Energy and Water Performance Benchmarking in the Retail Sector: NABERS Shopping Centres

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ABSTRACT

Greenhouse gas and water performance benchmarks have been developed for shopping centres in Australia for use in the National Australian Built Environment Rating System (NABERS) for shopping centres. The rating has been developed with data from over 100 sites, with strong industry support.

Performance ratings assess the actual resource consumption for the production of a given output. The challenge for benchmarking in the retail sector has been the definition and measurement of productive output due to a variety of services that shopping centres provide. Due to this diversity, few shopping centres have the same mix of facilities or are directly comparable. To address this, a component based benchmark and sub-benchmarks have been developed.

From these sub-benchmarks, an "industry average" consumption can be determined for a centre with a given mix of services. This paper presents the benchmarks and their development. Average greenhouse gas emissions can be predicted as

Average greenhouse gas emissions for a shopping centre in Australia can be predicted by:

$$kgCO_2/m^2 = GLAR*(82.4+0.036CDD_{15wb})*(0.9+0.3*S)+514CP_{MV}+111CP_{OA}$$
$$+GLAR*0.0017*HDD_{18db}*(0.9+0.3*S)$$

Where $kgCO_2/m^2$ is kilograms of carbon dioxide emitted per square metre of GLAR per year, CDD_{15wb} is the number of cooling degree days base 15°C wet bulb, S is the serviced percentage of the shopping centre's GLAR, CP_{MV} is the number of mechanically ventilated car spaces and CP_{OA} is the number of open air or naturally ventilated car spaces and HDD_{18db} is the annual heating degree days base 18°C dry bulb.

Water consumption (in kL/m^2 per year) for a shopping centre can be predicted by:

$$w = 0.686 + 0.000406CDD_{15wb} + \frac{(5.93A_{gym} + 18.9n_{fcs} + 814n_{theatrettes})}{A_{GLAR}}$$

Introduction

Much focus has been applied over recent years to benchmarking energy and water use in office buildings, which has resulted in a range of energy rating schemes in different countries, such as Energy Star in the US and NABERS Office in Australia. However, benchmarking in the retail sector has been substantially more elusive. Key to this challenge has been the focus on energy benchmarks measured against a single performance index, such as $kgCO_{2\text{-}e}/m^2$, or $kBTU/ft^2$. However, the retail sector exhibits substantial variation in the type of services offered at different centres, with a resulting diversity in energy or water consumption intensity. This paper explores the various drivers of energy and water consumption in shopping centres as a multi-dimensional problem. Note that this benchmark forms the basis for NABERS for shopping centres, which is a program tool targeted at greenhouse gas emissions. Hence, the benchmark outcomes are targeted at greenhouse emissions, but can equally translate to energy consumption. Certainly, in the Australian market, the ratio of greenhouse emissions between electricity and natural gas (0.94:0.21kg$CO_{2\text{-}e}$/kWh) is similar to the ratio of their typical costs ($0.15:$0.04/kWh), making this benchmark relevant for both emissions and energy cost.

Key to this paper are the boundaries of a shopping centre. Initially, the study was aimed at the total retail sector. However, through early rounds of analysis, it was found that there was too much diversity in tenant installations and usage patterns between different tenant types, such as supermarkets, department stores, and specialty stores. Furthermore, while water is typically metered through a master meter for each site, electricity is typically metered direct from the electricity retailer to the tenants, which makes the collection of this data more challenging due to the substantially increased numbers of survey respondents. Benchmarking of energy use within the tenanted spaces is an ongoing area of research for this project. The results within this paper refer to the entire site consumption for water benchmarking, but only to the "base building" or landlord services within shopping centres for greenhouse benchmarking.

Background on NABERS, and the Context for this Study

NABERS (www.nabers.com.au) is a performance rating scheme – in simple terms, measuring actual production against actual resource consumption and ranking it against average performance in the market. It is expressed as a 0-5 star scale, in half star increments. 2.5 stars represents average performance in the industry, while 5 stars represents an aspirational level of achievement, beyond what is being delivered by industry at the time the rating bands are constructed. Typically, 5 stars represents a reduction in resource usage of 60% from average, but varies slightly between building types. Key to interpreting NABERS ratings is that it is based upon real, measured performance, rather than predicted or simulated performance. The experience in Australia over the last 10 years has shown that there is a non trivial gap between predicted performance and achieved performance (Bannister, 2009).

