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Guide for the use of the Application for a friendly and easy management of the energy systems

WP4

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Publishable summary

The D4.13 “Guide for the use of the Application for a friendly and easy management of the energy systems” deliverable is a public document delivered in the context of WP4 and linked to Task 4.6: Development of BEMS for GSHP integration with multiple renewable sources and of an Application for easy management of energy.

The aim of the GEO4CIVHIC project is to foster the retrofitting of civil and historical buildings by facilitating installation, reducing costs and increasing efficiency of the different components through shallow geothermal systems. This will be achieved, on one hand by improving drilling machines and methodology, optimizing GSHE design and materials, and using more compact and hybrid HPs for high and low temperature terminals. On the other hand, a set of software tools will be developed to provide a holistic engineering solution to optimise installation and operation of GSHPs. One of these tools is the G4C_Monitor App (Task 4.6), described in this deliverable.

Abbreviations

GEO4CIVHIC	Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings
BEMS	Building Energy Management System
COP	Coefficient Of Performance
EER	Efficiency Energy Ratio
PV system	Photovoltaic system

Introduction

This App is designed to be used by users managing a building in which a BEMS-type monitoring/control system is installed. In fact, it takes all the information it uses, from the databases fed by that control system.

The *G4C_Monitor App* is not able to control or influence the system from which it receives data in any way; it simply reads the information and tries to process and present it to the user in a way that is useful to him/her.

The aim of the App is to inform users about their use of energy vectors in order to educate them to a conscious and virtuous use of energy resources. To do this, the App generates graphical reports of energy consumption and performs simple consumption analyses by evaluating user behaviour.

In particular, it is useful to focus on the aspect of electricity consumption, which is a figure that is easily translated into monetary terms. It is therefore appropriate to emphasise the savings resulting from, for example, the use of a photovoltaic system to support heat pumps, showing this benefit with simple numerical calculations. Just as it is appropriate to show, in a simple way, that energy consumption in recent weeks has been falling, perhaps thanks to virtuous user behaviour.

In essence, it is about empowering users by making them more sensitive to energy-saving issues.

The *G4C_Monitor App* was conceived for this very purpose:

1. Provide you with visual information in the form of easy-to-interpret graphs and gauges, enabling you to monitor (on-site or remotely), in real time, the consumption of your building. It is possible to set consumption thresholds at which Warning or Alert messages are issued (this possibility depends on the type of energy probes installed in the system).

2. To provide you with the possibility of querying historical data on the quantities of most interest in your house-plant system. The historical data are displayed in the form of easy-to-read bar or pie charts.

3. Educating you to use energy more consciously using simple quality indices based on your consumption data and showing the trends of these indices over time. Quality indices represent a kind of grade given to the user based on his consumption, taking into account his particular system/building. Remember that up to this level, the App is entirely personal, and your information is not made public in any way.

4. Assuming that the number of users using the *G4C_Monitor App* becomes sufficiently high, it makes sense to think about a Facebook page of the App where the user can publicly share his or her performance indexes. This will make it possible to draw up a public ranking list, where you can show off your ability to save energy.

1. What types of data are handled by the App

The data used by the App are of two types: descriptive building data, which are used to generate an estimate of the building's energy requirements. This will make it possible to calculate normalised performance indices and these will be comparable with each other even in different contexts.

Static type data (relating to the building and installed systems)

- Building surface area (sqm)
- Building volume (mc)
- Degree of insulation of the building
- Average number of people present
- Type of activity (residential, office, library, etc.)
- Times and days of use of the building
- Number of heat pumps installed
- Heat pump parameters (power, COP, EER, etc.)
- Photovoltaic system parameters (if any)
- Storage battery parameters (if any)
- Wind turbine parameters (if any)

Dynamic data (real time data read from sensors).

This is partly meteorological data (temperature, humidity, radiation); these data make it possible to estimate the need for heating and cooling and allow to estimate also the performance of the photovoltaic system (if present). Also of interest are the building's electricity consumption data related to the operation of geothermal heat pumps and water circulation pumps; solar energy production data, direct and battery self-consumption, as well as energy flows to and from the grid.

