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Integrated web-based system

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Ulf Wingstedt	02	26.02.2013	Introduction and introduction to section 2

Vivian Esquivias		8.03.2013	Section 3 added
Valerio Lo Verso		15.03.2013	Section 2.1 added
Vivian Esquivias		21.03.2013	Final changes before internal review
Anna Osello		26.03.2013	Internal review
Giorgio Pasquettaz		29.03.2023	Internal review
Vivian Esquivias		3.04.2013	Final version

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1 Introduction

This document describes the software deliverable (Demonstrator) *D5.5. Integrated web-based system*. The web based system includes a set of reports and tools for analysis of energy consumption and environmental data collected from the SEEMPubS pilot installations. A critical analysis of such data will enable identification of energy waste and reveal the most important energy saving opportunities. It will also support validation of applied control strategies by comparison of test and reference rooms.

Analysis of collected data in SEEMPubS implies that a large quantity of data must be processed and presented to users in a comprehensible format adapted to the analysis tasks.

The new reports and tools described in this document have been implemented as a part of the Community Web Portal described in e.g. *D3.2 Updated Specification of Intelligent Context Energy Awareness Service Framework and User Comm. Portal* and *D3.3 First Version of Intelligent Context Energy Awareness Framework and User Community Portal*. Also, the selection of reports have been designed with input from *D2.3.2 Updated Conservation Strategies* and in particular *D5.1 Data Format Definition*.

Section 2 discusses how the data is collected and elaborated as well as how it can be visualized to work as tools to help make the system more energy efficient.

Section 3 discusses the web portal from a usage point of view, more details about how the web portal was implemented and how it works can be found in D4.6.3.

The web portal can be found at: http://energyportal.cnet.se/seempubs/Index.aspx
To sign in as an employee use email: emp@cnet.se, password: hemligt.
To sign is as the energy manager use email: test@cnet.se, password: hemligt.
You can also select any room within the system by clicking on the “Buildings” icon on the top menu.

2 Data Collection and Elaboration

The deployed control and monitoring architecture has been described in detail in other deliverables and is summarized in *D5.1 Data Format Definition* that also describes a four levelled model for a continuous monitoring system (See Figure 1)

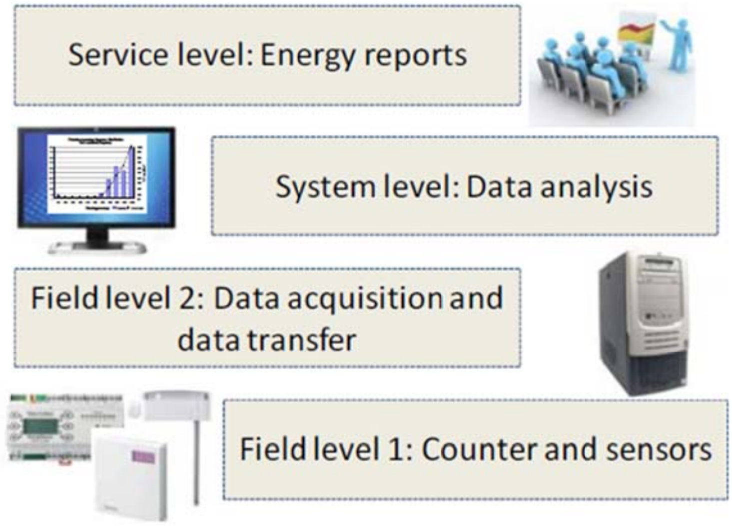


Figure 1: Four levels for on-going/continuous control and monitoring system [D5.1]

Data will be collected at the sensor level, transmitted by middleware and networks to the system level for analysis and elaboration. At the service level, appropriately designed reports and data selections are presented to ensure energy savings under acceptable comfort levels.

D5.1 suggests a set of data formats divided into four main categories, in summary:

1) Data related to comfort conditions including lighting conditions, indoor air temperature, temperature set point and indoor relative humidity.
2) Data related to thermal energy consumption based on supplied air temperature and fan coil velocity status
3) Data related to electric energy consumption for light and appliances
4) Data related to the use of spaces and building services originating from occupancy sensors and electrical switches.

Based on the data flows from deployed sensors, a number of online reports can be constructed to support user information requirements. Typical requirements are:

1) Historical data over configurable time ranges as well as current values (latest readings)
2) Trend indications
3) Possibility to get aggregated reports from room to floor level, from floor to building level
4) Various forms of comparisons, in particular
    a. Comparisons showing comfort level in relation to energy usage and savings, with possibility to include data from times when the space was occupied.
    b. Comparisons of test and reference rooms
    c. Normalized comparisons between rooms/floors /building of different sizes (e.g. consumption per m2/year)
5) Automatic identification of possible energy waste situations.

2.1 Data processing and format to visualize through the portal

Figure 2 summarizes the interaction between energy performance, environmental conditions and user actions which can be explored based on the monitored data.

Different categories of building users, namely the occupants, the facility and the energy manager, have a different interest in the energy or performance data characterizing the different spaces of the building: in short, the occupants are mainly interested in verifying the environmental conditions, in terms of thermal and visual comfort (typically in terms of temperature, relative humidity and illuminance level within a space), they experience during the working hours, while the facility manager is interested in verifying if and how the different HVAC and lighting system operate during both working and non-working hours. The energy manager is interested in all these aspects, aiming at verifying the global energy consumption for the building or for building zones (floors or single rooms) which is required to guarantee comfort conditions for occupants during the working hours, also quantifying at the same time the energy which is wasted, in order to identify possible energy efficiency measures.

The different viewpoints are described in more detail in the following sections.

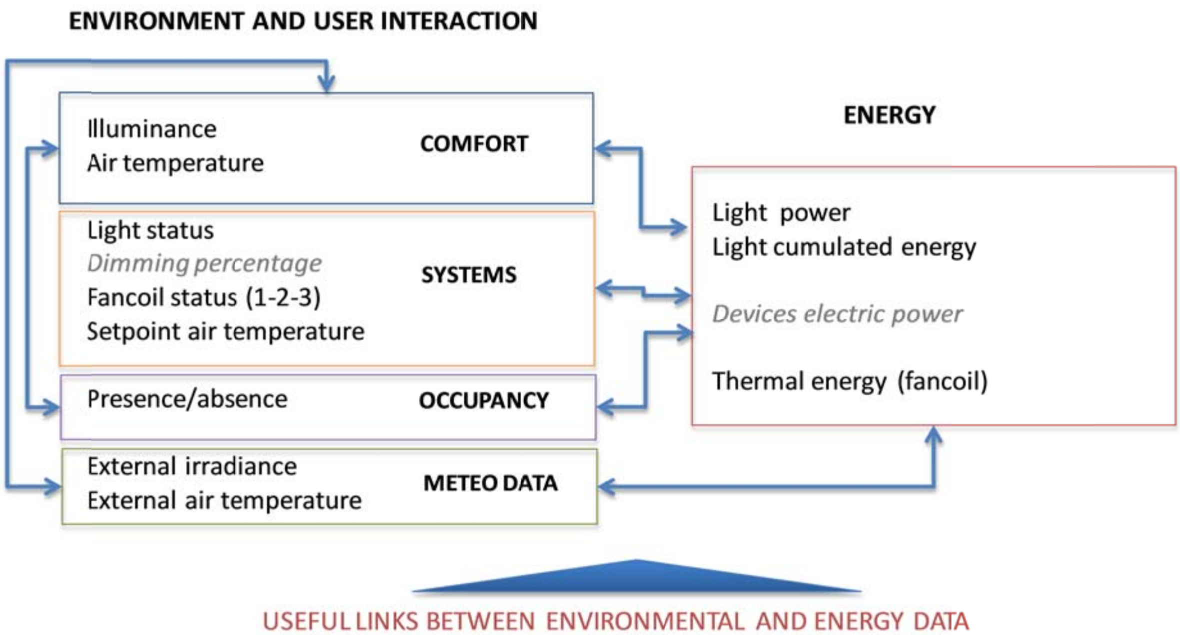


Figure 2: Interaction between energy performance, environmental conditions and user actions which can be explored based on the monitored data.

