PLAYING TO CONSERVE ENERGY: THE ICT-ENABLED ECO-CHALLENGE IN OFFICES

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ABSTRACT

The ECOFFICES - Energy Challenge within Offices - experiment is an energy competition between employees taking place in a building located in the Sophia Antipolis business park. The concept combines advanced energy metering, energy awareness and benchmarking to create an incentive scheme for energy savings. The contest is raising a high stimulation level by rewarding eco-friendly energy behaviour.

The paper elaborates on the challenge methodology/protocol, and its technological infrastructure. It presents both technical (energy savings, installation, reliability, etc.), socio-economic and behavioural (user acceptance, etc.) approaches.

ECOFFICES is a 'PACA Labs' project and involves four partners (OSMOSE, CSTB, INRIA and CASA) in the Provence-Alpes-Côte d'Azur region. It has started on September 2010 and will end on September 2011.

Keywords: Energy awareness, Energy metering, Eco-behaviour

INTRODUCTION

In a world where economic, energetic and environmental challenges increase (energetic safety, reorganization of world's growth, climate change, etc.), governments decided to act to limit CO2 emission and energy consumption. On December 1997, more than 158 countries met in Kyoto, Japan, to negotiate binding limitations on greenhouse gases for the developed nations. The Kyoto's protocol was born and it shows the worldwide willingness to fight against climate change. The EU and its member states ratified this protocol in late May 2002. In addition, a communication [1] from the European Commission sets the "20-20-20 objectives" (20% reduction in emissions, 20% renewable energies and 20% improvement in energy efficiency by 2020) and a "Green paper" [2] about energy efficiency gives practical guidance to save 20% of energy from now to 2020.

In France, the Environment Round Table (*le Grenelle de l'Environnement*) is here to define the key points of government policy on ecological and sustainable development issues. What emerges from this consortium is the priority to reach an important decrease on energy consumption, on each domain and especially on buildings. The building sector, that includes residential sector and service sector, is responsible for around 25% of CO2 emission, and represents 35% of energy consumption in Europe [3]. Indeed, buildings consume a lot of energy especially for ambient and hot water heating. It is therefore necessary to reduce energy consumption particularly in the construction industry. To achieve this goal, the French government put in place some measures to encourage both households and firms to go on this way, such as the 2005 Thermal regulation and decrees for Building & Dwelling Code [4].

Nowadays, users do not exactly know what they consume. A survey [5], made by the Oxford's University Environmental Change Institute, highlighted the importance of getting feedback on building's energy consumption. Smart meters are advanced energy meters that record electricity, water or gas usage in real time and that communicate the information to the utility. Dedicated user interfaces can be associated to these meters, so as to propose a service to the end-users (the occupant) to influence their behavior: this is the 'energy awareness' concept.

Another approach to make people aware of the importance of saving energy is to create a 'competition' framework. Several energy efficiency challenges were initiated in Europe. For example, the "Energy Trophy" [6] was a competition for saving energy in office buildings by change of behavior, between several companies in Europe. There was no implementation of ICT technology for this contest: electricity, gas and fuel oil consumptions were recorded manually by reading the energy meters. Another example is the "Challenge Energie" [7] organized by the city of Bruxelles in February 2009. It was a challenge between tenants to encourage them using gas, electricity and water more efficiently.

Relying on those approaches of 'energy awareness' and 'competition', the ECOFFICES project proposes a new challenge for saving energy in office buildings in the form of a game. The aim of this game is to get teams of employees from the same company to challenge each other, in order to encourage them to better use devices and energy systems in their workplace. Indeed, employees control about 70% of the office's energy consumption, so it is important to make them aware of eco-friendly energy behaviours and attitudes to embrace rational use of energy. This challenge is different from the others since it makes a comprehensive use of ICTs (Information and Communication Technologies) and includes an advanced usage analysis on the acquisition of eco-friendly behaviours generated by the challenge.

