# Heat Replacement Effect factors in Lighting – a review of new evidence

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## *Introduction*

This report reviews recent evidence from practical experiments carried out by the Lighting Association in February 2007 and considers if the HRE factors applied to low energy lighting in BNXS05 (and used in third Energy Efficiency Commitment illustrative mix) should be adjusted.

The heat replacement effect (HRE) is the name given to the process whereby energy savings achieved by reducing appliance consumption are fully or partially offset by a consequent increase in the energy required from the heating system. This occurs because the electrical energy used in appliances causes them to heat up, thus warming the air and other objects around them, contributing to the heating of the building. When appliance energy consumption is reduced, the contribution to space heating is reduced too. Where the temperature of a heated room is controlled by a thermostat the heating system will automatically increase its output in response to reduced heat gains, replacing some or all of the heat. The gross energy saving attributed to the reduced consumption of the appliance in isolation is thus offset by the extra energy required for heating.

## *MTP publications on HRE*

The following relevant publications can be found on the Market Transformation Programme (MTP) website at:
http://www.mtprog.com/SelectProductStrategy.aspx?intSelection=-1&intSector=13

- BNXS05 is the original paper, and discusses the factors that determine the proportion of the energy used by various appliances that will be replaced if their consumption is reduced and gives factors that can be applied easily to gross savings to convert them to savings that take reasonable account of HRE.
- BNXS29 describes the use of a software simulation of a typical dwelling to derive some of the HRE factors that are presented in BNXS05.
- BNXS24 provides a short overview and chronology of the heat replacement effect.

MTP produced these briefing notes because examples could be found amongst national literature which did not take proper account of HRE. In a number of significant projects gross energy savings had been attributed to the installation of energy efficient appliances and lights, leading to an overestimate of the true energy, cost and carbon benefits.

Following an earlier meeting[1] of a group of experts and interested parties, it was decided that it would not be feasible to design and undertake a practical monitoring study where the magnitude of HRE factors could be determined. In order to provide

[1] Notes from this meeting can be found at:
http://www.mtprog.com/ReferenceLibrary/The%20Heat%20Replacement%20Effect%20Minutes.doc

the necessary level of resolution, such a study would have needed to involve a very large number of dwellings monitored for a whole heating season both before and after the installations of low energy lights or appliances. Such a study would therefore be long and expensive, and would still require careful correction for differences between external temperatures and other weather related factors between the years monitored, leaving room for uncertainty. The use of simulation modelling was therefore seen as the only realistic way to derive reliable factors that could be applied to a typical UK home.

## *Discussion of testing work undertaken by Lighting Association Laboratories*

The Lighting Association has said that it believes the HRE factor for lighting given in BNXS05 is incorrect and that it unfairly reduces the carbon savings associated with low energy lights. This is significant because it affects the relative attractiveness of different carbon saving measures installed under schemes like the Energy Efficiency Commitment.

A report, ‘Energy efficient lighting – Practical heat replacement effect tests’, was produced by Lighting Association Laboratories (LAL) in February 2007 to consider whether the HRE factors applied to low energy lighting in BNXS05 (and used in the third Energy Efficiency Commitment illustrative mix) are accurate by undertaking practical experiments.

The following paragraphs consider this work. This is a brief analysis to discuss the overall robustness of the study’s conclusions, not a detailed critique of the methods used.

### Review of experiments undertaken by LAL

The temperature of a test room, roughly the size of a typical living room, was monitored in detail. The room contained a light fitting capable of holding a number of standard or energy saving lamps. The room also contained an electric heater operated by a thermostat on the wall of the room.

Experiments were carried out to measure the energy required from the heater while the number and type of lamps operating was varied systematically. By comparing cases with different levels of lighting, it was intended that the effect of the gains from lighting on heating requirement could be observed. For example, if all other variables were fixed, the heat required in a case with no lighting could be compared to one where lighting was present to show how much less heating is required when the lighting gains are present. The extra heating required, as a proportion of the lighting energy saved, would give the heat replacement factor during the test.

However, it was not possible to keep all other variables fixed during the experiments. Most importantly, the temperature outside the room varied significantly from test to test in such a way that the heat loss from the room would have differed. Variations in the heat required from the electric heater therefore cannot be attributed only to the change in the gains from lighting, which makes it impossible to draw quantitative conclusions about the HRE factor from the experiments. This fact is highlighted by one pair of cases which appear to show an increase in the amount of space heating required when additional lighting energy is provided, which implies a negative HRE factor - clearly not a valid result.

