*GreenSoul**

A Novel Platform for the Reduction of Energy Consumption in Communal and Shared Spaces

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***Abstract*— In order to achieve higher energy efficiency in buildings, it is essential that devices be consciously used. The GreenSoul project aims to build energy awareness to users and help them change their energy consumption behavior. This will be succeeded by changing the way people use energy consuming devices and by embedding intelligence in the devices themselves, which could autonomously decide about their operation mode and energy consumption. GreenSoul research and innovation focus on the reduction of the energy consumption above 20%, within the domain of public buildings or buildings of public use. GreenSoul forecasts that it is possible to surpass this target providing that a true collaboration among people, devices and buildings is achieved by putting in place the range of technological contributions set forward by this project.**

Keywords—GreenSoul; energy efficiency; buildings; users; energy consumption; reduction; user behavior.

I. INTRODUCTION

One of the main sources of unnecessary energy consumption is the misuse of energy consuming devices and systems in buildings. Notably, they account for 40% [1] (see in Figure 1 the sum of Households plus Services sectors in the energy consumption chart) of energy end-use in the EU. Trying to achieve the aim of 20% savings of the primary energy consumption by 2020, the energy target of EU 20-20-20 commands a reduction of greenhouse gas emissions by 20% compared to 1990, increase renewable energy sources' share in energy consumption to 20% and a 20% increase in energy efficiency. Making energy consuming devices more efficient is the key in order for the EU to achieve its goals on improving energy efficiency by 20%. The GreenSoul project aims to surpass EU energy consumption target with an Information and Communications Technology (ICT) platform empowered by a socio-economic and behavioural model, which will guide and aid more eco-aware practices on people, devices and buildings.

Within buildings, households have already been targeted successfully but public buildings or buildings of public use still demand a lot of attention from the research and industrial community. This is the reason why GreenSoul research and innovation focuses on going beyond the -20% energy consumption target within the concrete domain of public buildings or buildings of public use.

The view of GreenSoul is to surpass this target providing that a true collaboration among people, devices and buildings is achieved by putting in place the range of technological contributions set forward by this project. The target outcome of this project is to test the innovative ICT solution in public pilot buildings and proof that energy and CO_2 reductions of 20% in one year are possible. The three references mentioned-below are used for the prognosis of the targeted savings:

1) Sarah Darby [2] conducted a study in which she states that energy savings of up to 15% are possible through behavioural changes.
2) Delmas et al. [3] and Osbaldiston et al. [4] carried out meta-analyses. They concluded that an average reduction of the energy savings by 7,4% of the electricity consumption is possible with human behavioral strategies.
3) Anastasi et al. [5] conducted a study regarding intelligent devices and proved that a decrease of the energy consumption of these appliances of up to 30% is possible.

This conceptual paper aims to introduce GreenSoul project. The purpose of this project is presented in Section II, goals, objectives and expected outcomes are described in project description in Section III. The paper ends in Section IV with discussion and conclusions.

