Guidelines to make Victoria University School of Architecture and Design carbon neutral through minimising its reliance on carbon offsets

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Abstract

Universities have always had an important leadership role in society in demonstrating the types of changes that need to occur with respect to the prime issues of the time. All around the world, universities are lining up to declare themselves the next carbon neutral school as part of the global trend of becoming “sustainable.” But what does it really mean to be carbon neutral? In 2007 Victoria University’s School of Architecture and Design (SoAD) declared themselves the first carbon neutral campus in the world through the use of sponsored and purchased carbon credits. However 100% reliance on offset schemes is not the answer as it does not guarantee the capture of carbon forever. Also, the continuing purchase of carbon offsets could be costly and maintaining business-as-usual without any significant changes will result in continuing environmental degradation as a result of the SoAD’s unsustainable activities. This research explores various solutions for reducing the three biggest factors that contribute towards the emissions, which are energy, transport and waste. It looks at the difference between behavioural changes (low cost) and technological investment (high cost) in order for SoAD to reduce its carbon footprint to meet three possible reduction targets, established by this research as 25%, 50% and 90%. The findings are that 25% could be saved through simple behavioural changes which cost very little, as they are mainly related to avoiding wastage, 50% could be saved through a combination of low and high cost measures, and 90% comes from considerable investment in new technologies or drastic reduction in use.

A further aim of the research is to translate all possible savings into other means, such as knowing how much carbon or land is saved, using a measure such as the ecological footprint, and more importantly what these savings mean to the third world where resources are scarce and expensive. If SoAD’s wasteful activities from neglect can be translated into saving people’s lives in other

nations, it might lead to more responsible energy use. What this research indicates is that for SoAD to be carbon neutral various factors need to be considered and user behaviour is paramount.

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List of Acronyms

ACUPCC – American College and University Presidents Climate Commitment
AHU – Air Handling Unit
ALF – Annual Loss Factor
ASHRAE – American Society of Heating, Refrigeration, and Air-Conditioning Engineers
'BAU' - Business as Usual
BMS – Building Management System
BRANZ – Building Research Association of New Zealand
BREEAM – Building Research Establishment Environmental Assessment Method
CF – Conversion Factor
CO_2e – Carbon dioxide equivalent
EFTS – Equivalent Full time students
EMU – Electric Multiple Units
EPA – US Environmental Protection Agency
EUI – Energy Use Index
FoAD – Faculty of Architecture and Design
FM – Faculty Management
GHG – Greenhouse gas
HVAC – Heating, Ventilation, Air Conditioning
IPCC – International Panel on Climate Change
LEED – Leadership in Energy and Environmental Design
MED - Ministry of Economic Development
MfE – Ministry for the Environment
NGO – Non-governmental organisation
NZGBC – New Zealand Green Building Council
PBRF – Performance Based Research Fund
PV – Photovoltaic
RFI – Radiative Force Index
SoAD – School of Architecture and Design
VERs – Verified Emission Reductions
VOCs – Volatile Organic Compounds
VUW – Victoria University of Wellington
VUWSA – Victoria University of Wellington Students' Association
WCC – Wellington City Council

WRI – World Resources Institute

WWF – World Wildlife Fund

ZEV – Zero emission vehicle

1.0 Introduction

The economy is a wholly owned subsidiary of the environment, not the reverse.

- Gaylord Nelson (a governor and U.S. Senator as a Democrat)[1]

Figure 1:1 Promotional advertisement for WWF[2]

The current problem: The overshoot and limits of growth

There is a critical requirement for current global industrialised society to restructure its 'business as usual' (BAU) system which largely depends on fossil fuels for energy, motorcars for transport and its excessive consumerism for the continuation of the global economy with no regards to the depletion of valuable resources. A significant shift in this unsustainable system is necessary so that everyone can live within the capacity of the planet by using its resources

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[1] The University of Wisconsin Press, "Beyond Earth Day, Fulfilling the Promise", November 30, 2009, <http://uwpress.wisc.edu/books/2095.htm> [accessed 02 January 2010]
[2] The Inspiration Room, <http://theinspirationroom.com/daily/print/2009/5/wwf_ambulance.jpg> [accessed 02 February 2010]

sustainably and by switching to renewable resources.

