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Schools: An Untapped Opportunity for a Carbon Neutral Future

Portia Odell [1,*], Vanessa Rauland [2,3] and Karen Murcia [4]

[1] Climate Council, Melbourne, VIC 3000, Australia
[2] ClimateClever, Fremantle, WA 6160, Australia; vanessa@climateclever.org or v.rauland@curtin.edu.au
[3] School of Design and the Built Environment, Curtin University, Bentley, WA 6102, Australia
[4] School of Education, Curtin University, Bentley, WA 6102, Australia; karen.murcia@curtin.edu.au
* Correspondence: portia.odell@climatecouncil.org.au

Abstract: School buildings, like many buildings around the world, are rapidly aging and becoming increasingly inefficient, leading to unnecessary carbon emissions and high utility bills. School buildings can offer some of the most cost-effective carbon abatement opportunities; however, very few schools focus on quantifiable carbon reduction. This is despite the growing emphasis on school sustainability and there is a notable gap in the literature in this area. This study examined 13 schools that participated in an innovative 2-year Low Carbon Schools Pilot Program (LCSPP) in Perth, Western Australia and explores how schools can effectively reduce their carbon emissions and operational costs associated with their buildings and infrastructure. Utility data from electricity, gas and water from the schools were analysed in conjunction with the initiatives each school implemented to identify the highest impact initiatives. The study showed that schools reduced their carbon emissions on average by 20% on a per student basis and saved an average of 15% in costs. More than 70% of the actions identified by participating schools were low or zero cost. This study demonstrates the abundant opportunities available for schools to reduce their consumption of resources, carbon emissions and utility costs with minimal to no cost outlay.

Keywords: carbon emissions; school sustainability; emissions reduction; built environment; school building; carbon footprint

Citation: Odell, P.; Rauland, V.; Murcia, K. Schools: An Untapped Opportunity for a Carbon Neutral Future. *Sustainability* **2021**, *13*, 46. https://dx.doi.org/10.3390/su13010046

Received: 21 October 2020
Accepted: 21 December 2020
Published: 23 December 2020

1. Introduction

Climate change is at the forefront of a global agenda with many countries committing to targets to limit global temperature rise to 1.5 degrees [1]. The construction and operational energy use associated with buildings account for up to 40% of carbon emissions worldwide [2]. In Australia, buildings account for up to half of the national electricity consumption [3] and contribute to a quarter of the country's greenhouse gas emissions [4]. This demonstrates the imperative, and the significant opportunity, to address carbon emissions from this sector. School buildings in particular are rapidly aging and largely inefficient, with many studies highlighting this issue [5–8]. In addition, a 2012 Australian government study found that while energy consumption has decreased over the last 10 years in commercial and public buildings, energy consumption increased in schools, with further increases expected by 2020 [9,10]. These increases can be attributed to the increased use of technology in classrooms, new government requirements to climate control classrooms [11] as well as ageing infrastructure [12].

For these reasons and others, the education sector has also been identified as one of the most cost-effective contemporary carbon abatement opportunities within the built environment in Australia [12]. School decarbonisation also has many co-benefits, both to schools and society. An obvious benefit is the reduction in resource consumption and costs, which is demonstrated by programs such as ResourceSmart in Victoria, Australia, where the 1300 participating schools have collectively saved over AUD 20 million dollars and 60,000 tonnes of CO_2-e between 2008 and 2019 [13].

Schools also have the significant potential to act as a catalyst for community engagement around sustainability [14]. The implementation of sustainability initiatives, such as school gardens, can attract community interaction while promoting sustainability and activating students and staff to further increase the sustainability of the campus [15]. Lastly, and most importantly, school buildings themselves can act as an important influencer in the hidden curriculum (i.e., the unintended lessons students learn at school outside of the taught curriculum) [16]. The retrofit of an existing school building can provide a plethora of learning opportunities for students as they can witness first-hand the changes made and the effect they have on a building [17]. Other studies have also shown that involving students in a school energy efficiency program can result in an increase of student agency and enthusiasm for school programs [18,19].

The literature focussed specifically on carbon emission reduction in schools is sparse, with most articles focussed on specific components of a carbon footprint (largely energy) rather than holistic emissions reduction [20]. The literature focussing on energy use in schools includes solutions such as improving heating, ventilation and air conditioning (HVAC) systems and performing LED lighting upgrades and how these reduce consumption and cost [21–25]. Zeiler and Boxem (2013) note that energy and resource efficiency should always be the first step for an established school when beginning their carbon reduction journey [8]. However, others highlight that up to 70% of a school's carbon footprint can come from the emissions associated with procurement and transport (student and staff commute), and therefore suggest that focussing on just one resource area, such as energy, is inadequate [26]. In addition, while there are many standardised approaches to calculating the total carbon footprint of a building, such as the Greenhouse Gas Protocol [27], approaches like this can often be too difficult and detailed for schools with limited resources and expertise [14].

There is also a gap in the literature on holistic emissions reduction pathways for schools and how school stakeholders (e.g., principals, students, teachers) can actively reduce school emissions. Some solutions which do take into account holistic emissions reduction such as Life Cycle Assessment (LCA), are identified in the literature as an impactful approach to calculating the carbon emissions of schools [28–31]. However, LCA is incredibly complex as it involves the calculation of the environmental impact of every aspect of the building, including material extraction, construction, maintenance and operation [29] and is unlikely to be undertaken by many schools. While involving researchers and consultants in this process can lead to positive environmental outcomes, most schools are cash-poor and typically cannot engage with this type of expertise. Therefore, an approach such as LCA is not suitable for widespread school emissions reduction. In addition, most studies on school emissions reduction give little emphasis to the role that school stakeholders can play in reducing school emissions [20].

Despite the abundant environmental and social benefits, and the imperative to address rising emissions, utility consumption and costs, there has been mixed ambition and approaches from various levels of government in Australia to push quantifiable carbon reduction in schools [12,14]. The Australian Federal Government has supported areas like Education for Sustainability (EfS), a well-established field of knowledge related to integrating sustainability and environmental principles into education [32], however quantifiable carbon reduction has never been a key focus [14]. On a state- level, several programs do target various aspects of sustainability in schools such as energy, water or waste and provide abundant curriculum resources. However, like the federal government, very few programs focus on the quantifiable aspects of carbon reduction and management [14]. This is despite an increasing financial incentive for schools to pursue resource efficiency measures because of increasing school autonomy over budgets [14].

A Low Carbon Schools Pilot Program (LCSPP) was launched in Perth, Western Australia to attempt to address this gap. In total, 15 schools within the Perth metropolitan area were chosen to participate in the 2-year program which took place between 2015 and 2017. The program focused on empowering and upskilling school administrators and students with the information and tools needed to measure and monitor their consumption of resources and implement quantifiable carbon reduction initiatives to reduce their operational footprint and utility costs. This paper presents the range of initiatives and reduction strategies schools used, and the impact these initiatives had on their resource consumption, costs and carbon emissions.

2. Materials and Methods

2.1. Utility Consumption, Costs and Carbon Emissions

As part of their participation in the Low Carbon Schools Pilot Program (LCSPP), each school participant was provided with an emissions tracking excel spreadsheet (see Appendix A Figure A1 where they entered the utility bill data on their school's costs and consumption for electricity (total kWh), gas (total kWh) and water (total kL). This spreadsheet was created by a consultant engaged by the program deliverers, which calculated scope 1, 2 and 3 emissions for electricity, gas and water (shown by Appendix A Figure A2). This was conducted in accordance with the Greenhouse Gas Protocol following the Operational Control Approach [27]. Each year the emissions spreadsheets were updated with the latest emissions factors using Australian Government National Greenhouse Account Factors [33–35], shown in Appendix A, Figures A3 and A4.

The spreadsheets were filled in by various stakeholders at the school with most completed by either a teacher or the registrar/business manager, followed by parents or even students. Each school stakeholder entered the date range for each bill, the total consumption and cost for the bill period. Most bills were not structured according to calendar year (e.g., bill covered period from 15 December to 16 January) so total consumption and cost were divided by the number of days in the bill, then multiplied by the number of days in the calendar month for that period (e.g., the 16 days in January). This process took place for all bills in order to give a monthly consumption and cost for all months in the calendar year. These revised consumption figures were then converted to the appropriate unit of measurement (e.g., electricity (kWh), gas (GJ), water (kL)) and multiplied by the relevant Scope 1, 2 and 3 emissions factors.

When the initial spreadsheets were received from the schools, a significant number of schools had major errors in their spreadsheets, such as incorrect number entry, leaving sections incomplete or using incorrect figures from bills. At the end of the pilot, copies of the bills for electricity, gas and water for the base year (the year before the pilot began) and the 2 years of the pilot were requested from all schools to check the spreadsheet data against the actual bill data and errors were fixed. Complications arose around obtaining all the required utility bills from the schools, and several attempts were made to contact each school to locate missing bills. However, in some cases, bill data could not be retrieved by the school and therefore estimates were made based on the consumption and costs from the same period in earlier years where data was available. Due to restrictions with access to the data, waste data for the participating schools were not acquired.

Over 90% of the utility consumption and cost data were obtained from verified sources (i.e., directly from the utility provider or as a copy of the physical or electronic utility bill that the school received). All schools also provided permission to obtain their electricity interval data at 5-min intervals for all three years and the approximate square meterage of each school's total building space and green space were also calculated using Google Earth historical satellite data and the Google Earth Polygon tool in order to measure changes during the pilot. This method was chosen as there was no accurate or consistent record of square meterage data available for use either from school records or from the state Education Department. A numerical table of the number of transportable classrooms installed and removed between the base year and final year of the pilot was provided by a government department, along with the average square metres of the classrooms for all the schools participating in the research. A lack of publicly available data on the school sites, such as sizes and types of each building on campus, as well as no building submetering being present at any school, prevented more granular levels of analysis. There was also no funding available during this study to implement sub meters in the participating schools.

