digitaL frAmework for SmArt Grid and reNewable Energies (LASAGNE)

Progress Report 2023

2024

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1 Terms and definitions

B2C Business-to-Consumer
C2C Consumer-to-Consumer
DCE Discrete Choice Experiment
DSO Distribution System Operator
DT Digital Twin
E2C Edge-to-Cloud
EEV Edge Equipment Vendors
EV Electric Vehicle
GED Grid Edge Device
HP Heat Pump
HVAC Heating, Ventilation, and Air Conditioning
ICT Information and Communications Technology
IoT Internet of Things
ISV Independent Software Vendors
LSO Local System Operator
ML Machine Learning
NOW Need Owner
PoC Proof-of-Concept
SI System Integrators
TAM Technology Acceptance Model
TSO Transmission System Operator
HEMS Home Energy Management System
BESS Battery Energy Storage System
DUC Data Under Central
IMD Individual Metering and Debiting
BMS Building Management System
FCR-N Frequency Containment Reserve for Normal Operation
FCR-D Frequency Containment Reserve for Disturbances

2 Introduction

This report details the achievements of the LASAGNE project from April 2023 to March 2024. It also shows some of the tasks that will be completed over the coming months. The points in the annual report are the ones that help to reach the milestones M3 and M4.

Section 3 is dedicated to the definition of the architecture of the LASAGNE Framework.

Section 4 shows the main results of social acceptance and its objective for the next period.

Section 5 exhibits the results in developing and improving the performance of the coordination model proposed in LASAGNE.

Section 6 details a short list of the energy applications that were selected by the consortium. At least two of these applications will be developed and deployed at the marketplace platform to be set up within the project. This section represents Milestone 3 of the project.

Section 7 details the state of the deployments carried out in Switzerland and Sweden.

3 Global architecture

The energy applications targeted by LASAGNE (self-adaptive applications in Figure 1) focus mainly on energy flexibility. Flexibility is defined here as the ability to shift/shed the peak load from the demand side, and the capacity to manage the local renewable supply. This definition applies to different levels: grids, microgrids and buildings.

The energy applications are assumed to achieve several goals such as minimizing energy costs for Electric Vehicle (EV) charging, guaranteeing the timely and complete charging of vehicles, harnessing e-vehicles and charging stations as dynamic load suppliers to fortify the grid, safeguarding infrastructure performance, optimizing localized energy exchanges, ensuring voltage stability, and enabling the efficient aggregation of distributed energy resources, etc.

Needless to say, the energy applications targeted by LASAGNE must rely on forecasting tools that predict the consumption/production of energy. The prediction period depends on the application itself. For security reasons, these forecast modules are deployed close to the data (GED-based Edge-to-Coud infrastructure in Figure 1).

The LASAGNE Platform of Figure 1 is composed of:

- A microgrid infrastructure: A microgrid is deployed within a grid cell and spans mid- to low-level voltages (level 5 through 7). A microgrid is in general composed of households and factories employing several power sources (solar, wind, geothermal) and appliances (heat pumps, EV charging stations, HVAC, etc.).

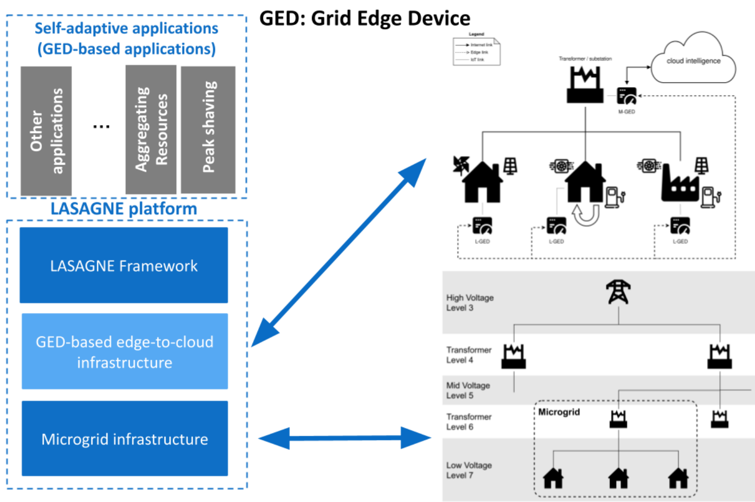

Figure 1: LASAGNE Global Architecture

- An edge-based digital infrastructure: Low-GED (L-GED) and Mid-GED (M-GED) are able respectively to act on behalf of households and micro-grids. L-GEDs and M-GED learn and anticipate the consumption/production of electric power at low (household) and mid (microgrid) levels and are then able to trade within the network of GEDs for energy exchange.

- LASAGNE Framework: Self-adaptive and context-aware consumption/production forecasting algorithms that are deployed, updated and managed thanks to the Nuvla/NuvlEdge solution provided by SixSq. It contains the coordination model presented in Section 5. There will be a module dedicated to the communication between the GED's.

4 Social acceptance

The question of social acceptance by design is studied in WP2, divided into three tasks:

- T2.1 – ethnographic survey,
- T2.2 – combination of technical and social attributes,
- T2.3 –conjoint analysis.

T2.1 and T2.2 were completed in 2022 and 2023 respectively, while T2.3 is still in progress.

For T2.1 and T2.2, a total of twelve interviews were conducted, to identify social and technical salient attributes linked to micro-grid communities. Eight of them were semi-directed interviews with respondents of various profiles:

- Two respondents who own and live in a house with solar panels they installed,
- One respondent who installed solar panels on a building they own but do not live in,
- One respondent who had wanted to install solar panels on their house but had to renounce due to various reasons,
- One respondent who lives in an eco-district,
- One respondent who works at a fuel cell company,
- Two respondents who work at companies which sell and install solar panels.

Four more interviews were conducted, based on a hypothetical scenario linked to living in a micro-grid community.

An additional focus group in a micro-grid community in Meyrin (Geneva, Switzerland) was also conducted to test out the list of identified salient attributes and to complete it.

A variety of salient attributes were identified during T2.1 and T2.2, covering the following themes: pricing, eco-friendliness, values, responsibilities, group cohesion, monitoring, emergency planning, living in a community, knowledge and information, consumption habits, administrative procedures, resource management, consumption rules, quotas, autonomy and electricity storage.

T2.3, the conjoint analysis, is currently being conducted, based on the results from T2.1 and T2.2. In total, five focus groups were conducted for T2.3. T2.3 is being conducted in two overlapping phases.

The first phase consists of a card system survey, where respondents have to choose between various profiles of micro-grid communities. Each profile has a different distribution of various attributes, with each of them having two levels (Appendix A shows the card used).The attributes are based on the results of T2.1 and T2.2, and they are the following:

- Grid connection
  - With: The community is connected to the regional electricity grid.
  - Without: The community is not connected to the regional electricity grid. It is self-sufficient.
- Electricity mix
  - Renewables: The electricity mix is made up entirely of renewable energies.
  - Mix: The electricity mix is made up of renewable energies and other energy sources.
- Pricing

  - Dynamic: Pricing is done on a dynamic basis, with prices adapted to supply and demand over the current period.
  - Peak/off-peak hours: There are two tariffs: peak hours (e.g. between 7 a.m. and 10 p.m.) and off-peak hours (e.g. between 10 p.m. and 7 a.m.).