The undeniable truth is that consumption is restricted by the environment’s capability to reproduce its resources whether it is plantations, animals, oil or minerals that people need. There is already considerable evidence that the planet is rapidly reaching peak oil production[3] and the continuing unsustainable practices are indicated by the global degradation of forests, soil, fresh water, fisheries, mineral resources (such as phosphorus and copper)[4], biological diversity and an increase in pollution. Past a critical point there is no point of return as these damages and losses to the environment will never be able to be recovered or replaced.[5] This is not solely an environmental problem but a humanistic one, as it will affect everyone living on the planet one way or another. The growth of human population results in increasing demand for food, water, oil and other valuable resources resulting in an increase in waste and sewage disposal, which puts the current ecological systems under strain. Currently the distribution of these resources is unjust and unequal as *United Nations statistics show that the 20% of the world’s population that lives in wealthy countries consumes up to 80% of the world’s resources.*[6] This shows excessive consumption by a minority group of people whose sole ethical responsibility could be said to lie in finding ways to reduce their ecological footprint while maintaining a good standard of living without compromising the prospect for growth and development of those whose basic standard of living is poor.[7] However in reality, the scarcity of resources results in international conflict and war and as a result an unequal distribution of resources among different nations and economic classes, with consequent decrease in quality of life for the underprivileged. The most

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[3] Aleklett Kjell and Campbell Colin J, ‘The Peak and Decline of World Oil and Gas Production’, *Minerals & Energy - Raw Materials Report*, 18, No.1 (2003), (p. 5–20)

[4] Thomas F. Homer-Dixon, ‘Environmental Scarcities and Violent Conflict: Evidence from Cases’, *International Security*, 19, No.1 (Summer, 1994), 5-40 (p.5-7) <http://www.jstor.org/stable/2539145> [accessed 11/11/09]

[5] Wackernagel Mathis and Rees William, *Ecological Footprint, Reducing Human impact on earth,* (New Society Publishers 1996), p. 155.

[6] Ibid. p.149

[7] Ibid. p.154

immediate and rational way to limit this conflict and inequality would be to take drastic steps to reduce the heavy fossil-fuel dependency of developed countries. This requires the will power to change current lifestyles and the inefficient system on which these lifestyles are based, at a scale from individuals to the larger collective group such as governments, policy makers, institutions and corporations by setting an example and achieving target goals to reduce their ecological footprint. Issues of sustainability need to be more than just environmental – they need to embrace ethical, economical, political and social concerns.[8]

The Institution's response – Universities as an agent of change

As a response to these pressing issues, there is increasing participation and involvement from universities around the world in the practice of sustainability. The potential for an academic institution to become the driver for change is huge. Its role of practicing leadership in its community can be utilised to encourage and influence more carbon neutral living.[9] The roles of the universities are becoming progressively more important as they start tackling the current issues and needs of today using technological advancement through research and producing the young leaders of tomorrow.[10]

For example,

June 2008, Victoria University of Wellington (VUW), School of Architecture and Design (SoAD) became the world's first School of Architecture and Design to become certified carbon neutral through carbon credits from Meridian Energy's wind farm projects in New Zealand (NZ).[11] Certification was approved by Landcare Research a

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[8] Rui H. Dos Santos Martins, Journals ISSS, International Society for the Systems Sciences, <http://journals.isss.org/index.php/proceedings53rd/article/viewFile/1156/459> p.3, [accessed 03 February 2009]

[9] Harre Niki, Atkinson Quentin D, *Carbon neutral by 2020, How New Zealanders can tackle climate change*, (Craig Potton Publishing 2007), p.29

[10] Altbach, P. *University Reform.* Cambridge, Massachusetts, (Schenkman Publishing 1972)

[11] Faculty of Architecture and Design, Victoria University of Wellington, *Greenhouse Gas Reduction Plan*, May 2008,

renowned environmental research organization, (under the 'carboNZero' program). Participating in the carboNZero program is a practical action to mitigate the large GHG contribution the built environment makes due to its construction, demolition and significantly through its operation and maintenance.[12]

Professor Gordon Holdon, Dean and Deputy Pro Vice-Chancellor (and previous Head of SoAD) stated that this project's main purpose was to be an example and testing model for other faculties of VUW to follow. He goes on to state the carbon neutral vision for the school:

> *Through education and research the Faculty is in an important position to reduce the significant impact the built environment has on the ecosystem by helping to change the way buildings and the larger built environment, is planned, designed and constructed. Since 2003 we have taken steps to become leaders in teaching and research in sustainable design and construction. Becoming certified carbon neutral is a significant part of the Faculty's environmental responsibility.*[13]

