



MASTER OF SCIENCE  
IN ENGINEERING

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# Master of Science HES-SO in Engineering

Orientation: Software Engineering

## Towards a digital platform for the collection, storage and processing of heating installation data

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# Abstract

Buildings' heating installation needs a periodic check-up and maintenance to guarantee their full operability. Today caretakers and technicians work together to prevent any issue that might affect the comfort of the residents. The settings of the heating facilities depend heavily on the weather and the occupancy of the buildings. These settings require continuous monitoring and periodic technical visits to optimize energy consumption while guaranteeing the comfort of the residents. The maintenance of heating installations is therefore expensive and time-consuming.

To address these shortcomings, the SG-Energies company is developing and marketing the SG-Box device. This device makes it possible to (1) collect data and measurements from the control units of heating installations, (2) pre-process them, and (3) transfer them in a unified form to an IT system. Anomalies, breakdowns, and reconfiguration needs are therefore quickly identified. The main purpose of the SG-Box device is to reduce the frequency and duration of heating system breakdowns by establishing communication with the main control unit of the installation.

This master's thesis target three objectives:

1. Design, setup and deploy an SG-Box based IoT infrastructure. This IoT infrastructure will retrieve data from a heating installation through the SG-Box device
2. Design and develop a "technician application" which assists technicians during their technical visits and allows them to remotely monitor the heating installations.
3. Design and develop a "report application" which generates reports based on templates, user inputs, and data collected from the heating installations.

The two applications rely on the SG-Box based IoT infrastructure.

**Key words:** Edge device, SG-Box, Heating installation, Control unit, IoT



# Résumé

Les installations de chauffage des bâtiments ont besoin d'une vérification périodique et d'un entretien pour garantir leur pleine fonctionnalité. Aujourd'hui, les concierges et les techniciens travaillent ensemble pour prévenir tout problème qui pourrait affecter le confort des résidents. Les réglages des installations de chauffage dépendent fortement de la météo et de l'occupation des bâtiments. Ces réglages nécessitent une surveillance continue et des visites techniques périodiques pour optimiser la consommation d'énergie tout en garantissant le confort des résidents. L'entretien des installations de chauffage est donc coûteux et prend du temps.

Pour remédier à ces lacunes, la société SG-Energies développe le dispositif SG-Box. Ce dispositif permet de collecter des données et des mesures à partir des régulations des installations de chauffage, de les prétraiter et de les transférer sous une forme unifiée vers un système informatique. Les anomalies, les pannes et les besoins de reconfiguration sont ainsi rapidement identifiés. L'objectif principal du dispositif SG-Box est de réduire la fréquence et la durée des pannes des systèmes de chauffage en établissant une communication avec la régulation de l'installation.

Ce mémoire de master vise trois objectifs :

1. Concevoir, mettre en place et déployer une infrastructure IoT basée sur SG-Box. Cette infrastructure IoT récupérera des données à partir d'une installation de chauffage via le dispositif SG-Box
2. Concevoir et développer une "application technicien" qui assiste les techniciens lors de leurs visites techniques et leur permet de surveiller à distance les installations de chauffage
3. Concevoir et développer une "application rapport" qui génère des rapports basés sur des modèles, des entrées d'utilisateurs et des données collectées à partir des installations de chauffage

Les deux applications reposent sur l'infrastructure IoT basée sur SG-Box.

**Mots clés :** Edge device, SG-Box, Chaufferie, Régulation, IoT





# Contents

<b>Acknowledgements</b>	<b>iii</b>
<b>Abstract (English/Français)</b>	<b>v</b>
<b>Contents</b>	<b>ix</b>
<b>Abbreviations</b>	<b>xi</b>
<b>List of Figures</b>	<b>xii</b>
<b>List of Tables</b>	<b>xii</b>
<b>Introduction</b>	<b>1</b>
<b>1 Monitoring and maintenance for heating installation</b>	<b>3</b>
1.1 Context . . . . .	3
1.2 Elainnovation - Bluetooth gateway and sensors . . . . .	4
1.3 SG-Energies - SG-Box . . . . .	5
1.4 E-nno - E-nno Box . . . . .	6
1.5 Comparison summary . . . . .	6
<b>2 SG-Energies Ecosystem</b>	<b>9</b>
2.1 Workflow . . . . .	9
2.2 Technologies . . . . .	11
2.3 Communication protocols . . . . .	13
<b>3 Technician Application</b>	<b>17</b>
3.1 Internal company data structure . . . . .	17
3.2 Application requirements . . . . .	18
3.3 Application design . . . . .	19
3.4 Application realization . . . . .	22
<b>4 Reporting application</b>	<b>33</b>
4.1 Application requirements . . . . .	33
4.2 Application design . . . . .	33
4.3 Application realization . . . . .	34
<b>Conclusion</b>	<b>37</b>
<b>References</b>	<b>39</b>



# Abbreviations

**API** Application Programming Interface. 5, 31

**HTML** HyperText Markup Language. 22

**HTTP** Hypertext Transfer Protocol. 5

**IoT** Internet of Things. 1, 11, 37

**IP** Internet Protocol. 9, 14, 15

**JSON** JavaScript Object Notation. 22, 36

**LoRa** Long Range. 1, 5, 9, 11

**MQTT** Message Queuing Telemetry Transport. 5, 11

**PLCs** Programmable Logic Controllers. 3, 13, 14

**REST** Representational state transfer. 5

**RTU** Remote Terminal Unit. 15

**SCADA** Supervisory control and data acquisition. 12

**SMS** Short Message Service. 13

**TCP** Transmission Control Protocol. 9, 15

**TTN** The Things Network. 10

**VPN** Virtual Private Network. 10

# List of Figures

1.1	Operating schema of a heating installation . . . . .	3
1.2	Operating schema of a heating installation with data collection . . . . .	4
1.3	Operating schema of a heating installation with Elainnovation's Bluetooth Gateway . . . . .	5
1.4	Operating schema of a heating installation with SG-Energies' SG-Box . . . . .	6
1.5	Operating schema of a heating installation with E-nno box . . . . .	6
2.1	Schema of the SG-Energies ecosystem workflow . . . . .	9
2.2	Schema of the heating installation of Vernier city with the SG-box . . . . .	10
2.3	Photo of the intern composition of the SG-Box device . . . . .	11
2.4	Screenshot of Node-RED's interface . . . . .	12
2.5	Schema of Ignition server's place and inter-connections . . . . .	12
2.6	BACnet priority array and description[17] . . . . .	14
3.1	Realtime research bar . . . . .	19
3.2	Mock-up of the last operations view . . . . .	20
3.3	Mock-up of the chart view . . . . .	20
3.4	Mock-up of the contacts view . . . . .	21
3.5	Mock-up of the new feedback view . . . . .	21
3.6	Summary mock up of technician application . . . . .	22
3.7	Technician application top-bar . . . . .	23
3.8	Technician application top-bar's dropdowns . . . . .	24
3.9	Technician application side-menu . . . . .	24
3.10	Technician application last operations view . . . . .	25
3.11	Technician application chart view . . . . .	26
3.12	Technician application contacts view . . . . .	27
3.13	Technician application new feedback view . . . . .	28
3.14	Technician application new feedback scenarios' list . . . . .	28
3.15	Scenario global variable structure . . . . .	29
3.16	Technician application feedback list view . . . . .	30
4.1	Report generation with the reporting application . . . . .	35
4.2	Reporting application view . . . . .	35

# List of Tables

1.1	State of the art comparison table . . . . .	7
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# Introduction

Nowadays, buildings need to have their own heating installations to provide heat for apartments' heaters and domestic hot water. For comfort and sanitary reasons, those installations must fully work all the time. This implies that any problem must be detected, handled and solved as quickly as possible to avoid any disturbance to the building's comfort. Managing heating installation consists of periodic check-ups to monitor or adjust values like temperatures and performing visual check-ups of the components. If a check-up reveals an issue, it will be fixed by repairing the material or by placing an order to replace the broken piece. An experienced caretaker can perform a quick visual check of the installation and report any issues they might detect. In general, the company mandated to perform this kind of maintenance, visits the installation regularly depending on the contract established with the building owner. By those facts, the delay in resolving an issue is mostly impacted by the amount of time elapsed between the date of failure and the date of repair.

SG-Energies[1] is a Swiss heating management company developing a project, named STEP. STEP aims to develop an Internet of Things (IoT)-based system to make a "step" forward by developing the capability to remotely monitor and control heating installations. The main objective is to (1) reduce the frequency and the downtime and (2) limit the unnecessary on-site visit of the technicians. To this purpose, SG-Energies has developed an "edge" device, namely SG-Box, to interface the heating installation with the IT infrastructure. SG-Box is charged to retrieve data from the heating installations and temperature sensors placed in apartments and communicate through Long Range (LoRa) protocol.

After focusing on the development of the SG-Box device, the STEP project created pilot deployments in three different places around Geneva. Each deployment retrieves data from the main control unit of the heating installation and, after local processing, sends them to a central server where they are stored for later use.

This master thesis has three objectives:

1. **Build an IoT infrastructure** able to collect data from heterogeneous heating installations and store them in standard format
2. **Develop a high-level application targeting the technicians** by enhancing the remote monitoring capabilities and improving the technical operations reporting capabilities
3. **Develop a high-level application targeting SG-Energies supervisors** by generating performance reports about solar installations

This report is organized as follows: the first chapter presents the state of the art related to the IoT infrastructures similar to the one developed in this work. The second chapter exposes the IoT ecosystem deployed within the STEP project. Finally, the third and fourth chapters deal respectively with the two applications detailed above.



# 1 | Monitoring and maintenance for heating installation

## 1.1 Context

As soon as heating rooms were automated with small Programmable Logic Controllers (PLCs) and sensors, like temperature sensors, data was generated. For years this data was only used to create in-the-moment behavior for managing the efficiency of the installation. If the outside temperature went down, the temperature in the heater circuit increased (see Figure 1.1). Overtime, small PLCs have become automatons, managing rules with multiple sensor data.

The centralized data was employed exclusively for live computation and was not retained in storage at any stage for any further analysis.