- Information transfer
  - Systematic: All information concerning the community is systematically transmitted to all members.
  - Punctual: Only information directly affecting the member in question is transmitted.

- Data sharing
  - With: All residents have access to the electricity-related data of other households.
  - Without: Only the person responsible for drawing up the reports has access to the electricity data of other households.

- Consumption comparison
  - With: On the electricity reports, there is a comparison of consumption with other households with the same profile. The data remains anonymous.
  - Without: On the electricity reports, there is no comparison of consumption.

- Community meetings
  - Monthly: Community meetings on electricity-related issues are held once a month.
  - Annual: Community meetings on electricity-related issues are held once a year.

- Electricity regulations
  - Precise: The community has precise and exhaustive rules that cover a wide range of situations.
  - Self-regulation: There are only a few general rules.

- Quotas
  - With: Each household has a quota (the amount of electricity that can be used) that must be met. The quota is set according to the number of people living in the household and the surface area of the apartment.

  - Without: No quota (quantity of electricity that can be used) is imposed on households.

- Infrastructure management
  - External: The infrastructure is managed by an external company.
  - Internal: The community participates in managing the infrastructure.

The second phase consists of establishing a share-of-choice optimisation model, which will help determine the most economical configuration for micro-grid communities, based on social attributes identified previously. This will be possible through conjoint analysis, by extracting part-worth (utility functions) to feed the share of choice optimisation models, which consider different prosumer profiles as well as cost structure. It will provide a prosumer role design maximising social acceptance towards achieving a CO2 reduction goal. The conjoint analysis will be used to determine which attributes of a product or service are important, through examining which trade-offs consumers are willing to make.

A paper on the share-of-choice optimisation mode was submitted on March 31st 2024 to the 23rd International Conference on Informatics in Economy (https://www.conferenceie.ase.ro/), with the title *Enhancing Social Acceptance: Share-of-Choice Optimization in Microgrid Implementation.*

Globally, WP2 is involved in investigating means to active prosumers. Indeed, by investigating the social acceptance of the Grid Edge Devices, this work package will help understand which functionalities – which we call attributes – are likely to be accepted by end-users – in our case, prosumers – and thereby make it possible to design GEDs which have the highest probabilities to be adopted by the population. Thus, the findings of this work package will provide indications about the solutions that receive highest social acceptance, among those that are both technically feasible and economically viable.

Moreover, the WP is also involved in investigating means to involve citizen groups in energy efficiency activities, through the ethnographic survey whose sample is made of citizens to verify different aspects of social acceptance.

5 Coordination model and intelligent digital twins

In 2022, we set up a coordination platform and implemented intelligent digital twins that interact with each other via the coordination platform to exchange energy and regulate production/consumption. The preceding technical report (Milestone-2_report.pdf) presents and explains in detail the various concepts used. In 2023, we have continued to work on this platform to meet the project's goal (Developing a digital framework for collaborative learning among GEDs).

5.1 Tuning of the coordination platform in a four nodes topology

In the coordination platform simulator, we have made it possible to configure the list of nodes and assign a node to each device according to its location. This configuration is written as a mapping table in a configuration file as shown in Figure 2. Before launching the simulator, an instance of the coordination platform must be launched for each node, with the appropriate configuration of the node and its direct neighbours. At launch, the simulator retrieves the list of devices to be integrated into each node and requests the server of each coordination platform to initialise these devices. Digital twins are then generated for each node's coordination platform, and energy exchanges are carried out across the set of nodes.
On the one hand, we set up an environment to experiment with a simulation of the Vergers living lab, using different kinds of graph topologies to define the links between the Grid Edge Devices. In addition, we have adapted the coordination platform so that it can run with other services in a lightweight environment with less disk and memory space, such as a Raspberry-3 edge device. Finally, we integrated the "gossip" federated learning distribution framework using coordination laws. The following sub-sections detail each of these points.

Figure 2: Nodes configuration by location

As shown in Figure 3, the configuration of each node includes the addresses of its direct neighbours. This can be modified when the server is running. In this way, it is possible to define and update the topology of the various nodes. The network graph can be made "full" by attaching all the other nodes as direct neighbours to each node.

Using scenarios from the Les-Vergers living lab, we have experimented with distributing the devices in a set of 4 nodes, with one node for each geographical location: the primary school, the gymnastic room, the after-school room, and the under-ground. We have also experimented with 2 extreme network topologies:

- The minimal topology (see figure 4, of the chain type, for which a node has 2 neighbours, or a single neighbour at the end of the chain.
- The maximum topology (see figure 5, of the 'full' type, in which all the

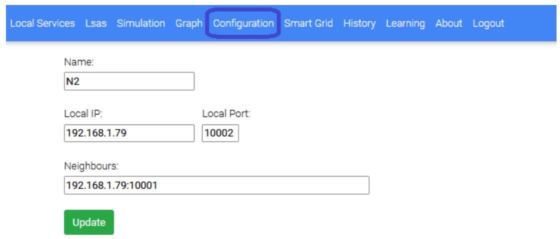

Figure 3: A Node configuration

nodes are completely interconnected.

The experiments confirmed that the chain topology has the advantage of reducing the number of data transfers between nodes but, on the other hand, increases the number of cycles required to exchange energy between digital twins, particularly when the consumer and producer are at the two extremes of the chain.

Conversely, the "complete" topology increases network traffic drastically but reduces the number of cycles required to exchange energy.

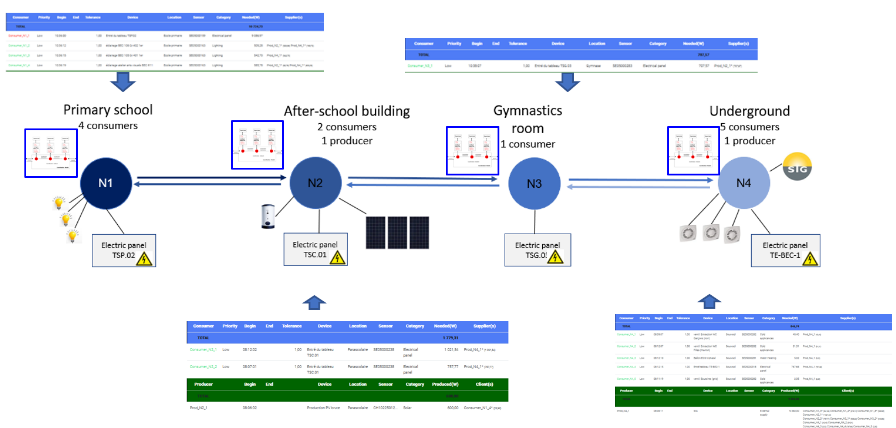

Figure 4: Chained graph topology

5.2 Adjustments to the propagation mechanism for indirect links between nodes

In the early 2023 version of the coordination middleware, we have identified a regression in the propagation coordination law mechanism. The latter does not manage the sending of data to indirect neighbour nodes: each propagation stops

