STAKEHOLDER ANALYSIS (PRE & POST IMPLEMENTATION)

James Allan

Ali Hainoun

Sebastian Stortecky

Daniel Horak

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TABLE OF CONTENT

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ERA-Net Smart Energy Systems (ERA-Net SES) is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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1 EXECUTIVE SUMMARY

This deliverable documents the stakeholder engagement activities that guided the development and evaluation of the Digicities platform, spanning from initial surveys through use case refinement to post-implementation assessment. The report is structured around three phases: initial stakeholder profiling (Section 2), use case refinement workshops (Sections 3–4), and post-implementation evaluation (Sections 6–7).

The initial surveys profiled data exchange practices across energy utilities, digital service providers, and municipal planners in Switzerland and Austria, uncovering recurring pain points around data fragmentation, inconsistent formats, time-consuming data preparation, and limited transparency of assumptions in energy planning workflows. These findings directly informed the conceptual architecture and use case definitions, with stakeholder-generated user stories shaping the platform's modular design and the prioritisation of semantic data products, scenario management, and service API integration.

The post-implementation evaluation was constrained by the project timeline. Technical challenges during platform development meant that a functional prototype was only available in the final phase of the project. As a result, post-implementation stakeholder assessment was limited to the energy planning use case (Swiss UC2), where need-owners, comprised of a utility company and a municipal planner, were surveyed following a demonstration of the prototype platform. The hydro scheduling use case (Swiss UC1) was evaluated through simulated performance comparisons rather than stakeholder survey, with a live testing phase at SES planned for early 2026. The Austrian use cases were not subject to post-implementation stakeholder evaluation within the project timeline. These limitations mean that the post-implementation findings represent an early-stage assessment based on exposure to a prototype rather than a comprehensive evaluation of operational deployment.

Within these constraints, the post-implementation assessment yielded findings that are consistent across the two stakeholder groups consulted. Digital service providers identified tangible benefits: reduced data integration workload, accelerated user data preparation, expanded market reach through simplified interfaces, increased confidence in API data quality, and improved efficiency handling multiple scenarios. Energy planning need-owners expressed interest primarily in data infrastructure capabilities, such as standardised terminology, data ingestion improvements, traceability mechanisms, and workspace management, rather than computational efficiency gains. However, they identified migration costs and workflow transition as the primary barrier to adoption, with concrete proof through additional case studies and quantified time savings as essential prerequisites before commitment decisions.

These findings suggest that the platform's near-term path to adoption runs through service provider integrations and targeted pilot deployments that progressively build the evidence base needed to overcome end-user reluctance. Future stakeholder engagement should prioritise extended piloting periods, broader participant inclusion across use cases and geographies, and structured feedback mechanisms embedded in the platform itself..

2 INITIAL STAKEHOLDER SURVEY

The purpose of profiling the inputs and outputs of our digital services is to understand the types of data they need and the value they can generate on it. This will enable a common understanding of how to prepare and exchange data for the data generators and the third parties. This will also help us identify conflicts of interest. It is also possible for the need-owners to work on the data themselves, but this is often outside the scope of their business activities. The objective of the initial survey was to uncover the data exchange practices occurring in the data-insight cycle shown in Figure 1.

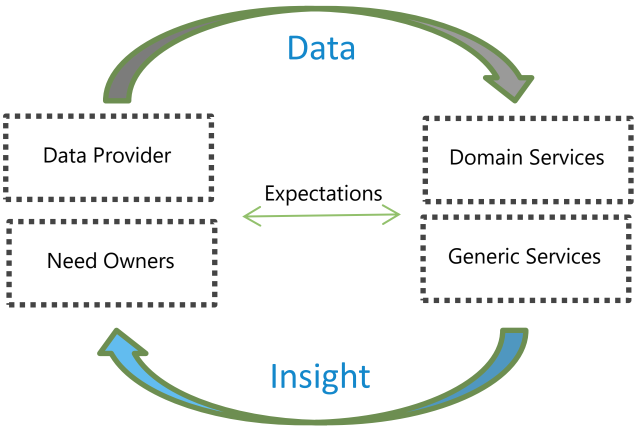

Figure 1: Data-Insight Cycle

2.1 Survey of present data usage of need owners

The need owners of this project are energy utilities. Three energy utilities provide energy to the region of this study and participated in the Digicities kick-off meeting. The following questions were asked about the present operation of the company:

- *What is your company's offering?*
- *How important is INTERNAL data in your actual/future business.*
- *How important is EXTERNAL data in your actual/future business.*
- *What INTERNAL data are you currently using?*
- *What EXTERNAL data are you currently using?*
- *How are you obtaining INTERNAL data?*
- *How are you obtaining EXTERNAL data?*
- *What are the pains obtaining data?*
- *What are the pains dealing with data?*
- *What are the main uses you make of data?*
- *How do you deal with low quality data (wrong/missing samples)?*

2.2 Survey of present future usage of need owners

The utilities were then asked the following questions about their intended future use of data:

- *What data are you missing?*
- *What are the hurdles obtaining that data?*
- *What are you doing to fill the gaps?*
- *Are you generating proprietary data?*
- *Would you be willing to sell your proprietary data on a data exchange?*
- *Would you need raw data or pre-defined Insights? Which ones?*
- *What are the NEW uses you would make of new data / insights?*
- *Would certification of a data exchange be valuable in your business?*
- *What would be a "dream tool" based on data that would boost your business?*

2.3 Design of conceptual architecture

The requirement of the conceptual architecture was designed according to the results from the stakeholder survey workshop. The process is shown in Figure 2.

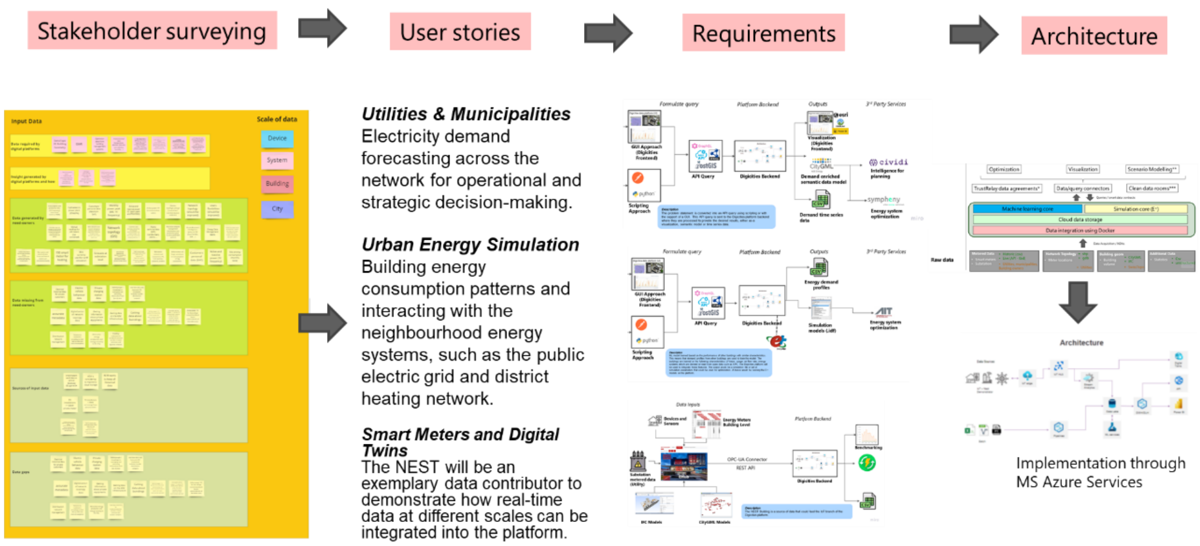

Figure 2: The process to design the conceptual architecture of the Digicities platform. The user stories were generated from the results of a stakeholder survey were analysed.

3 USE CASE REFINEMENT WORKSHOP

In the mid-point of the project, we presented the vision of Digicities to the stakeholders and then refined use cases with the relevant stakeholders. An overview of the data interaction with the Digicities platform is shown in Figure 3.

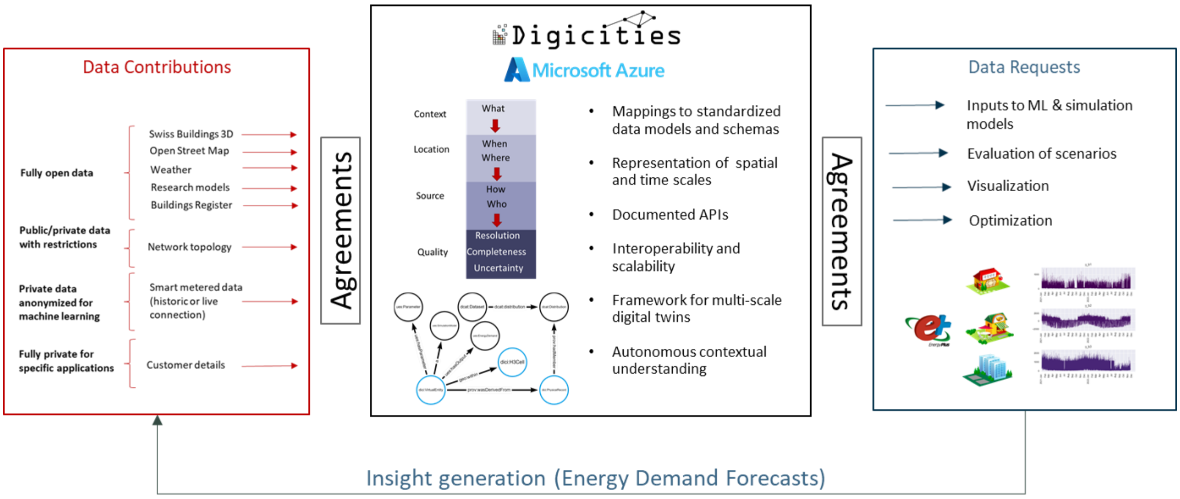

Figure 3: Data interaction with the Digicities platform

This workshop provided input to help us further refine the use cases. A template was used to systematically identify the following for each use case:

- Use Case Description
- Objectives
- Stakeholders
- Collaborators
- Input & Output Data
- Required Resources
- Plan & Milestones
- User Stories

The following section summarises the refined description of each use case using the template.