Australia has had office energy performance ratings available for over 10 years. Ratings were available under the Australian Building Greenhouse Rating (ABGR) scheme, which was later absorbed into the National Australian Built Environment Rating Scheme (NABERS), as other performance ratings were released. Currently the NABERS program includes energy, water, waste and indoor environment ratings for office buildings, energy and water ratings for hotels, shopping centres, houses and hospitals, with ratings for schools and data centres currently under development. The data and benchmarks within this paper formed the basis for NABERS for Shopping Centres.

NABERS has been widely accepted within the office market, with over 60% of the total floor area in Australia having been assessed at least once (DECCW, 2009). NABERS has had a significant impact on the Australian market, with it now being linked to rental premiums, longer leases and rental reviews through green leases (DECCW, 2009). Demand from tenants has generated a substantial premium for buildings operating at 4.5 or 5 stars, with this demand (and contract risk) being passed on to developers and design teams.

The prevalence of NABERS ratings in the office environment is highlighted by the proposed mandatory disclosure legislation currently before parliament (DEWHA, 2009). This legislation requires the disclosure of actual energy performance over the last 12 months for office buildings of greater than 2000m^2 (22,000ft^2) net lettable area at key points in their life cycle, such as building sale and signing of new leases over 2000m^2. The introduction of mandatory disclosure to other building classes, such as hotels and shopping centres is proposed for 2012.

The purpose of this study is to develop predictive performance benchmarks for greenhouse emissions and water consumption for a shopping centre with a given set of consumption drivers, to allow a buildings performance to be assessed against the performance of its peers.

Data Collected

Data was collected from the Australian shopping centre industry via a voluntary survey process. To assist in this process, a technical advisory group (TAG) was formed. Included within the TAG members were 8 of the largest shopping centre owners in Australia, and representatives of the major supermarket and department store chains.

The benchmark development and data collection were an iterative process, with early rounds of benchmarking indicating areas where the collected data was insufficient. A number of data collection phases were conducted to obtain sufficient data to develop the rating system. Distribution of surveys was predominantly through the TAG members, with some other participants invited on an individual basis.

Survey forms requested a broad range of qualitative and quantitative information from shopping centres, to help determine the empirical relationships between shopping centre background parameters and greenhouse emissions or water consumption.

Data collection occurred in three main phases:

- Initial data collection – conducted by the New South Wales Department of Environment, Climate Change and Water in 2005;
- Main round of data collection – expanded with specific questions on issues such as servicing of tenants. Commenced in 2008;
- Supplementary survey – sub-metering data (car parks and common area), more details on gyms and cinemas. Commenced in late 2008.

Within each round of data collection, there were numerous liaisons with property owner and management groups to obtain responses. In some cases, multiple requests and one on one sessions were required to obtain complete information.

Data Responses

The intent of the survey was to collect a representative sample of Australian shopping centres upon which to base the analysis. Critical to this is achieving a suitable coverage and diversity of the distinguishing parameters for shopping centre function. In particular, it was critical to have a suitable distribution across:

- Shopping centre sizes;
- Tenancy sizes and types, such as supermarkets, gyms, cinemas, food courts and large and small retailers;
- Car parking facilities – including both centres with mechanically ventilated and naturally ventilated/open air car parks;

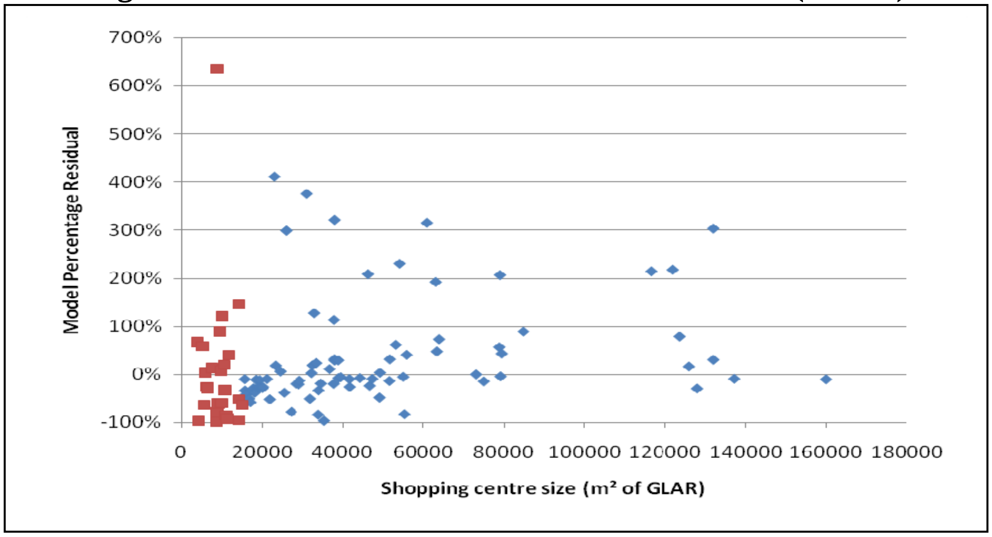
- Geographic distribution (for climatic impacts);
- Servicing of tenancies.