Qualitatively speaking, some of the LAL experiments clearly show that where the energy consumption for lighting is increased the energy required from heating is lower. For example, the results from cases 8, where there are 5 CFLs present and 9, where there are 5 GLS lamps present show a dramatic difference in the amount of heating required from the electric heater, despite the fact that the external temperature is similar in both cases, which clearly indicate that heat replacement is taking place significantly. Other cases also clearly show this (e.g. cases 15 and 16).

Even if the experiments had been undertaken in perfect circumstances it would not be possible to consider the two key factors which underpin the HRE, which both relate to the coincidence between the use of lighting and heating. The first and most important is the proportion of the annual lighting consumption that occurs during the heating season. When the heating is off, which is typically for 5 months of the year for a UK home, there can be no heat replacement effect. The second relates to the proportion of the remaining 75%[2] that is potentially subject to heat replacement. Since some lighting gains occur before or after the heating periods of the day, this is rather more difficult to estimate. It is determined by the efficiency of the building fabric at storing heat released outside a heating periods until the next one begins (e.g. after the heating has gone off for the night). The difficulty in assessing this proportion is the main reason why simulation modelling was needed to obtain the figures in BNXS05. Unfortunately, the monitoring undertaken by LAL provides no additional evidence relating to this.

## Possible improvements if future work is undertaken

Certain alterations could be made to the method used by LAL to make the experiments undertaken more useful, although it should be made clear that this type of study will probably never be able to answer questions that depend on the thermal properties of a real house and on real weather interactions. The following suggestions are made:

- If it is not possible to stabilise the external temperature, it may be possible to limit the discrepancies it causes by only undertaking tests when the temperature is within certain bounds and by devising a correction process, based on a 'degree day' type correction (i.e. by devising the mathematical relationship between the temperature difference between inside and out and the heat requirement of the room).
- Run tests where the heating and lighting is programmed to come on and off at realistic times, as in a real home. This would need to be run for a longer period (perhaps a week). The heat capacity of the room should firstly be adjusted to match that of a real house (perhaps by adding a suitably large pile a bricks). This would allow the proportion of the heat released during the hours when the heating is turned off that is usefully contributing to heating to be assessed. Perhaps then an investigation could be undertaken to consider how useful an hour of lighting gains is at various times of day and night in an house that is heated intermittently.

The suggestions above might allow some further conceptual insights to be made into the factors which affect the annual HRE factor, though they will not be able to show what it should be in a typical UK home, averaged over a typical year.

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[2] Source: 'End use demand profile data (1996-97) from Electricity Association, UK', which shows that 75% of lighting is used during the 7 months when heating is required.

## Relevance of experiments to HRE factors presented in BNSX05

Other than to show that HRE does take place, by demonstrating that gains from lights reduce the need for space heating, the LEL experiments undertaken do not provide any evidence for using factors that differ to those given in BNXS05.

The major assumptions used to derive the HRE factors in BNXS05 were:

- Thermal properties of a typical UK dwelling
- Typical heating demand times and temperatures
- Use of lighting energy by time of day and time of year

The thermal properties of a typical UK dwelling are known well from many years of survey data (e.g. English, Welsh and Scottish House Condition Surveys; Domestic Energy Fact File). Heating demand times and temperatures are known from survey data, though this was collected mainly in the 1980s and 1990s, so more work on this would be helpful (EST are planning a study on this). The time of day and year at which lighting energy is used is known with reasonable accuracy from the Electricity Association monitoring study, although further work would be useful to confirm the validity of that.

A further significant assumption inherent in the derived HRE factors is that the simulation modelling provides realistic predictions.

The LAL study provides no evidence to support or challenge these assumptions, nor could it in the case of the bulleted points. If carried out more carefully, it may be capable of highlighting areas where the limitations of the simulation modelling result in a demonstrably wrong prediction. However, such simulation modelling is very well established now and it is unlikely that any significant inconsistencies between measured and modelled behaviour would be found.

## *Conclusions*

HRE is dealt with in BNXS05 using the best of current knowledge. No changes in the way HRE is taken account of are required in response to findings from the LAL HRE study at this stage, but consideration should be given to any further work undertaken.

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