



On the behavioral effects of residential electricity submetering in a heating season



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ABSTRACT

In general, occupants' only visible connection to their energy consumption is the bimonthly or monthly statements that summarize the cost of their energy use. However, a quarter of Canadian households do not directly pay for their energy bills. Instead, the landlord, property manager, or the condominium corporation are responsible for energy bills. As such, there is no monetary incentive for tenants to make energy-saving retrofits or modify their behaviors to save energy. In this study, a questionnaire survey was carried out with 20 participants who were responsible for their energy bills and 20 participants who were not responsible for their energy bills. Temperature loggers were placed in the living rooms and bedrooms of these participants' apartments during two consecutive heating seasons in Ottawa, Ontario. Results showed that occupants who were responsible for their energy bills were more diligent and active in controlling indoor air temperature. These occupants chose to heat different areas of their units at different times. On the contrary, the occupants, who were not responsible for their energy bills, rarely adjusted their thermostat settings or setback their thermostats. Furthermore, the occupants who were not responsible for their energy bills maintained their apartments about 2 °C higher than their counterparts who were responsible for their energy bills.

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1. Introduction

A major challenge in promoting residential energy conservation, as stated by Brandon and Lewis [1], is to increase the visibility of energy consumption in homes and occupants' awareness to the connection between their behavior and financial/environmental consequences. Typically, occupants' only apparent connection to their energy consumption is their bimonthly or monthly statements that summarize the cost of their energy consumption. However, the Survey of Household Energy Use (SHEU) in 2007 revealed that 26% of the Canadian households (3.1 million households) were not responsible for their energy bills [2]; instead the landlords, property managers, or the condominium corporations were responsible for any energy bills. Similarly, the rental agent survey within the residential energy consumption survey (RECS) in the United States reported that 829 out of the 12,083 respondents were not responsible for their utilities [3]. In this paper, we define

this group as the households living in bulkmetered buildings. All others are defined as the households living in submetered buildings.

Levinson and Niemann [4] reported that rents and monthly condominium payments are notably higher in bulkmetered apartments compared to submetered apartments, however the premiums that bulkmetered apartment renters are willing to pay typically exceeded the cost of their energy consumption. This suggests that tenants place significant value on having the freedom to use energy freely without concern for monetary consequences. However, occupants failed to see this implicit cost of energy—perhaps due to a lack of feedback on household energy consumption [5–7]. In fact, this lack of energy use feedback may result in significant impacts on residential energy consumption [8]. Anecdotal evidence [4,8–12] suggests that submetering of household utilities, as opposed to including energy costs with rent or condominium payments, can result in 30% energy savings. For example, the monthly electricity use metered in a large electrically heated/cooled residential building (280 units) near Toronto, Ontario is shown in Fig. 1. In these apartments, the heating and cooling were provided through terminal units controlled by the

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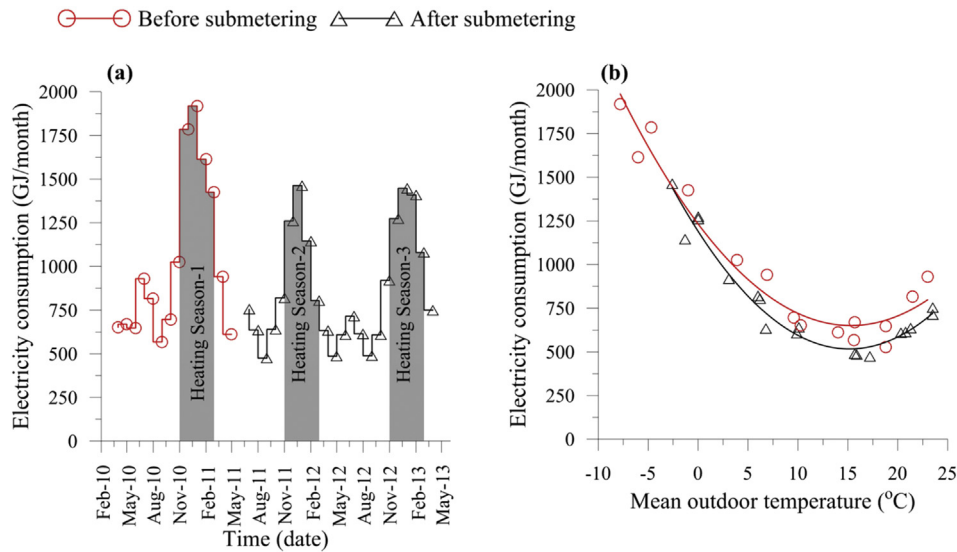