A total of 103 survey responses were received. Of these, 65 were used for greenhouse gas benchmarking, and 74 for water benchmarking. The responses from some sites were too incomplete, or implausible to be useful, so were excluded. Note that some sites were only able to provide energy data or water data, so may not appear in both energy and water samples.

Responses were received from shopping centres varying in size from 4000m^2 (Gross Lettable Area Retail (GLAR), i.e. the tenanted space) to a maximum of 160,000m^2, although only centres with a GLAR of greater than 15,000m^2 were used in the analyses.

Shopping centres of less than 15,000m^2 of GLAR were shown to have substantially different energy consumption characteristics than for centres with GLAR of greater than 15,000m^2. This is largely because the type of tenant mix, and the quantity of services provided at very small centres differ from that of larger centres. The distribution of residuals (the difference between actual and predicted energy consumption) from the analysis of the whole data set is shown Table 2. The plot demonstrates the distributional differences between sub 15,000m^2 buildings and the remainder of the shopping centres tested. Smaller centres perform disproportionately well, due to lack of common areas, and other services provided to shoppers. With the exception of three sites which provided car park sub-metering data, these centres were excluded from the benchmark development.

Figure 1. Distribution of Residuals and Centre Size (GLAR)



Energy Benchmarking

Shopping centres are diverse in the types of services offered to their tenants. This can pose a challenge to the creation of fair and relevant benchmarks, as few shopping centres are directly comparable or have the same mix of services. Two methodologies were considered for this study:

- Multiple regression of all parameters
- A model built up from a number of sub-benchmarks

Many benchmarking tools (such as Energy Star) have been based upon multiple regression models. However, this type of model presented two key challenges for the data in this sample, being:

- Completion of data. Many survey respondents did not, or were not able to answer particular questions in the survey. Multiple regression with data covering different responses can lead to spurious results.
- Cross correlation of parameters. Climate data in particular is inversely correlated. A site with high heating degree days will have low cooling degree days. But sites at either extreme will have increased energy consumption. Multiple regression can result in spurious results with highly correlated parameters.

Hence the method of benchmarking shopping centre consumption has been based upon the build-up of sub benchmarks for each of the major drivers for energy consumption which warrant correction. For example, a shopping centre in Sydney that provides full HVAC servicing to its tenants and has a car park will have sub-benchmarks for consumption due to its size, climate, tenant servicing and car park. The benchmark for this centre would be different to shopping centre with a similar size, but in a different location, with no tenant servicing and without a car park. This can then be used to assess an individual site, by comparing its actual measured consumption and measured production against the modeled energy consumption for a centre with the same facilities.

Calculation of a Site's Actual Greenhouse Emissions

The greenhouse intensities of different fuel types used by the shopping centres are based on the Australian Greenhouse Office's (AGO) "Factors and Methods Workbook 2008" (DEWHA 2009). These are full fuel cycle emissions, and due to the prevalence of coal in Australia's electricity generation, are high by international standards, with an average of approximately 1.06 $kgCO_{2\text{-}e}/kWh$ (SGE_e) for electricity, and 0.066 $kgCO_{2\text{-}e}/MJ$ (SGE_g) for natural gas, and 2.89 $kgCO_{2\text{-}e}/litre$ (SGE_d) of Diesel. Emissions coefficients vary from state to state within the country, with state specific quantities used within the study.

The actual greenhouse gas emissions per m^2 of GLAR were calculated based upon:

$$Actual\_emissions = \frac{SGE_e \times electricity(kWh) + SGE_g \times gas(MJ) + SGE_d \times diesel(l)}{GLAR(m^2)}$$

Site Production Metrics

Performance benchmarks are to allow the comparison of site consumption between sites offering different types and quantities of production. As the primary "production" of shopping centre owners is leasing retail space, the quantity of retail space is of first order importance.