The SoAD saw this as a way to showcase the university's role as a place for critical thinking, questioning major issues and problem solving. There are also added marketing benefits by being carbon neutral as it promotes the school as being engaged with sustainability.[14]

<http://www.victoria.ac.nz/home/about/publications/2008_GHG_emission_reduction_plan_-_FoAD.pdf> p.2, [accessed 03 February 2009]

[12] carboNZero, Certified Organisations, <http://carbonzero.co.nz/members/organisations_certified.asp#VUW> p.2, [accessed 02 February 2009]

[13] Victoria University of Wellington, Carbon Neutral Faculty, <http://www.victoria.ac.nz/home/about/CarbonNeutralFaculty.aspx> [accessed 04 February 2009]

[14] Kodikara Tushara, Salient, The student magazine of Victoria University of Wellington, *Why Victoria University should become carbon neutral,* 12 May 2008, <http://www.salient.org.nz/features/why-victoria-university-should-become-carbon-neutral> [accessed 09 February 2009]

Business-as-usual no longer an option

The purchase of electricity that is generated by renewable resources such as wind or hydro power is a valid and effective way to reduce SoAD's carbon emissions from electricity use. The carbon credits are purchased to offset the remaining emissions which include factors such as transport, waste and gas use. Although the carbon offsets have been pursued in conjunction with implementing reduction measures to decrease emissions, the latter have only achieved a small reduction and therefore it is insufficient to boast about the school's 'sustainable' practice. Holding a reputation as part of NZ's capital city university, SoAD has social obligations to practice what it preaches, and relying mainly on carbon credits is a "business-as-usual" response without the necessity for encouraging individuals and the school to change consumption patterns profoundly together with its social, economic and political structures. Also it could be a future problem as purchasing offsets in a free market is not always reliable and the scientific foundation of offsetting is complicated to calculate and often not precise.[15] (See 2.4 Problems with Carbon Offsetting schemes)

What SoAD can and should do

This thesis examines a way for the SoAD to become truly carbon neutral by minimising its reliance on (sponsored) carbon offsets and by dramatically reducing its most significant contributors of GHG emissions (hence its ecological footprint) to meet three appropriate goals. The challenge here is for VUW to demonstrate to the NZ public that it can still remain part of a modern society by remaining comfortable and improving the quality of life even when the ecological footprint of the school has been reduced to be within the capacity of the planet. The most important thing to note is that the

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[15] Smith Kevin, *The Carbon Neutral Myth, Offset Indulgences for your Climate Sins,* (Transnational Institute, The Netherlands, February 2007), p.6 <http://www.carbontradewatch.org/pubs/carbon_neutral_myth.pdf> [accessed 16 March 2009]

longer the problem is ignored the less chance is offered for a *smooth transition to sustainability*.[16]

Today, technology plays a vital role in the critical changeover to a low resource, low carbon economy especially for the developed nations, in terms of making energy use more efficient, developing more sustainable infrastructure, generating greater renewable energy, maximising waste materials that are re-used/recycled and minimising waste going to landfills. However, regardless of technological benefits, the limits of technology should be acknowledged; particularly the fact improved technological efficiency should not be used as a justification to continue over-consumption, which in turn leads to increasing material inequity. Also despite man-made technology, the plain fact is that human survival and well-being is dependent on natural resources to provide vital needs that man-made systems simply cannot replace. These natural resources are needed to ensure the continuation of the species and the functioning of the ecosphere.[17] Therefore the challenge is to reduce the ecological footprint successfully through behavioural changes together with the most efficient and advanced technology available in order to secure a sustainable future without compromising the needs of future generations.

1.1 Aims and contribution of this thesis

The aim of this thesis is to assess the carbon neutral status in VUW, SoAD for the year 2007 to see how dependent the faculty is on carbon offsets to reduce GHG emissions and how it can become truly sustainable by changing the 3Bs: Building, Behaviour and the 'Bigger Picture' (Wellington city's urban fabric and NZs government policies). This will determine what factors are within SoAD's control and what issues are outside SoAD's control.

[16] Wackernagel Mathis and Rees William, *Ecological Footprint, Reducing Human impact on earth, (*New Society Publishers 1996), p.154
[17] Ibid. p.149

The contribution of this thesis is to show the implications of what needs to be done to achieve different reduction goals for the three significant contributors of GHG emissions. These are energy, transport and waste. It therefore compares and analyses the different solutions available with today's technology and considers the cost implications of each solution. The aim is for this thesis to be both a general guideline for institutions around the world and a specific reduction program for SoAD, by analysing its micro and macro context.