While the carbon calculations undertaken in the program were conducted in line with the GHG protocol, a complete carbon footprint as per their guidelines, including other recommended sources such as waste, refrigerants, flights, business-owned vehicles and paper, was not possible due to several factors. Firstly, there was limited availability of school data, for example, waste bills did not provide sufficient data to calculate emissions and records of business owned vehicles were difficult to obtain. Secondly, the intention of this study was to not only understand the opportunities that existed to assist schools in reducing their carbon footprint, but also to ensure that the processes undertaken would be able to be replicated by other schools who wanted to reduce their carbon footprint. As schools have limited time, resources and expertise in this area, it was decided to focus on key sources of emissions, with easily accessible data (i.e., utility bills).

Considering the varying student, campus sizes and types of buildings at the schools, several metrics were considered for carbon emissions calculations and comparison of utility consumption and costs. The primary metric used for this research was 'per student' and is especially relevant to Western Australian schools since they receive funding on a per student basis. It is also a useful metric when comparing schools to understand whether a school has high carbon emissions, consumption or costs relative to its student population. This per capita approach is commonly used when discussing carbon emissions on a global scale between countries. However, total and square metre metrics are also discussed if additional insights can be gained. Within energy efficiency literature, it is common for electricity consumption to be analysed on a per square metre basis [36]. However, while 'per student' will be the primary metric, total emissions, costs and consumption will also be used to provide a more holistic picture of the data.

Several articles noted the difficulty in benchmarking and predicting energy or carbon emissions in schools due to the large number of variables contributing to a school's resource consumption pattern [37–40]. Examples of this include inconsistencies between electricity use and factors such as size of school and number of students, suggesting there are other elements at play, such as leaking windows and the energy use behaviours of teachers and students [37,41]. These issues highlight the importance of taking into account the context of each school, as well as using relevant terms and variables (e.g., CO_2 per student) when comparing consumption and emissions between schools [37].

Weather Normalisation of Data

Weather is a variable that can greatly influence energy consumption, and studies have explored the role of weather, such as the influence of ambient air temperature on energy consumption [42,43]. There are various ways to calculate the effect of weather on energy consumption, with one of the most common being Heating Degree Days (HDD) and Cooling Degree Days (CDD) [44]. Since all schools had either reverse cycle air-conditioning systems in at least two or more buildings or a combination of air conditioners and gas heaters, both HDD and CDD were considered. While using degree days to normalise consumption for weather can be challenging in some contexts, such as commercial buildings and the complexities of large-scale HVAC systems, the smaller size of school buildings allows a greater deal of thermal comfort control that can be exercised by the school [45]. Given that there is a great opportunity for control (and often poor thermal comfort levels in their buildings), it could be argued that schools are likely to react more to temperature fluctuations, making their consumption more closely correlate with HDD.

When total gas consumption was observed across the schools, 2016 showed a significant difference in consumption than 2015 (the baseline year) and 2017 for all schools. When the number of HDDs was observed for each year (2015–2017), it showed that 2016 had the most HDDs than in the last 10 years for the Perth Metropolitan region, making it an unusually cold year. Interestingly, 2016 had 18% more HDDs than the 10-year average, whereas 2015 and 2017 had 8% and 1% less HDDs, respectively.

When a regression analysis was performed between average Heating Degree Days (HDDs) and gas consumption for each year, there was a significant correlation between monthly gas consumption and the number of HDDs, as shown in Appendix B Figure A5. Cooling Degree Days (CDDs) were not measured in relation to monthly gas consumption because gas was not used for cooling in any of the school buildings. A regression was performed for both HDDs and CDDs in relation to monthly electricity consumption because some schools had reverse cycle air conditioners, meaning electricity could be used to both heat and cool the buildings. However, the regression showed that the electricity consumption patterns were not correlated with HDDs or CDDs (see Appendix B Figure A6). This weak relationship indicates that there are many other factors that came into play with the schools' electricity consumption. Therefore, electricity consumption was not normalised against CDDs or HDDs. However, it was determined that to better understand school gas consumption patterns and given the strong correlation between gas consumption and HDD's, a weather normalisation technique would be applied for gas consumption and HDDs, which is described in more detail in the following paragraphs.

A key aspect of calculating HDD or CDD relates to the base thermal comfort range for indoor environments, which is between 12 and 18 degrees Celsius for heating and 18 and 24 degrees Celsius for cooling. The upper limits of these ranges (18 degrees and 24 degrees) were used, as this is what is recommended by the Bureau of Meteorology [46]. The HDD and CDD figures from 2005 to 2017 were obtained from DegreeDays.net, which uses weather data from the Perth Airport weather station. The method used to calculate the HDD and CDD took the average temperature for each day in the year and for each day when the temperature was above or below the base thermal comfort range (18 degrees in winter and 24 degrees in summer) it was counted as a heating degree day (HDD) or cooling degree day (CDD) [47]. The equations used for the calculation of weather-normalised gas consumption can be seen in Equations (1) and (2) where HDD_m^{ref} is the 10-year average of HDDs, P is gas consumption in kWh and $Q_{m,y}$ is the weather-normalised gas consumption (kWh). Gas consumption and costs for each school from 2015 to 2017 was adjusted using the below formula. The adjusted consumption and costs were used for analysis.

$$HDD_m^{ref} = \frac{1}{n} \sum_{y\,=\,2005}^{2005\,+\,n} HDD_{m,y} \tag{1}$$

$$Q_{m,y} = HDD_m^{ref} \frac{P_m}{HDD_{m,y}} \tag{2}$$

2.2. School Initiatives

At the beginning of the program, each school was also provided with an action plan template where they kept track of the low carbon initiatives they planned and implemented throughout their participation in the LCSPP. Throughout the program, schools were given ideas about zero, low or high-cost initiatives they could pursue across energy, waste, water and transport. The schools chose initiatives that were most relevant to their school and added to their action plans on an ongoing basis.

3. Results

3.1. Schools Overview

The participating schools in this study had a wide range of variation between student numbers. Some school populations were as few as 90 students, with other secondary schools reaching over 1700 students. Student numbers increased by an average of 15% over the 2-year program, with two secondary schools increasing their student numbers by over 50% during this time and only one school decreasing. Schools also had varying proportions of building sizes and green space, as shown in Figure 1. A total of five schools increased in total square metres (m^2) due to the installation of transportable classrooms to accommodate additional students, with two secondary schools installing at least 12 transportable classrooms each. There were also significant differences in the density of students in their school buildings (i.e., number of square metres per student). Some schools had a large amount of space per student (25 m^2 per student), whereas one of the smallest schools had the highest density (6 m^2 per student).

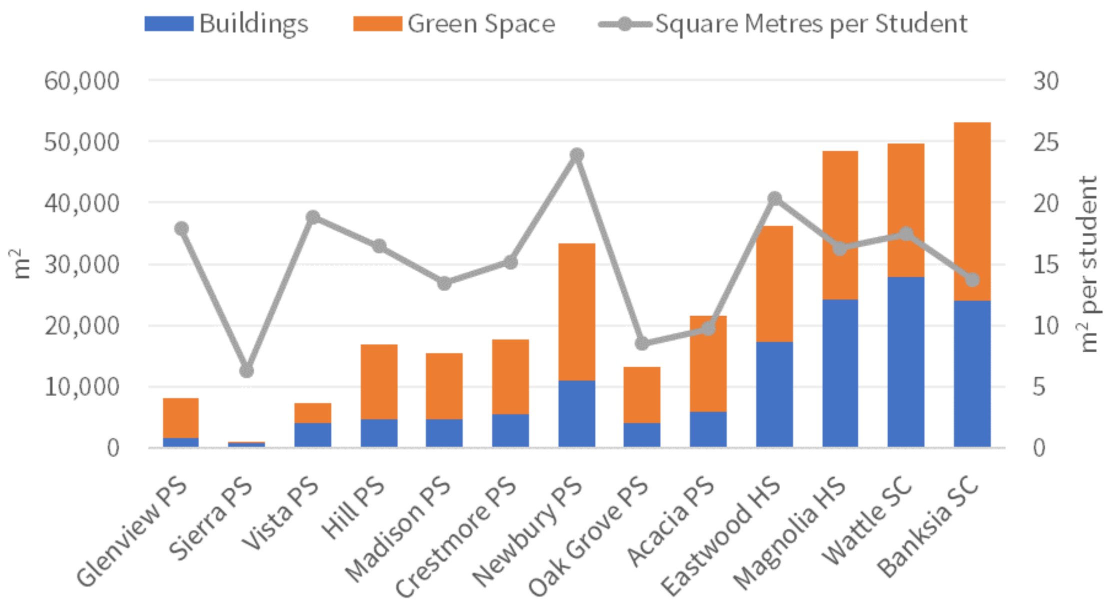


Figure 1. Total building and green areas in square metres (m^2) and square metres per student (m^2/student) for 2017 for all schools. Schools are ordered left to right from smallest to largest number of students.

3.2. Low Carbon Initiatives

A total of 636 actions were identified by 12 schools (one school did not complete an action plan). All actions were categorised as being zero, low, medium or high cost. Low-cost initiatives were less than AUD 1500, medium cost initiatives cost up to AUD 5000 and high-cost initiatives more than AUD 5000. The biggest area initiatives targeted was energy (36%), with waste forming the second largest category (26%), despite utility bill data not being collected from waste. The rest of the actions fell into water (19%), transport (7%) and 'other' (12%) categories. The number of initiatives in each category is shown in Table 1 below.

Table 1. Total number of initiatives in each category for all 12 schools.

