Energy Analysis of Pembroke College

For period June 2006 – May 2007

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Benjamin Russell

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1. Outline of current energy usage

From the energy bills the total utilities energy consumption of Pembroke College for the period June 2006 till May 2007 was determined. This is comprised of four sections: Gas and Electricity for both the *College Site* and the *Hostels*, figure 1a. However, each kWh of electrical energy produces 0.43 kg of CO_2 and for Gas the figure is 0.19 kg CO_2. Figure 1b gives the relative impact of each of these sectors in terms of tonnes of CO_2.

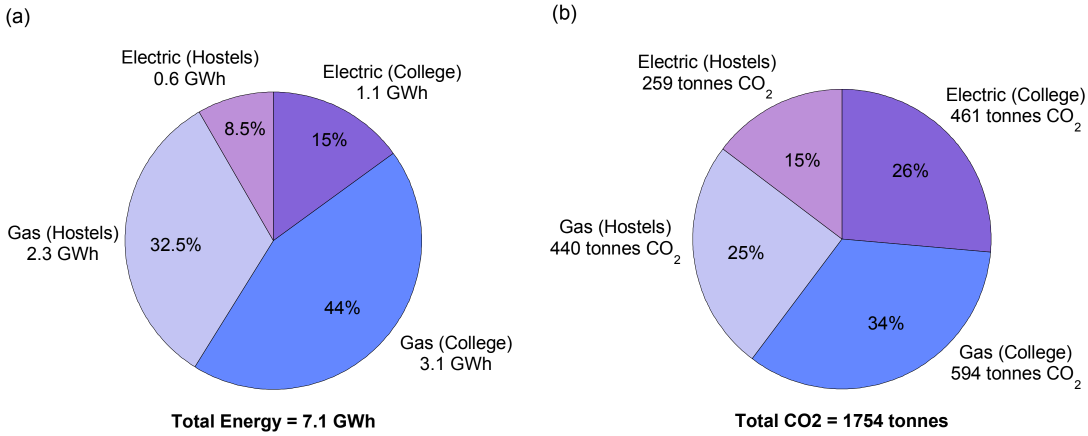

Figure 1: Break down of energy by (a) GWh energy units, and (b) tonnes of CO_2

The contributions of various college activities are estimated for each of these sections as far as possible. The cost of electricity over this period averages at 8 pence per kWh, and for gas it is 2 pence per kWh. Pembroke college spent £132k and £112k on electricity and gas respectively this period.

1.1 College site - Gas

Gas usage makes up the largest proportion of the energy consumed on the college site. Total gas usage though out the year follows roughly the variation in average monthly temperature, figure 2. About 2500 MWh (80%) of gas is used in hot water and heating for the residents and staff. A further 200 MWh (7%) is used in the porters lodge. Cooking accounts for 311 MWh (10%).

There are a number of gas meters on the college site including a separate meter for the kitchens. This enables a convenient break down and estimates to be made on the main uses: cooking, hot water and heating, figure 3.