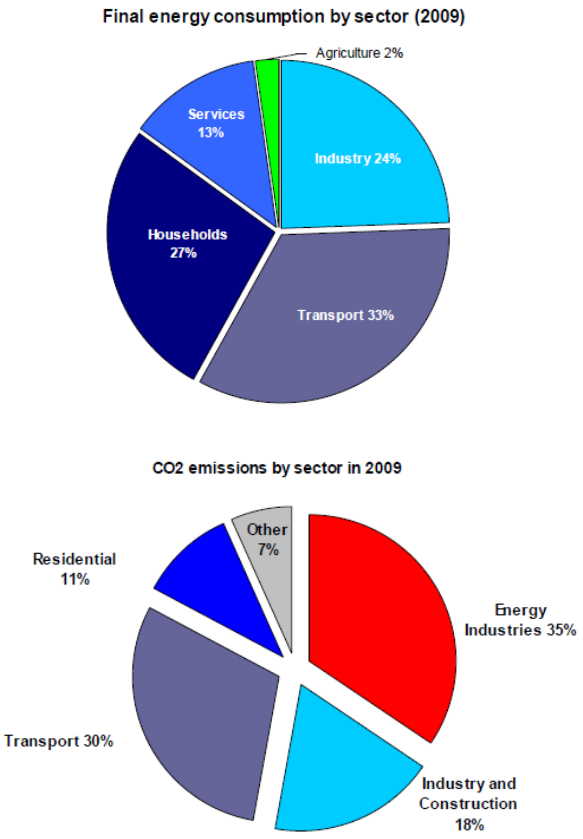

Fig. 1. Market Observatory for Energy. *Source: Eurostat, May 2011.*

II. PURPOSE

Consumer behaviour and practices are influenced by many factors. Technological developments, considerations of the general economic situation, age, social norms, beliefs and cultural traits, marketing strategies: all play an important role in defining what a normal way of life is considered. In GreenSoul, the economic, psychological, sociological and educational aspects associated to energy use will be taken into account in order to understand better how people use energy, both as individuals (or group) and as part of different collectives. GreenSoul's key contribution will be to transform the energy consumption practices of people, particularly, but also the operation mode of the energy consuming devices they interact with, and the environments where they populate or work.

The GreenSoul aims to provide a low-cost energy-efficient ICT platform, which enhances a traditional public-use building with a set of advantages (apps, interactive interfaces, device adaptors, smart meters and a Decision Support Engine (DSS) engine) that mediate in the interactions of users with their environments and the energy consuming devices and systems present in them. GreenSoul foresees public use buildings as ecosystems of GreenSoul devices, which cooperate with other devices, standard Smart Meters and, very importantly, with eco-educated and eco-aware users to minimize unnecessary energy consumptions.

The GreenSoul ICT platform will be powered by a supporting socio-economic behavioural model providing the behaviour understanding to turn energy consuming devices into active pro-sustainability agents that manifest to their surrounding users how well or badly they are being manipulated (energy-wise), offer tips on how to use them more energy efficiently and even automatically adapt their own functioning to avoid unnecessary waste of energy.

The purpose of GreenSoul is to design and develop an integrated ICT platform, which will:

a) enhance users awareness regarding their energy consumption habits;

b) investigate people's ecological behaviour in shared environments;

c) analyse the effectiveness of different persuasion techniques;

d) assist users through a decision-support engine's recommendations; and

e) provide socio-economic evidence about the viability of the changes proposed.

III. PROJECT DESCRIPTION

GreenSoul project will combine several data sources in order to deliver the final product, which will be a low-cost energy efficiency ICT platform to help users be more conscious with the energy consumption of their electrical devices in buildings of public use. In order to succeed this goal, it is essential to collect data by the users and their energy usage behaviour; the devices' energy consumption; and the buildings' indoor environment as well.

The first step is to examine users' behaviour through a socio-economic behavioural model. Users' behaviour with energy consuming devices will be analysed and alternative mechanisms to motivate them to save energy will be evaluated. Next, the integration of Smart Adaptors in energy demanding devices follows. The adaptors will also monitor other users in the same building and offer data regarding the associated energy consumption of all the devices that are used at the same time. Moreover, a Smart Analyser will monitor energy generated from renewable energy sources. The analyser will integrate with environmental measuring sensors and interoperate with an external decision support mechanism to orchestrate the devices connected to an electric installation so that sophisticated energy efficiency policies may be applied. Besides, a great amount of real-time information is necessary to be acquired from various heterogeneous sources in the buildings. Therefore, building-related aspects (static and dynamic) will be investigated, such as the energy management, context information (e.g. location, time, or other meta-information useful for decision making), occupancy related information (occupancy, preferences, etc.), and indoor environmental conditions (such as temperature, etc.).

All the above data will be collected and analysed by an analytics engine, which will feed a decision support engine, in order to take autonomous decisions in case energy inefficient behaviours are detected. The heterogeneous information (energy consumption, device state, building information, occupancy,

etc.) will be correlated and analysed to this end through novel big-data analytics techniques. Last but not least, persuasion and incentivisation interfaces will be applied. Social and contextual applications will be used to help user supervise the energy consumption of his/her devices. Furthermore, using these applications the user will be able to compare his/her device with the one of other users with the same profile. These applications could offer suggestions and tips to the user towards the reduction of the energy consumption of his/her device, based on the decisions made by the analytics and decision support engine. Finally, GreenSoul-ed devices will have capabilities to react independently or under the environment's requests, in order to autonomously meet local and global energy savings' policies.

A combination of correlational and experimental methods will be used. Correlational methods are those using surveys to collect data, asking participants about psychological processes, such as social norms, values, attitudes and identity. Experimental methods are those that examine interventions by manipulating independent factors, e.g. feedback visualizations that are thought to encourage green behaviour.