Category	Number of Initiatives
Transport	42
Other	75
Water	124
Waste	163
Energy	232

Over 60% of the actions the schools identified involved zero cost, with another 10% of initiatives involving a low cost (under AUD 1500). The actions were also categorised according to the type of action. For example, the largest category of actions was classified as 'infrastructure' (32%) and were actions that focussed on implementing tangible infrastructure changes at the school, such as retrofitting taps or switching to LED lights. The second biggest category of initiatives were classified as 'investigation' (26%) and involved activities that gathered more information, such as investigating resource consumption, conducting audits of appliances or fixtures or getting quotes for solar PV. Behaviour change initiatives were also common at the schools (20%), with about half of the behaviour change initiatives focussing on changing the behaviour of staff (e.g., using less paper), and the other half focussing on changing the behaviour of students (e.g., improving recycling habits). Educational activities (14%) were those that were specific to educating students, such as a classroom activity on water conservation. Nearly half of all actions identified actively involved students in some way. The following sections discuss the emissions category areas energy, water and gas in more detail.

3.3. Energy

There were 226 energy actions listed by schools, and almost half were ongoing or completed by the end of the program. The rest were still under investigation or not yet started. There were several electricity initiatives that were commonly implemented or explored across the schools, which are summarised in Table 2. Most of the energy initiatives most implemented involved no cost.

Table 2. Most common energy actions listed on all school low carbon action plans.

Initiative	Number of Schools Implemented	Cost
Implement switch off protocol for end of school day and school holidays	10	Zero
Investigate timers on devices	8	Low
Change fluorescent lighting to LEDs as lights expire	7	Medium
Conduct type 1 Energy Audit	7	Low
Investigate/change electricity tariff	6	Zero
Investigate electricity bill consumption & ongoing monitoring	5	Zero
Put switch-off stickers near lights and computers	5	Zero
Conduct fridge audit	5	Zero
Create low carbon/renewable energy policy	5	Zero
Implement computer auto-shutdown	4	Zero
Colour code electronics that can be turned off	4	Zero
Start "switch off award" for classrooms during lunch	4	Zero
Unplug water cooler fountains	4	Zero
Make reminder signs for staff/students to turn off lights	4	Zero
Audit all energy consuming devices	3	Zero
Remove lighting in refrigerators	3	Zero
Reduce temperature of hot water	2	Zero
Investigate eco-switches	2	Low

One secondary school's (Eastwood HS) investigation identified that there were several refrigerators located throughout the school campus that were previously donated by community members. Most of these fridges were completely or mostly empty yet were still plugged in and running all year. This investigation led the school to remove several refrigerators. This action, combined with other small behavioural change initiatives targeted at staff, enabled the school to save over 25,000 kWh between the base year and the end of the program. After Eastwood HS shared this activity with other schools in the program at a monthly meeting, many other schools followed suit and investigated the number of fridges and their level of use.

All schools implemented some behaviour change initiatives, such as getting students to create signs to remind staff and students to turn off lights and placing stickers next to computers and lights as reminders. A few schools also unplugged their chilled water fountains from power and reported that no staff or students noticed the change in water temperature. A total of four primary schools also started a "switch-off award" where classrooms were encouraged to turn off their lights during lunch and the classrooms with the greatest number of days with no lights on throughout the school term received an award.

Many schools investigated the feasibility of timers on electronic devices, such as computers, but only one school implemented timers. However, half the schools did install timers on the hot water urns in their staff rooms, which involved minimal cost outlay. Around half the schools were also in the process of changing their fluorescent tubes to LEDs as the old light bulbs expired. While all schools wanted LEDs across their school, most lacked the upfront funds to replace all lights at the same time. The most cost-effective way to approach the replacement of LEDs was incrementally, as lights needed to be replaced. In total, seven schools also participated in a Type 1 energy audit that was provided free of charge by a partner of the LCSPP, which gave them insight into their highest energy consumption areas.

Another example of a high impact area that many schools investigated, but were unable to pursue for financial reasons, was the replacement of outdoor security lighting (which can use upwards of 4000 kW) to LED security lights, which use significantly less energy. Most schools investigated how to replace their security lights and received quotes; however, the majority could not afford the cost associated with replacing them. Only one school (Madison PS) was able to switch their security lights to LEDs. Most schools also wanted to install solar PV. However, like LEDs, the cost was prohibitive. Only one primary school, Oak Grove PS, was able to install solar PV by funding their panels partly through their own budget and ran a community fundraiser to obtain the remaining funds. Eastwood HS was also in the process of installing solar PV and was in the unique position of having enough upfront capital to purchase them outright. However, despite the school starting the process of obtaining approval for their solar PV from the Department of Education (DoE) at the beginning of the second year of the program, the lack of DoE policies around school solar installation, created significant delays and there had still been no progress with Eastwood HS's solar installation by the time this study concluded.

3.3.1. Electricity Consumption and Costs

When the total electricity consumption for each school is compared from their baseline year to the end of the LCSPP, nine of the schools reduced their electricity consumption while four schools increased their consumption. Figure 2 shows each school's yearly total electricity consumption between the three years (the baseline year and 2 years of the pilot). The differences in consumption between primary schools and high schools is evident. The school that had the largest reduction in total electricity consumption was Madison PS. They were the only school that switched all their external security lighting on all buildings to LEDs and were in the process of installing LEDs throughout the school. These two initiatives greatly impacted the schools' consumption saving them over 30,000 kWh, totalling a cost savings of over AUD 7000.

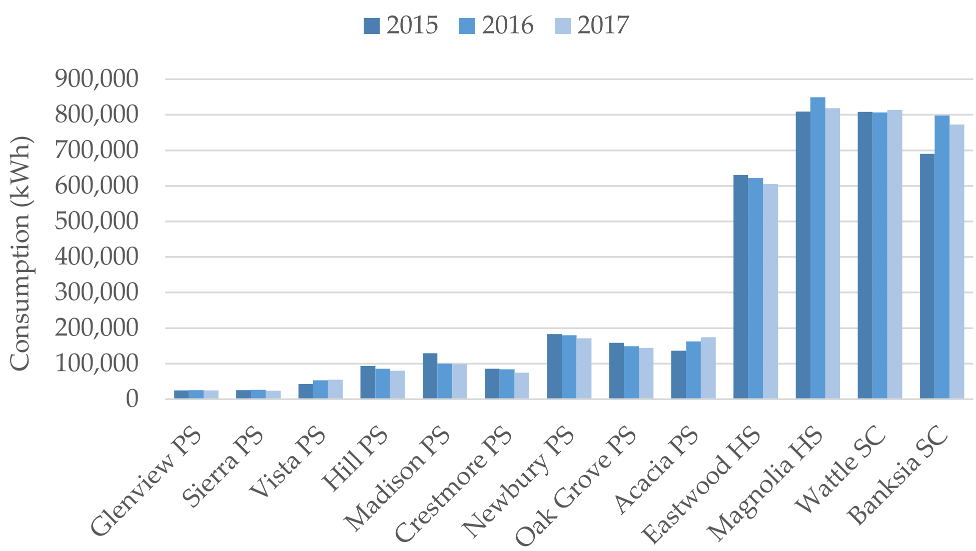


Figure 2. Total electricity consumption (kWh) for all participating schools (2015–2017). Schools are ordered left to right from smallest to largest number of students.

On a per student basis, 11 of the 13 schools reduced their electricity consumption by an average of 16%, with the largest reduction seen by Banksia SC. As shown in Figure 3, while Eastwood HS used the least amount of electricity out of all the high schools, they had the highest electricity consumption per student than any other school. Further, some of the smallest primary schools used the same amount of electricity per student than schools over three times their size. This could be due to efficiencies of scale (i.e., larger schools have more efficient infrastructure) or the use of school facilities by other community organisations outside of school hours.

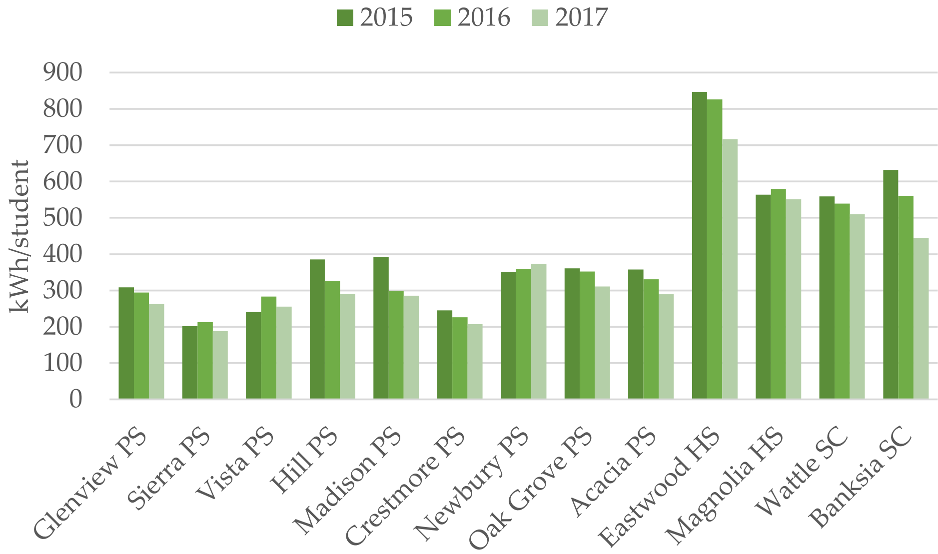


Figure 3. Electricity consumption per student (kWh/student) for all participating schools (2015–2017). Schools are ordered left to right from smallest to largest number of students.

Figure 4 shows each school's electricity consumption per square metre and shows that several primary schools used a considerable amount of electricity per square metre compared to other schools, even those that were significantly larger. Oak Grove PS used the most electricity per square metre, which could indicate some inefficiencies with their lighting and use of electricity. However, Oak Grove PS was also the only school that installed a solar PV system during the program period.

