BEHAVIOURAL APPROACH TO REDUCE ENERGY CONSUMPTION IN PUBLIC BUILDINGS

Rabab AKKOUCHE, MINES Paris, PSL University, Centre for Applied Mathematics (CMA), France, +33614018364, rabab.akkouche@mines-paristech.fr
Sandrine SELOSSE, MINES Paris, PSL University, Centre for Applied Mathematics (CMA), France, +33493678917, sandrine.selosse@mines-paristech.fr
Gilles GUERASSIMOFF, MINES Paris, PSL University, Centre for Applied Mathematics (CMA), France, +33493957446, gilles.guerassimoff@mines-paristech.fr

Overview

According to International Energy Agency, buildings and buildings construction sectors combined are responsible for almost one-third of total global final energy consumption and nearly 15% of direct CO_2 emissions (IEA, 2021). In France, public buildings account for 75% of the total consumption of municipalities. Thus, any work that reduces energy consumption in the medium and long terms, beyond renovation, is encouraged both by legislation and by initiatives and support addressed to local authorities. On the other hand, efforts towards raising energy efficiency in buildings have to take into consideration many parameters, the building, its environment, its equipment and above all the behaviour of its users.

The objective of our work is integrating the behaviour of the users of a building in its energy management from the use of IoT and of nudges (Sunstein and Thaler, 2010), a concept from behavioural economics, to encourage energy savings. To do this, experiments and behavioural analyses of building users are particularly useful in order to evaluate the important elements to change in order to manage energy consumption in the building through the dynamic involvement of its users.

The combination of a technological and behavioural approach will make it possible to think a real smart building, making it a key player in the future smart city and the energy transition.

Methods

Because of the important role occupants' behaviour plays in raising or reducing energy consumption in buildings (Sun and Hong, 2017) (Vorger, 2015), especially those where occupants don't have to pay energy bills, it was important to understand behaviors related to occupants actions while consuming energy. We have chosen to study a public building in order to investigate the impact of using nudges, as an actual incentive used by many public policies (Moseley, 2020), on occupants' behaviour in this type of building. The first step was to define the constructs that explain occupants' behaviour based on different theories of behaviour (Ajzen, 1985) (Stern et al., 1999) (Triandis, 1979) (Coulbaut-Lazzarini and Bailly, 2015). A framework based on psychological theories and previous works has been created as a model for our work. The second step was to conduct a survey in the studied building in order to evaluate the different constructs. The objective of the survey was also to know about current occupants behaviours related to reducing energy use in the building. Sociodemographic data was also collected. Based on the pre-established constructs, a k-means clustering was applied to define relevant occupant's profiles depending on their intention to change behaviour, their motivations, and problems that may block energy saving actions. Some constructs were also used in order to attribute theoretically a specific type of nudges to the adequate profile with the hypothesis that it may have more impact on their behaviours. Meanwhile, an experimental study was conducted using sensors to collect data about respondents' consumption of energy while using computers, lighting and some electrical appliances. The building management system was also used to collect data concerning heating set points chosen by occupants and temperatures inside the studied offices and window openings. An interface has been developed in order to send different types of nudges to participants depending on their profiles. The objective of the experimental study is to investigate the link between different profiles, incentives, the adoption of energy saving behaviours and the amount of energy reduction in the building. This study is important to take into consideration as a basis in dynamic thermal simulation to define occupants' activities depending on their profiles. Different types of buildings, energy systems, occupants behaviours were simulated with Comfie-Pleiades, a thermal dynamic simulation tool, in order to investigate the impact of the studied incentives on reducing energy consumption on the scale of the building and then on larger scales.

Results

The survey was a valuable way to identify extra use of energy in the building as well as different profiles of energy users in the building. Energy consuming behaviours were important to identify in order to emphasize on changing them through the investigated incentives. The analysis of data collected from survey responses helped us define five types of energy users especially related to their intention to reduce energy consumption in the building and to adopt energy saving behaviours. (1) Conscious and dedicated to environmental issues users: characterised with a high environmental consciousness, always ready to save energy and well informed about how to do it. (2) Ready to save energy users facing obstacles: they have a high intent to reduce their energy consumption but still face some obstacles such as the priority they give to comfort, laziness, difficulty to adopt some behaviours and others. (3) Responsible but lacking awareness and knowledge users: this type of users is ready to change behaviours but doesn't have enough knowledge and awareness to motivate him taking actions especially that he has a low perception of being able to do it. (4) Aware but escaping responsibility users: This type of users is aware of the need to reduce energy consumption in the building yet escapes its responsibilities to act towards less energy consumption. (5) Indifferent, not ready to change users: They have the lowest intent to save energy in the building. They lack environmental consciousness and are the lowest to adopt energy saving behaviours.

