BETTER INFORMED NEW ZEALAND ENERGY MODELS

SHAAN CORY[1], ANDREW POLLARD[2], AND MICHAEL DONN[1]

1. *Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand*
2. *BRANZ, Private Bag 50 908, Porirua 5240, New Zealand*

ABSTRACT

Currently, the New Zealand building design industry assumes various building model inputs regarding what lights and appliances consume and when they are turned 'on'. This paper aims to better inform industry energy modellers as to how typical commercial buildings are operated. The paper presents a set of New Zealand relevant commercial building operation parameters. Typical operation information is provided for three commercial building types: 1) office, 2) retail, and 3) mixed/other. The information provides low, typical, and high installed building load and operation pattern scenarios for the three building types. The typical data is significantly different than the required and assumed installed loads and patterns of use presented in the New Zealand Building code (Standards New Zealand, 2007a, 2007b).

The results established in this paper are informed by data gathered in the Building Research Association of New Zealand (BRANZ) Building Energy End-use Study (BEES) (BRANZ Ltd, 2013a). The purpose of BEES is to increase knowledge on energy use patterns for the entire New Zealand building stock (Isaacs et al., 2009). As part of the BEES modelling research, a set of EnergyPlus Template models were developed. The aim of the template models was to reduce the difficulties associated with energy modelling; this related to the ease and speed of creating a model to produce reliable results(Cory et al., 2009). The initial idea of the New Zealand relevant template models was for them to be adaptations of the US Department of Energy (DOE) benchmark/ reference models (Deru et al., 2011; Torcellini et al., 2008). There are a number of limitations associated with the template models. The largest of which relates to the installed building loads and their operation patterns. The building load and operation patterns presented in this paper aim to provide real information to update the BEES template models to make available better informed energy models for the New Zealand industry.

KEYWORDS:

Building Energy Modelling; Building Load; Operation Patterns, BEES; Monitored data.

INTRODUCTION

The aim of this report is to present the typical, high and low building load densities and patterns of use for commercial buildings in New Zealand. Patterns of use refer to the daily usage profiles of the load presented as the percentage of load 'on' at different time intervals throughout the day. The report has the goal to better inform energy modellers of new and existing buildings. Another goal is to highlight the differences between assumptions made when meeting the New Zealand Building Code (NZBC) using the modelling method and what is occurring in real buildings (Department of Building and Housing 2011).

The research is a part of the Building Research Association of New Zealand (BRANZ) Building Energy End-use Study (BEES). BEES is a "6-year long project monitoring and analysing the energy and water consumption of non-residential buildings around New Zealand" (BRANZ Ltd 2013). The purpose of BEES is to increase knowledge on energy use patterns for the entire New Zealand building stock (Isaacs et al. 2009). Real data is collected through the BEES programme from the monitoring of temperature, humidity, light levels, $C0_2$ levels, occupant and equipment schedules, internal loads, and fuel consumption within selected premises.

BACKGROUND

Currently, the New Zealand building design industry assumes various building model inputs regarding what lights and appliances consume and when they are turned 'on'. There is currently a lack of information on the typical building load power densities found in commercial buildings that is based on measured data. Energy modellers assessing energy may use the New Zealand Building Code (NZBC) Lighting Power Density (LPD) value as a base case scenario for what is currently installed in commercial buildings. 50% of commercial buildings were built before the year 2000 which pre-dates the NZBC clause that regulates LPD. This can cause modellers to use an assumption that may not be typical of what is found in existing buildings. Additionally, there is no such NZBC regulated density value for other building loads, such as office equipment and hot water. The result is when modellers input a value for an Equipment Power Density (EPD) and Hot Water Power Density (HWPD) they are purely guessing or using assumptions found in the NZBC modelling method to prove a building design meets the NZBC. Table 1 displays the power density assumptions found in the NZBC.

Table 1 – NZBC Power densities. Table created using (Standards New Zealand, 2007a, 2007b)

Building Type	Power Densities (W/m^2)		
	Regulated LPD	Assumed EPD	Assumed HWPD
Office	12 W/m^2	8.1 W/m^2	Not required
Retail	8-16 W/m^2 depending on retail type	1.1-2.7 W/m^2 depending on retail type	Not required
Mixed/Other	8-18 W/m^2 depending on use type	1.1-8.1 W/m^2 depending on use type	Not required

Note: the Retail and Mixed/other power densities have a range due to the different building types.

The same problem occurs for the operation patterns of building loads. No measured information for the patterns of use of building loads in real buildings is currently published. As a result, an energy modeller will assume when equipment is turned 'on' and when it is turned 'off'. As an example, one could assume the pattern of use assumptions found in the NZBC energy modelling method for proving whether a building design meets code. Table 2 presents the patterns of use assumptions found in the NZBC for different building types. These assumptions found in the NZBC may not be relevant to how real commercial buildings in New Zealand consume energy.

