London-
Loughborough Centre
for doctoral research
in energy demand

ANNUAL COLLOQUIUM 2010

Sensitivity and Uncertainty in BREDEM-8 Predictions

Masters Research Project

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Introduction

A research project was carried out to investigate some of the assumptions made about the input parameters used with the building energy model BREDEM-8. To test the model the input parameters were varied by carrying out sensitivity analyses. A single dwelling was used for the project, it was initially considered to be in a poor state of repair, and was then refurbished and altered to determine how this would influence the results.

Aims and Objectives

The project aimed to test the BREDEM-8 model through local and global sensitivity analyses, which would systematically vary the model input parameters to provide a range of possible results.

The main objective in carrying out this project was to determine whether the standard tables of data provided for use with BREDEM models give a realistic estimation of energy use. When information is not known about a building, such as wall U-Value or boiler efficiency, then this information can be found in a table provided for use with the BREDEM models. It is the validity of using such standard tabulated data that is being questioned.

Project Justification

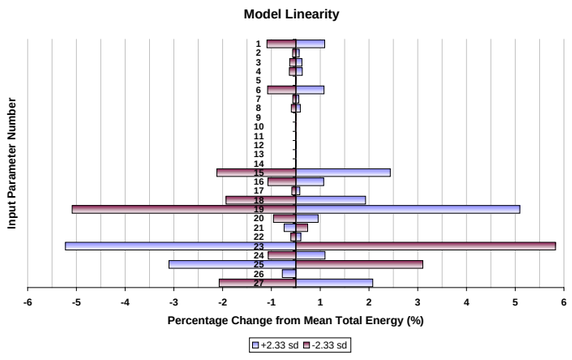
Building models tend to be complex since there are numerous parameters that influence performance; including the building fabric, dimensions, heating system, and electricity use. The task of fully defining all the interactions that occur in buildings is a difficult task, and is still not fully understood. It is essential to test the validity of models, because without validation it is not clear if the model makes useful, accurate predictions. It was considered particularly important to test the validity of BREDEM input tables since the UK government's Standard Assessment Procedure, (SAP and rdSAP), is based on the simplified model, BREDEM-9, which uses the same tabulated data. SAP and rdSAP are used to create Energy Performance Certificates, (EPCs), which must be created whenever a property is built, sold or leased, this is a legal requirement of the Energy Performance of Buildings Directive EPBD (2010).

Therefore the justification for this project is simple: EPC are a legal requirement and their rating is derived from SAP which is derived from BREDEM. The rating on an EPC is generally considered accurate and representative of the building it describes, however for some of these certificates much of the input data could have been taken from standard tables. It is therefore necessary to test some of the assumptions made in these tables, to determine whether they are reliable. During the literature review no information was found that tested BREDEM or SAP tabulated data in this way.

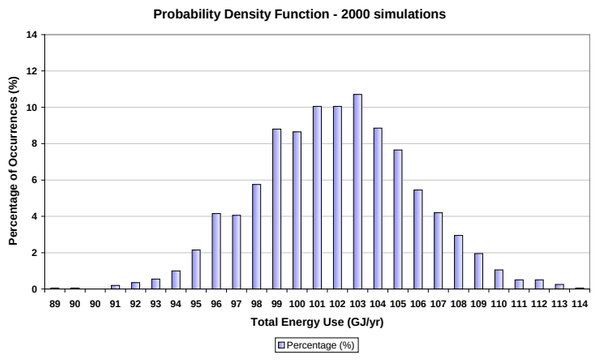
Methodology

During the initial stages of the project an extensive literature review was carried out to look for similar projects, and to search for real measured building data in order to to establish whether any gap exists between the BREDEM tabulated data and real measurements. It was decided that a differential sensitivity analysis, (DSA) and a Monte Carlo analysis, (MCA) would be carried out, to investigate the sensitivity of the model to changes in its input parameters. A post 1919 semi-detached house was selected to test the model as this is the most commonly occurring house type in the UK. The building was first assumed to be unaltered from its initial construction circa 1919; subsequent alterations were then made to simulate refurbishment, a building extension, and changes to the ground floor layout, all of which were considered common modifications. From a total of around 75 input parameters for the building, 27 were chosen to vary, (either continuously or discretely), and the nature of their distributions was defined. The programming language Visual Basic for Applications was used in conjunction with Excel to automate the sensitivity analyses and to save the results. A statistical analysis was carried out on the results.