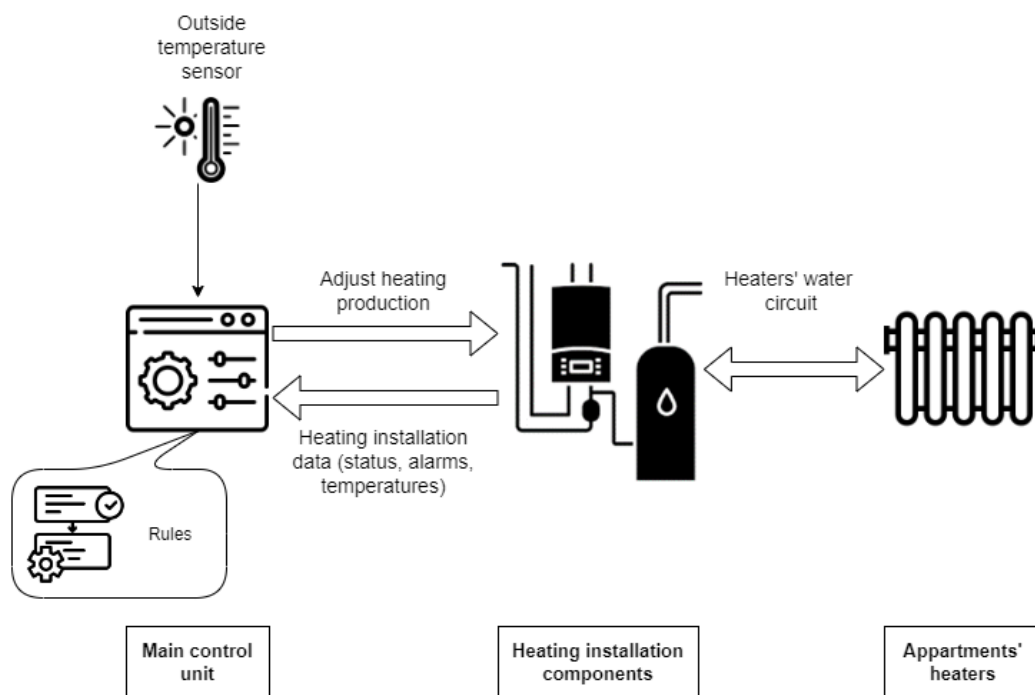


Figure 1.1 Operating schema of a heating installation

Today, with global warming, many governments[2] are applying environmental measures by reducing energy losses and introducing laws requiring building owners to enhance their climate footprint and have better management of their heating installation. To do so a microcontroller can be added to the heating installation to retrieve data and send commands to the main control unit (see Figure 1.2).

The goal of this chapter is to compare three solutions with respect to five criteria/features:

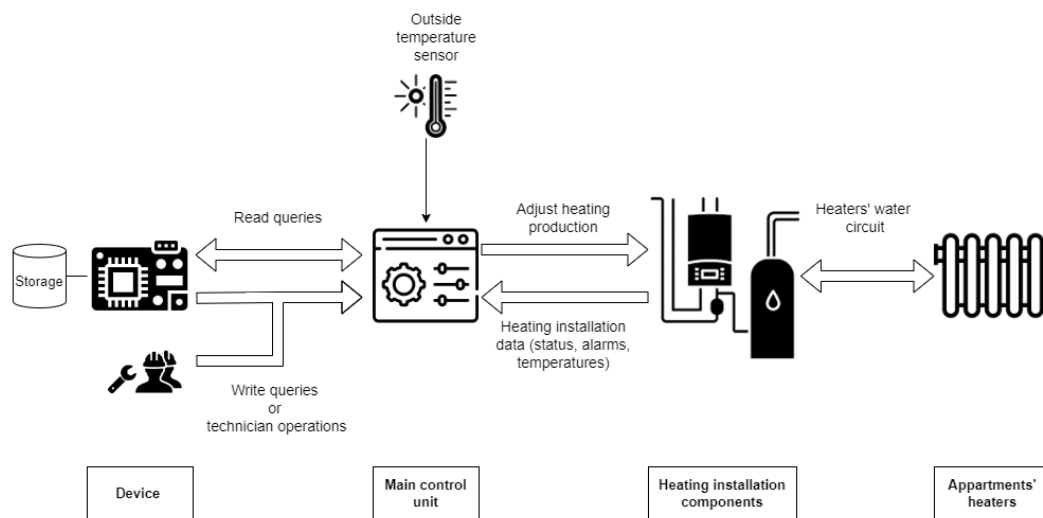


Figure 1.2 Operating schema of a heating installation with data collection

- **Remote monitoring:** Capacity of the solution to provide monitoring from outside the heating station
- **Remote maintenance:** Capacity of the solution to set values in the automaton of the heating room remotely to avoid the travel of a technician
- **Local storage:** Capacity of the solution to store the data locally if internet connection is not available
- **Multiple heating room device supported:** Capacity of the solution to be compatible with multiple heating room automaton that can have different communication protocols
- **Prediction:** Capacity of the solution to analyze the collected data from the heating installation and other sources (e.g. weather) and make predictions on how the heating installation should work in the following hours.

This chapter will present three available solutions from three different companies that help to monitor a heating installation in order to do upgrades and maintenance that will respond to the new climate laws.

### 1.2 Elainnovation - Bluetooth gateway and sensors

**Elainnovation**[3] is a French company which designs and manufactures beacons and sensors for identification, measurements and localization. Their equipment can be used to localize tagged objects or persons or to control the access of an area.

To provide monitoring for a heating installation, multiple devices can be used. Temperature probes and sensors can be used to measure temperature in the heating installation components, inside and outside the building (see Figure 1.3). To avoid having long



wires or multiple gateways, each probe or sensor is connected to a Bluetooth emitter to transmit its data. All the data are retrieved by a **Bluetooth gateway**[4] built on a Raspberry 4.

The gateway includes a web App to access the collected data and provide services to send the data to other devices by Message Queuing Telemetry Transport (MQTT) or Application Programming Interface (API) Representational state transfer (REST) (Hypertext Transfer Protocol (HTTP)).

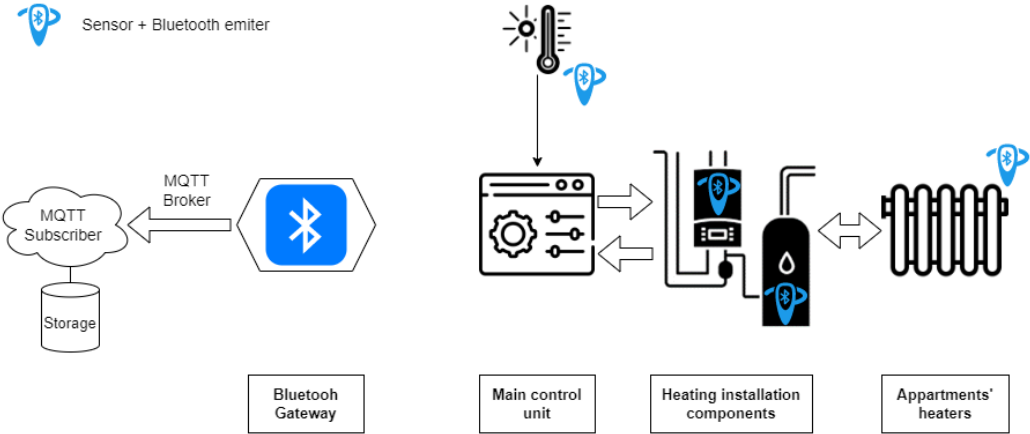


Figure 1.3 Operating schema of a heating installation with Elainnovation's Bluetooth Gateway

### 1.3 SG-Energies - SG-Box

**SG-Energies** is a Swiss heating management company that manages heating stations around Geneva. Their solution is actually used internally to provide an easy way for technicians to monitor heating installation and manually optimize it.

To retrieve heating installation data, the SG-Energies device, named **SG-Box**, is directly connected to the automaton that manages all the components of the installation. It can be connected either by ethernet or with serial communication like the RS-282 connection. Every 15 minutes the device will send requests to the automaton to have the actual data and will directly send it to a cloud to be stored (see Figure 1.4).

The SG-Box also has a LoRa antenna and is used as a local LoRa gateway to relay transmissions of temperatures installed by the company in some apartments to retrieve the building temperature in addition to all retrieved data.

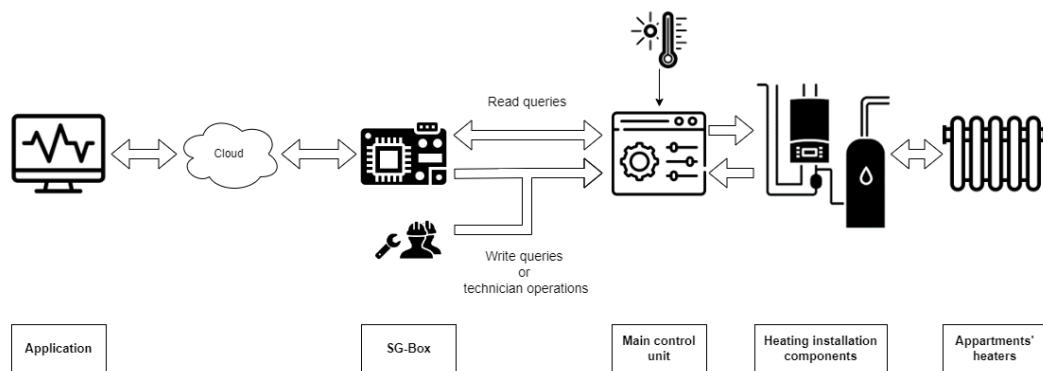


Figure 1.4 Operating schema of a heating installation with SG-Energies' SG-Box

## 1.4 E-nno - E-nno Box

**E-nno**[5] is a Swiss company which aims to accelerate the energy transition with heating data. Their solution provides optimization for heating systems by making automatic adjustments to them depending on the weather and the building compartment.

To retrieve heating installation data E-nno have developed their own device[6], named **E-nno box**, composed of an electronic board coupled to a compute module that is responsible for storing temporarily retrieved data, transmitting it to the cloud to persistent storage and adjusting the heating systems depending of the weather data and the current time of the day. Every 15 minutes as well, the box retrieves heating installation data to perform optimization with it, with weather data and taking into account the building heating compartment (see Figure 1.5).

The E-nno box goal is to optimize the heating system of each building where it is installed without disturbing the action and maintenance of the heating technicians.