Table 2 – NZBC Lighting and Plug Load patterns of use. Table adapted from (Standards New Zealand 2007a, pp.30-31)

Building type	Day type	Patterns of use (% of load 'On')				
		12am-8am	8am-11am	11am-6pm	6pm-10pm	10pm-12am
Office	Week	5%	90%	90%	30%	5%
	Saturday	5%	30%	15%	5%	5%
	Sunday	5%	5%	5%	5%	5%
Retail (Restaurant)	Week	5% (15%)	90% (40%)	90% (90%)	50% (90%)	5% (50%)
	Saturday	5% (15%)	90% (30%)	90% (80%)	30% (90%)	5% (50%)
	Sunday	5% (15%)	40% (30%)	40% (70%)	5% (60%)	5% (50%)
Mixed/Other	Week	5%	90%	90%	5%	5%
	Saturday	5%	24%	5%	5%	5%
	Sunday	5%	5%	5%	5%	5%

Note: Retail has two patterns of use presented as restaurants a different to general retail. Also, Mixed/Other are the assumptions for a warehouse, but it could be a mixture of all three use types.

New Zealand is not alone in these assumptions and lack of information. The current state of the art in prototypical building models can be found in the US set of prototypical building models. These are based on informed engineering judgements about 'typical' or 'design' values for building loads and their operation (Torcellini et al., 2008). As part of the BEES modelling research, a set of EnergyPlus

Template models (BRANZ Ltd, 2013b) were developed which followed the same format as the US prototypical models. The aim of the template models was to reduce the difficulties associated with energy modelling; this related to the ease and speed of creating a model to produce reliable results (Cory et al., 2009). The BEES models had the same short comings in that they are built on assumptions about the building loads and their operation. If the BEES models were updated using the measured data presented in this report, they would be ahead of any prototypical models currently found. The biggest single advantage of updated models with measured building load and operation patterns is that they offer the potential for building design teams to examine the risk that a predicted building performance is dependent on, with respect to the assumptions about people, lighting and equipment used in the design modelling. There have been criticisms of high performance designs that only perform well in the particularly narrow focused situation ‘assumed’ during the performance modelling (Bordass et al., 2006). The low and high building loads data from BEES allows the design team to quickly test realistic design scenarios and establish how robust their design concept is.

METHODOLOGY

This study uses the measured data for lighting, equipment and hot water energy use from the BEES sample of commercial premises. Data collection was performed over a four year period from 2008 to 2012 by the BEES team. Energy was measured at a minutely interval for a 2-3 week period. The weekly periods are spread throughout the year for different buildings. This means that the energy results could be from a two week period in summer or a two week period in the winter. As this report deals with only lighting, equipment and hot water, it is seen as a minor limitation as the outdoor conditions will have a minimal impact on their energy use. This is the case even for lighting as there were no daylight induced electric lighting dimming in any of the premises.

This report presents the power density and patterns of use for lighting, equipment, and hot water. is strictly indoor lighting used to provide task lighting to the occupants. Equipment is made up of a number of appliances that are used by occupants to undertake day to day tasks and enable businesses to provide a service. Appliances range from computers, printers, servers, refrigerators, chillers, water coolers, water boilers, phone systems, security systems, ovens, stove tops, deep fryers, and other appliances used in the day to day use of commercial buildings. Hot water energy use covers the energy used to provide hot water for domestic use, such as hand washing and showers, and commercial use, such as dishwashing.

All results were calculated using the measured average weekday and weekend 10 minutely load. Meaning, each 10 minute interval measured is averaged against other weekday and weekend 10 minute measured intervals. The power densities were calculated by dividing the maximum measured load (for lighting, equipment, and hot water), by the monitored floor area. The operation patterns were calculated by dividing the measured load by the maximum measured load to establish the percentage of load ‘on’ during that 10 minute interval.

A typical energy load scenario is presented in this report. The typical scenario is the Median (50th percentile**)** load and pattern of use found across the sample of building premises. The median is used because it is a better indicator of the most typical value as the sample has outliers which can differ greatly from other values (Urdan, 2010). The sample sizes vary between the lighting, equipment and hot water assessments and are:

- Lighting sample size: 101 premises
- Equipment sample size: 83 premises
- Hot water sample size: 30 premises

The time intervals used in the patterns of use analysis were decided upon by assessing natural breaks across the whole data set in the amount of load ‘on’ during each hour. For example, 12am to 5am is used as there was no change over 10% different between the hours. Hence, the hours were averaged to get a percentage value of load ‘on’ across the 5 hours. The report presents the building load analysis for 3 different building types. It is split by building use type because the NZBC regulates load for different building types. Also, the use of different commercial buildings result in very different building load attributes. Table 3 displays the three building types assessed (Office, Retail, and Mixed/Other) and the detailed uses found within each of the three are.

Table 3 – Building type categories

Building type	Commercial Office	Commercial Retail	Commercial Mixed/Other
Specific building use types found in each building type	Office-type use	Retailing use, Motor vehicle sales and services, Liquor outlets including taverns, Service stations, Tourist-type attractions	Warehouses, service buildings, and buildings with a mixture of commercial uses on one site

One further breakdown is made when assessing the lighting, equipment and hot water power densities. The breakdown assesses the impact of building floor area size. Building floor area size is assessed as the NZBC regulates building loads for only 'large buildings' which it deems is 300m^2 or greater. The assessment of size intends to indicate whether building size has a significant impact on the building loads. Table 4 displays the breakdown of the different building floor area sizes assessed (small, medium and large), and what percentage of the total commercial building floor area each building size makes up.

