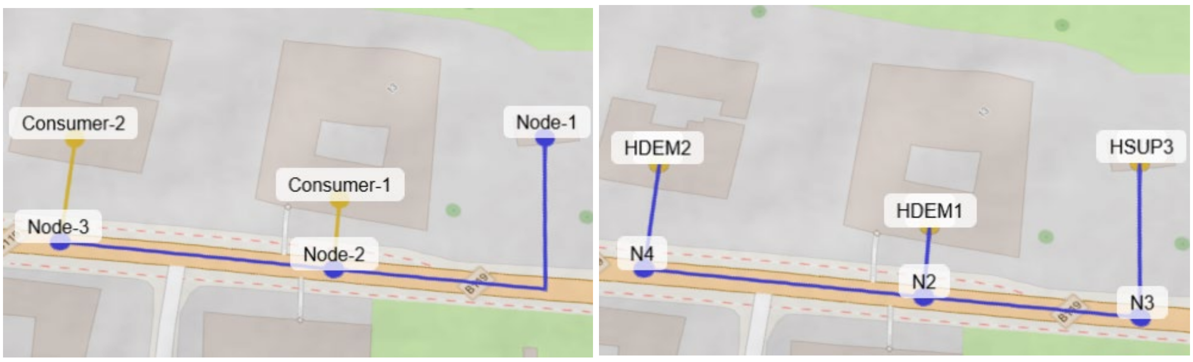


Figure 1. Comparison of an example network modelled by GET (left) and by ENCO (right)

When a network is modelled, it corresponds to the GET network model and it is necessary to create the corresponding Encoord network model before running any ENCO simulation. To create the ENCO network model, enter on the "Data" module in the "ENCOORD" tool and select the network that does not have the ENCO network model yet. The ICT tool detects the lack of an ENCO network model and offers the option to create that model. Before creating the ENCO network model, however, it is advised to make sure that the GET network's layout is the definitive one, since each future change in the GET model would not be applied to the corresponding ENCO network model.

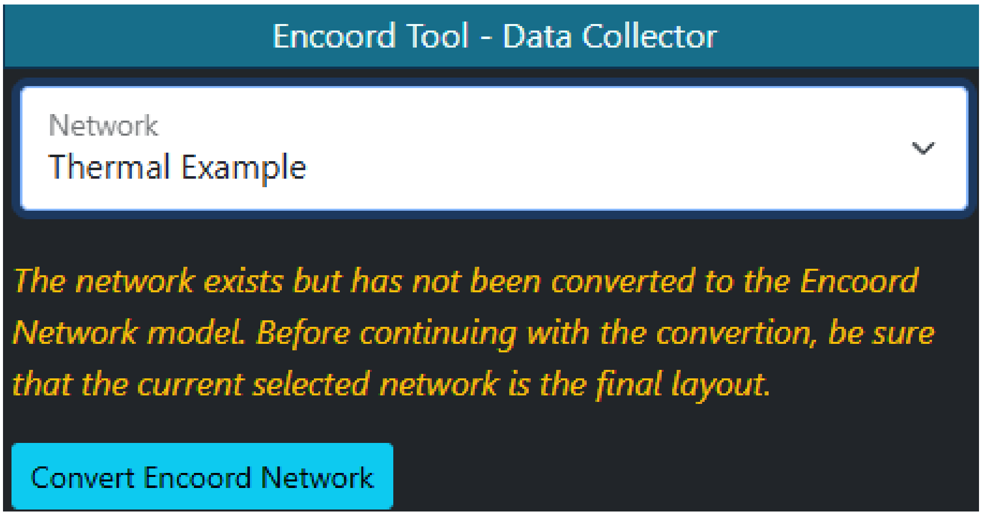


Figure 2. Encoord Tool: creating an Encoord network from a GET network.

Finally, when creating the ENCO network model, the externals corresponding to the network consumers will be automatically created from the consumer points defined in GET's network model, but the externals corresponding to the suppliers need to be added manually. To add the suppliers in the ENCO network model you need to enter the "Data" module in the ENCOORD tool and select the corresponding network. Then go to the "Nodes" tab and click on the green information button of the node corresponding to the external.

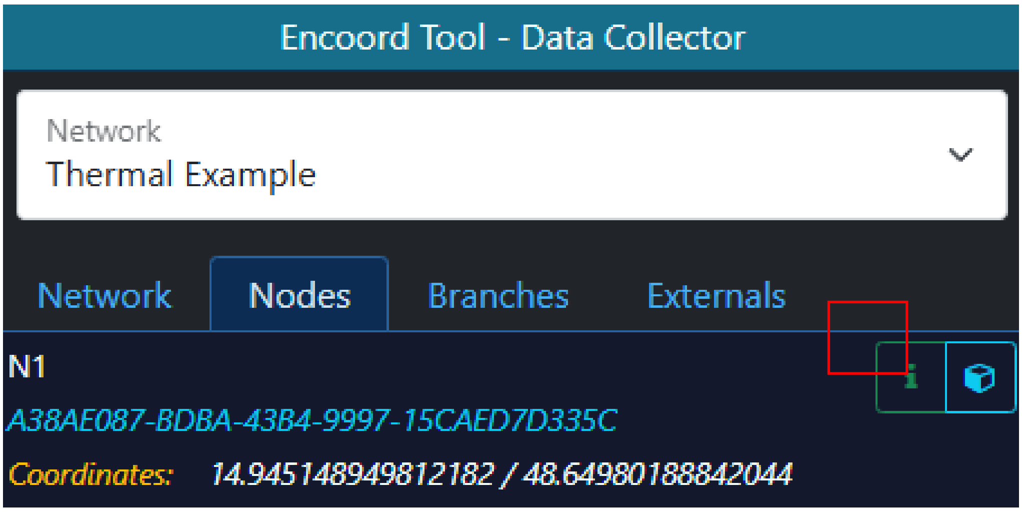


Figure 3. Editing the node data in the ENCO network model.

Then check the "Is External?" option, select the corresponding type of supplier (HSUP for thermal networks and HYDP, HGEN, PV, ESTR or XGEN for electric networks) on the "ExternalType" select list and click on the green "Save changes" button. This will create a new external on the coordinates of the selected node.

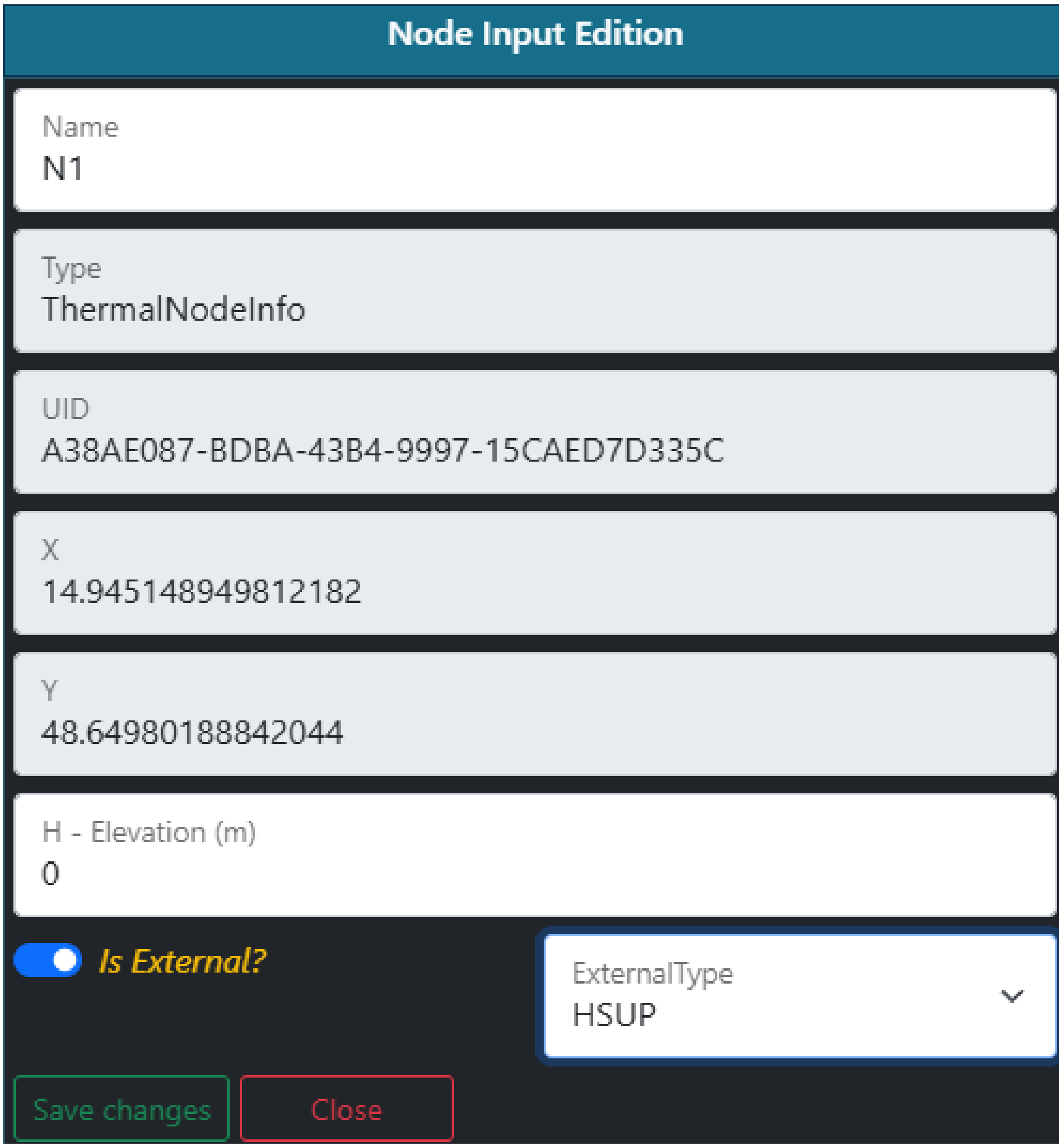


Figure 4. Creating an external from a node in the ENCO network model on a thermal network.

You can check the new created node's data and edit it by going to the "Externals" tab in the same module where you just created the external (make sure that the selected network in the "Network" select list is the right one) and by clicking on the green information button of the corresponding external.