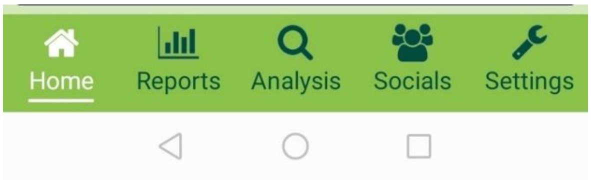
- Solar radiation [W/m^2]
- External temperature [°C]
- Internal temperature [°C]
- Internal humidity [%]
- Electrical energy from photovoltaic system [W]
- Electrical energy from wind system
- Electrical energy stored into the battery
- Electrical energy self-consumed from the battery

- Electrical energy self-consumed in real-time
- Electrical energy withdrawn from the grid
- Electrical energy sent to the grid
- HP electrical consumption

Dynamic data are those that will be shown to the user in the form of continuous line charts (e.g. to show the trend of a temperature or electrical power in real time), or in the form of bar charts (histograms, simple or stacked, used for historical reports or consumption analyses).

2. APP Structure

The B4C_Monitor App has a navigation bar that allows you to move easily through its five sections.



The five sections are called: Home, Reports, Analysis, Socials and Settings.

Let's take a look to every section.

2.1 Home section: real-time display of quantities

The homepage is the default screen of the app. It contains two very useful and immediately readable gauges: the first can shows the instantaneous electrical power used by the system in real time, or the photovoltaic power generated, if available; the second gauge shows the amount of electrical kWh consumed during the day. These values are updated every 60 seconds.

The first indicator allows you to easily see if the electrical power you are using is getting too close to the maximum threshold (which is a parameter set in the initial settings of the app). The approach to the threshold limit is also signalled by a message displayed in the lower notification area: this message can take on two levels of severity, ranging from a simple Warning to an Alert, which can also be accompanied by an acoustic signal, which can be set at the settings section.

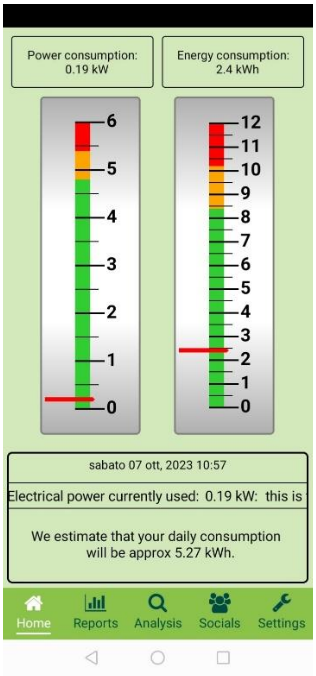
The second indicator, which shows the energy consumed during the day, has a cumulative value that increases continuously as time passes, resetting at midnight each day. The full scale of this indicator corresponds to what should be your typical daily energy requirement.

This full-scale value can initially be set by yourself but will later be suggested by the app; in fact, as it gains experience, it will provide an increasingly precise value that will set the consumption considered ideal for your building.

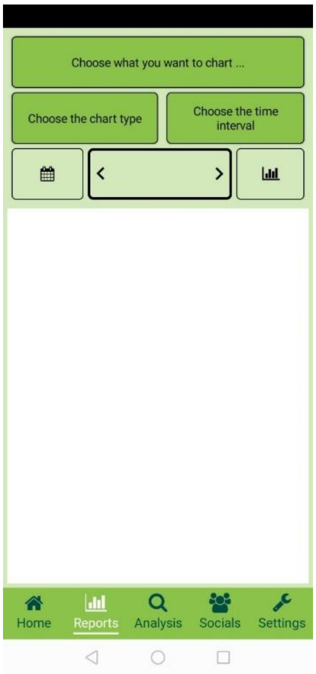
At the bottom of the gauges area is a button to show the power trend over the past hour in the form of a line chart.

Throughout the day, on an hourly basis, messages will be sent to you in the notification section informing of your consumption trend, to keep your attention on this aspect, which is directly related to energy saving.

To summarise, the home screen contains four basic objects: two gauges that monitor power and energy, a multiline graph showing the powers (consumed or generated) in the last hour and a notification area that contains the messages that the App generates for the user to convey various types of information.



2.2 SECTION Report: Viewing the measurement history



The second button in the lower menu bar leads to the Reports section. All quantities read by the sensors and made available to the App can in fact be represented in graph form. The Reports screen is structured as follows: an upper part contains three buttons that allow a series of choices.

The first button “Choose what you want to chart” allows you to choose the physical quantity to be graphed.