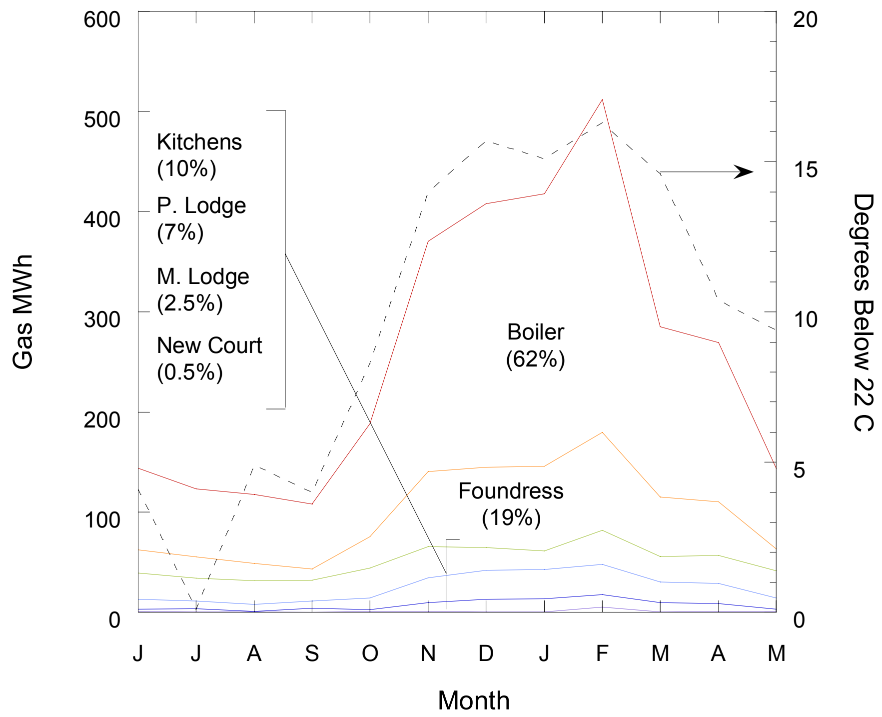

Figure 2: Gas usage per month. Dashed line indicates the number of degrees below 22˚C, showing a common trend with gas consumption

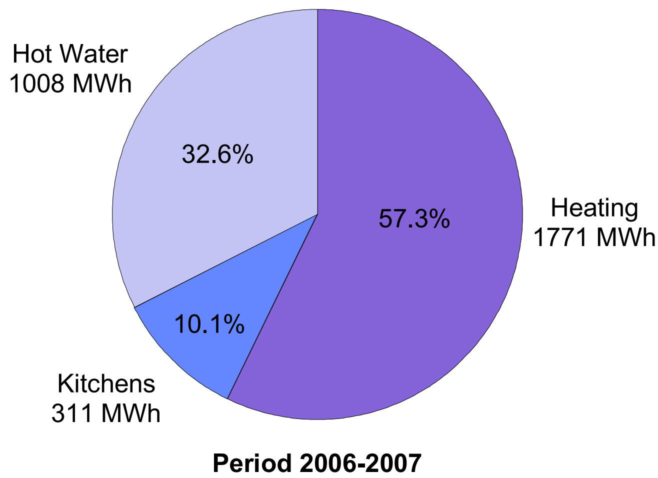

Figure 3: Gas division by usage

1.2 College site - Electricity

The electricity is more varied over the course of the year. This reflects the more direct usage by residents of the college (particularly undergraduates who are in residence for well defined terms). Unfortunately, electricity is billed for the whole college with no break down into distinct college areas. Therefore a series of estimates for key energy applications have been made, and the energy profile over the year reconstructed. A reasonable fit is obtained (figure 4) and numbers are given in table 1.

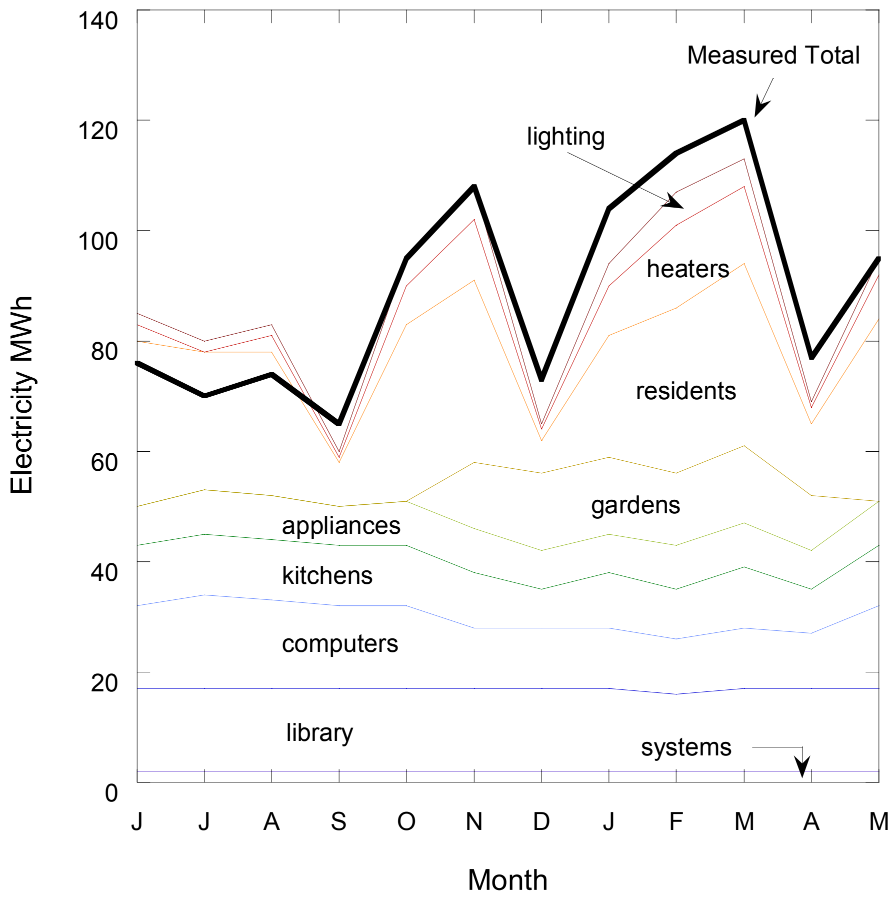

Figure 4: Black line gives the actual energy consumed over the year, rainbow contours are an estimated break down of usage