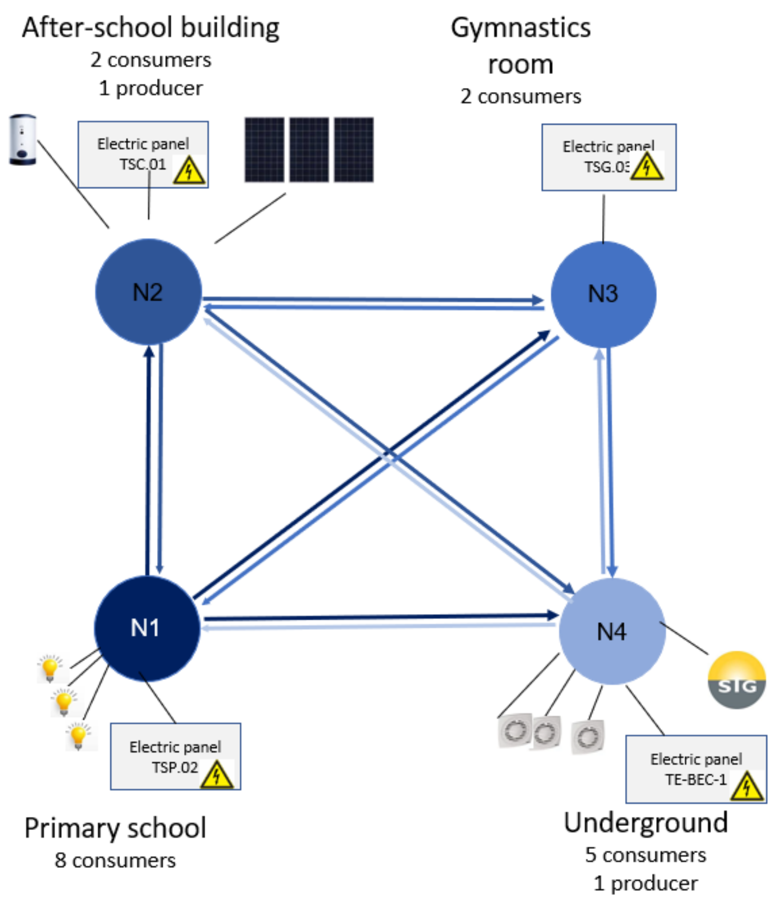

Figure 5: Full graph topology

at each coordination cycle.
The mechanism has been corrected to ensure indirect spreading: A node having received a message in the previous cycle repeats the sending of this same message to all the nodes which have not already received this message. A property has been added to each message to store the sender and the list of nodes that have already received the message.

5.3 Preparation of the Raspberry-pi3 edge device computing version

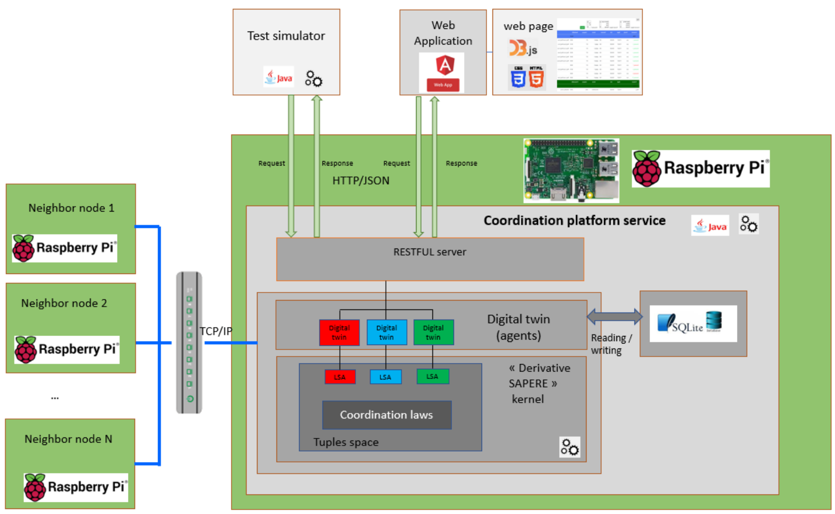

Figure 6: Integration of the coordination platform in a Raspberry Pi device

For recall the CLEMAP device is an augmented and enhanced Raspberry. Since we are running several independent services on the same Edge device (See Figure 6 , it was necessary to undertake a number of tasks to reduce the memory consumption of the coordination platform, which totalled over 300 megabytes.

1. Monitoring of used memory:
   Firstly, we have monitored the memory usage by the coordination platform, to detect memory leaks or identify excess memory consumption. For this, we used the Visual VM tool which enables real-time monitoring of memory consumption by each instance of the coordination platform. This tool makes it possible to monitor consumption for several hours at the level of each Java class of the application. Consumption is then logged and displayed on a graph. Following various simulations, several memory leaks were identified in the coordination platform (see figure 7). Thanks to

these leak detections, we continued investigations and made the necessary fixes to various locations in the application to resolve these leak problems. After each patch, we re-monitored memory consumption with VisualVM and ensured that memory leaks disappeared.

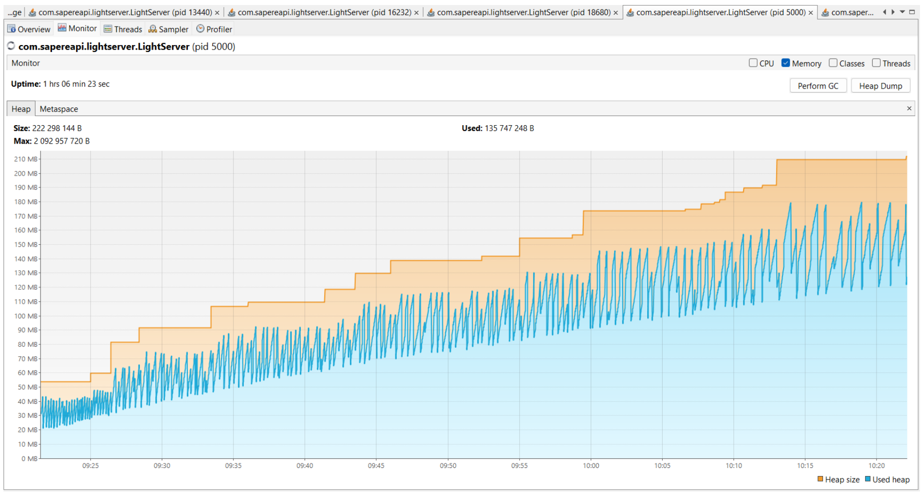

Figure 7: Detecting Memory Leaks Using Visual VM.

The instantaneous consumption appears in blue, and the space allocated by the VM appears in orange. In this screenshot, we can notice that the allocated space increases significantly over time and never decreases, which shows the existence of leaks.

2. Replacement of spring-boot server by a lighter server:
   The coordination platform includes a REST server that receives creation, modification and deletion requests from the various consumers and producers. This server uses Spring-Boot technology, which provides many features to facilitate web application development, but its memory consumption is not suitable for an environment with limited memory space, such as a Raspberry Pi. To reduce memory consumption, we replaced spring-boor with a more basic Rest server that uses the java library com.sun.net.httpserver.HttpServer.