1. METHODOLOGY

The service sector is usually the most energy-consuming sector because of its needs but also because of the low-level of energy efficiency of its buildings. Moreover, as the employees do not pay for the company's bill, they pay less attention on their behaviours toward energy. Hence, to address this issue, the ECOFFICES challenge proposes a competition between employees in their workplace through the energy awareness concept. The challenge consists in monitoring in real time energy consumption of the building, and at the same time informing the user about the consequences of his actions. This is possible thanks to a wireless network of sensors, allowing feedback on energy consumption. With this feedback, employees will be able to track their own consumption and to modify their daily behaviours to act more efficiently.

The goal of the game is twofold: to win the challenge, each team not only has to reduce its energy consumption, but also must minimize its energy-consuming behaviours. To reach these objectives, the teams are classified according to two criteria: the percentage of savings achieved at the end of the challenge, and the number of "bonus-malus" obtained (Table 1).

To evaluate how much energy saving is performed during the challenge, consumptions will be metered and compared to previous consumptions used as the baseline reference. The difference will enable to see whether the consumptions are decreasing or increasing, and to calculate the percentage of energy savings achieved.

As it is tricky to measure the impact of the employees' behaviours on the building's energy consumption, it was important to get another notation system. Good practices allowing saving energy will give bonuses, while bad practices that increase consumption will give malus, that is to say negative marks. Thereafter, the challengers have the possibility to see on their interface what behaviours they had, and which among them caused bonus or malus. This aspect is important because it helps people to understand their current energy practices, and it gives practical guidance to improve them. A list of bonus and malus has been established for the project. Most of them are easy to "measure" with the information from the sensors. During the challenge, the number of bonus and malus for each team is defined proportionally to the number of employees in the building.

Malus	Heating switched on and windows open
	Air conditioner switched on and windows open
	Heating on and air conditioning on at the same time
	Having office equipment (light, computer, etc.) switched on during non-office hours
	Having the light switched on whereas the natural daylight is sufficient
	Having the office temperature higher than 19°C and heating switched on (Building & Dwelling Code's references) [8]
	Having the office temperature lower than 26°C and air conditioner on (Building & Dwelling Code's references) [9]

Bonus	Heating switched off when windows are open
	Air conditioner switched off when windows are open
	Light switched off when leaving the office
	Computer screen in stand-by mode when leaving the office for more than 15 minutes
	Computer switched off when leaving the office for more than 1 hour

Table 1: Sample of bonus-malus actions

The concept of this challenge is built on a win-win situation for the company and its employees: the winning team gets a prize for their effort and good behaviours towards energy savings, and the company benefits directly from the savings achieved. This project aims to change people's habits to make them actors of energy efficiency, whether at work or, on the long run, at home.

2. PROTOCOL

The experimental protocol of the ECOFFICES project is divided into 4 parts: the first part is related to technical aspects and the three others aim to compare behaviours before, during and after the challenge.

- **Phase 0: Completion of the prototype and instrumentation**

This phase consists in acquiring the materials needed for the bench test, installing it in the different offices, finishing the implementation of the technical framework and making tests for its validation. In the technical framework, most important tasks were to finalize the user awareness interfaces (and identifying the relevant indicators to display for the challengers) and the algorithms for behaviours recognition.

- **Phase 1: Bench test without challenge (frame of reference and interface impact)**

During this stage, a frame of consumption and behaviours references will be established for 6 weeks on each office equipped with sensors. This phase is divided in 2 periods of 3 weeks each:

- First, the participants act normally without receiving feedback. They do not know how much they consume or if their behaviours are eco-friendly or not.
- Then, the user awareness interfaces activated, and the participants receive feedback on their consumption and behaviours.

It is therefore possible to check whether the user interface is efficient or not, and if the participants are interested in using it without specific incentive (no challenge).

- **Phase 2: Bench test with challenge**

One company; 3 teams of 16-17 employees spread on 3 wings of the building; each office is equipped with a network of sensors; every participant has access to the user interface; they are aware of the rules of the game: the challenge can start, and will last 4 months.