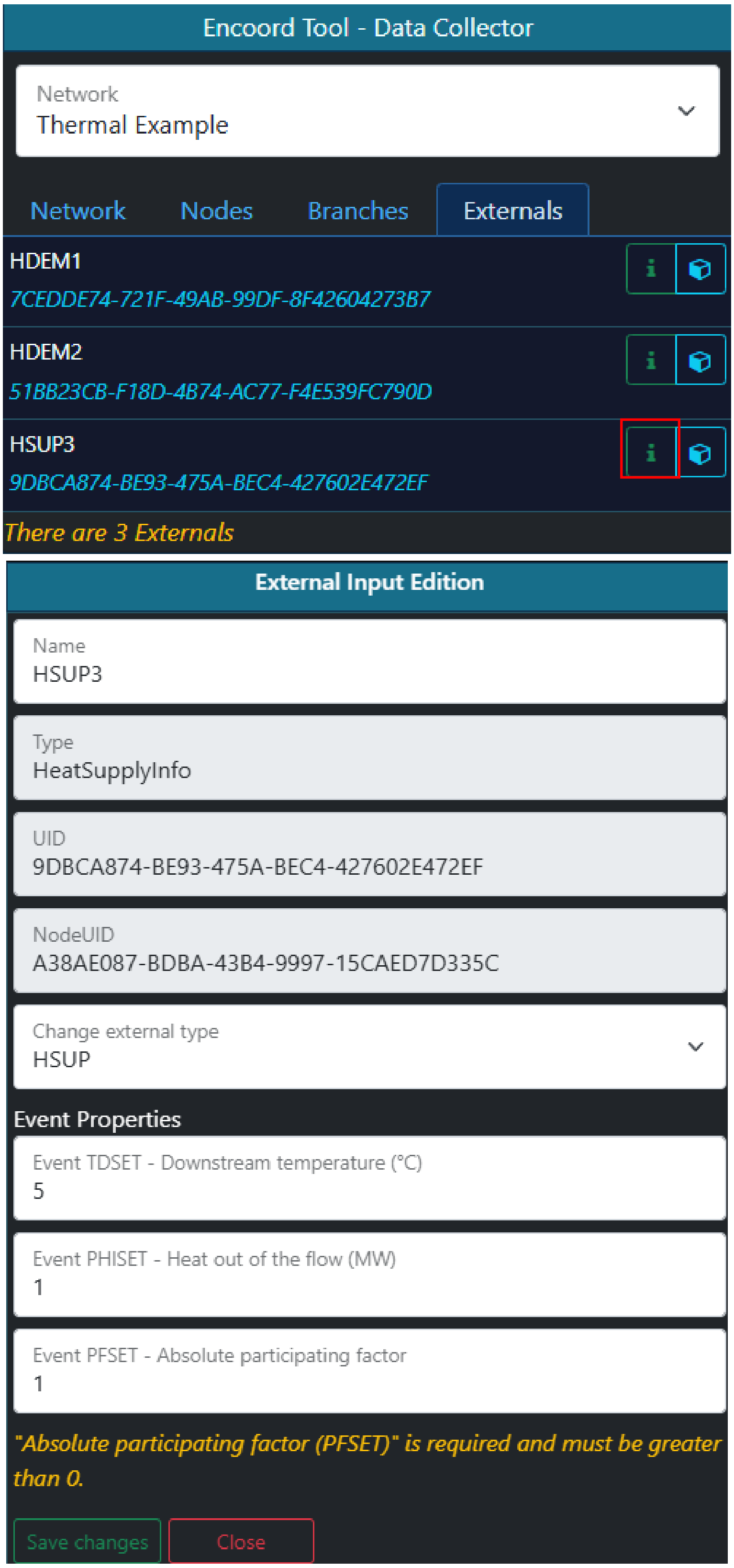


Figure 5. Editing an external from an ENCO network model on a thermal network.

Using the “Simulation” module of the ENCOORD TOOL you can run a simulation of a thermal or electric network. Select the network you want to run the simulation for, or the network which’s simulation results you want to consult in the “Network” select list on the module. Each simulation is related to a “scenario”, which has a name to identify it, a time step, a time interval (start and end date times of the simulation) and a scenario type (“SteadyThermal” for thermal networks and “SteadyACPF” for electric networks) and is related to an ENCO network model.

To create a new scenario in order to run a new simulation, click on the green “Add new scenario” button. You will be asked to provide a name, start and end dates and time step (in seconds) for the new scenario, the “ScenarioType” property will be automatically set depending on the type of network (thermal or electric network) of the ENCO model network selected on the “Network” select list.

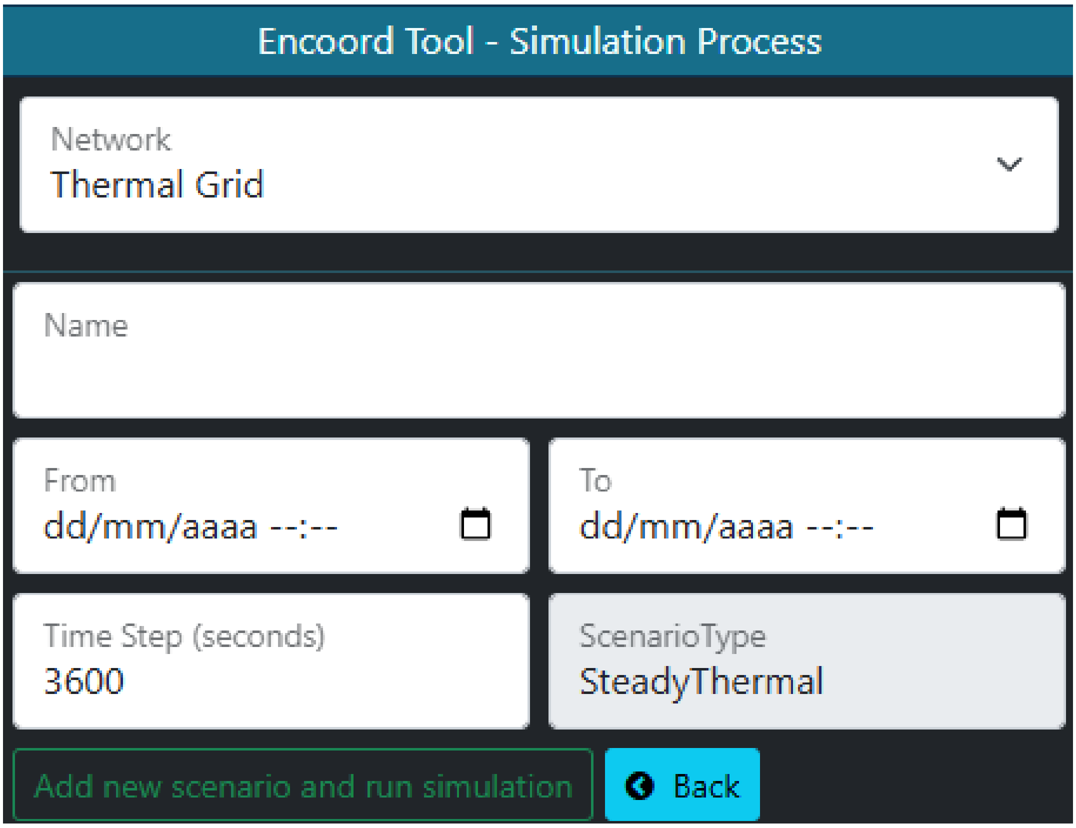


Figure 6. Creating a new scenario for an ENCO network model.

Once you filled the scenario form, click on the green “Add new scenario and run simulation” button to execute those actions or click on the blue “Back” button to go back to selecting a scenario.

To consult existing simulation’s results, select the corresponding scenario in the “Scenarios” select list. This will display a view with different tabs containing the simulation results of the network and of each of the elements that constitute the network as mentioned in the tab names “Nodes”, “Branches” and “Externals”.

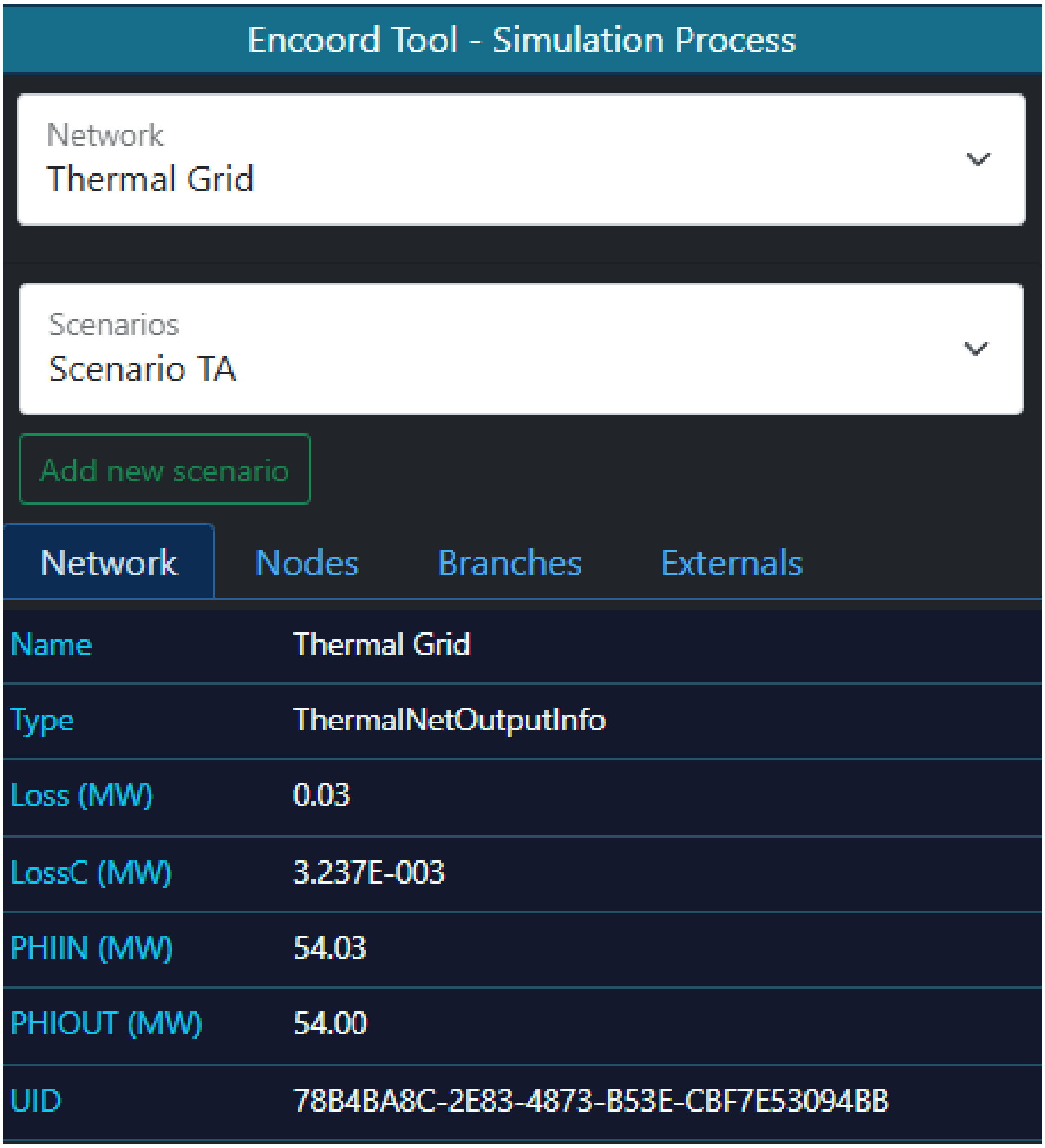


Figure 7. Consulting the ENCO simulation results of a thermal network.