The physical quantities available to the App are initially set during the setting phase, when the App is first connected to the general database. The type and number of measurable quantities depend on the layout of your system.

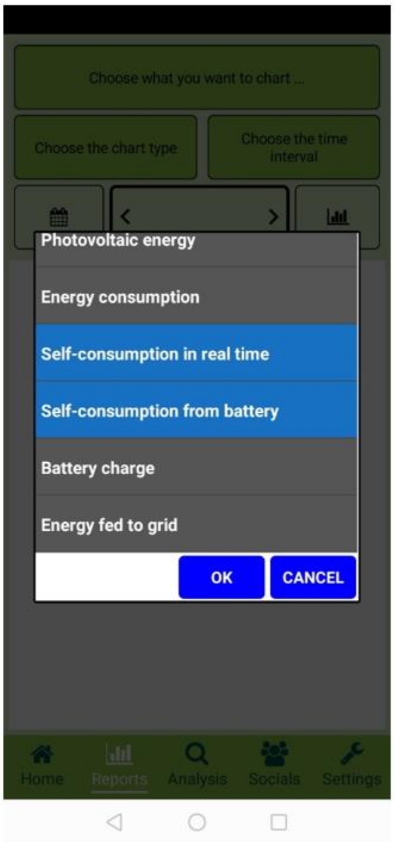
For example, a system in which a photovoltaic system is installed will provide certain physical quantities characteristic of the PV system, such as energy produced, self-consumed energy and energy sent into the grid. Similarly, a system equipped with a storage system will account for its variable capacity, expressed in kWh, and the energy it may supply to users.

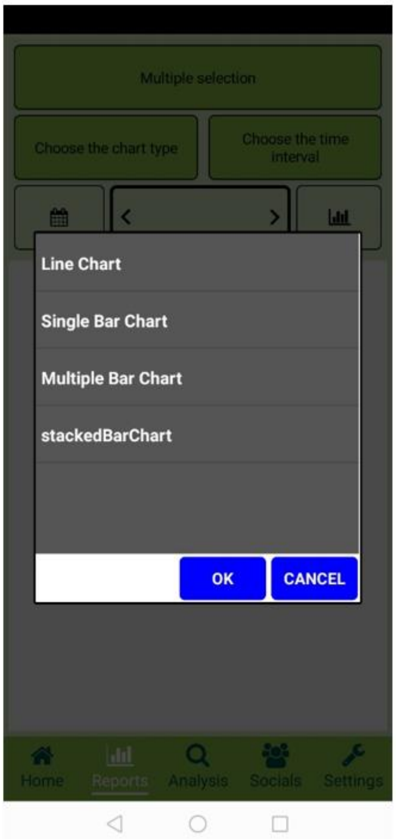
Once the App reads the plant description from the static database and the dynamic database, it is able to know which n sensors (and thus physical quantities) it is responsible for. It will then import the credentials of these quantities and create a list of physical quantities on which the software will be able to perform all the queries and subsequent operations foreseen.

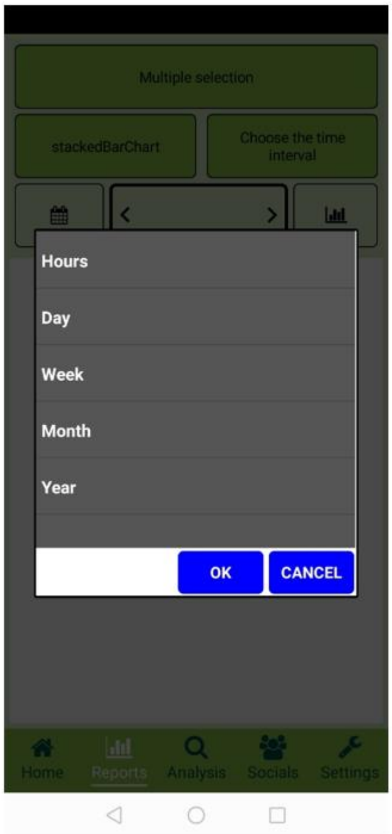
This list can be filtered by the user in the settings phase in order to exclude datafeeds deemed unnecessary (e.g. a datafeed associated with a humidity sensor can be hidden if it is deemed uninteresting).

