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Agent based modeling for estimating energy-saving potential of offices under different pricing mechanisms

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Abstract

An agent-based model is developed to estimate the potential of energy savings of an office room under different pricing mechanisms. For this aim, an energy balance model was developed to simulate the operation of air conditioner operation, the heat flux of different behavior and the electricity consumption of different types of appliances according different energy consumption patterns was investigated in detail. The total electricity consumption reduced 3.9%-17.1% under different pricing mechanisms. Light's energy saving potential is the biggest among the electric appliances. The maximum-saving behavior is investigated and the total energy saving potential of it is 26.91%.

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Keywords: agent-based model; energy-saving potential; electricity price; public building; electricity consumption

1. Introduction

Public buildings such as office buildings, hospitals, hotels and shopping centers have contributed to a majority of electricity consumption in urban cities [1]. Indoor electricity equipment, including lighting systems, accounts for a large proportion of the total building energy consumption [2]. Especially in summer, air conditioners (ACs) are widely used for cooling and the energy consumption accounts for about 30% - 50% of the daily electricity consumption [3].

Energy use in buildings is highly dependent on people's behavior [4], which can be significantly influenced by the electricity price. For reducing electricity consumption and promoting reasonable resource allocation and utilization, Chinese government implemented peak-valley pricing (PVP), critical peak pricing (CPP) and tiered pricing (TEP) mechanisms [5]. Regarding the impacts of various pricing mechanisms on the patterns of energy consumption, [6] and [7] evaluate consumers' responses to CPP and

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other dynamic pricing mechanisms. TEP has been implemented in China for nearly four years and is generally considered to have positive effects on reducing electricity consumption [8, 9]. Because people's behavior is random and interdependent, most existing studies are mainly based on statistics of residential electricity consumption and very few studies have investigated the relationship between people' behavior, electricity price and energy consumption.

This paper employed an agent-based model (ABM) to study people's behavior and energy consumption under various pricing mechanisms. ABMs have become an increasingly popular tool for studying energy systems, especially those involving high uncertainty about people's behavior and evolutionary changes in systems[10, 11]. An agent in a building energy system can be used to simulate the actions and operations of occupants and appliances and also the interactions between the occupants/appliances and the environment [12, 13].

The aim of this paper is to develop an ABM to estimate the energy-saving potential (ESP) of an office room under different pricing mechanisms. To this aim, a comprehensive energy balance model was developed to determine the AC's operation pattern, which is further integrated in the ABM. Firstly, the simulation was under single pricing (SGP), AC' consumption at different setting temperature were contrasted, the heat flux of different behavior and the electricity consumption of different types of appliances were investigated in detail. Then, the results under SGP were further compared with that under CPP, PVP and TEP, the ESP of different mechanisms and each appliance were discussed respectively. People's energy saving awareness getting higher while electricity price raising. Finally, we assume that all the people in the model have the highest level of energy saving awareness, the maximum-saving behavior (MSB) and the ESP of it was investigated.

2. Model description

The study developed an agent-based model of an office room to simulate the electricity consumption and investigate the ESP. The empirical data in the model was based on an experiment in an office in the Qianfoshan campus of Shandong university, Jinan, China. The electricity consumption is mainly for the operation of different appliances, such as lights, computers and ACs, which are controlled by the students and teachers. There are 20 persons in the chosen office room, 20 computers, 1 router and 1 printer are the office equipment associated with the users. 1 AC, 1 water cooker and 60 electricity saving lamps are the life assurance equipment in the office room. The model overview is shown in Fig.1. The basic information about the agents and the office room are reported in Table 1. The model was implemented in AnyLogic.

Table 1. Basic information of the agent-based model.

Equipment power(W)							Area(m^2)		
Light	Computer		AC			Base load	Floor	Window	Door
On	On	Standby	On	Standby	Cooling	On			
50	95	45	4000	100	12000	240	91	15.4	3.6

5 types of agents are defined in the model: 20 electricity user agents, 20 computer agents, 20 light agents, an AC agent and a base load agent. Electricity consumptions by other types of appliances like water cookers, printers and routers are combined into the base load. A light agent and a computer agent are associated with a user agent.

Electricity user agents represents students and teachers working in Shandong University. The agents have five states in the model: at home, working, relaxing, eating and meeting. The details about the user agents' behavior regarding electricity consumption in each state and the rules for their transitions between