Table 4 - Building size groupings

Building Size	Small	Medium	Large
Building floor area range	5 to 649m^2	650 to 3,499m^2	Over 3,500m^2
Percentage of all commercial floor area	20%	40%	40%

RESULTS

All results displayed in the graphs below are documented on the Victoria University of Wellington Centre for Building Performance Research (CBPR) website in a tabular form. The tabular results enable energy modellers to enter the values into energy models more precisely and easily when compared to the graphs presented in this report.

Lighting Power Density (LPD)

Figure 1 displays the typical, high and low LPDs' for an average commercial building (White), Offices (light grey), Retail (dark grey), and Mixed/Other commercial use types (black). As can be seen, Retail use types have the highest installed LPD's. This is followed by Offices, and Mixed/Other commercial use types. This trend mimics the trend of the maximum allowable LPD set by NZBC (Standards New Zealand, 2007b). It is noteworthy that the typical LPDs found in offices are slightly lower (11W/m^2) than the value set by the NZBC of 12W/m^2 and are above the sample average (Standards New Zealand, 2007b). Whereas the LPDs found in Retail premises are similar to the minimum set out in the NZBC. For retail the NZBC requirement is 8-16W/m^2 depending on retail use type, and the typical measured LPD across all retail use types is 14W/m^2 (Standards New Zealand, 2007b). The typical LPD measured in Mixed/Other commercial use type premises are much lower than the NZBC requirement. NZBC allows for a maximum of 8-18W/m^2 depending on use type, and the typical measured LPD is 6W/m^2. Mixed/Other commercial LPD's are below the sample average, but the high scenario (20W/m^2) is not largely different to the retail (26W/m^2) and office (21W/m^2) high values as the low and typical scenarios.

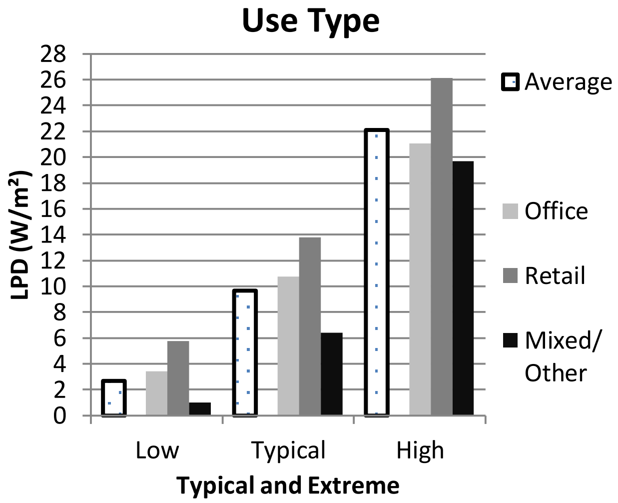

Figure 1 – Typical, High and Low LPDs' for different commercial building types

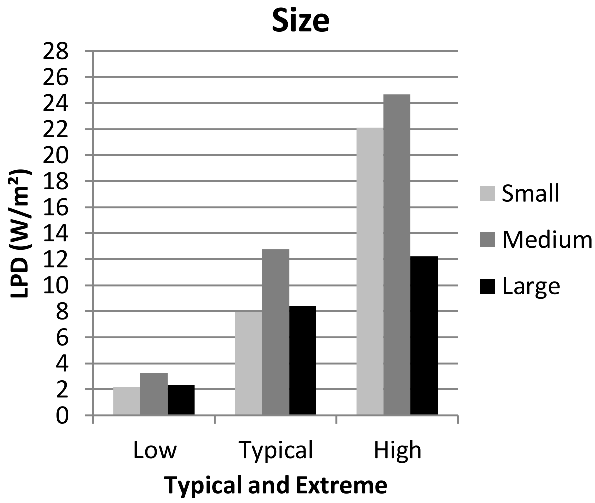

Figure 2 – Typical, High and Low LPDs' for different sized commercial buildings

Figure 2 presents the typical, high and low LPDs' for Small buildings (light grey), Medium sized buildings (dark grey), and Large buildings (black) to assess if size has an impact on the installed LPD. As can be seen, Medium sized buildings have the highest measured LPDs with a typical value of approximately 13W/m^2. The LPDs found in Small and large buildings are the same with 8W/m^2. The high scenario results suggest that lighting is most dense in Medium and Small sized buildings due to the Large building high value being half the Small and Medium sized buildings LPDs.

Lighting Operation Patterns

Figure 3 displays the typical (green), high (orange), low (blue) and NZBC (Black) patterns of lighting use for Offices, Retail and Mixed/Other commercial use types. As can be seen, Offices have the largest difference in usage patterns between weekdays and weekends. The typical lighting usage of an Office is higher (80-90% turned 'on') than retail and Mixed/Other commercial uses during the weekdays (70-80% turned 'on'). Retail and Mixed/Other commercial uses have less difference in usage patterns between weekdays and weekends (20-40% difference) when compared to Offices (60-70% difference). This highlights that Retail and Mixed/Other commercial use buildings have more intense and longer weekend hours when compared to office buildings. Furthermore, the high use Retail and Mixed/Other use types have almost as intense weekends as weekdays. Whereas, lighting in high use Offices do not reach the same peaks in the weekend as they do in the weekdays.