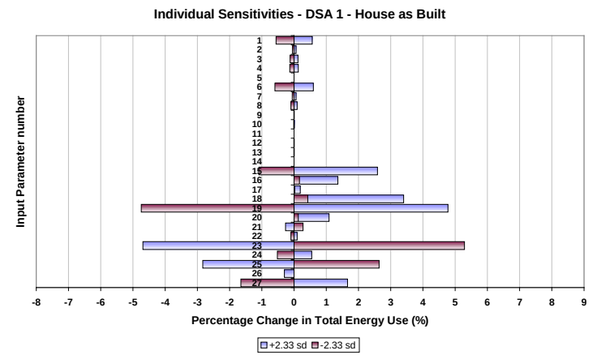
Results



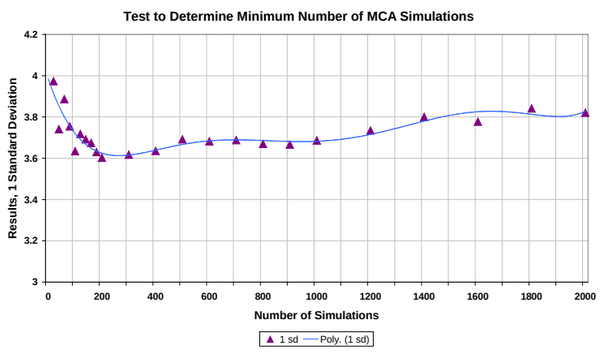
The model responded linearly to changes in most input parameters.



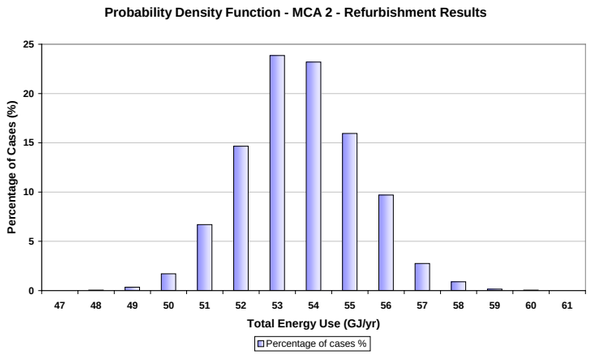
The First MCA showed a large range of possible results implying a large uncertainty. The probability density function is normal in shape exhibiting a slight negative skew.



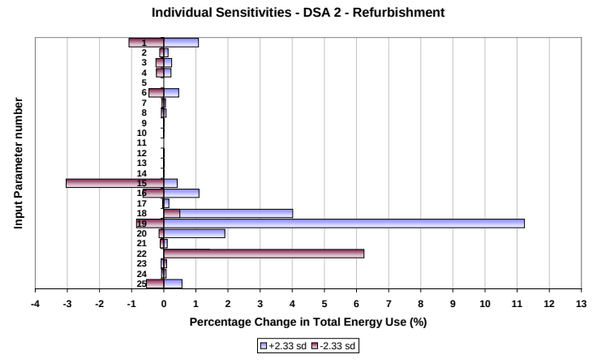
The first DSA showed the model was most sensitive to the inputs with the largest uncertainties: boiler efficiency, external wall U-Value, hot water tank volume and hot water insulation thickness.



The number of MCA simulations required was investigated and a minimum of 2000 specified.



After refurbishment, the second MCA showed a much smaller range of results and hence a smaller uncertainty. The distribution is no longer skewed.



The second DSA also showed the model was most sensitive to the most uncertain inputs: boiler efficiency, external wall U-Value, roof U-Value and pressurisation result.

Conclusions

If was found from the MCAs that the distribution of results depended on the building described; the spread or the results was found to vary as was the skewness. The range of results, and hence uncertainty in results, fell dramatically after the building refurbishment, most likely because the uncertainty in some of the input parameters could be more closely defined, most notably in the hot water cylinder volume and insulation. This finding implies the assumptions made in SAP about inaccessible boilers could result in highly spurious results if the assumption is incorrect.

The base case values from the BREDEM tables were found to significantly under predict the mean energy in the MCAs, however this is likely due to assumptions made about the variation in input parameters. From the literature review is was found that there is not enough data available on real dwelling performance, because so little monitoring is done of the UK housing stock, this needs to change for large improvements in performance to be achieved..

Finally, it is concluded that tabulated data in BREDEM models cannot accurately define the real input values for all the housing stock, buildings are too variable. Instead it is believed that building models should move to incorporate the uncertainties in input parameters, (even small, assumed uncertainties), to give a better prediction by demonstrating a range of results rather than one unique value. The technological capabilities certainly exist to be able to incorporate uncertainties into models easily.