4 DESCRIPTION OF USE CASES

4.1 Austria

4.1.1 AUC1, Zero Energy Building of the Enkplatz School

The first Austrian use cases (AUC1) in DIGICITIES project deals with the middle school “NMS Enkplatz” in Vienna, which is designed as zero energy building (ZEB) and will demonstrate the applicability of the conceived integrated data architecture. The use case builds upon the recently completed monitoring and evaluation of the H2020 project Smarter Together (Smarter Together-Vienna, 2021), (Neuman et al., 2021). In cooperation with the need owners represented by MA34 and MA56 of Vienna city, the technology provider Vasko& Partner and the long experience of AIT in urban energy system modelling and simulation, a simulator for the ZEB will be developed and validated using the dynamic measured building operation data (with 5-15 minutes frequency). The simulation model will be validated using measured monitoring data for at least two years. The established and validated ZEB-simulator will enable predicting the building operation behaviour considering the variability of daily, weekly and seasonal energy demand-supply. The simulator will be used to support the need owner in assessing the ZEB performance and optimizing its operational scheme to achieve the desired annual zero energy balance under different internal and external conditions. The established digital layers will be integrated into the smart city Wien data platform which is supervised by MA01 of Vienna city and being supported from various city stakeholders. Thus, this Austrian living lab will build upon existing activities and experience to address both data collection and evaluation as well further utilization for assessing and optimizing the energy performance of buildings using dynamic measured data.

Enkplatz case study is the first implemented case for the data exchange architecture developed during the H2020 project Smarter Together and expanded further within DIGCITIES project. The established methodology to build up a data exchange architecture can be divided into three pillars: monitoring infrastructure set-up, data collection and transfer to the cities DMP and data processing including quality check, cleansing and analysis. The data was sent, using sensors to the MA34 via a Siemens system, and finally transferred to the data platform.

4.1.1.1 Energy System and meter concept of the school NMS Enkplatz

The use case of the secondary school NMS Enkplatz is located at Enkplatz 4 in the 11th district of the city of Vienna. The testbed includes a public gym, which was reconstructed and modernised, and in addition 16 classroom. The use case has gross floor area of about 3,800 m². After refurbishment, the building energy performance (space heat energy demand) was improved from 104 kWh/m².a to 27 kWh/m².a (Smarter Together, 2019a)[1].

[1] https://doi.org/10.3390/en15196907

The sustainable energy concept of the secondary school includes a mix of different renewable energy sources, comprising a solar thermal system, a PV-system and a heat pump for geothermal energy. The district heating at one hand works as backup system and on the other hand takes over the heat excess from the solar thermal system especially during summer times. Furthermore, the heat pump works for cooling (in the summer) and a heating (winter) to compensate the heat loss of ground water. For optimum indoor air quality, a ventilation system with heating register was planned for the gyms (Smarter Together, 2019b).

Moreover, the external electricity supply and a photovoltaics system with an overall nominal power of 67 kW cover the electricity demand of the school. The energy of the photovoltaic system is primarily consumed by the school, and the surplus energy is used to feed into the public grid. The heat pump in the school is 2-stage, that means that the output is controlled by 2 compressors, which each have a separate electric meter (Beigelböck et al., 2021). Figure 4 illustrates the energy concept of the Zero-Energy-Building of the secondary school NMS Enkplatz. The figure shows the interaction of all of the energy systems and the main energy consumers. The innovative character of this energy concept is the bidirectional interaction with the district heating grid. That makes the whole system more efficient than a stand-alone system.

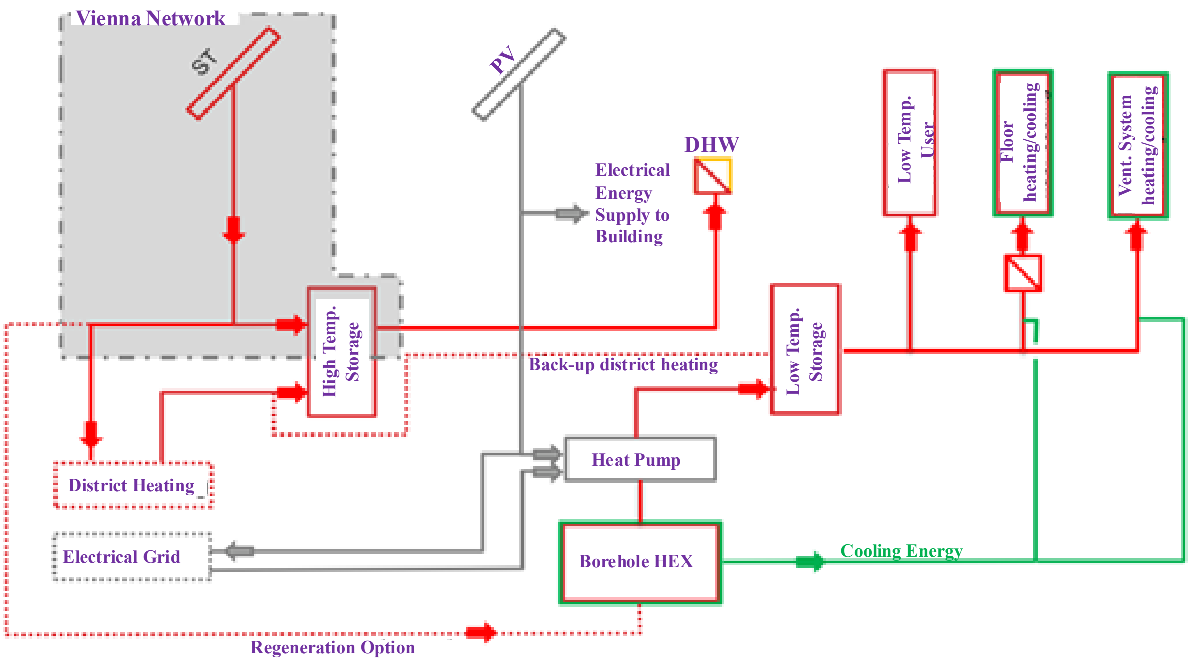

Figure 4: Simplified flow-chart of the energy concept of the Zero-Energy-Building of the secondary school NMS Enkplatz

4.1.1.2 Data exchange architecture in NMS Enkplatz

This part elaborates on the data exchange architecture set-up within the SMARTER TOGETHER project framework, focusing on the case study of the NMS Enkplatz identified as a use-case for the DIGICITIES project. The process followed to build up the data exchange architecture can be divided into five steps presented in Figure 5.

The established methodology to build up the integrated data architecture covers the following steps that are correlated with the associated digital layers:

- set-up of monitoring infrastructure,
- data collection and transfer to the cities DMP (or local server for data storage and maintenance),
- data processing including quality check, cleansing and analysis.
- Mapping of datapoints to DIGICITIES IDA and ontologies, e.g., Brick (Fierro et al., 2020),
- Transfer of data to DIGICITIES IDA
- KPIs calculation: The processed data are used to calculate several KPIs around the building energy.

Monitoring infrastructure set-up:

The onsite meters for electricity, heat, gas and water are equipped with an M-Bus module and linked further to an M-Bus Master. Data collection and transfer to the city data management platform: the measured data are then transferred to the Energy Management System (EMS) of MA34 (Municipal department, Building and facility management) relying on the Supervisory Control and Data Acquisition (SCADA) system.

Development of Building Simulator Using IDA ICE Model

The processed and evaluated data are used to support the validation of the building simulator under development using building energy simulation software IDA ICE. Required building specifications and plans for the simulator development are provided by different involved stakeholders (MA34, MA56, V&P).

The validated simulator aims to help optimizing the building energy performance towards achieving the set target of ZE). For this purpose, the simulator should provide indications for operating strategies that optimally use the energy supply technologies based on the thermal properties and use patterns of the building. Here, a feedback loop to the first step (Onsite meters) is necessary to monitor the results of the simulator in real practice.

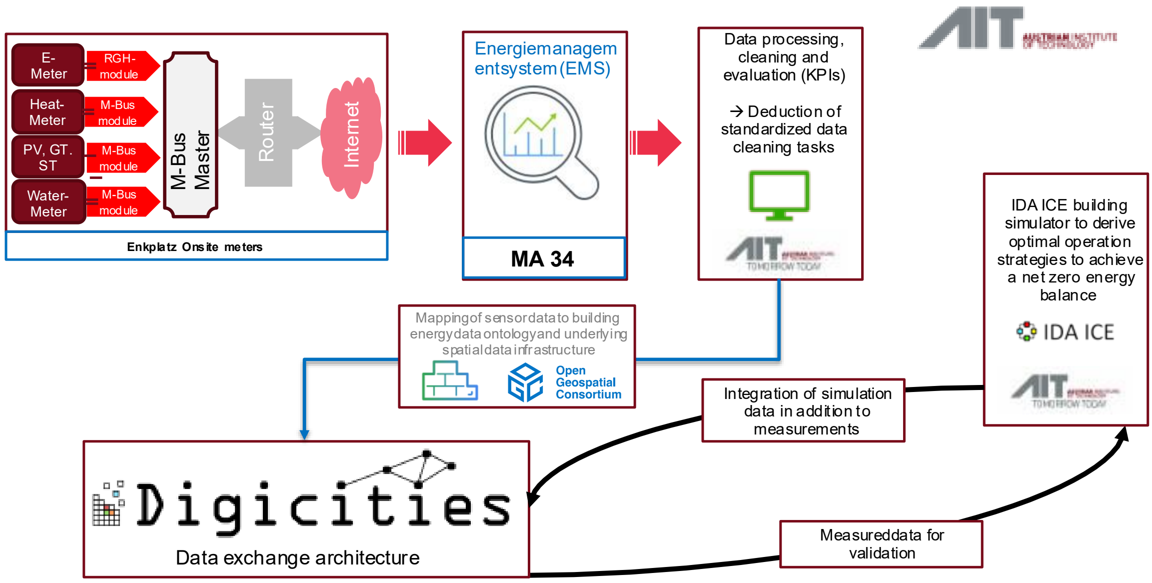

Figure 5: Schematic flow diagram of the integrated monitoring process for the Vienna lighthouse demo sites in the project DIGICITIES[2]

The target of developing the simulator is to support the energy planning of buildings and neighbourhoods and the replication and exploitation of Zero Energy Buildings in the city of Vienna. Moreover, the replication and replication strategy feeds also in the city decarbonisation strategy.