The typical lighting pattern of use for offices is similar to the NZBC assumed pattern of use. However, the Retail and Mixed/Other patterns of use sit between the typical and high scenario patterns of use. Therefore, if the NZBC assumptions are used in an energy model, they will be slightly overestimating the amount of lights turned 'on' in a typical building.

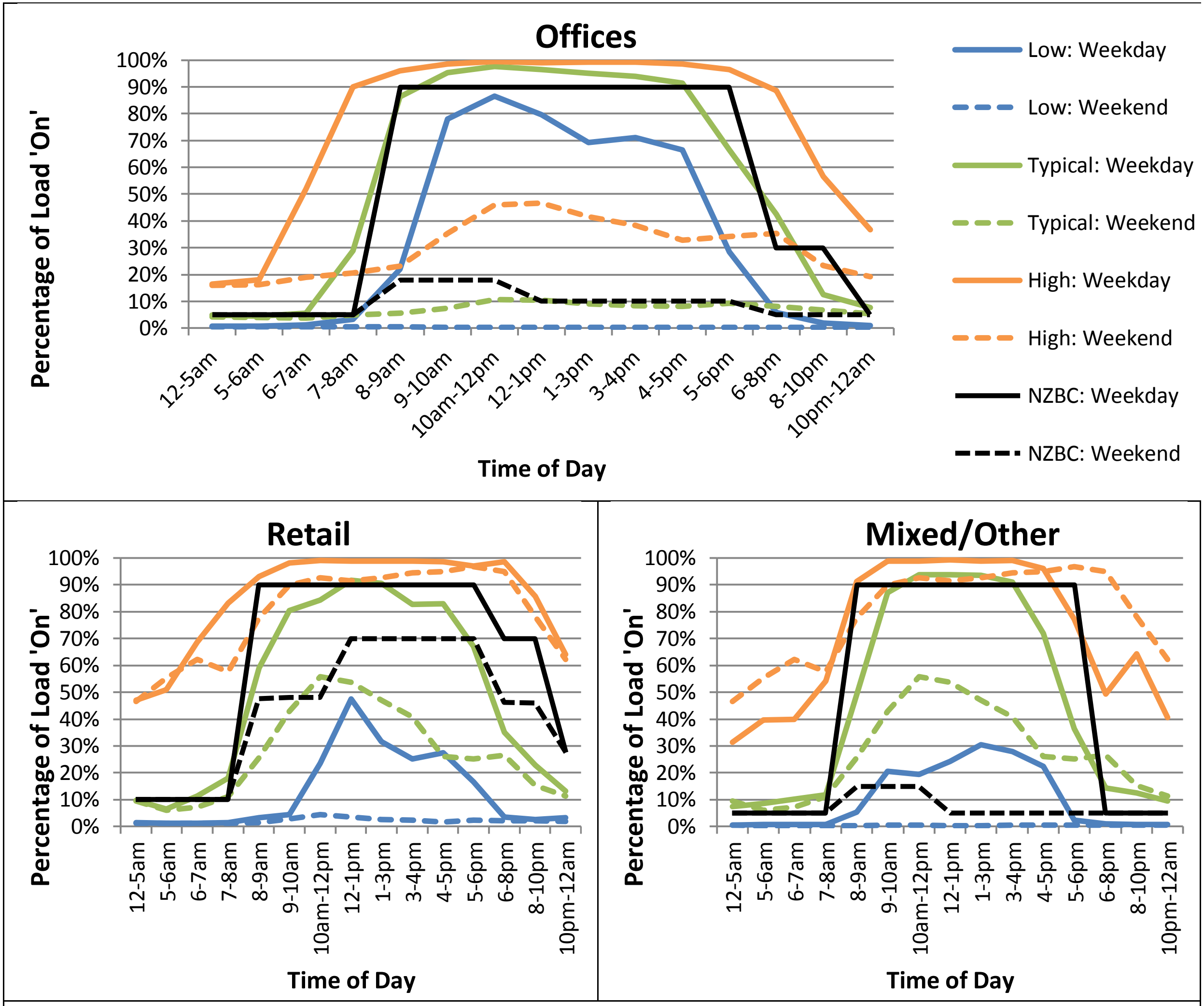

Figure 3 - Typical and Extreme Lighting Patterns' of use for different commercial building types

Note: The retail pattern of use is an average between the NZBC retail and restaurant patterns. The weekend patterns are an average of the NZBC Saturday and Sunday patterns of use.

Equipment Power Density (EPD)

Figure 4 displays the typical, high and low EPDs' for the average commercial building (White), Offices (light grey), Retail (dark grey), and Mixed/Other commercial use types (black). Mixed/Other commercial use types have the lowest typical EPD with 5W/m^2. Offices are the second lowest equipment focused use type with a typical EPD of 8W/m^2. Retail has the highest typical EPD of 15W/m^2. It suggests that retail buildings are the highest equipment energy intensive building type. This makes sense as retail buildings contain premises which pertain to Food uses that are refrigeration and cooking orientated. Also, Retail has by far the most dense high scenario EPD of 58W/m^2. Offices typical EPD is similar to the NZBC assumption of 8W/m^2. Whereas, the other two building types typical EPD's are well above the NZBC assumed EPDs (refer to Table 1 for NZBC assumptions). This highlights the difference between the theoretical and the real buildings. The impact this has on energy models would be large considering the amount of internal heat gains that is not modeled if the NZBC assumptions are used.