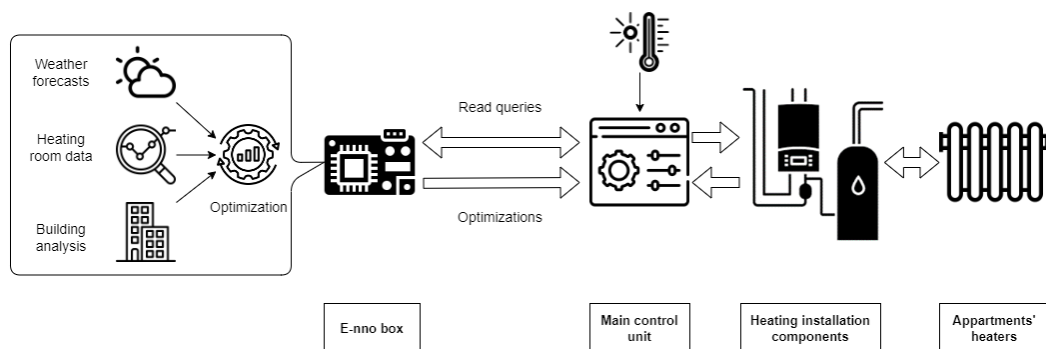


Figure 1.5 Operating schema of a heating installation with E-nno box

## 1.5 Comparison summary

The Table 1.1 summarizes the five features described above with respect to the three providers **BLE Gateway**, **SG-Box** and **E-nno Box**:

	<b>Remote monitoring</b>	<b>Remote maintenance</b>	<b>Local Storage</b>	<b>Multiple device</b>	<b>Prediction</b>
<b>Elainnovation BLE Gateway</b>	Yes	No	No	Yes	No
<b>SG Energies SG-Box</b>	Yes	Yes (Planned)	No	Yes	No
<b>E-nno E-nno box</b>	Yes	Yes	Yes	Yes	Yes

Table 1.1 State of the art comparison table



## 2 | SG-Energies Ecosystem

This chapter details the SG-Energies platform used to monitor and control heating installations and carried out within this master thesis. It will present the global workflow used and each technology taking part of it. The chapter is organized as follows: the first section details the workflow of the SG-Energies solution, the second section presents the different technologies involved and the third section lists the different communication protocols managed by the SG-Box.

### 2.1 Workflow

The workflow can be divided into three different parts (see Figure 2.1). The first one, consists of connecting an edge device, developed by SG-Energies, called SG-Box to a heating installation interface: the main control unit.

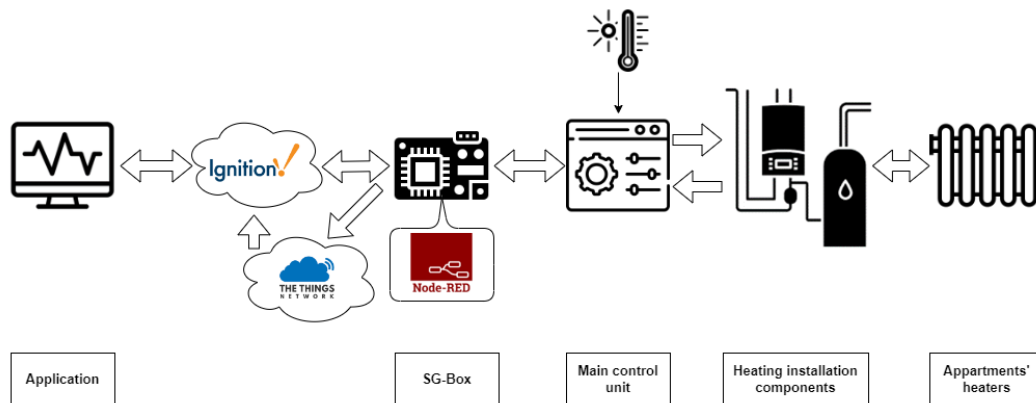


Figure 2.1 Schema of the SG-Energies ecosystem workflow

The main control unit supports all programmed rules which ensure the operation of the heating installation. To do so, the main control unit retrieves all sensor data of the different components of the heating station (boiler, pumps, temperature of water tank)(see Figure 2.2).

The main control unit has its own communication protocol to manage rules and data. Today the SG-Box can communicate with the language used by the main control units: BACnet and ModBUS. Each communication protocol has its own properties as will be presented below.

To use those communication protocols, SG-Box uses the Node-RED programming tool to receive and send messages through the communication protocols. The two communication protocols rely on either Ethernet (and then Transmission Control Protocol (TCP)/Internet Protocol (IP)) or Serial Port plugged through a USB port in the SG-Box.

In addition, SG-Box also supports the LoRa[7] protocol to retrieve measures from temperature sensors installed in the households of the buildings.

## Chapter 2. SG-Energies Ecosystem

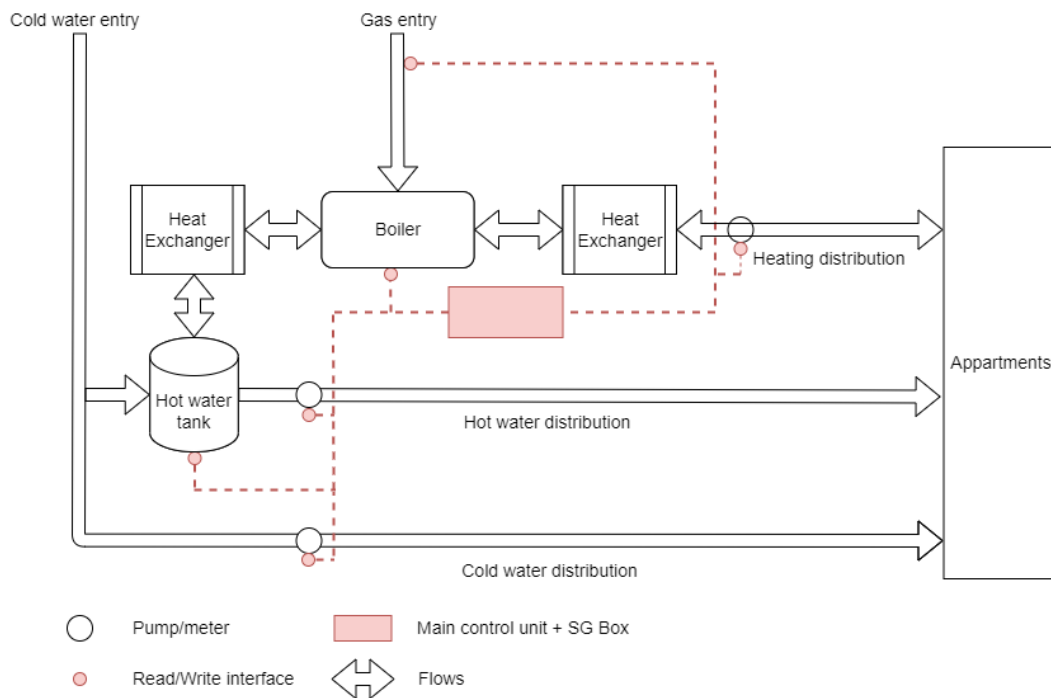


Figure 2.2 Schema of the heating installation of Vernier city with the SG-box

SG-Box is also responsible for sending retrieved data to two servers: Ignition and The Things Network (TTN)[8]. Ignition Server's role is to (1) centralize, store and send commands to the SG-box and (2) visualize the retrieved data.

During the past months, the STEP project focused on the communication part between the main control units, SG-Box and Ignition server to ensure reliable data collection and interaction with the main control units. In this context, SG-Energies has deployed four pilot installations to test and validate this communication part: two deployments using ModBUS and two others using BACnet.

Finally, each SG-Box has a Virtual Private Network (VPN)[9] connection to the Ignition Server. This feature provides an easy way to deploy updates and interact with the boxes without any move to the heating installation.

## 2.2 Technologies

### 2.2.1 SG-Box

The **SG-Box** device is composed of a Raspberry Compute Module 4 and a LoRa module (see Figure 2.3). Two antennas are connected to the box, one for the 4G network, the other for the LoRa network



Figure 2.3 Photo of the intern composition of the SG-Box device

### 2.2.2 Node-RED

**Node-RED**[10] is a programming tool based on NodeJS and offers a flow-based development tool for visual programming (see Figure 2.4). Its main goal is to connect hardware devices to online services as part of the IoT. Node-RED is based on the event-driven model<sup>1</sup>: each block is reactive and runs when it receives an input: the payload. Node-RED project is named flow: this is the addition of all blocks linked to perform a runtime at the execution. The interface provides predefined blocks to simplify the flow of programming. JavaScript function blocks offer more flexibility to develop logic that is not included in existing blocks.

- interacting with the main control unit of the heating room.
- formatting data to be sent to the Ignition server through an MQTT Broker.