To consult the data of a specific element in the network, go to the corresponding tab for the element which's data you wish to consult. Then click on the green information button, which will open a new popup window containing the simulation results for that node. To close the popup window, simply click on the red "Close" button.

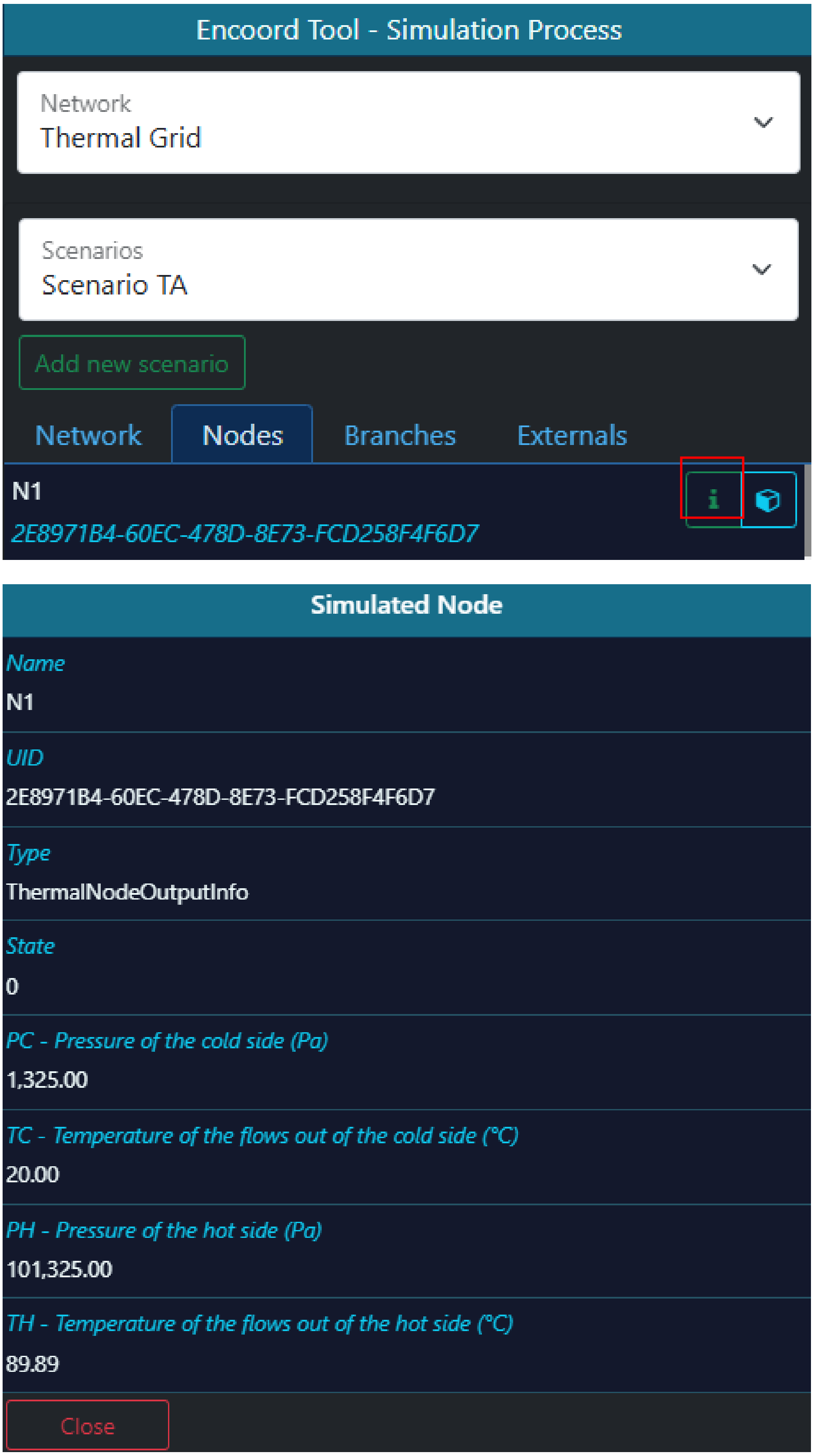


Figure 8. Consulting the ENCO simulation results of a node of a thermal network.

3.1 SONNENPLATZ LiL

The Sonnenplatz LiL underwent modelling using IDP's BIM-GIS toolkit designed for DHC network piping and configuration planning within the HYPERGRYD project. Leveraging this advanced ICT tool, partners from Sonnenplatz effectively modelled various buildings and pipeline networks associated with the HYPERGRYD initiative.

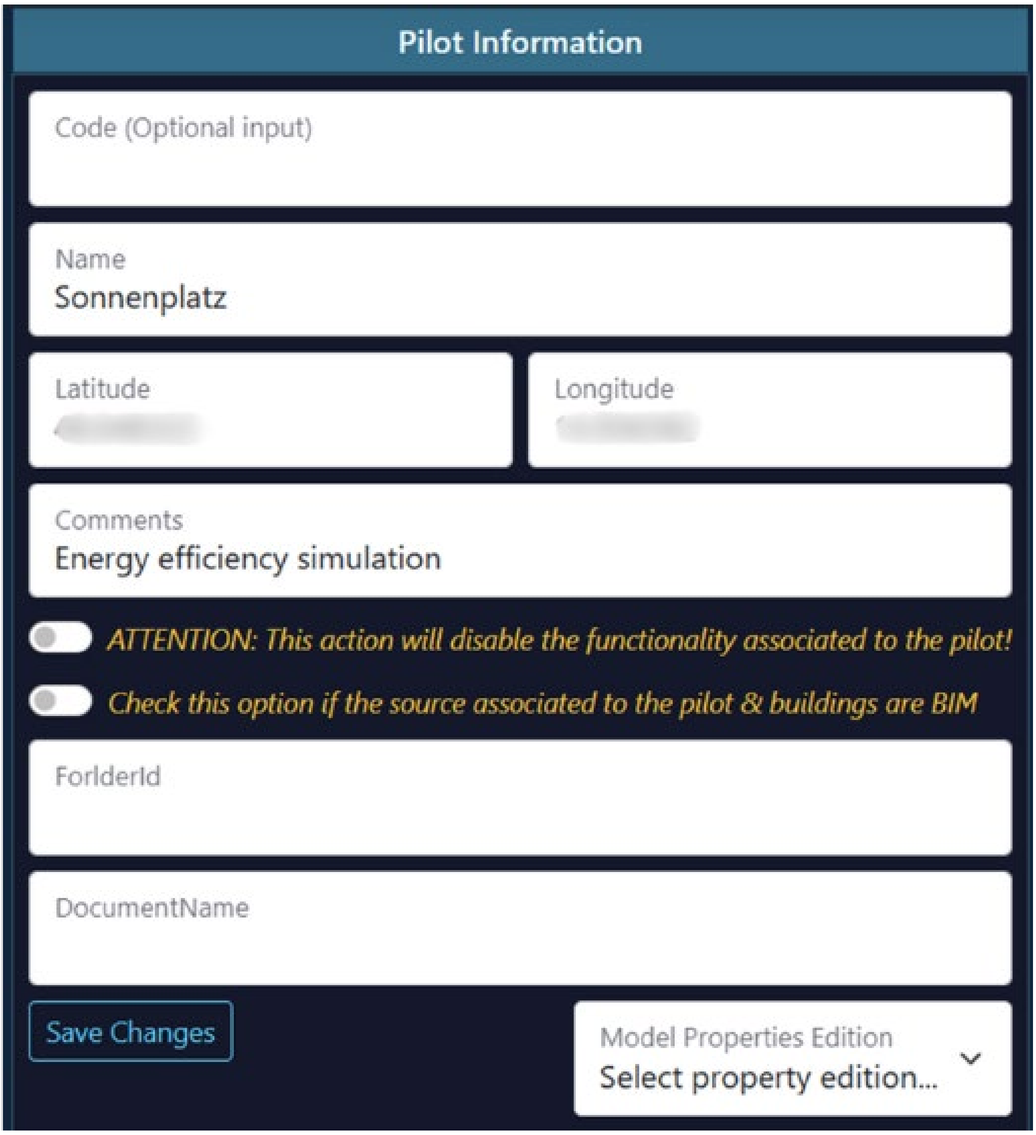


Figure 9. SONNE pilot information.

Figure 10. SONNE in the world map.

The subsequent images present the comprehensive BIM-GIS model of the Sonnenplatz LiL, comprising 24 consumer buildings, 1 supplier building, and their thermal piping network.

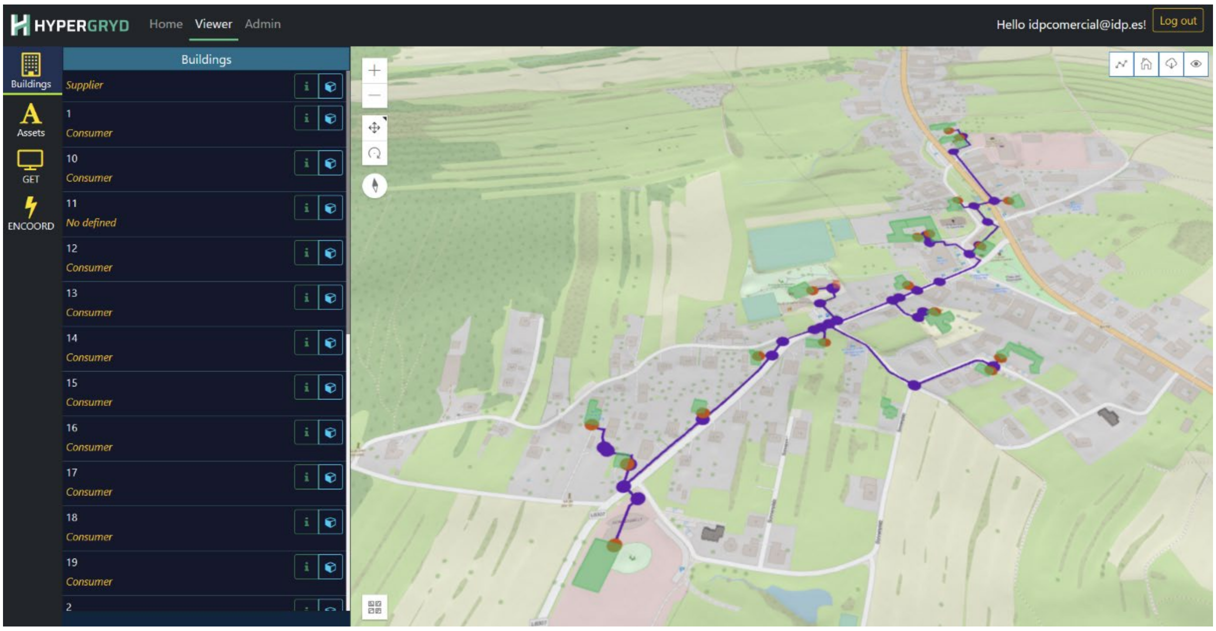


Figure 11. SONNE BIM-GIS model.