Steps to do for generate a report:

1. Press the “Choose what you want to chart” button and select one or more datafeed
2. Press the “Choose the chart type” button and make your choice
3. Press the “Choose the time interval” button select a time interval for your query
4. Press the Chart button in the right side for generating the chart.







At this point, as mentioned, pressing the first button shows the list of available feeds for the charts.

Multiple selection is permitted for certain types of feeds; this is particularly true for feeds representing the same electrical quantity (power or energy).

This makes it possible to graph related quantities simultaneously, such as the energy self-consumed immediately, the energy self-consumed by the battery and the energy withdrawn from the grid. This generates a high-impact graph that clearly and immediately shows which part of electricity consumption is met by the photovoltaic system rather than energy bought from the grid.

The second button “Choose the chart type” allows you to choose the type of graph to be generated. These are available:

- *continuous line graphs*, i.e. real-time graphs that will show the values of the last hour or shorter time intervals. Since the data sampling rate is one per minute, the last hour's graph will contain 60 points, which is considered reasonable for a graph that can be read on a smartphone display. For continuous line graphs, it is possible to use multiple selection in order to easily represent the trend of related quantities (e.g. an outdoor and an indoor temperature).

- *single and multiple bar charts*, which makes it possible to represent energy values in given time intervals, e.g. the daily consumption of a week or a month. Multiple bar charts show selected quantities side by side and are therefore very useful to get an immediate idea of the mutual proportions of the values involved.

- *stacked bar charts*, i.e. with several quantities stacked on top of each other, for example to show how the building's consumption is covered by the contributions of instantaneous self-consumption (photovoltaic), deferred self-consumption (from battery) and energy drawn from the grid.

- *Pie charts* are used when one wants to show in what proportion the components of a whole are (e.g. the energy consumed, which is obtained by the contribution of the three components direct self-consumption, self-consumption from the battery and withdrawal from the grid).

The third button “Choose the time interval” allows the user to choose the time interval over which the data are to be graphed. As far as this aspect is concerned, the limited space available on the smartphone display must be taken into account; in any case, it will be possible to execute historical queries relating to:

- hourly and/or daily trends of slowly changing quantities such as temperature and humidity (continuous line graph)

- hourly trends of electrical power (continuous line graph)

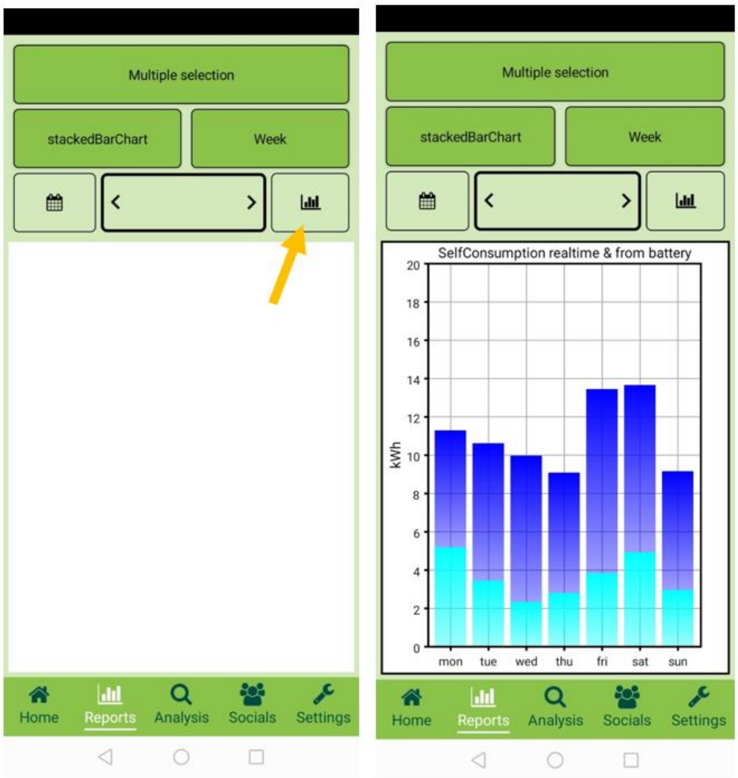
- hourly consumption over a day (24-bar histogram)

- daily consumption over a week (7-bar histogram)

- daily consumption over a month (30/31 bar histogram)

- monthly consumption in a year (12-bar histogram)

The start date of historical reports can obviously not be earlier than the date of commissioning of the system (automatically read in the settings section).



