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Towards a Cognitive Agent-Based Model for Air Conditioners Purchasing Prediction

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Abstract
Climate change as a result of human activities is a problem of a paramount importance. The global temperature on Earth is gradually increasing and it may lead to substantially hotter summers in a moderate belt of Europe, which in turn is likely to influence the air conditioning penetration in this region. The current work is an attempt to predict air conditioning penetration in different residential areas in the UK between 2030-2090 using an integration of calibrated building models, future weather predictions and an agent-based model. Simulation results suggest that up to 12% of homes would install an air conditioner in 75 years' time assuming an average purchasing ability of the households. The performed simulations provide more insight into the influence of overheating intensity along with households' purchasing ability and social norms upon households' decisions to purchase an air conditioner.

Keywords: agent-based modelling, energy behaviour prediction, climate change, decision making, air conditioning penetration

1 Introduction

Climate change causes increases in the annual average surface temperature of the Earth. It is estimated that by 2050 the annual temperature will increase by 4 degrees Celsius (Auffhammer & Aroonruengsawat, 2011). Countries where air conditioning in buildings is not considered the norm are likely to experience increasing numbers of heatwaves during this time. This may influence residents within those countries to purchase Air Conditioning machines (A/C). This is especially plausible in relatively wealthy European countries, for instance France, Germany and UK and in the countries with growing economies in Asia such as China and India.

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According to some forecasting models, (e.g. Isaac & Van Vuuren, 2009), the energy demand for cooling buildings will be much greater than that for heating by 2090. This implies that the future penetration of A/Cs will have a greater impact on climate change than heating because the carbon emissions for electricity are currently higher than the emissions for fuel use for heating. As annual temperatures rise as a result of these emissions, the demand for air conditioning will increase exponentially creating a vicious cycle of rising temperatures. To mitigate these events, the systematic study of air conditioning penetration processes in potential areas is vital. So far this issue has received little attention in Europe and there is no available statistics on the usage of A/Cs at a national level in Northern Europe. Several studies have attempted to quantify and predict air conditioning penetration. Sailor and Pavlova (2003) quantified the relationship between cooling degree days and the penetration level of air conditioners across 39 US cities. Using a similar approach, McNeil and Letschert (2008) modelled the adoption of air conditioning across different regions including Western Europe. They estimated a logistic relationship between penetration rates across countries, income and forecasted air conditioning penetration up to year 2030. Both these studies considered climate and income as influencing factors only, and did not account for dynamic climate change. Auffhammer (2014) extended the model proposed by McNeil and Letschert (2008) using the A/C utilisation data in China and included weather variability as a factor for air conditioning penetration. His findings suggest that "global warming may […] not only lead to higher saturation levels of air conditioners, but also their speedier adoption" (Auffhammer, 2014).

These studies take a population-based econometric approach to modelling air conditioning penetration forecasting and energy demand, by modelling macroeconomic variables and climate variables. This approach provides little insight into the behaviour of individual residents and fails to address the role of social influence. In contrast, we propose an agent-based computational model of air conditioning penetration in three residential areas in the UK. By using agent-based modelling (Jennings, 2000), we strive to simulate the behaviours of individual households and their interactions with the environment and buildings to provide insight into more global behaviour at a population level. This approach is crucial for designing energy reduction interventions and policies aimed at individual households.

Our methodology integrates future weather files, building models and an agent-based purchasing decision-making model. To our knowledge, there has been no research on air conditioning purchasing prediction that considers the building characteristics and resulting indoor overheating intensity. We adopt a psychological model, the Theory of Planned Behaviour (Ajzen, 1991), to model agents as it accounts for the role of social influence (and other cognitive influences of deliberative behaviour). Although the methodology is applicable to other countries, the study was limited to the UK due to the availability of resources.

2 Modelling Methodology

Most models for air conditioning penetration described in the literature are population-based models developed in the econometric tradition. Although these models might make quite good predictions at a global level, due to the great level of abstraction, they lack the transparency of micro-models that model the world as consisting of interactive microelements. Agent-oriented approaches have been widely used for modelling complex socio-technical systems from the micro-level perspective (Jennings, 2000). The essence of agent-based modelling is the agent-oriented world view that implies that the world consists of active, purposeful agents that interact to achieve their objectives. This is particularly relevant for modelling human cognition and behaviour in the context of building-occupant bi-directional interactions. Agent-based modelling can provide more insight into the emergent behaviour of the whole system given the behaviour of its small parts. It is especially important for the application of future policies and interventions aimed at solving the problem at hand.