3. Replacement of MariaDB & MongoDB by SQLite3:
   The coordination platform used initially 2 different databases:

   - a MariaDB database to store the history of electricity requests and exchanges
   - a MongoDB database to store the configuration

As both of these database servers consume a lot of memory and are not suitable for an environment with limited memory capacity, we have replaced them with an SQLite-type database: the latter offers fewer functions but is better suited to this type of environment as it only uses a file to store data and does not require a server. This saves disk space and memory and makes deployment easier. We undertook the migration in 2 stages:

- Merge the two existing databases into MariaDB so that all data and queries are stored in a single database. As the MongoDB database contains far less data and queries, we transferred the data and queries to the MariaDB database.
- Replacing MariaDB with an SQLite3 database. This part of the migration was the most time-consuming, given that the functionalities offered by SQLite are fairly limited. For example, we had to replace SQL functions and stored procedures (which are not accepted in SQLite) with processing to be carried out in the calling code. In addition, most of the queries have been revised, due to the differences in SQL syntax between MariaDB and SQLite.

4. Deactivation of functionalities not used (prediction, quality of service):
In the version of the coordination platform used for the Raspberry-pi edge device, predictions are already calculated by the prediction service and the results of the predictions are retrieved from that service: as a result, the coordination platform does not need to calculate the predictions by itself; this latter feature tends to use up a significant amount of memory and processing time; we therefore added an option to disable prediction using a configuration parameter in the coordination platform. This allowed us to reduce memory space in the Raspberry Pi version. Similarly, we have disabled the quality-of-service assessment functionality, which is based on reinforcement learning to help assess the usefulness of different services created on the fly. This functionality is not used in the Lasagne project.

5. Deployment of for the Energy Data hack days challenge 2023 [1]:
As part of the "Energy Data Hack Day 2023" challenge, we have developed a version of the coordination platform that can run on an environment similar to that of a raspberry3 and that can communicate with the forecasting service to retrieve the results of energy production and consumption predictions. We generated a Docker image of the coordination platform and deployed and ran the platform on a VM environment with characteristics similar to that of a Raspberry Pi3.

As shown in table 1, tests on a 4-nodes configuration have confirmed a significant reduction in the amount of memory used after the application of updates on the coordination platform.

[1] https://energydatahackdays.ch/english

	Node 1	Node 2	Node 3	Node 4
Memory used before corrections(MB)	221.60	130.95	200.74	135.75
Heap size before corrections(MB)	332.40	274.76	325.06	222.30
Memory used after corrections(MB)	17.13	10.51	13.52	14.15
Heap size after corrections(MB)	25.17	20.97	20.97	20.97

Table 1: Comparison of memory usage and heap size (in megabytes), before and after corrections, running 4 instances of the coordination platform in a 4-node chain topology. These simulations were carried out with the prediction feature disabled.

5.4 Integration of the generic gossip-based federated learning mechanism

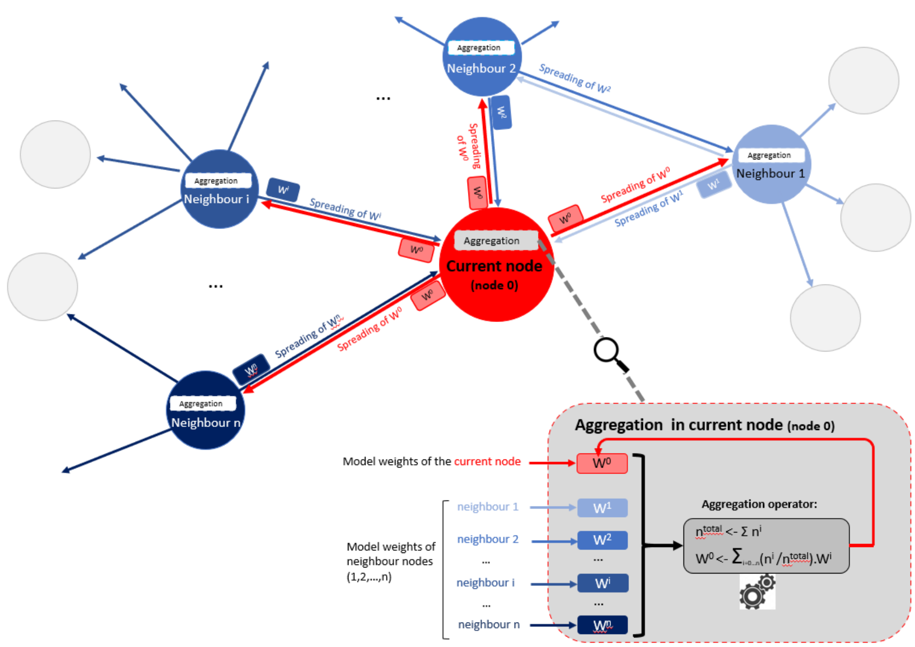

Figure 8: Principle of gossip-based federated learning

Federated learning (FL) is a paradigm in which multiple machines collaboratively train a Machine Learning model while keeping their training data local. This paradigm makes it possible to benefit from the learning experience of several nodes, by reaching a consensus on the knowledge acquired. Thus, the machines involved in learning send the models learned on their local training data, not the data itself, to a central machine. According to Liu et al.[2],

[2] [Liu et al.(2022)Liu, Chen, and Zhang] Wei Liu, Li Chen, and Wenyi Zhang. Decentralized

distributed federated learning approaches tend to reduce communication traffic between nodes and prevent the disclosure of sensitive local data to other nodes. The "gossip-based" variant of Federated Learning is completely decentralised of Federated Learning in which the different node not only participates to the model training by also participate to the distribution of the model. This variant does not require a server that centralises the distribution for all nodes. Each node thus executes phases alternatively (see figure 8):

- The local model computation: the node updates its local model using its own private data.
- The models aggregation: the node merges its own model and the different models received from the direct neighbours. The aggregation function used during the merging can be chosen (it can evaluate weight using the model sample numbers and the loss result of each model assessed with the evaluation dataset).
- The model distribution: the node spreads its model to the direct neighbour nodes.

Indeed, the gossip pattern, which combines the aggregation and the spreading, can be integrated in the coordination platform using the aggregation and the spreading coordination laws (see figure 9).

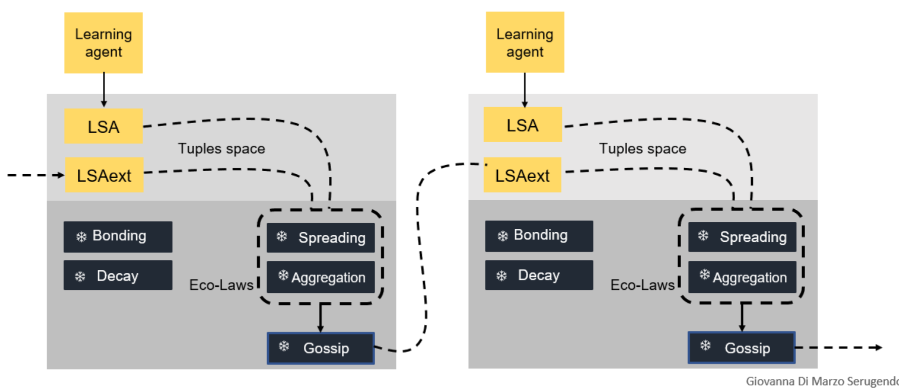

Figure 9: Integration into the platform

Regarding the implementation, we started from the existing version of the coordination middleware and adapted it to integrate the Spreading and Aggregation mechanism used in Gossip. The Spreading law was already implemented. We made a patch that concerned the sending to indirect nodes (see

federated learning: Balancing communication and comput- ing costs. IEEE Transactions on Signal and Information Processing over Networks, 8:131–143, 2022 paragraph 5.2). Concerning the aggregation mechanism, we started from an old implementation which already included "standard" aggregation mechanisms applied to basic data such as numbers or character strings. We created a subcategory of aggregators called a "customised" aggregator that can be applied to any object class and any aggregator that we define in that class. The aggregation mechanism takes the aggregator of this class as a parameter, as well as the name of the aggregation operator itself so that the aggregation operator can compute the aggregator of the class. It is important to note that this implementation makes it possible to make the aggregation mechanism (defined in the coordination model middleware) independent of the definition of the aggregation function, which is found in the calling code, i.e. in the class of objects that we wish to aggregate, with the possibility of defining several different variants (one for each operator to be defined in the calling code).

