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Electricity consumption forecasting models for administration buildings of the UK higher education sector

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ABSTRACT

Electricity consumption in the administration buildings of a typical higher education campus in the UK accounts for 26% of the campus annual electricity consumption. A reliable forecast of electricity consumption helps energy managers in numerous ways such as in preparing future energy budgets and setting up energy consumption targets. In this paper, we developed two models, a multiple regression (MR) model and a genetic programming (GP) model to forecast daily electricity consumption of an administration building located at the Southwark campus of London South Bank University in London. Both models integrate five important independent variables, i.e. ambient temperature, solar radiation, relative humidity, wind speed and weekday index. Daily values of these variables were collected from year 2007 to year 2013. The data sets from year 2007 to 2012 are used for training the models while 2013 data set is used for testing the models. The predicted test results for both the models are analyzed and compared with actual electricity consumption. At the end, some conclusions are drawn about the performance of both models regarding their forecasting capabilities. The results demonstrate that the GP model performs better with a Total Absolute Error (TAE) of 6% compared to TAE of 7% for MR model.

1. Introduction

This research attempts to identify the relationship among the daily electricity consumption of an administration building and weather parameters such as solar radiation, ambient temperature, wind speed and relative humidity and also with the type of week day (i.e. either it is a working day or non-working day) for the purpose of predicting the building's future electricity consumption. Electricity is a key energy source and plays an important role in facilitating a country's economic development [1]. In the UK, electricity is generated typically in conventional power plants and contributes to 30% of the UK's total carbon emissions [2]. As a result of the UK government's initiatives, mild winter, energy efficiency and tight economic conditions, electricity consumption in the UK in 2011 decreased by 6.9% compared to the 2007 consumption level [3]. Energy consumption in buildings makes up over 40% of all UK energy use [4]. The higher education (HE) sector in the UK spent £400 m on its energy bills in 2012 [5]. Fig. 1 shows the sector's annual energy consumption for 2009, 2010 and 2011. In 2011, electricity was directly responsible for 63.4% of the HE sector's total carbon emissions [6].

In a typical HE campus, different building types have different energy consumption profiles. e.g. academic or administration buildings will require energy during the day time only whereas a student residential hall or a chemical laboratory will require energy throughout the day. Therefore, for the evaluation of potential energy usage, it is necessary to understand the types of building and categories of space in a university campus. Based on five years data (from year 2003–2004 to 2007–2008) collected from 70 UK universities, the academic space (teaching and research) has seen a 2% reduction from 44.2% in 2003–2004 to 42.2% in 2007–2008. During the same period, the second largest space category, i.e. administration space has risen from 24.8% to 26% [7]. Fig. 2 presents a breakdown of different space types in a typical HE campus in the UK for the period 2007–2008. It is apparent that after academic facilities which occupy 42% of a campus space, administration facilities are the second largest space category with a share of 26% in the UK [7].

Electricity consumption in administration buildings is mainly linked with heating, ventilation and air conditioning (HVAC)

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Nomenclature

AC	air conditioner
CFL	compact fluorescent lamp
GIA	gross internal area
GPM	genetic programming model
HE	higher education
HECI	hourly electricity consumption intensity
HVAC	heating, ventilation and air conditioning
kW h	kilowatt hours
LV	low voltage
MLRM	multiple linear regression model
MR	multiple regression
RH	relative humidity
S	solar radiation
T	ambient temperature
UK	United Kingdom
VIF	variance inflation factor
W_{di}	weekday index
w	wind speed

components, lighting, IT equipment, lifts and other equipment. A small proportion of daily electricity consumption occurs in the appliances used for cleaning, and charging of mobile devices. Major components of a HVAC system include air conditioners, air handling units, fans, pumps and boilers. In the UK, HVAC components are the major electricity users (41%) in administration buildings, followed by lighting (33%), IT equipment (15%) and other equipment (11%) [8].