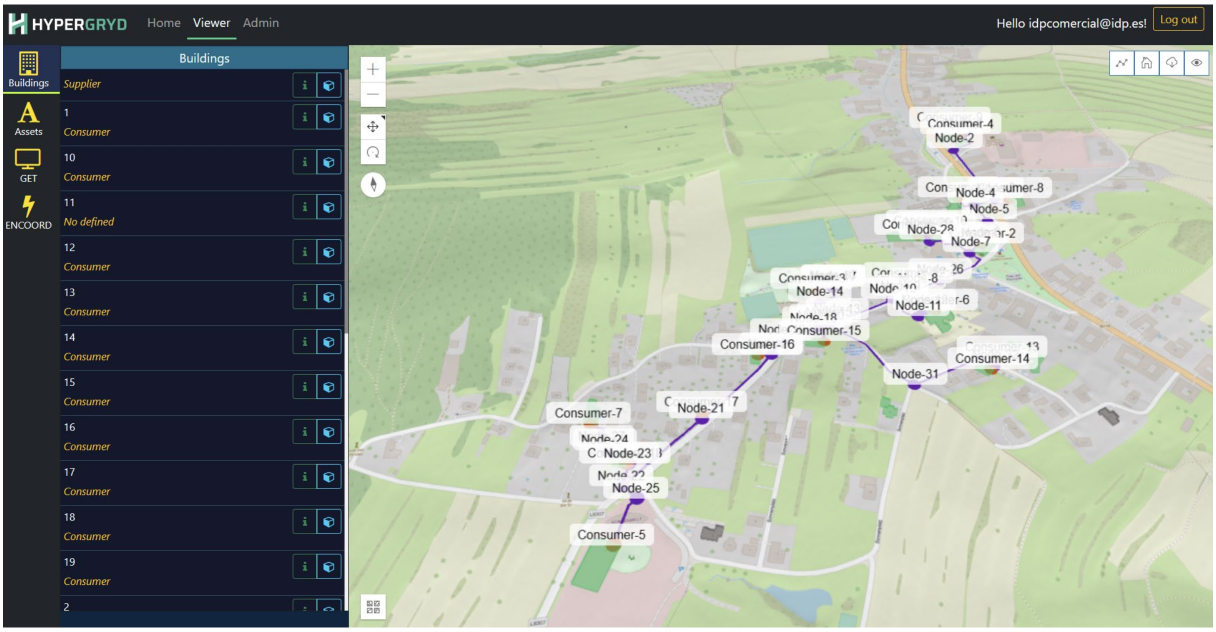


Figure 12. SONNE buildings and nodes.

The following images depict the implemented definition for the modelled thermal network piping within the framework of the modelling process.

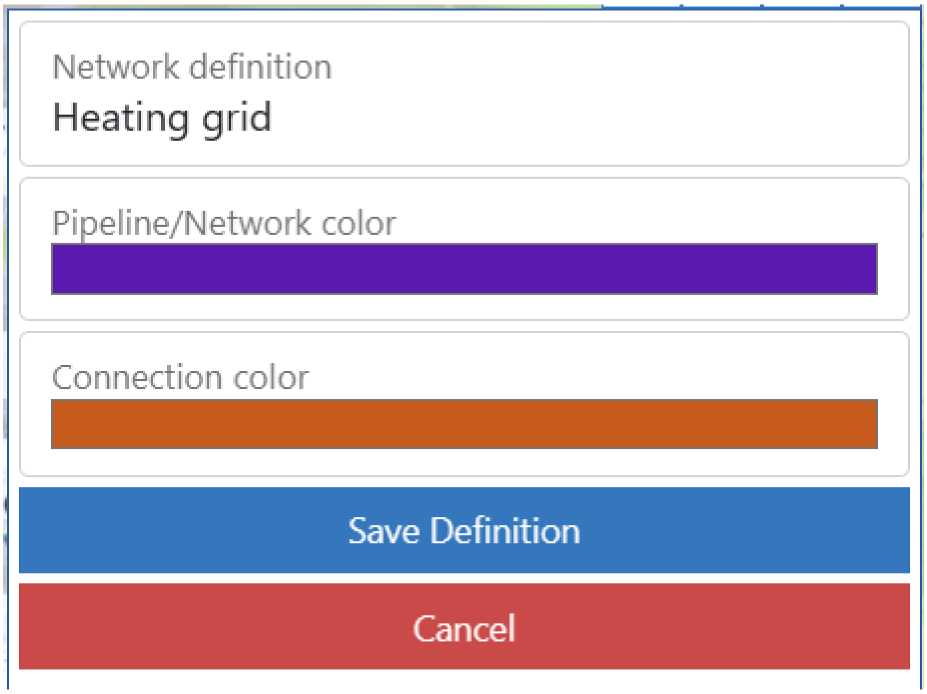


Figure 13. SONNE heating grid description.

The following images illustrate examples of the static information stored from various consumer and supplier buildings within the Sonnenplatz LiL. To safeguard user privacy, details such as the address and cadastral code of the buildings have been obscured.

Building Details	
Building Name	24
Building Code	
Address	
Building Type	
Built/Restore Year	0
Cadastral Code	
Use	Consumer
Height	3
Built Area	194.185546875
Plot Area	0
Perimeter	59.205185706088784
Volume	0
Construction Value	0
Cadastral Value	0
consumer_num	8
connected_load	15
pressure_loss_oneway	33898.9427703616
pressure_lost_all	117797.8855407232
edge_id	65

Edit Building Close

Figure 14. SONNE building details example.

Building Details	
Building Name	
Building Code	
Address	
Building Type	
Built/Restore Year	0
Cadastral Code	
Use	Supplier
Height	3
Built Area	-57.875
Plot Area	0
Perimeter	30.67341679597679
Volume	0
Construction Value	0
Cadastral Value	0

Edit Building Close

Figure 15. SONNE supplier details example.

The subsequent images highlight examples of the static information stored from various nodes and thermal piping segments within the network, as provided by the BIM-GIS modelling toolkit. This crucial information is essential for both GET and ENCO to execute their respective calculations and simulations effectively.

Node Edition

Pipeline Definition	Heating grid
Entity Type	Node - Network
text	[23, 47]
connected	[23, 47]
connected_number	2
x	-102610.22771353435
y	391286.67871609196

Edit Node Close

Figure 16. SONNE node details example.

Pipeline Details

Pipeline Definition	Heating grid
Entity Type	Pipeline
Length	0
confirst	[24, 22, 23]
conlast	[23, 47]
confirst_number	3
conlast_number	2
nodeidin	15
nodeidout	16
length	31.555132178479447
heating_grid_grid_type	heat
heating_grid_grid_diameter	65
heating_grid_predecessor	47
heating_grid_tied	{22,24,47}
heating_grid_successor	{22,24}
heating_grid_flow	17310.856929211724
heating_grid_pressure_drop_pipe	8716.50558294938
heating_grid_pressure_drop_sum	12992.949137537653
heating_grid_pressure_drop_specific	276.2309957584023

Edit Pipeline Close

Figure 17. SONNE piping segment details example.

The readily downloadable GeoJSON file from the HYPERGRYD PaaS/SaaS platform facilitates the access of BIM-GIS modelled information through a GIS software such as QGIS, which is free and open-source.

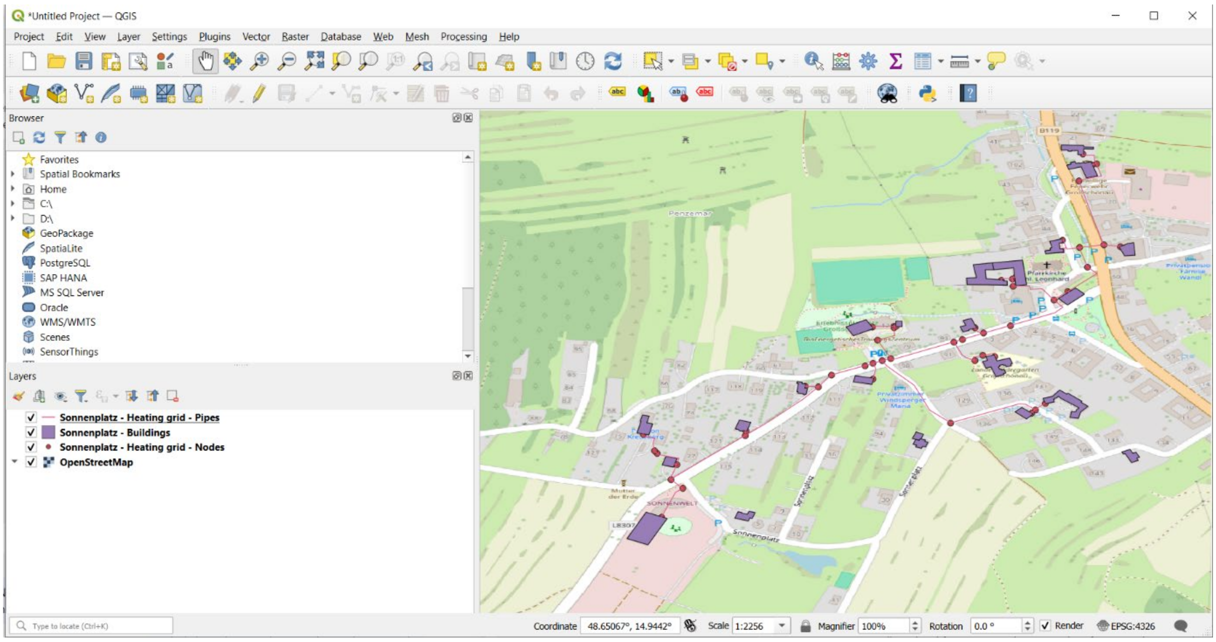


Figure 18. SONNE downloadable GeoJSON file opened in QGIS.

The Sonnenplatz LiL includes simulation data for the thermal grid related to the consumers of the network and to the different pipes that constitute this network. This data consists on values for 10 different variables (thermal load, flow, flow temperature, return temperature, pipe pressure loss, specific temperature loss, sum of pressure loss, flow target temperature at consumer, exergy difference and heat losses) from the 1st of July of 2023 to the 1st of July of 2024, for the summer and winter seasons, represented in a line chart together with two flat lines that indicate the mean value of the variable for each of the 2 seasons.

The simulation data, provided by GET, can be accessed from the “Simulation” module in the GET tool. On this module you first need to select the type of data you want to consult on the “Simulation Source” select list. This will load a list with each of the consumers (if you are consulting the costumer consumption data) or a list with each pipe (if you are consulting the pipes information) on the heating grid.

