Energy and Buildings 76 (2014) 661–668

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Saving energy when using air conditioners in offices—Behavioral pattern and design indications

Xiangling Zhuang[a,b], Changxu Wu[a,b,*]

[a] Chinese Academy of Sciences, 52 Sanlihe Rd., Beijing 100864, China
[b] State University of New York at Buffalo, 3435 Main St, Buffalo NY 14214, United States

ARTICLE INFO

Article history:
Received 7 March 2013
Received in revised form 26 October 2013
Accepted 9 November 2013
Available online 27 November 2013

Keywords:
Government regulation
Temperature sensation
Behavioral pattern
energy saving
Health

ABSTRACT

Air Conditioners (ACs) in office buildings consume so much energy that the Chinese government enacted a regulation to limit the temperature setting range. To evaluate its effectiveness and provide clues for new behavior change methods, the study surveyed 527 office workers' knowledge of the compulsory approach, temperature sensation and preferences. The latter is included to evaluate the reasonableness of the regulation. Their actual behaviors covered in this survey include factors influencing temperature setting, operating patterns in setting, and readjusting behaviors after setting. The aim is to find possible ways to encourage higher temperature setting and correct operation. The results show that although the regulation is reasonable (within the [26 °C to 28 °C] range), more than half of the users violate it with an average setting at 24.9 °C. The low awareness of the regulation (31.9%) can only account for part of the ineffectiveness: people with knowledge set higher, but still below 26 °C. The survey also found some non-comfort motivations that can be potentially used to encourage higher temperature setting: personal health, noontime napping, connecting with nature, and protecting the environment. On the contrary, office workers would set the temperature lower when they first entered the office. It should be noted that office workers strongly consider colleagues when setting the temperature, but generally do not consider electricity consumption. Some of their operating patterns should also be paid attention like setting a low initial temperature; and constantly shutting off and turning on the AC. The discussion includes applications of these findings in terms of enhancing user motivation and simplifying thermostat operation.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

1.1. Energy problem: ACs play a large part

With a higher standard on the thermal comfort, people are relying more on air conditioners (ACs) to gain comfort in modern life. In developing countries like China, ACs are covering increasing building areas. According to [1], the sale of air conditioners is currently increasing at a 20% annual rate in China. This leads to a rapid growth in energy consumption by ACs. For example, in Shanghai, one city of China with a hot summer and cold winter climate, central air conditioning consume almost 31.1% of the total energy consumption in large-scale public buildings [see in [1]]. The energy challenge also exists in developed countries where HVAC almost consumed half of the energy in buildings and 20% of the overall national energy consumption [2]. Both residential and commercial buildings contributed to this consumption [2], and among them, office buildings have a large share. In office settings, people are not as free as they are at home where they can change clothes easily or open windows when they want, thus increasing the possibility of air conditioner usage. Hwang et al. [3] showed that 57% of office workers chose to turn on air conditioners over other approaches to make themselves comfortable, as compared to only 16% in residential homes. Therefore, it is important to decrease the energy consumption of ACs in office buildings.

Although various ways including technological innovation can decrease energy consumption of ACs, changing user behavior is critical to energy saving. In fact, researchers have constantly found a "rebound effect" of energy efficient products [4,5]: people use the products more when they know the products are energy efficient. Studies in residential houses also showed that electricity consumption varied a lot with user behaviors [6–9]. The consumption sometimes can be as high as 4:1 in identical houses [10]. Therefore, this study aims to survey office workers' ACs using behavior, seeking chances to save energy via behavior change. Since in most Chinese cities, the electricity shortage usually happens in hot summers when ACs are pervasively used, the target behavior is limited to the summer season.

* Corresponding author. Tel.: +1 000 1000000.
E-mail address: changxu.wu@gmail.com (C. Wu).

0378-7788/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2013.11.042

1.2. Two possible behavioral changes to save energy

Due to the reliance on ACs to cool off in offices [3], behavior changes for energy saving had better focus on changing the process of operating instead of trying to reduce using. This leaves us two possible behavior changes: set at a relatively higher temperature, and adopt correct operating patterns.

1.2.1. Increase the temperature when setting air conditioners

Higher temperature setting is not easy to obtain because thermal comfort is usually the most important motivation to use ACs, and it can only be attained within a temperature range. The first way to overcome the comfort need is resorting to compulsory forces. The regulation on AC temperature control from the State Council of China is one of these restrictions [11]. According to the regulation, in public places including offices, temperatures should be set at no lower than 26 °C in the summer. Although the regulation has been disseminated via various media forms, the effectiveness of the regulation hasn't been evaluated. Previous studies on government restriction hasn't been successful as expected: Luyben [12] found that only 27% of the families responded to the president appeal on the thermostat setting, and those who knew the appeal did not behave differently from those who did not. The author concluded that room temperature might be more important than antecedent conditions like appeal or price. This is supported by another study where people did not follow the government suggestion of setting at 28 °C and use the ACs along with fans to cool off in the summer [3]. People simply did not want to adopt this measure at the sacrifice of their comfort. Judging from these evidences, the awareness of rules is only a necessary but not sufficient condition of behavior change. It must be reasonable in terms of comfort. Therefore, besides the investigation of office workers' knowledge of the regulation and actual setting, their temperature sensations and preferences were also addressed in the study to get a proper range of temperature settings.