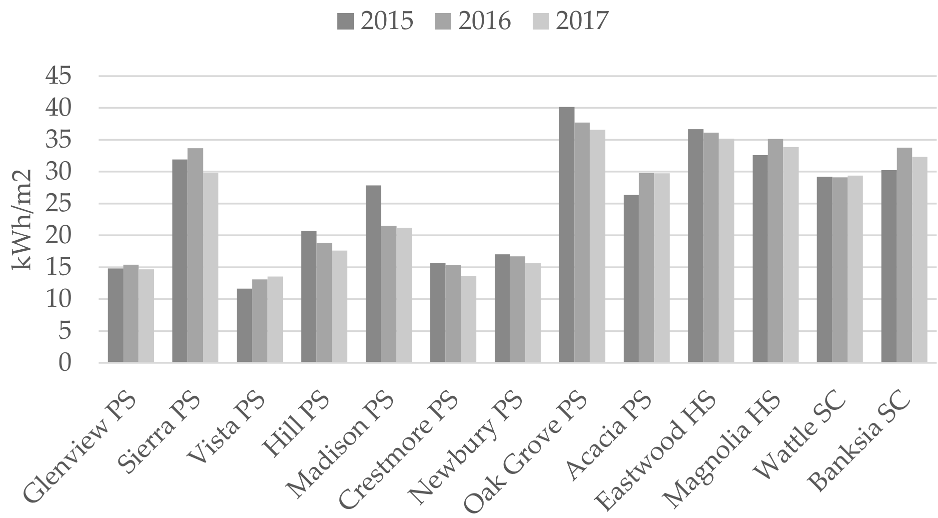


Figure 4. Electricity consumption per square metre (kWh/m^2) for all participating schools (2015–2017). Schools are ordered left to right from smallest to largest number of students.

Nine schools reduced their electricity cost per student by an average of 19%, saving them AUD 21 per student on average on their electricity. Oak Grove PS reduced the most on utility costs than any other school, saving over AUD 18,000 on their total electricity costs by switching electricity providers and renegotiating their electricity tariff. However, a decrease in consumption was not followed by a proportional decrease in costs for most schools. This can be explained by the energy retailer imposing a 20% average increase in cost per kWh for all except one school (which had a different retailer). In addition to this higher electricity rate, the schools with the largest difference between their consumption and costs also had changes in their consumption patterns, where they used more on-peak electricity, which was charged at nearly double the standard electricity rate.

3.3.2. School Holiday Switch-off Protocol

One of the highest impact initiatives that most schools implemented was a switch-off protocol. The switch-off protocol was a process schools followed to ensure no energy consuming devices were left on while no one was at the school once school concluded each day, and during school holiday periods. Most switch-off protocols involved turning off air conditioners, lights, printers, computers, hot water urns and refrigerators. The majority of schools implemented a switch-off protocol by mid-way through the first year of the program (late 2015) upon recommendations from the LCSPP. Most schools focussed largely on the school holiday period, aiming to reduce the number of electronics left on when no one was at the school.

On average, all schools reduced their total electricity consumption during school holiday periods by 12% between the base year and final year. Schools reduced their consumption specifically during the 2-week October school holiday period by an average of 28% (see Figures 5 and 6). However, only three schools actually saved money due to the increased energy prices. Schools that reduced their costs during school holiday periods saved an average of AUD 994, with two schools saving over AUD 2000 over a single school holiday period.

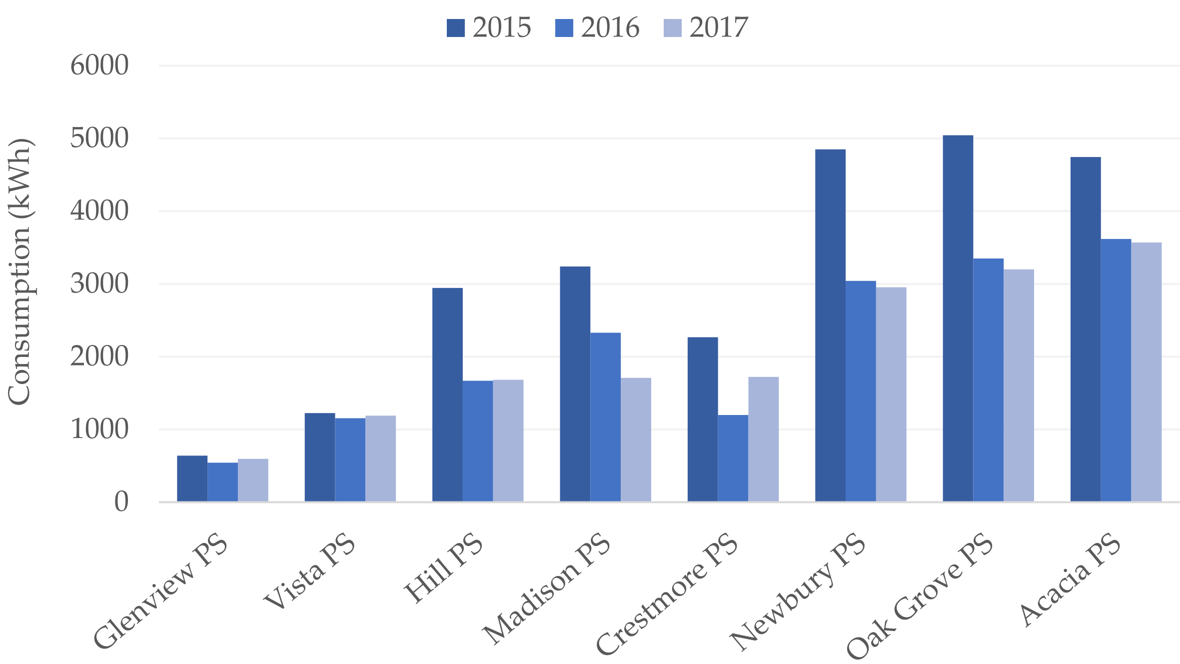


Figure 5. Total electricity consumption for the 2-week October school holiday periods for all primary schools (2015–2017). Schools are ordered left to right from smallest to largest number of students.

Figure 6. Total electricity consumption for the 2-week October school holiday periods for three secondary schools (2015–2017). Schools are ordered left to right from smallest to largest number of students.

3.4. Water

The schools identified 119 actions in the water category, with nearly half of their actions involving students. Unlike the energy category, which involved largely zero-cost initiatives, most water saving initiatives involved a low to medium financial investment. However, the most common initiative did not involve any upfront cost and involved initiatives around engaging students in water conservation activities. These included school incursions and activities to talk about water conservation, and two primary schools held International Water Day events for the students.

Two schools (Madison PS and Eastwood HS) also had free data loggers installed at the school from the state-owned water company. These two schools were identified as the highest users of water in the cohort and the water company agreed to closely monitor their consumption to determine whether the schools had leaks. Just under half of the schools also participated in a water audit that was provided at low cost by a partner of the LCSPP. Through this partner, four schools installed flow restrictors on their bathroom taps. Some schools also investigated the installation of a water tank to capture rainwater to water gardens. Others planned on pursuing options for expanding automatic irrigation on school gardens and ovals (see Table 3 below).

Table 3. Common water actions listed on all school low carbon action plans.

Initiative	Number of Schools Implemented	Cost
Student water conservation education activities	8	Zero
Investigate water bills for usage/leaks	6	Zero
Water audit	5	Low/Medium
Install signage around school to conserve water	5	Zero
Install flow restrictors in taps	4	Low/Medium
Investigate bore use	3	Zero
Check bathrooms for leaks	3	Zero
Change toilets to low flush	2	Low
Replace bathroom taps with push-activated	2	Low
Investigate automatic irrigation for ovals	2	Low/Medium
Investigate water tank	2	Low
Install water data logger (from water company)	2	Zero

Water Consumption and Costs

Total water consumption decreased for half the schools at an average of 46%, with the remaining schools increasing their consumption. Figure 7 shows the yearly total water consumption for each school, with a number of suspected water leaks due to a significant change in consumption. However, only one school (Madison PS) confirmed a water leak in 2017. Wattle SC saw the largest decrease in water consumption by 75% with an obvious decline in usage after the school put flow restrictors in most faucet taps in bathrooms, which reduced the flow from 9 L to 2 L.