This stage has three main objectives:

- To measure the savings realized by a collective action on energy consumption;
- To increase participants awareness of energy savings by making them realize the impact of their daily efforts;
- To improve their sustainable use of office equipments.

At the end of this phase, the winning team will be announced. The reward is a team building activity: half a day sailing on the Mediterranean Sea together with a lunch at the restaurant.

- **Phase 3: Bench test without challenge (appropriation of good practices)**

The last 2 months will be used to notice if the behaviours' changes due to the challenge remain or not. Data are still recorded and the user interface is still available for each participant, even if the information regarding team ranking or comparisons has been removed.

Through this stage, it will be possible to analyze the continuity of the project, and its long-term impact. Thus some questions, such as "Have people adopted long-lasting energy-efficient manners? Do they go back to their previous behaviours? Do they continue to check their energy consumption through the interface?" will find an answer.

3. PILOT

The Centre Scientifique et Technique du Bâtiment (CSTB) of Sophia Antipolis, France, was chosen as the pilot site for this project.

The chosen building is entirely composed of traditional offices, and does not include research labs or other highly energy-consuming facility: energy is only used for traditional office equipments (computer, printer, etc.) and users' comfort (individual control for heating and cooling in each office room). So the consumption of energy can be modified by the users according to their comfort needs and whether they are aware of energy-consuming behaviours or not.

The building has 36 offices. 49 employees spread on 3 teams are taking part to the ECOFFICES challenge. More than 400 sensors have been deployed over the building for the needs of the project.

4. TECHNICAL INFRASTRUCTURE

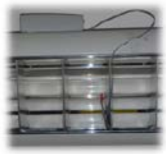
The central acquisition is done by the CSTBox, which is a data concentrator allowing:

- Remote communication with sensors
- Data storage
- Checking radio reception's quality and load control of sensors' battery
- Collection and interpretation of data in the building

The CSTBox implements an OSGI (*Open Services Gateway Initiative)* platform.

Figure 1: CSTBox – CSTB Sensing and Tele-monitoring Box

According to the requirements, post-processing algorithms can be implemented on demand, including remote transmission functionalities. As the CSTBox has an Ethernet interface, data is sent by default through the Internet, but any other support can be accepted thanks to the appropriate hardware interface (GSM/GPRS for example).
The CSTBox used for the ECOFFICES project is based on an ASUS EeeBox. Collected data are sent every day in "zip" format to an FTP host.

Sensors	Description	Picture
Opening conditions	These sensors allow noticing doors and windows opening. The information is sent by the sensors to the CSTBox at each change of position.	
Indoor temperature	This sensor sends the temperature of the office to the CSTBox at regular intervals. It displays the temperature, and can be used to control and set the room temperature, but this function is not used during the challenge.	
Outdoor temperature	This sensor is almost the same than the previous one, except that it does not display the temperature.	
Electrical device usage	These plugs come with a resolution of 1 Watt-hour, and allow to meter energy consumption of office equipments. A multiplug is associated to this plug in order to take into account every devices used by the participant. Moreover, on the plug, there is a push button allowing to easily cut off the electricity supply. Data are sent every 10 minutes.	
Lighting sensor	Data sent by this sensor allows knowing whether the light is switched on or off. Data are sent every minute.	
Daylight	This sensor allows to know the intensity of natural light, to be cross-checked with the use of artifical lighting.	
Heater/ Air conditioner	This probe is linked with heating and air conditioning, to monitor the temperature and deduce whether the device is used or not. Data are sent when temperature changes from more than 5°C.	
Motion sensor	These sensors are originally used for alarm system. Data are sent every 3 to 5 minutes. They are installed on a straight surface, and are placed in such a way that they only take into account the user and not people behind him/her.	

Metering consumption, TYWATT	The Tywatts are placed on the electrical boards of the building, allowing to know the exact consumption for each building wing (and therefore for each team) of: Lighting / electrical plugs / HVAC equipments. Data are sent every 10 minutes.	
CSTBox interface	Connected to each CSTBox's USB port, it allows to catch all the information wirelessly sent by all sensors.	