<sup>1</sup>An event-driven architecture uses events to trigger and communicate between decoupled services

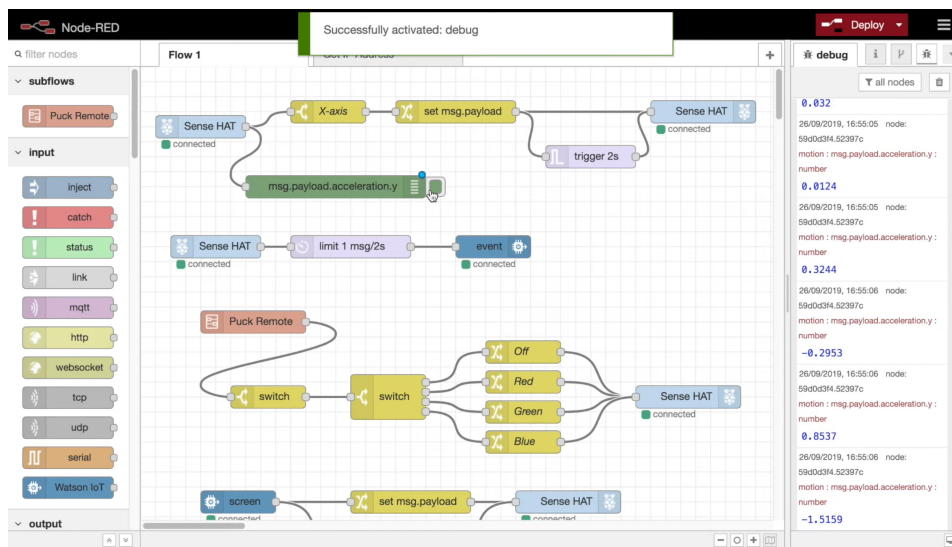


Figure 2.4 Screenshot of Node-RED's interface  
Source: [www.nodered.org](http://www.nodered.org)

### 2.2.3 Ignition

**Ignition** is a software released by Inductive Automation in January 2010[11]. It is an integrated software platform for Supervisory control and data acquisition (SCADA) systems. The main features of this software are:

- centralizing data and storing them in Structured Query Language (SQL) databases
- providing tools to build interfaces for data visualization

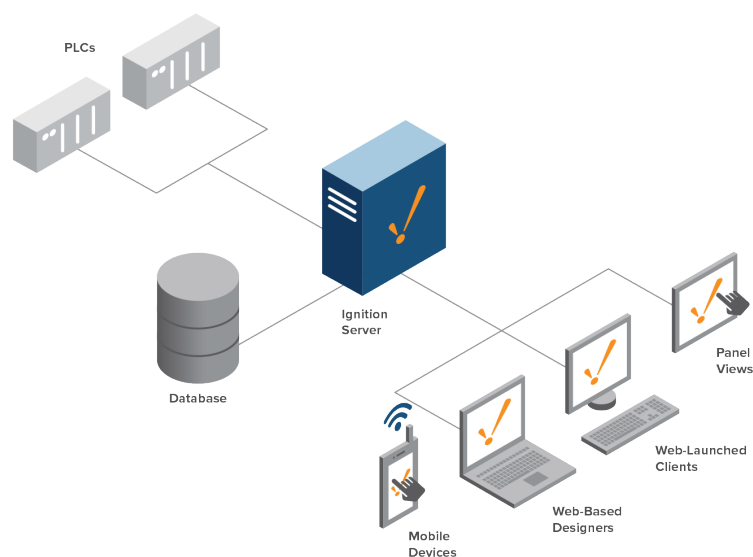


Figure 2.5 Schema of Ignition server's place and inter-connections  
Source: [www.inductiveautomation.com/scada-software/](http://www.inductiveautomation.com/scada-software/)



Ignition is composed of several modules. The main ones are SQL Bridge to connect PLCs and SQL databases (see Figure 2.5), Perspective to design and run specific interfaces for data visualization, Reporting to create dynamic PDF reports to have a regular overview of the managed data and Short Message Service (SMS) Notification Module to send alarm notifications directly through mobile network. Ignition is one of the main building blocks of the STEP project. This software is responsible for receiving collected data from the different SG-Boxes and displaying them on graphical interfaces, alerting by SMS and creating operating reports for technicians and building managers.

## 2.3 Communication protocols

### 2.3.1 BACnet

**BACnet**[12] is a communication protocol for Building Automation and Control (BAC) networks created by American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE[13]). This protocol is used to control building systems such as heating, ventilating and air-conditioning. To manage those systems, a set of rules is set and the automated control unit has to manage the system by applying those rules when needed with the help of sensors (temperature, pressure, etc.). The reliability of this protocol is given by the standards it meets (ANSI[14] and ISO 16484-5[15]). Those standards specify 60 standard object types. Each of the 60 different types is not necessarily needed in every system. Each data point can be accessed by a unique couple of integers:

- the ID of the “object type”
- the ID of the “object identifier” of the given type (called also “object instance”)

Other fields in a data point are mandatory in addition to the previous ones:

- The “object-name”, to allow human recognition of the data point more simply. A unique string ID can be used
- The “device ID”, to identify to what automated control unit the data point is attached to.

All of these mandatory fields do not provide the core information, the “Present-Value” optional field is the field with the actual value measured for a sensor (readable only) or the value set for a rule of runtime (readable and writable).

This protocol is based on rules priority. Each writable data point is described by an array of 16 inputs that can be different (see Figure 2.6). The index of each command in the “Priority Array” is important, the one with the higher priority will be taken as valid for the automated control unit and set in the runtime of the system. Priority 0 is the higher priority used by fire services for example to override any previous input in case of emergency, Priority 8 is used when a command is set manually by an operator and Priority 16, the lower one, is the rule set to run the installation normally.

## Chapter 2. SG-Energies Ecosystem

The BACnet protocol can be deployed on two communication materials (Layer 2 of the OSI model) different. The first one uses Ethernet and interconnects the devices through IP: BACnet/IP implementation. The second one uses serial communication through a serial port: MS/TP Protocol[16]. The first one offers more security, performance and accessibility to the BACnet installation between different BACnet devices all around the building installation than the second one.

Priority	Standard (according to [1])	Recommendation	Description / example
1	Manual Life Safety	Manual Life Safety	e.g. key control for fire services etc.
2	Automatic Life Safety	Automatic Life Safety	e.g. in the case of a fire alarm circuit/override by a fire emergency control
3	Available		
4	Available		
5	Critical Equipment Control	Critical Equipment Control	May only be used if the total losses to be avoided outweigh the possible device losses as the minimum on/off times are overridden. e.g. load shedding
6	Minimum On/Off	Minimum On/Off (cannot be written by external parties)	For minimum on/off times for devices which would otherwise suffer damage. e.g. gas lights
7	Available	Manual from the system	Local operation of the entire system by a chosen user
8	Manual Operator	Manual from the OWS	Manual activation of an OWS user
9	Available		
10	Available		
11	Available		
12	Available	Central functions	e.g. lighting for cleaning
13	Available		
14	Available	Timers, central controls	To be used for BIBB scheduling / central timer programme
15	Available		
16	Available	Automatic operation control	Automatic operation control functions
-	Relinquish_Default	Relinquish_Default	Permanently integrated into the device during planning.

Figure 2.6 BACnet priority array and description[17]

### 2.3.2 ModBUS

**ModBUS**, named after the creator's company name, is a data communication protocol published in 1979 by Modicon for use with its PLCs. With time, this protocol came rapidly to a standard and was used for connecting industrial electronic devices because it was openly published and royalty-free[18].

ModBUS protocol separates the data object into four different types addressable through, at maximum, 50000 different addresses. One address corresponds to one data point with one value. To read each type of data ModBUS protocol proceeds through a different function code which accesses a specific split of addresses where a certain type

## 2.3 Communication protocols

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of data is stored. This is the same concept for writing values into data objects, but not all the registers can be written, some of them are only giving information from a sensor and it will be nonsense to try to change their value.

No description is provided when a data point is read. A database needs to be present beside to identify the correspondence of each data point.

The ModBUS protocol can communicate through different formats:

1. Remote Terminal Unit (RTU)
2. ASCII
3. Transmission Control Protocol (TCP)

The first two formats communicate with serial communication on RS-282 or RS-485. The last one is based on Ethernet and IP protocol.

The ModBUS protocol is currently constrained by its age and limited support for data types, resulting in the inability to support large binary objects. Furthermore, there is no universally accepted approach for designing and describing data objects. It is also important to note that the ModBUS protocol does not provide any security measures to protect against data interception or prevent unauthorized commands.



# 3 | Technician Application

This chapter details the specification, design and development of the technician application. This application allows the user to visualize technical and administrative data related to a given heating installation. The technicians use this application to generate reports that will be submitted to SG-Energies for validation.

The structure of this chapter is the following: the first section lists the internal company data structure, the second section presents the application requirements, the third section details the application design and the fourth section presents the application realization.

## 3.1 Internal company data structure

Each heating installation can be identified by three general properties:

1. a three-letter abbreviation for the customer (such as building manager/owner) coupled with a unique number. Example: DAU 530, customer: Building manager Daudin, installation number 530
2. an address, just a way to internally identify the heating installation
3. a database ID

Each heating installation that has a deployed SG-Box is registered as follows in the Ignition data points retrieval hierarchy of four level:

1. customer, example: DAU
2. installation number, example 530
3. data source: Either "Régulation" for data coming from the main control unit or "LoRa" for data coming from apartments' temperature sensors
4. data point name

Each data point name has the same format:

- the data environment source. For example: data points from a gas boiler will start with "GAZ" code
- the data point type. For example "ME" for a measure, read-only
- the data point information. For example "TEMP" for a temperature
- the data point information complement. Free of any format. For example "depart" for data points taken at the beginning of the circuit

## Chapter 3. Technician Application

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In addition, SG-Energies has a report application called “RealTime”[1]. SG-Energies uses this application to:

1. register any operation related to any heating installation
2. keep track of the history of operations
3. grant customer access to the tracking with personal logging

### 3.2 Application requirements

Currently, The installations are maintained through regular technician visits. All operations are reported on paper with a formatted document. The goal of SG-Energies is to optimize technician visits and digitize operations.

For this to happen, the application must support these features:

#### **“As a technician user I would like to”:**

- search for a heating installation by its properties: Customer abbreviation and installation number or installation’s address
- check a list of all recent actions related to the selected heating installation
- check a chart containing different data points stored in time to monitor a specific heating installation
- check the contacts and references related to a specific heating installation
- submit a report, named “feedback”, of an intervention to a technician supervisor

#### **“As a supervisor user I would like to”:**

- consult all feedback previously created by technicians

#### **“As a user (technicians or supervisors) I would like to”:**

- login with personal credentials
- have access to the application with a tablet
- have access to the application with a desktop computer

The application must be implemented inside the Ignition software with the Perspective module (as explained in chapter 2) and using the retrieved data (each data point is called a tag) from the heating installation.

### 3.3 Application design

The design of the technician application will be driven by the RealTime application. The goal is to keep the same user reflexes. The main research bar (see Figure 3.1) will be reproduced from it .

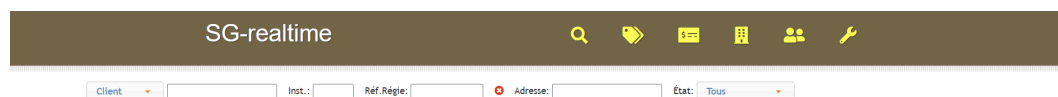


Figure 3.1 Realtime research bar

The organization of this section is as follows: The first subsection introduces the main components, and the second subsection describes the last operation view. The third subsection provides details on the chart view, while the fourth subsection presents the contacts view. Lastly, the last subsection outlines the feedback views.