2.1.1 Information useful for the energy manager

As far as energy managers are concerned, the required information is related to different aspects of the building performance, in terms of how the energy is efficiently used in order to provide visual and thermal comfort when occupants are carrying out their activities or how the energy is wasted, both during working time and when rooms are unoccupied. In particular, the following aspects represent interesting data information:

- building energy consumptions
- building energy waste
- building energy performance versus environmental performance
- building environmental performance (comfort).

2.1.1.1 Building energy consumptions

The energy consumptions monitored in the SEEMPubS project are related to HVAC systems, lighting systems and other appliances. The electric energy consumptions (for lighting and appliances) are measured directly through a number of smartplugs and plugwises installed in various rooms, while the thermal energy consumption for HVAC systems (heating and cooling systems) is obtained indirectly, through analytical equations, starting from measurements of the supplied air temperature and the fan-coils air speed, with regard to both the heating and the cooling season.

In this regard, the following information to assess the building energy performance will be provided to energy managers:

- Energy consumed for lighting of for cooling/heating for each month during a year and for the whole year.

  Data presented to energy manager will be both absolute energy consumption values (expressed in KWh or MWh) and energy performance indexes.
  The **LENI** (Lighting Energy Numerical Indicator), expressed in [kWh/(m^2 month)] or in [kWh/(m^2 year)] and the **energy performance indices for cooling $EP_{cooling}$ and for heating $EP_{heating}$**, expressed in [kWh/(m^2 month)] or in [kWh/(m^2 year)], respectively, will be used as energy performance indicator of a single room or of the whole building.
  The knowledge of LENI, $EP_{cooling}$ and $EP_{heating}$ values allows the energy manager comparing the energy performance to:

  - benchmark values (for the energy consumption for lighting, for instance, could be taken from the standard EN 15193, in terms of maximum LENI values for a given building usage)
  - performance classes (available for $EP_{cooling}$ and $EP_{heating}$)
  - performances of other buildings or other rooms of the same building.

  The comparison can be done for performance relative to entire years (comparing one year to another) or within the same day, month by month (comparing the energy consumption of different months or for the same month in different year). This way, the energy manager has an aggregate or disaggregates view of what the energy consumption for the building is during the course of a year or year after year

- Energy consumed for lighting or for heating/cooling during working days, non-working days or during night hours, with regard to single months or to the whole year.

  Disaggregated data, referred to working days, non-working days and night-time is a first step to provide the energy manager with more detailed information on the energy usage in buildings/rooms and on possible energy wastage.

Once more, data presented to energy manager will be both absolute energy consumption values (expressed in KWh or MWh) and energy performance indexes (expressed in [kWh/(m^2 month)] or in [kWh/(m^2 year)]).

Data concerning energy consumption will be also compared to meteorological data:

- Energy which is consumed daily for lighting or for cooling/heating related to the external conditions. For instance electric energy consumed for lighting can be related to external irradiance and thermal energy consumption can be related to external irradiance, air temperature and relative humidity.

  This information is useful for the energy manager to connect the energy usage to the boundary external conditions, which depend on the climate characteristics of the site as well as on the period of the year. For instance, a peak in the energy consumption for cooling could be due to an extremely hot and sunny day in summer (during which high irradiance and air temperature values are measured); or a peak in the energy consumption for lighting could be due to a cloudy day in winter (during which low irradiance values occur).

In table 1 some examples of graphs representing the previously described building energy performance information are presented (note that reference data were used to plot all the graphs, which are intended to be examples of the possible visualizations).

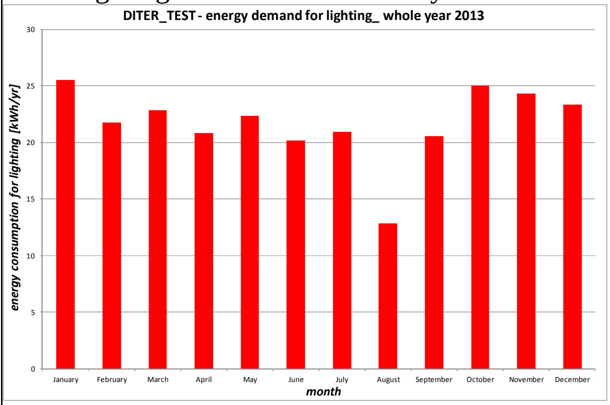
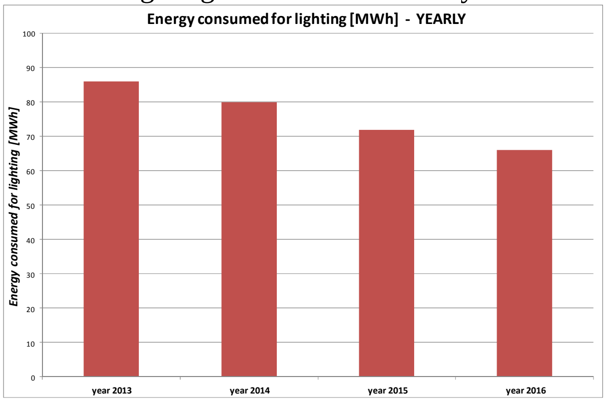
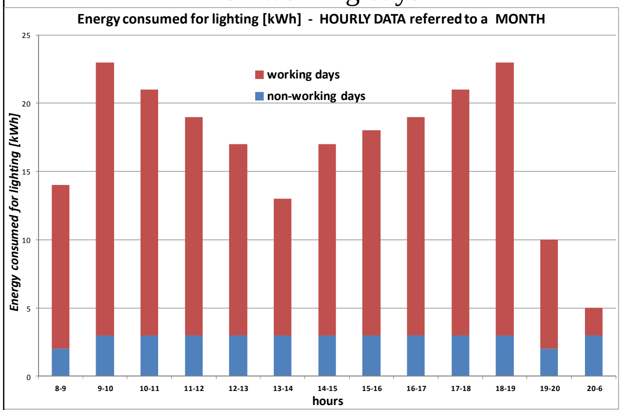
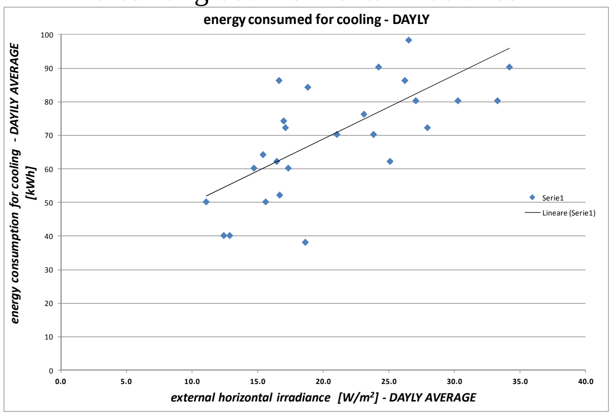
Example of graph showing the energy demand for lighting referred to the whole year 2013	Example of graph showing the energy demand for lighting referred to different years
	
Example of graph showing the monthly energy consumption for lighting, split into working and non-working days	Example of graph showing the energy consumption for cooling plotted versus the external global horizontal irradiance
	

Table 1: Examples of graphs visualizing information useful for energy managers to assess the building energy consumption.