4.1.1.3 Monitoring and evaluation of NMS Enkplatz

The setup of the monitoring infrastructure is a fundamental first step towards the definition of a data exchange architecture is. This includes sensors, meter-buses and the logistic for data acquisition. This section details on the existing monitoring and evaluation infrastructure used in NMS Enkplatz to collect and process comprehensive data on the building energy demand and supply (heating, cooling, ventilation, lighting and other ICT consumption beside the operation of photovoltaic system (PV), solar thermal system (ST) and geothermal heat pump.

A total of 11 electricity meters and 21 heat meters are installed on-site. The monitoring plan of NMS Enkplatz is presented in Figure 6. Using an M-Bus interface, each of the onsite meters for electricity, heat, gas and water is equipped with an M-Bus module and linked further to an M-Bus Master. The sampling frequency of raw data measurement is 15 minutes and depends on the physical behaviour and the underlying process of the measured parameters. Relying on this monitoring infrastructure, the following data can be automatically collected: thermal energy consumption after refurbishment, electric energy consumption after refurbishment, thermal energy generated by solar thermal collectors, thermal energy generated by

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[2] https://doi.org/10.1016/j.enbuild.2025.115906

heat pumps, nominal power of PV and electric energy produced by PV (Smarter Together-Vienna, 2021), (Neuman et al., 2021), (Hainoun et al., 2022).

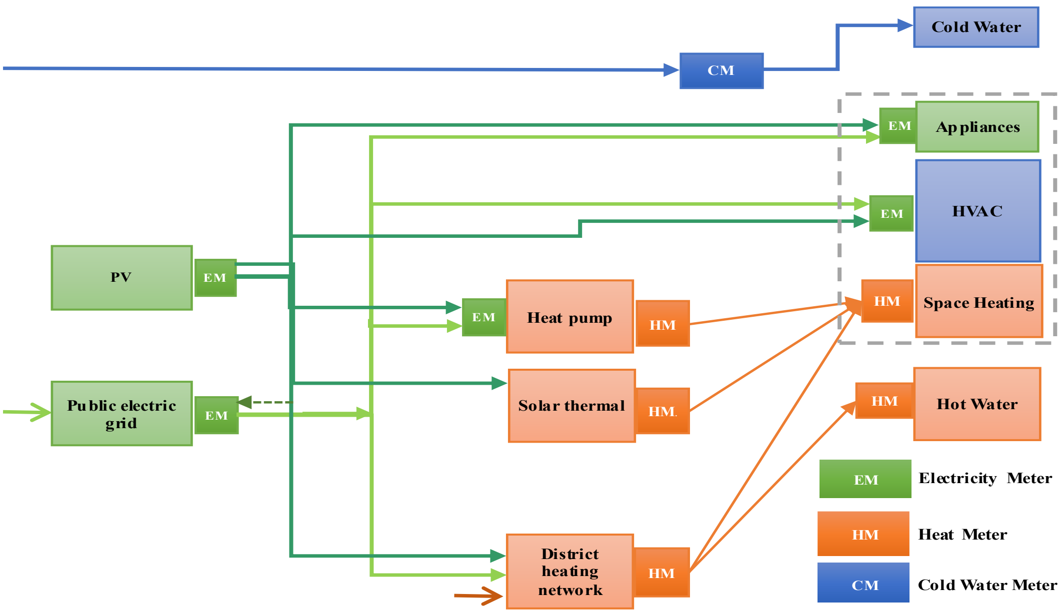

Figure 6: Monitoring concept of NMS Enkplatz,[3]

Figure 6 illustrates, that the heating supply (solar thermal system, heat pump and district heating) is monitored by three meters. The space heating supply concept sets the successive priority of solar thermal energy, followed by geothermal heat pump and the last choice of district heating in case the first two options fail to cover the heat demand. On the other hand, the hot water consumption is solely covered by the district heating option. For monitoring and controlling the heat demand (space heating and hot water consumption) 15 meters are considered. The building electricity consumption is monitored by 8 meters covering the end-uses for the heat pumps, appliances, the electronic measuring, control and regulating technology and the HVAC (Heating, Ventilation and Air Conditioning) (Smarter Together, 2019a). Electricity supply is monitored by 2 meters for the local PV panels and the public grid. The cooling and heating energy consumptions are recorded by combi-meters, i.e., one meter can measure both cooling energy (negative values) and heating energy (positive values) at the same time and the data can be stored separately. Additional meters are devoted to measure temperatures, flow rates, and the heating capacity (Beigelböck et al., 2021).

4.1.1.4 Data processing, visualization and quality check

The data undergo a systematic process of cleaning, evaluation and visualization whereby the issues of data privacy and transparency are addressed in cooperation with the city stakeholders and the need owner. The open-source software aggregates data from various sources and turns numbers into actionable insights. To prepare the monitored data for the KPIs calculation, a quality check and cleansing

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[3] https://doi.org/10.3390/en15196907

process is performed. This includes a check for data completeness, for time gaps, for empty meters readings and an evaluation of outliers using standard deviation and box plot. The flow chart presented in Figure 7 details the main steps of the quality check process followed.

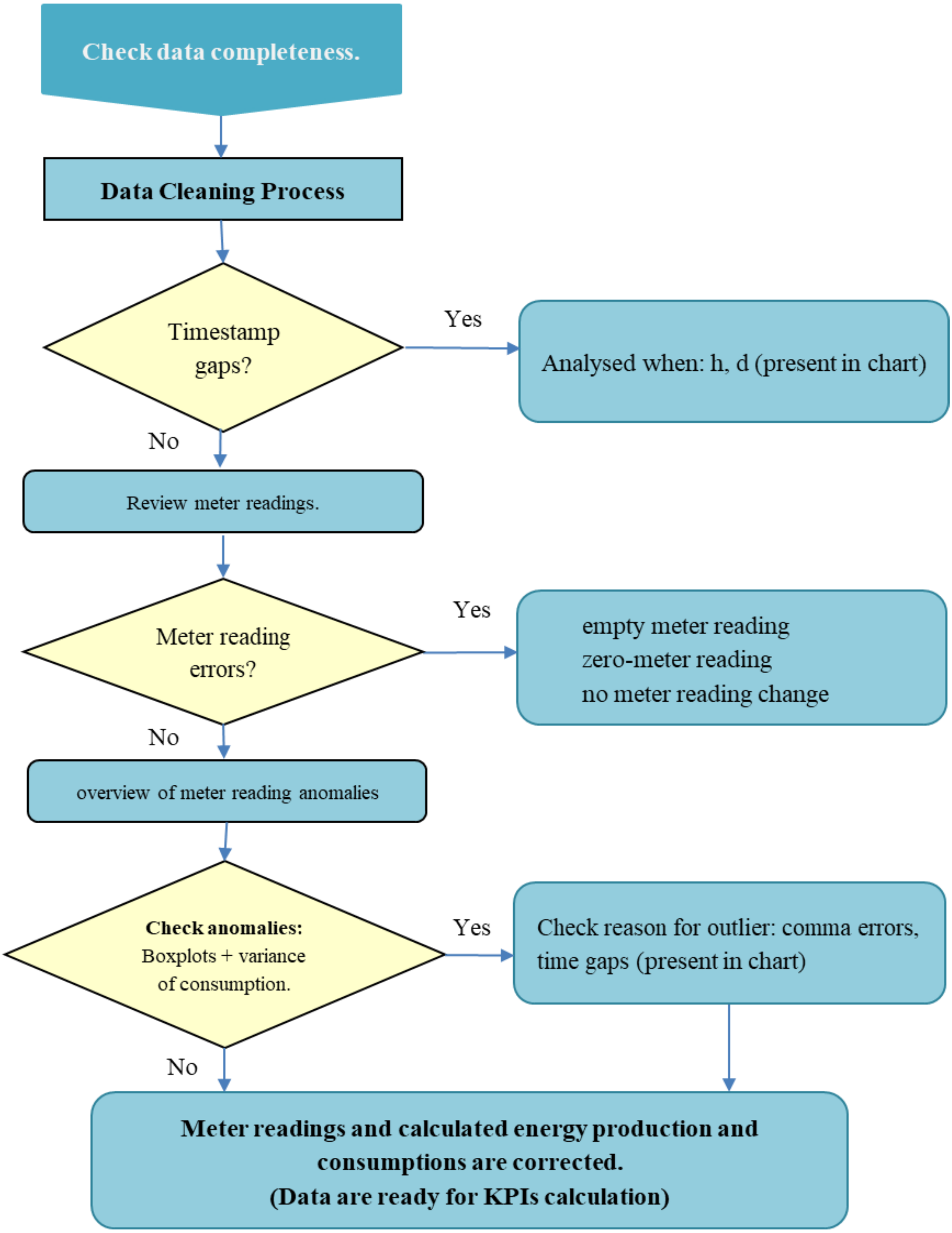


Figure 7 Main steps of the cleaning process of the measured monitoring data.

A suite of data cleaning routines is developed based on the data collected in AUC1. The aim of the data cleaning is twofold: on the one hand, the AUC1 dataset needed to be improved to serve as a basis for the validation of the AUC1 building simulator. On the other hand, data cleaning routines are developed in such a way that they are generalized to energy metering data sets other than the one from AUC1, thus allowing automatic execution and therefore their inclusion in the DEP. A version of the data cleaning routines is developed as a Python data science stack.