Figure 19. SONNE list of consumers in the heating grid.

On these lists, you can check the simulation data of a consumer or pipe by clicking on the green information button, which will open a popup window displaying a table containing information about the consumer or pipe with the values of some variables, and a select list. In the select list you can select between each of the variables mentioned before to display its values together with its mean value in a line chart. You can navigate horizontally with the mouse cursor over the chart to consult the values of the variable for each season at a certain date time, those values will be displayed in a popup over the chart. The mean value of the variable during the whole interval of time (from the 1st of July of 2023 to the 1st of July of 2024) is displayed on the line chart legend. You can also zoom in and out in the line chart by using the mouse wheel. To close the popup window displaying the simulation information simply click on the red "Close" button.

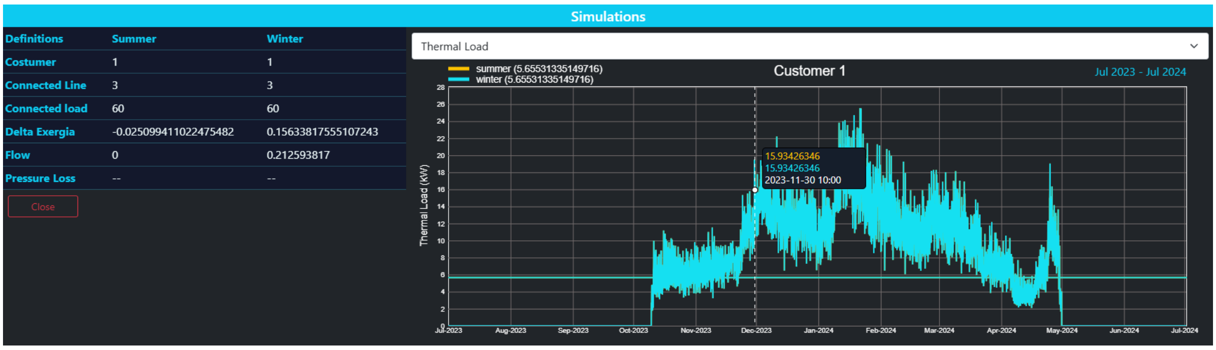


Figure 20. Simulation data of the thermal load for Customer 1 in the heating grid, in the SONNE LiL.

Some thermal simulations have been executed for the heating grid in the Sonnenplatz LiL, successfully obtaining useful results.

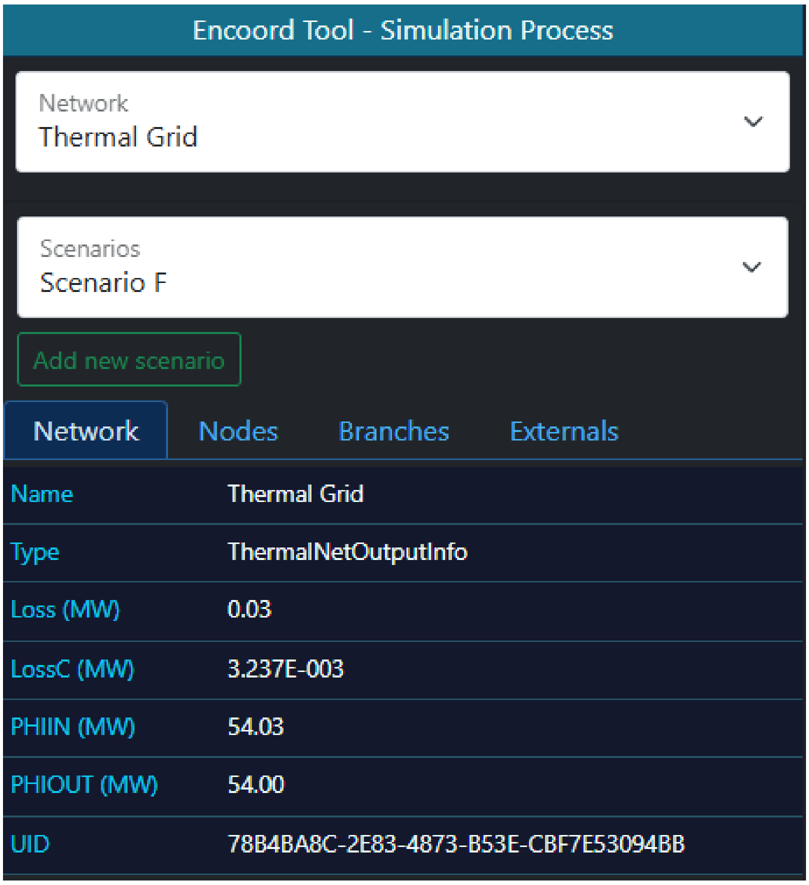


Figure 21. Simulation results in the heating grid.

Figure 22. Simulation results of the node N1 in the heating grid.

Simulated Branch

Name
TPI1

UID
8ED8261D-2BA5-47AD-9859-54D7BEA4F7B4

Type
ThermalPipeOutputInfo

State
0

From UID
2E8971B4-60EC-478D-8E73-FCD258F4F6D7

To UID
708DE37E-BEB8-4B90-8615-9DFEE35468B4

Q - Mass flow rate of the hot side (kg/s)
-6.85

TDH - Downstream temperature of the hot side (°C)
89.89

TDC - Downstream temperature of the cold side (°C)
20.00

TDROPH - Temperature drop on the hot side (°C)
1.100E-002

TDROPC - Temperature drop on the cold side (°C)
1.376E-003

PD - Pressure difference between the nodes of the hot side in the branch direction "PI" - "PO" (Pa)
-1.169E-005

PDC - Pressure difference between the nodes of the cold side in the branch direction "PIC" - "POC" (Pa)
1.169E-005

Loss - Heat transferred from the hot side to the surroundings (MW)
3.149E-004

LossC - Heat transferred from the cold side to the surroundings (MW)
3.940E-005

Close

Figure 23. Simulation results of the branch TPI1 in the heating grid.

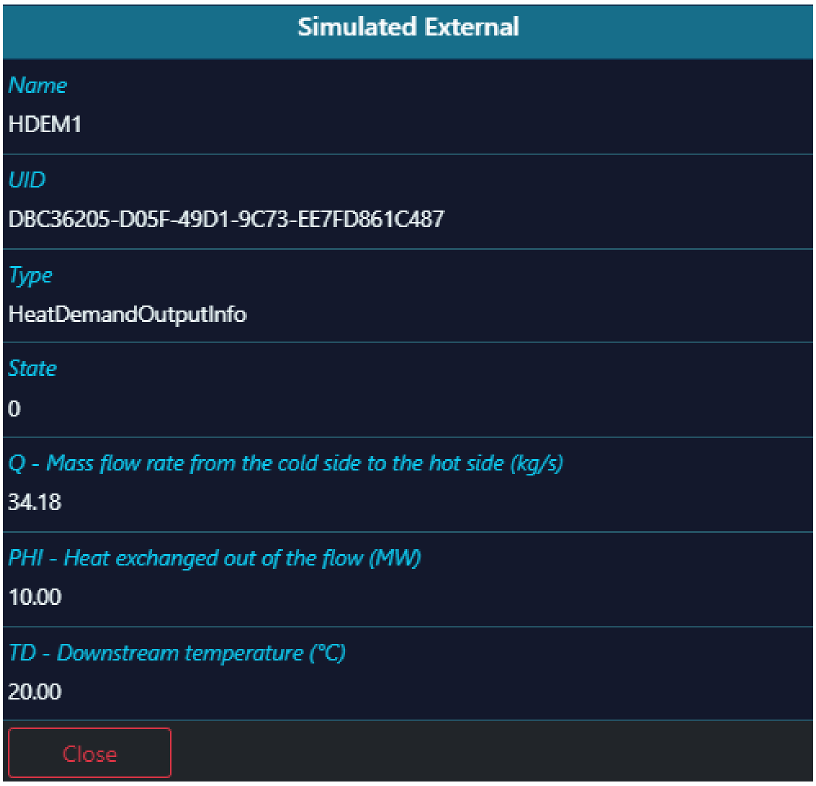


Figure 24. Simulation results of the external HDEM1 in the heating grid.

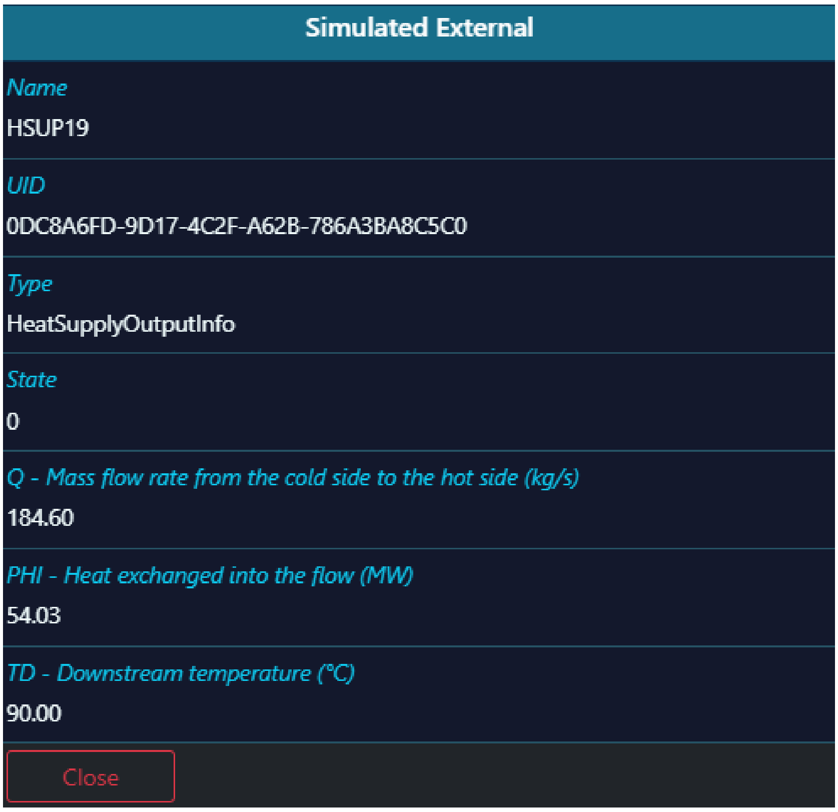


Figure 25. Simulation results of the external HSUP19 in the heating grid, corresponding to the only supplier of thermal energy in the network.

3.2 ENVIPARK LIL

Similar to the Sonnenplatz LiL, the Envipark LiL was also meticulously modelled using the IDP's BIM-GIS toolkit tailored for DHC network piping and configuration planning within the HYPERGRYD project. This powerful ICT tool enabled Envipark partners to accurately model various buildings and pipeline networks integral to the HYPERGRYD project's scope.