To be able to integrate and experiment with the Gossip mechanism on the learning model used (Markov chain):

- Firstly, we have defined the class containing the Markov model data (with the different transition matrices)
- Secondly, we have defined the aggregator. For now, we have defined a simple aggregator which calculates the average obtained over all the transition matrices, by applying a coefficient which is based on the total number of observations.
- Then, we have integrated the call to the Gossip mechanism from the learning digital twin: we added the learning model in the LSA properties so that the model can be transmitted to other nodes and automatically aggregated by the aggregation coordination law. Then we processed the reception of the aggregation result by the learning twin, so as to update its learning model at each reception of the aggregation result.

5.5 Social acceptance by design

In 2022, we have already implemented a few simulation scenarios to highlight social acceptance issues that emerge from the behaviour of digital twins. We have, for example, experimented with a common tragedy scenario, which corresponds to the case where the best individual decision for a given digital twin turns out to be the worst case scenario for them as a group. In addition, we focused on protecting the sensitive data of digital twins: for example, a producer twin only has access to the consumption data of its own supplies. The same consumer twin may well use other supplies, and the producer has no visibility of these.

For next year, we plan to integrate the new elements that emerge from the study carried out by HES-SO//Valais into Work-package 2 (for example, the different attributes of the profile of a member of a microgrid community, the idea of implementing a utility function to optimise these different attributes, as well as economic and environmental aspects).

6 Energy applications.

This section details the energy applications chosen by the consortium. A minimum of two of these applications will undergo development and deployment on the marketplace platform established within the project framework. This section marks the accomplishment of Milestone 3 in the project timeline. The template used for each of the applications presents the following elements:

- The title: the name of the application.
- The goal of the application: the problem the application wants to solve.
- Who is the customer? The users of the proposed solution (end-users, DSO, TSO etc.).
- Who is the system integrator? The entity that resembles all the stakeholders around to provide the final solution.
- What is the business model? How we can make a profit from the application
- Which Forecast algorithm? Which of the forecasting algorithms within the LASAGNE Framework is used by the application?
- Which dataset to use? The data used by the application and their provenance.

6.1 Application 1: Dynamic tariff applied to charging stations

Goal: Minimise energy cost for EV charging, while, at the same time, ensuring that the car is charged once it has to be used.
Who is the customer?

- Users of charging station (the one paying the electricity).
- Tenant residing in a multi-family home.
- Users of charging stations (the ones paying the electricity).
- Companies that provide dedicated parking facilities for its staff, complete with charging stations.
- An employee in a company that provides dedicated parking facilities for its staff.

Who is the system integrator?

- Electrical installer offering EV charging stations.
- Charge Point Operators.

What is the business model? Automatic optimization of charging allows the end user to save X money per year. To have this functionality enabled, the end-user has to pay a monthly fee to the provider.
Which Forecast algorithm? The forecasting algorithm plays a crucial role in determining the optimal level of recharging restrictions, ensuring that the electric vehicle is sufficiently charged at the desired time of use. Specifically, an 18-hour prediction window is employed to account for the duration required to fully charge the vehicle, even when operating with reduced power.

Furthermore, the algorithm considers the anticipated disconnection time of the car from the charging station, enabling the optimization of the recharge process to align with the vehicle's usage pattern. This comprehensive approach ensures that the charging strategy is not only aggressive in limiting recharging but also tailored to meet the customer's preferences and operational needs.
Which dataset to use?

- Tariff data - API - 15 minutes day ahead tariff published every day in the evening.
- Anonymized charging usage data from CLEMAP

6.2 Application 2: Flexibility applied to charging stations

Goal: Use e-vehicles, through charging stations, as a flexible load supplier to support the grid.
Who is the customer?

- Users of charging station (the one paying the electricity):
- Tenant residing in a multi-family home.
- Users of charging station (the one paying the electricity)
- The company providing dedicated parking facilities for its staff
- An employee in a company that provides dedicated parking facilities for its staff
- Swissgrid, flexibility pooling provider.

Who is the system integrator?

- Flexibility pooling provider (interface to Swissgrid)
- Electrical installer offering EV charging stations.
- Charge Point Operators.

What is the business model?

Automatic optimization of charging allows the end user to save X money per year. To have this functionality enabled, the end-user has to pay a monthly fee to the provider.

Which Forecast algorithm?

Accurately predict energy consumption by utilising 15-minute data intervals, considering specific events such as Electric Vehicle (EV) arrivals and departure times. This includes estimating the amount of energy (in kWh) the EV is expected to load within a given timeframe.

Additionally, provide insights into the expected availability of flexible power (for example EV will load with 11kW or 5kW) by closely monitoring EV charging activities at 15-minute intervals for the upcoming week. This comprehensive forecast will enable better planning and optimization of power resources based on real-time data, ensuring efficient utilisation and management of energy resources.

Which dataset to use?

Anonymized charging usage data from CLEMAP

6.3 Application 3: Infrastructure performance (through flexibility)

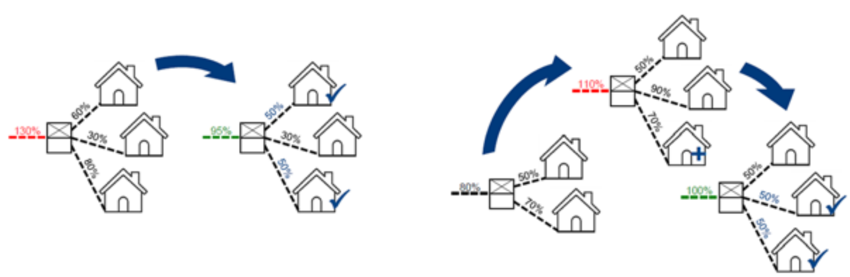

Figure 10: Infrastructure performance

Goal: Ensure infrastructure performance.

The electricity is transported from the producers to consumers through a network composed of interconnected lines. These transmission lines have finite capacities (represented by percentages in Figure 10) and the flow requires a high resistance during its transmission. The aim is to reduce the flow on the grid while respecting the limits, for instance between the microgrid and the substation as much as possible (Figure 10).

Who is the customer? Distribution System Operators (DSOs). If able to leverage their final clients' flexibility, DSOs can optimise both the planning and operating of the distribution grid by shifting load peaks instead of replacing and/or reinforcing the electrical infrastructure.