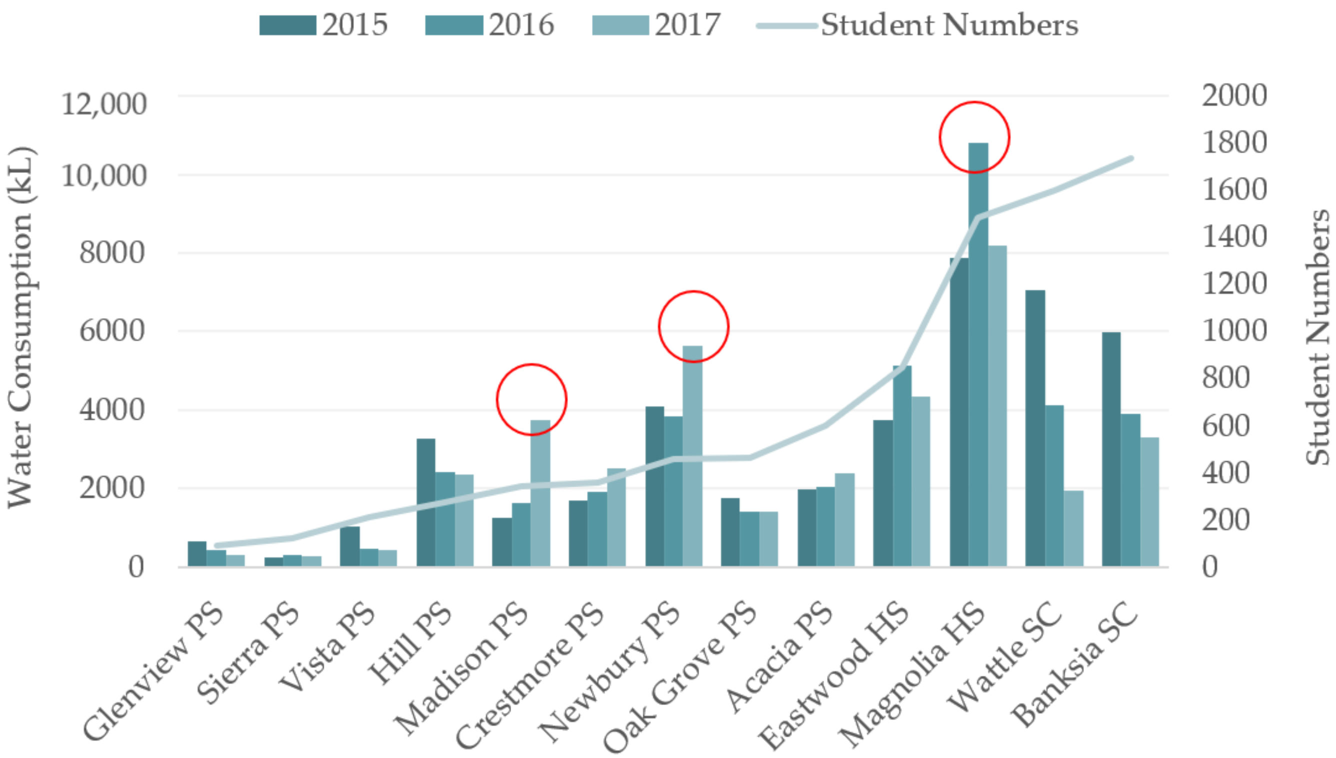


Figure 7. Total water consumption for all schools (2015–2017). Areas circled in red are years where the school experienced a known water leak. Schools are ordered left to right from smallest to largest number of students.

On a per student basis, water consumption also only decreased for half the schools, which were not all the same schools who decreased total water consumption. The schools with the largest student numbers showed the largest reduction in water consumption per student. However, some primary schools, such as Newbury PS and Hill PS, showed a high amount of water used per student. This could be due to their relatively large amount of green space requiring watering and maintenance. When each school's total water consumption was divided by the total square metres of green space, it showed the primary schools were generally less efficient with their water use than secondary schools.

Similar to electricity consumption, water costs did not decrease proportionally to decreases in consumption, as shown in Figure 8. The comparatively modest decrease in water costs compared to larger decreases in consumption was due to fixed service charges for each school's toilets and urinals (i.e., water fixtures). The water company charged a fixed cost per water fixture and these fixed costs typically represented over 80% of a school's water bill. Most schools paid around AUD 90 per fixture. The water company raised prices per fixture by 17% and the cost per kL by 14% between the base year and end of the program, meaning fewer schools saw the financial benefits of their water conservation initiatives. For one primary school, there were also discrepancies between how many fixtures the school had on site and how many they were being charged for. When the error was amended, the school saved AUD 1904 per year just from these revised fixture charges alone.

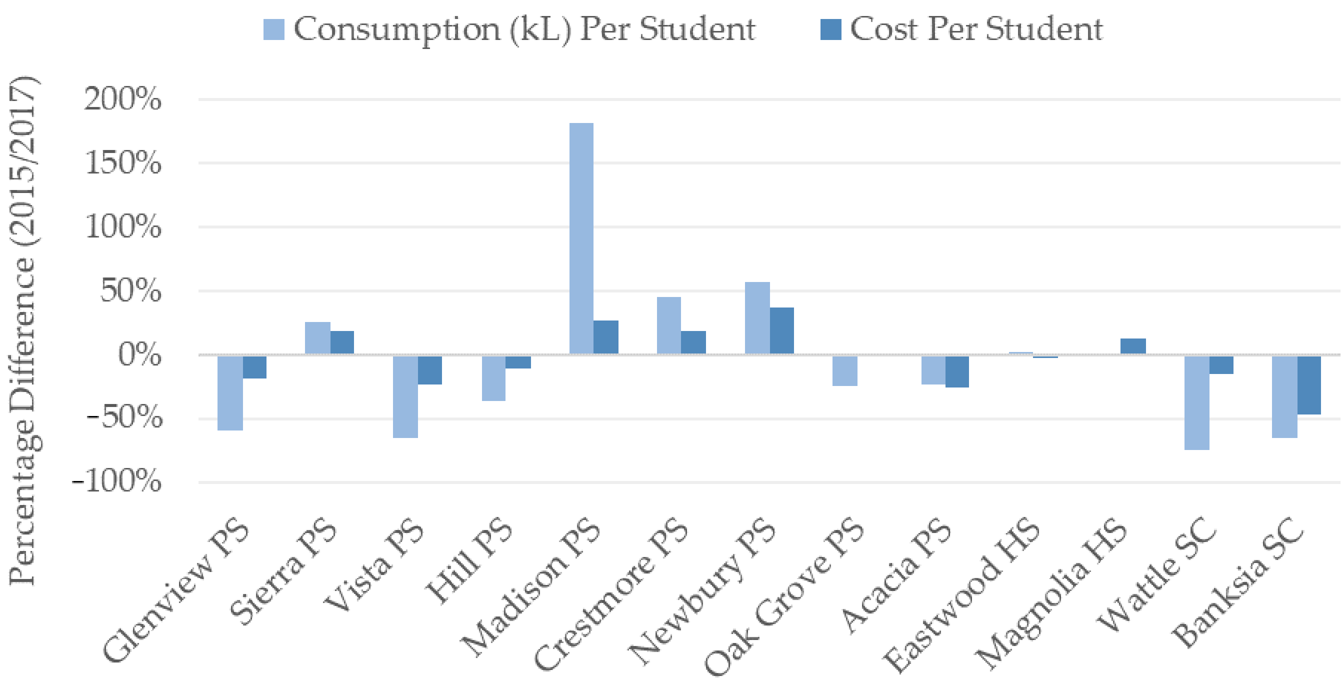


Figure 8. The percentage difference between 2015 and 2017 of water consumption per student and water cost per student for all schools. Schools are ordered left to right from smallest to largest number of students.

3.5. Gas

While most schools did not list specific gas actions on their action plans, all were encouraged to investigate gas leaks and monitor gas usage for any unusual consumption or cost patterns. Several schools actively investigated their gas consumption, with some identifying leaks as a result of their consumption monitoring. In addition, most schools implemented processes for ensuring gas heaters were turned off at the end of school days and during school holidays, as part of their switch-off protocol.

Gas Consumption and Cost

All except two schools reduced their gas consumption per student, at an average of 31%. Figure 9 shows the amount of gas per student each school used varied significantly, with the smallest school using the most gas per student. The number of gas versus electric heaters in each school played a significant role in their gas consumption, in addition to the potential presence of any unknown leaks. After investigating their consumption, one secondary school (Eastwood HS) discovered that pilot lights for heaters across the school were lit by Department of Education (DoE) staff several weeks before they were needed and left on throughout a school holiday, without the school's knowledge. Turning these off resulted in approximately AUD 3000 in savings for the school and showed a substantial 30% reduction in their gas consumption per student.

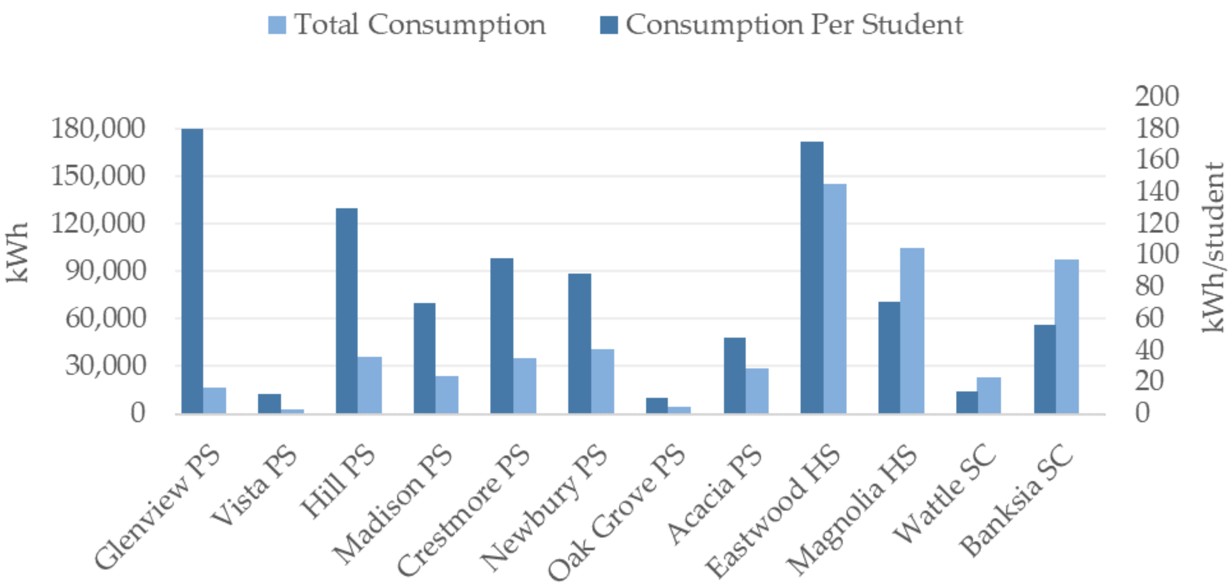


Figure 9. Total gas consumption (kWh) and gas consumption per student (kWh/student) for all schools (2017). Schools are ordered left to right from smallest to largest number of students.

3.6. Total Utility Costs

From a cost perspective, 9 of the 13 schools increased in total utility costs by the end of the LCSPP, as shown in Figure 10. All the schools that increased in overall utility costs also saw increases in cost per unit of electricity, imposed by the energy retailer. As discussed, both electricity and water cost tariffs increased by at least 15% during the program, which played a significant role in the schools' total costs. In addition, over half of the schools increased in student numbers, which for some meant the installation of additional transportable classrooms, causing an increase in resource consumption and subsequently costs.

