Energy Book for Buildings
Occupants Incorporation in Energy Efficiency of Buildings

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Abstract: This paper addresses a bottom-up approach for energy management in buildings. Future smart cities will need smart citizens, thus developing an interface to connect humans to their energy usage becomes a necessity. The goal is to give a touch of energy to occupants' daily behaviours and activities and making them aware of their decisions' consequences in terms of energy consumption, its cost and carbon footprint. Second, to allow people directly interacting and controling their living spaces, that means individual contributions to their feeling of comfort. Finally, a software solution to keep track of all personal energy related events is suggested and its possible features are explained.

1 INTRODUCTION

Energy consumption and consequently CO2 emissions have been grown by 49% and 43% respectively. It is predicted that each year energy consumption is increasing by the rate of 2% and this value is 1.8% for CO2 emission (Pérez-Lombard et al., 2008). Therefore global efforts have been initialized to reduce consumption of energy and emission of CO2.

Buildings are the main energy consumers inside grids. Thus, achieving efficient optimization in their energy management can save a considerable amount of energy. Despite a large number of papers proposing new and more efficient methods for building energy management, the penetration of these technologies in the market and real life is a few.

Recently, researchers have become interested in developing sustainable strategies and technologies under the vision of intelligent buildings. Such a building responds to occupants requirements in energy conservative manner. In this framework, buildings are designed to perform according to standard set points which are supposed to satisfy majority of occupants' comforts (Andersen et al., 2009). Studies have shown that habitants are not always satisfied with living in such buildings and their predefined set points do not guarantee occupants' comfort and satisfaction together with energy efficiency. That is mainly due to the difficulty of defining comfort for different people, thus occupants' behaviors and preferences have major influence on buildings' energy consumption and carbon footprint (Halfawy and Froese, 2005).

Indeed, presence of occupants inside building is a main factor for its energy demand. In residential buildings occupants are responsible for building control and its costs, therefore the motivation to keep the balance between their comfort preferences and energy related behaviors with energy consumption are generally high (Bourgeois et al., 2006). In contrary to this, in commercial buildings, occupants are not aware of consequences of their energy related behaviors and they are not involved in building control, though the gap in communication among occupants and buildings is felt. In some cases it may happen that occupant's preference is not aligned with energy goals of building, then adjusting occupants behavior in a way that he does it with self-motivation is a crucial fact in order to increase building energy efficiency (Nicol and Humphreys, 2009).

Dynamic occupant's behaviors and preferences are the factors that have been forgotten in the operation of current Building Energy Management Systems (BEMS). In other words, due to complexity and diversity of habitants' behavioral patterns, usually a typical occupant's activities is taken into consideration for control of environment (Mahdavi, 2008).

In this paper the importance of occupant's awareness of energy consumption and CO2 emission con-

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sequences of different behaviors (Darby, 2006) is addressed. We propose web based framework for keeping occupants informed about energy issues and motivated to care about their consumptions. This paper is organized as follow: in the first section we gave a brief introduction about energy concerns in buildings, the second section describes our preposition for human-building interactions platform, in the third section its impact in daily life is addressed and finally comes the conclusion and future work.

2 OCCUPANTS AND ENERGY CONSUMPTION PLATFORM

Currently, there are intelligent buildings that somehow benefits from automation using different sensors and actuators. Various control and learning approaches have been applied in their performances (Hsu et al., 2010)(Malkawi and Srinivasan, 2005). The problem is, such methods are too sophisticated or they do not fulfill comfort requirements by occupants (DeWaters and Powers, 2013). In many cases they predict about occupant's presence or preferences which is not always aligned with reality (Gunay et al., 2014). On the other hand, putting mechanical devices to control building components such as windows and facades are costly. Regarding drawbacks and sophistication of such management systems, the question comes to mind why not using occupant for intelligent management of his own environment.

There are a lot of software solutions and products to present building's monitoring and its energy consumption but to our knowledge except the ones which took average from whole energy consumption of building divided to number of occupants, there is no personalized software that shows each person's real time energy consumption. Informing occupants about total consumption of the living space or building is not of great advantage. Studies have shown that usually occupants do not care about it, especially if the living space is their office building (Jazizadeh et al., 2014), since they share the living space with others and it is not exactly defined their individual contribution to the total energy consumption of the living space. Therefore, the first goal is to develop a personalized software product that can label people in terms of their energy consumption (Griffith, 2008). We suggest three different labels:

- Green energy-labeled for the ones who care about their daily energy consumptions and green gas emissions to be kept below the predefined standard quota.
- Yellow energy-labeled for the ones who are around the quota limits positively.
- Red energy-labeled for the ones who are consuming more than quota limits.