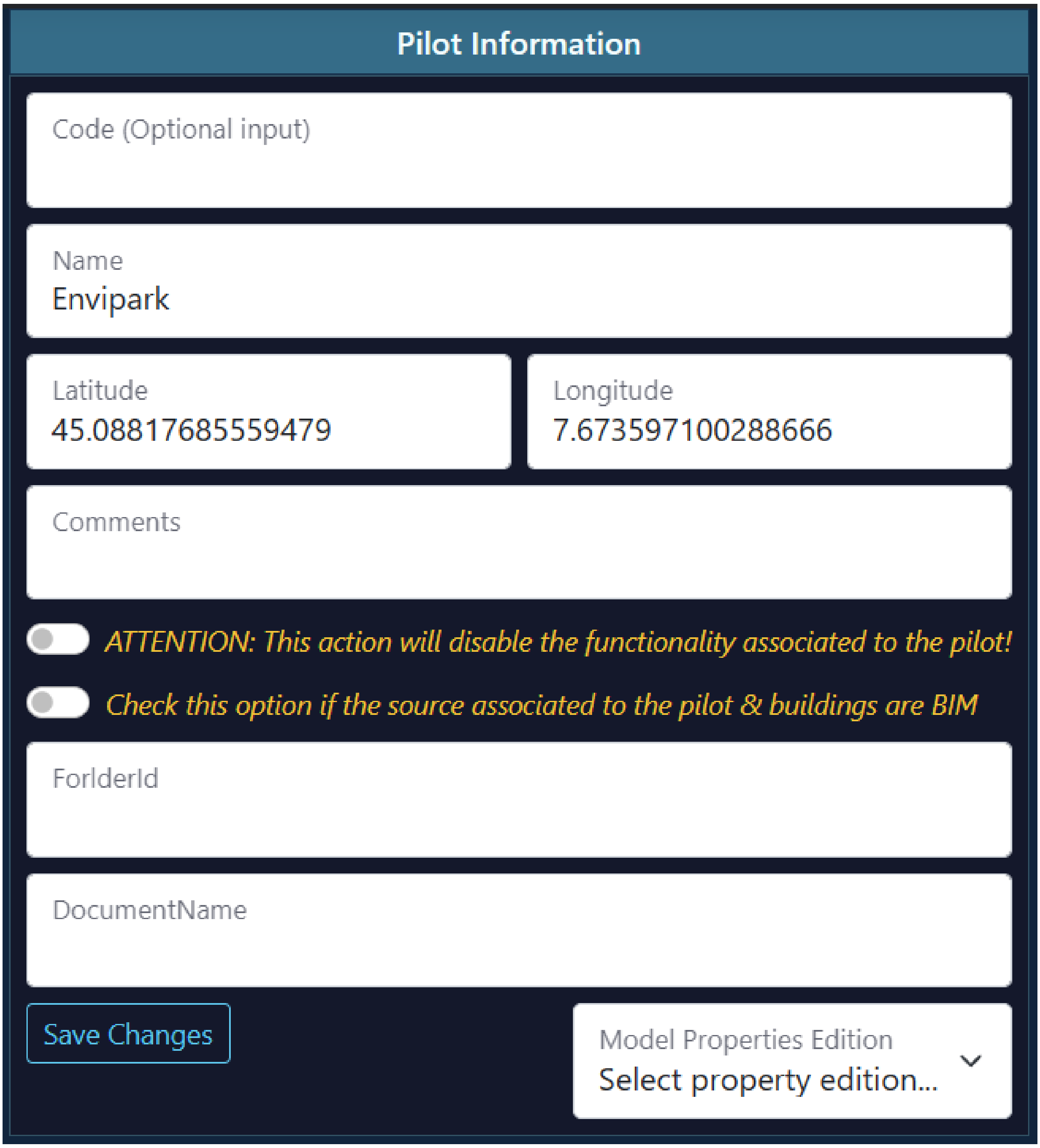


Figure 26. ENVI LiL information.

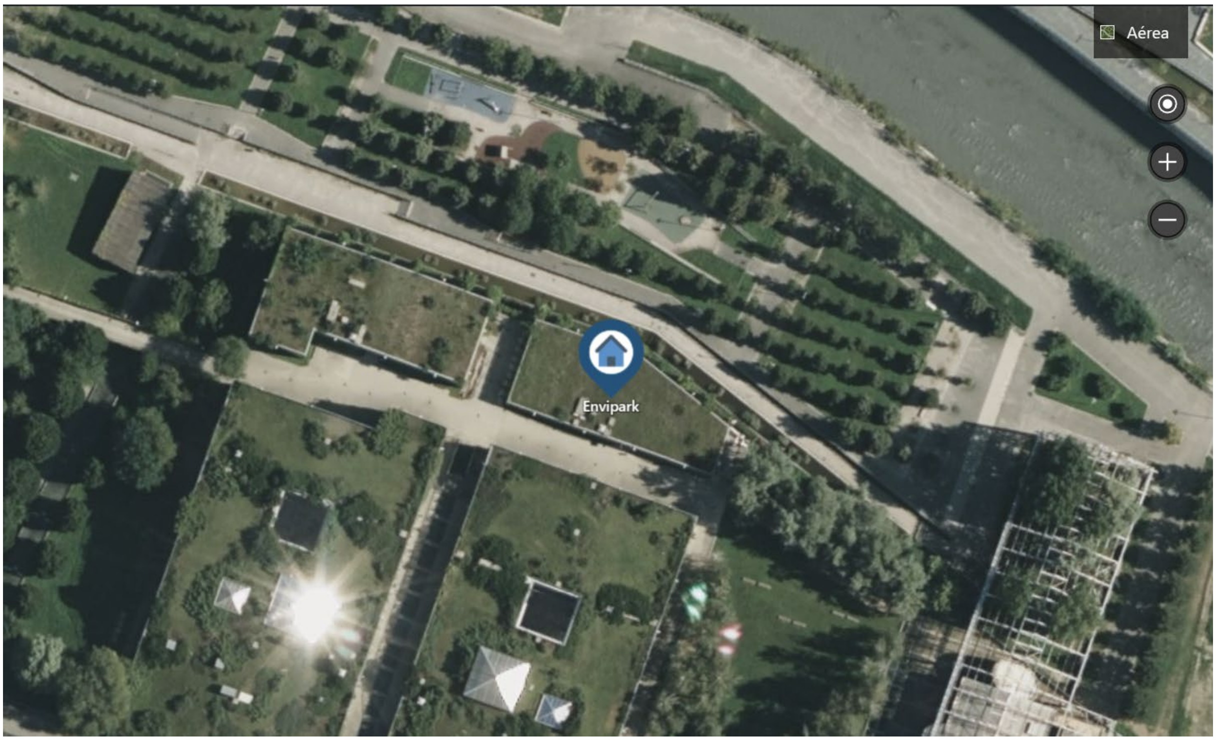


Figure 27. ENVIPARK LiL location in the world map.

The image below displays the complete BIM-GIS model of the Envipark living lab (ENVI LiL), featuring 10 consumer buildings, 2 supplier buildings, and their associated electric and thermal piping networks.

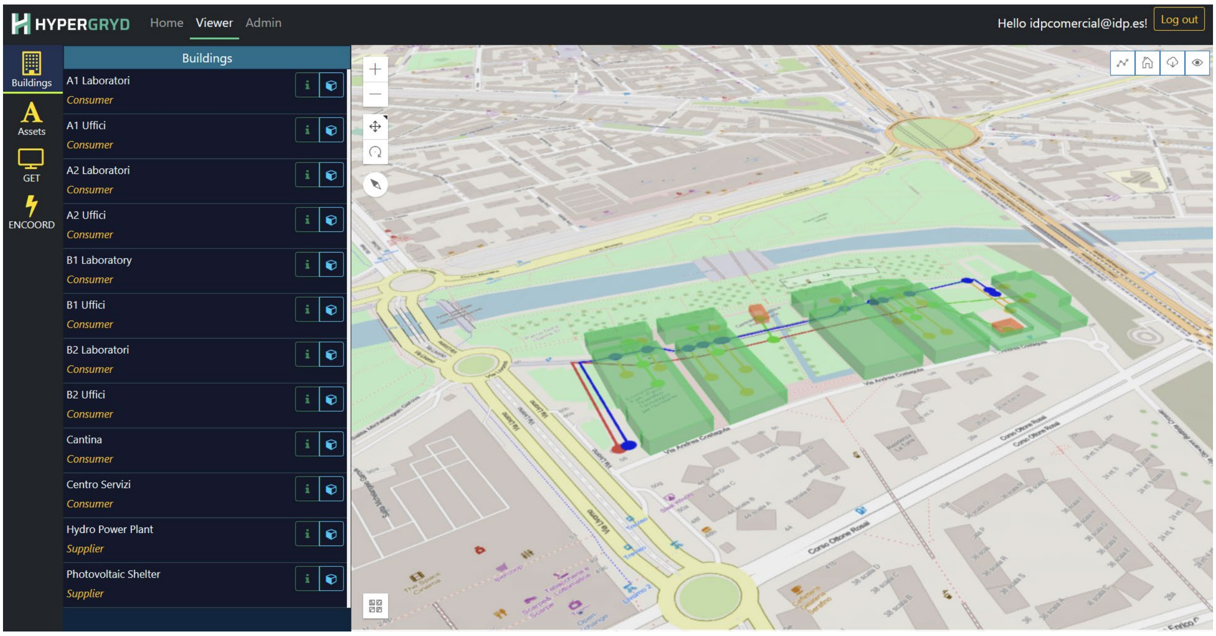


Figure 28. ENVIPARK LiL.

The following images illustrate the implemented definitions of both the electric and thermal network piping within the modelling framework.

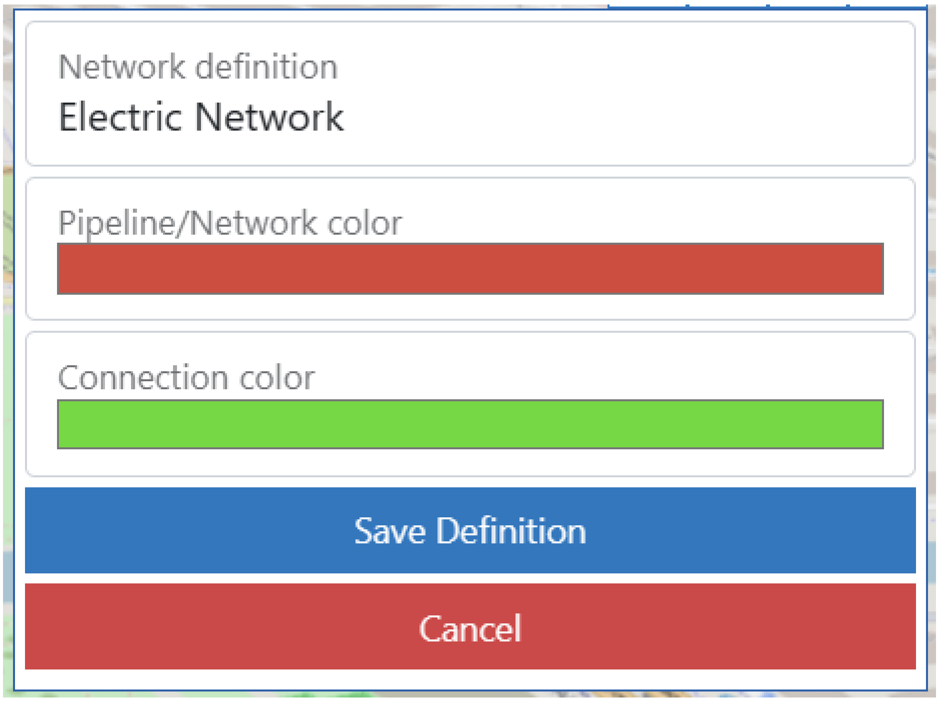


Figure 29. ENVIPARK electric network piping definition.