#### 3.3.1 Main components

The top-bar will serve as the primary point of reference for identifying which heating installation is being worked on. This can be accomplished through a search function that allows the user to enter either the installation's unique identification (consisting of the customer abbreviation and installation number) or its address. Once a selection has been made, the current date and contract type of the chosen heating installation will be displayed, providing a clear and immediate view of the customer's payment information. This feature streamlines the navigation process and enables the user to easily determine the specific services that the customer has paid for.

To create a user-friendly and focused experience on a tablet, a collapsible side menu can be opened by selecting a button on the top bar. This menu will contain clickable links to various views that are available based on the user who is currently logged in, enabling a simple navigation and maximizing screen space

#### 3.3.2 Last operations view

The first view available for all kinds of users is the "Last operations" view (see Figure 3.2). With the "Real Time" application, technicians don't have any access to it. The goal of this view is to offer them a quick list order by descending date of the recent action linked to a heating installation. This feature will offer them the clearest view when they are directly doing operations in the building. It consists of retrieving, from the "Real Time" application database, all the actions of an installation and listing them line by line by specifying the date, subject, status and the person who was responsible for an action done.

*Dernières Interventions*

Date	Motif	Statut	Intervenant
05/02/2021	Détartrage bouilleur effectué	OK	Détartrage Secours
22/01/2021	Appel Di Maggio, apt. 4ème, radiateur froid	OK	Ismaël
07/01/2021	Panne brûleur	OK	Serv. Gen. de Chauff.
22/12/2020	Offre remplacement circulateur	en cours	SG
14/09/2020	Appel Mme. Müller, apt 6ème, pas d'ECS	OK	Ismaël

Figure 3.2 Mock-up of the last operations view

### 3.3.3 Chart view

The second view, with the same availability as the previous one, is the core view for live monitoring of a heating installation. The goal of this view is to visualize selected tags, that can represent temperature for example, of specific components of the installation. With this chart (see Figure 3.3) , the effect of outside temperature can be easily compared to how the heating installation manages the temperature in the heater circuit and see the effect of it by watching the apartment's temperature curve.

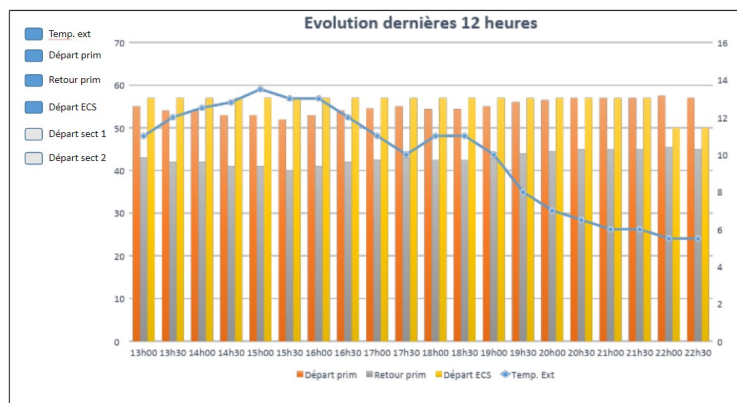


Figure 3.3 Mock-up of the chart view

To increase the detection of potential issues during monitoring the chart must be dynamic as possible with an appropriate data retrieval frequency, free choice of what data is shown and the choice of different scales of time to show only the last hour of data or also the last 12 hours.

Finally, the curves for environment temperature as outside or inside apartments temperature must be displayed as simple line curves and for others, like components ones, they must be displayed as bars.



### 3.3.4 Contacts view

The goal of the third view, named “Contacts view”, is to list in the same place all useful contacts about the heating installation for any users who need it during simple monitoring from the office or a technician doing operations in the building (see Figure 3.4). In addition, it will show resources related to the brand of the components of the installation. Finally, this view will display which technician is responsible for the installation.

All of this data will be retrieved from the internal database of SG-Energies used in part for the “Realtime” application.

*Références / Contacts*

Régie: Baezner Interlocuteur: Mme  
 Concierge: Mme F Tél: 079  
 Entretien brûleur: Serv. Genev. de Chauff. Tél: 058 Tél: 079  
 Tech SG: Jaouad  
 Manuels : [manuel Diematic M3](#)  
                   [manuel brûleur Cuenod XXW](#)

Figure 3.4 Mock-up of the contacts view

### 3.3.5 Feedback views

To write and manage feedback, users will have two views: one for creating new feedback and another one for visualizing previous feedback and editing them (see Figure 3.5). The first idea for the view to create feedback is to have three main blocks. The first one describes the date of the intervention, and arrival and departure time. The second one consists of a list containing all the technicians' observations during his interventions and operations made. The last one contains two text blocks to write what actions were realized and if any follow-up needs to be done after his intervention on site.

*Feedback*

Heure arrivée sur site:                      Heure départ:

Temp	Apt.	Pièce	Heure	Commentaires
21	5ème, Mme Perroud	Salon	17h30	Radiateur derrière canapé

Actions menées

Suite à prévoir

Figure 3.5 Mock-up of the new feedback view

## Chapter 3. Technician Application

The design of this view has slightly evolved during the project impacting the third block. The two text blocks merged to leave a place for a file upload block to add some pictures of the interventions.

The second view will mostly concern office people for managing the written feedback of technicians. To do so, all of them need to be grouped in a sortable list. This list will display a summary of the feedback to recognize when, where and who did it. A second time, the user will be able to expand selected feedback to see all details saved. The supervisors will be able to make corrections to the feedback and change the status of the feedback to “Terminated” to close the intervention concerned.

### 3.3.6 Summary

The design of the technician application is composed of two main components to help to navigate between five different views. The design is made to be fully expandable by adding other views dependent or not on a heating installation. To access any information on the application, the user will have to click at most three times to make his way: this design can guarantee the simplicity of the user experience. The Figure 3.6) give a global mock-up of the application.

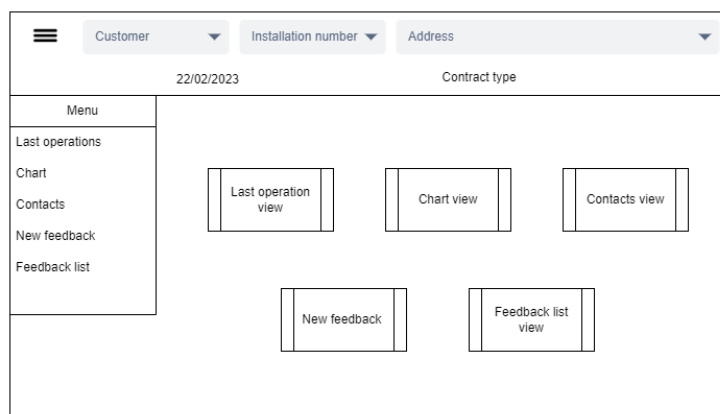


Figure 3.6 Summary mock up of technician application

## 3.4 Application realization

The realization of the application takes into account the Ignition architecture and how different blocks and components interact with each other. Ignition can attach Python (Python 2.7) scripts on components and views. The goal of this realization is not only to use scripts to make the application works, Ignition includes other features, like “property bindings”, that are taken into account during the application building.

The different views explained in the last section use the Perspective module[19] of Ignition. This module allows the developer to build mobile-responsive HyperText Markup Language (HTML) applications that run natively on any screen. It simplifies the build by abstracting most parts of the HTML and CSS code by translating the main properties of it into JavaScript Object Notation (JSON) properties of each component. It implies having a set of components ready to use, so Ignition proposes this. A set of more than fifty elements ready to configure in the wanted way to avoid creating complex components with basic ones.

Each realized view is realized using a main flex container[20] (organized in columns) that dynamically sets the components' size inside it to fill the maximum available space. This allows the developer to simply build a responsive application suitable for mobiles, tablets and desktop computers.

### 3.4.1 Main components

Ignition is made in such a way that any view can be anchored to one of the four sides of a window (top, bottom, left or right) and a view is taking place in the center. As its name suggests, the top-bar is anchored to the top of the window to allow the user permanent access to it. The top-bar (see Figure 3.7) is composed of two main flex containers (I and II). Each container can have either a row or column organization to locally change the way of assembling different components between them.



Figure 3.7 Technician application top-bar

The first container is composed of four components: one button(I.1) and three dropdowns(I.2, I.3, I.4) menus. The button is a “hamburger button” that opens or closes, on-click, the side menu view. To do so, a dock action is linked to the event “OnClick”. It will toggle the view containing the side menu.

The three dropdown menus are in charge of the research of a heating installation by its properties. Ignition solutions have two types of dropdown: one where the user can only make a single selection and another where he can make a multi-selection. Each of the three dropdown menus is configured as a single selection.

The first one (I.2) lists all the customer abbreviations. To get all of those, the SQL module of Ignition has the “Named Query” feature. In this feature, you can prepare and test SQL requests with parameters to have all of them named and grouped outside any code or properties. To get this list, a named query is saved and triggered at each start of the application. Each element available in a dropdown menu combines two parameters: a label and a value. The label is the property that is displayed to the user and the value is the property used by the application. For the customer abbreviations list, the labels are the abbreviation itself and the values are the client ID linked to it.

The second one (I.3) lists all the installation numbers, the same method is used to retrieve this list. For the installation numbers list, labels are the installation number and values are the installation database ID (see Internal company data structure).

The last one (I.4) lists all the installation addresses, where the labels are the addresses and the values are the installation database ID as well.

Given that the user can research either by installation number or by address, the other selection must be updated when one is selected. To perform this “Change scripts” are done. The first dropdown's only goal is to display the customer abbreviation, for this version of the application it doesn't have any effect on another component.

## Chapter 3. Technician Application

The second dropdown and the third dropdown change each other's value when one is changed and this will adapt the first one too to have the full installation properties corresponding to the research of the user (see Figure 3.8).

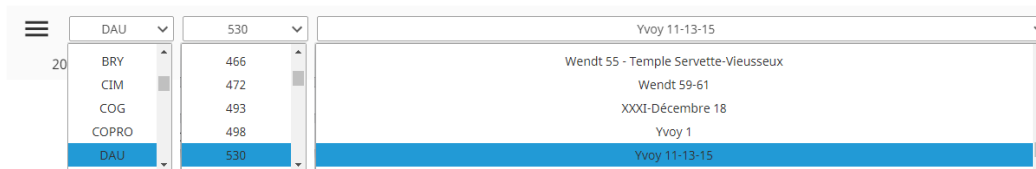


Figure 3.8 Technician application top-bar's dropdowns

Each change on a dropdown menu is not only impacting the others, it will affect four session variables to store and avoid further requests to databases. The building number and database ID, the customer abbreviation and the installation address are stored in those variables. This session storage allows the other view to simply access the context defined in the top bar, to retrieve information on the selected installation.