Table 2: Description of the sensors used for the challenge

There is one CSTBox per team, and it is located in the centre of each part of the building occupied by the team. All equipped offices have more or less the same configuration, depending on the number of employees inside: 1, 2 or 3 employees.

On each office, there are: 1 sensor for each window/door; 1 indoor temperature sensor; 1 lighting sensor; 1 sensor for each heater/air conditioner; 1 "electrical device usage" sensor for each challenger; 1 "motion" sensor for each challenger. Tywatt modules are installed on each electrical cabinet.

5. TECHNICAL APPROACH

Data processing

Raw data gathered into the CSTBox are compressed and sent to a central FTP server. SQL treatments are then executed in order to allow:

- the smoothing of data by using an adequate time interval (every quarter of an hour);
- the measurement of energy consumptions;
- the calculation of energy wastage;
- the determination of the number of bonuses and malus.

User Interfaces

The ECOFFICES website (www.ecoffices.com) is one of the public interfaces for the challenge. It explains the project and its objectives, provides information about eco-behaviours, and allows people to test their knowledge about energy through quizzes. In the building, at the reception space, another interface is installed on a TV screen. It shows information about the challenge, including the ranking of the day and the actual energy consumption of each team.

Through the ECOFFICES website, every challenger can also access the private interface, by using dedicated logins and passwords. This private interface gives access to tailored information classified in 3 different sections:

- Challenger information: my energy consumption, and my own bonus/malus (doors, windows, comfort, movement, night);
- Team information: energy consumption (total and by consumption item – Figure 2), bonus/malus (Figure 3) of the team I belong to ; my own ranking within the team;
- Challenge information: graphs to compare the teams according to their energy consumption, wastage, bonus-malus; current ranking and history since the beginning of the challenge.

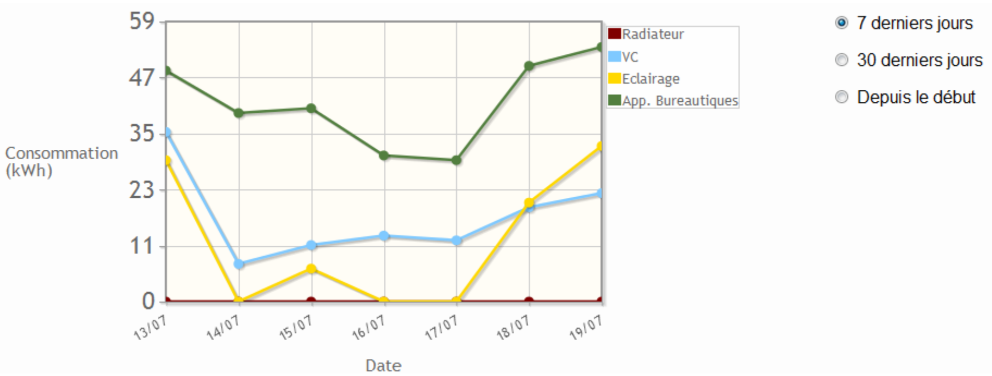


Figure 2: Energy consumption by item in kWh for the last 7 days (Team 1)