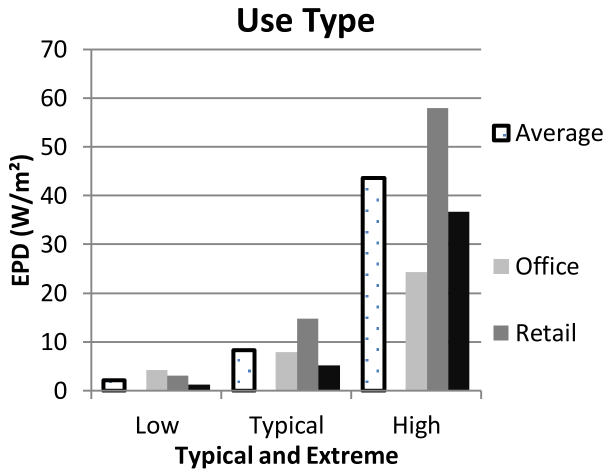

Figure 4 – Typical, High and Low EPDs' for different commercial building types

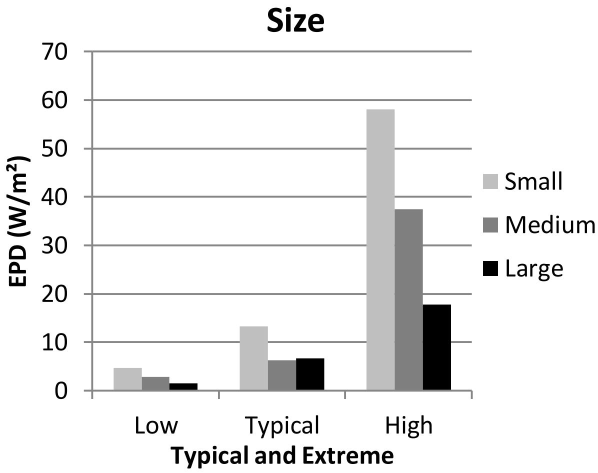

Figure 5 – Typical, High and Low EPDs' for different sized commercial buildings

Figure 5 presents the typical, high and low EPDs' for Small buildings (light grey), Medium sized buildings (dark grey), and Large buildings (black) to assess the impact of building size on the installed EPD. Small sized buildings are most equipment focused with a typical EPD of $13W/m^2$. Medium and Large buildings have the lowest density of equipment installed with a substantially lower typical EPD of $6W/m^2$ and $7W/m^2$ respectively. This trend follows in the high EPD scenario. However, small buildings have much larger EPD of $59W/m^2$ when compared to both Medium and Large sized buildings, which have high EPDs of $38W/m^2$, and $18W/m^2$ respectively. This suggests that Small and Medium sized buildings are dominated by Retail loads. While larger buildings are dominated by Office loads.

Equipment operation patterns

Figure 6 displays the typical (green), high (orange), low (blue) and NZBC (Black) patterns of equipment use for Offices, Retail and Mixed/Other commercial use types. Offices have the least energy intensive patterns of use as seen by the amount of load that is left 'on' during unoccupied periods. This is shown by the weekend and night load percentages. Also, Offices have the biggest difference between night and daytime load patterns. This is highlighted by the larger peaks in equipment energy use of approximately 30-50% during daytime hours. Office weekday patterns of use have a consistent peak of use. Whereas, their weekend schedules are more or less consistently flat throughout the weekend. This is shown by the weekend day loads not being radically different to the overnight use. Retail buildings have the most energy intensive patterns of use. This is highlighted by the larger percentage of equipment 'on' and for longer periods of time. It is further reinforced by the fact that Retail buildings have higher EPD's (refer to section 4.3). Also, the more energy intensive a retail premise is, the closer the weekend pattern of use is to the weekday pattern. The daytime pattern of use peak in retail premises (20-30% more equipment 'on') is not as large when compared to offices (30-50% more equipment 'On'). This could be due to the large refrigeration loads running consistently throughout the whole day, and only a small number of appliances are turned 'on' during occupied hours. Unlike Office and Retail, the weekend patterns of use are higher than the weekday patterns of use in Mixed/Other commercial use buildings. Also, both weekdays and weekends on Mixed/Other use buildings have a definite daytime peak of equipment use. However, like retail, the daytime peaks are not as large as offices, but there is a bigger daytime peak during weekdays when compared to the weekends. Also, the weekend loads are more consistently 'on' and the weekend night loads are greater than the weekday night loads. This could be due to premises with restaurant and other food type having longer weekend hours.