Who is the system integrator? Home Energy Management System (HEMS) Integrators, Aggregators. Final clients interested in making their flexibility available need both control systems capable of managing their appliances (EV, HP, etc.) and an intermediary to negotiate with the DSOs: while a single client's flexibility does not represent much interest, aggregating a large number of clients can offer sizeable amounts of electrical power available for flexibility. What is the business model? Instead of spending funds for infrastructure replacement and reinforcement that would be over-dimensioned for most of the usual power loads, DSOs leverage their final clients' flexibility to implement peak shaving and load shifting. Clients involved are financially compensated, and the overall costs across the entire grid are lowered when avoiding costly new construction projects. Which Forecast algorithm? Flexibility for the DSOs used for peak shaving and load shifting is best suited for short-term grid operation. Day-ahead and week-ahead forecasting are best adequate here.

Which dataset to use?

- Aggregators: Key-value pairs of clients with available flexibility, exclusively for consumption. Clients are identified by a unique identifier common to the aggregator and the DSO. Values are provided in time-series form, displaying the amount of available flexibility in kW.
- DSOs: Grid and Network Information System (GIS, NIS) database, informing about the connectivity of clients in the grid.
- Aggregated load profiles across loaded infrastructure elements (substations, powerlines).

6.4 Application 4: Ensure Voltage stability (through flexibility)

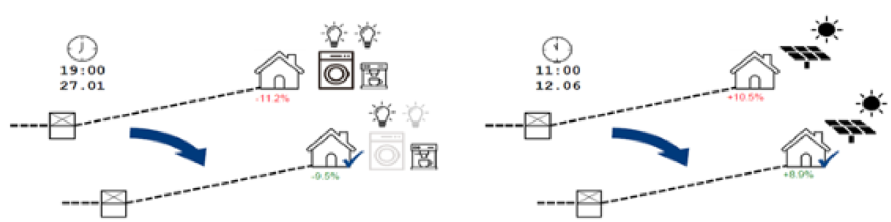

Figure 11: Voltage Stability

Figure 11 illustrates a simple scenario. On the left side, on 27/01 at 19:00, a specific user is detected as highly consuming without respecting limits (red). An intervention will therefore take place and consists of deactivating some resources (washing machine, lighting).

A second scenario is illustrated on the right, there is production at 11:00. In this case most people are not home at this time, so we are asking him to produce less.

Who is the customer? Distribution System Operators (DSOs). If able to leverage their final clients' flexibility, DSOs can optimise both the planning and operating of the distribution grid by reducing voltage drops and rises instead of replacing and/or reinforcing the electrical infrastructure. **Who is the system integrator?** Home Energy Management System (HEMS) Integrators, Aggregators. Final clients interested in making their flexibility available need both control systems capable of managing their appliances (EV, HP, etc.) and an intermediary to negotiate with the DSOs: while a single client's flexibility does not represent much interest, aggregating a large number of clients can offer sizeable amounts of electrical power available for flexibility. **What is the business model?** Instead of spending funds for infrastructure replacement and reinforcement that would be over-dimensioned for most of the usual voltage differentials, DSOs leverage their final clients' flexibility to implement voltage drop and raise limitations. Clients involved are financially compensated, and the overall costs across the entire grid are lowered when avoiding costly new construction projects.
Which Forecast algorithm? We haven't defined it yet.
Which dataset to use?

- Aggregators: Key-value pairs of clients with available flexibility, both in consumption and production. Clients are identified by a unique identifier common to the aggregator and the DSO. Values are provided in time-series form, displaying the amount of available flexibility in kW.
- DSOs: Grid and Network Information System (GIS, NIS) database, informing about the connectivity of clients in the grid.
- Aggregated load profiles across loaded infrastructure elements (substations, powerlines).
- Voltage variations simulation results across the client's nodes in the grid.

6.5 Application 5: Optimise localised energy exchanges (through flexibility)

Figure 12 shows two scenarios. At 19:00 a consumer is overloading the network by charging his electric vehicle while another one is producing electricity from solar panels installation. The electricity produced by the solar panels is injected into the system which is then used by a consumer who needs it to charge his vehicle. The energy is not physically transmitted between the consumer and

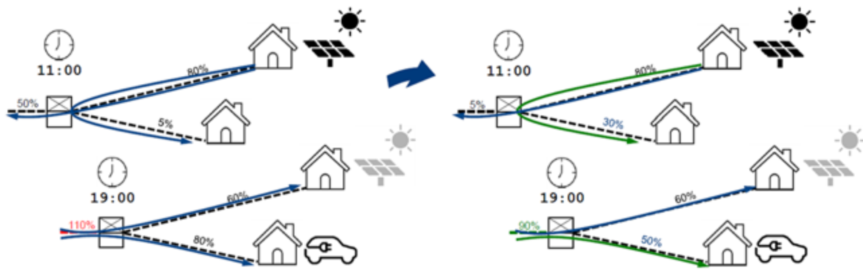

Figure 12: Energy exchange

producer, the producer will inject it and the consumer will use the energy in the system.

Who is the customer? Distribution System Operators (DSOs), Final Clients If final clients are able to generate enough energy to supply their needs and their neighbours, they could exchange this energy between them directly. Doing so reduces the load transiting through the upstream electrical infrastructure, optimising its operation for the DSOs.

Who is the system integrator? Home Energy Management System (HEMS) Integrators, Aggregators, Brokers An exchange platform is required for the final clients to be able to trade energy between local producers and consumers. Ideally, clients can virtualise their appliances (EV, HP, etc.) using HEMS, showing total energy offer and demand that can then be aggregated for a local pool of clients.

What is the business model? Final clients directly sell and buy their energy locally generated. The energy costs are therefore locally managed between the clients, without having to rely on the DSOs as energy providers. Based on grid constraints, the DSOs financially incentivise clients to use local sources of energy at key moments and places in the grid to optimise the operation of the infrastructure.

Which dataset to use?

- Aggregators: Key-value pairs of clients with available flexible consumption appliances and production installations. Clients are identified by a unique identifier common to the aggregator and the DSO. Associated values provide the type of consumption appliance and production installation, with for each the corresponding electrical power in kW.

- DSOs:
  - Grid and Network Information System (GIS, NIS) database, inform-

ing about the connectivity of clients in the grid.

 – Aggregated load profiles across loaded infrastructure elements (substations, powerlines).

6.6 Application 6: Aggregation of distributed energy resources.

Goal: Monitor and control energy assets (heating pumps, EV charging stations, Batteries, Energy production..) in an energy community (At the moment, the energy community consists of 9 housing associations, approx. 900 apartments) to create new revenue streams
Who is the customer? The Energy Community and also the housing communities that are part of the Energy Community.

Who is the system integrator?

- Local system operator or consultancy company working on energy optimization that handles the procurement of energy-saving resources such as Building Management Systems, heating pumps etc.
- The Aggregator (Recap Power) is a system integrator when installing Energy monitoring and control gateways.
- Charge point operators
- BESS installations companies
- Building Management System providers
- External company that works with integrations to energy assets

What is the business model?
Aggregation of distributed energy resources that will create a virtual power plant. The aggregated volume of power will be crucial to be possible to place bids at different flexibility and ancillary markets. The business model is based on that the Aggregator shares the revenues created from the markets with the asset owners. The Aggregator takes a percentage of the revenues or the savings that can be created.

Which Forecast algorithm? We haven't defined it yet.

Which dataset to use? We haven't defined it yet.

7 Deployment

7.1 Deployment Swiss Pilot

7.1.1 The two deployments

The deployment architecture is shown in Figure 13. We have five components: Digital Twin & Coordination Platform, Forecasting, Database, Data Gathering, and SmartGrid-Ready interface library.