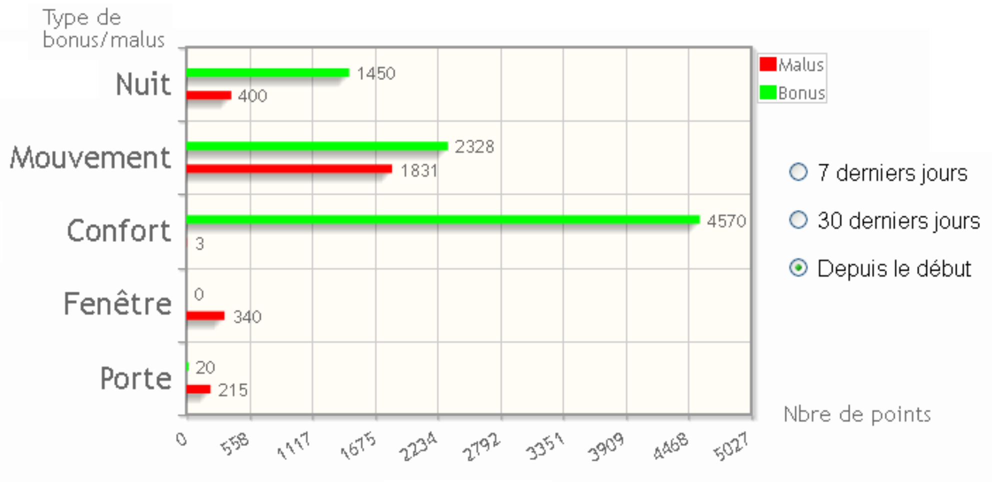


Figure 3: Bonus/malus counter since the beginning of the challenge (Team 3)

6. SOCIO-ECONOMIC AND BEHAVIOURAL APPROACH

It is agreed that there is a large gap, or at least not under control, between energy performance given by simulation tools and real consumption. This was the conclusion of the first part of the SIMBIO project [10] which brought together lead French research players in this field.
Among the factors responsible for this gap, user's behavior is most probably the main cause, even if there is also the climatic change, the usage of bad quality materials or the degradation of their properties over time, the inaccuracy of the models used for calculation or the usage, etc.
The accurate evaluation of user's behaviors is presently a major interest in the scientific community. For example, many European collaborative projects are combining energy efficiency and user behaviour approaches, such as BeAware [11], DEHEMS [12] or Beywatch [13].

It is often argued that, in addition to political decisions, sustainable development will rely on in depth individual and collective behavioral changes. Providing to people feedback about the impacts of their behavior is supposed to be an efficient mean to provoke these changes.
The stress is put on one main question: will the provided feedback in the challenge context provoke sustainable behavioral changes according to the equipment use?
More precise questions are:

- Will the users process the provided feedback so that they can evolve towards ecological behaviour? The conclusion will be established by comparing the two phases out of challenge : with and without user interface ;
- Does the challenge situation have a powerful effect on behavioural changes? Do the challengers modify the way they use equipment? The answer will be given by comparing the situation with/without challenge ;
- If any behavioural changes are recorded, how sustainable are they, as it is well known that a leopard cannot change its spots? The comparison of data recorded during and after the challenge, will provide insight on this question.

Multidisciplinary analysis approach (Ergonomics & Data Mining)
Consumption data and events are recorded at each stage of the experimentation as soon as sensors and servers are active. So it is possible to track challengers behaviors and, from well suited data mining algorithms, to have a clear picture of behavioral changes, if any.
The adopted usage analysis will be driven by a multidisciplinary approach managed by AxIS research team (INRIA) with a close implication of challengers, as shown in the Figure 4. Both quantitative and qualitative analysis will be performed on various types of logs and on qualitative data, and will be correlated.