Size Metrics

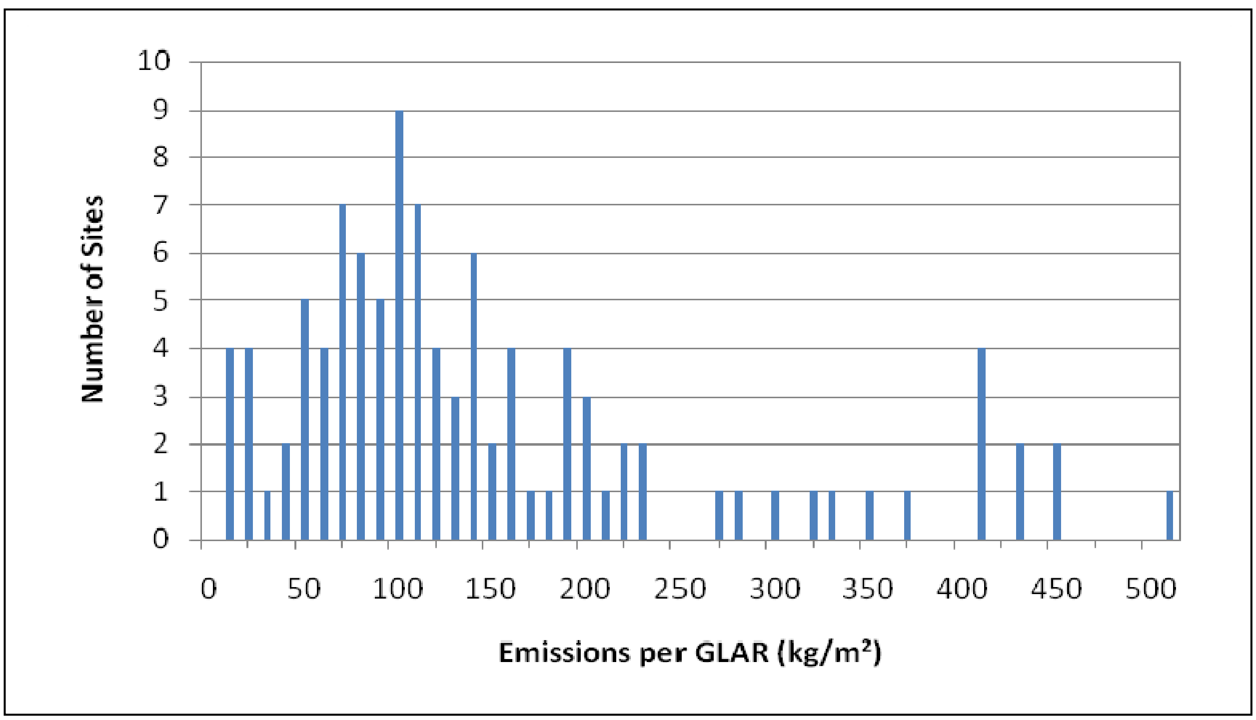
A number of energy use drivers are related to the size of the shopping centre, such as air conditioning and lighting loads. For the majority of shopping centres, shopping centre size is determined by a combination of the common area and the area that can be leased to tenants (GLAR).

Energy consumption is likely to be driven by the combination of these two parameters. However, there are some significant differences between them, being:

- Quality and transparency of data. GLAR is a commercial quantity – it is the primary unit in which tenants are billed. It has a third party standard of assessment, and is used in substantial financial transactions.
- Availability of data. All sites were able to report on GLAR with certainty. However, only a subset of sites were able to report common area, with variation in the definition of common area. The inconsistency in assessment, and the lack of existing data makes it a poor choice for a benchmark parameter
- Productivity. GLAR is a commodity that is directly demanded by the building users (tenants), and directly used for their "production". Common area is required to facilitate this production, but not directly "sold" to tenants.

GLAR, or lettable (leasable) area can be shown to have a significant relationship to energy consumption, with emissions density falling into a typically Poissonian distribution. The Poissionian distribution means that standard statistical tests may result in spurious conclusions, as the distribution is far from a normal distribution, with an extended tail. This extended tail in the distribution is because there is a physical limit to how low consumption can go (zero), but no physical limit to how high consumption can go.