Government regulation is an external reinforcement of setting high temperatures, but users do have internal reasons that can be enhanced to deviate from the most thermally comfortable setting. According to Fanger and Toftum [13], thermal comfort is determined by air temperature, air humidity, mean radiant temperature, relative air velocity, activity level and thermal resistance of clothing. However, Williamson and Riordan [14] found that about 25% of the heating or cooling events were due to non-comfort factors. One of the prominent factors is the energy cost. In fact, this is the underlying logic of some feedback-based interventions [15–17], which promote energy-saving settings by informing people of their consumptions. However, these interventions are designed for residential buildings where people pay their own electricity costs. In the office context, energy cost may not remain to be a good motivator because they do not pay for it [18]. Besides the energy cost, people's actual behaviors may be determined by factors like care for environment and other people. For instance, environmentalists do not feel comfortable in hot summer weather as other people, but they prefer to set the temperature high to avoid high CO_2 emission, whether it is at home or in offices. Apparently, the feedback device displaying the factor the users concerned most will be the most effective. Hence, this study surveyed the factors that affect people's AC settings to find the potential best-performed motivators in feedback devices. On the contrary, those factors urging lower temperature settings were also investigated for restriction purposes.

1.2.2. Adopt correct operating patterns of air conditioners

Temperature is not the only setting that can be controlled by office workers. A thermostat is usually also equipped with the functions of adjusting wind speed, humidity, etc. Programmable thermostats also have scheduling features that allow people to program the ACs to run or shut off at certain times. Judging from this, a good combination of these features can save a lot of energy. For instance, office workers have relatively fixed schedules, so it is very suitable to time the ACs in case they forget to shut them off. However, it has been found in residential houses that the use of the schedule features in programmable thermostats is limited [19]. In office settings, the usage of the programming function and other features still need investigation to find possible energy saving opportunities.

Setting a thermostat is not the end of thermal context control. Due to the delayed feedback from room temperature change and general misconceptions, people usually find their initial setting inappropriate and have to adjust again after some time [20]. In this process, inappropriate operation patterns may lead to energy waste. For instance, when operating air conditioners at home, a popular misconception is that the lower the setting, the faster the air conditioner will cool the room [21,22], so the corresponding behavior may be setting the thermostat at a low temperature and setting it back when it cools off. Readjusting patterns like this need to be explored to check whether office workers have the same problems.

To sum up, ACs consume lots of energy in office buildings, contributing much to summer electricity shortages in China. To change office workers' behavior in terms of setting higher temperature and adopt correct operating patterns, this study first evaluated a compulsory approach to save energy and then checked its reasonableness considering temperature sensation and preference. To find out internal factors that can be enhanced by feedback devices to promote voluntary behavior change, the questionnaire also included items focusing on non-comfort factors that may influence office workers' temperature settings. Current AC operating patterns were also addressed, including the functions used and the readjusting behaviors. Section 2 of this paper introduces the development of the questionnaire and the distributing process; this is followed by the results of knowledge about the compulsory regulation, temperature sensation, internal factors that influenced temperature setting, and operating patterns. Finally, the indications for designing energy saving thermostats are discussed based on the findings from the survey.

2. Method

Questionnaires were used to address the topics above. As adopted by Lin and Deng [23] and Frontczak et al. [24] in thermal environment studies, this method is well fit for exploring people's knowledge and behavioral patterns. However, the survey is different with current studies in sensation measurement [e.g. 25, 26], thus needing further remarks. The temperature sensation in this study is not the sensation when people are answering the questions (under certain contexts), but perception of temperatures in general. Although personal activity, clothes, sunlight, etc. also affect people's sensations, they cannot be isolated from temperature in practice. In daily life, people build a match between the sensations resulting from the mixed effects of all these factors and temperature information gathered from thermostat displays. The government regulation on temperature setting also only restricts the "temperature", considering all other factors as the typical contexts people are usually in (i.e. background context). Therefore, to evaluate the reasonableness of the regulation, general rather than specific temperature sensations should be rated based on personal experience.

Download English Version:

https://daneshyari.com/en/article/6733982

Download Persian Version:

https://daneshyari.com/article/6733982

Daneshyari.com