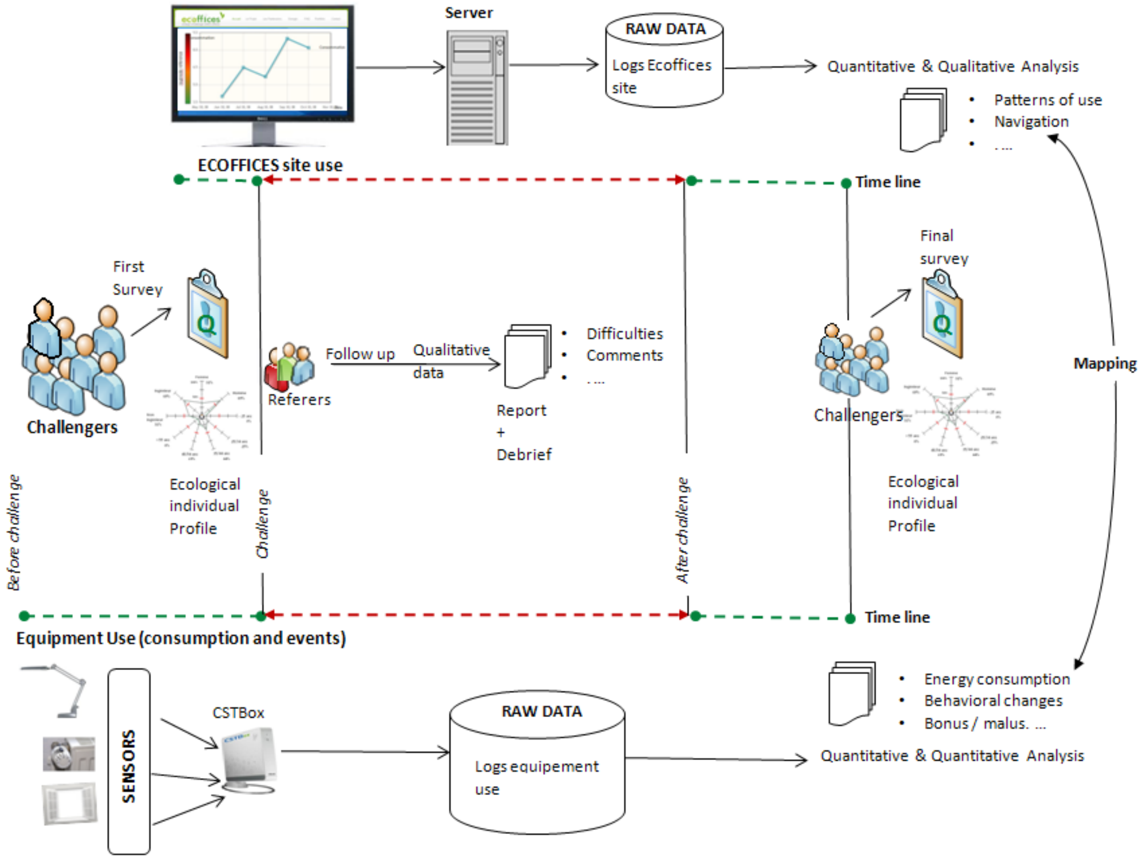


Figure 4: Multidisciplinary analysis method based on data collected at each challenge stage

Available data

- Equipment use

Raw data collected by sensors are processed to identify behaviors at various granularities (team, office/individuals) by OSMOSE and INRIA. Consumption evolution is tracked and from classification algorithms, it will be possible to get a clear picture of the challenge effectiveness.

- ECOFFICES Website use

From the information displayed on the user interface, the challengers will gain knowledge of their results (consumption, number of bonus and malus) and they will be able to monitor the impacts of their behaviour changes.

Interface references will be tracked:

⇨ Number and detail of occurrences of public space reference (project/energy pages, news, etc);

⇨ Number and detail of occurrences of challenger's space reference (rank page, team consumption and bonus/malus page, personal consumption and bonus/malus page).

Qualitative analysis based on challenger profiles and various surveys

Qualitative data: challengers profiles – initial survey

Challengers' profile is first established from a first survey.

- Sociological profile :

- Average profile: more men than women, aged between 35/44 years, R&D Engineer;
- Team 1: Atypical for gender criteria (mainly men);
- Team 2: Profile close to average profile;
- Team 3: Atypical for gender, age and position: more women, 45/54 years old, not engineers.

	Team 1	Team 2	Team 3
Women	6%	31%	56%
Men	94%	69%	44%
Engineers	76%	69%	38%
Not engineers	24%	31%	63%
-25 year old	6%	6%	6%
25/34 year old	29%	25%	19%
35/44 year old	41%	44%	25%
45/54 year old	24%	19%	31%
+55 year old	6%	6%	19%

Table 3: Participants' profile used for analyzing eco-behaviours

- Ecological profile

On each team, there is a strong awareness of saving energy (see Figure 5 below). Both teams pay global attention to ecology, energy consumption at home and in their professional life. The expectations of the outcomes for each team are specific: their answers show that they will have to make different efforts to reduce equipment use.