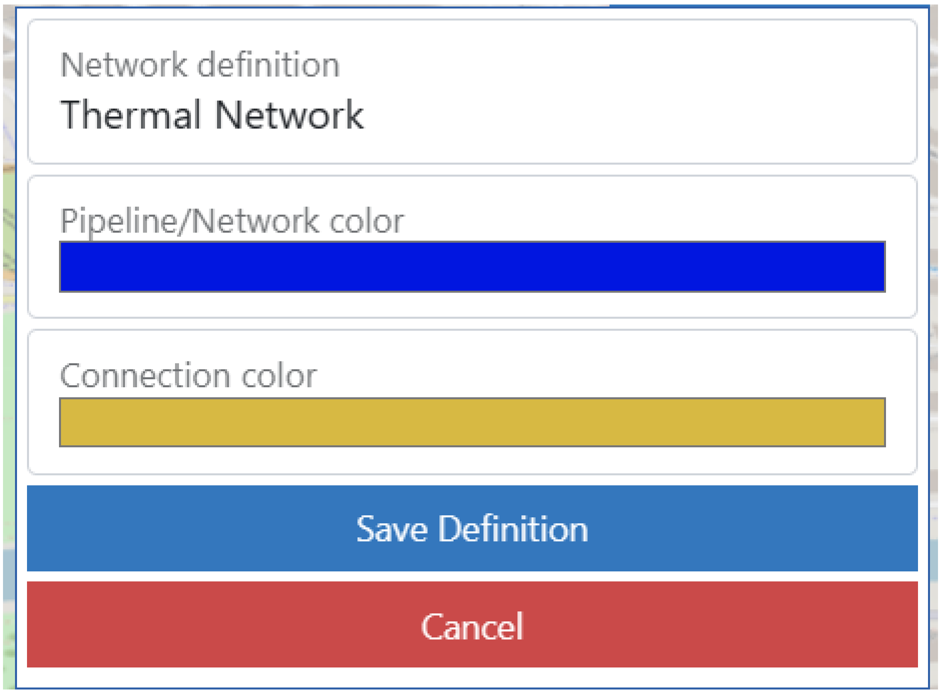
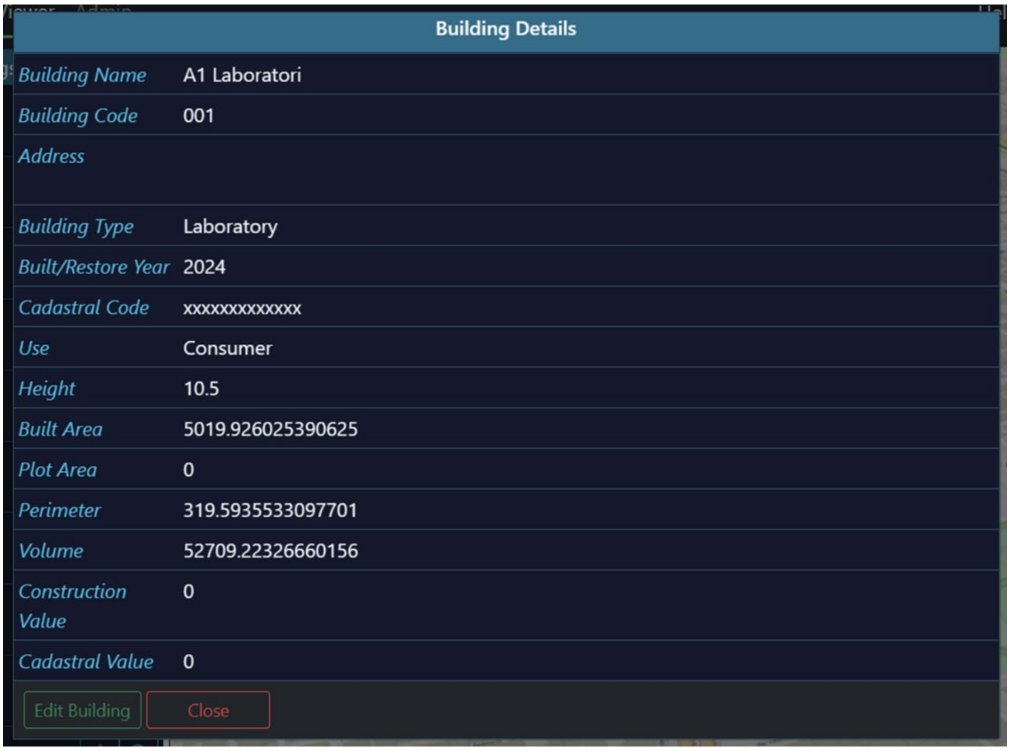


Figure 30. ENVIPARK thermal network definition.

The subsequent images depict examples of the static information stored from various consumer and supplier buildings within the ENVI LiL. To protect user privacy, the address and cadastral code of the buildings have been concealed.



Building Details	
Building Name	A1 Laboratori
Building Code	001
Address	
Building Type	Laboratory
Built/Restore Year	2024
Cadastral Code	xxxxxxxxxxxxx
Use	Consumer
Height	10.5
Built Area	5019.926025390625
Plot Area	0
Perimeter	319.5935533097701
Volume	52709.22326660156
Construction Value	0
Cadastral Value	0

Edit Building Close

Figure 31. ENVI building detail information example.

Building Details	
Building Name	Hydro Power Plant
Building Code	HPP
Address	
Building Type	Supplier Plant
Built/Restore Year	2024
Cadastral Code	ADDRF
Use	Supplier
Height	5
Built Area	176.06298828125
Plot Area	0
Perimeter	56.7227539220699
Volume	880.31494140625
Construction Value	0
Cadastral Value	0

Edit Building Close

Figure 32. ENVI supplier plant information example.

The readily downloadable GeoJSON file from the HYPERGRYD PaaS/SaaS platform facilitates the access of BIM-GIS modelled information through a GIS software such as QGIS, which is free and open-source.

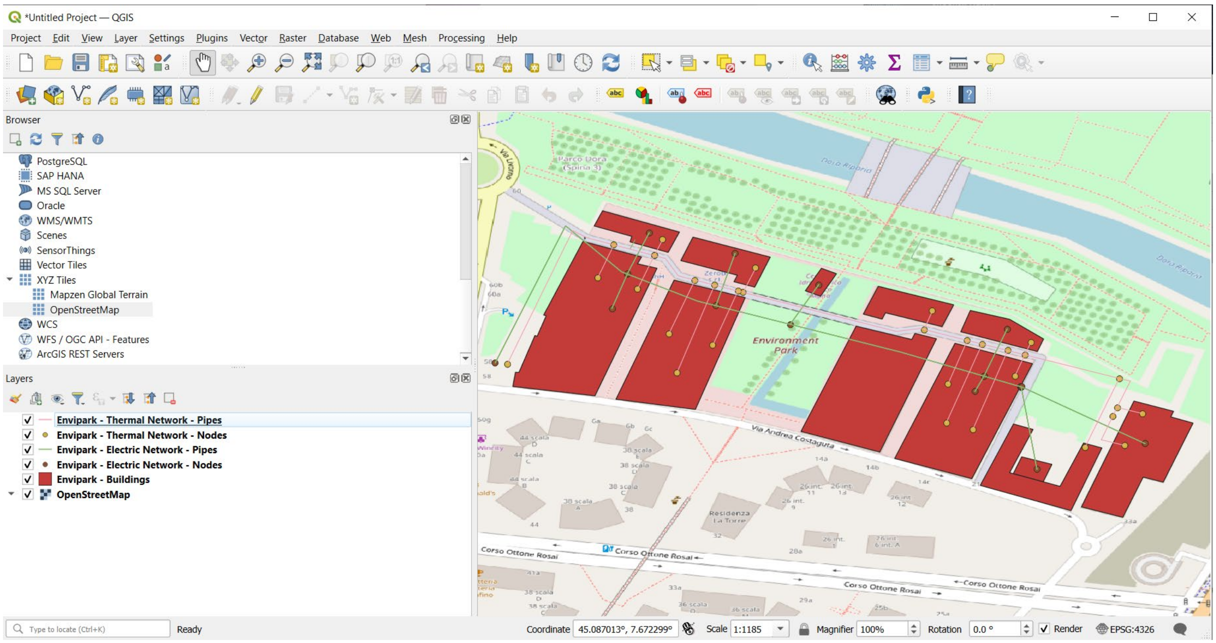


Figure 33. ENVI downloadable GeoJSON file opened in QGIS.

Some thermal simulations have been executed for the thermal grid in the Envipark LiL, successfully obtaining useful results.

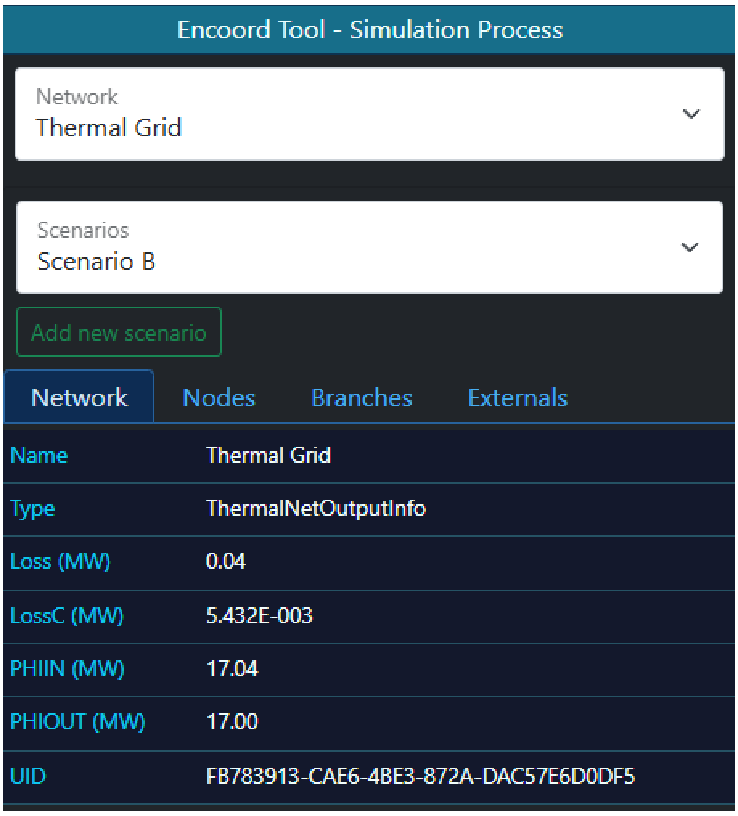


Figure 34. Simulation results in the thermal grid.