The view of the GreenSoul project is that programmes, which are designed to encourage users' behaviour change, must accompany technical interventions in buildings. In the next paragraphs of this section the goals and objectives of the project, its architecture, pilots and outcomes are extensively addressed.

A. Goals and Objectives

GreenSoul provides a novel platform for the reduction of the energy consumption in communal and shared spaces (e.g., workplace). By using the information provided by energy-meters and practices of persuading users' consumption, global socio- economic goals can be achieved. This persuasion is achieved using not only widespread mobile social web applications but also Internet-connected enhanced everyday things.

The technological objectives of GreenSoul are listed below:

i. The implementation of a GreenSoul Smart Adaptor in order to turn everyday things into persuasive, cooperative and reactive networked eco-aware things. Adding a green-soul to everyday energy consuming devices implies that those devices will manifest to surrounding users their associated energy consumption or the means to reduce it in a persuasive manner, either by connecting generic interfaces (e.g. physical displays or software widgets and apps) or custom-built visualization cues (e.g. ambient lights that fade from green to red). Those devices will have capabilities to react autonomously or under the environment's requests, in order to autonomously meet local and global energy savings policies.

ii. The extension of existing Smart Meters with GreenSoul properties. This project encourages minimal, low-cost and easily deployable, existing environments' infrastructure instrumentation. An existing Smart Meter (e.g. WeSave Energy Monitoring System from WSC) will be adapted, with a set of extrapolate-able modules to:

   a) gather energy data and environmental contextual data (e.g., CO_2, temperature, humidity),

   b) communicate with GreenSoul augmented devices and

   c) interoperate with the GreenSoul Analytics and Decision Support Engine, which will help it to take action on its own or to delegate reactivity to networked devices.

   These modules will be applied to the Smart Meter solutions already available in the target pilot sites. The objective is to turn Smart Meters into Smart Analysers, which transit from simple monitoring to environment's energy consumption practices understanding and reaction.

iii. The implementation of an Analytics and Decision-support engine driving the eco-behaviour of an environment. This engine will analyse the aggregated data obtained from GreenSoul-enhanced devices and Smart Meters in order to learn the energy consumption patterns of users and devices within an environment. Predictive analysis will be carried out in order to anticipate to users' non-sustainable practices. A rule-based decision-support engine will enable the application of different strategies at environment's global level or specific-device local level to pursue unnecessary waste of energy.

iv. The development of an assortment of mobile social web apps and physical interfaces associated with e-consuming devices to persuade and incentivise users towards more responsible energy consumption in public spaces. These interaction tools will enable users to be more aware of their energy consumptions. They will give users tips on how to improve, energy-wise, their interactions with the environment.

Furthermore, the Socio-economic objectives of GreenSoul are listed below:

i. To provide a better understanding of the users' eco-friendliness and attitudes towards sustainability in shared spaces (e.g. workplaces or sport centers). This improvement will be achieved researching on the behavioural models, attitudes and values that characterise the interaction of different user profiles (e.g., age, gender, socio-economic status and education) in different spaces with the equipment they use in their everyday interactions.

ii. To improve users' self-eco-awareness in shared spaces through persuasive interfaces and mobile social web applications. These applications will register users and reward them (through a points system) every time they visualize other users comments on energy efficiency initiatives. Surveys on eco-behaviour and suggestions on how to improve sustainability in the building where the user is located will also provide him with additional points.

iii. To promote an intelligent eco-wise and self-configurable environment reacting to users' behaviour. This objective is complementary with the previous one: whenever users behave in a not too eco-friendly manner, there is room for the equipment self-configuration. This self-configuration will align the overall energy saving goal with users' usage preferences in a transparent manner for the latter ones.