The second flex container contains only two simple components: one label displaying the current date (II.1) and the other label displaying the services contract (II.2) of SG-Energies linked to the selected heating installation. To retrieve this information, another named query has been made.

The side-menu (see Figure 3.9) is a view composed of only one component: a menu tree component. This view is anchored at the left of the client window. The view is set to be visible only "onDemand" to be toggled by the "hamburger button" of the top-bar. When toggled the side-menu view comes to cover the content of the active view without covering the top-bar to avoid hiding the menu button for closing it after.



Figure 3.9 Technician application side-menu

Each item displayed in the menu allows the user to navigate through available views for his account. Unavailable views for his role account are not displayed.

### 3.4.2 Last operations view

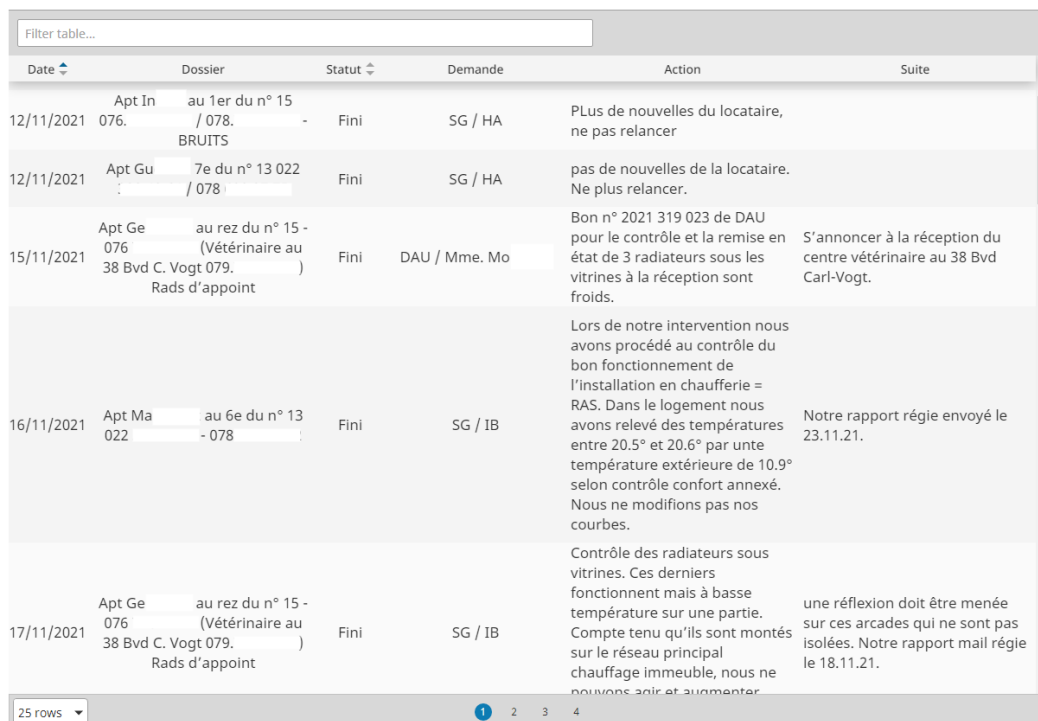
The last operations view (see Figure 3.10) is also composed of only one component: a table component. This component offers the possibility to group a list of elements in a table that can be searchable and ordered by columns and each piece of information might be edited.

## 3.4 Application realization

To fill this table, named queries have been made to retrieve all operations and interventions related to the selected heating installation. Each entry is composed of 6 fields: the date, the main topic for the action or issue registered, the status of the entry, the person or organism who has generated the entry, the operation performed and an optional follow-up.

The goal of this table is only to visualize the data from the “Realtime” database so the cells are not writable.

To find information needed quickly, users can search on all the cells for a specific keyword with the research bar included and can order the table either by date or by status.



Date	Dossier	Statut	Demande	Action	Suite
12/11/2021	Apt In 076. au 1er du n° 15 / 078. BRUITS	Fini	SG / HA	PLus de nouvelles du locataire, ne pas relancer	
12/11/2021	Apt Gu : 7e du n° 13 022 / 078	Fini	SG / HA	pas de nouvelles de la locataire. Ne plus relancer.	
15/11/2021	Apt Ge 076 au rez du n° 15 - (Vétérinaire au 38 Bvd C. Vogt 079. Rads d'appoint)	Fini	DAU / Mme. Mo	Bon n° 2021 319 023 de DAU pour le contrôle et la remise en état de 3 radiateurs sous les vitrines à la réception sont froids.	S'annoncer à la réception du centre vétérinaire au 38 Bvd Carl-Vogt.
16/11/2021	Apt Ma 022 au 6e du n° 13 - 078	Fini	SG / IB	Lors de notre intervention nous avons procédé au contrôle du bon fonctionnement de l'installation en chaufferie = RAS. Dans le logement nous avons relevé des températures entre 20,5° et 20,6° par une température extérieure de 10,9° selon contrôle confort annexé. Nous ne modifions pas nos courbes.	Notre rapport régie envoyé le 23.11.21.
17/11/2021	Apt Ge 076 au rez du n° 15 - (Vétérinaire au 38 Bvd C. Vogt 079. Rads d'appoint)	Fini	SG / IB	Contrôle des radiateurs sous vitrines. Ces derniers fonctionnent mais à basse température sur une partie. Compte tenu qu'ils sont montés sur le réseau principal chauffage immeuble, nous ne pouvons agir et augmenter.	une réflexion doit être menée sur ces arcades qui ne sont pas isolées. Notre rapport mail régie le 18.11.21.

Figure 3.10 Technician application last operations view

After some reviews, the margin between columns and the text size has been increased to display a more readable table, especially on tablets.

### 3.4.3 Chart view

The chart view has several steps towards its realization. The goal of this view is to choose in a tag list which ones the chart should display to have a dynamic user experience.

At first, Ignition native chart components were used. A comparison between the time series chart component and the XY chart component was made and several criteria made during the design could not be met. It was not possible to combine a line chart for

### Chapter 3. Technician Application

the temperature curve and a column chart for some heating installation's datapoint and it was not simple to shorten the tag list in order to avoid having all the tags available which would have involved a complex user experience.

After consulting with an Ignition expert, it revealed that Ignition supports the addition of external modules. ApexChart JavaScript library[21] was chosen to match the design criteria. Developers from the Ignition community have made a module[22] for the ApexChart library to make it available and simple to use like regular Ignition components.

After some tests, the combination of line and column graphs is fully functional and the use of the library is simpler than the use of Ignition components by having much more properties to set and fully detailed documentation[23].

The view (see Figure 3.11) is composed of three components: two dropdown menus grouped in a flex container and an Apexchart component.

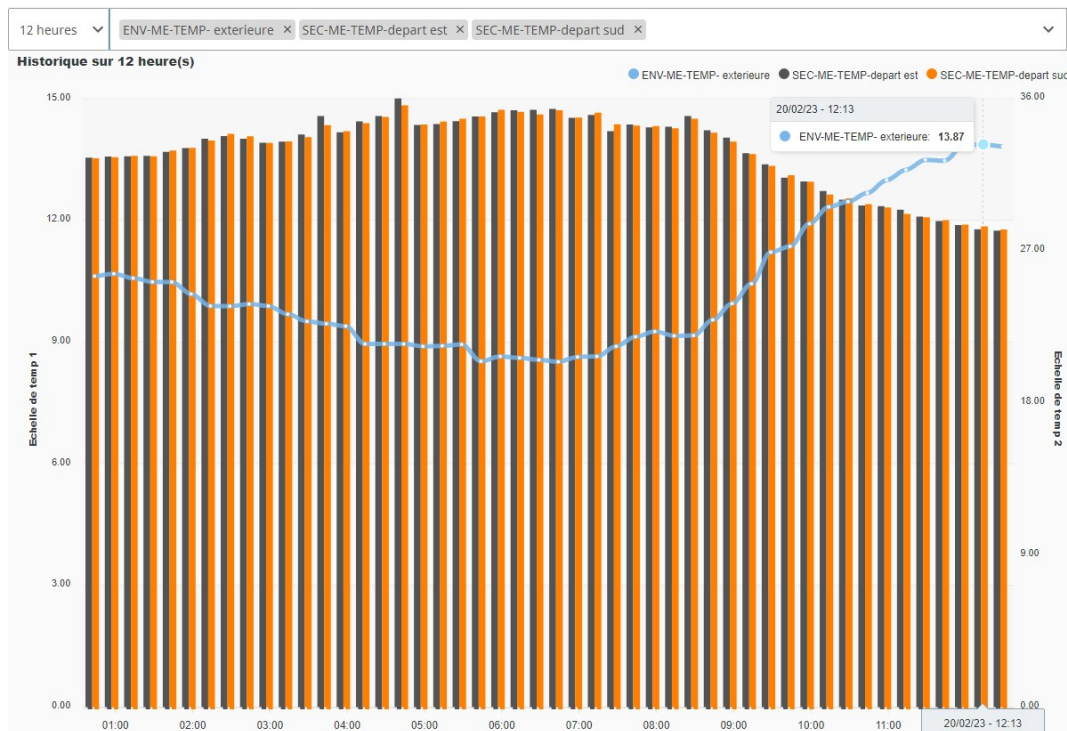


Figure 3.11 Technician application chart view

The first dropdown is used to set the time range to display in the chart: it offers the choice to display data from 1 hour to 24 hours back in time from the actual time. The second one can have multiple values because its role is to list all the tags that can be viewed in the chart. To ensure enough visibility in the chart, only 5 tags at the same time can be shown.

Finally, the last component is the Apexchart component. It regenerates itself when a tag is added or deleted in the selection dropdown.


To retrieve data, the component takes the path of each selected tag and retrieves, through the Ignition tag history query, one value per 15 minutes.

