LIGHTING IN NEW ZEALAND HOMES
– lighting efficiency as a sustainability indicator

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ABSTRACT

The artificial lighting used in the New Zealand residential sector is investigated, and the use of energy efficient lighting is assessed as an indicator of housing sustainability.

A randomised survey of 150 homes in New Zealand identified that there are an average of 30 light bulbs installed per home, of which 18 are incandescent bulbs, 6 are compact fluorescent bulbs (CFL's), three are halogens, one is a fluorescent tube, and two are other types that were not identified. A comparison with the results from previous studies shows that there are now three more bulbs (of any type) per home, that five of the incandescent bulbs have been replaced by five CFL's and that there are 1.5 fewer halogens per home. The type of bulb with the highest daily average use is a 50 W halogen downlight, which is used for over twice as long as the standard incandescent bulb. It was found that the total number of bulbs is mainly associated with the physical characteristics of the home, which in turn relate to the size and complexity of the home, and is not dependent upon social factors. The main driver for the installation of energy efficient bulbs was found to be energy efficiency and not the retail price of the bulb.

KEYWORDS:
Lighting; energy-efficiency; survey; sustainability.

INTRODUCTION

This paper presents some results of a survey into the use of artificial lighting in 150 randomly selected New Zealand homes, identifying the number, hours of use and types of lighting. The work was undertaken by BRANZ Ltd in association with CRESA (Centre for Research Evaluation and Social Assessment) in order to assist the New Zealand Electricity Commission (EC) to improve the efficiency of electricity consumption in New Zealand homes. This research helps to fill the knowledge gap in the extent, usage and distribution of different lighting technologies across the New Zealand housing stock.

METHOD

A representative random sample (150 homes) of the occupied dwellings in New Zealand[1] (Statistics New Zealand, 2006) was drawn from the dwellings recognized in the 2006 census. The sample was both stratified and clustered, where the five main New Zealand urban areas were used as strata, and eight clusters were randomly selected from the area units used in the census. The number of homes randomly drawn for each strata was proportional to the dwelling population in that strata (43 for Auckland, 16 each from Wellington and Christchurch, and five from Dunedin). Nine dwellings were randomly drawn from each of the eight clusters to complete the sample. Further details of the location of the population can be found in the report produced for the Electricity Commission, available on their website[2].

To assess potential regional variation, the country was divided into three climatic/geographic regions, based on the zones and boundaries of New Zealand Standard NZS4218 Energy Efficiency – small building envelopes (SANZ, 2008). Region A is the upper North Island representing Zone 1 from NZS4218, Region B is Zone 2, and Region C is Zone 3, except that the volcanic plateau in the North Island (part of climate Zone 3) was attributed to Region B. Other differentiation in the sample was made on the basis of home typology, (stand-alone or apartment etc), on the home zones (Living, bedroom, utility, exterior) time of day, and other parameters that are discussed in the full report[2].

Two separate survey instruments were designed and applied: a telephone survey, and an on-site survey. The telephone survey was designed to collect occupancy, demographic and behavioural information. It was employed by a survey company (Infield International) in April 2009, with the data returned to BRANZ for analysis. This was followed up with a site survey in May 2009, performed by selected electricians from throughout New Zealand to collect the detailed technical information of bulb, fitting, and home types. The data was imported into the S+ software package for checking, cleaning and analysis, with Microsoft Excel used for tabulation and graphing.

The sample showed little bias for any of the parameters, except that the sample population comprised a greater proportion of owner-occupied homes (88%) than was found in the 2006 census of population and dwellings (67%), (Statistics New Zealand, 2006). While the number of rental homes in the sample (27) was large enough to allow valid comparisons for most parameters of interest, the sample set became too small to allow valid comparisons of tenure by region.

Weighted averages of the data were calculated along with standard errors, which were checked against other statistical methods for estimating bias and standard error (jack-knife estimates). Linear models were used to analyze factors influencing the number of bulbs, lighting hours and predominance of CFL technology.

The wealth of data collected enabled many lighting issues to be examined, and a selection of the results pertinent to the sustainability of the NZ built environment is presented in this paper. The survey results were compared to results from the BRANZ Household Energy End-use Project (HEEP) (Isaacs, 2004), which used data gathered between 1999 and 2004.