Systems [fire and security systems, servers, networking electronics]
These items are all running continuously and using a steady amount of power. Figures were derived by taking typical power usages for components (e.g. CCTV camera) and multiplying by the size of the system.

Library (Rare book rooms) [Air-conditioning and de-humidifying units]
Due to the considerable proportion of power that is consumed in this application it is given a separate section. The energy accounted for here is just for the 3 sets of air-conditioning units and de-humidifiers. This does not include any lighting or other use of electricity in the remainder of the library.

Computers [computer labs, office computers, stand alone units]
Computers which are switch off, but still ON at the socket consume up to 80% of their power consumption at full capacity. Newer computers (smaller shuttle types, as are

found in the library) are much more efficient and standby power is as low as 20-30%. A conservative estimate of 50% of the ‘switched on’ power is used to estimate machines that are powered down over night and at the weekends. Office computers are assumed to run for 8 hours a day, 5 days a week. Certain computers will run 24 hours, 7 days (e.g. security camera screens, and email points in the porters lodge).

Kitchens [walk-in fridge/freezer, heater serving counters, various appliances]
Estimates were used for the power consumption of the walk in fridge and freezer (5kW each) and the heated counter (10kW).

Appliances [refrigeration units, kettles (in gyp rooms), washing machines, vacuum]

Gardens [heated green house]
20kW heater assumed to operate during the winter months. The average monthly temperature are taken into account and the power varied accordingly.

Residents [non-communal use, excluding lighting, heating, gyp room and laundry]
Term dates for students were accounted for in this category (and also for Heaters and Lighting)

Heaters [convection heater units]
Average monthly temperatures are taken into account. Usage of heaters is assumed to be 1% of the total resident population.

Lighting [rooms, communal spaces, outdoor lighting]
Seasonal variations in day length were taken into account when calculating duration of use. An average value for bulb wattage of 60 W was used. This is based on a 80:20 mix of candescent (100 W) and energy efficient (21W) bulbs.

Table 1: Estimated energy usage

		MWh	% total	cost
Fixed	Systems	20	1.8	£1,600
	Library (RBR)	185	17.2	£14,700
	Computers	158	14.8	£12,700
	Kitchens	120	11.2	£9,600
	Appliances	88	8.2	£7,000
Seasonal	Gardens	78	7.3	£6,200
	Residents	292	27.3	£23,300
	Heaters	75	7.0	£6,900
	Lighting	37	3.5	£3,000

1.3 Hostels

Variation between college houses means that estimations of energy usage is much more difficult to ascertain. Gas use is typically for heating and hot water. While electricity is for lighting, cooking and room sockets. As most bills are based on estimates and not actual readings, the pattern of use over the year is hard to see, although the final year figures are generally accurate and have been corrected for.

A baseline figure for gas usage may indicate the hot water use over the year, as this is not expected to fluctuate with the seasons. Any use over this base line is for heating, so guesses can be made as to the relative fractions of these uses.

Electricity is much harder to estimate than gas as its use varies much more due to students having more direct control over this source of energy.

2. Recommendations

Several recommendations can be made in light of the analysis in section 1. Some of these initiatives are already in progress, e.g. bulb replacement, installing additional insulation in hostels.

2.1 Lighting

Replacement of all candescent bulbs with energy saving bulbs is currently under way. Lighting energy (on college site) was 37 MWh (3.5%) and cost £2960. Assuming 100% replacement this would reduce to 12 MWh and cost £960 per annum.

2.2 Loft insulation

Fitting of loft insulation into all hostels and in college where possible. In general most gas is used to heat the home, for Pembroke hostels the figure is estimated to be between 60 and 80%. About 30% of heat lost is through the roof. Assuming a 10% saving on gas, annual saving returned by loft insulation amount to 162 MWh, 30.8 tonnes CO_2 and £3,200. Cost of installation for 42 hostels at £500 per hostel would cost around £21,000.