2.3 SECTION Analysis: algorithms and performance index

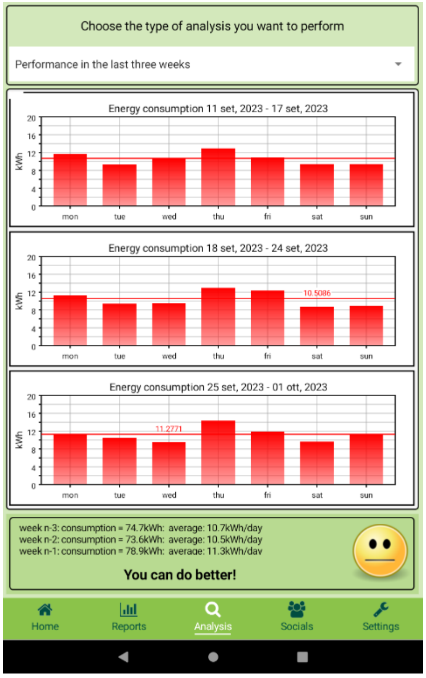
Pressing the third button in your navigation bar you reach the Analysis section. At the top of the screen you will read “Choose the type of analysis you want to perform”. By clicking under there you will see the list of the available options.

The App provide users with some tools that allow a meaningful analysis of the data. This will show if you are using your energy in a good way. In this way, you will be gradually educated towards an increasingly virtuous use of your energy.

A first simple algorithm that can be used is to *analyse consumption over the last period*.

Algorithm 1: Analysis of consumption over the last n weeks

This simple algorithm requires a query on the consumption of the last n weeks and aims to display the trend of energy use. The chosen time interval is reduced to n = 2 or 3 weeks in order to avoid the detected consumption variations being attributable to natural phenomena such as seasonal changes. In this way, the comparison made on the same days of the week can highlight the effects of conscious behaviour by the user.



The user is informed about the outcome of the analysis in a graphically friendly form (through the use of special smiles). A smiley face means that you are doing well, i.e. that you are improving your performance over time. This means that you are saving energy... and therefore money!

On the contrary...a gloomy face indicates that you don't care enough about your consumption, and you are losing money.

Algorithm 2: consumography

This algorithm starts with a graphical representation of the seven days of the week divided into 24 hours; it then constitutes a grid of 7 x 24 cells, which are coloured with a hue of intensity proportional to the amount of energy consumed in that hour.

The final visual effect is particularly interesting as it immediately shows which are the periods of highest consumption during the day with the immediate possibility of visual comparisons with the same times of the previous or following days.

In addition to the visual aspect, which can immediately highlight consumption anomalies, the algorithm carries out an analysis of consumption for several days at the same times, calculating the average and the mean square deviation, again with the aim of detecting anomalous situations with regard to electricity consumption.

It is possible to set thresholds, above which warnings or alerts are generated, which can be notified to the user in sound or graphic form on the home screen.

Indexes generated by the algorithms

Each consumption survey method must have its own evaluation criteria that allow a 'grade' to be given to each analysis carried out, quantifying the level of goodness of the performance analysed. This 'grade' is represented by *indexes* that are unambiguously defined and are derived from a mathematical formula that acts on the consumption data.

Performance *indexes* are automatically calculated by the App every week. Initially they are not visible to the user but become visible as the App gains experience and is able to get an idea of the level of user behaviour.

The indices will appear on the home page by clicking simultaneously on the two gauges of power and energy. On this page you will also see the global index, which takes into account all the other indices; this is the index that, if you give your consent, will be shared on the social platform accessible from the Socials button in the menu.

Non-normalised indices

Index I_0

A first simple class of indices is that which measures the user's energy performance in order to compare it with previous ones relating to the user. For example, using Algorithm 1, the C_0 consumption of the week just passed can be compared with the C_{-1} consumption of the previous week or with the average C_m of the consumption of the two, three previous weeks.

If the index $I_0 = C_0 / C_{-1}$ is less than 1 this is a sign of a decrease in consumption. This index does not need to be normalised as it always refers to the same building-plant group, but only has meaning for the user carrying out the test.