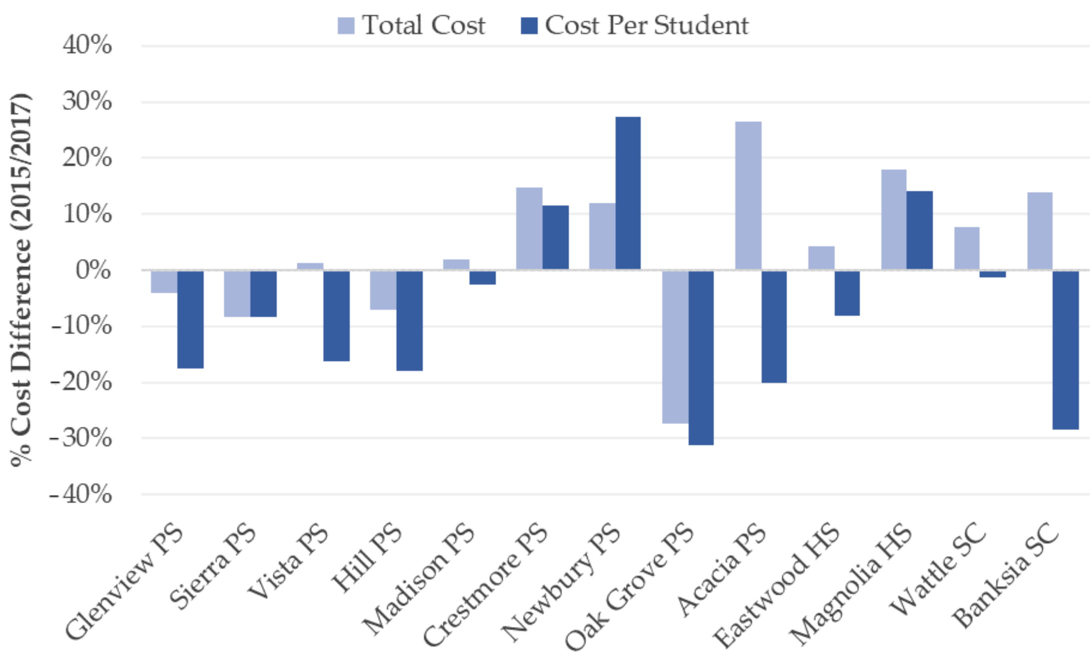


Figure 10. The percentage difference between 2015 and 2017 of each school's total utility costs (electricity, gas and water) and utility cost per student (AUD /student). Schools are ordered left to right from smallest to largest number of students.

Therefore, when examining the total costs on a per student basis, most schools decreased utility costs from electricity, water and gas, as shown in Table 4, by an average of 15%. The nine schools that decreased saved an average of AUD 31.49 per student on their utility bills. The largest reduction in average cost per student came from gas, followed by electricity, then water.

Table 4. Average cost per student for each utility across all schools (2015–2017).

Utility	2015	2016	2017
Electricity	AUD 107	AUD 101	AUD 96
Water	AUD 78	AUD 73	AUD 76
Gas	AUD 12	AUD 9	AUD 8

3.7. Carbon Emissions

Between the baseline year and the end of the program, 10 of the 13 schools reduced their total carbon emissions, with the steepest reduction in total emissions seen in electricity, as shown by Figure 11. This represented a total carbon emissions reduction across all schools of 8%, which saved 266 tonnes of CO_2-e. Considering electricity accounted for most of the carbon emissions, it is unsurprising that the schools which saved 15% or more on their total carbon emissions are also the schools that had the largest reduction in total electricity consumption.

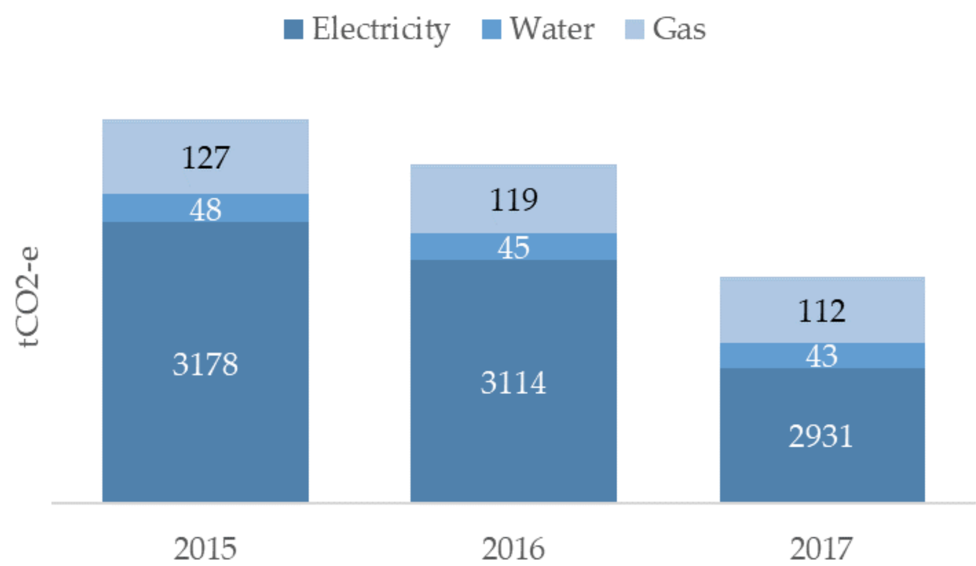


Figure 11. Total carbon emissions (tCO_2-e) by source (electricity, water and gas) for all 13 schools between 2015 and 2017.

On a per student basis however, all 13 schools reduced their carbon emissions. Table 5 shows the total carbon emissions per student for all schools for each year. The primary schools, despite their differences in student numbers, generally had similar carbon emissions per student. However, the smallest secondary school (Eastwood HS), had the highest carbon emissions per student than any other high school, both in terms of student population and school square metres, indicating their school buildings are likely to be less efficient than other schools.

Table 5. Total carbon emissions per student for all schools (tCO_2-e/student) (2015–2017) and percentage difference between 2015 and 2017.

School	2015	2016	2017	Difference (2015/2017)	Difference (2015/2017)	Difference (2015/2017)
Glenview PS	0.32	0.28	0.24	−14%	−14%	−26%
Sierra PS	0.17	0.17	0.15	1%	−15%	−14%
Vista PS	0.21	0.23	0.20	11%	−14%	−5%
Hill PS	0.36	0.29	0.26	−20%	−12%	−30%
Madison PS	0.35	0.26	0.24	−26%	−6%	−31%
Crestmore PS	0.23	0.21	0.18	−11%	−10%	−20%
Newbury PS	0.32	0.32	0.32	0%	0%	0%
Oak Grove PS	0.31	0.29	0.24	−8%	−15%	−22%
Acacia PS	0.32	0.28	0.23	−12%	−17%	−26%
Eastwood HS	0.76	0.70	0.58	−8%	−17%	−23%
Magnolia HS	0.49	0.48	0.44	−1%	−8%	−10%
Wattle SC	0.48	0.43	0.39	−9%	−9%	−18%
Banksia SC	0.55	0.46	0.35	−16%	−24%	−36%

It should be noted that there are several reasons why a school's carbon emissions may fluctuate year to year, which are not always correlated with consumption or growth in students. This is discussed further below.

4. Discussion

The results from the 13 schools demonstrate how a range of zero to low-cost initiatives can successfully reduce school carbon emissions. Over half of the initiatives that schools listed in their action plans involved zero cost, and many schools focussed on behaviour change initiatives such as signs to remind staff and students to use less water or switch off lights. While anecdotally, schools reported that these types of initiatives typically had a high level of success, it was not possible to measure the effectiveness of most of these behaviour change initiatives, apart from the switch-off protocol. Nevertheless, several studies have identified positive environmental outcomes associated with relatively simple behaviour change initiatives [48–51]. However, others also highlight the importance of implementing interventions on an ongoing basis to ensure behaviours stay changed [52,53]. The most impactful zero-cost behaviour change initiative that most schools implemented was an end of day, and end of school term, switch-off protocol. The success of switch-off protocols is demonstrated in other studies [54,55] and is a key recommendation of most energy audits [23].

In addition to most schools implementing a switch-off protocol, all except two schools conducted both a Level 1 energy audit and basic water audit. A water audit helped some schools save thousands of litres of water and costs on bills and energy audits enabled them to identify high-usage school activities that could be easily addressed, such as turning off unused fridges or switching off large cool-rooms for parts of the year. The use of audits to understand consumption is a critical part of increasing the resource efficiency of a building [55] and provides valuable insights [23]. Several schools reported that conducting audits was an extremely useful exercise as it allowed them to better understand their consumption and the actions they could implement. It is important to note, however, that for schools in this study, the energy audit was provided free of charge by a partner of the LCSPP and the water audit was provided at a discounted rate. Without these discounts, many schools may not have gone through an auditing process because of the associated costs. While schools can successfully conduct energy audits themselves, it requires a concerted effort by several key members of the school, a level of knowledge of what to look out for, strong leadership within the school and the presence of external motivators [56]. Alfaris et al. (2016) noted the importance of schools having professional help to conduct an energy audit because of the large amount of time and commitment it requires. This highlights that while audits are highly beneficial for schools, there are knowledge and cost barriers to uptake. This is an area where local, state or national governments could intervene by providing access to free or discounted audits.