Depending on their profiles and other constructs, we assigned each participant with a type of nudges taking into consideration their preferences (pictures, messages, graphs …) in order to test their impact through experimentation using sensors to evaluate behaviour change as regards the use of energy in the building. The incentives used are as follows (1) Peer to peer comparison, appealing to one's inclination to adopt the same behaviour of one's peers. It will consist of benchmarking energy consumptions and eco-friendly behaviours of other occupants. (2) Feedback and tailored messaging, appealing to one's desire to build an eco-friendly self-image. (3) Cognitive messages, based on giving information in a way that is easily understood (4) Moral Appeal, appealing to one's culpability towards behaviours that lead to global warming. (4) Social reviews, appealing to one's desire of being part of the majority adopting the right behaviours.

Simulating different types of profiles in the same building gave us interesting conclusions about the impact of occupants' behaviour on energy consumption in the building and how using tailored incentives to raise awareness and larger adoption of energy savings can lead to significant energy reduction in the building. The orientation of the building and the type of energy management system play also an important role in defining the annual energy consumption of the building especially when occupants change their behaviour.

Conclusions

While dynamic thermal simulation is largely used as a design tool in order to predict the energy consumption of the building and improve its design, more works aim to introduce occupant behaviour in these simulations in order to have more accurate results and avoid gaps between predicted and real energy consumptions in buildings (Darakdjian, 2017) (Kashif, 2014) (Sun and Hong, 2017). A way to tackle this problem is to educate occupants in order to have common conscious behaviours that ensure a minimum amount of energy consumption in buildings. The objective of this work *is* to estimate the impact of low cost and easy to establish solutions based essentially on changing behaviour beyond major renovation works. This behavioural approach *is* interesting since it conside*rs* occupants depending on their profiles, motivations and adequate incentives to change their behaviour rather than their independent behaviours, which give more possibilities to generalisation of results.

References

IEA (2021), Tracking Buildings 2021, IEA, Paris https://www.iea.org/reports/tracking-buildings-2021

Ajzen, I., 1985. From Intentions to Actions: A Theory of Planned Behavior, in: Kuhl, J., Beckmann, J. (Eds.), Action Control: From Cognition to Behavior, SSSP Springer Series in Social Psychology. Springer, Berlin, Heidelberg, pp. 11–39. https://doi.org/10.1007/978-3-642-69746-3_2

Coulbaut-Lazzarini, A., Bailly, G., 2015. People in Smart Buildings: Daily Practices in Automated Areas, in: Helfert, M., Krempels, K.-H., Klein, C., Donellan, B., Guiskhin, O. (Eds.), Smart Cities, Green Technologies, and Intelligent Transport Systems, Communications in Computer and Information Science. Springer International Publishing, Cham, pp. 104–127. https://doi.org/10.1007/978-3-319-27753-0_6

Darakdjian, Q., 2017. Prédiction des performances énergétiques des bâtiments avec prise en compte du comportement des usagers.

Kashif, A., 2014. Modélisation du comportement humain réactif et délibératif avec une approche multi-agent pour la gestion énergétique dans le bâtiment (thesis). Grenoble.

Moseley, A., 2020. Nudging in Public Policy [WWW Document]. Oxford Research Encyclopedia of Politics. https://doi.org/10.1093/acrefore/9780190228637.013.949

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review 6, 81–97.

Sun, K., Hong, T., 2017. A simulation approach to estimate energy savings potential of occupant behavior measures. Energy and Buildings 43–62. https://doi.org/10.1016/j.enbuild.2016.12.010

Sunstein, Cass.R., Thaler, R.H., 2010. Nudge Émotions, habitudes, comportements : comment inspirer les bonnes décisions.

Triandis, H.C., 1979. Values, attitudes, and interpersonal behavior. Nebraska Symposium on Motivation 27, 195–259.

Vorger, É., 2015. Étude de l'influence du comportement des habitants sur la performance énergétique du bâtiment.