Therefore, it can be seen who are the waster and economizer of energy in building scale view or further in city scale view. Limits are defined based on cultural elements and governmental energy policies. They can be set adaptively throughout the year based on different energy needs or cultural events. In this section a normalized human-building software product will be defined and described.

2.1 Energy Book Motivation

In a current daily life, there are social networks like Facebook and Twitter that we can check updates from our friends or persons whom we are interested in. Why not to have a similar web-based framework to check the appliances we use and own and personal status as an energy consumer. It can feature comparison among different occupants as a means of competence to achieve efficiency goals. We name such a software solution as **E**nergy **B**ook in courtesy of the main idea originating from face book.

Thanks to building's equipment with wireless sensor and actuator networks, we are able to monitor any energy concerning event happening in the building. Added to energy-based events we are able to track indoor environmental changes which have direct consequences in appliances usage. The main challenge is to personalize this event-based infrastructure. Therefore each permanent or temporary inhabitants can make personal profiles which introduce them as occupants of the host buildings in order to handle their comfort in parallel with their energy consumption.

2.2 Conceptual Model

Applying this software product, user can interact with his own comfort parameters (temperature, luminosity, scheduling, budget, etc.), energy consumption and carbon foot print (Paul and Taylor, 2008). Nowadays, such a software solution is undefined and unrealized for many reasons (O'Brien and Gunay, 2014). Indeed, this software product should be independent from the buildings' types of control and infrastructures. Its back-end is capable to create a transparent dialog between any building and occupants. Therefore, a dynamic generation of software products for building environments that actively adapts to user and data environment is in need. The general goal is, interfacing human with comfort, power and energy in a manner that is depicted in figure1.

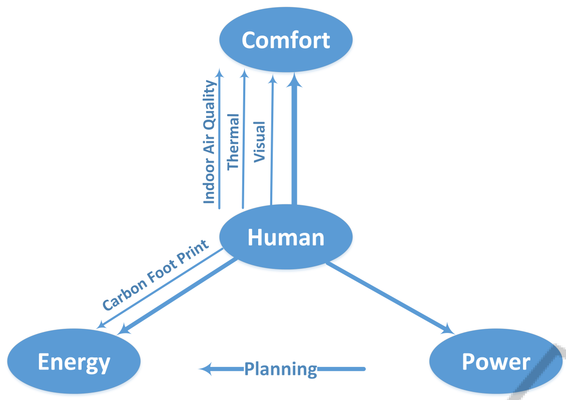

Figure 1: Conceptual Diagram.

While time relates power to energy consumption and these two are deterministic and can be formulated, the third which is based on human feelings is totally stochastic. Human comfort itself has multiple dimensions. Thermal, visual, acoustic, air quality are some of these comforts. In this work, we aim to come up with a transfer function which relates human comfort to energy consumption and coming finally to efficiency that satisfies the comfort constraints in a given period. There should be always a trade-off between human comfort, peak of power, energy and carbon footprint.

2.3 Infrastructure Overview

Nowadays, typical infrastructure for an intelligent building is a network of sensors together with actuators which monitors environmental parameters (Wood and Newborough, 2003) and act on some selected loads. Indeed, we benefit from such a framework with some differences.

We define different living spaces inside building as cells. Each cell depended on its shape is equipped with one or two wireless sensor node. They are capable of measuring temperature, humidity, luminosity and presence. On the other hand, all the electrical devices are equipped with smart plugs which are based on standard commercial components. They are able to measure power consumption of devices being attached to them and send the measurements through power line communication (PLC) to a central server. Additional to these abilities, one can turn the device on and off remotely. When the load can be dimmed i.e. lights, the plugs are able to perform dimming up or down.

The mentioned above infrastructure enables load monitoring and assessing its consumption through out the day. History of measurements is saved as time series data base. A web application deals with presenting each sensor or plug measurements and status. A real time server guarantees receiving and representing the most recent measurements and changes. Such an infrastructure is designed to be an open environment and it can be applied for any type of building. We call the buildings equipped with such a platform As smart buildings to be listed in our software platform.

3 ENERGY BOOK IN DAILY LIFE

It is important to develop Energy Book as appealing and user-friendly as possible. First, it must be presented as means of comfort manipulation and maximization. It should be taken into consideration that in many buildings people are not in charge of paying energy costs, so in those buildings another policy must be thought of. Its widespread usage as a new type of social network and its performance as an enterprise or cooperation can be planned from business-models point of view.