The financial year in the UK universities runs from 1 August to 31 July. Energy managers are responsible for preparing a budget forecast for their university buildings. To calculate the annual budget for electricity purchase, a reliable forecast of electricity consumption is desirable. Other benefits of reliable electricity forecasting include the followings:

(a) identification of variables having a significant effect on electricity consumption;
(b) identification of electricity saving potential;
(c) estimation of electricity consumption for similar types of buildings;

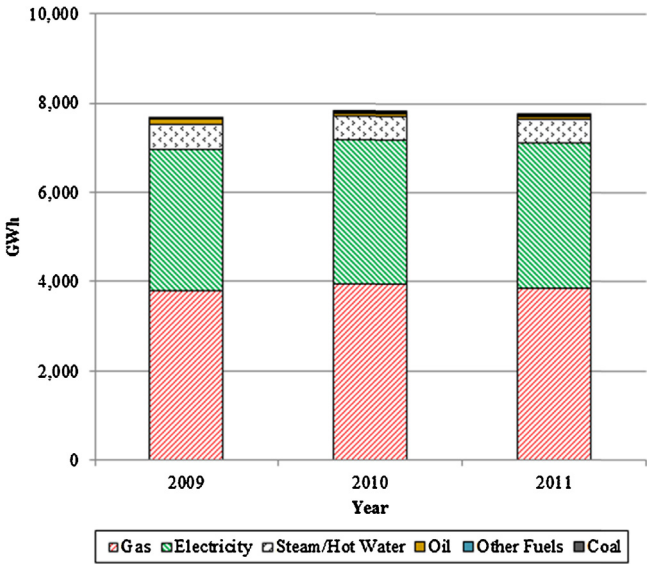

Fig. 1. Energy consumption in the UK HE sector.

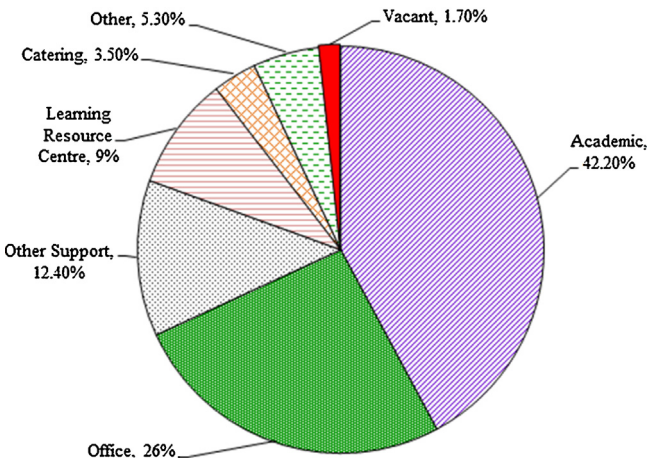

Fig. 2. Breakdown of different space types in a typical HE campus.

(d) policy development and improvement of production and distribution facilities for electricity;
(e) for the utility companies, a reliable model helps in understanding the peak and base load demands of different consumers during the different periods of a year.

An administration type building "Technopark" located at London South Bank University (LSBU) has been considered in this study and its daily electricity consumption data was obtained from the office of the energy manager at LSBU for the period 1 January 2007 to 31 December 2013. Two kinds of models have been developed and tested in this study. One model is based on multiple regression (MR) method and the other model is based on genetic programming (GP) method. Both modeling techniques have been comprehensively discussed with their background and with their advantages and disadvantages in Section 2. Their use in the forecasting of energy consumption has also been discussed in detail with relevant literature review.

2. Background of modeling techniques used

As described in Section 1, a reliable forecast of energy consumption of a building helps the energy managers in a number of ways. Now a day there are a number of building simulation software (e.g. Energy Pro, DOE2) available in the market for the forecasting of a building's energy consumption. However, their use requires a high level of training for the users and simulation requires a comprehensive input data required such as; description of the building layout, constructions, usage, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building energy consumption.

On the other hand there are other statistical techniques such as MR and GP which are relatively simple, reliable, accurate and quick methods to predict the energy consumption of buildings and requires much lesser data compared to the simulation models. In this study two types of models have been developed and used for forecasting daily electricity consumption of an administration building called "Technopark". The first model is MR model while the second model is based on GP. Both models are then tested in order to identify their respective errors.

In the next two sections (i.e. Sections 2.1 and 2.2) we will explain the basics of MR and GP models.