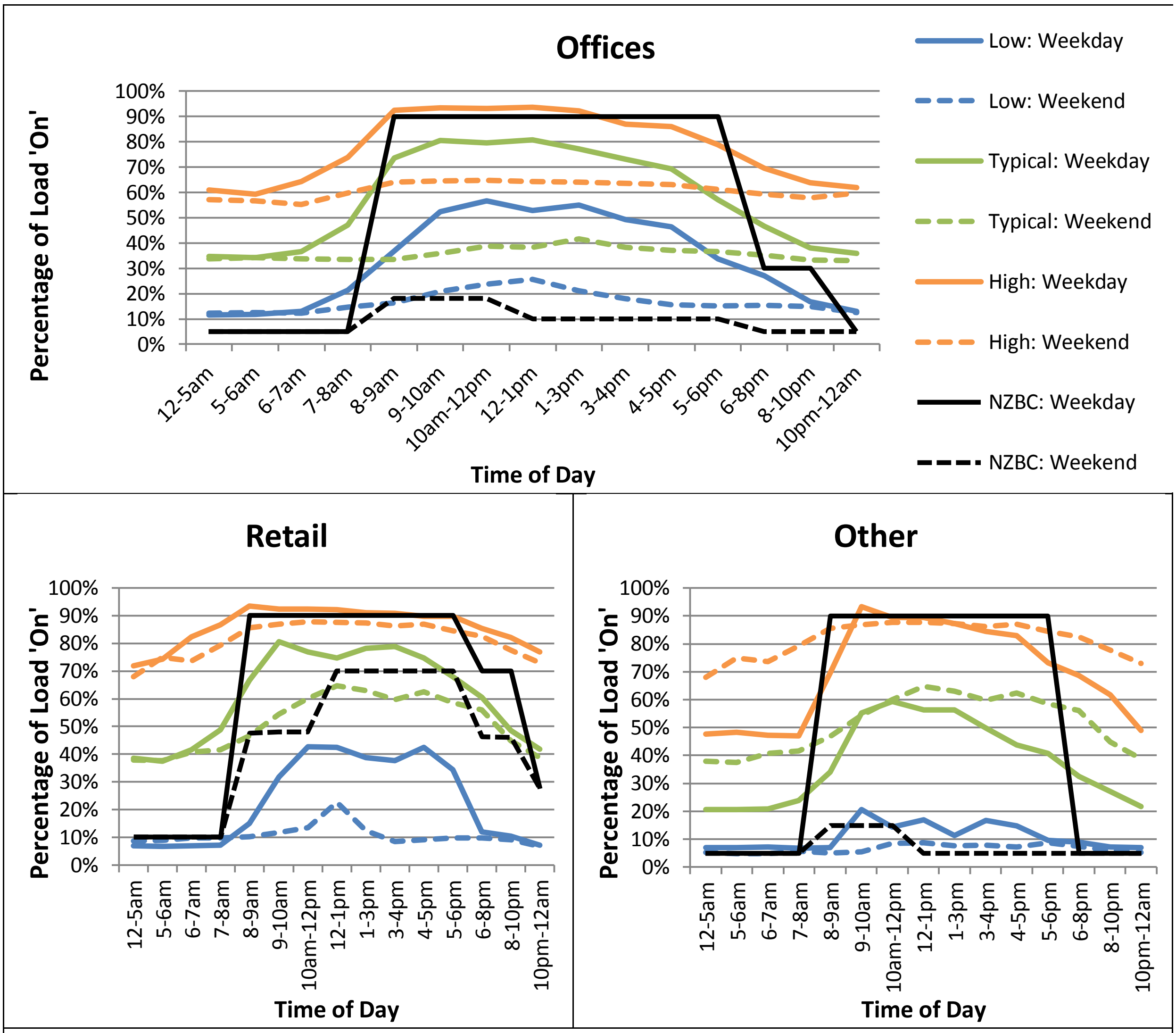

Figure 6 - Typical and extreme equipment patterns' of use for different commercial building types

Note: The retail pattern of use is an average between the NZBC retail and restaurant patterns. The weekend patterns are an average of the NZBC Saturday and Sunday patterns of use.

The results indicate that the common perception of equipment being left 'on' during unoccupied hours is true. Half of the installed equipment load in Offices is left on overnight. Over a yearly period this equates to a large sum of energy that is essentially wasted. Couple with this being typical across the commercial building stock, it would seem there is large potential for energy savings if equipment is turned off over night.

The NZBC patterns of use assume that 10-20% more equipment is turned 'on' during daytime hours in Office and Retail buildings, and 10-30% more in Mixed/Other buildings. The NZBC patterns of use sit between the typical and High scenarios for all three building types. Therefore, if the NZBC assumptions are used in model, they will be overestimating the amount of equipment turned 'On' in a typical building.

Hot Water Power Density (HWPD)

Figure 7 displays the typical, high and low HWPDs' for average commercial building (White), Offices (light grey), Retail (dark grey), and Mixed/Other commercial use types (black). Retail has the largest HWPD with $7W/m^2$ for a typical building and $24W/m^2$ for high use buildings. This is most likely due to the food use types associated with Retail using larger amounts of hot water when compared to

Offices and Mixed/Other commercial use types. Office and Mixed/Other use type HWPD's are below the average for commercial buildings with 3W/m^2 and 2W/m^2 respectively. Also, their high scenario HWPDs are significantly lower than the Retail HWPD.