Fig. 1. Electricity use of a large electricity heated building in Toronto, Ontario before and after submetering with respect to (a) date and (b) mean outdoor temperature (outdoor temperature data was taken from Environment Canada [13]).

residents of each apartment. The building was bulkmetered until June 2011 and, then, it was retrofitted with submeters in each unit. No other retrofits in the envelope or HVAC systems or change in the level of occupancy were reported for the building. The monthly electricity use with respect to the mean monthly outdoor temperature data reported by Environment Canada [13] is shown in Fig. 1b. Once the data (see Fig. 1b) were fitted with two second-order polynomial models, both of them resulted in a coefficient of determination of 0.95. By observing these polynomial curve fits, it can be seen that the baseline electricity use during the shoulder seasons and the electricity use during the heating season decreased notably after submetering. In line with these observations, Maruejols and Young [14] analyzed SHEU data in 2003 [15] and reported that bulkmetered households consumed significantly higher energy, maintained their units at higher temperatures during the heating season, and were less likely to undertake adaptive measures, such as clothing level adjustments and night-time or holiday thermostat setbacks. However, it should be noted that the SHEU in Canada is not designed for such high resolution information. For example, to reveal temperature preferences during the heating season in 2003 SHEU [15], participants were asked to answer the following question:

At what temperature did you usually maintain the largest heated area in your dwelling in the daytime (roughly 6 a.m. to 4 p.m.), in the evening (roughly 4 p.m. to 11 p.m.), at night (roughly 11 p.m. to 6 a.m.)?

It is difficult to draw quantitative conclusions based on this question for numerous reasons: (1) the indoor temperature is a spatiotemporal distribution rather than a single number. (2) In 2007, about 10% of the households did not own a thermostat [2]. (3) It is likely that the setpoint readings of the HVAC unit (possibly further corrupted due to miscalibration) were perceived as the temperature of the living space [5,16]. These findings and observations formed the basis for the following research questions: (1) do occupants apply adaptive measures (e.g., turning off lights and idling appliances, clothing level choices, window and blind adjustments) more consciously and responsibly, if they are responsible for paying their own energy bills? (2) Does living in a

bulkmetered, instead of a submetered, building affect occupants' indoor temperature settings?

The current paper presents an observational investigation of forty occupants living in submetered and bulkmetered buildings in Ottawa, Ontario to reveal behavioral, attitudinal, habitual, and perceptual differences about heating energy use, as posed in the first research question. Furthermore, the indoor air temperature was measured during the heating season in the living rooms and the bedrooms of participants. These data were analyzed to answer the second research question.

2. Methodology

2.1. Participants

Participants in this study were largely university students or young professionals living in small downtown dwellings (one or two bedroom apartments) in Ottawa, Ontario. After receiving approval from the Research Ethics Board to conduct the study, participants were recruited using postings left on the bulletin boards of six high-rise residential buildings. These buildings were all constructed during 1970s with similar construction characteristics. The study's sample is comprised of a diverse group of participants (e.g., nationality, age, sex) living in different types of apartments (e.g., storey, facade orientation). However, before the recruitment process the key characteristics that can bias the study's results were identified. These were reported as the age and gender of the participants [17], the duration that participants lived in Canada and in their apartments [18], the apartments' facade orientations, and the storey number [19]. Thus, particular attention was paid to preserve the distribution of these characteristics in both groups (see Table 1).

Forty participants, each living in separate apartments, were recruited. Of these, 20 were living in bulkmetered apartments and twenty were living in submetered apartments. Heating systems in all the apartments were packaged terminal units with electric heaters and baseboard heaters. All participants had control over these heating systems to maintain their preferred indoor environment. Baseboard heaters were provided with a separate control in each room and controlled by the occupants with an adjustable

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