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[1] The size of the sample frame was 1.5 million homes, which includes all private homes that are normally occupied, and homes that were under construction at the time of the census in 2006. To represent the number of bulbs that are available for use in New Zealand, the figure of 1.6 million homes has been used, reflecting the latest available data from Statistics New Zealand – June 2009, which includes homes that are not normally occupied – e.g. holiday homes.

[2] The full report produced for the Electricity Commission is available here: http://www.electricitycommission.govt.nz/pdfs/opdev/elec-efficiency/programmes/lighting/further-info/Lighting-Survey-2009.pdf

RESULTS AND DISCUSSION

The results and discussion of the survey findings are presented in the following sections covering the aspects as below, so that the sustainability implications may be revealed:

- number of bulbs in NZ homes,
- lighting influencers,
- lighting power density (not illumination level),
- lighting hours per home,
- winter lighting hours per bulb,
- use of energy efficient lighting,
- survey comparison.

All the lighting analysed was fueled by electricity, with bulbs associated with rangehoods and other appliances (where lighting is a secondary function), not included in the survey.

Number of bulbs in NZ homes

The survey found that there will be nearly 50 million bulbs used in New Zealand homes, of which about

- 30 million are incandescent bulbs
- 10 million are CFLs
- five million are halogens and
- the remaining bulbs are fluorescent tubes and other bulb types that were not specifically identified.

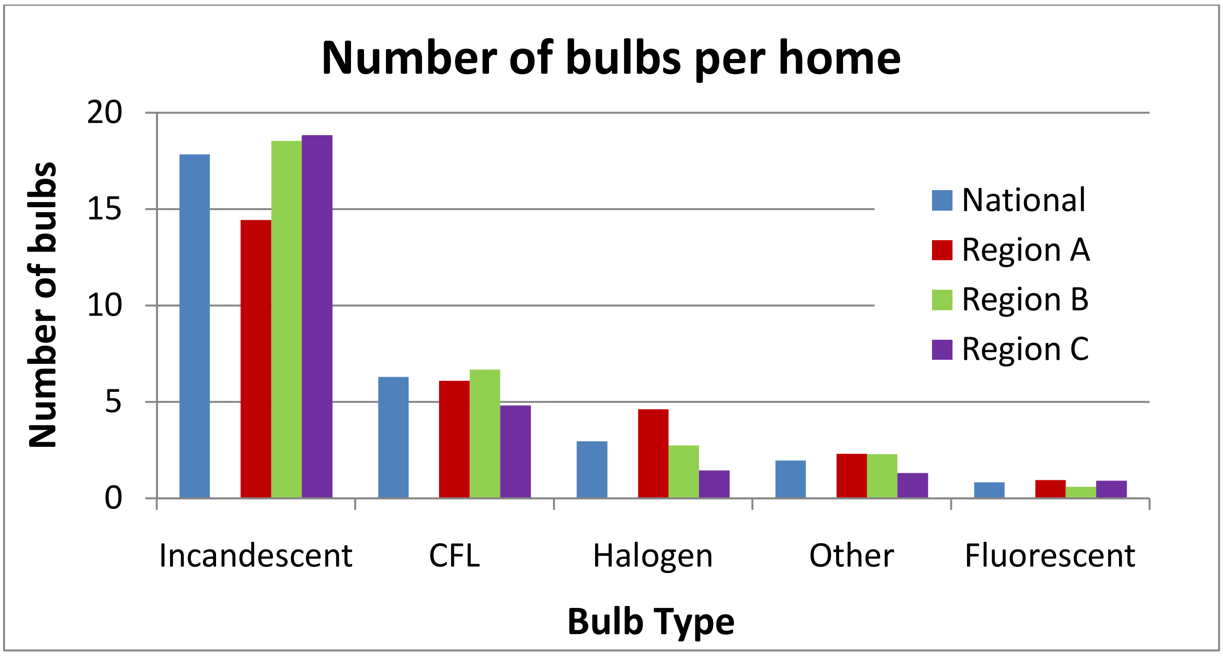

Figure 1: Bulbs per home by technology group

Based on the survey, the average number of bulbs per home is 30, with 18 incandescent bulbs, 6 CFL's, 3 halogens, 1 fluorescent, and 2 unidentified bulbs – or bulbs of other types. These data are shown by technology group in Figure 1, disaggregated by region – where 6 individual lighting technologies are represented by the Incandescent technology group, 11 technologies forming the CFL group, 6 forming the Halogen group and 1 in the Fluorescent group.