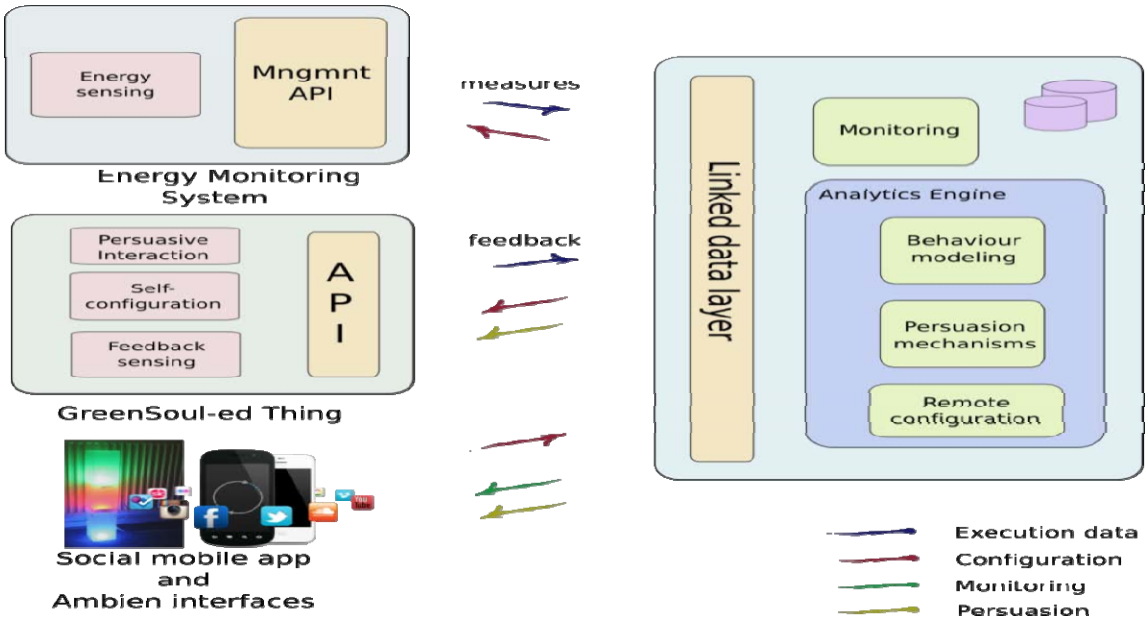

Fig. 2. GreenSoul overall architecture.

iv. To research on the alignment of the organizations' energy efficiency goals with the individuals' ones. Users might not be involved in an organization's energy efficiency goals due to responsibility dilution, comfort or simply unawareness of the impact of their actions over unnecessary energy waste. GreenSoul will investigate:

   a) how to coordinate individual motivations to achieve an aggregated saving (assuming that individual savings might not always translate in overall aggregated savings) and

   b) organization driven persuasion mechanisms (e.g. promoting a social reconnaissance).

v. To apply evidence-based analysis using the data collected in the five validation pilots from two visions: the behavioural and the socio-economic one. The behavioural vision will validate whether users' eco-friendliness in shared spaces has increased and if they are more aware of their actions' impact in energy efficiency, both within the shared space or outside in other shared public spaces or their own households.

vi. To elaborate a business plan for the commercial exploitation of the system at a European level considering market entrance one year after the project end.

B. Architecture

The overall architecture of the GreenSoul project is illustrated in Figure 2. The project will be built around the following features:

- Socio-economic behavioural model which will analyse users' behaviour and propose and assess alternative mechanisms to motivate them to save energy depending on the features of their shared spaces and the collectives of people in them.
- Smart Analyser. GreenSoul will control the use of existing and ready-to-use smart-meters and their integration with the proposed platform. Actually, the project targets turning Smart Meters into Smart Analysers, which do not only monitor and react, but they can also organize the energy consuming devices and suggest persuasion and incentivisation for users and groups as result of the continuous analysis of their energy consumption behaviour practices.
- Green-souled Things. GreenSoul aims to add an energy consumption awareness and reactivity to any energy demanding device. Therefore, place will be given to the 'Smart Adaptor' (SA) a device easily attached to everyday appliances, which will turn them into user-friendly Internet-connected energy-aware things. The 'advanced' appliances will interact with users to help them reduce their energy consumption. Rather than designing and creating these devices from scratch, which would involve changing the old-fashioned objects by new and smart ones (and probably dispose of them to the landfill), the objective is to use the existing objects enhanced with low-cost technology, which will supply data to the Smart Analysers.
- Analytics and decision-support engine. GreenSoul envisages to distribute the application of intelligence mechanisms for energy saving and emission reduction among GreenSoul-ed things, Smart Analysers and a Cloud-based analytics and decision-support engine. The GreenSoul adaptor will be powered with an embedded rule engine to help it take autonomous decisions in case an energy inefficient use of the device is detected, e.g. switching themselves off when they are in stand- by mode

for a period of time. GreenSoul-ed things will propagate Linked Data about their energy consumption patterns and the user interactions producing them to the Smart Analyser. This latter element will have the capability to map global (building-wide) energy saving goals into local (device-specific) energy savings goals. It will also be powered by a built-in rule engine, which will analyze the current status of the linked devices and distribute the global energy savings into them according to their status and the status (energy consumption, occupancy, temperature, luminance, etc.) of their location/space.

