Office Comfort in Smart Cities with Big Data

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Abstract

Two scenarios are outlined for Smart Cities, one in which intelligent systems manage data flows in the city and provide centralized control, the other approach is bottom-up, and is based on empowering citizens to create meaningful links to information and utilize big data in useful and perhaps unforeseen ways. In this paper a vision and work to date aimed at reducing office greenhouse emissions in Amsterdam, as a large scale living lab test environment, is described. The goal is to enable office workers in open or closed spaces to democratically share and control comfort settings while being aware of and reducing energy consumption. A combination of self-reporting inputs and sensor data is used to reflect upon and create an aggregate view on office indoor climate comfort. Using meta-data at the city level, changes in occupancy energy behavior between similar building types and functions could be made observable.

Author Keywords

Sustainability, Big Data, Office Comfort, Smart Cities

ACM Classification Keywords

H.5.m. Information interfaces and presentation. H5.3. Collaborative computing.

Introduction

The commercial and residential building sector accounts for 39% of carbon dioxide (CO_2) emissions in the United States per year, more than any other sector. U.S. buildings alone are responsible for more CO_2 emissions annually than those of any other country except China. Most of these emissions come from the combustion of fossil fuels to provide heating, cooling and lighting, and to power appliances and electrical equipment [1].

The growing number of office workers in cities will negatively impact urban CO_2 emissions. Today over half of the world's population (54%) lives in urban areas. The proportion of the world's population living in urban areas is expected to increase, reaching 66 per cent by 2050 [1].

Reducing CO2 office emissions

While sustainable building technologies can help reduce CO_2 emissions, changes in office occupant behavior can also contribute to CO_2 reductions. For example, Staats et al, [2] were able to decrease natural gas use by six percent and maintain such reductions by having office workers make two simple behavioral changes, namely uncovering radiator grates and maintaining office radiators at equal settings. Similarly, a five percent reduction in campus energy over 12 months was achieved at Loughborough University through the "it's better off" campaign [3].

A range of methods for creating awareness and behavioral change among office workers with an emphasis on organizational factors and staff roles is described in the UK Carbon Trust Campaign management guide [4].

Democratizing office comfort & energy use

Rather than relying on fully automated systems to control heating as a top-down approach to managing building comfort, there is a potential for energy savings by enabling building occupants to regulate their own building comfort, while taking measures such as turning off heating in unused space or wear a sweater to work.

Participatory sensing has been adopted by the energy building research community as a means to develop energy performance systems that respond to real time comfort needs of occupants. Thermovote [6] is an example of this research effort. With the goal of overcoming the burden of predicting comfort via methods such as Predicted Mean Vote (PMV), Thermovote uses humans as sensors to adjust temperature more accurately through inputs based on occupant comfort preferences. Whereas the aim of such work is on optimizing temperature management and control, the socio-technological approach presented here seeks to empower a community of occupants such that they can reflect on and manage their energy and comfort related practices.

As a bottom-up approach, energy feedback combined with community-based approaches has been proposed for residential smart grid communities [5]. This could include for example, facilitating interaction between end-users, thus making social norms explicit and stimulating cooperative activities or challenges within a community. A similar approach could be applied to buildings in cities in which open data can be accessed.

The availability of big data at the city level implies that building occupants could become aware of office energy behavior in similar buildings. A framework is required to enable sharing of energy data. To this extent, the ongoing work described in this paper is being developed as a project in the recently founded Amsterdam Metropolitan Institute (AMS). As a Living Lab in the city, AMS fosters the creation of urban solutions, in areas such as water, energy, waste, food, and data management, through the collaboration of academic and research institutions, enterprise, municipalities and local residents. AMS is linked to the Amsterdam Smart Cities Big and Open Data project [7].

Sensor Nodes & Self Reporting

To collect data relating to office comfort, including sound levels, light, CO_2 concentrations, fine particles, air temperature, and humidity, a custom wireless sensor was developed and piloted in local offices (Figure 1). The sensors run on a XBee Series 2 ZigBee mesh network, which provides a robust infrastructure. All of the data is sent to remote servers, with a database to analyze objective sensor data linked with subjective self-reporting data as described below.

Users can provide subjective comfort feedback via a self-reporting application and can comment on the objective data. Through an interactive design process the self-reporting application is being developed as a co-creation design process with companies. Initial workshops have shown office workers have a desire to gain insights into comfort, which can serve as a channel into shaping energy behavior. The goal of the customizable application is thus to enable office workers to reflect on the objective data and report on their own sense of office comfort. Furthermore, the application is being developed to provide comparative statistics for similar buildings and office types in the city. In an earlier study a physical comfort dial was tested in residential settings to report subjective comfort (Figure 2). In the residential context an aquarium like metaphor was used to reflect objective temperature (color of main fish) and subjective comfort (color of smaller fishes) in relation to the eco system. Fogy water was equated to CO_2 levels and the number of plants to level of humidity. The number and flow of bubbles was related to energy consumption (Figure 3).

Figure 1. Wireless sensor node for measuring office comfort.

Figure 2. Wireless dial to report subjective indoor comfort.

Figure 3. Equarium metaphor equates the eco-system with environment. Multiple fishes are used to reflect the subjective comfort of a number of office workers. The fish is also able to give messages, and collect feedback from users.

Next Steps

Smart City infrastructures, including open energy data, can enable citizens to share and reflect upon their energy behavior. In order to enable such a social-technical systems, whereby comparisons between departments in a given building or between buildings in the city can be made, a database of performance benchmarks related to the type of office activity and layout will be required. The average amount of energy per square meter can be calculated from building specific Meta data. Rich and intuitive data visualization metaphors will be required to enable communities to reflect on common energy related behavior. Upcoming pilot studies work will focus on evaluating the impact that a bottom-up approach may have on energy behavior and a potential CO_2 reduction, given the ability of office workers to share and reflect on energy related practices and building comfort. Building comfort is an area of common concern for occupants across building types and can serve as a motivator for self-reporting at the community level.

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