Lighting Influencers

Linear regression analysis was used to identify the three major factors that were found to affect the total number of bulbs in New Zealand homes as:

- the number of rooms
- the floor area
- the number of levels in the home

This analysis showed that the following five factors had little or no influence on the average total number of bulbs used in New Zealand homes:

- the Region that the home is in;
- the age of the home;
- whether an occupant works from home;
- whether occupants are over 65 years of age;
- whether there have been, or will soon be, changes to the lighting.

This shows the total number of bulbs used in New Zealand homes is mainly associated with the size and complexity of the home, and is not directly dependent upon social factors.

Lighting Power density

The lighting power density (LPD) was calculated as the rated wattage on the bulbs, divided by the floor area served by the bulbs, and therefore does not necessarily represent illumination intensity given varying lighting efficiency and other factors. The 15 types of rooms identified in the survey were agglomerated into four Zones (as shown in Figure 2 and Figure 3**Error! Reference source not found.**), so that the national average LPDs for each Zone could be calculated, as below:

- Utility Zones (the aggregation of bathrooms, toilets, and laundries etc) – 21 W/m²
- Bedroom Zones – 10 W/m²
- Living Zones (lounge, kitchen, dining etc) – 13 W/m²

No calculation of the LPD was possible for the exterior zone, since illuminated area could not be determined.