The developed cleaning routines involve an initial step tailored to the AUC1 data in which different time series batches are reconciled due to non-uniform datetime indices, different time zone encodings and time overlaps, the latter of which are resolved by taking the maximum of multiple values that are specified at some datetime. The cleaning continues with the following generalised steps, aimed at providing maximally reliable energy (not power) values. First, all zero values are set to “missing” as the sensors record energies (cumulative data) with recording starting at zero and a constant value indicating the absence of change. Next, errors in the order of magnitude of a value – caused e.g. by a misplaced decimal point in the raw data – are identified by comparison to neighbouring values (requiring ratios close to 100, 1000 etc.) and remedied. Subsequently, stark outliers are removed, defined as deviations from a time series’ median by more than 10 times the difference between the 90% and 10% percentiles. Then, all time-series are converted from energy to power by differencing, after unbounded forward-filling of the energy values to enable a later recovery of energy values by integration. In the representation as power values, pairs of a negative followed by a positive value are identified (by requiring similar absolute values and temporal proximity) and then levelled out. Further, negative values preceded by a sharp but non-instantaneous rise of similar magnitude (e.g. over one day) are identified and levelled out. Finally, the remaining negative power values are set to zero, and for a return to energy values an integration is carried out. Figure 8 illustrates the effects of sequentially applying the cleaning steps on a selected sensor time series with poor initial data quality.

AUC1 serves as a test bed for deriving common data cleaning challenges that can be automated, enhanced by machine learning and be defined as standard requirements on data quality for the contribution of energy meter data to the DIGICITIES data exchange architecture. Furthermore, the meter data will be mapped to the building energy data ontology implemented within the DIGICITIES platform, serving as demonstrator of the platform’s capabilities. Beside the integration of metered data, AUC1 will be enhanced by the development of a simulator that is being implemented using the simulation software IDA ICE. The simulator will be validated with metered data and is conceptualized to be implemented in a model predictive operation scheme of the building’s energy system to help optimize building energy performance and achieve a conceived ZEB scheme.

Figure 8 Illustration of the effects of sequentially applying the cleaning steps on a selected sensor time series with poor initial data quality.

4.1.1.5 Selected results

The innovative energy concept of the school building focuses achieving a zero-energy building (ZEB), where on annual basis the energy consumption can be covered by locally generated renewable energy sources. As elaborated beforehand, the realised sustainable energy strategy for covering building power and heat demand integrates diverse RES covering solar thermal collectors, PV panels, and geothermal heat pumps. To ensure energy flexibility and balance energy surpluses and deficiencies -over the year- the building energy system interacts with the public electric grid and district heating network beside the buffer storage tanks connected to the solar collector for short-term heat storage.

The comparison of monthly total heat energy consumption and production is illustrated in . The data indicates that during the period from June 2020 to September 2020, the minimum consumption recorded was 1,398 kWh, coinciding with the COVID-19 pandemic. Following this period, consumption gradually increased, reaching a peak of 29,863 kWh in January 2021. Concurrently, energy production also exhibited a gradual increase, achieving a total of 30,765 kWh in January 2021.

During the aforementioned period from June to September 2020, the school experienced no occupancy, resulting in thermal energy generation solely from the solar thermal collector, which fed directly into the district heating network. Notably, consumption exceeded production only during the months of November and December 2021, with recorded values of 1,754 kWh and 3,685 kWh, respectively. This discrepancy arose due to the absence of thermal energy generation from the solar thermal collectors, leaving the heat pump the sole source of heat production.

 presents also the monthly electric energy balance, integrating both production and consumption data. The findings reveal that energy production surpassed consumption during the lockdown period with a maximum production value of 9,343 kWh. Conversely, production diminished during the winter season, reaching a minimum of 982 kWh in December 2021. In that month, the disparity between consumption and production peaked at 10,612 kWh, necessitating imports from the public electric grid. Detailed elaboration on the monitoring results of the the ZEB can be found in https://doi.org/10.3390/en15196907.

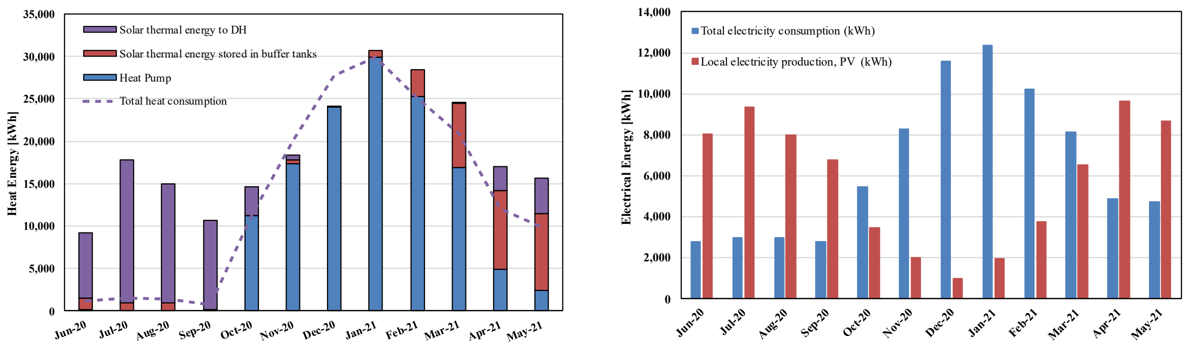


Figure 9 Monthly energy balance in new school extension building: Thermal Energy (left), Electrical Energy (right)

4.1.1.6 KPIs calculation:

The processed data are used to calculate several KPIs around the building energy demand and supply like building energy performance, load curves of electricity and heat consumption, PV production curve and COP of the heat pumps at different time scale. The most prominent high-level KPI is associated with the building annual energy balance to check and evaluate the criteria of achieving ZEB under the prevailing operational limits and conditions. Table 1 summarizes the key findings based on selected KPIs, highlighting the achieved RES integration, building energy efficiency measures, local energy production, energy consumption, import and export and the resulting CO_2 emission reductions.

Table 1: Selected KPIs Assessing the Impact of Implemented Measures in the ZEB

KPIs	Unit	value
Refurbished floor area	m2	3740
New constructed area	m2	4140
Installed capacity, PV	kWp	67
Installed capacity, Heat Pump (thermal)	kW	111
Installed capacity, Solar Thermal	m2	318
Electricity generated by PV	MWh/a	69.1
Thermal energy generated by solar and HP	MWh/a	225.9
COP of the heat pump (average annual)	-	4.05
Achieved energy savings by building efficiency measures	MWh/a	192.5
Total local RE production (power and heat)	MWh/a	295
Total energy consumption (power and heat)	MWh/a	238.4
Electricity import	MWh/a	77.1
Heat export (feed in the DH network)	MWh/a	-60.2
Self-supply ratio (annual)	-	1.24
Total CO2-reduction	tCO2/a	162.2
Total energy savings (specific)	kWh/m2.a	24.4
Total CO2-reduction (specific)	kg-CO2/m2.a	20.6

4.1.1.7 Brick data model of AUC1

For digitally representing the building layer within the data exchange platform (DEP), a Brick data model was developed as a knowledge graph to provide metadata of physical and logical entities of the school building and it's HVAC system (heating, ventilation, cooling). The task was to map all relevant building locations, HVAC equipment, data points and their interrelationships. Therefore, three different sub-models were created, the building model (known as the location model), the HVAC system and the energy monitoring models. Figure 10 shows the ontology of the complete heating supply system as an example. It is divided into four Brick sub-systems listed as follows:

- Subsystem 1 includes a ground source heat pump which utilizes borehole heat exchangers and decouples their hydraulic loop over a water tank with the primary distribution connector (loop 1+2). A free-cooling mode is also possible over a parallel connected heat exchanger (loop 3).

- Subsystem 2 consists of a solar thermal collector field and hot water storage tank system (loop 8). It is also connected to the main distribution connector of system 1.
- Subsystem 3 is comprised of a transfer station which connects the local district heating network with the distribution connector of the old building stock as a secondary distribution connector and is mainly used for system 4.
- Subsystem 4 represents the domestic hot water supply of the school. In form of a storage - charging station hot water is provided over district heating.

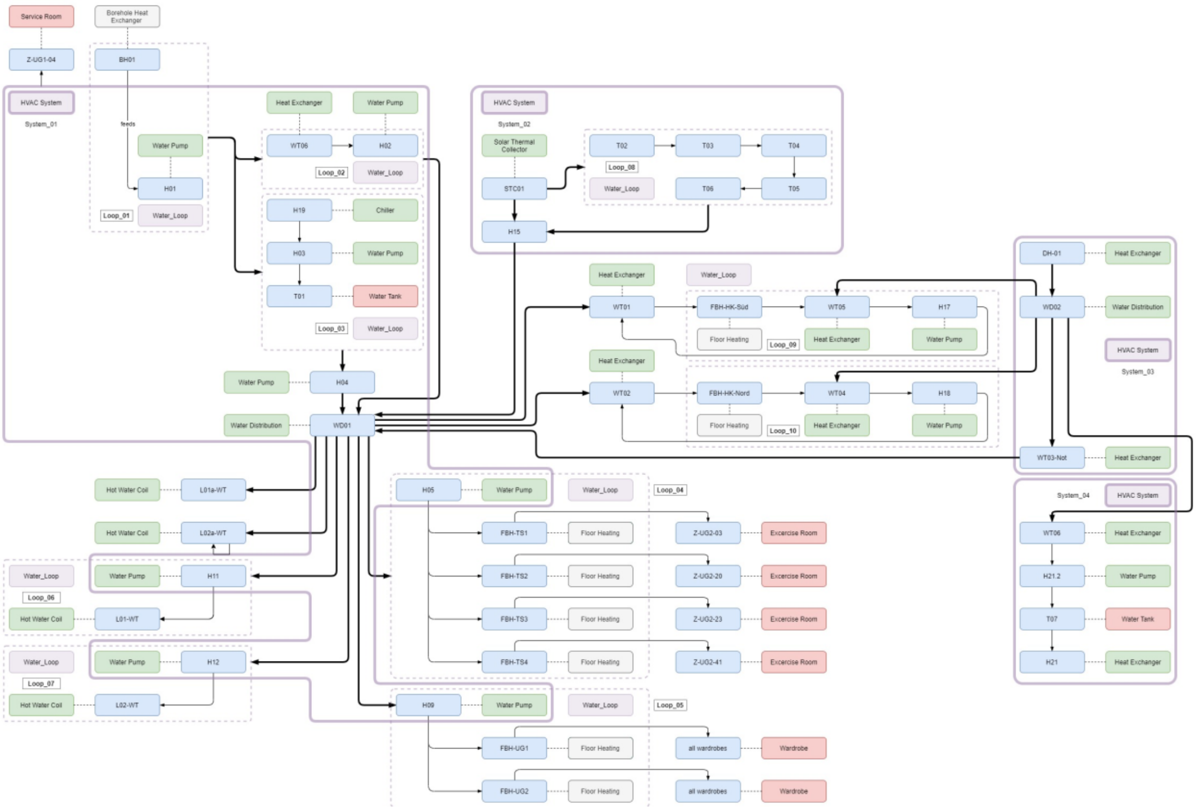


Figure 10 AUC1 - Ontology of the heating supply system

All systems are ordered in hydraulic "loops". They enable a logical and sequential connection of Brick entities (valves, pumps, tanks, etc.) to a hydraulic system. Loop 4 and loop 5 show the floor heating systems of the school. Loop 6 and loop 7 supply the heating coils of both main air handling units. Loop 9 and loop 10 act as cross-sectional distribution between the systems. Several systems and loops are related to locations where they are physically situated.

