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Case Study of Smart Meter and In-home Display for Residential Behavior Change in Shanghai, China

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Abstract

Smart meters and in-home displays (IHD) have been recently adopted to help give residential consumers more control over energy consumption, and to help meet environmental and security of supply objectives. The paper aims to identify the effectiveness of smart meters and real-time IHDs in reducing Shanghai household energy consumption through a pilot investigation. The research results demonstrate the improved awareness, understanding, and attitudes towards the energy saving by smart meters and IHDs.

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Kyewaords: Smart meter; In-home display; Residential; Behavior change

1. Introduction

In the context of growing global concerns about climate change and energy security, energy saving would become the priority within China's energy policy over next a few decades. In China, the building sector is fully aware of its huge responsibility in being the highest energy consumer and the main contributor to carbon emissions. Nowadays, the primary energy demand in built environment mainly comes from electricity. Thus, reducing the electricity demand in buildings have become a priority and a challenge, as seen throughout the recent national research and low-carbon economic plans.

With the development of information and communication technologies (ICTs), new strategies options for energy saving have been brought forward, such as smart meters and real-time in-home displays (IHD),

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which link through individuals, technologies and society, and their effectiveness to the energy saving have been already demonstrated in the UK [1, 2]. The article would implement the smart meter and IHDs in Shanghai, China, to indentify the residential behavior behind electricity consumption. The research result is expected to lead people to become more aware of their energy consumption, change their corresponding behaviors, and provide social-technical basis for future economic leverage of government and the bidding competiveness of power-related industries. Fig 1 shows the main objects of the research.

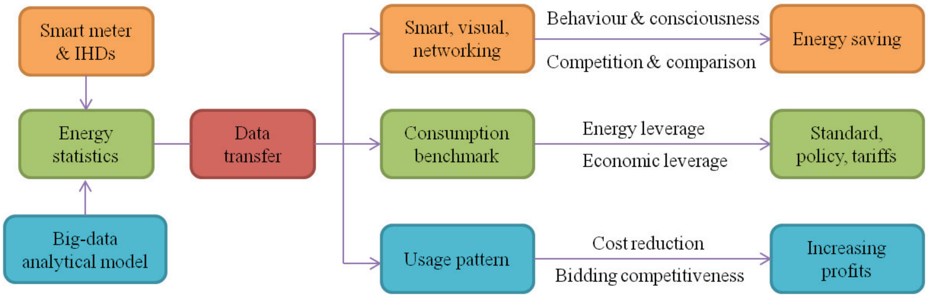

Fig 1. Primary research objectives of the smart meter and IHD

2. Description of the project

2.1. Technologies of smart meter and IHDs

Fig 2 presents the real images of some devices that were utilized in this system, such as IHD, smart meter and their onsite installation. Schematic of the smart metering and IHD framework is illustrated in Fig 3. The whole system includes the smart metering unit, IHDs, data transfer network (ICT), three databases, statistical analytical unit, web server and customer computers. The electricity data is collected by the smart meter from the individual electricity box of each household and further transmitted to the IHDs and the GPRS terminals through the ZigBee network. Thanks to the GPRS terminals, a remote and secure transmission of the electricity data to the databases can be achieved. There are three databases established in this system: the first database is to store the raw electricity data from the GPRS terminals; the second database is designed for storage of the statistical data; the third database has the function to store the background information, such as customer account, household information, home appliances, building location, collecting point IP address etc. A website based interface (http://www.ihomee.com.cn/) is also involved for customers to check energy bills, compare local energy utilization, save history electricity data, and seek potential energy-saving suggestions.