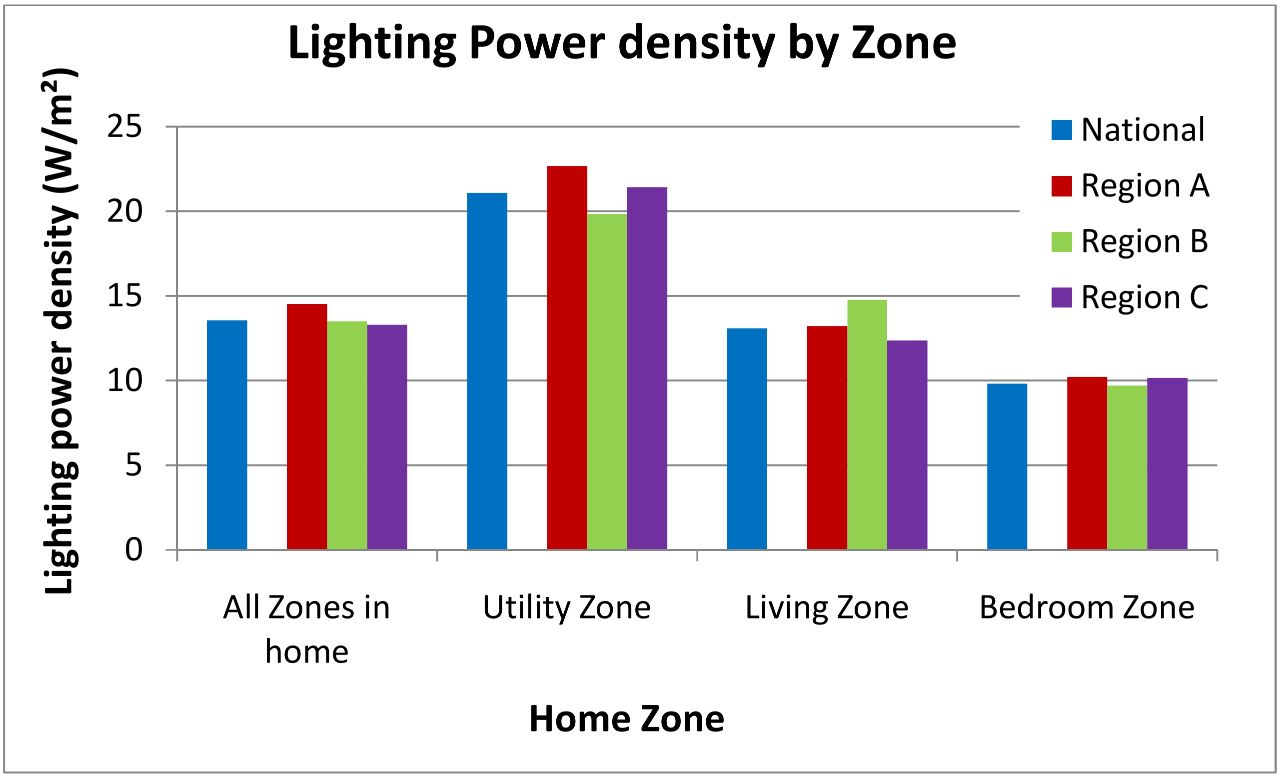

Figure 2: Lighting power density by zone per region

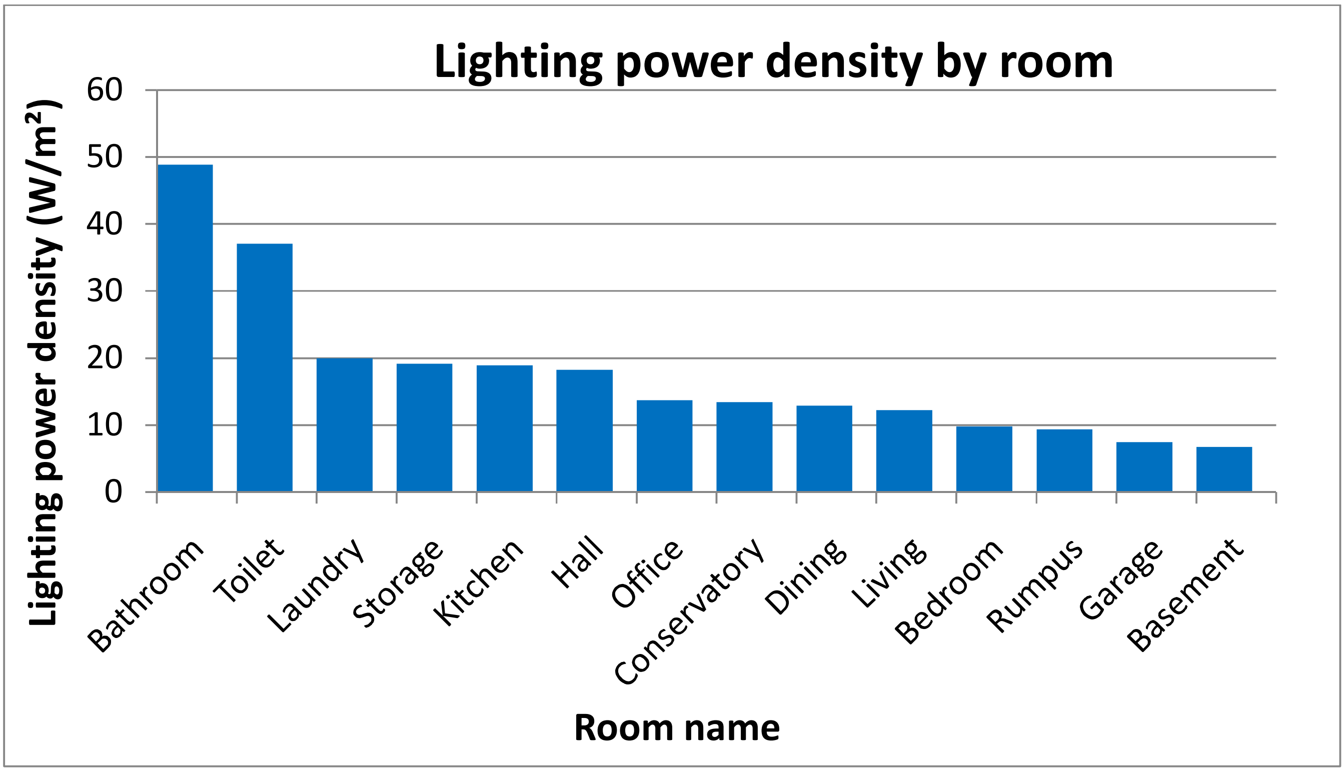

Figure 3: National average lighting power density by room

The LPDs by individual room types are shown in Figure 3. The highest LPDs are in the:

- Bathroom – 49 W/m²
- Toilet – 37 W/m²

The lowest LPDs for individual rooms are:

- Garage – 7.5 W/m²
- and the basement 6.7 W/m²

This is consistent with the expectation of high lighting intensity in the bathroom and toilet and low lighting intensity in the infrequently-used service rooms. It is assumed that both: the floor area of bathrooms and toilets (5m²) are typically an order of magnitude smaller than the floor area of garages and basements (50m²), and; that the required lighting intensity is higher in bathrooms than in basements. Both these factors serve to decrease the LPD in the garage and basements.