Figure 2. Distribution of Emissions Density for All Completed Surveys



Greenhouse Emissions – Other Empirical Relationships

The statistical relationships of greenhouse emissions and drivers of greenhouse emissions within shopping centres are complex and difficult to display for an individual greenhouse driver. This is because the first order impact changes from site to site. For example for one site tenanted area may be the primary driver, with the provision of car parking being a secondary driver. Whereas for another site, with a far higher provision of car parking, and the provision of car parking for non-retail purposes, the car parking may be the first order driver of consumption. This mix of first and second order impacts means that the net impact across all the population only becomes apparent when a multi-dimensional analysis is undertaken.

Climate

Australia encompasses a diverse range of climates, from cool temperate conditions in the south, to highly arid climates in the centre, and the tropics in the north. This provides a challenge for energy ratings, as the thermal loads in these areas varies substantially.

Climate presents a challenge to correct empirically, as both heating and cooling requirements can impact upon greenhouse gas emissions. Hence, the empirical correlation of greenhouse gas emissions and either heating or cooling degree days can be complex – high heating sites have comparatively high greenhouse emissions, temperate sites have comparatively low emissions, and high cooling sites have comparatively high emissions.

Climate driven heating loads. In the shopping centres in the sample, the majority of sites within temperate and cold areas use natural gas for space heating, with relatively few sites in climates with significant heating loads using electric fuelled heating. Because of this separation, there is potential to separately benchmark heating against natural gas consumption.

Use of this approach avoids the potentially spurious results from regressing with inversely correlated parameters.

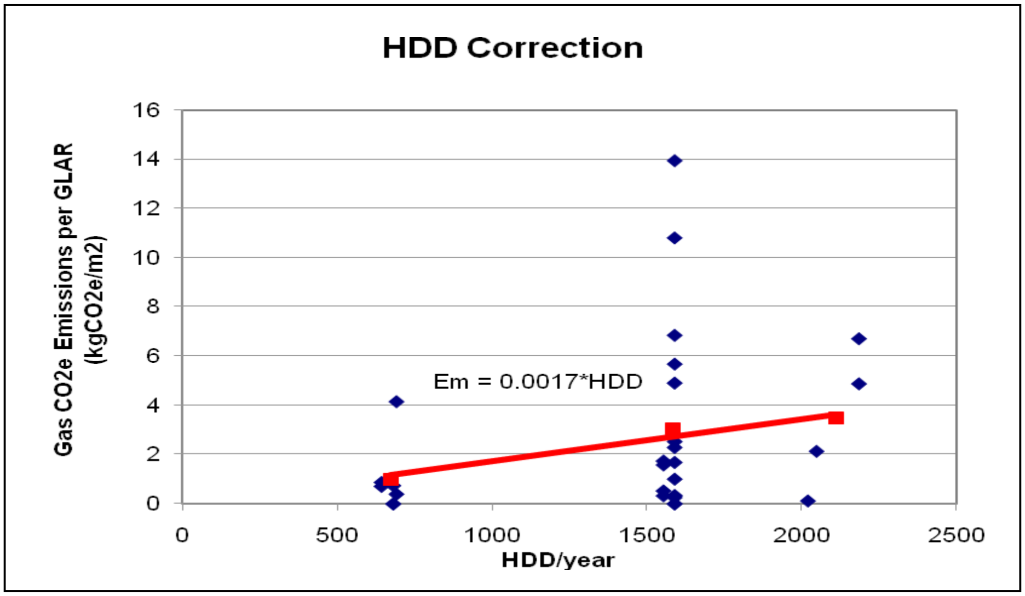
The quantity of heating required by a site is a function of both the magnitude (how cold), and the duration of heating load. To benchmark against a combination of these metrics, the heating degree day has been used, with a base of 18°C dry bulb (HDD_{18^oDB}). Heating degree day data has been based upon data provided by the Bureau of Meteorology.

Natural Gas Regression Model

Figure 3 shows the correlation between average natural gas consumption and climate driven heating loads (in heating degree days) for each of the shopping centres which reported their natural gas consumption. Note the red (square) points represent the averages of the centres in each climate zone, which help to remove the visual effect of outliers. An averaging approach has been used to remove the bias imposed by large numbers of samples in some locations.

A single variable, ordinary least squares regression was used to evaluate the relationship between the heating load of the shopping centres and actual natural gas consumption. Natural gas consumption data obtained during the survey process was only available for 30 of the buildings and contained a significant level of variability. Hence, the data was not able to support a statistically significant conclusion. However, the relationship suggested by the regression of averages for each climate group, provides a reasonable best estimate of the effect of climate based heating loads on natural gas consumption.