4.1.1.8 IDA-ICE Simulator of the School building

Having demonstrated the data collection, processing and cleansing, the cleansed data are being used for calculating KPIs and validating a simulator being developed for the whole school building using the IDA ICE software. The established validated simulator will support the decision-making process in testing various operation scheme of the school energy system and recommend best combination to reach zero energy balance considering the prevailing internal (demand load, user behaviour) and external building conditions (production of local renewable energies). This simulator can be used for planning and designing similar building in Vienna. This demonstrates how the DEP architecture and digital services could scale to need-owners in other regions.

IDA ICE (IDA Indoor Climate and Energy) is an advanced Building Energy Simulation (BES) software designed for detailed analysis of indoor climate and building energy consumption under varying conditions. It utilizes cutting-edge simulation models that have been rigorously tested against international standards such as ISO 13791 (now ISO 52016–1:2017), EN 15255 and 15265, and ASHRAE 140.

The core of IDA ICE is based on differential-algebraic equations (DAE) and features a comprehensive library in the neutral model format (NMF). This unique architecture enables users to freely modify how components are interconnected, offering a level of modelling flexibility not typically found in other BES tools. This flexibility is particularly beneficial for creating sophisticated models of building envelopes and integrating multiple physical and performance aspects without the need for co-simulation routines, which are often necessary in other BES applications for handling complex structures or simultaneous multi-domain simulations. The plant model for the AUC1 is depicted in Figure 11. Detailed elaboration can be found under https://doi.org/10.1016/j.jobe.2025.114401.

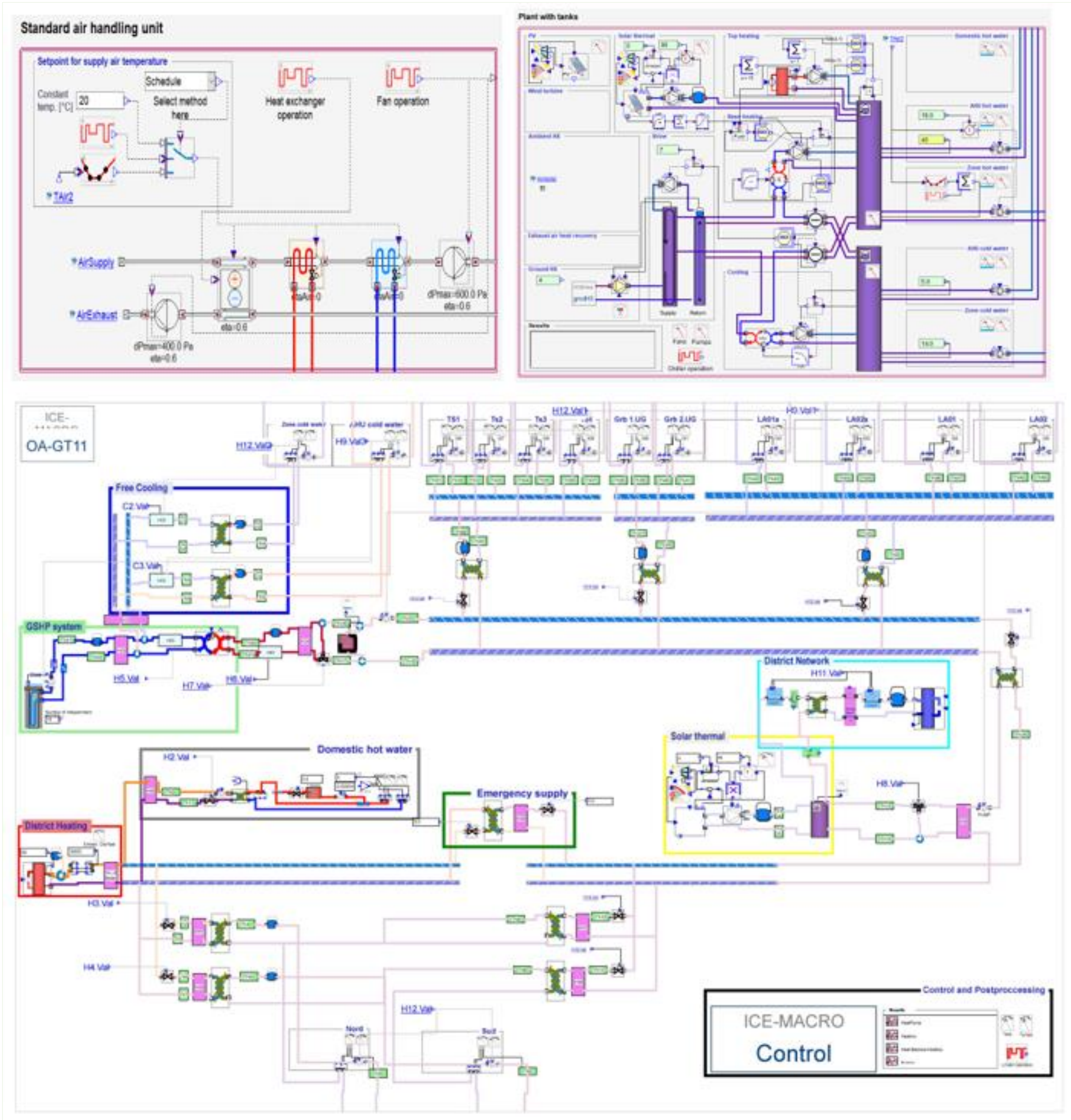


Figure 11 Screenshots of the IDA ICE plant model

4.1.2 AUC2, Internal Room Comfort

The second Austrian use case represents the new AIT office building so-called "FUTURE BASE" in Vienna. To heat or cool the offices, concrete core activation is used. Several factors specify the operation modes for heating and cooling the Future Base. On the one hand, the outdoor temperature defines whether heat energy is needed or not, but also the required cooling energy. The restricted groundwater extraction does also influence the mode of operation, as permanent cooling with groundwater would exceed the maximum quantity. On the other hand, cooling appliances should be used efficiently throughout the year.

As an example, Figure 12 shows operation mode 1 which is activated at outdoor temperatures lower than 13°C. Additionally, this mode aims to restrict the groundwater use to not exceed the daily and annual quantity restrictions. Regarding the available data, various sensors and meters are installed. Thereby, each zone is measured by the same set of sensors e.g., zone temperature and concrete core temperature. Additionally, an IoT sensor network is installed in the first and third floor to collect indoor environmental data of investigated zones / rooms (room air temperature, relative humidity, VOC, door and window contact, occupancy, brightness). All the collected building related data along with weather forecast is then used in data models to derive the expected comfortability. In case the expected comfort level breaches the defined “comfortability span”, the heating/cooling is adjusted accordingly by the operator. Thus, the second use case uses different data types, namely IoT and BACnet data and demonstrates the incorporation such into the platform.

A brick model was developed to determine the data required for each room. The actual data is derived from cloud-based data collection, namely the IoT sensor network and the OpenMeteo weather data service. The retrieved data is then analyzed in detail and subjected to various cleaning and processing (introducing a 15-minute time grid, removing outliers, filling in missing values, etc.). For ML models, the variables for each room are categorized into three groups:

- Targets: room temperature, room humidity, concrete core activation temperature
- Future features: including room influence cooling & heating, weather (temperature, humidity, wind, radiation, precipitation)
- historical features: including information on concrete core activation (valve positions, temperature setpoints), room (temperature, door and window contact)

Using this data, a training period and a validation period are defined for each room and an ML model is trained for each, in this case for three days ahead and with delays for all time grid values on one, two and six days before the prediction period.

Subsequently, the results are appealingly visualized in a dashboard which includes a comfort field. Thus, it supports operators of building energy systems.