To have a good vertical scale of the chart, the line curve representing the outside temperature has its own dynamic scale displayed on the left of the chart and the other temperature scale for bars is shown on the right of the chart. This implementation detail is to avoid having only one scale for all the graphs which will cause the outside temperature curve to be flattened at the bottom of the graph because its values will not exceed 30 degrees while the other heating installation's temperatures are usually around 60 degrees. With the two different scales, the line curve is in the middle of the graph and its variations are clearly visible.

After some reviews with SG-Energies, some colors have been added and the format of the date adjusted.

### 3.4.4 Contacts view

The contacts view (see Figure 3.12) is only composed of components retrieving data from the "Realtime" database through named queries.



Nom	Rôle	Tel. Fixe	Tel. Mobile	E-Mail
M. Serge	Gestion	022.		s. @daudin.ch
Matos	Conciergerie		076.	
Mme. Filippina	Gestion	022.		f. @daudin.ch

Figure 3.12 Technician application contacts view

Firstly, two labels are grouped in a flex container showing the full name of the building manager of the heating installation and the technician responsible for it.

Secondly, a label shows if there are any remarks linked to the heating installation: it could be, for example, the way to access the heating installation in a huge building.

Finally, a table component regroups all contacts listed in the database linked to the building installation or building manager which can be useful. For each one, it lists the name, the role (management, building janitor, . . . ), phone number(s) and e-mail.

Actually, this view is not displaying resources linked to the brand of the different components of the heating installation because the related database is not populated yet.

### 3.4.5 Feedback views

Finally the feedback view (see Figure 3.13) is the one where the users can enter information for further treatment.

## Chapter 3. Technician Application

The feedback is not only a text area where the technician can write his report when he is doing an intervention. It will be organized. This view gives a template to write feedback and a reminder of what parts of the heating installation need to be checked depending on the type of intervention.

I

Date : 20/02/2023    Heure d'arrivée 13 : 47    Heure de départ 13 : 47

Type d'intervention

Observation(s) :

+

-

III

Action(s) menée(s)  
/ Suite à prévoir :

Fichier(s)  
:

Nom du fichier ↕  
Pas de fichiers

Enregistrer

Figure 3.13 Technician application new feedback view

The first flex container (I) consists of registering the date of the intervention, the arrival time on site and the departure time from it. All of those inputs use a datetime picker component.

The following two flex containers (II and III) are for listing the different observations made during the intervention regarding a specific format in a table. First, the technicians will have to choose from a dropdown menu a scenario (see Figure 3.14) in a list previously set by SG-Energies.

^

Chauffage des locataires

Chauffage général ou secteur

ECS

Figure 3.14 Technician application new feedback scenarios' list

To make scenario list changes more easily, a list of scenarios and their different columns can be edited in a session variable array (see Figure 3.15). Each element of this array has a name, a scenario name, and a list of columns with their label. With this structure easily reachable the addition of a setting view can offer the possibility to change the scenarios list without making changes in Ignition but directly in the application itself.





Figure 3.15 Scenario global variable structure

After selecting a scenario the technician hit the “plus” button to add a new observation. This will create an element in the table component with the columns of the selected scenario.

He can edit each cell of this new observation to put his remarks in it. In this table, the technician can add as many observations as he needs and he can delete one of them by selecting it and pressing the “minus” button.

The last flex container (III) displays two functionalities: a text area to summarize the intervention and an upload files area to link pictures, for example, to the feedback.

The first functionality contains only a text area component that allows the user to enter as much text as he wants. The second one is composed of the file upload component that will upload files through a named query as a blob.

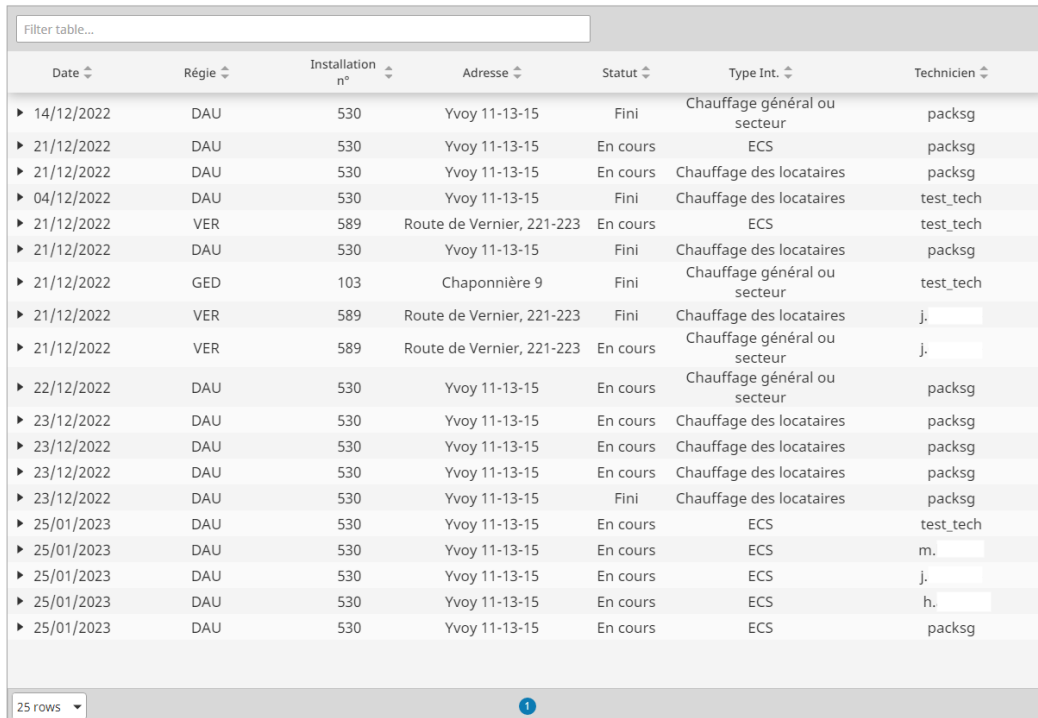
Given that a feedback table link with a feedback files table is a “one to many” link, a file upload will automatically trigger the feedback saving to retrieve the feedback ID to link it in the new file to save in the files table. On the contrary, when feedback is deleted, it will delete “on cascade” the files linked to this feedback.

Finally, a group of different buttons is available depending on the role of the logged-in user. Technicians users have only access to the saved button, and if the feedback is saved, a “undo” button is available to restore the last save of the feedback. In addition to these buttons, supervisor users have access to two more buttons: the first one allows this kind of user to delete feedback and the other to switch the feedback state between “in progress” and “ended”.

This view offers the possibility to visualize a feedback but only a new one being edited and not a past one. To ensure the possibility to edit past ones, the second view related to feedback offers a list (see Figure 3.16), displayed in a table component, of all available ones for supervisor users and only “In progress” feedback related to the logged technician. The table component offers the possibility to expand a line with a

## Chapter 3. Technician Application

“subview”. Therefore each expanded line will open a feedback view, previously detailed, with the data linked to it in each field of the newly opened view and give the possibility to update all the fields of a previous component.



Date	Régie	Installation n°	Adresse	Statut	Type Int.	Technicien
▶ 14/12/2022	DAU	530	Yvoy 11-13-15	Fini	Chauffage général ou secteur	packsg
▶ 21/12/2022	DAU	530	Yvoy 11-13-15	En cours	ECS	packsg
▶ 21/12/2022	DAU	530	Yvoy 11-13-15	En cours	Chauffage des locataires	packsg
▶ 04/12/2022	DAU	530	Yvoy 11-13-15	Fini	Chauffage des locataires	test_tech
▶ 21/12/2022	VER	589	Route de Vernier, 221-223	En cours	ECS	test_tech
▶ 21/12/2022	DAU	530	Yvoy 11-13-15	Fini	Chauffage des locataires	packsg
▶ 21/12/2022	GED	103	Chaponnière 9	Fini	Chauffage général ou secteur	test_tech
▶ 21/12/2022	VER	589	Route de Vernier, 221-223	Fini	Chauffage des locataires	j. [redacted]
▶ 21/12/2022	VER	589	Route de Vernier, 221-223	En cours	Chauffage général ou secteur	j. [redacted]
▶ 22/12/2022	DAU	530	Yvoy 11-13-15	En cours	Chauffage général ou secteur	packsg
▶ 23/12/2022	DAU	530	Yvoy 11-13-15	En cours	Chauffage des locataires	packsg
▶ 23/12/2022	DAU	530	Yvoy 11-13-15	En cours	Chauffage des locataires	packsg
▶ 23/12/2022	DAU	530	Yvoy 11-13-15	En cours	Chauffage des locataires	packsg
▶ 23/12/2022	DAU	530	Yvoy 11-13-15	Fini	Chauffage des locataires	packsg
▶ 25/01/2023	DAU	530	Yvoy 11-13-15	En cours	ECS	test_tech
▶ 25/01/2023	DAU	530	Yvoy 11-13-15	En cours	ECS	m. [redacted]
▶ 25/01/2023	DAU	530	Yvoy 11-13-15	En cours	ECS	j. [redacted]
▶ 25/01/2023	DAU	530	Yvoy 11-13-15	En cours	ECS	h. [redacted]
▶ 25/01/2023	DAU	530	Yvoy 11-13-15	En cours	ECS	packsg

Figure 3.16 Technician application feedback list view

### 3.4.6 Users tests feedback

After having realized and tested the application, a presentation and a live test with four SG-Energies’ technicians are organized to retrieve their feedback about the work done.

The overall impression is very positive. All the technicians find the application very intuitive, simple and clear.

Each view is presented and tested, and all the technicians that are working mostly with paper reports today have the same feeling: working with this application on a tablet will make the creation and understanding of the reports much simpler and time will be saved during interventions.

The most present suggestion is to offer the possibility to have their own schedule synchronized and included in the application especially with the feedback application to create a link with the technician’s calendar event related to the intervention. Some other suggestions have been proposed like adding the possibility to take a picture directly in the feedback file options instead of taking a picture with the native photo application and importing the file.

Finally, some minor bugs have been found in the tag retrieval to create the list of tags available for the chart and the zoom feature that needs to be disabled on the graph because there is no available space to add a reset for the zoom.