Lighting hours per home

Residents were asked about the number of hours that lights were illuminated in the mornings and evenings of typical winter and summer days, where mornings were defined approximately as the period from rising till midday, and evenings as the period from 5pm to bedtime. The number of hours that lights were used in New Zealand homes was not found to be related to any physical or social factors examined in this study. Occupants use their lighting as shown in Figure 4, with the numbers on average being:

- 1 ½ hours on winter mornings
- 5 hours on winter evenings
- half an hour on summer mornings
- 2 ½ hours on summer evenings

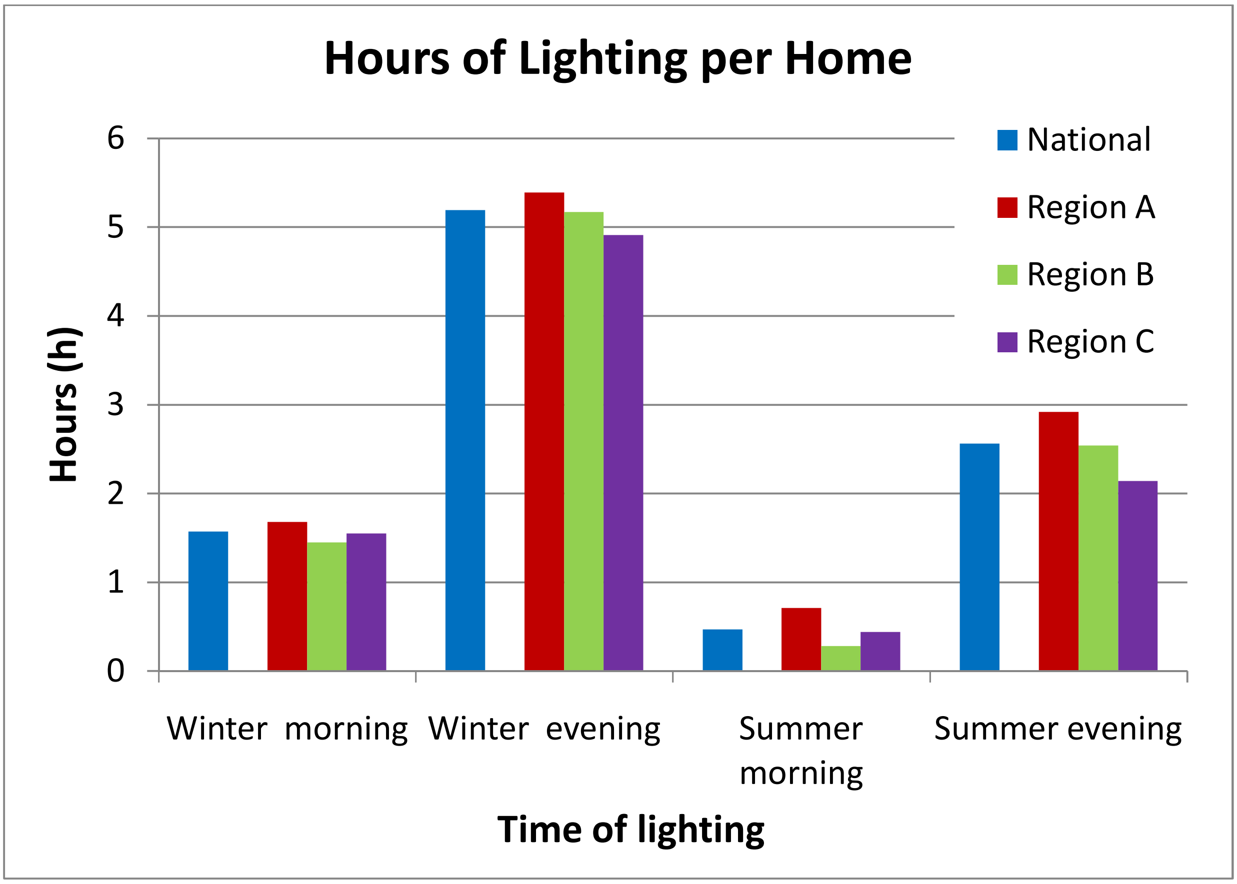

Figure 4: Average hours of lighting per home by Region, time of day and season.