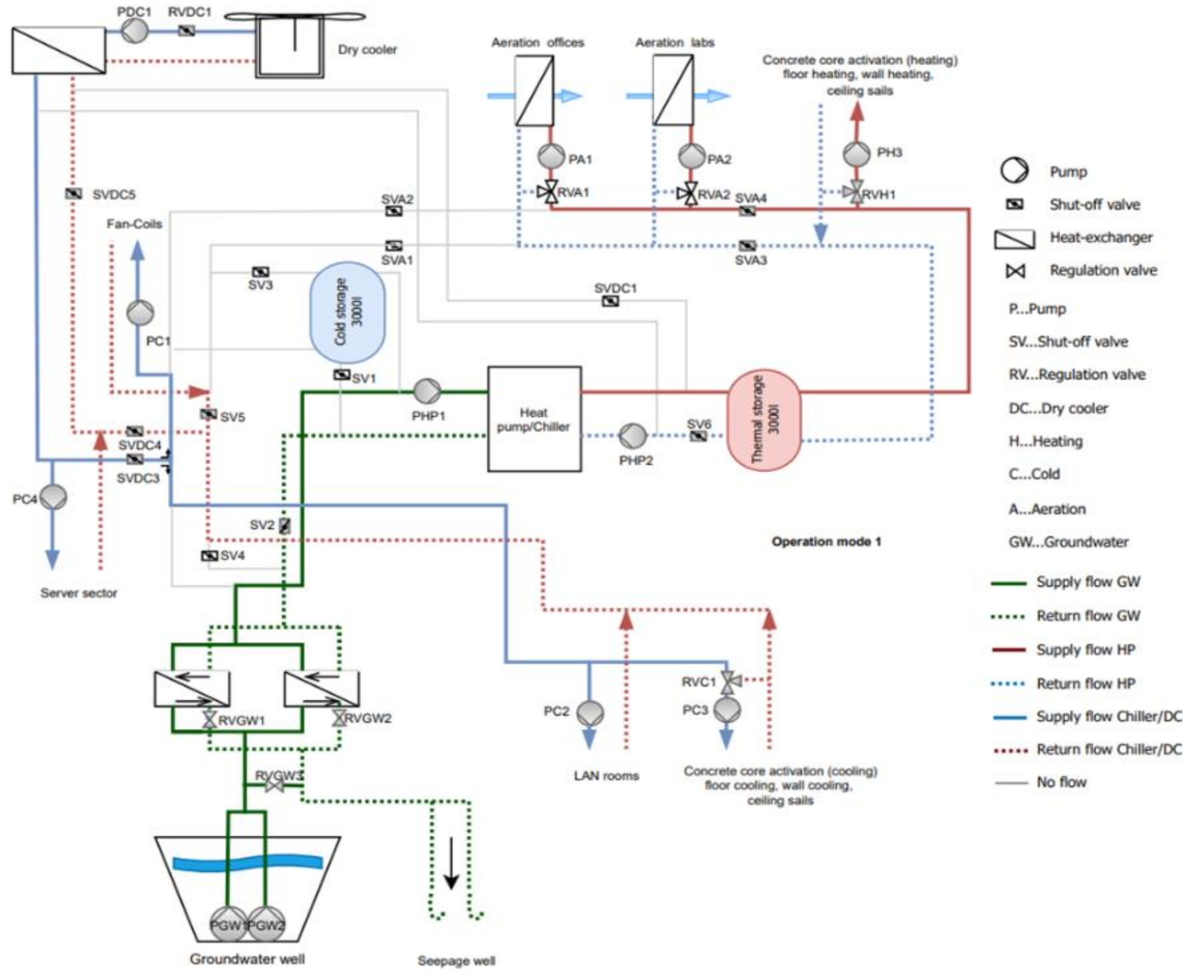


Figure 12 Simplified flowchart of the energy concept of (AUC2) of Future Base, operation mode 1, Vienna.

4.1.2.1 AUC2 – Brick data model development (FUTURE BASE)

Figure 13 outlines a part of the data model for the building automation and HVAC system of which the sub-system HK01 represents the main heat / cold supply system. HK01 is feeding O1HK which is located on Floor_U1 and contains O1HK_V02, a water system for concrete core activation. Within every sub-system entity like equipment (chiller, pumps, etc.), points (sensor types, etc.) exist and are somehow related to each other. For example, O1HK_V02 compose two regulating valves to control the volume flow of the heating (O1HK_V02_BTA_HV) or cooling (O1HK_V02_BTA_KV) circuit. These valves in turn include data points like a valve position command.

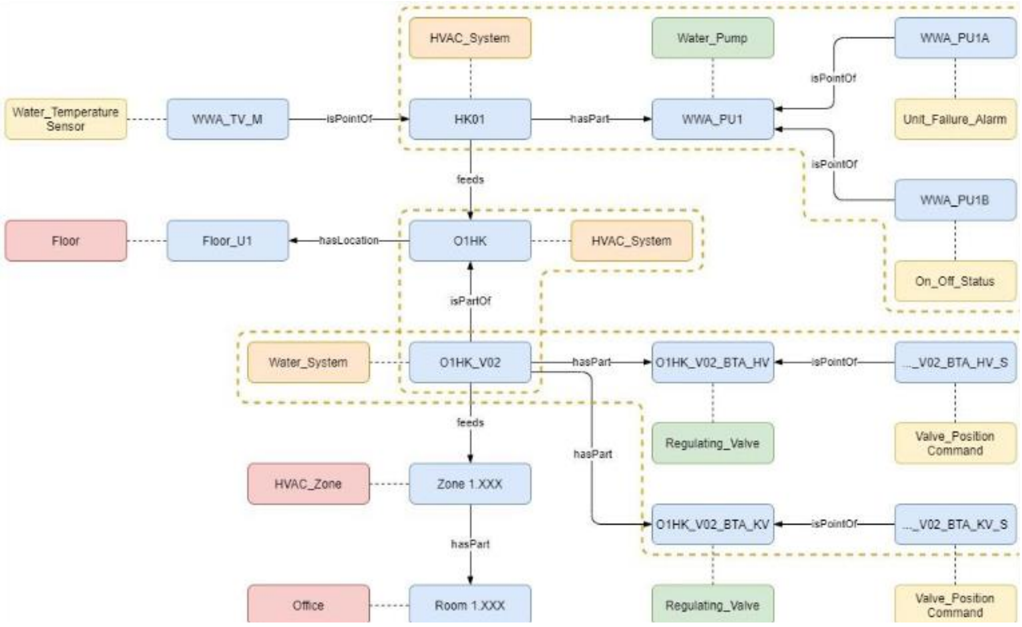


Figure 13 AUC2 – Ontology of the HVAC sub systems

An overview of the data model structure regarding the IoT sensor network is shown in Figure 14 in which the installed sensors for an office room are illustrated. Further, an HVAC zone which is a logical entity to connect several rooms together, e.g., meeting rooms and offices. In these offices there are several different IoT sensors (temperature, humidity, contact, illuminance) placed. The sensors themselves provide the meta data of their unit.

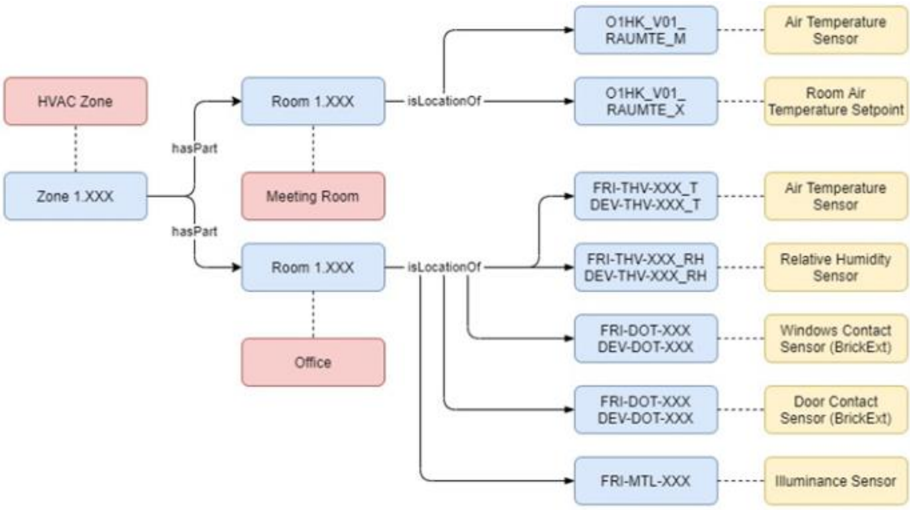


Figure 14 AUC2 – Ontology of the IoT sensors in office rooms

The BRICK ontology was applied to map sensors to rooms. In total, 36 rooms (19 on the 1st floor and 17 on the 3rd floor) were extracted from the dataset. For each room, 50 features were prepared, including indoor temperature, window/door status, outdoor temperature, setpoint values, heating supply/return temperatures, and heating/cooling flow rates.

Based on the historical data, three variables are predicted: concrete core temperature, room temperature, and indoor humidity.

Predictions are generated using a LightGBM model implemented via the Darts library. This gradient boosting approach incrementally improves model performance and is computationally efficient compared to similar methods. A separate model was trained for each room using data from 08/09/2022 to 09/12/2023 (detailed elaboration on data prediction are documented in deliverable D3).

4.2 Switzerland

4.2.1 SUC1 Operational Decision Making

This use case focuses on optimising energy storage management by assisting operational decision-making. In particular, we focus on water storage for small hydro power plants and battery storage for self-consumption communities. Utilities and self-consumption communities often rely on them to shave the energy demand peaks. This may reduce the cost of energy, as in self-consumption communities better matching between the consumption and generation can maximize self-consumption, while for utilities, smaller peaks correspond to a lower price on the energy market. On the other hand, a smoother profile of the energy demand facilitates the distribution grid operation.

Optimal management of energy storage is often based on predictive control, in which decision-making is based on energy demand forecasts. Those forecasts require managing different sources of data, manipulating, combining, and constantly updating them to train data-driven forecasts of the relevant time series (energy demand, photovoltaic production, availability of water, etc.). Besides, high quality data must be fed into the controller in real-time to allow its field operation.

Data scientists recognize the data pre-processing step as the most time-consuming and least enjoyable step[4]. Thus, although utilities acquire the skills necessary to implement machine learning approaches, the difficulties of obtaining reliable data and managing and cleaning them often represent the greatest limitation to implementing forecasting models that may help energy management.

To meet this need, Digicities is building an infrastructure that will organize the data to be readily available for training and operating machine learning models, focusing on time series forecasts, which are involved in a large fraction of ML applications in the energy field.

Objectives

- Evaluate the time savings made possible by Digicities in developing time series predictive models and improve flexibility. This will be compared to

[4] Cleaning Big Data: Most Time-Consuming, Least Enjoyable Data Science Task, Survey Says. Forbes Inc. https://www.forbes.com/sites/gilpress/2016/03/23/data -preparation-most-time-consuming-least-enjoyable-datascience-task-survey-says/#4db1b036f637, 2016.

developing it from original data managed by the companies and eventually combined with public repositories (e.g., for weather forecasts or measurements).

- Show how such models allow improved peak shaving by optimal control for current operator scheduling, resulting in a consequent reduction of the cost of electricity and optimization of water usage for clean energy production.