2.1.1.2 Building energy waste

An issue to which the energy manager pay special attention is the improper use of the energy for lighting and for heating/cooling, which represents an energy waste: this condition may happen both for times during which a room is unoccupied (for instance, all electric lights should be switched off but some remain on; or heating/cooling systems keep operating when a room is unattended) and during the occupancy time, for instance for cases in which an illuminance value far over the minimum target level over the working plane is detected, which shows an oversized use of electric lights.

With regard to the energy waste concerned with lighting or with heating/cooling systems, the following information to assess the building energy performance will be provided to energy managers:

- Energy consumed for lighting or for heating/cooling during non-occupied hours (with respect to occupied hours).

  The information allows the energy manager quantifying the energy which is used during the occupancy hours, but especially the energy which is used (and wasted) during the periods of time in which the occupant are not present in their room (even during the working hours, because of a temporary absence). This is particularly useful for electric lighting consumption, in fact high values of energy consumption during unoccupied time could mean that the control systems are not working properly (in case occupancy sensors are installed in the rooms) or that energy saving measure could be applied to improve the building energy performance.

- Energy consumed for lighting during occupied hours when $E > E_{target}$ (for rooms equipped with photo-dimming sensors only), energy consumed for heating during occupied hours when $t > t_{setpoint,\ winter}$ and energy consumed for cooling during occupied hours when $t < t_{setpoint,\ summer}$.

  Through this kind of information, the energy manager has the chance to identify an improper use of energy to guarantee an environmental performance far greater or far lower a standard requirements, in terms of both an illuminance over the working plane ($E_{measured} > E_{target}$) and of an air temperature measured within the room over the required value during the heating season ($t_{measured} > t_{setpoint,\ winter}$) or below the required value during the cooling season ($t_{measured} > t_{setpoint,\ winter}$). This extra amount of used energy represents a waste in the case dedicated sensors are installed in the room to dim the light output in response to the daylight availability over the working plane or to switch off the heating/cooling systems when the setpoint is reached.

In table 2 some examples of graphs representing the previously described building energy wastages are presented (note that reference data were used to plot all the graphs, which are intended to be examples of the possible visualizations).

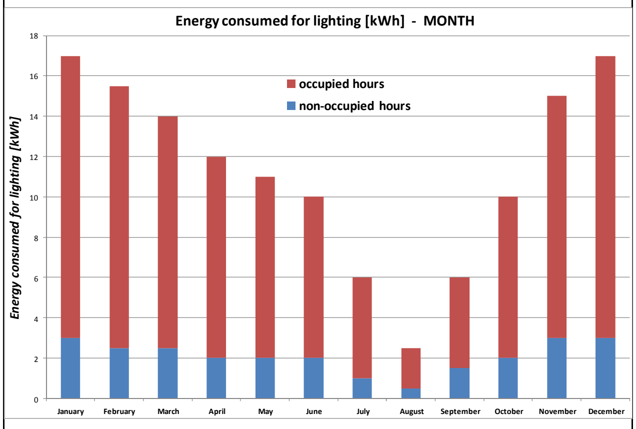
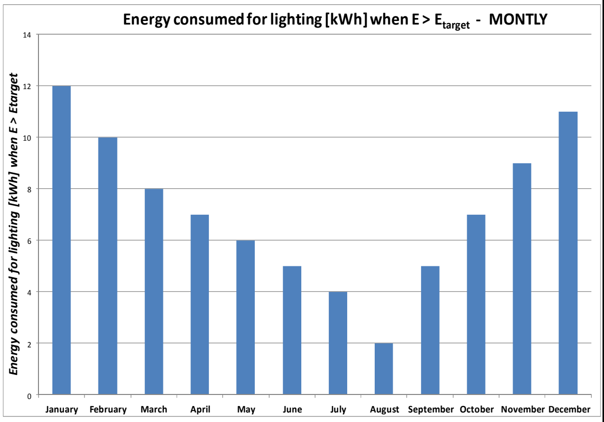
Example of graph showing the monthly energy consumption for lighting, split into occupied and non-occupied days	Example of graph showing the monthly energy consumption for lighting when the illuminance over the working plane is over the target illuminance
	

Table 2: Examples of graphs visualizing information useful for energy managers to assess the building energy wastage.

2.1.1.3 Building energy performance versus environmental performance

The energy manager is also interested in quantifying the energy which is used by the building systems (lighting and HVAC systems) to guarantee given comfort levels for the occupants, as prescribed by standards, in terms of both illuminance values over the working plane and air temperature values within the room. This is an amount of energy which is 'necessary', as the comfort for the occupants is one of the primary goals, but which can be optimised through appropriate control strategies and systems (such as the use of photo-dimming sensors).

Appropriate performance indices, which correlate energy consumption to environmental condition will be provided, in particular to compare the performance of different control systems or control strategies (for instance Test and Ref room in this project).

2.1.1.4 Building environmental performance (comfort)

The energy manager is interested in visualizing the environmental comfort through analysis graph of the variation of air temperature and illuminance values during the course of the year. In particular, the following information will be provided:

- Verification if comfort conditions are met (in terms of air temperature values or illuminance values over the working plane).

  The comfort conditions will be assessed by visualizing how frequently air temperature or illuminance values lie within acceptability ranges, defined by the energy manager. Figure 3 shows an example of such a plot, referred to an analysis of the frequency of temperature values in the range 21°-23°C as defined as comfort range for class A in winter, according to the standard ISO 7730.