A primary focus of the LCSPP was providing school stakeholders with the information and tools to help them investigate and track their electricity, gas and water consumption and costs in order to save carbon emissions. A key aspect of this involved data collection and interpretation at the school level—i.e., school stakeholders were responsible for collecting their data and educated on how to interpret it. This was designed to help schools increase their knowledge about resource consumption and prompt them to act. Providing information such as electricity consumption to home owners has also shown to increase the likelihood of reducing their consumption in several studies [57–59] and when school administrators are provided with utility consumption data, they are more likely to take actions to reduce utility consumption [17,23]. Some schools also created management plans to actively monitor and reduce consumption and costs of utilities like electricity or water, as well as sustainable procurement. The use of specific, measurable, ambitious, realistic and time-bound (i.e., SMART goals) in organisations has shown to drastically improve sustainability outcomes [60], showing the importance of establishing specific school emissions targets.

Schools were also provided with comparisons between the schools to allow for an enriched understanding of what consumption and costs were normal between similarly sized schools and to highlight where there might be anomalies. It is known that social comparisons can have an effect on reducing household electricity consumption [61–63]. While this research was unable to measure the direct impact school comparisons had on consumption, nearly all school committee members said comparing their school's consumption and sharing experiences with other schools was very useful. One primary school principal even mentioned that comparing his school's gas consumption with another school (which revealed multiple gas leaks) was the reason the school started their carbon reduction journey. This shows the significant influence comparison data can have on taking action.

However, caution must also be taken when comparing school utility consumption and cost data, as differences between each school can significantly affect comparisons. Factors such as size of school grounds, classroom density, building age, school student population growth and presence of facilities, such as pools, can all have a significant impact of a school's utility consumption and costs [37]. When only total utility consumption amounts are used, it does not provide any meaningful insights since it does not consider any contextual factors. Within energy efficiency literature, it is common for consumption to be calculated on a per square metre basis for schools [36]. While this is useful in some circumstances, there are also limitations with this metric when comparing consumption between schools because it does not account for student density and growth.

For schools who receive their funding on a per student basis, calculating carbon emissions and resource consumption on a per student basis is a logical method. A per capita approach is already widely used on a global scale to gain insights into the carbon intensity of countries [64]. By extension, this research provides evidence to suggest this method of viewing carbon emissions in schools on a per student basis is ideal for gaining insight into how schools compare to one another. However, it should be noted that calculating emissions and consumption on a per student basis may also have drawbacks and should never be the sole metric used.

There are many other external factors that can also influence whether school carbon emissions increase or decrease. For example, in addition to influences from weather which can significantly impact consumption, the carbon intensity of the electricity grid changes yearly depending on the energy sources (particularly the amount of renewable energy) feeding into the grid. This affects the emission factors associated with electricity, which can lead to a situation where a school's consumption stays the same, but their emissions decrease due to a lower grid emission factor for that year (or vice versa). In Western Australia, the electricity grid provided for all the participating schools (Southwest

Interconnected System (SWIS)) had more renewable energy in the grid in the final year of the program than in the base year, resulting in an 8% decrease in the carbon emissions factor for indirect emissions from purchased electricity [35].

While many carbon footprints for larger organisations typically include emissions sources from several areas such as energy, water, transport, waste and procurement [65], the LCSPP only focussed specifically on emissions from electricity, gas and water. While some studies have suggested more comprehensive carbon footprints for schools [26], Rauland et al. (2014) suggest that schools lack the time and resources to conduct detailed carbon footprints and therefore the scope should be limited to make it easier for schools to begin the process. This was confirmed in this study, with many schools expressing difficulties when collecting their bill data due to inadequate record-keeping of utility bills. This may suggest that any additional scope may prove too daunting for most schools. Given that schools generally lack the funds to hire consultancies to undertake more comprehensive carbon footprints, this further demonstrates the importance ensuring an achievable carbon footprint scope that is easily managed by school staff, such as teachers. While it is important to include carbon emissions from sources outside of just electricity, gas and water, approaching the process in stages may be the most suitable method for schools [14].

5. Conclusions

Energy consumption in Australian schools is expected to increase in the coming decades due to an increased use of digital technologies, aging building stock and poor minimum efficiency standards. This, combined with expected increases in utility costs, will put additional financial stress on schools. There is also a heightened urgency to reduce global carbon emissions, requiring action from all sectors of the economy. Regardless of where a school is located, effective management of school buildings provides a prime opportunity to reduce emissions.

This study showed that the most impactful initiatives schools implemented were ones that involved no or low cost. Most of the initiatives that school stakeholders chose to implement primarily focussed on behaviour change. Conducting electricity and/or water audits and the process of investigating utility consumption and cost data was a first key step for many schools and enabled school staff to discover large inefficiencies that could easily be addressed. School stakeholders also found the process of comparing data between schools highly useful. Considering there is often little information available to help them to understand whether their resource consumption is higher than it should be, there is potential for governments to establish a standardised way of enabling data comparisons between schools to encourage increases in efficiency, which could involve the establishment of a program similar to the LCSPP. Such a program (or future research) would benefit from collecting more detailed data from the school, including appliance, fixture and asset data, which could be analysed in conjunction with time of use resource consumption data to provide a more detailed examination of the potential opportunities for reduction. Once a clear understanding of school emissions has been established, this provides an opportunity for activities such as offsetting to occur.

The benefits of addressing school carbon emissions are abundantly clear; not only can it have a significant impact on addressing climate change, but it can help to reduce utility costs in schools, increasing their individual financial resilience, as well as reducing costs across entire Education Departments. Reducing emissions in schools can also provide hands-on learning opportunities for students and help schools address sustainability topics, which is a national focus. Today's youth are the generation that will feel the effects of climate change more than any other generation. The youth climate strikes across the world have demonstrated how important this issue is for them, yet they often feel powerless about their ability to act and make change themselves. Involving students directly with school low carbon initiatives and enabling them to see the results of their actions can provide them with a sense of agency and purpose and school buildings can offer a key pathway towards a carbon neutral future.

Author Contributions: Conceptualization, P.O., V.R. and K.M.; methodology, P.O., V.R. and K.M.; validation, P.O. and V.R.; formal analysis, P.O.; investigation, P.O.; resources, V.R.; data curation, P.O. and V.R.; writing—original draft preparation, P.O.; writing—review and editing, P.O., V.R.; and K.M.; visualization, P.O.; supervision, K.M. and V.R.; project administration, P.O. and V.R.; funding acquisition, V.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the CRC for Low Carbon Living, grant number RP3020e1.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Curtin University Human Research Ethics Committee (EC00262), Approval Number #RDHU-57-16.

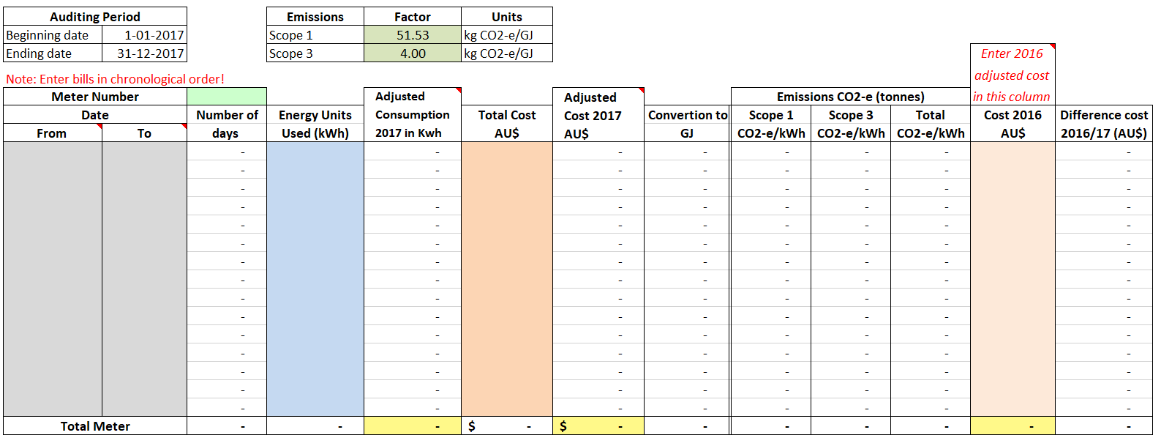
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to conditions imposed by the Department of Education and their policies on research conducted with schools.

Acknowledgments: The authors would like to acknowledge the City of Fremantle for providing in-kind support to the project, WA Department of Education for provision of data, and Building Management Works for data and relevant information.

Conflicts of Interest: The project was funded by the CRC for Low Carbon Living and co-delivered by Curtin University and SimplyCarbon. At the time, Rauland was a Director of SimplyCarbon.

Appendix A



Auditing Period	
Beginning date	1-01-2017
Ending date	31-12-2017

Emissions	Factor	Units
Scope 1	51.53	kg CO2-e/GJ
Scope 3	4.00	kg CO2-e/GJ

Note: Enter bills in chronological order!

Meter Number								Emissions CO2-e (tonnes)			Enter 2016 adjusted cost in this column	
Date		Number of days	Energy Units Used (kWh)	Adjusted Consumption 2017 in Kwh	Total Cost AU$	Adjusted Cost 2017 AU$	Convertion to GJ	Scope 1 CO2-e/kWh	Scope 3 CO2-e/kWh	Total CO2-e/kWh	Cost 2016 AU$	Difference cost 2016/17 (AU$)
From	To											
		-		-		-	-	-	-	-		-
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Total Meter		-	-	-	$ -	$ -	-	-	-	-	-	-

Figure A1. Example spreadsheet for gas emissions calculation used by school stakeholders. This figure is a direct screenshot of the carbon emissions spreadsheet used by school stakeholders in the program, the column colours were only used to help schools easily see which columns needed data entered. The font colours of the spreadsheets were used to draw attention to important parts of the spreadsheet.