2.3 Boiler Replacements

Replacement of hostel boilers with condensing boilers. Based on figures from the energy saving trust boiler replacement would save 36 MWh, 7 tonnes CO_2 and £700 annually. Boilers cost £700 each totalling £30,000 for 42 hostels.

2.4 Double glazing

Double glazing could reduce usage by 31 MWh, 6 tonnes CO_2 and save £600 each year. However, to cost is likely to be upward of £50,000 to fit all hostels.

2.5 Draft exclusion

Fitting draft proofing, jacket on hot water tank, pipe lagging, filling gaps in skirting boards/floor boards could save 20.4 MWh of gas, 4 tonnes CO_2 and £400 for the hostels, based on energy saving trust data. Cost for installation would be £13,000.

2.6 Purchasing changes

Buy only the most efficiently rated appliances (e.g. A++ rated fridges). Certain appliances and electronics are replaced periodically. For example computers operate on a 3 year life cycle in college. Newer computers can have lower standby power ratings. Energy efficient appliances should replace the less efficient products as these come to the end of their life. No changes need to be made, only to ensure the chosen products are the most efficient. Savings of 3 MWh (£250) per annum on computers alone.

2.7 Fitting of electronic descalers

The build up of lime scale on heating elements can significantly reduce the efficiency of water heaters. Calcium carbonate has a thermal conductivity ~2-3 W m^{-1} K^{-1} which is very low compared with copper 401 W m^{-1} K^{-1}, which is the typical conducting media in water heaters. Hence even a thin layer of scale can cause a large increase in the time taken to heat water, and hence a decrease in efficiency. Gas is typically used for heating as it has a lower cost per kWh.

Hostels

Hostels gas usage accounts for 32.5% of energy and 25% of carbon dioxide emissions of the energy total. It is estimated (see appendix A) that between 20 and 40% of gas burnt in hostels is for heating water.

The introduction of electronic descaling devices could have a significant impact on the energy consumption savings. Assuming a conservative estimate that lime scale reduces efficiency by of boilers by 5%, this equates to 34 MWh of gas or 6.6 tonnes CO_2 or £700 of savings annually.

The cost of implementation is the cost of the meter plus the running cost of the meter. Meters retail for around £150. The unit is rated at around 7 Watts (1/3 of an energy saving light bulb) which would use 61 kWh per year (costing around £5). Multiply £155 by the number meters required for hostels: 42, gives a rough costing of £6,500.

College site

On the college site, 32.6% of gas is estimated to be used for heating water. Using the same calculation: savings of 50 MWh, 9.6 tonnes CO_2 and £1000 achieved per annum. The cost of implementation is potentially much less than that of hostels, as fewer meters would suffice.

These estimates are also applicable to electrically heated boilers, although the amount of CO_2 saved would be greater.

Further notes on the device

Installation is simple and does not require fitting by a specialist. The unit does not require any changing to the existing plumbing. The system works even if the pipe work and boiler are coated in lime scale. The treated water will re-dissolve the existing scale in the plumbing, recovering the efficiency of the boiler.

Additional benefits

Removal of lime scale from shower heads (according to the student hand book) and taps is carried out each year. This requires use of chemical cleaning agents. This task would be redundant. Life times of washing machines/kettles would also be extended and the quantity of soap required for washing reduced.

2.8 Metering of college residents

On the college site students use approximately £17,100 worth of electricity per year compared to the £8,000 they are actually billed for. Student use is un-metered and therefore most are probably unaware of their consumption.

Metering the students would help students to be more award of there own impact, as well as potential energy savings driven by more conscientious use, this is a good opportunity for social awareness of environmental issues. A semi-metered approach might work best, by banding various levels of use. A reasonable usage could be defined (e.g. 2 kWh per day and taking into account seasonal variations). Set this level of usage as the GREEN band. Define the AMBER band as 4 kWh per day average, and anything exceeding this as RED band. A flat rate would be paid for the GREEN and AMBER bands, based at the current rates £10 and £20 per term respectively. The RED band could either be a higher tariff or metered for the exact amount used. This would be printed on the college bill so the students would be aware of their environmental impact.

This approach has numerous advantages: the meters are already in place for many of the rooms in college, it raises awareness of environmental issues and links lifestyle to the environment. There is a financial incentive to maintain an appropriate usage and the system would be financially self balancing from the perspective of the college.