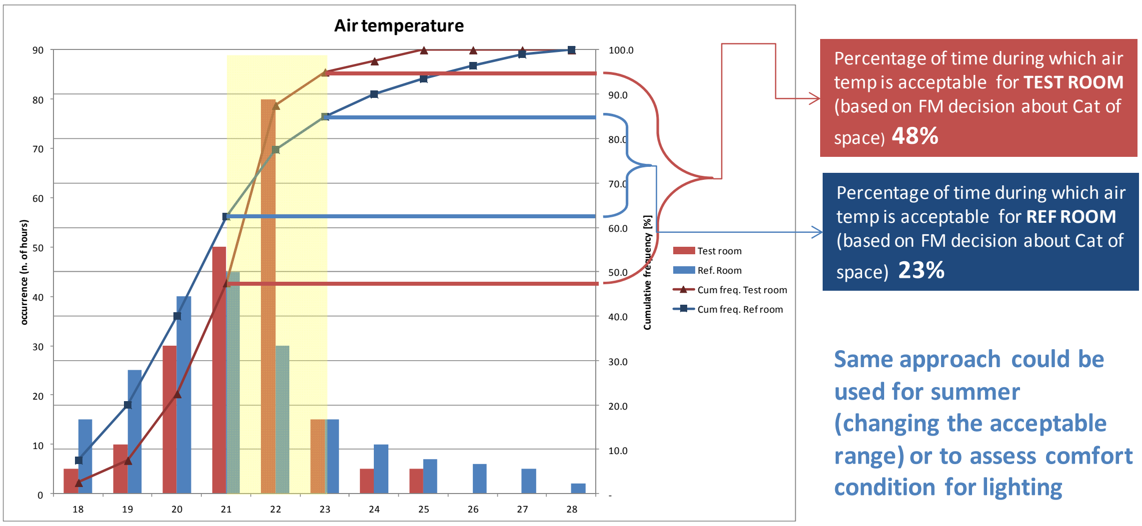


Figure 3: Example of graph showing the frequency of temperature values lying in the range 21°-23°C for the winter period (corresponding to the comfort class A according to the standard ISO 7730)

The graph plots the number of air temperature values occurring within the interval 18-28°C for a test room and its corresponding reference room, as well as the corresponding cumulative frequency curves. The comfort range selected by the energy manager (21-23°C in the example) is also displayed and allows calculating on the graph directly the percentage of occupied time during which the air temperature is acceptable (that is in the range 21-23°C). Plotting two series of data for two different rooms allows a quick and direct comparison of how frequently the comfort conditions are observed within the two spaces.

In the graph (shown as an example) the temperature occurrence is shown but similarly the occurrence of illuminance values could be plotted and analysed in terms of an acceptability (for instance, the range 300-2500 lux).

- Dynamic variation of temperature or illuminance values throughout the year (days and months).

  With reference to the lighting sector, for instance, a carpet diagram could be plotted, in which each pixel represent the illuminance value for a specific moment of the year (month, day and time). Three areas are highlighted with different colours in the diagram:

  - area with values below the target illuminance (Blue area)
  - area with values around the target illuminance (Yellow area)
  - area with values over the target illuminance (Red area)

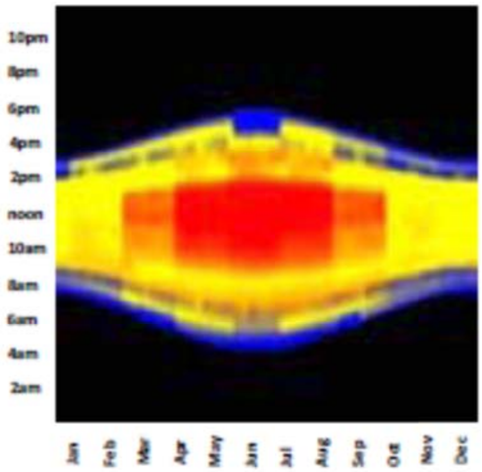


Figure 4: Example of graph showing the variation of illuminance values over the working plane throughout the year

This kind of representation will be possible not only with regard to the whole year, but for any user-defined day or week or month.

A similar graph could be plotted with regard to the variation of temperature values.

2.1.2 Information useful for the facility manager

From the facility manager's viewpoint, the interest is concerned with supervising if and how the building systems operate. In this regard, the trend of each monitored data (environmental and energy data) should be available in the web portal (see also data format suggested in D5.1). Furthermore, different monitored data could be plotted together to make easer the interpretation of the systems performance (e.g. environmental condition versus occupancy, energy consumption versus occupancy, etc.).

3 Web portal & mobile web app

The work around the web portal has been well documented from concept and requirement gathering in D3.1 to the initial prototypes in D3.2 and D3.3 to the final results in D3.4 and D4.6.3. Just to summarize, the web portal was created with the goal of engaging people within the Politecnico di Torino campus to be more conscious about the energy consumption in their working/studying place. Three groups of users where identified: the students, the employees and the energy manager. For each group there is a special profile in the web portal, the students are allowed to access information about public rooms without any type of identification. The employees can access all public rooms and also their personal office, for the latter the user is required to sign in. The energy manager has access to every room as well as his/her own page (sign in is required) with a set of tools used to find energy waste situations.

This section focuses on how the different tools within the web portal can be used by the different users and how it raises energy awareness or even leads to actions that help save energy consumption.

3.1 Energy awareness tools

Showing the user real-time data (cf. Figure 5: Current energy consumption, temperature, lightning and occupancy status) as well as trends can make the user stop and think for a second about what is going on right now, these are real values, the room is actually consuming e.g. 40 kW this very moment, this is the first step of making the user aware. If the user already is aware and prepared to change her behaviour towards a more energy efficient direction, this tool can be used to check how she is doing at the moment e.g. is she using more energy than usual right now and how come this is happening.

Current temperature values is always interesting users and even if the information itself not always leads to saving energy it is a way of triggering the user to use the system and discover other tools. Occupancy information is also interesting, especially for public rooms and this information combined with temperature, lightning and current energy consumption can actually lead to energy savings. This is exactly what has been tested in the project using control strategies, where the system combines information from different sources and takes action. For instance, if the room is vacant and the lighting level signals that the lights in the room are on. Switching the lights can save energy.

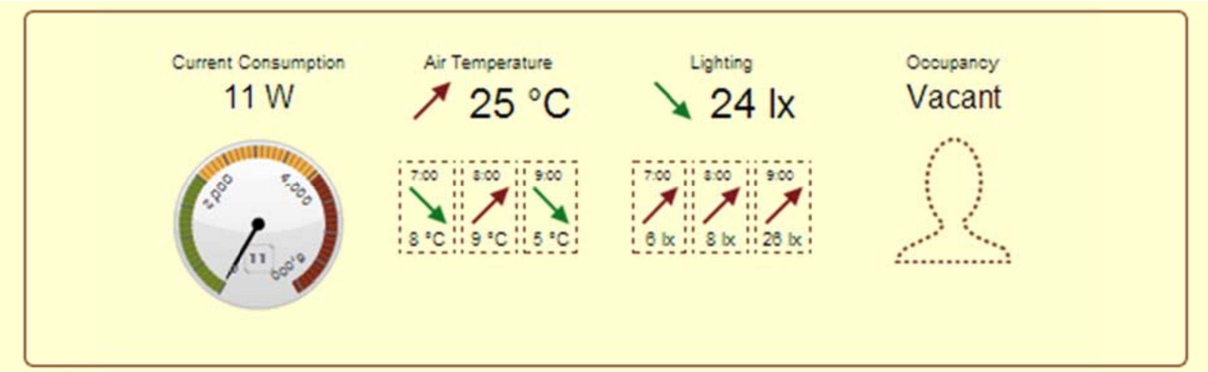


Figure 5: Current energy consumption, temperature, lightning and occupancy status

Another way to keep the user interested and engaged with the system is to add a little competition or simply allowing the users to compare themselves to others. This is done in the web portal by comparing indoor temperature between rooms within the same building (cf. Figure 6: Room comparisons, top). This also indicates the energy consumption in the room. For instance, if my temperature is much lower than average a summer day, means that the cooling system is using more power to keep the room cooler.