GREENHOUSE GAS EMISSIONS INVENTORY

EMISSIONS SOURCE	Consumption Units	Consumption	CO_2-e tonnes	Proportion % Total Inventory
Direct Emissions (Scope 1)				
Purchased natural gas for water heating	GJ	-	0.00	0.00%
Total Scope 1 Emissions			**0.00**	**0.00%**
Indirect Emissions (Scope 2)				
Purchased electricity	kWh	-	0.00	0.00%
Total Scope 2 Emissions			**0.00**	**0.00%**
Optional Emissions (Scope 3)				
T&D line losses for purchased electricity	kWh	-	0.00	0.00%
Reticulated water supply	kL	-	0.00	0.00%
Wastewater emissions	kL	-	0.00	0.00%
T&D line losses for all purchased natural gas	GJ	-	0.00	0.00%
Total Scope 3 Emissions			**0.00**	**0.00%**
Total Scope 1+2 Emissions			**0.00**	**tonnes CO_2-e**
Total Scope 1+2+3 Emissions			**0.00**	**tonnes CO_2-e**

This GHG inventory has been developed according to the GHG Protocol and following the Operational Control Approach

Figure A2. Emissions summary on Low Carbon Schools Pilot Program carbon emissions template. This figure is a direct screenshot of the carbon emissions spreadsheet used by school stakeholders in the program, the column colours were only used to help schools easily see which columns needed data entered. The font colours of the spreadsheets were used to draw attention to important parts of the spreadsheet.

EMISSION FACTORS SUMMARY

Scope 1 and 2 Emissions Factors

Emissions Source	Emissions factor (kg CO2-e/kWh)	Source / Notes
Consumption of purchased electricity		
2015	**0.76**	Table 5 Page 18, National Greenhouse Accounts Factors, August 2015
2016	**0.72**	Table 5 Page 18, National Greenhouse Accounts Factors, August 2016
2017	**0.7**	Table 5 Page 18, National Greenhouse Accounts Factors, August 2017

Emissions Source	Emissions factor (kgCO2-e/GJ)			Emission factor (kgCO2-e/GJ)	Source / Notes
Natural gas distributed in a pipeline					
	CO2	CH4	N2O	CO2-e	
2015	51.4	0.1	0.03	**51.53**	Table 2 Page 12, National Greenhouse Accounts Factors, August 2015
2016	51.4	0.1	0.03	**51.53**	Table 2 Page 12, National Greenhouse Accounts Factors, August 2016
2017	51.4	0.1	0.03	**51.53**	Table 2 Page 12, National Greenhouse Accounts Factors, August 2017

Figure A3. Emissions factors and sources for scope 1 and 2 emissions. This figure is a direct screenshot of the carbon emissions spreadsheet used by school stakeholders in the program, the column colours were only used to help schools easily see which columns needed data entered. The font colours of the spreadsheets were used to draw attention to important parts of the spreadsheet.

Scope 3 Emission Factors

Gaseous fuels	ECF (MJ/m3)	Emissions factor (kg CO2-e/GJ)	Source / Notes
Natural Gas			
2015	**38.456**	4.0	Table 37 Page 65, National Greenhouse Accounts Factors August 2015
2016	**38.456**	4.0	Table 37 Page 65, National Greenhouse Accounts Factors August 2016
2017	**38.456**	4.0	Table 37 Page 65, National Greenhouse Accounts Factors August 2017

Emissions Source	Emissions factor (kg CO2-e/kWh)	Source / Notes
Purchased electricity by end users - Western Australia		
2015	**0.07**	Table 41 Page 69, National Greenhouse Accounts Factors August 2015
2016	**0.07**	Table 41 Page 69, National Greenhouse Accounts Factors August 2016
2017	**0.06**	Table 41 Page 71, National Greenhouse Accounts Factors August 2017

Emissions Source	Emissions factor (kg CO2-e/GJ)	Source / Notes
Reticulated water supply		
2015	**0.78**	Table 2.6 Page 21, National Performance Report - Urban Water Utilities 2015 - 2016
2016	**0.78**	Table 2.6 Page 21, National Performance Report - Urban Water Utilities 2016 - 2017
2017	**0.78**	Table 2.6 Page 21, National Performance Report - Urban Water Utilities 2017 - 2018

Figure A4. Emissions factors and sources for scope 3 emissions. This figure is a direct screenshot of the carbon emissions spreadsheet used by school stakeholders in the program, the column colours were only used to help schools easily see which columns needed data entered. The font colours of the spreadsheets were used to draw attention to important parts of the spreadsheet.

Appendix B

The following graphs demonstration the relationship between the number of Heating Degree Days (HDDs_ and Cooling Degree Days (CDDs) per month and the monthly electricity and gas consumption. Figure A5 shows there is a significant correlation between monthly gas consumption and the number of HDDs in that month. CDDs and monthly gas consumption were not calculated because all schools used gas to only heat their buildings. Figure A6 shows there is no significant relationship between HDDs or CDDs and monthly electricity consumption.

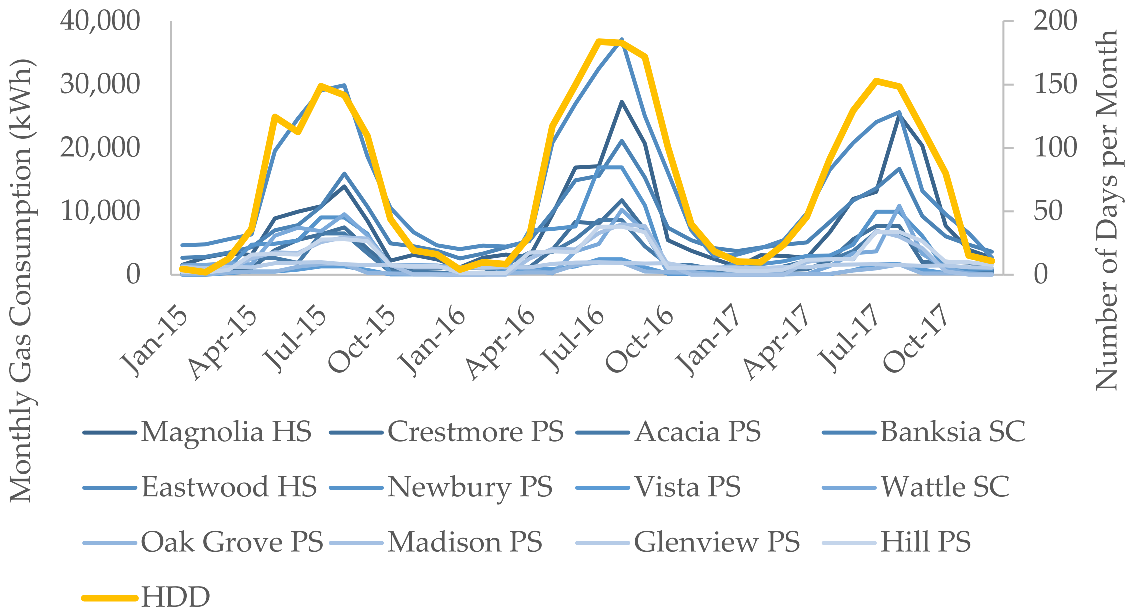

Figure A5. Monthly total gas consumption and relationship to number of Heating Degree Days (HDD) and Cooling Degree days (CDD) per month for all schools.

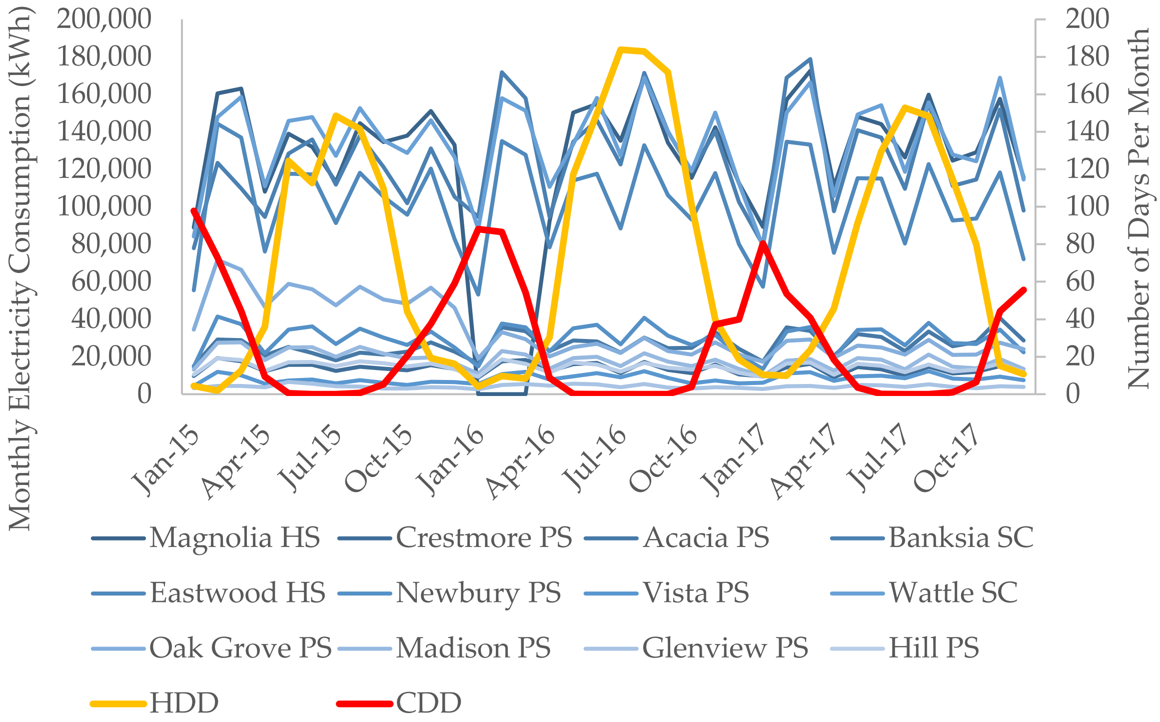

Figure A6. Monthly total electricity consumption and relationship to number of Heating Degree Days (HDD) and Cooling Degree days (CDD) per month for all schools.

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