1.2 Objectives

The specific objectives of this thesis are to:

- Identify the significant contributing factors in terms of GHG emissions in the university - specifically The School of Architecture and Design (Chapter 3)
- Investigate ways of reducing these main contributing factors by the 25%, 50% and 90% reduction goals (Chapter 7, 8 and 9)
- Identify the benefits of changing the 3Bs: Building, Behaviour and the 'Bigger Picture' (Chapter 7, 8 and 9)
- Analyse how the building directly contributes to total GHG emissions and how renovation might reduce its ecological footprint (MICRO SCALE)
- Analyse how the behaviour of the occupants, urban fabric/infrastructure and government policies and systems contribute to total GHG emissions (MACRO SCALE)
- Establish a general guideline for other universities (Chapter 7, 8 and 9)
- Identify what has been done in universities around the world, in terms of reducing impact (Chapter 5)
- Move from carbon footprinting to land footprinting (Chapter 4)
- Discuss what 'truly' sustainable means, and how this relates to relying on offsets (Chapter 10 and 11)

- Compare what proposed savings equate to if invested elsewhere – especially in 3rd world countries (Chapter 7)

2.0 Carbon Neutrality in SoAD

This chapter discusses the very nature of being 'carbon neutral,' and what has been implemented in SoAD since it has been credited as carbon neutral. It critiques the pros and cons of the use of carbon offsetting as part of attaining carbon neutrality and the problem of depending heavily on such schemes to reduce the emissions. It discusses why SoAD's carbon neutral status was not renewed for the following years and looks at the problems of purchasing credits rather than actually making reductions in operational emissions.

2.1 The Role of Carbon Neutrality

The Oxford American Dictionary included 'carbon neutral' in 2006. It was defined as:

> *Being carbon neutral involves calculating your total climate-damaging carbon emissions, reducing them where possible, and then balancing your remaining emissions, often by purchasing a carbon offset: paying to plant new trees or investing in "green" technologies such as solar and wind power.*[18]

Remaining emissions can be balanced by:

- *Purchasing carbon offsets which are funding projects such as planting new trees that will sequester the carbon emissions (or other forms of carbon sequestration)*[19]

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[18] PR Newswire, *The New Oxford American Dictionary Announces the Word of the Year: 'Carbon Neutral,'* November 13, 2006, <http://www.encyclopedia.com/doc/1G1-154319503.html> [accessed 12 February 2009]

[19] Revkin, Andrew C. New York Times, "Carbon-Neutral Is Hip, but Is It Green?", published 29 April 2007, <http://www.nytimes.com/2007/04/29/weekinreview/29revkin.html?ex=1335499200&en=d9e2407e4f1a20f0&ei=5124> [accessed 12 February 2009]

- *Investing in renewable technologies (such as solar or wind power) which would compensate and prevent GHG emissions that would otherwise have been released from burning fossil fuels in the future*[20]
- *Replacing energy use with a renewable energy source that has no net emissions (in its manufacture and generation of energy) to eliminate energy related emissions, while extra credits from surplus energy generated can be used to offset other non-energy related emissions*[21]

These actions are usually done in conjunction with energy saving measures or other GHG reduction schemes.

2.2 SoAD's carbon neutral vision

In June 2008, a donation of 200 tonnes of international gold standard carbon credits from Meridian Energy's wind farm project in NZ, led to the school being certified as carbon neutral. By calculating the faculty's annual GHG footprint in the year 2007, (the total GHGs emitted from the faculty's operations) and using the donated offsets combined with the faculty's purchase of an additional 135.5 tonnes of carbon credits, SoAD effectively reduced its emissions from 335.5 tonnes per year to zero, in one year.[22] In addition, to respond to the NZ government's Kyoto Protocol obligations requiring emissions to return to 1990 level by 2012 (around a 25% reduction), SoAD also set its goals as committing to further reducing its faculty emissions by

[20] L.J. Martin, Carbon Neutral - What does it mean? 2006, <http://www.eejitsguides.com/environment/carbon-neutral.html> [accessed 17 February 2009]

[21] Revkin, Andrew C. New York Times, Carbon-Neutral Is Hip, but Is It Green?, published 29 April 2007, <http://www.nytimes.com/2007/04/29/weekinreview/29revkin.html?ex=1335499200&en=d9e2407e4f1a20f0&ei=5124> [accessed 12 February 2009]

[22] Faculty of Architecture and Design, Victoria University of Wellington, *Greenhouse Gas Reduction Plan*, May 2008, <http://www.victoria.ac.nz/home/about/publications/2008_GHG_emission_reduction_plan_-_FoAD.pdf> p.4, [accessed 13 February 2009]

25 percent per student and staff member by 2012.[23] The base line year to measure reductions against is 2007. A GHG Emissions Reduction Plan was compiled in June 2008 to include actions to meet the faculty reduction goal.