Other types of comparison is shown in Figure 7, where energy consumption is compared between devices and also daily, monthly and yearly in combination with occupancy.

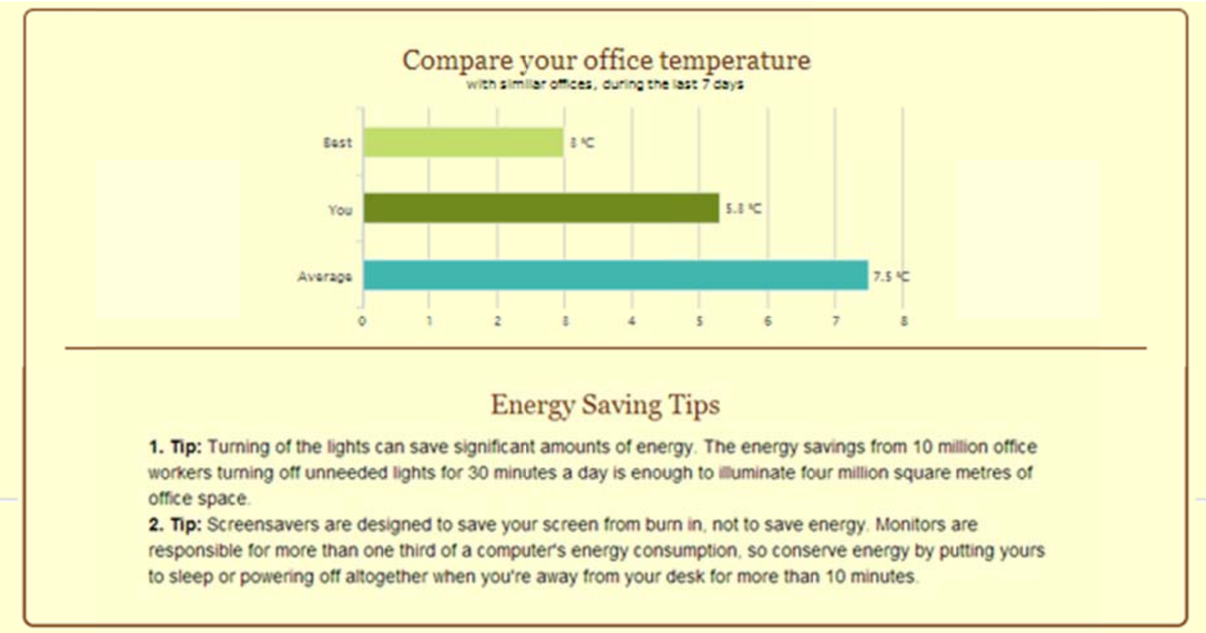


Figure 6: Room comparisons and tips

Also, a simple by perhaps very effective way to incentive the user to save energy is by providing her/him with useful tips on what she/he can do. Both general and specific, this function can be found in the web portal where the specific tips are created by the user (cf. Figure 6: Room comparisons and tips bottom).

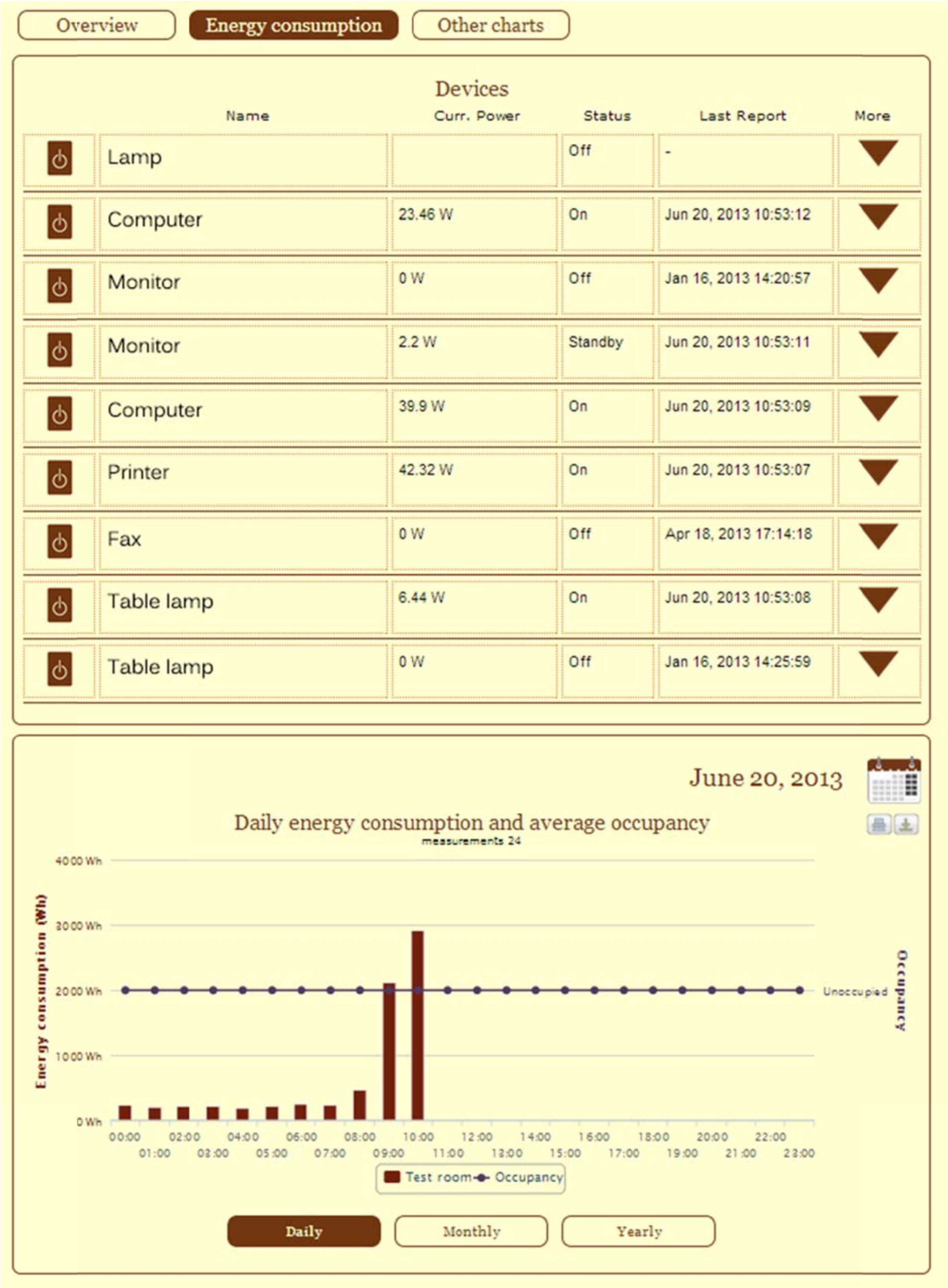
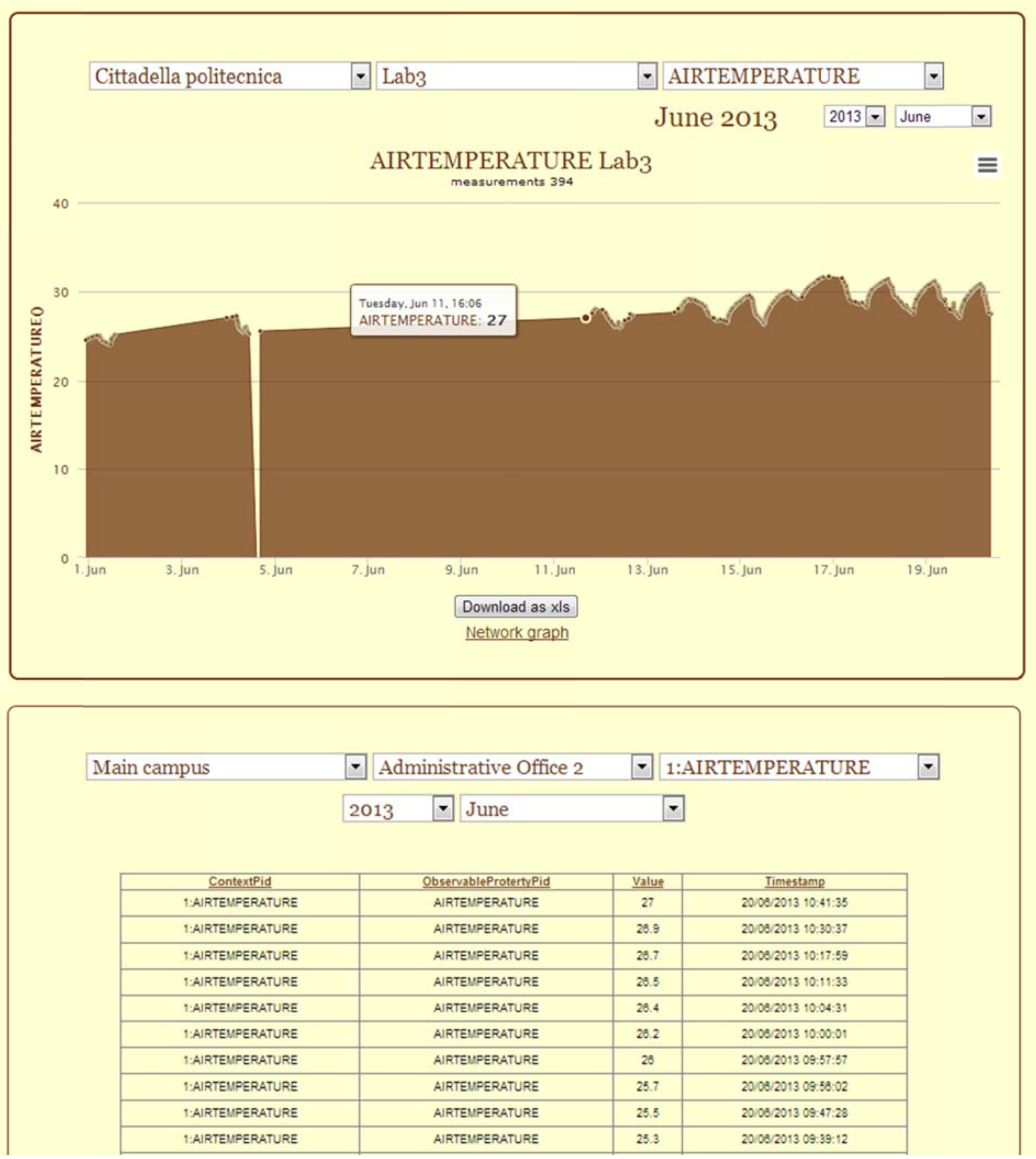