- Persuasion and incentivisation interfaces. Mobile social and contextual applications will help the user monitor his/her equipment consumption, compare it with that one of similar profile users and give him/her hints to reduce this consumption based on the decisions made by the analytics and decision support engine. Several conceptual interfaces will be adopted with ultimate goal to educate them and change their behavior. All these will be also enriched with effective persuasion and incentivication mechanisms (e.g. gamification, etc.) adapted to the users' profiles, so as to even increase the result and effect on the users. Furthermore, the experience in the development of such app for households' energy monitoring will be applied in the development of a new app for public use shared buildings. Thus, apart from giving advice through a mobile social application, GreenSoul will create a serious game to engage the user in an enjoyable manner.

C. *Pilots*

Different pilot sites will be analysed according to their architecture and existing equipment. The test buildings in the project are spread over four different European zones and are buildings with different types of public uses, thus allowing meaningful comparisons to be made and, eventually, solutions developed for a pan European market. The pilot-buildings and their main features are listed below:

i. Offices in Seville, Spain. The building has total area of 6.043,82 square meters and consists of a basement, three floors and roof.

ii. Public building in Thessaloniki, Greece. The building has total area of 7.598 square meters and consists of a basement, two buildings and roof garden.

iii. Offices in Bilbao, Spain, with area of 22.000 square meters, which consists of a basement, ground floor and two floors.

iv. Sports center in Cambridge, UK, with area 1.258 square meters.

v. Business center in Cambridge, UK, with area of 3.251 square meters.

vi. Innovation center in Wiez, Austrian state of Styria, which consists of three buildings with total area of 7.508 square meters.

Furthermore, associated users will be analysed in order to identify the customization needs for the installation of the GreenSoul platform. This platform will provide technical tools and methodological guidelines to execute, monitor and log the results in the different pilots. The guidelines will help coordinating the activities among the different pilots, by establishing efficient communication, problem collection procedures and sharing best practices. These guidelines will also serve as input for the technical evaluation of the GreenSoul platform and as a reference guide for the adoption of the GreenSoul solution by other stakeholders.

D. *Outcomes*

GreenSoul aims to reduce the energy misuse in public spaces. Rather than replacing the equipment with more efficient machinery, GreenSoul's approach to achieve this goal is the persuasion of the people who populate or work at these spaces to change their, often unconscious, inefficient energy consumption practices. For that, this project will create the GreenSoul platform, i.e. an energy consumption awareness and management solution which aims to change the eco-behaviour of environments inhabited by a range of proactive GreenSoul-ed appliances and eco-conscious users.

A full-duplex, i.e. bidirectional, communication between energy consuming devices and users will take place from which, through non- obtrusive/obnoxious interaction cues and social apps, users will progressively become more energy consumption sensitive and thus follow a more sustainable usage of their everyday devices both at work and home. GreenSoul-enhanced everyday things (e.g. appliances, light & HVAC systems) will manifest intuitively their energy consumption "feelings" to end-users, thus educating and influencing users.

Moreover, they will subtly propose how to efficiently operate the devices and ultimately, adapt their own operation in case that they are not being used in an eco-responsible manner.

IV. Discussion & Conclusions

This project will extensively analyse the following: a better understanding on the people's attitude towards energy consumption in shared spaces, their current behaviour and how different variables (socio-economic, environmental, demographic, attitudes, norms, knowledge, beliefs, perceptions, etc.) affect their green behaviour.

Moreover, the project will take into account how emissions reductions from possible energy savings will affect younger and older groups, how possible tax discounts will affect them, how various rewards (vouchers, coupons, etc.) will affect older humans, younger humans, employees, visitors, etc.

The implementation of the "GreenSoul" solutions in existing public buildings will directly address one of the most important sources of inefficiencies within the European Economy (the high energy demand rate per m^2 of public buildings) reducing their energy consumption and the environmental impact.

The combination of the low-cost easily deployable energy-efficient technological assets and the novel socio-economic

behavioural model, which helps in the understanding of users' energy consumption practices proposed by GreenSoul will drive energy consumption and emission reductions which surpass EU's -20% energy consumption target.

ACKNOWLEDGMENT

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