### 3.4.7 Possible improvements

The goal of this proof of concept was to create the first usable application to prove that retrieved data from a heating installation can be displayed for monitoring it. Now this proof of concept works, this application can be integrated with other services already available at SG-Energies like the calendar or other third-party services available through an API like weather service for example. It can be expanded with more management views and by developing the remote interaction with the heating installation through the SG-Box.



# 4 | Reporting application

This chapter will present the requirements of SG-Energies, the design and the realization of the reporting application. The goal of this application is to offer a proof of concept of a tool to generate reports defined by a template and filled either with data from heating installation or by introducing personal texts or data. The structure of this chapter is the following: the first section presents the application requirements, the second section details the application design and the third section presents the application realization.

## 4.1 Application requirements

At present, SG-Energies produces reports manually to be provided to clients, detailing the efficiency of a specific component of their installation. As this procedure is time-consuming, SG-Energies seeks an automated solution for generating and delivering these reports.

In what follows, we provide the specification of this report application:

### “As a supervisor user I would like to”:

- choose the type of report to produce depending on the building concerned
- to have a pre-generated report from a template that I can complete with comments or others pertinent data
- export the report as a PDF file

The application must be implemented inside the Ignition software with the Reporting module, using the data stored on SG-Energies databases.

## 4.2 Application design

The main goal of this proof of concept is to create the report generation for one type of report and a base for the generation of other reports. The report that will be involved is the VeriSOL report. This report is charged for describing the solar installation on a building, showing the savings made and offering a comparison between the theoretical efficiency that could be reached according to the manufacturer of the solar panels, to the adjusted theoretical efficiency according to SG-Energies and the real production numbers.

### 4.2.1 Report template

The report is composed of two pages. The first one is a short summary of the solar installation. The second page is a graph offering a comparative view between theoretical and real efficiency.

The first page is composed of three blocks.

## Chapter 4. Reporting application

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The first block provides an overview of the installation context, including its general properties, the current date, and the report's relevant period. The second block consists of two arrays. The first array details the solar installation specifications, such as the number of solar panels, surface area, exposure, and theoretical efficiency. The second array provides statistics related to the total solar energy utilized in the production of hot water and the resulting savings. Finally, the last block is designated for comments from SG-Energies.

The chart will take up almost the total available space in a landscape orientation on the second page. This will make the graph easily readable for the customer. He can quickly check the solar installation efficiency.

### 4.3 Application realization

The realization of the application keeps taking into account Ignition architecture. The module Reporting of Ignition allows creating a template and adding data input to fill the report dynamically either with user inputs or database queries. The reporting module is able to generate scheduled reports but in this case, it will need to have all the data filled in. For the VeriSOL report user inputs are required and the reporting module does not have any user interface. Therefore a report creation view needs to be created.

#### 4.3.1 Report template

The Reporting module, like the Perspective module, offers multiple native components to create the different parts of the report.

To do the first block of the first page (see Figure 4.1), all the properties and concerned periods are given to the report module as named inputs to be correctly placed into the report. Only the current date is internally obtained.

The second block is made of two simple tables where rows and columns are statically defined given that the data will always have the same label and it won't have more or less. The first table size is 2 rows by 5 columns and it displays, on the second row, the different specifications retrieved from databases about the solar installations concerned by the report.

The second table size is 2 rows by 2 columns and it displays the user inputs for the solar energy used for hot water production and saved money user entry fields. Finally, the last block only displays the text given by the comments user input field.

On the second page, to create a graph, a time series chart is used. This chart has three different curves: the first one for the theoretical manufacturer efficiency depending on sunshine duration by month, the second one for the theoretical efficiency adjusted by SG-Energies depending on sunshine too and finally the real efficiency of the solar installation.

#### 4.3.2 Report creation view

The report creation view (see Figure 4.2) is accessible only for supervisor users by the side menu. All others are not seeing the reporting entry in the collapsible menu. The location of this view comes with the idea to centralize all the different applications in a unique way to access them to have a good user experience.

## 4.3 Application realization

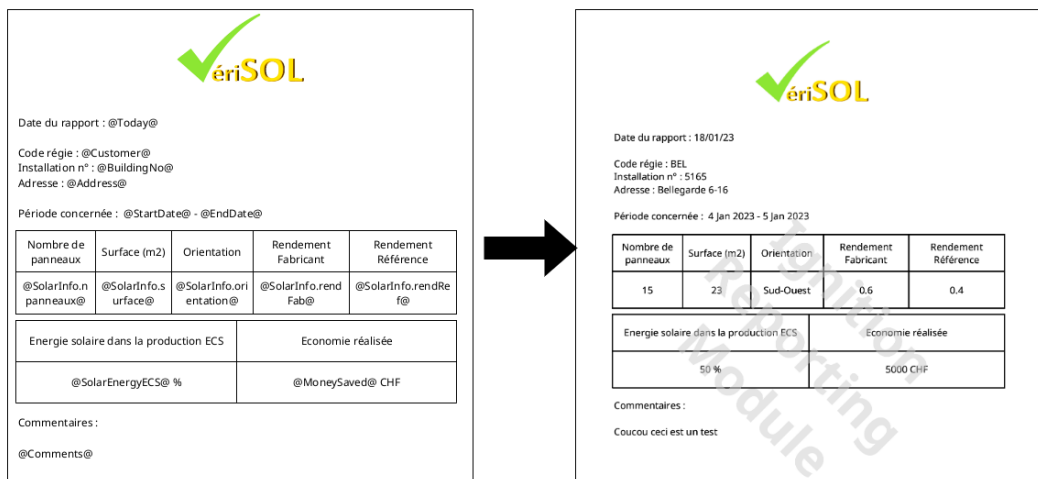


Figure 4.1 Report generation with the reporting application

The view is designed to be accessed and used on desktop computers with regular screens and not tablets.

It is composed of two blocks, one on each side of the screen: on the left the user inputs to fill the report and on the right the report preview.

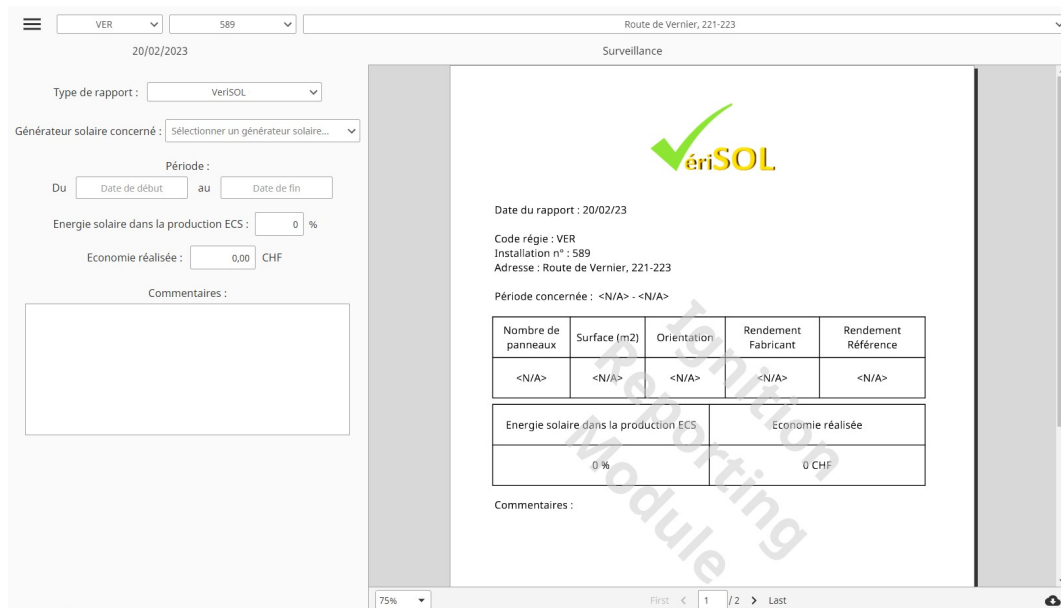


Figure 4.2 Reporting application view

In the left block, the user needs to first choose the report type with a dropdown menu component. Actually, only the VeriSOL report will be available but this dropdown is the common base for further integrated reports that will be designed in Ignition software. Once the selection is done, user inputs corresponding to the report that needs to be filled are displayed. For this report only four types of components are used: dropdown

## Chapter 4. Reporting application

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menus when the choices are coming from a database list, a datetime picker for date and/or time selection, a text field for small text or number inputs and a text area for larger text inputs like comments for the VeriSQL report.

In the right block, Ignition offers a way to link the Perspective and Reporting modules with the report viewer component. The JSON properties of these components include a “params” one that will fill the report with the user’s inputs. On every input change, the report is automatically regenerated to have a quick overview of the changes made. At the bottom of this component, a download button is included to download the latest generated report. The name of the report can be set in a property of the component to ensure a good dynamic naming of the file.



# Conclusion

Both preventive and corrective maintenance of heating installations are often time-consuming and expensive. Several digital solutions are proposed to automate the maintenance of these installations. The first chapter of this report detailed three of these solutions. Each solution was evaluated based on five criteria that represent the main capabilities of the market.

SG-Energies, a Geneva based private company, is developing a digital IoT solution for the management and control of heating installations. This IoT solution is based on a device, called SG-Box, which collects data and measures from the control units of heating installations and transfer them to an IT platform. The second chapter of this report detailed the architectures and features of this SG-Box based IoT infrastructure.

The infrastructure is composed of three levels. The first level corresponds to the source of the data, namely the heating installation and its main control unit. The second level is represented by the edge device, which is connected to the main control unit and responsible for extracting the collected data from the heating installation. The third and final level is the IT infrastructure, which is responsible for retrieving data from the edge device and storing it together with the data from other devices.

Several end-user applications can be developed on top of the SG-Box based IoT platform. Two of these applications are detailed in the third and fourth chapters.

The first application utilizes the collected data to assist technicians in monitoring heating installations remotely or during operations, while providing an operation report tool to digitize reports and attach photos, making the reporting process easier for supervisors.

The second application enables supervisors to generate reports using a pre-designed template. A template for the VeriSol report has been created for this purpose, which retrieves solar data collected to visualize the efficiency of the solar installation.

The results of the early adopters tests are positive, with each view being presented and tested in real-life situations to ensure the most accurate representation of its use. Each user recognized the potential for improving their work with the aid of these applications and suggested small improvements from their perspective as field experts.



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