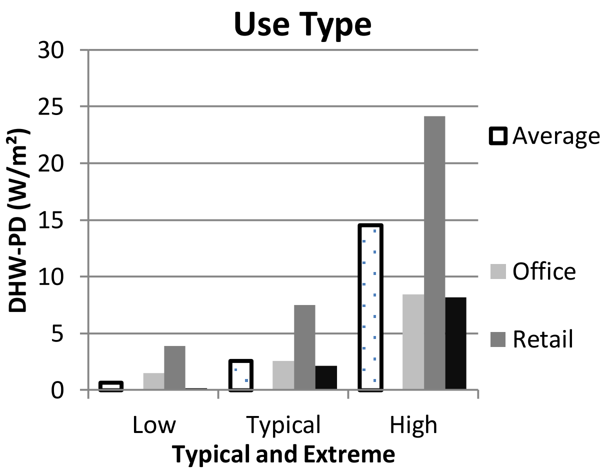

Figure 7 – Typical, High and Low HW-PDs' for different commercial building types

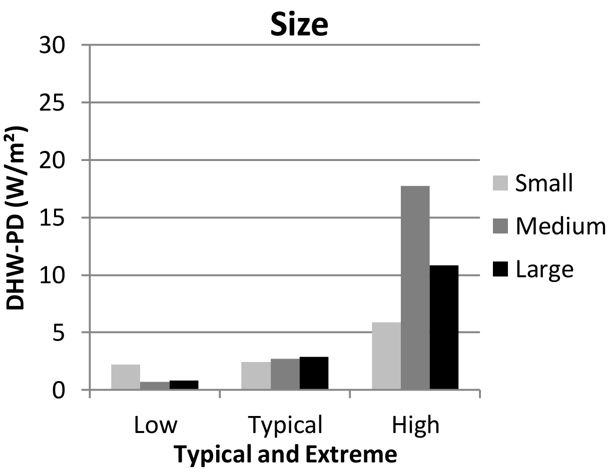

Figure 8 – Typical, High and Low HWPDs' for different sized commercial buildings

Figure 8 presents the typical, high and low HWPDs' for Small buildings (light grey), Medium sized buildings (dark grey), and Large buildings (black) to assess if size has an impact on the installed HW-PD. The typical HWPD is relatively similar for each of the three building size groups. However, the 'high' scenario indicates that Medium to Large sized buildings are more hot water orientated, which could be attributed to larger buildings having more occupants to service.

4.6 Hot Water operation patterns

Figure 9 displays the typical (green), high (orange) and low (blue) patterns of hot water use for Offices, Retail and Mixed/Other commercial use types. Office hot water energy use is very different between weekday and weekend, but also from night to day time use. Office hot water use is much lower overnight, by approximately 30-40%, and during the weekend as there is a 20-40% smaller daytime peak of hot water energy usage. Retail hot water energy use patterns have consistent trends across both weekdays and weekends. Also, the intensity of use between weekdays and weekends does not change considerably (less than 10-20%). Mixed/Other commercial use types consume more hot water energy in the weekends than during weekdays. This follows the equipment patterns of use for Mixed/Other use types as well.