Figure 3. Natural Gas Emissions and Heating Load. Squares Indicate Climate Zone Averages



The correction for greenhouse gas emissions due to climate based heating loads is therefore:

$$G_{Gas} = 0.0017 \times HDD_{18^\circ DB}$$

Where G_{Gas} is the natural gas correction in kg of CO_2 emitted per m^2 of GLAR per annum and $HDD_{18^\circ DB}$ is the annual heating degree days.

There are other potential users of natural gas within shopping centres, such as food courts and domestic hot water production. However, as these emissions are likely to be related to the other benchmark parameters, they have been included in the general greenhouse model.

General Greenhouse Model

After applying the heating climate correction, and normalizing against GLAR, the residuals were tested against a broad range of production metrics. Of those tested, cooling load, the quantity of car parking provided and the quantity of tenanted area that is air conditioned by the shopping centre owner were found to be substantiated energy drivers.

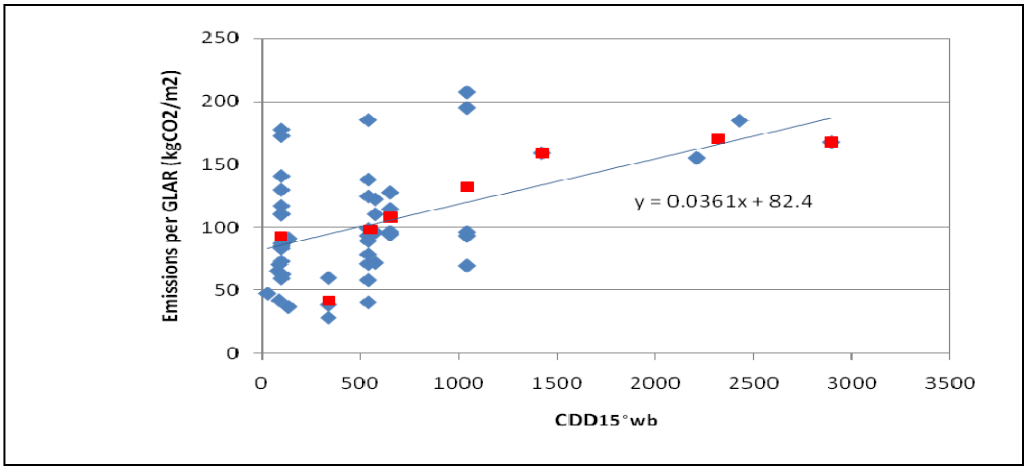
Climate Driven Cooling Loads

The provision of space cooling and HVAC services is a major end use of shopping centre electricity. However, only a portion of this is climate dependent. In order to fairly compare shopping centres in different climates, a correction for the climate dependant portion of the load is required.

A useful metric for the magnitude and duration of cooling loads is the number of cooling degree days (CDD) in a year. For the purposes of this report and analysis, a base of 15ºC wet bulb is used ($CDD_{15°WB}$), which will take into account the latent and sensible cooling loads. CDDs are an integral of the time (days) spent at temperatures above the base temperature. CDD values used in the analysis were provided by the Bureau of Meteorology for each climate zone.

The correlation between CDD and average emissions per square metre for that climate zone is shown in figure 4:

Figure 4. Cooling and Emissions. Squares Indicate Averages for a Climate Zone



The noise in the data is primarily due to the level of variation in greenhouse emissions from other energy drivers. The confidence level from the regression of emissions per m^2 of GLAR for each centre against cooling degree days was greater than 99%.

The climate driven cooling load correction used is:

$$G_{cooling} = 0.036 CDD_{15^{\circ}wb} * GLAR$$

Table 1: Results from Regression of Climate Based Cooling Loads ($CDD_{15°wb}$) Against Individual Centre's Emissions

Variable	Coefficients	P-value
Intercept	82.39456	6.6301E-14
CDD (individual centres)	0.036107	0.00043992

Car Parking

For many shopping centres, the provision of car parking is an integral component of the service provided by the centre. However, the quantity of car parks is not just related to the shopping centre size. Some centres may have a higher or lower level of parking associated with the centre due to zoning or development approval requirements. This means that the number of car parks being provided is often outside the control of the shopping centre.