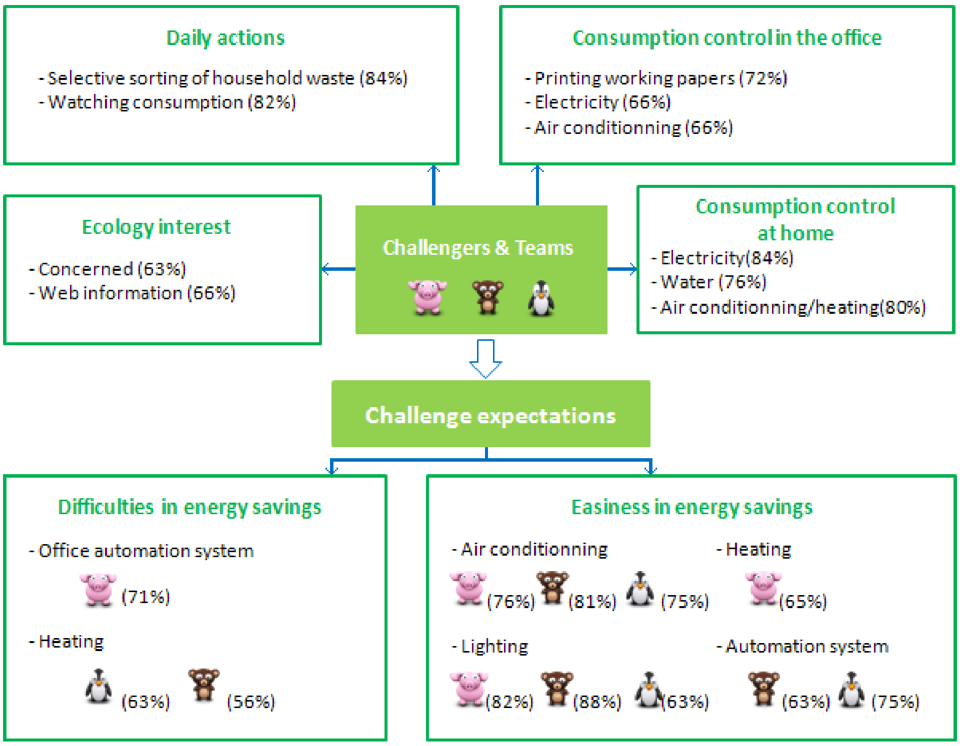


Figure 5: Teams interests and activities regarding ecology

Qualitative data: challengers profiles – final survey

The questionnaire will be submitted at the end of the study and compared to the first answers, in order to point out attitudes and opinion changes in relation to behavioral modification.

Debrief

Users' needs and feelings about the interface and the challenge will be collected by regular debrief with challengers before, during and after the challenge.

These user feedbacks allow the improvement of the user interface. At the end, the user interface will perfectly match with the user needs in energy saving in the context of challenge.

Quantitative analysis from data logs

Data mining algorithms from INRIA Axis [14] work will be used to process raw and aggregated data. We plan to use mainly ATWUEDA for analyzing evolving web usage data developed by Da Silva in her PhD-thesis (2011), which aims to characterize the changes undergone by the usage groups (e.g. appearance, disappearance, fusion and split) at each timestamp and which has been applied in electric power monitoring [15].
The analysis will be conducted at various granularities: global, by team and by office.

Analysis	Detail
Energy consumption	before / after challenge before / during /after challenge
Behavioral changes: number of Bonus/malus	before / after challenge before / during /after challenge
Temporal evolution	Analysis evolving behaviors according to : Various time span : week, month, day Consumption Bonus/malus
User interface Use	Frequency Navigation clusters
Classification scheme	According to sociological criteria (gender, work …)

Table 4: Current analysis plan

7. PRE-CHALLENGE ENERGY REPORT

The table below presents the baseline consumption for one team that has been monitored from February to June 7th 2011 (the challenge started on June 8th). An extrapolation has been made to compute the rest of the baseline for one full year, based on the energy bills of the last 3 years.