Figure 7: Historic energy consumption

3.2 Energy manager tools

The first tools shown in Figure 8 shows data in at very detailed level, both chart and table includes every measurement that has been reported from a specific sensor (selectable). This can be used by the user to detect inconsistencies or make calculations to detect energy leakage. More about how these functions are used could be found in D4.6.3.



ContextPid	ObservableProtertyPid	Value	Timestamp
1:AIRTEMPERATURE	AIRTEMPERATURE	27	20/06/2013 10:41:35
1:AIRTEMPERATURE	AIRTEMPERATURE	26.9	20/06/2013 10:30:37
1:AIRTEMPERATURE	AIRTEMPERATURE	26.7	20/06/2013 10:17:59
1:AIRTEMPERATURE	AIRTEMPERATURE	26.5	20/06/2013 10:11:33
1:AIRTEMPERATURE	AIRTEMPERATURE	26.4	20/06/2013 10:04:31
1:AIRTEMPERATURE	AIRTEMPERATURE	26.2	20/06/2013 10:00:01
1:AIRTEMPERATURE	AIRTEMPERATURE	26	20/06/2013 09:57:57
1:AIRTEMPERATURE	AIRTEMPERATURE	25.7	20/06/2013 09:56:02
1:AIRTEMPERATURE	AIRTEMPERATURE	25.5	20/06/2013 09:47:28
1:AIRTEMPERATURE	AIRTEMPERATURE	25.3	20/06/2013 09:39:12

Figure 8: Detailed data visualization

The following charts might seem familiar since they were previously discussed in section 2.1.1.4; this tool will be describe in more details in D4.6.3, section 5.1.5. The first chart is based in temperature and the second chart is based on lighting.