Energy Book development can be organized as software engineering project. National energy goals and governmental energy policies should be taken into the account. This bottom-up approach can be upscaled to the grid and demand-side management towards smart cities. In this section we try to explain different modules in such a software product. The overview of it is depicted in figure 2. Like other web applications, it should have a module to handle user sign up/in and out. We escape explaining this module as it works on the same basis. User profile design and settings are categorized in the same module.

3.1 Occupant Living Spaces

During the day, we spend our lives in different places. In a residential building as our home, in a commercial or an office building as our working place and finally in public places like commercial centers, gyms, cinemas, etc. as locations for our leisure/outgoings time passing. Depended on being equipped with monitoring sensors/actuators and being registered in Smart Building Web Application, occupants can choose daily living buildings in their own profile whether it is residential, office/commercial or public one, thus they can proceed to choose corresponding living spaces throughout the list of cells being listed in each smart building. For the buildings have not been smart and listed in website yet, the software package should provide special spaces for users to define, describe and categorize the buildings virtually.

Inside buildings we have shared or personal living spaces. For instance, in a residential building, the

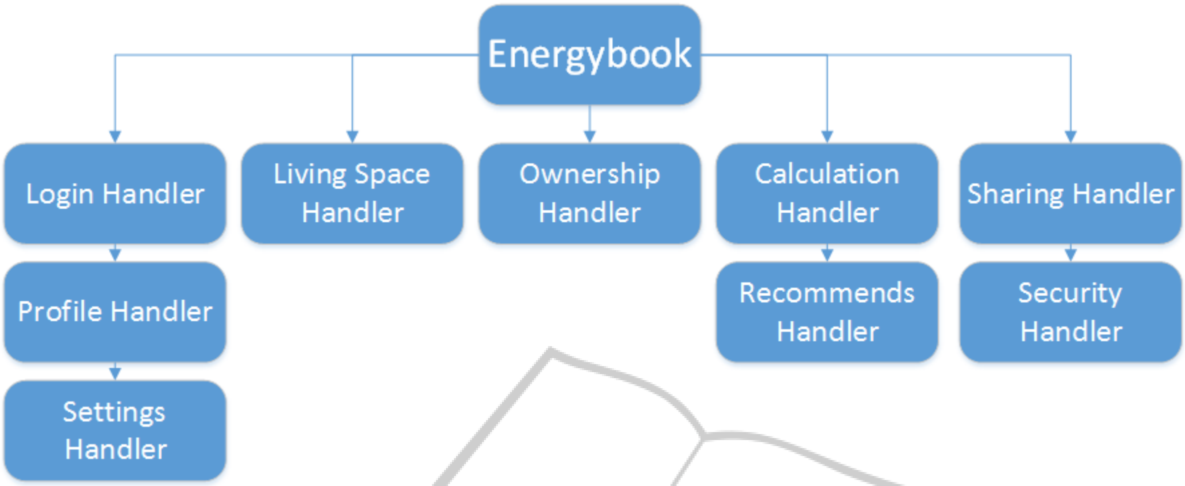

Figure 2: Energy Book software product modules.

spaces can be categorized as personal or shared, that is in a typical family apartment, bedrooms and private bathrooms if any, are personal while living rooms, kitchen and bathroom is shared. Thanks to current database architecture in our smart building web application, one can select his own living spaces whether it is personal or shared throughout the list of living spaces inside each building. Further, they will be able to add non-listed buildings and configure them manually to be accepted by website development team as virtual living spaces that have not been smart yet. Such tasks and performance will be the job of living space handler module.

3.2 Ownership Definition

The procedure continues to electrical devices selection regardless of being owned by one or multiple person. To do so, after user login into website and selection of buildings and living spaces inside them, the registered electrical devices in each selected living spaces will be presented to user. The occupant can choose his ownership of devices. If the appliance is selected by one person it would be categorized as personal and its power measurements is summed in its owner's profile, however if a device is used by multiple persons its power consumption is shared between the people who has registered themselves as its operators. Adaptive parameters should be thought up to be assigned to each user's corresponding consumption. The issue can be handled by using owners' schedule and data mining algorithms. Ownership Handler module is responsible for this job. Finally, each occupant has his own list of appliances and he can control them using the plugs ability to be handled remotely throughout the web. Apart from such smart devices, there may be some that has not been specified in the system or equipped with measurement technology, the software solution is to prepare user with an environment to select or define his load. Different loads can be categorized as IT, beauty, kitchen and so on. Based on their brand and type, the typical power usage should be searched and proposed to user or he can define it his self. These virtual loads are to be handled properly and be distinguished with those who benefits from real time power measurements.