- Integrating battery control, the data-driven predictive model can improve community self-consumption and reduce demand peaks at different grid levels.

- Establish through simulations how battery capacity influences peak reduction at different NE levels.

4.2.2 SUC2 Energy Planning and Resource Optimisation

The management of digital replicas using Digicities aims to empower municipalities and utilities to generate and track the assumptions behind mandatory energy reporting and planning. Municipal planners require more control and awareness of the data used for reporting and planning in accordance with the objectives of the Swiss Energy Strategy. They have also expressed a need to minimize the uncertainty of forecasts and require a transparent process that can be updated and extendable to new data sources and assumptions, e.g., the inclusion of charging stations for electric vehicles. Once the sources of generation and consumption are established, they also need to take measures to optimize their operation.

A core objective of Digicities is to connect digital services along the digital value chain. Each use case has its own value chain, and in this example, we have included a digital service provider that provides optimal energy planning and reporting based on data inputs. Our surveys revealed that digital service providers struggle with data preparation, resulting in additional features to be developed into their interfaces. This overcomplicates the process. The benefit of Digicities is that it handles the digital replica to interface with the services offered by the provider efficiently. In this use case, we have partnered with a digital service provider to streamline the outputs of energy reports for energy system optimization. This use case has integrated two sub-cases – an energy planning module and an energy optimisation module.

Objectives

- Support obligatory municipal energy reporting

- Track assumptions and uncertainty associated with scenarios

- Provide energy planners with the best available data for their project

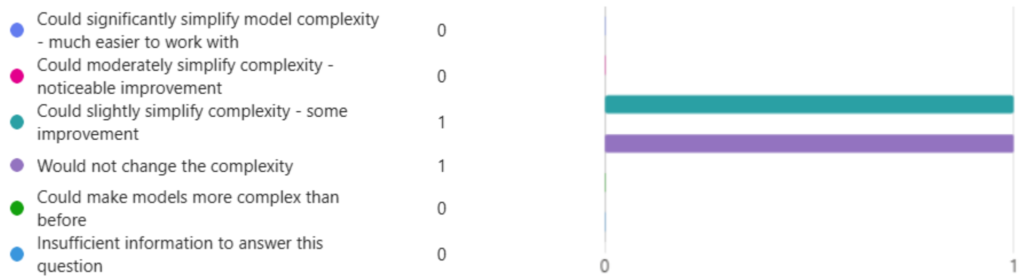
- Transparency of models used in forecasting and the quantification of uncertainty wherever possible

- Ability to track the progress and validity of a pathway
- Provide a means to evolve according to new datasets

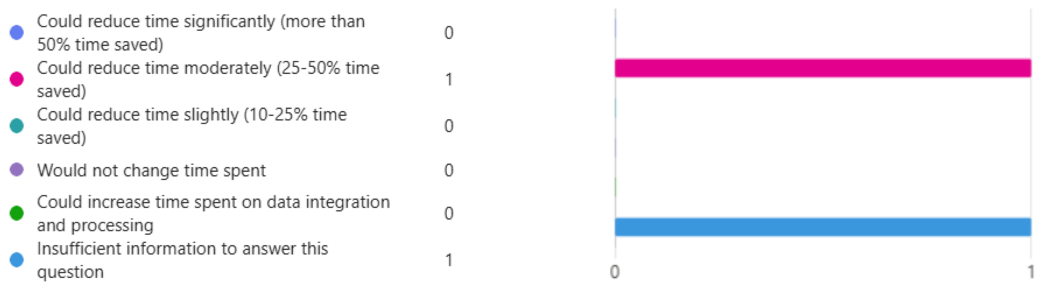
5 PRE-PILOT SURVEYING

An anonymised, pre-piloting survey was provided to the need-owners of the UC2 - Energy Planning and Resource Optimisation. The questions and responses are given below:

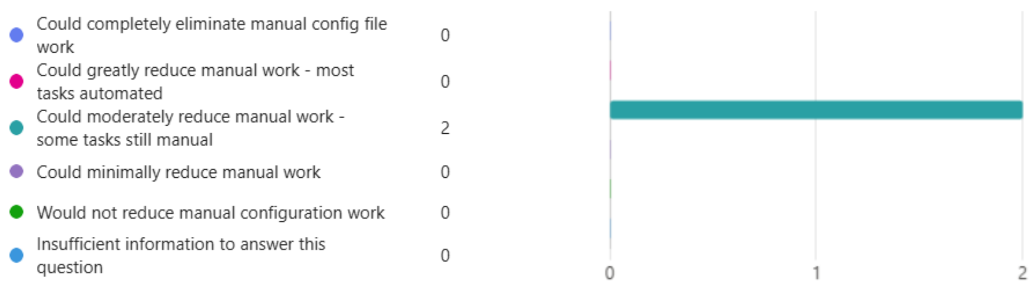
1. Based on your understanding of the platform: How well could the Digicities platform address the complexity of energy models in your workflow?



2. Based on your understanding of the platform: To what extent could Digicities reduce the time you spend on data integ ration and processing?



3. Based on your understanding of the platform: How effectively could the platform eliminate manual and tedious config uration file modifications?



4. Based on your understanding of the platform: How much could Digicities improve your confidence in data sources used for energy planning?

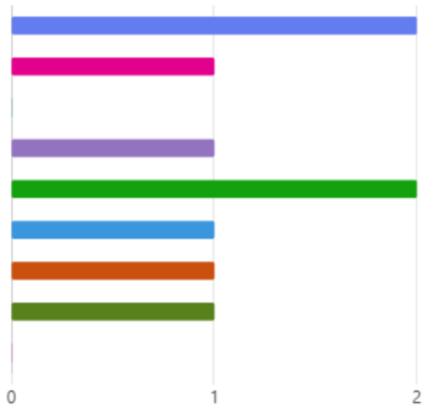
Could greatly improve confidence - clear data provenance and quality indicators	0
Could moderately improve confidence - better visibility into data sources	2
Could slightly improve confidence - some additional information available	0
Would not change confidence levels	0
Could decrease confidence in data sources	0
Insufficient information to answer this question	0

5. Based on your understanding of the platform: To what extent could Digicities provide transparency and replicability in energy studies?

Could provide complete transparency - all studies fully replicable	1
Could provide high transparency - most aspects replicable	1
Could provide moderate transparency - some replicability challenges remain	0
Could provide limited transparency	0
Would not improve transparency or replicability	0
Insufficient information to answer this question	0

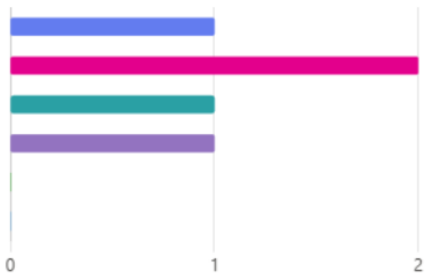
6. Based on what you know about the platform, please identify the features of Digicities that would be critical to your current workflow (Multiple Answers)

Managing data using standardised terms	2
Having a workspace to manage all data on physical infrastructure	1
Quickly generating scenarios for physical infrastructure and systems	0
The ability to exchange data easily with various services	1
Ingestion of open and private data products directly into models	2
Allowing traceability and repeatability in results from colleagues and contractors	1
Decentralised data storage to manage the workspace	1
Providing an ecosystem where quality data can be obtained and used for a purpose	1
None of these features are critical	0

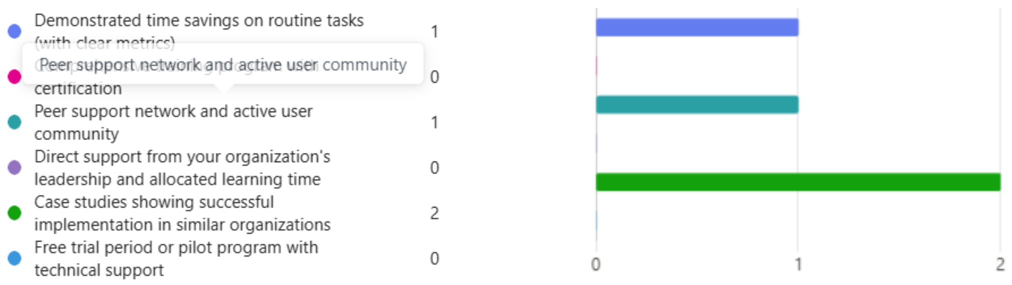


7. What do you anticipate as the main barriers to adopting the Digicities platform? (Multiple Answers)

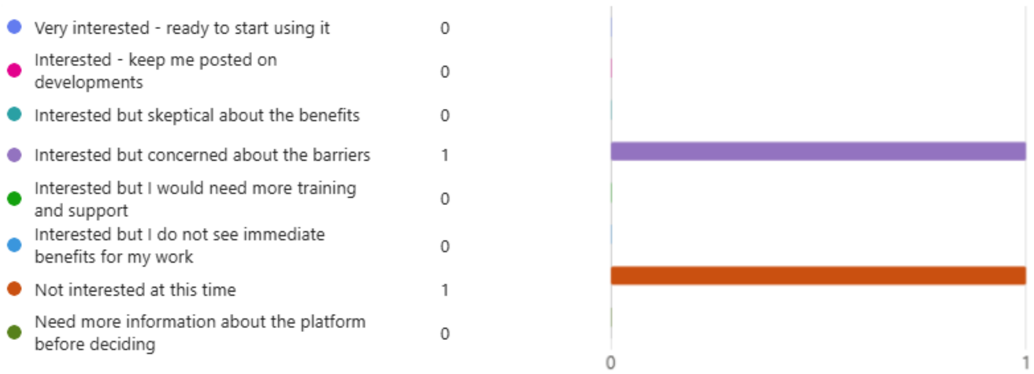
Complexity of the platform and steep learning curve	1
Time required to migrate existing workflows and data	2
Resistance to adopting new systems and changing established processes	1
Concerns about data security and compatibility with existing tools	1
Lack of sufficient training resources and support	0
Insufficient understanding of the platform to identify barriers	0



8. What incentives would motivate you to invest time in learning and adopting the Digicities platform? (Multiple Answers)



9. Based on your current understanding, how likely are you to use the Digicities Platform if it were made available to you?