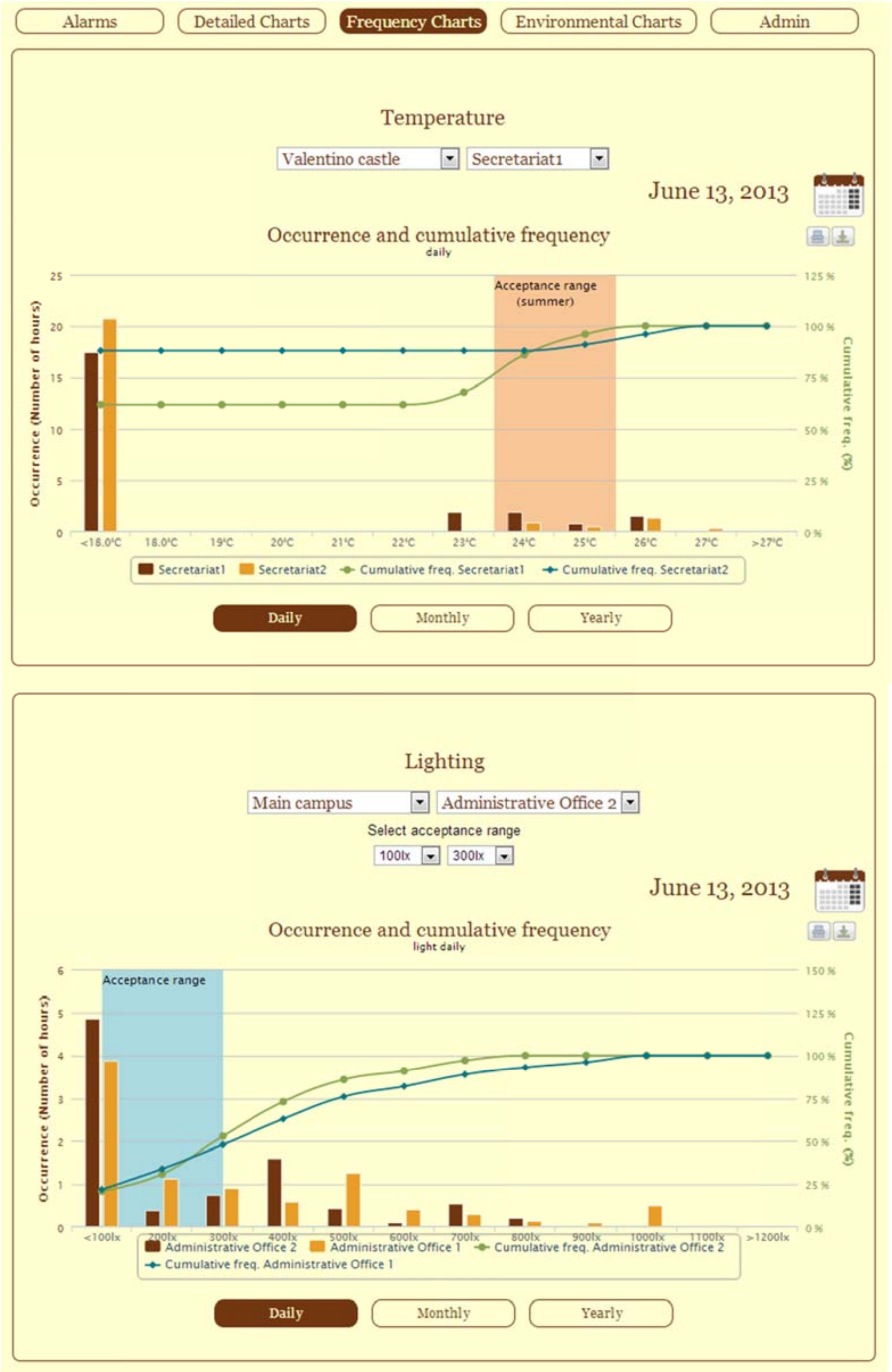


Figure 9: Frequency charts

The last tool, shown in Figure 10 allows the energy manager to compare temperature, lighting or energy consumption in a room as well as occupancy daily, monthly and yearly. In this way the manager can analyse these values at different periods of time and for different types of measurements.

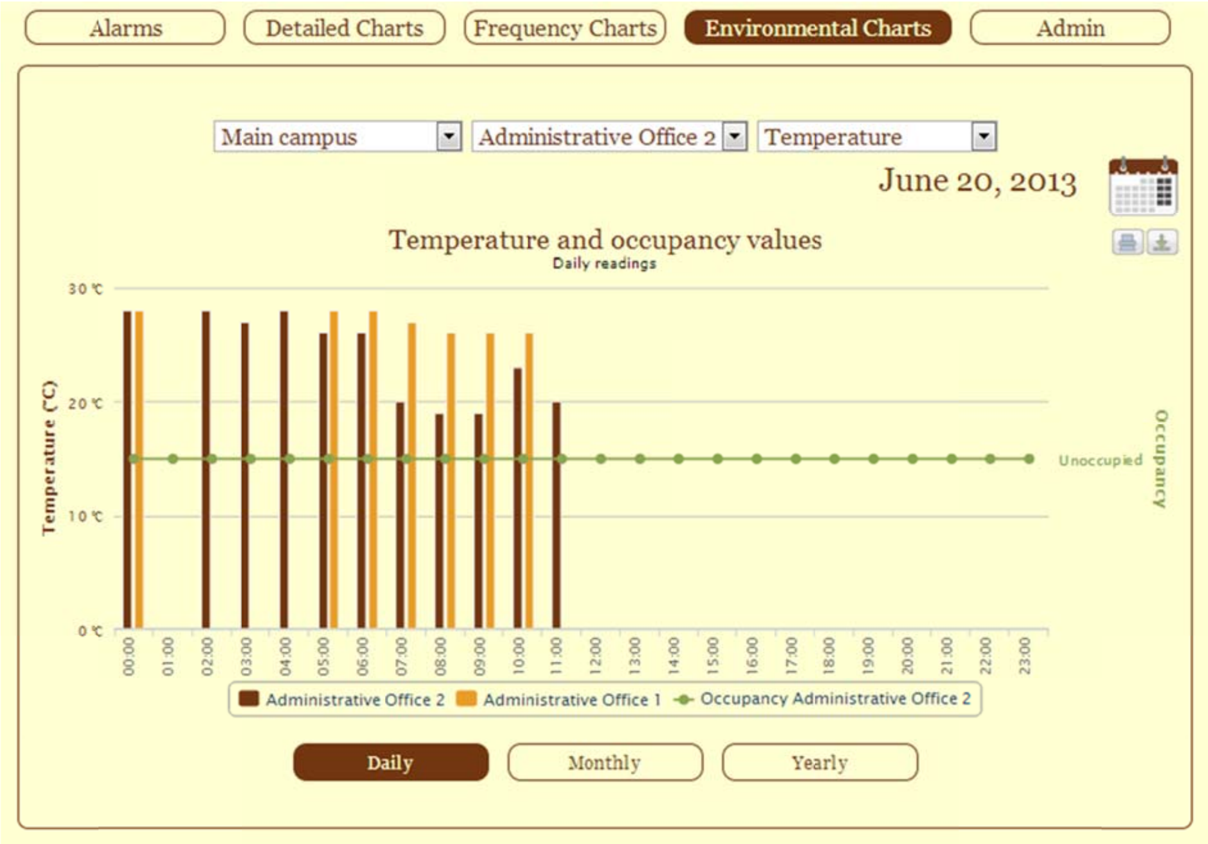


Figure 10: Environmental charts

3.3 Voting and check in mobile web app

As an extension of the web portal, a mobile web app was created (cf. Figure 11). For a more detailed description see D4.6.3. This app is meant to be used mainly by student but also employees as a tool to influence their own environmental situations and get more familiar with the system. This is how it works:

1. Scan QR code: For each room there is one or more polls concerning the temperature, air quality and lighting in the room. These polls can only be accessed by people in the room by scanning[1] the room specific QR code placed somewhere in the room.
2. Vote or Check in: Once the user has access to the web app she can select a poll, vote and leave a comment for others to see (this is optional), check in to the room or just see the results of the polls and read the comments.