Figure 35. Simulation results of the node TNO_32 in the thermal grid.

Figure 36. Simulation results of the branch TPI.TPI_31 in the thermal grid.

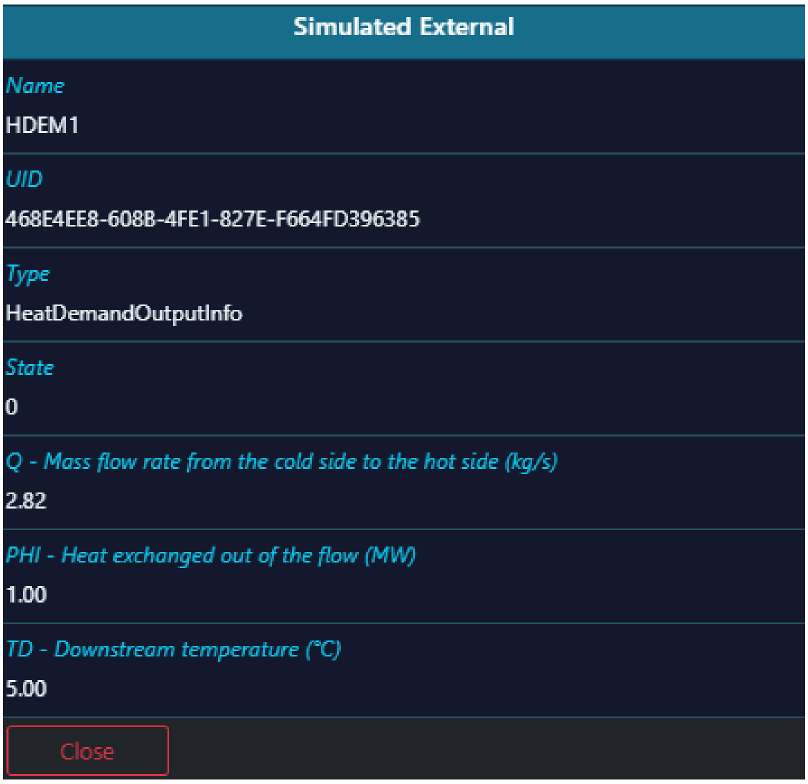


Figure 37. Simulation results of the external HDEM1 in the thermal grid.

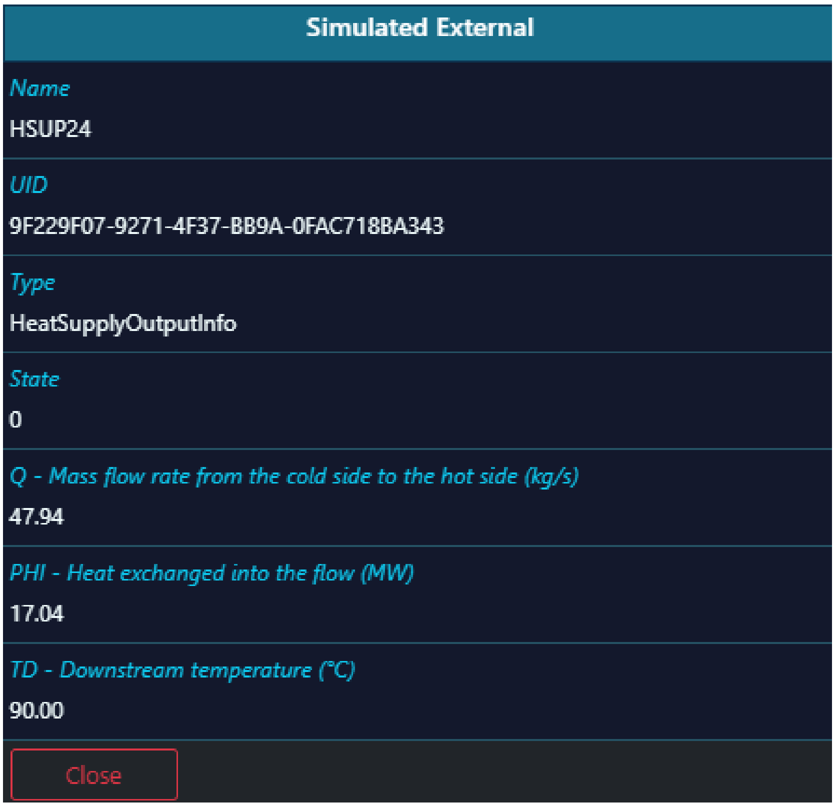


Figure 38. Simulation results of the external HSUP24 in the thermal grid, corresponding to the only supplier of thermal energy in the network.

En electric simulation has been executed for the electrical grid in the Envipark LiL, successfully obtaining useful results.

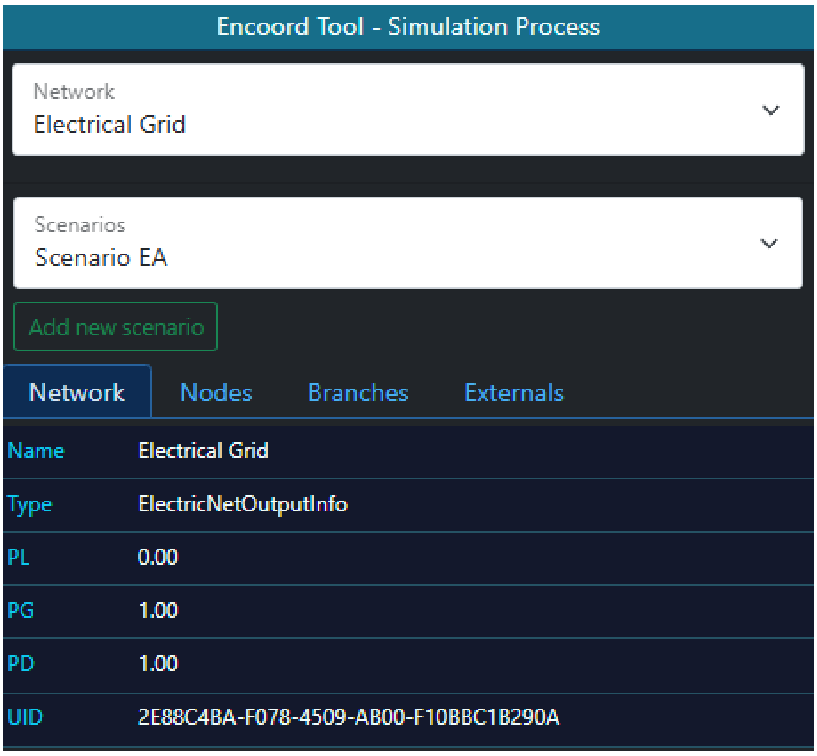


Figure 39. Simulation results in the electrical grid.

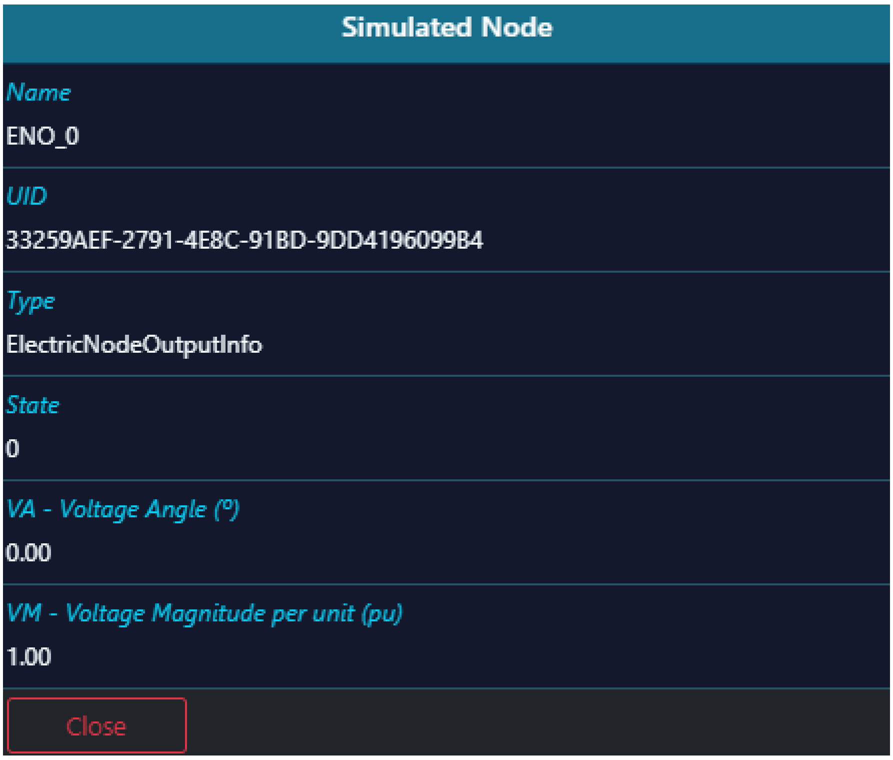


Figure 40. Simulation results of the node ENO_0 in the electrical grid.

Figure 41. Simulation results of the branch LI.LI_0 in the electrical grid.

Figure 42. Simulation results of the external EDEM1 in the electrical grid.

Figure 43. Simulation results of the external PV12 in the electrical grid, corresponding to the solar generator that provides energy to the electrical grid.

Figure 44. Simulation results of the external XGEN11 in the electrical grid, corresponding to another generator that provides energy to the electrical grid.

4 Conclusions

The successful modelling and development efforts carried out for the Sonnenplatz and Envipark living labs within the HYPERGRYD project highlight the effectiveness of IDP's BIM-GIS toolkit for DHC network piping and configuration planning. Utilizing this advanced ICT tool, partners from both Sonnenplatz and Envipark meticulously crafted models of various buildings and pipeline networks, significantly advancing the project's objectives.

These models are not just a static representation; they are designed to be functional and interoperable. They play a crucial role in the implementation of the GET and ENCO tools, facilitating their respective mathematical calculations and simulations within the Sonnenplatz and Envipark living labs. The BIM-GIS toolkit provides the models which are essential inputs for the GET and ENCO tools, enabling them to perform their specific calculations and simulations. This demonstrates effective communication between the tools and a streamlined workflow for energy network design and analysis. The outcomes of these implementations will be documented and reported in deliverables D5.5 – "Demonstration and Validation of LECs coupled network models" and D5.6 – "Demonstration and Validation of HYPERGRYD ICT tools".

5 References

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