Potential drawbacks are that meters would need to be read 3 to 4 times a year. 300 meters might account for 16 hours of labour. This would be offset by the savings (£9,100). Energy saved would obviously be variable, but at least the cost would be paid for. Assuming all kept the GREEN band tariff, energy savings of 72 MWh, carbon dioxide savings of 31 tonnes CO_2 and financial savings of £5,700.

2.9 Library rare books rooms

The rare book rooms situated in the basement of the library consume 185 MWh of electricity per year. This is 17.2% of the total electricity used on the college site, and is estimated to cost the college £14,700 per annum, the cost of servicing these units, which is carried out every 6 months, has not been included in this figure. This electricity is used to run air-conditioning units and dehumidifiers only.

The books are required to be kept at a low humidity (<15%?) to inhibit damage due to growth of mould. The current level of humidity is approximately at 17%, and with the current system, never drops below this figure. This means that the air-conditioning units and dehumidifiers are running at 100% continuously. Currently there are plans to put in place extra dehumidifiers.

The reason for the high levels of humidity is damp seeping through the walls of the basement. The addition of extra dehumidifiers is unlikely to make much difference as moisture will continually be drawn through the wall by osmosis.

The situation is analogous to trying to empty a bath which is continually being filled with water, by increasing the size of the plug hole. What really needs to be done is to turn off the taps! If the problem is damp then this can be treated by a damp proofing course. A physical barrier needs to be put in place to prevent the flow of moisture into the basement. The cost of such treatment is likely to be very high, and I would recommend an estimate be sought from a surveyor. However, considering the value of the rare books, which are not adequately protected and the cost of energy, long term savings would be significant.

2.10 Prototype Eco-hostel

Whilst the savings are significant, the investment required to kit out all of Pembroke's hostels is substantial. A trial could be conducted on either one or a couple of houses, which would be kitted out with all the aforementioned energy saving measures, figure 5. A direct comparison of the performance of the property could be made with neighbouring properties (good candidates would be the Lensfield road or Panton street hostels). In addition to these energy saving features, this would also be a good opportunity to try out power generation solutions such as solar water heaters, and perhaps photovoltaic cells.