Indexes I_{cons}

Consumography is a form of hourly consumption analysis that identifies periods of energy overload. Knowing the power available (data provided in the settings section), a threshold limit is established beyond which hourly consumption is considered too high. Having established, for example, a threshold limit L_0 = 75 per cent, the consumption algorithm calculates how many times this threshold is exceeded during the week, and by how much.

At this point, the following 3 indices can be calculated:

I_{Acons}: indicates how many times the threshold is exceeded during the week; obviously, the closer the index is to zero, the better the situation. This index is highly dependent on the value set for the threshold L_0, and only has meaning in the context in which it is calculated.

I_{Bcons}: gives the ratio between the average value of hourly consumption exceeding the threshold value and the threshold value itself. This ratio must tend to 1.

I_{Ccons}: gives the standard deviation of the hourly consumption exceeding the threshold value, compared to their average value.

Example: Let threshold L_0 = 7 kWh be set, which is exceeded 5 times with the following consumption: c1=7.2 c2=7.4 c3=7.3 c4=7.2 c5=7.5

I_{Acons}= 5

I_{Bcons}= ((7.2+7.4+7.3+7.2+7.5)/5)/L_0 = 7.32 / 7 = 1.05

I_{Ccons}= 0.117

The comparison of these indices with those of previous weeks gives the user an idea of the dynamic trend of his consumption. The algorithm will give a visual representation of the result using the usual mechanism of smiley icons.

Normalised indices

In order to develop the 'social' part of the APP, the possibility of comparing the results of individual users with a view to drawing up a kind of ranking list should be envisaged.

To do this, it is necessary to have indices that are independent of the building or installation; that is, these indices must be normalised. If we take the volume V of the building expressed in m^3 as a normalisation parameter, we will have that the index I_0, which represented the weekly consumption of the entire building, becomes the index $I_{0N} = I_0 / V$ and is expressed in kWh/m^3.

Now the parameter refers to the cubic metre, which is an equal quantity for everyone, so the index becomes comparable to others.

Of course, the argument is not so simple as one has to take into account the different structural types of buildings and the climate to which they are exposed. A good parameter for normalisation can be the building's heat demand, which includes in its value all issues related to dispersing structures and the external climate. If the heat requirement refers to the surface area of the building, it will be in $kWh_{thermal}$/sqm and the resulting IN index will be, calling Eel the electricity consumption and Ep the heat requirement per square metre:

$$\mathbf{I_N = E_{el} / E_p}$$

which indicates how much electrical energy had to be consumed to meet the building's heating requirements per square metre. Decreasing values of this index indicate an improvement in energy performance, and the normalisation parameter also makes it possible to compare indices for different buildings and geographical areas.

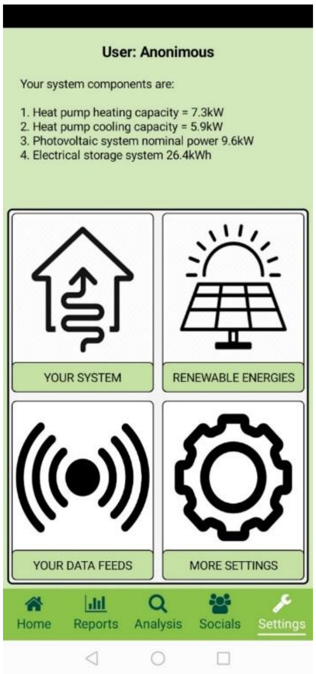
2.4 SECTION 4: Link to social platforms

It is planned to create a private group on the Facebook platform associated with the G4C_Monitor App in order to enable the sharing of the performance of individual users. This section will only be activated when a sufficient number of installations are available whose users have decided to use the G4C_Monitor app.

Interested users will have the opportunity to join the group and submit their normalised performance index packet with a simple click. This information will be used to create a ranking of 'virtuous' users that will be made public on the app's Facebook group page.

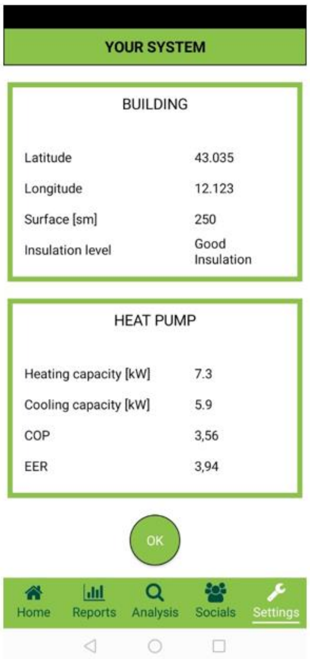
Come and fight with the other energy-saving virtuosos!