[1] Using a QR reader usually downloaded as an app for smart phones

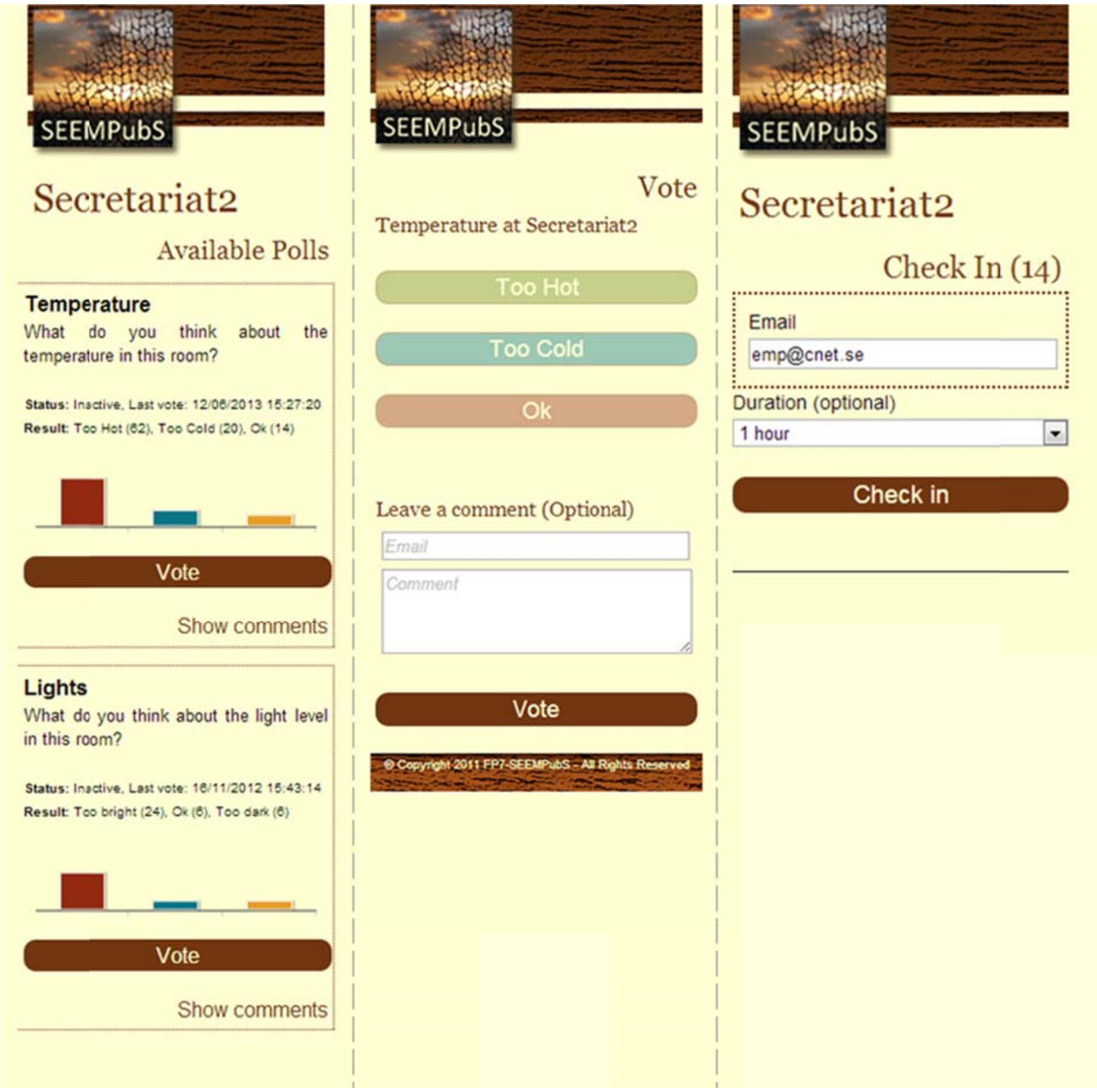


Figure 11: Voting & check in mobile web app

The voting results are also presented to the energy manager and used as a tool to determine the comfort level in the rooms. Every vote can be seen as a measurement made a “human sensor”, of course the votes are not as reliable as measurements coming from sensors since humans are more complex but the data can still be used in different ways. For instance, if many persons are voting that one specific room is very hot, than it might actually be a problem with the cooling system leading to unnecessarily high energy consumption. The comments made by the user might also be helpful for the energy manager.

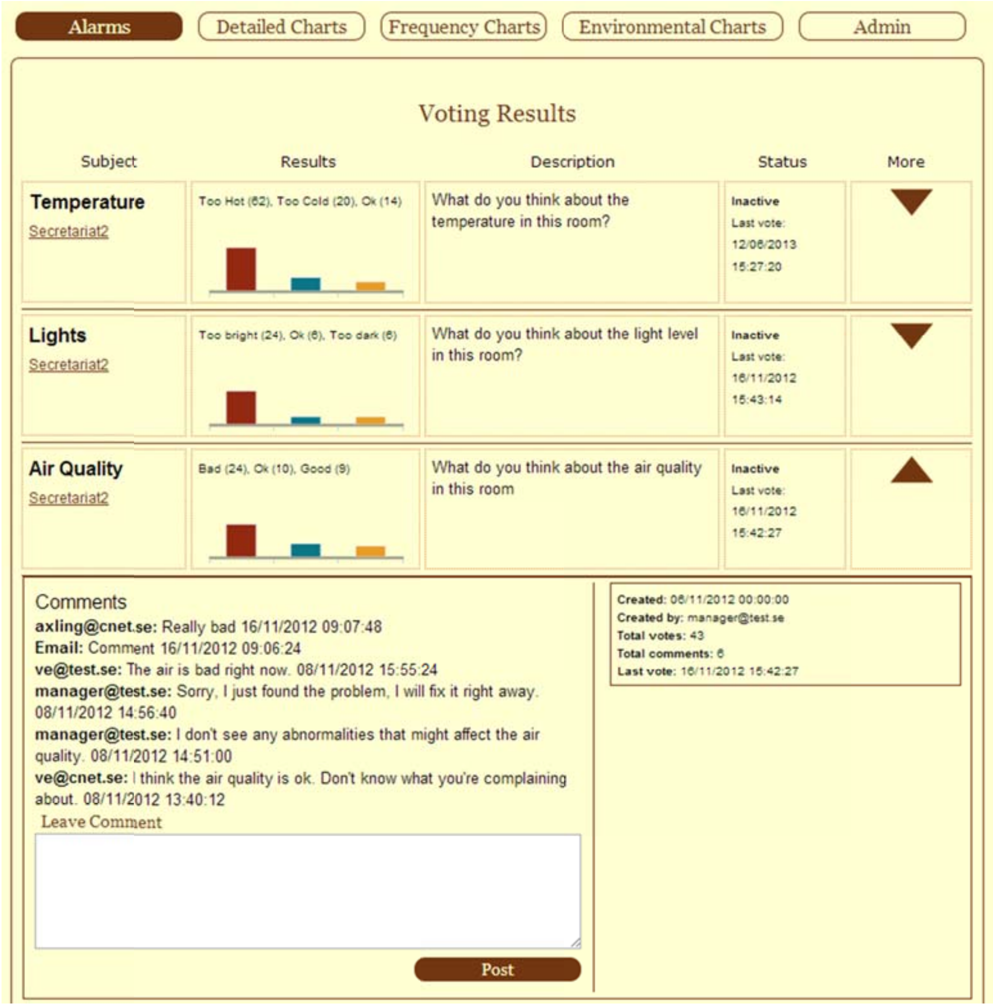


Figure 12: Voting results for energy manager

4 References

[D3.2] Updated Specification of Intelligent Context Energy Awareness Service Framework and User Comm. Portal, 2012

[D3.3] First Version of Intelligent Context Energy Awareness Framework and User Community Portal, 2012

[D2.3.2] Updated Conservation Strategies, 2012

[D5.1] Data Format Definition, 2012

[D3.4] Final Intelligent Context Energy Awareness Service Framework and User Community Portal, 2013

[D4.6.3] Final Prototype of the SEEMPubS platform, 2013