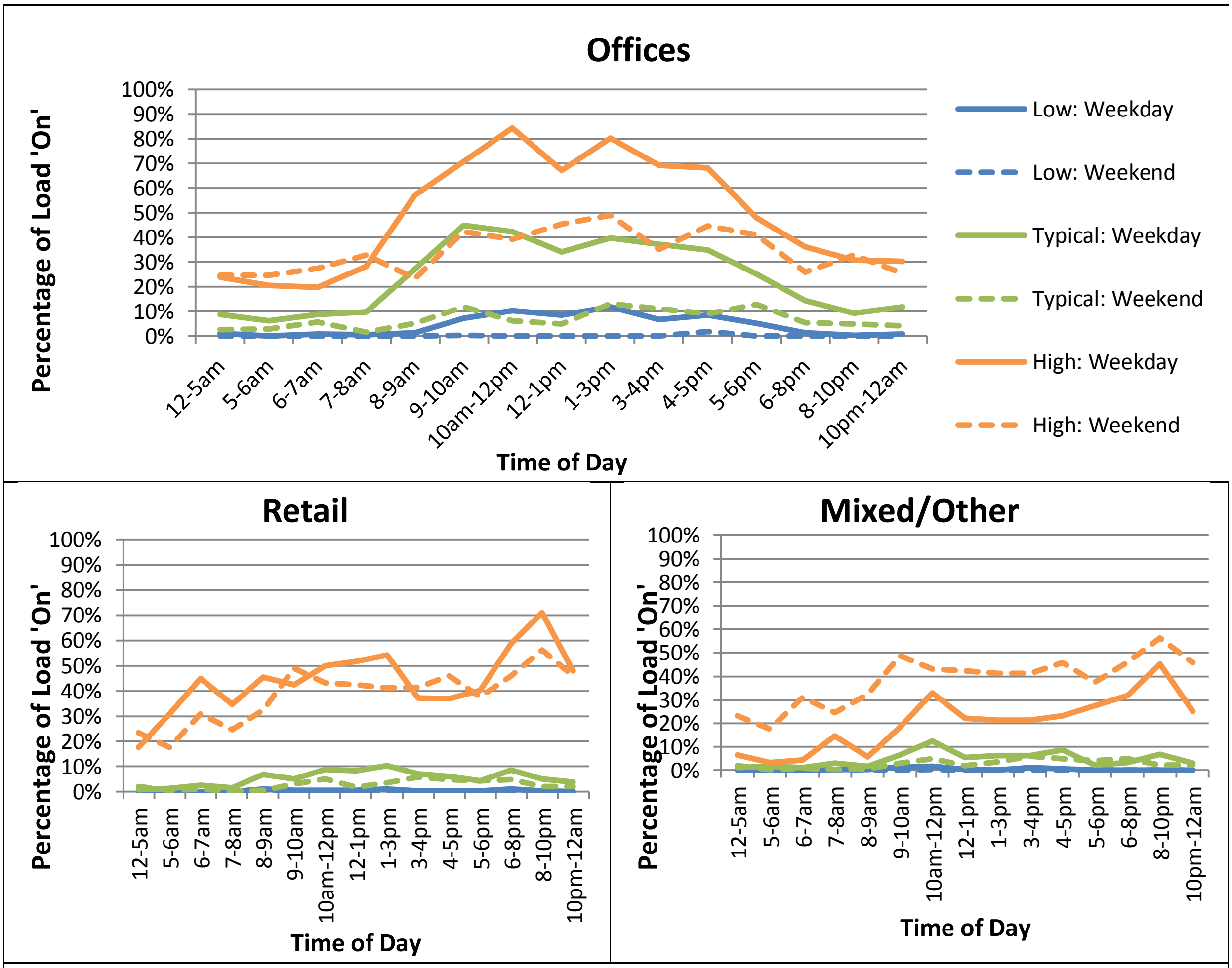

Figure 9 - Typical and extreme DHW patterns' of use for different commercial building types

CONCLUSION

In conclusion, this report presents the typical, high and low building load densities and their operation patterns for commercial buildings in New Zealand. It fills the gap for the shortfall in information available for commercial building designers and environmental engineer. The shortfall pertains to the lack of information regarding building loads found in real commercial buildings. Furthermore, it compares the building loads found in real commercial buildings to that of the loads regulated in the NZBC and assumptions stated to be used in the modelling method for comparing energy use to prove the building code has been met. It has been found that the NZBC values for the LPD are indicative of the typical LPDs found in existing buildings. It suggests that typical commercial buildings are designed to just meet the code and not to be any more energy efficient as they need to be. The Retail and Mixed/Other lighting patterns of use overestimate the amount of weekday lighting turned 'on'. The EPDs found in real buildings are significantly higher for Retail and Mixed/Other commercial use type buildings than the assumptions made in the NZBC modelling method. The result is an underestimation in energy models of equipment energy use and internal heat gains if the NZBC values are used.

Additionally, the common perception that equipment is left 'on' during unoccupied hours is true. Half of the installed equipment load in Offices is left 'on' overnight. Over a yearly period this equates to a large sum of energy that is essentially wasted. Couple this with the values being typical across the commercial building stock; it would seem there is large potential for energy savings if equipment is turned off over night in Offices.

FUTURE WORK

Future work is to update the BEES template models (BRANZ Ltd, 2013b) to include typical building load information. Furthermore, a more detailed breakdown into end-uses such as refrigeration and cooking could be undertaken. As well as, a breakdown of what typical individual appliances consume, such as computers, laptops, and printers.

REFERENCES

Bordass, B., Cohen, R., Field, J., 2006. Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap. Presented at the Buildings Performance Congress, William Bordass Associates; Energy for Sustainable Development Ltd; Target Energy Services Ltd, Frankfurt, p. 10.

BRANZ Ltd, 2013a. Building Energy End-use Study (BEES) [WWW Document]. BRANZ. URL http://www.branz.co.nz/BEES (accessed 8.26.13).

BRANZ Ltd, 2013b. BEES for energy modelling [WWW Document]. URL http://www.branz.co.nz/cms_display.php?sn=169&st=1&pg=9690 (accessed 11.13.13).

Cory, S., Hsu, C., Donn, M., 2009. Template files for commercial building stock energy simulations. Centre for Building Performance Research, Wellington [N.Z.].

Deru, M., Field, K., Studer, D., Benne, K., Griffith, B., Torcellini, P., Liu, B., Halverson, M., Winiarski, D., Rosenberg, M., Yazdanian, M., Huang, J., Crawley, D., 2011. U.S. Department of Energy Commercial Reference Building Models of the National Building Stock (No. NREL/TP-5500-46861). NREL, Golden, CO.

Isaacs, N., Saville-Smith, K., Bishop, R., Camilleri, M., Jowett, J., Hills, A., Moore, D., Babylon, M., Donn, M., Heinrich, M., Roberti, H., 2009. Building Energy End-Use Study (BEES) Years 1 & 2 (Study Report No. SR 224 (2009)). BRANZ, Porirua, New Zealand.

Standards New Zealand, 2007a. NZS 4243: Part 1: Energy efficiency: large buildings. Standards New Zealand, Wellington [N.Z.].

Standards New Zealand, 2007b. NZS 4243: Part 2: Energy Efficeincy: Large Buildings. Standards New Zealand, Wellington [N.Z.].

Torcellini, P., Deru, M., Griffith, B., Benne, K., Halverson, M., Winiarski, D., Crawley, D., 2008. DOE Commercial Building Benchmark Models (No. NREL/CP-550-43291). NREL, Golden, CO.

Urdan, T.C., 2010. Statistics in Plain English, Third Edition, 3 edition. ed. Routledge, New York.