Winter Lighting hours per bulb

As distinct from the seasonal lighting hours per home, the lighting hours **per bulb** also varies. The bulbs with the highest number of lighting hours used in the winter are Halogens and CFL's, as can be seen in Figure 5. The bulbs are located and illuminated per day on average for:

- living areas (3.2 hrs)
- bedrooms and utility areas (1.1 hrs)
- exterior bulbs (0.4 hrs)

It was also found that apartments had higher lighting hours than stand-alone homes, and suggests that lighting efficiency improvements could be achieved by targeting lamps in living zones and apartments as a priority.

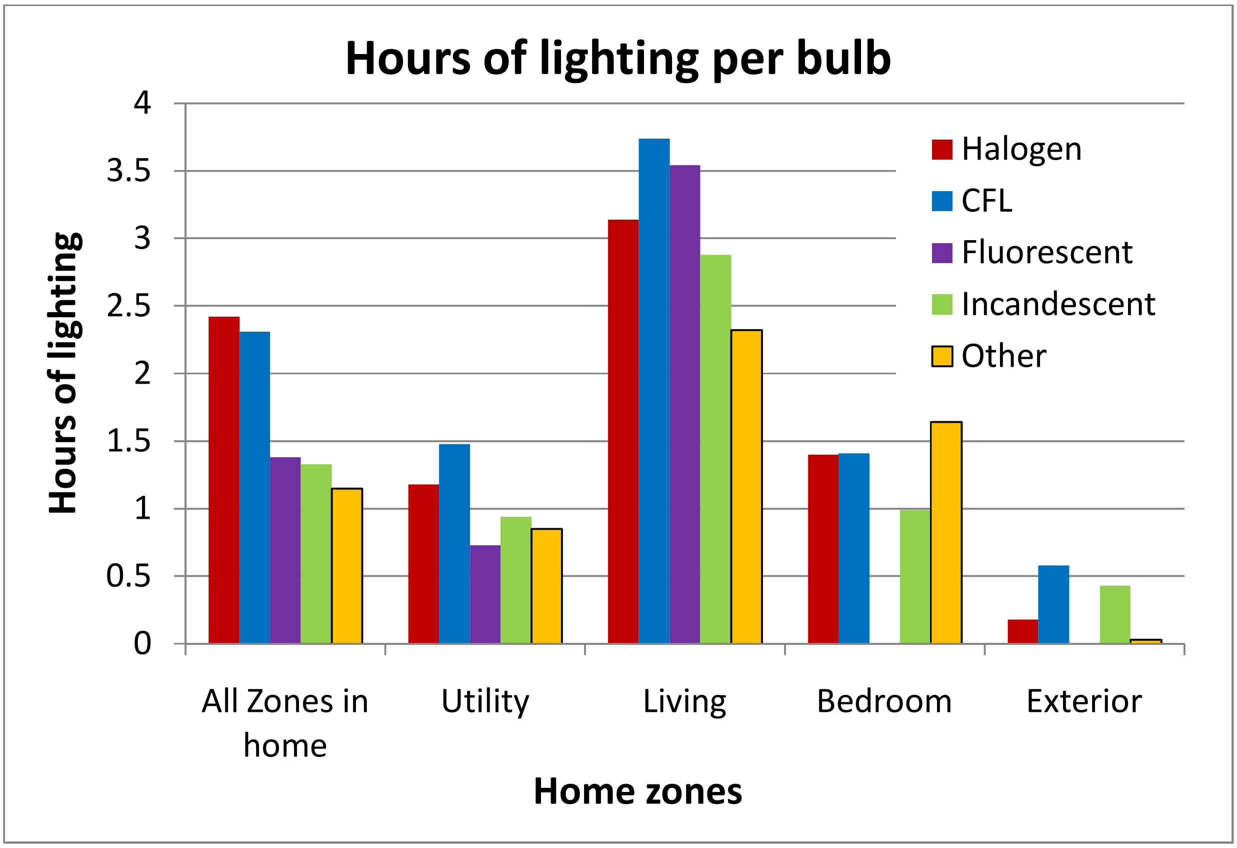

Figure 5: Average hours of lighting used in winter per bulb by technology group per Zone

Use of Energy Efficient lighting

A key area of interest was the use of energy efficient lighting. The survey asked about the presence, motivations and determinants for installing energy efficient lighting, and found that

- Most households (84%) have one or more CFLs
- Few households (13%) have more than 50% CFLs in their home
- The main driver for the installation of energy efficient lighting reported by occupants, is energy efficiency (at nearly 60%)

In comparison with previous work (Isaacs, et. al, 2004), the survey revealed that there has been an energy efficiency improvement seen in approximately 6 million bulbs nationwide in the last two years. However the absence in our study of the potentially more efficient LED technology indicates that this option still has market barriers which need to be identified and overcome. This may not be surprising since LED technologies are still relatively new, and there are functional differences which make this type of lighting not ideally suited, and currently very expensive, for domestic use.