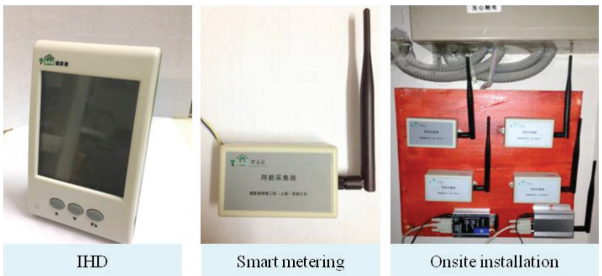

Fig 2. Real images of IHD, smart meter and onsite installation

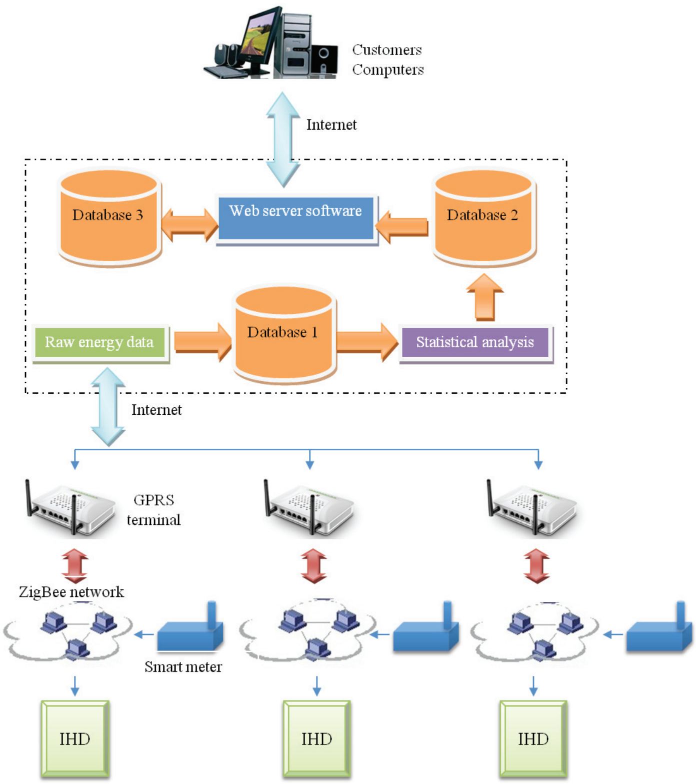

Fig 3. Framework of the smart metering and IHD networks

2.2. Project operation

The project was carried out at two new-built apartments in Shanghai, China. The original research sample comprised 172 respondents but with only 131 effective samples at the standard apartments, which was arranged as 2 groups for discussions: 76 without IHD and 55 with IHD. The sample was designed to embrace a spread of family number, age, income, gender, occupation and area. As this is the first pilot project, the sample size will increase during further investigation. A checking responder was specially designed inside the IHDs which would automatically record the customers' checking frequency per day (multiple IHD checking in 5 minutes is regarded as 1 checking). There were 4 smart metering device installed on each floor while only 1 GPRS terminal installed in each building. The data collecting frequency is set at 15 minutes currently. Although the whole system starts to work from May 2013, some missing data still occurs during practical operation. As a result, we selected a group of relatively complete electricity data in whole November 2013 for detailed analysis in this article.

3. Results and Discussions

3.1. IHD checking frequency

The IHD checking frequency was initially analyzed in order to determine whether the basis of social-behaviour energy-saving method was established. The IHD checking frequency in one single household is summarized in Fig 4. It was found the IHD was checked by a single household maximally 8 times/day and averagely 1.57 times/day. The monthly average IHD checking frequency in one single family was about 4.83 times/day in maximum and 1.56 times/day in average. The standard deviations of checking frequently in one single household were 2.66 in maximum and 0.93 in average, which illustrated that the data were very concentrative. However, there was also some household who didn't check the IHD at all. The total checking frequency of all the collecting samples against the recoding date is given in Fig 5. The checking frequency varied from nearly 210 times/day to about 280 time/day, which was a little bit higher at the beginning and the end of the month. This phenomenon may be due to the economic habits of customers at that moment, such as available date of energy bills, salary data and pressure for payment of credit cards. The checking frequency was observed much lower in the mid of the month when the fatigued state of mind may occur and most customers would ignore the IHD reading instead.