Month	Light Aioli (kWh)	Convector Aioli (kWh)	Heater Aioli (kWh)	Office devices Aioli (kWh)	Total Aioli (kWh)
February 11	343	379	2647	1070	4439
March 11	251	391	2025	1260	3927
April 11	138	356	489	1278	2261
May 11	98	374	0	1456	1928
June 11 until the 7	44	94	0	319	457
1st phase Total	874	1594	5161	5383	13012
Daily Average	6,83	12,45	40,32	42,05	101,66

Table 5: 'Team 2' energy consumption's monitored before the challenge kick-off

In order to compare the consumptions between the different phases of the project, the following indicators will be used:

- The percentage of energy saving by consumption item
- The benchmarking of time usage by equipment
- The total amount of electricity and CO_2 savings

The calculation of these parameters will be renewed at the end of each project phase.

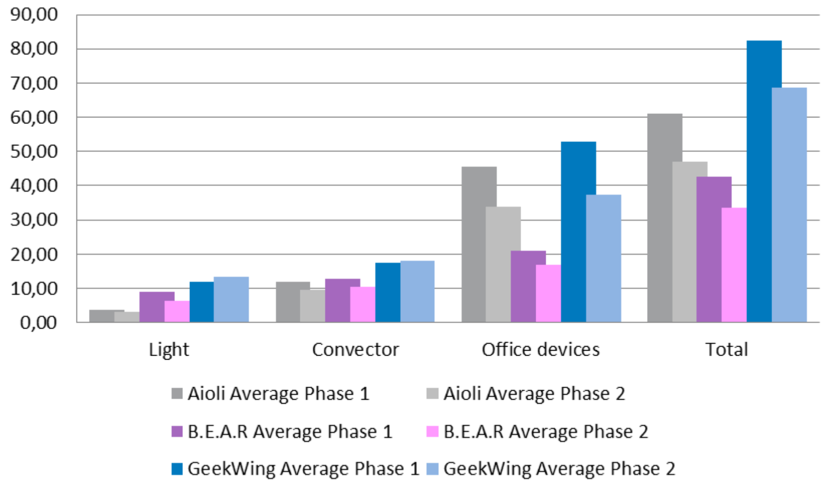


Figure 6: Consumption's average evolution between the two first phases for the 3 teams

A first analysis of the actual consumption vs. the baseline has been realized between phase 1 and the beginning of phase 2 (see section 2-Protocol). The average saving achieved for the 3 teams is 37.01 kWh per day, representing a 20% reduction of energy consumption.
The most important impact has been recorded on the use of office devices with a 26.2% reduction, while 6.5% and 9.6% reductions have been observed on the use of lights and convectors. Considering an energy price of 0.11€ /kWh, such a reduction over one year would represent a 1500€ economy per year, and 2.7t of CO2 avoided.

These results are quite promising, although they rely on a short period of analysis, correlated with the challenge kick-off bringing a lot of motivation to the challengers. Results will be further analyzed all along the challenge (and even after, during the third phase 'appropriation') to evaluate the savings on the long term.

CONCLUSION

The ECOFFICES project proposes an innovative solution which meets economic, energetic and environmental challenges, by reducing energy consumptions.

The 3 main objectives of this project are:

- Technical: by metering in real time energy consumption and having feedbacks of user's behaviours ;
- Economical: by making energy savings and money savings ;
- Social : by making people aware of energy savings and communicating about this project through word of mouth.

The technical platform developed for the project is composed of many recent innovative technologies. The proposed experimental methodology is based on an original multidisciplinary usage analysis and is the first one implementing the concept of "energy challenge".

This project is a novelty as the idea of an ICT-enabled energy challenge has not been realized in offices before. It is about innovation of practices, with a better understanding of the building's energy equilibrium and feedback to make people aware of eco-behaviours. This is one of the first ICT-enabled analysis of people's practices concerning eco-behaviours in offices. The challenge final results, both technical and socio-economic, will be made public at the end of 2011. At the end of the project, it will be envisaged to replicate this experiment in other buildings.

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