The survey found that 23% of energy efficient bulbs are controlled by dimmer switches, and it is expected that many of these bulbs are not suitable for the purpose[3]. It is suggested that continuing education be targeted at home owners to help address this issue, since inappropriate use of CFLs may be detrimental to the continued market penetration of energy efficient lighting technology into New Zealand homes.

The occupants were asked about recent changes made to lighting, and found that of the changes to bulb types in New Zealand homes in the last two years, 75% of the changes were from an incandescent bulb to a CFL bulb. This is in spite of the 7% of the population who expressed a negative reaction to the use of energy efficient bulb technology, and the 16% of New Zealand homes that do not have any CFLs.
The most common person/agency making the changes to lighting in New Zealand homes is almost equally the occupants, and the electrician, and not landlords, indicating that education regarding the installation of energy efficient lighting technologies should be directed primarily to these groups.

Survey Comparison

Comparison with previous work (Isaacs, 2004) has shown that the average number of bulbs in homes **per square meter** in 2009 has not changed since the 2001-2004 study period (0.15 bulbs/m²). However, the number of bulbs **per home** has increased, from 26 to 30. This is in line with the increase in the floor area of new homes, rising by 11% in six years from 176m² in 2003 to 196m² in 2009 (Stats NZ, 2009).

Other findings

Although bulbs in the bathroom and toilet do not always have high hours of use, their usage is high enough that replacement with high efficiency bulbs is cost effective, particularly if these rooms only have one bulb. While the bathroom may require high illumination intensity in some areas, this may not be the case in all areas of larger bathrooms, or in a room containing a toilet and no other facilities.

Two other important findings of this work are:

- that apartments use bulbs for longer than all other types of homes

This possibly results from the smaller room sizes, lower number of external walls (and therefore natural light from windows) and a lower number of light fixtures per room in apartments, but suggests that effort could be targeted to the efficient use of lighting in apartments.

- The bulb with the highest hours of use in New Zealand homes is the 50 W mains-powered halogen downlight (MR16/GU10)

The MR16/GU10 is a 50 W halogen downlight of 50mm diameter, with better efficiency than the older incandescent downlights, which typically fit into a 100-200mm diameter recess in ceilings; however there are several points to note:

1) many higher efficiency alternatives are available for the MR16, including a higher-efficiency CFL, a higher efficiency halogen (the infra-red-coated halogen) and a higher efficiency LED. Any of these options would be a more sustainable choice for lighting than the standard MR16 with GU10 base.
2) MR16 downlights are typically found in groups, where many bulbs are often used to replace an individual, or several incandescent bulbs. This means that the overall sustainability of the lighting may be reduced, and contributes to the increase in bulb numbers in homes.

[3] That is, that they are likely to be CFLs that are not designed for use in dimmer circuits. Although no dimmable CFLs were found in this work, it is possible that some dimmable CFLs were mis-classified as non-dimmable CFLs.

3) Use of large numbers of MR16 bulbs in ceilings of single storey dwellings can significantly reduce the efficacy of ceiling insulation, and pose problems for the placement of retrofit insulation.

CONCLUSION

The sustainability of domestic artificial lighting in New Zealand could be improved by providing education regarding the use of energy efficient lighting technology.

Specifically, the survey reported on in this paper, indicates that the following areas should be targeted for improving the energy efficiency of lighting in New Zealand homes.

- Promotion of more energy efficient substitutes for the 50 W MR16/GU10 mains-powered halogen downlight
- Education on the use of energy efficient bulbs, particularly those used in conjunction with dimmer switches
- Education on replacement options for incandescent and low-efficiency bulbs of any type, particularly for living spaces, and in apartments.
- The use of efficient lighting in the bathroom and toilet of homes

ACKNOWLEDGEMENTS

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