This results show reserved scepticism about the platform after the first hands-on presentation.

6 POST-IMPLEMENTATION MONITORING

6.1 Scope and Limitations

The original measurement concept planned pre- and post-implementation evaluation of each use case against KPIs covering data access, decision-making support, and energy sector impact. In practice, the scope of post-implementation monitoring was substantially narrower than planned, for reasons that should be stated directly.

The platform's development trajectory involved significant architectural pivots, most notably the abandonment of the Azure Digital Twin Platform in favour of a custom GraphDB-based architecture, and the migration from Azure Active Directory to Keycloak for identity management. These decisions were technically sound and produced a more capable platform, but they consumed development time that had been allocated for piloting and evaluation. The functional prototype that stakeholders could interact with was only available in the final months of the project. As a consequence, the post-implementation assessment has the following limitations:

Only the Swiss UC2 (Energy Planning) stakeholders were formally surveyed post-implementation. The Swiss UC1 (Hydro Scheduling) evaluation was conducted through quantitative simulation comparisons (operator vs. scheduler performance, reported in the national final report) rather than through stakeholder survey of the platform itself. A live operational testing phase at SES was planned, with operator feedback expected in early 2026. The Austrian use cases were not subject to post-implementation stakeholder evaluation within the project timeline.

Stakeholders were exposed to a prototype demonstration rather than extended hands-on use. Their responses therefore reflect first impressions and perceived potential rather than validated experience with operational workflows.

The pre-piloting survey was conducted only with UC2 energy planning need-owners. No comparable structured survey was administered to UC1 or Austrian use case stakeholders post-implementation.

These limitations are acknowledged throughout the following analysis. The findings should be interpreted as indicative of stakeholder perceptions at prototype stage rather than as a comprehensive evaluation of platform adoption readiness.

6.2 Evaluation Approach

For the energy planning use case, a demonstration session was conducted with the need-owners, a utility company and a municipal planner, in which the platform's core workflow was presented: ontology-guided data preparation, semantic data product loading, scenario construction, assumption modification, and API submission to the Sympheny regional planning service. Following the demonstration, stakeholders were surveyed on their perceptions of the platform's value, usability, and barriers to adoption.

For the hydro scheduling use case, the evaluation took a different form. Rather than surveying stakeholders on the platform interface, the evaluation focused on quantitative performance comparison between the automated scheduler and experienced human operators, using historical data over multiple monthly test periods. This approach was appropriate given that UC1's primary value proposition is operational performance improvement rather than workflow transformation. A subsequent live testing phase was arranged, in which daily data feeds would be processed through the forecasting and scheduling pipeline, with the scheduler's production decisions provided alongside the operator's own plans for comparison.

For digital service providers, feedback was gathered through ongoing collaboration the development process and is synthesised in Section 7.2.

6.3 Future Monitoring Provisions

To address the limitations of the current evaluation, provisions have been made for continued feedback collection beyond the project's conclusion. The SES live testing phase will provide the first operational validation of the scheduling pipeline with real stakeholder feedback expected in early 2026. The platform's deployment in ongoing projects provides opportunities for extended piloting with broader stakeholder groups. Should the consortium proceed with the open-source release under consideration, community feedback mechanisms (issue tracking, feature requests, usage analytics) would provide a continuous stream of stakeholder input that was not available during the project's constrained evaluation window.

7 POST-IMPLEMENTATION ANALYSIS

7.1 Energy Planning Need-Owners

The energy planning end users, a utility company and a municipal planner, were surveyed following a demonstration of the prototype platform. Their responses reveal a pattern of cautious interest: recognition of the platform's potential value in specific areas, tempered by practical concerns about the effort required to realise that value.

Interest focused on data infrastructure rather than modelling efficiency. Stakeholders expressed strongest interest in capabilities related to data management and governance: standardised terminology that reduces ambiguity when working across organisations, improved data ingestion that reduces manual formatting effort, traceability mechanisms that document the provenance and assumptions behind planning inputs, and workspace management that provides a structured environment for organising project data. Notably, computational efficiency gains were not identified as primary motivators. This suggests that the platform's positioning for energy planning audiences should emphasise data quality, transparency, and governance benefits rather than analytical performance.

Migration challenges were identified as the primary adoption barrier. Stakeholders indicated that the time and effort required to transition existing workflows to the platform currently outweighs the anticipated benefits. Municipal planners and utilities have established relationships with contractors and consultants who use familiar tools and formats. Adopting the Digicities platform would require not only learning new tooling but also convincing collaborators and service providers to participate in the new workflow. This institutional inertia is a well-documented barrier to platform adoption in the energy sector and is not unique to Digicities.

Concrete proof was identified as an essential prerequisite. Stakeholders consistently indicated that commitment decisions would require demonstrated case studies from comparable organisations showing quantified time savings and tangible workflow improvements. Abstract descriptions of semantic interoperability benefits were insufficient to justify the investment in migration. This finding underscores the importance of expanding the platform's deployment across additional energy planning studies, where each successful application provides the evidence needed to persuade subsequent adopters. This finding supports the use case driven approach of this project.

The KPIs originally defined for UC2 could not be fully evaluated. The measurement framework specified KPIs across data access (quantity of data sources, time saved accessing and processing data, time saved creating usage agreements), decision-making (accuracy of projected baseline, user evaluation, stakeholder reach, metrics reported), and energy impacts (percentage of self-consumption, carbon intensity of future scenarios). Of these, only the user evaluation was assessed through the stakeholder survey. Time savings could not be quantified because stakeholders did not use the platform for a complete planning cycle. Baseline accuracy, energy impact metrics, and stakeholder reach were not evaluated because no energy planning study was completed through the platform within the project timeline. These gaps are a direct consequence of the late prototype availability discussed in Section 0 and represent the most significant limitation of the current evaluation.

7.2 Digital Service Providers

Feedback from the digital service providers who collaborated on the project was gathered through ongoing project interactions rather than formal post-implementation survey. While this limits the methodological rigour of the assessment, the consistency of the feedback across providers lends it credibility.

Service providers identified five areas of potential benefit from the Digicities platform:

- **Reduced data integration workload**. Service providers typically invest significant effort in custom integration for each client — developing bespoke data parsers, validating inconsistent input formats, mapping client-specific schemas to service requirements. The platform's standardised data structures and semantic validation were seen as having potential to streamline this process substantially.

- **Accelerated user data preparation**. By providing ontology-guided templates and validation feedback, the platform could reduce the time clients spend formatting and preparing data before it reaches the service API. This shifts data preparation effort from an ad-hoc, error-prone process to a guided, validated workflow.
- **Expanded market reach through simplification**. Simplified, standardised service interfaces could make energy planning tools accessible to organisations that currently lack the technical resources for complex API integration. This was identified as a meaningful market expansion opportunity.
- **Increased confidence in API data quality**. Standardised inputs validated against ontology-defined service requirements provide greater assurance that data reaching the API is complete, correctly formatted, and semantically consistent. This reduces support overhead and troubleshooting effort.
- **Improved efficiency handling multiple scenarios**. The platform's scenario management capabilities enable clients to submit multiple analytical variants through a single standardised workflow, increasing service utilisation without proportional increases in integration support.

It is important to note that these benefits were identified based on prototype interaction and collaboration experience rather than measured through operational deployment. Whether the anticipated efficiency gains materialise at scale remains to be validated through extended use.

7.3 Hydro Scheduling Stakeholders

The hydro scheduling use case was not evaluated through a formal stakeholder survey of the platform interface. Instead, evaluation focused on the quantitative performance of the scheduling system, which is reported in detail in the national final report. In summary, the automated scheduler consistently outperformed experienced human operators in peak demand reduction across both utilities tested, with estimated monthly savings of 16 kCHF (AEM) and 96–220 kCHF (SES). The utility expressed willingness to proceed with a live testing phase, indicating positive reception of the system's demonstrated capabilities even in the absence of a formal platform evaluation.

The live testing at SES would provide the first opportunity for direct stakeholder feedback on the operational integration of the system. This feedback, would be valuable for understanding the practical considerations (trust in automated recommendations, integration with existing operational procedures, operator interface requirements) that determine whether demonstrated technical performance translates into sustained operational adoption.

7.4 Synthesis

Despite the limitations of the evaluation scope, several findings are sufficiently consistent to inform future development priorities.

The divergence between service provider enthusiasm and end-user caution is the most prominent pattern. Service providers see immediate, tangible benefits in reduced integration effort and standardised data quality. End users see potential value in data governance capabilities but view migration costs as prohibitive without demonstrated proof. Therefore, the recommendation is to build the evidence base through service provider integrations and targeted pilot applications, then expand to broader end-user adoption as the catalog of case studies and ready-to-use data products grows.

Stakeholder interest in data governance over computational efficiency was a finding that the project team did not fully anticipate. The platform's development prioritised technical capabilities but the stakeholders who would use it daily cared most about terminology consistency, data provenance, and reducing the manual burden of data preparation. This finding should inform how the platform is presented and prioritised in future development. For example, governance and quality assurance capabilities should be foregrounded, with computational and analytical features positioned as downstream benefits enabled by better-managed data.

The inability to quantify time savings is the evaluation's biggest gap in expectation. Addressing this requires extended piloting where stakeholders complete actual planning workflows using the platform, with systematic measurement of effort compared to their existing processes. This should be a priority for any continuation of the work, whether through ongoing research projects or through community-driven deployment enabled by a potential open-source release.

8 CONCLUSION

The stakeholder engagement progressed from initial surveys that shaped the platform's conceptual architecture, through use case refinement workshops that defined concrete data requirements, to a post-implementation assessment revealed that digital service providers identify immediate value in reduced integration workloads and standardised data quality, while energy planning end-users recognise the platform's potential in data governance and traceability but view migration costs as prohibitive without demonstrated proof through additional case studies and quantified time savings, a gap that can only be closed through extended piloting and broader deployment across real-world energy planning workflows.

9 ACKNOWLEDGEMENTS

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