3.3 Energy and Carbon Footprint Calculator

Having listed all energy-consumers' belongings in different locations in the smart city, users are able to monitor and maintain their daily energy consumption and consequently carbon footprint. The calculations is based on power consumption measured by plugs attached to the devices. Energy calculation can be done on hourly, daily or even quarterly and yearly basis. Therefore, people can be categorized as green, yellow or red energy labeled. From building point of view, using the aforementioned labels, there is an overview of occupants' behavior. We assign calculation handler to do all calculations and analyses regarding the energy. Consumption reports to the occupant is in his own national currency in order to attract more attention from his part. Governmental pricing for energy and their fine policies for extra usage are taken into consideration for reported values.

The calculation handler could be extended by giving a user an estimate of consumption using physics models and laws especially for indoor climate control (Yang et al., 2014). Therefore, user can calculate energy consequences of his own comfort decisions beforehand. Then he can decide in a more conscious and intelligent manner instead of using trial error approach to adjust his comfort settings.

We believe providing occupant with information in terms of the money he should pay as the expenses of his specific energy-related behaviors, will direct him to care more about his usage (Brounen et al., 2013). The additional value of such a system is that based on occupants type of energy behavior, building management system can provide recommendations of saving strategies to occupants. These prepositions can be categorized as general or personal ones. They can receive votes from occupants such as like/dislike. The vote record system can help recommendations to be promoted as persistent or degraded to temporary ones. The less useful suggestions are discarded.

3.4 Sharing and Competence in Energy Goals Achievements

No method is more efficient than comparing individuals with others. Competitions have been always interesting for human beings. Behavioral studies confirm that sharing information about others performances are the best way to encourage people to behave differently. Occupants who co-habit in the same living space can share their individual energy consumptions corresponding to that common living space with each other and compare their personal usage and their contribution in total energy consumption of the specific living space . Although they can set personal or common energy goals to be achieved in short or long term (Diamantaki et al., 2013). They can add co-habitants or other occupants as their friends to share their energy achievements. Sharing Handler is responsible to offer such services.

Here comes the security issue which is an important matter to be dealt with. Security in such a web service should be handled in a way that does not harm personal privacies or confidential buildings facts. They can be defined as general privacies to be applied for all buildings, loads, and occupants or building specified securities that may differ from one to another. Giving rights of control and monitoring of some loads to specific or VIP occupants is an example of such building-specific privacies, which emphasize that enormous attention should be paid to security issues in Energy Book.

For loads that are categorized as personal, it should be considered that no one else could access to its consumption monitoring and control. For shared devices, sometimes it is needed to put a limit on number of owners and define privacy not to be accessed from strangers. We believe that security issues is one of the biggest modules to be handled in such a product and meticulous planning and design should be applied for it. Security handler will be the part to deal with such issues. Indeed, the mentioned above tasks are of great importance in the software package.

3.5 Further Extensions

In fact, such a web-based service can be extended to an ecosystem with different tasks and versatilities. Indeed, a lot of new applications could be added when it is in beta. We believe that many interesting applications will arise when it is applied in real life. The software product should be designed systematically to accept further improvements and extensions. Contributions from users to expand its application and services should be acceptable. For different countries, various cultural elements should be included in this software solution.

4 CONCLUSIONS

In this paper, we suggest a software product which provides occupants with a platform that makes them aware of their personal energy consumption in order to encourage them with a helping approach for their behaviors modification towards energy efficiency in buildings. The platform could be accessed through web services on any kind of smart devices and it guarantees real time streaming of energy data and control over personal or shared equipments. It has been proven that in the buildings providing informative and comparative feedbacks can be used as an effective incentive for occupants to adopt energy efficient behaviors.

Such a software product will be fully developed and incorporated in real life examinations. To list some of the future work, it will be expanded to be applied in future smart cities. Also, the effect of nominative information about how occupants personal energy-conserving behaviors is compared with others in the same living space will be tested. Anthropological studies can be conducted using this software solution in order to more deeply analyze human behaviors concerning energy. Study and development of comparative and competitive strategies for efficiently encouragement of users will be one of the most important research areas to invest on.

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