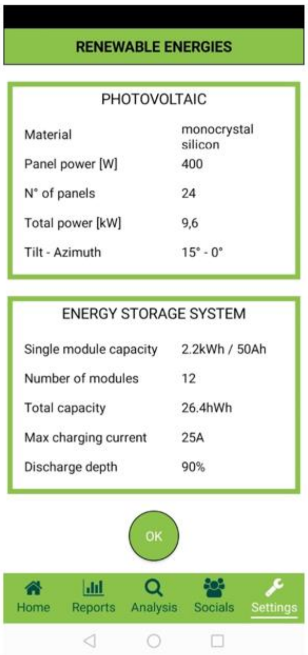
2.5 SECTION 5: Building-plant system configuration



The fifth section, which is dedicated to the settings of the *G4C_Monitor app*, contains information that is indispensable for the correct functioning of the previous sections. This section is largely generated when the App first connects to the general database.

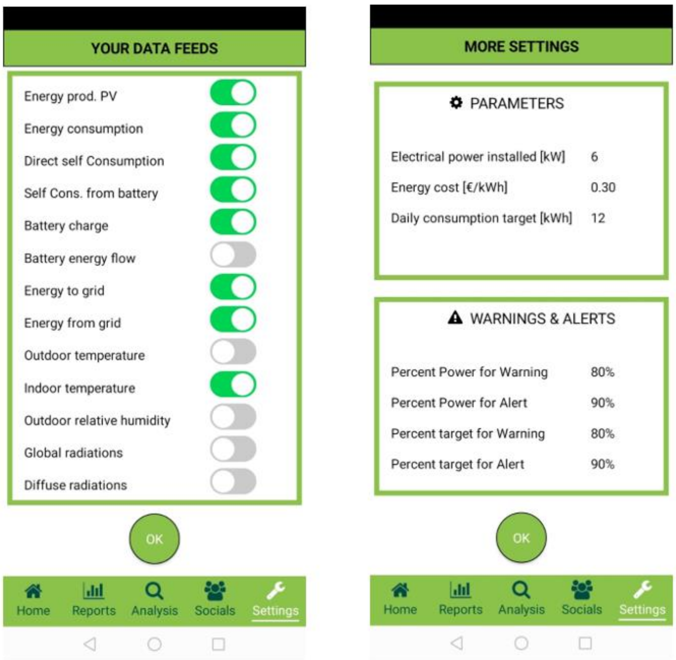
Your system is composed of the building and the installed geothermal system, plus any other installations (photovoltaic system, storage system, wind power system, etc.). All this information is made available to the app, which acquires it with a query made on the central database and stores it in the app's own internal database.





Along with general information on the status and location of the building/installation, the App makes a query to obtain a list of the physical quantities measured by the sensors installed at the user's location. User can deactivate the quantities he/she is not interested in using the switches next to them. In this way, the App will only work on the quantities that remain active. All this information is saved in the user's local device. At this point, the user must manually provide some further information.

You must enter a price for electricity, enter a daily consumption target (which will later be calculated by the App that will gain experience of the user's behaviour); enter Warning and Alert thresholds that will then be managed by the appropriate message.



3. Conclusions

The purpose of the G4C_Monitor App is to provide a friendly visual interface that helps users become aware of their energy consumption. This is done by using graphs that are easy to interpret and avoiding showing data in tabular form.

The App also informs the user about electricity use by highlighting critical situations through a series of notifications at various levels. Indeed, we believe that drawing the user's attention to certain abnormal situations can raise awareness.

The App gains experience as it analyses the user's consumption and refines threshold levels to guide the user more and more consistently toward virtuous energy use.

The App generates simple quality indices that describe user behaviour by giving it a grade: the user is informed of the result of the analysis in a friendly graphical form using emoticons.

We believe that this approach may be welcome and may help to encourage the use of the software, introducing a playful component that is always appreciated.

The user still has the option of analysing the results of the analysis numerically, turning any positive evaluation into a concrete saving of energy and thus money.

We also believe that the ability to share the evaluation of one's behaviour with other users, by entering a special ranking made public on social media, can be a stimulus for one's own improvement.