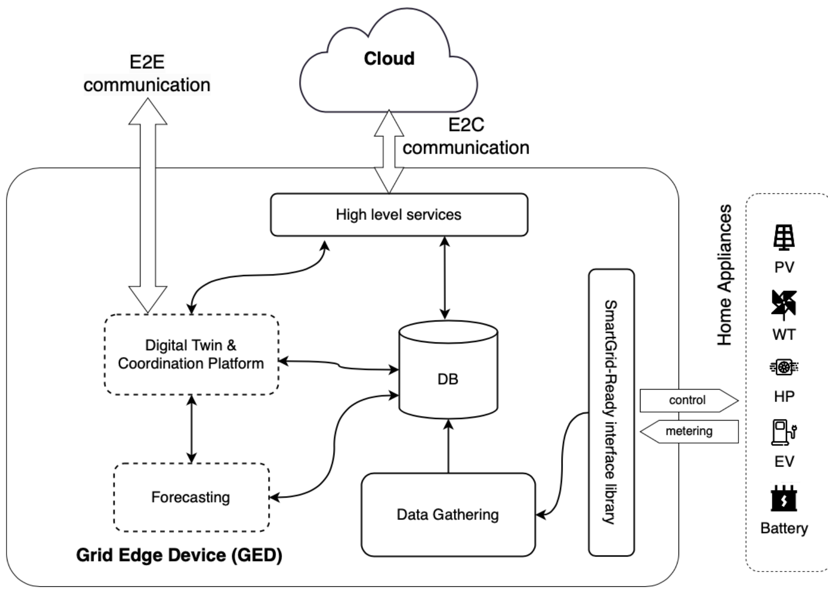

Figure 13: GED Components

We are working on the integration between Digital Twin & Coordination Platform, Forecasting.

The five components are containerised into the CLEMAP device as shown in Figure 13. The goal is to deploy them through the Nuvla/NuvlaEdge E2C solution (red boxes) and it requires containers.

We have two deployments in Chêne-Bougeries and Meyrin (two communes in Geneva Canton). In Meyrin, we have seven CLEMAP devices collecting data in three public school buildings. In Chêne-Bougeries, we have 5 CLEMAP devices collecting data. The device measures allow us to deduce the energy consumed/produced. In the proposed deployments the edge device is equipped with self-adaptive and context-aware forecasting Models for predicting energy consumption/production.

In Meyrin, seven CLEMAPs. have been installed in the school. They are distributed across three buildings and four areas: the kitchen, gymnasium, classrooms, and ventilation systems. Figure 15 shows the location where we have

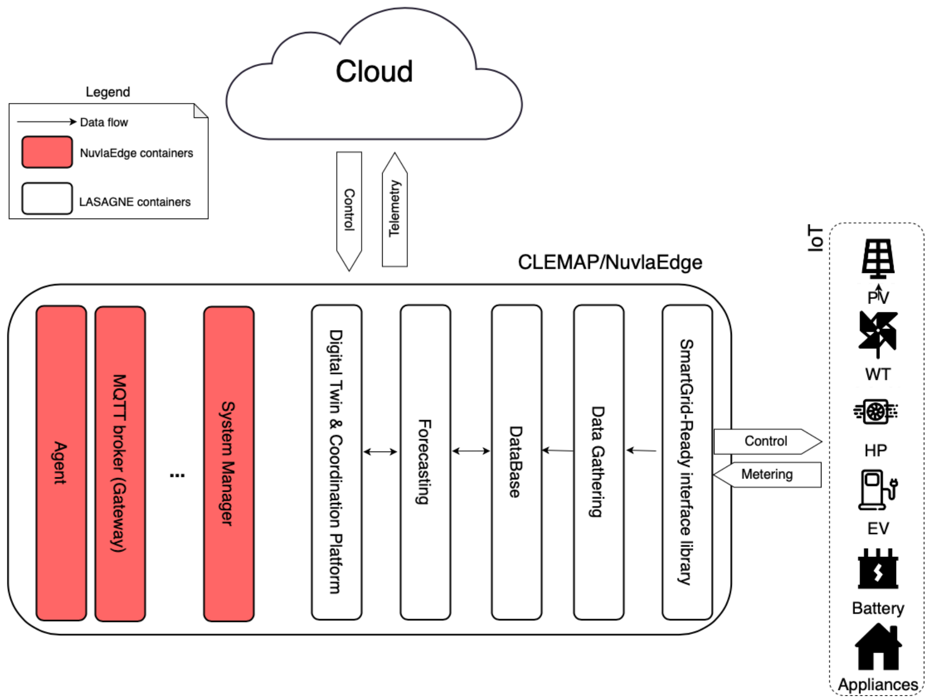

Figure 14: GED containers

installed the CLEMAP devices.

Figure 16 shows the location where we deploy the CLEMAP devices, situated on Jean-Jacques Rigaud Street (Geneva). It is a cooperative comprised of 7 buildings.

The schematic outlines the following for Jean-Jacques Rigaud Street (the value is maximum sensor current) :

- Building F includes a laundry room (80 A) and a common area (80 A).
- Building D has a common space (42 A) and a boiler room (200 A).
- Building C features a common area with laundry facilities (80 A).

7.1.2 Data Collection

In Meyrin, we have been collecting data since June 2022. In Chêne-Bougeries, data collection began in November 2023. The edge devices supplied by CLEMAP collect electricity data, in particular, measured power values (Current, voltage and power for the 3 phases). We have two datasets: The first one: that data is collected using a local MQTT broker every 10 seconds and sent every hour to an Exoscale S3 bucket. The second one: data is written to a local Sqlite database