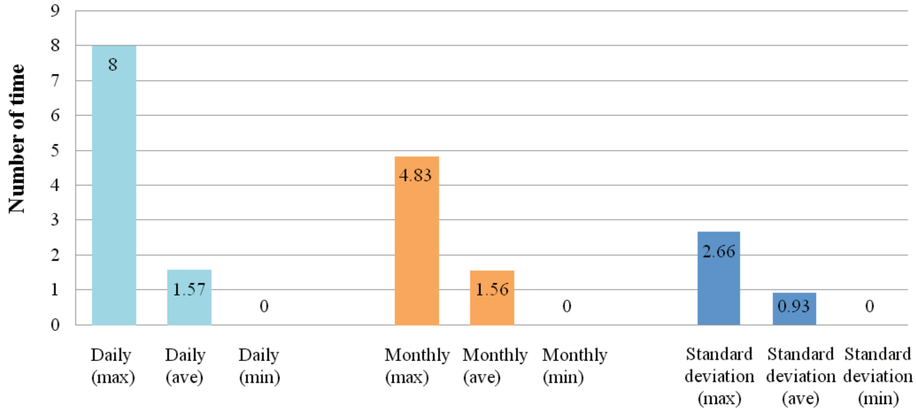

Fig 4. Average IHD checking frequency by one single household

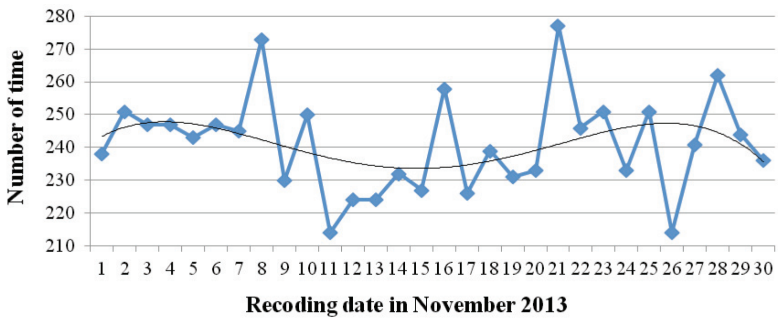

Fig 5. IHD checking frequency of total household samples

3.2. Electricity energy saving

The direct comparison results in electricity energy saving between the two groups with or without IHD are shown in Fig 6. The monthly average electricity consumption by a single household with IHD was about 91.0 kWh while it increased to nearly 100.1 kWh in a single family without IHD, leading to around 9.1% in reduction of electricity consumption. The maximum electricity consumption in the household without IHD reached nearly 287.5 kWh while only 180.6 kWh was found in the household with IHD. The standard deviations of monthly electricity consumption in one single household indicated the data were discrete to some extent. Although the minimum electricity consumption in the household with IHD was higher than that without IHD, which might due to the longer home stay or other factors, the positive impact of the IHD can be easily observed from the average, maximum and standard deviation values.

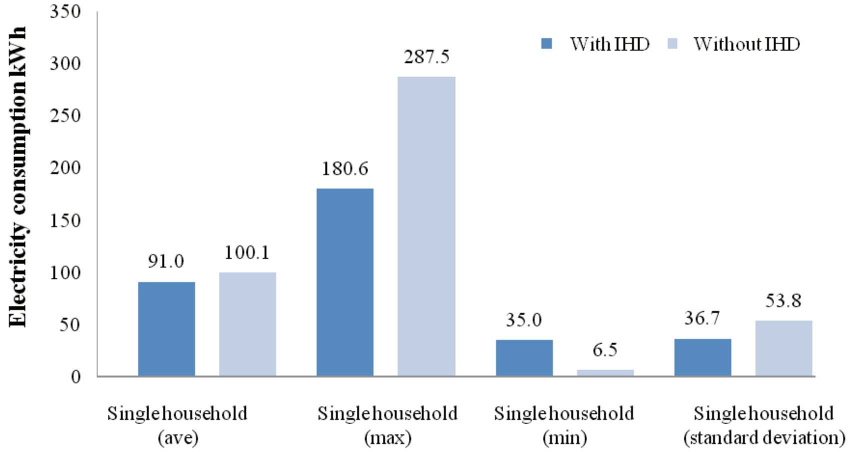

Fig 6. Monthly electricity consumption of a single household with or without IHD

3.3. Standby power saving

Standby power is regarded as another important energy-saving potential in domestic. Comparison results in standby power saving between the two groups with or without IHD are given in Fig 7. The daily standby power by a single household with IHD was only about 27 W while it was high to nearly 31 W in a single family without IHD, yielding around 12.9% in reduction of standby power. This result also partially explained the overall electricity saving by the IHD and further demonstrated the positive impact of IHD on people's behavior change.