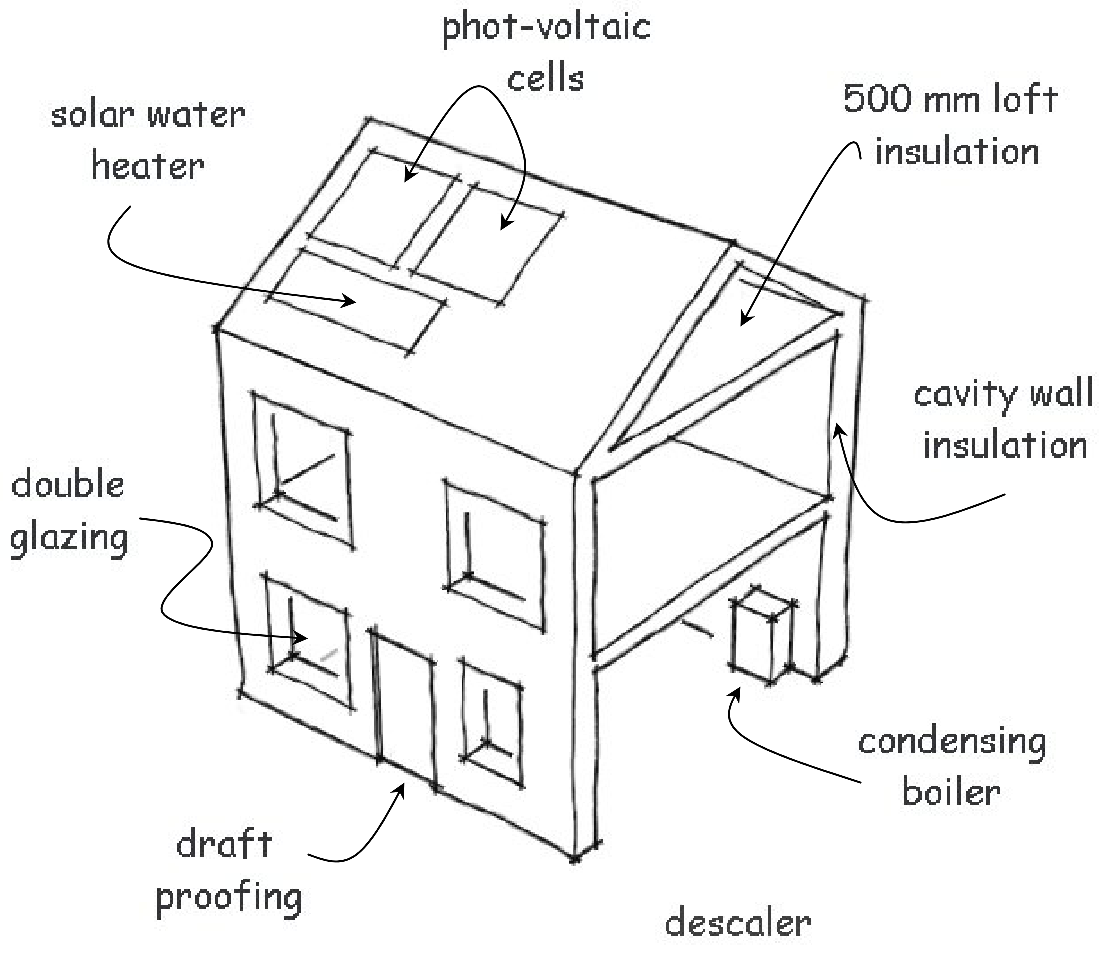

Figure 5: Eco-hostel fitted with energy saving measures and power generation systems

3. Summary

Table 2: summary of costs and saving of various energy saving initiatives

Measure	Savings (Annually)*	Instalment Cost
Lighting (college site)	25 MWh (electricity) 10.8 tonnes CO_2 £2,000	(80% of 1000 bulbs) £1600**
Loft insulation***	162 MWh (gas) 30.8 tonnes CO_2 £3,200	£21,000**
Replacement boilers***	36 MWh (gas) 7 tonnes CO_2 £700	£30,000**
Double glazing***	31 MWh (gas) 6 tonnes CO_2 £600	>£50,000**
Draft exclusion***	20.4 MWh (gas) 4 tonnes CO_2 £400	£13,000**
Purchasing changes	3 MWh (electricity) 1 tonne CO_2 £250	-
Descalers	130 MWh (gas) 24.8 tonnes CO_2 £2,600	£7,800 (Hostel)** ~£1,000 (College)**
Metering	72 MWh (electricity) 31 tonnes CO_2 £5,700	Cost of meter installations
Rare book rooms	139 MWh (electricity) 59.6 tonnes CO_2 £11,100 (Assuming 75% reduction)	£100,000 ?? Need estimate
Total	618 MWh 175 tonnes CO_2 £26,700 (11% Total Bill)	£224,400

* Based on average rates for 2006-2007 period

** Labour not accounted for

** * Local councils can often give significant subsidies for certain energy saving features. These are worth investigating for cost savings.

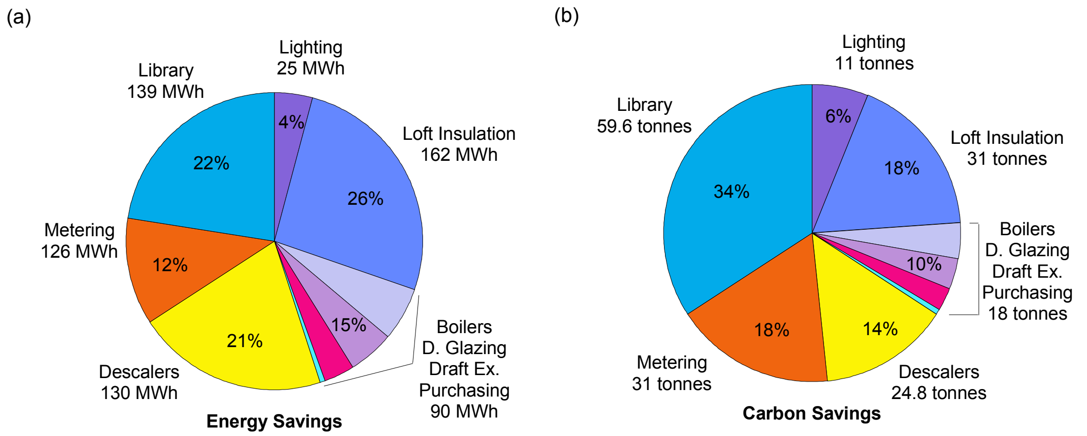

Figure 6: savings in terms of (a) energy and (b) carbon dioxide