Of the shopping centres surveyed, eight were able to provide sub-metered car park consumption data. Although the sample size is smaller than ideal, the data was sufficient to support statistically significant correlations between the number of mechanically ventilated and naturally ventilated or open air car spaces on the car park's electrical consumption.

The car park sub-metering data provided included the total electricity consumption of the car park, the operational hours of the car parks and the number of spaces of each type. The operational hours and total consumption were used to produce an estimate of the electrical load of each car park (in kW). Tests for the effect of each car park type on the electrical load were run against this total electrical load figure.

The results of a regression run on the effect of the number of each type of car space on the shopping centre's emissions is outlined in Table 2. The confidence level for the combined effects of each type of car park was greater than 99% for the 8 sites used. However this confidence drops substantially when this is applied across the general shopping centre population.

Table 2: Car Park Correction Figures

	kW per Space	P-value	kWh per Space per Year (based on 70 hours per week)	$kgCO_2$ per Space per Year
Mechanically Ventilated	0.13286	0.000169	485	514
Open Air or Naturally Ventilated	0.02884	0.024585	105	111

In the data provided, there was a small degree of diversity in the opening hours of car parks. Because of the generally comparable operating hours, with an average of 70 hours per week, a fixed correction per car park has been developed:

- 485 kWh (514 $kgCO_2$) per mechanically ventilated space per year
- 105 kWh (111 $kgCO_2$) per open air or naturally ventilated space per year

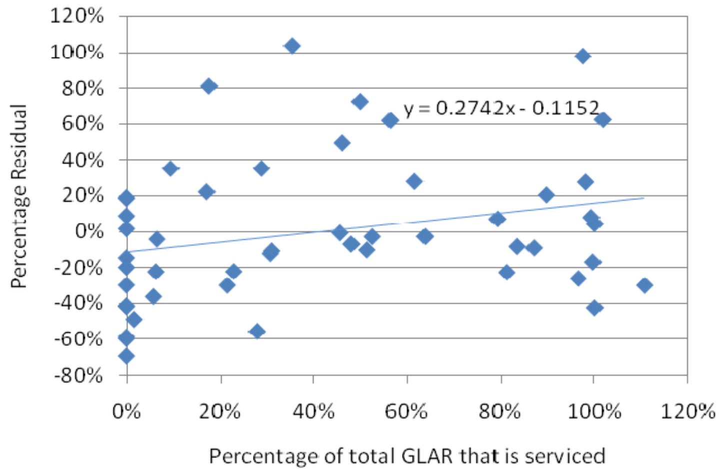
Tenant and Common Area Servicing

The degree of HVAC servicing supplied to tenants and the common areas varies significantly between shopping centres. Conditioning to tenants can be provided by either the shopping centre or by tenants themselves. For the majority of shopping centres surveyed, there is some mix of serviced and un-serviced tenancies.

The percentage of the centre serviced is determined by the percentage of the GLAR of the centre for which full HVAC services are included within the centre's energy consumption. For the purposes of this study, full HVAC services means that all thermal (space heating and or cooling), air movement and ventilation is provided by the shopping centre. As an example, a tenancy supplied with condenser water only is not deemed to be serviced by the centre.

The impact of providing servicing to tenants on a centre's emissions is affected both by the centre's size and climate based loads. The magnitude of this correction has been determined by examining the proportion of serviced GLAR against the residuals of sample sites.

Figure 5: Servicing of Tenants



The results of the regression are shown below.

Table 3: Tenant Servicing Regression

Variable	*Coefficients*	*P-value*
Intercept	-0.1152	0.175005
Serviced Percentage	0.274194	0.068823

The correction is applied as an adjustment factor to the predicted emissions from climate and GLAR related loads, but not to unrelated loads, such as car parks.

The correction for servicing used is an adjustment of the emissions by up to 30% ranging from allocating 90% of the predicted emissions for centres with no serviced GLAR to 120% of the predicted emissions for centres with all GLAR serviced, based upon the regression in table 3.