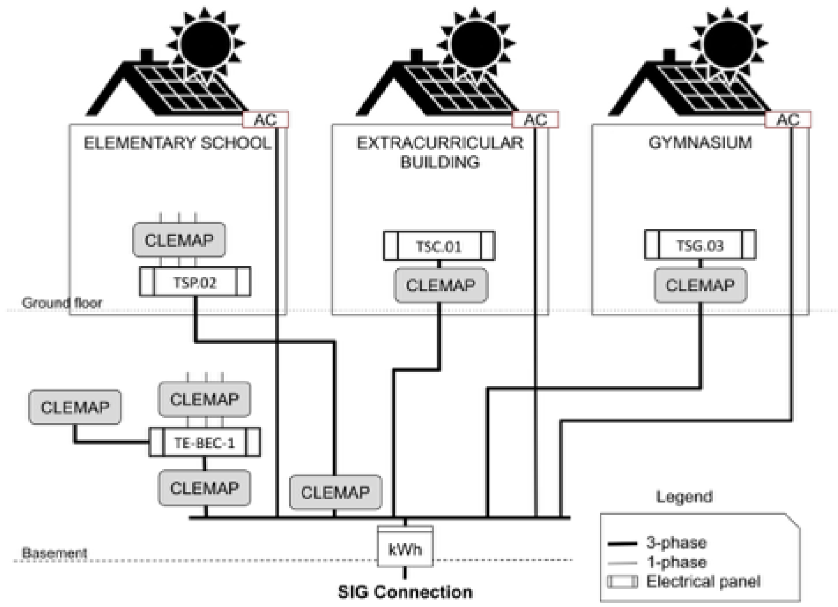

Figure 15: Deployment in Meyrin

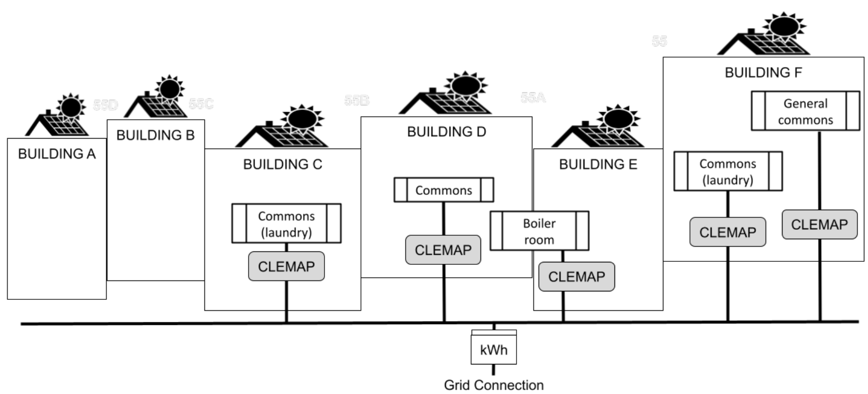

Figure 16: Deployment in Chêne-Bougeries

every minute and sent to an Exoscale S3 bucket every 8 hours. These data are stored in an S3 bucket for training the forecasting algorithms.

7.2 Deployment Swedish Pilot

The energy community consists of 9 members of housing associations. A housing association is a cooperative where the members (the residents in the tenant-owned housing) own a share of the housing association which in turn owns the housing.

The plan is to start with two housing associations to evaluate, demonstrate potential, and measure the effects of the implementation. The expectation is that these results will form the basis to motivate further implementation in additional housing associations.

The energy community has 427 EV (electric vehicle) charging points in total.

- 6 members have PVs and at least 2 more are planning on investing in PVs.
- One member has already invested in BESS (Battery Energy Storage System).
- 5 members have IMD (individual metering and debiting: the electricity is metered separately at the apartment level and the residents pay for their consumption).
- 6 members have heating pumps.
- All have BMS (building management systems), DUC (data under central) that make control of climate system possible.

In Housing Association 1, the goal is to monitor and control EV chargers and potentially also heating pumps. Housing Association 2 will install batteries during the coming months. TVINN will be the aggregator.

7.2.1 Pilot 1: Housing association 1 (Brf Strandkanten)

EV chargers (Installed January 2022)

- 20 Charge Amp Halo EV chargers located in the garage. 6 of them have dynamic load balancing.
- 11 kW single outlet 3-phase 16 A Halo charger.

Heat pumps

- 3 heat pumps (Thermia Mega XL och L)

The technology will be implemented gradually, starting with the integration of Recap Nebula EMS hardware to enable control of resources. The next step includes testing services to save energy costs (such as scheduling based on electricity prices). Additionally, the ambition is to create income streams derived from the flexibility and ancillary services extended to local energy companies (DSOs) or Svenska Kraftnät's (TSO) markets.

7.2.2 Pilot 2: Housing Association 2 (Brf Hammarby Kaj)

Have invested in two BESS for their two houses, one BESS in each building. The BESS is delivered by project partner Ferla comes from Danish supplier Xolta and has Li-ion LFP battery chemistry. Each BESS has an installed power capacity of 100kW. The BESS will be used for delivering ancillary services to Svenska Kraftnät (TSO).

The housing association also has an interest in using the BESS for other local services like improved self-consumption from their installed Solar PV, peak shaving and spot price arbitrage in the future. Installation of BESS and aggregator system in March 2024. Predicted to be qualified for the FCR-D, and FCR-N markets on August 24.

8 Conclusion

This report detailed the results and some actions to be taken during the next period. The report shows that we have made good progress in setting up the applications. It also shows that this process requires a lot of work to prepare the GED environment. The social acceptance will conduct a DSE during the next period. We will replicate this experimentation in Sweden.

The integration of certain modules will be at the heart of our actions during the next period.

9 Appendix

9.1 Appendix A - Card System used in the POLYGONES community

The integrated users classify the cards (A, B, C, D, E, F, G, H) in order of preference.

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Sans
- Mix électrique : Renouvelables
- Tarification : Dynamique

Vie en communauté

- Événements communautaires : Annuel
- Règlementation : Auto-régulation
- Quotas : Avec

Informations et données

- Transfert d'informations : Systématique
- Partage de données : Sans
- Comparaison de consommation : Sans

Infrastructure

- Gestion de l'infrastructure : Interne

A

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Avec
- Mix électrique : Renouvelables
- Tarification : Heures pleines / creuses

Vie en communauté

- Événements communautaires : Mensuel
- Règlementation : Précise
- Quotas : Sans

Informations et données

- Transfert d’informations : Ponctuel
- Partage de données : Avec
- Comparaison de consommation : Avec

Infrastructure

- Gestion de l’infrastructure : Interne

B

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Sans
- Mix électrique : Mélange
- Tarification : Heures pleines / creuses

Vie en communauté

- Événements communautaires : Annuel
- Règlementation : Auto-régulation
- Quotas : Sans

Informations et données

- Transfert d’informations : Systématique
- Partage de données : Avec
- Comparaison de consommation : Avec

Infrastructure

- Gestion de l’infrastructure : Externe

C

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Avec
- Mix électrique : Renouvelables
- Tarification : Dynamique

Vie en communauté

- Événements communautaires : Mensuel
- Règlementation : Précise
- Quotas : Avec

Informations et données

- Transfert d’informations : Ponctuel
- Partage de données : Sans
- Comparaison de consommation : Sans

Infrastructure

- Gestion de l’infrastructure : Interne

D

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Sans
- Mix électrique : Mélange
- Tarification : Heures pleines / creuses

Vie en communauté

- Événements communautaires : Mensuel
- Règlementation : Auto-régulation
- Quotas : Avec

Informations et données

- Transfert d’informations : Ponctuel
- Partage de données : Avec
- Comparaison de consommation : Sans

Infrastructure

- Gestion de l’infrastructure : Externe

E

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Avec
- Mix électrique : Mélange
- Tarification : Dynamique

Vie en communauté

- Événements communautaires : Annuel
- Règlementation : Précise
- Quotas : Sans

Informations et données

- Transfert d'informations : Systématique
- Partage de données : Avec
- Comparaison de consommation : Sans

Infrastructure

- Gestion de l'infrastructure : Externe

F

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Sans
- Mix électrique : Renouvelables
- Tarification : Heures pleines / creuses

Vie en communauté

- Événements communautaires : Annuel
- Règlementation : Auto-régulation
- Quotas : Avec

Informations et données

- Transfert d'informations : Ponctuel
- Partage de données : Sans
- Comparaison de consommation : Avec

Infrastructure

- Gestion de l'infrastructure : Externe

G

Dans quelle communauté préféreriez-vous vivre ?

Réseau

- Connexion au réseau : Avec
- Mix électrique : Mélange
- Tarification : Dynamique

Vie en communauté

- Événements communautaires : Mensuel
- Règlementation : Précise
- Quotas : Sans

Informations et données

- Transfert d’informations : Systématique
- Partage de données : Sans
- Comparaison de consommation : Avec

Infrastructure

- Gestion de l’infrastructure : Interne

H