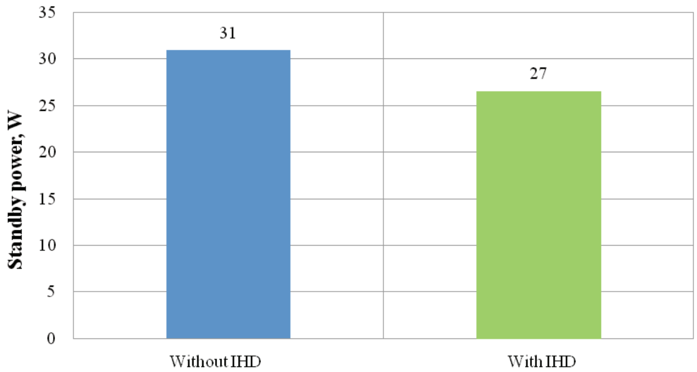

Fig 7. Daily standby power of a single household with or without IHD

3.4. On-peak and off-peak power

The on-peak (6:00 – 22:00) and off-peak (22:00 – 6:00) power comparison between single household with or without IHD are presented in Fig 8. It is easily seen that the household with IHD has a much smoother variation of up to 300 W powers and the maximum power appeared in off-peak period. But the household without an IHD showed a sudden power increase highest to 1600 W during the on-peak period. Some electric activities also occurred in the household with an IHD during the mid night instead of that without an IHD. The overall daily power of the household with an IHD was much smaller than that without an IHD. This also contributed the overall electricity saving by the IHD and proved the positive impact of IHD on people's behavior change.

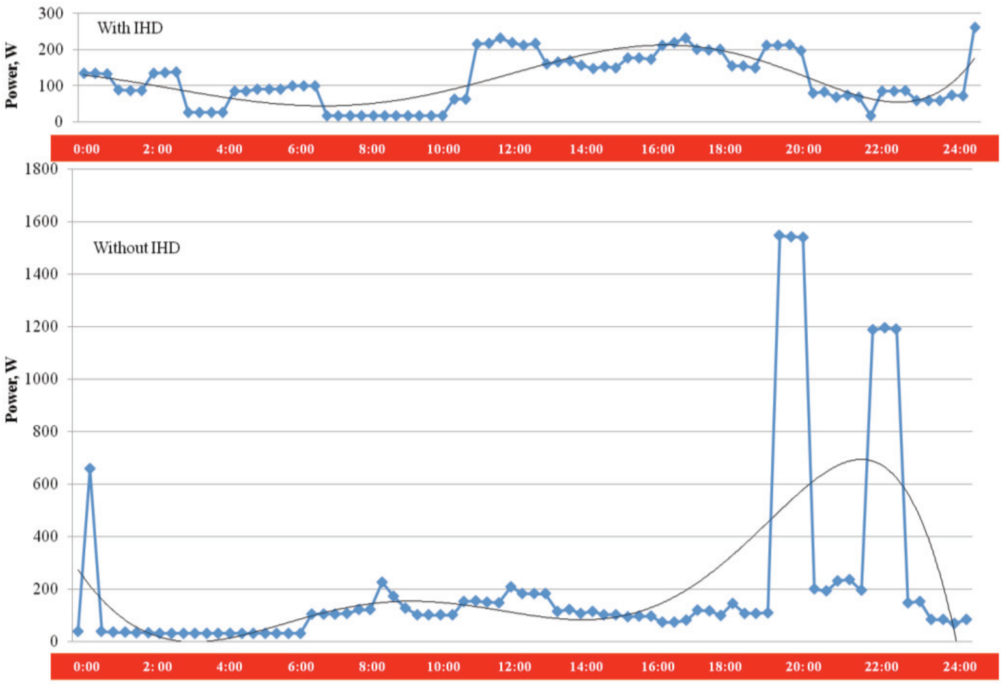

Fig 7. Daily on-peak and off-peak power of single household with or without IHD

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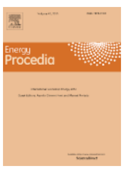

Biography

Dr. Zhang is currently an Assistant Professor at the Department of Architecture and Built Environment, University of Nottingham, Ningbo, China. He has active research interests in solar energy, green-building design and consultancy, simulation and monitoring of building energy performance, energy efficient techniques and building economics.