The correction applied for the serviced percentage of the centre, also affects the allocation of emissions due to HDD. The correction for gas emissions, due to climate driven heating loads become:

$$G_{gas} = GLAR * 0.0017 * HDD_{18db} * (0.9 + 0.3 * S)$$

Predicted Emissions

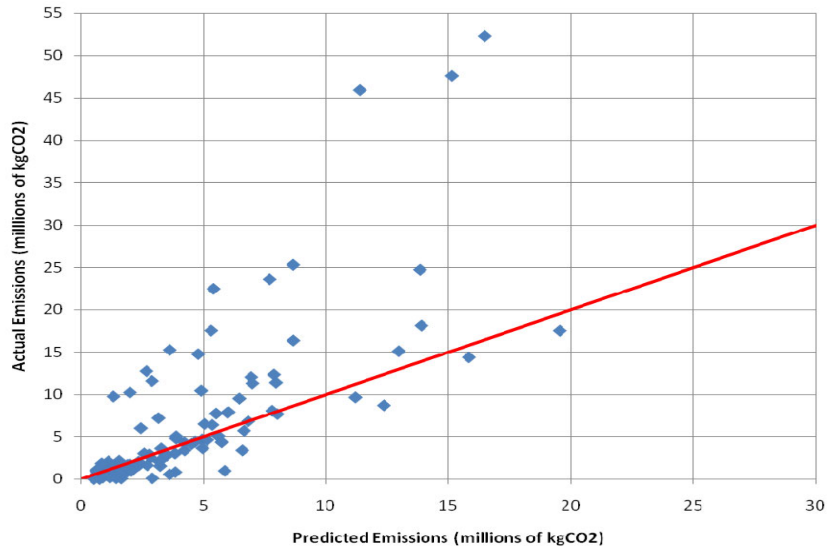
Based upon the combination of the previous results, average greenhouse gas emissions for a shopping centre in Australia can be predicted by:

$$kgCO_2 / m^2 = GLAR * (82.4 + 0.036CDD_{15wb}) * (0.9 + 0.3 * S) + 514CP_{MV} + 111CP_{OA}$$
$$+ GLAR * 0.0017 * HDD_{18db} * (0.9 + 0.3 * S)$$

Where $kgCO_2/m^2$ is kilograms of carbon dioxide emitted per square metre of GLAR per year, CDD_{15wb} is the number of cooling degree days base 15°C wet bulb, S is the serviced percentage of the shopping centre's GLAR, CP_{MV} is the number of mechanically ventilated car spaces and CP_{OA} is the number of open air or naturally ventilated car spaces and HDD_{18db} is the annual heating degree days base 18°C dry bulb.

The correlation between predicted and actual greenhouse emissions is shown below in Figure 6:

Figure 6: Predicted vs. Actual Shopping Centre GHG Emissions



When applied to the total data set expressed in total $kgCO_2$, the regression equation has an R^2 of 0.56, indicating that the factors represented in the regression equation account for 56% of the variability in the data set. Note that the line within this graph is a 1:1 relationship, and not a trend-line.

In order to evaluate the efficiency of the shopping centre against this metric, the actual consumption of the centre should be compared against the predicted emissions for an “average” centre with the same characteristics. Measured consumption that is lower than predicted consumption indicates better than average shopping centre greenhouse emissions.

Water Benchmarking

A similar process was used to develop water benchmarks, with the key difference that water consumption includes water consumption of tenants, as most sites have a single main water meter. The water model has a substantially better fit to the underlying data than the energy model, with the water model explaining 89% of the variation in water consumption.

Key parameters within the water consumption model are:

- The Gross Lettable Area Retail, in square metres, A_{GLAR}
- The quantity of cooling degree days in the year, base 15°C wet bulb, $CDD15_{wb}$
- The area of gymnasium tenants, in square metres, A_{gym}
- The number of food court seats provided, n_{fcs}
- And the number of cinema theatrettes, $n_{theatrettes}$

Using these parameters, the predicted water consumption (in kL per year per square metre of GLAR) can be predicted by:

$$w = 0.686 + 0.000406 CDD_{15wb} + \frac{\left(5.93 A_{gym} + 18.9 n_{fcs} + 814 n_{theatrettes}\right)}{A_{glar}}$$

Conclusions and Further Research

This study has developed greenhouse and water performance benchmarks for use in the shopping centre industry in Australia. These benchmarks have formed the basis for the development of the NABERS retail tool (www.NABERS.com.au), which has found substantial interest from the shopping centre industry (Westfield, Colonial, Mirvac and Stockland, who between them represent over 50% of Australian shopping centres, among others are trialing this tool). Shopping centre portfolios have begun maneuvering to align their portfolios to be assessable under NABERS, and to be able to promote ratings within their corporate reporting.

Research is continuing into developing sector specific benchmarks for individual store categories, such as supermarkets, department stores, hardware stores and bulky goods stores is required, and will require input, feedback and support in the form of data from these industries.

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