The objectives stated in the GHG Emissions Reduction Plan were to:[24]

- *Demonstrate management commitment to reducing GHG emissions by being the pilot carboNZero campus for Victoria University and for NZ.*
- *Maintain and introduce effective GHG emissions accounting procedures, to provide accurate or estimated measurements of the Faculty's direct and indirect emissions.*
- *Take social and cultural considerations as well as economic costs (over time as well as first cost) into account when considering GHG reduction initiatives.*
- *Target both the most significant and the easiest to address emissions where appropriate.*
- *Target reductions of emissions that are significant, but considered to be outside the scope of the Faculty's operations such as staff and student commuting.*
- *Report on the emissions reduction progress of the Faculty, and adjust, amend or add to the emissions reduction plan annually.*[25]

The reduction schemes included proposals to reduce air flight emissions by using video-conferencing and web technologies, to

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[23] Rowe, Ethan, Salient, The student magazine of Victoria University of Wellington, *World's first carbon neutral Faculty of Architecture and Design*, 8 September 2008, <http://www.salient.org.nz/news/world%E2%80%99s-first-carbon-neutral-faculty-of-architecture-and-design> [accessed 15 February 2009]
[24] Faculty of Architecture and Design, Victoria University of Wellington, *Greenhouse Gas Reduction Plan*, May 2008, <http://www.victoria.ac.nz/home/about/publications/2008_GHG_emission_reduction_plan_-_FoAD.pdf> p.2, [accessed 13 February 2009]
[25] Ibid, p.2

reduce landfill waste by reducing material needs for scale models, to recycle materials, increase the use of double-sided photocopying, promote the use of sustainable transport such as “green” taxis, buses and car-pooling for local travel, install increased efficiency gas boilers, and be active leaders in SoAD and Wellington City Council emissions reduction opportunities.[26]

What has been implemented since then?

Since the GHG Reduction Plan was implemented in 2008, certain savings have been made at SoAD. Waste was reduced by 16.3% and energy use has been reduced by 4.7%, although this still not quite the 25% reduction required by 2012. A digital conference studio was installed to help reduce emissions from air travel. Across the VUW faculty, paper use was reduced by 40% as a result of making double-sided printing the default setting and introducing recycling bins to all campuses. In addition, sustainable design principles have been incorporated into future building construction briefs.[27]

Based on the SoAD GHG Emissions Reduction Plan Progress Update November 2008 report by Andrew Wilks (FM for VUW), several things have happened in relation to the Faculty’s carbon neutral status since June 2008. Architecture students have worked on voluntary behaviour change initiatives addressing carbon emissions in the school through papers offered to 2nd year architecture students. There have been posters, events and, activities to create awareness of student impact on the environment. In September 2008, an email was sent to all students with links to the emissions reduction plan and inventory and a list of how they could participate. Several talks were given at the beginning of semester one and the middle of semester two to students during class. Some of the reduction initiatvies from the GHG report have been completed and some have been ignored. Those responsible for ensuring these

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[26] Ibid, p.5-12

[27] Fowler Nina, Salient; The student magazine of Victoria University of Wellington, *Carbon Neutral Victoria?* 20 July 2009, <http://www.salient.org.nz/features/carbon-neutral-victoria> [accessed 09 November 2009]

schemes are working have not been available at times due to staff leave, absence, change of roles and lack of management.

Below is a list of prominent changes made in the school since the carboNZero program[28]:

- *The heating set point in the building has been lowered by 1 or 2 degrees to 20 degrees as standard across the University for terminal units*
- *The boiler controls for SoAD have been reviewed, with a fault causing longer run-time than necessary identified and corrected*
- *A recycling paper bin has been placed next to every printer and copier. Additional paper recycling boxes have been ordered along with more recycling bins. All student copiers / printers have paper recycling bins next to them*
- *All cardboard is recycled in the new cardboard recycling facility downstairs. This formerly accounted for a lot of waste going into skips.*
- *Staff have been encouraged to reduce paper waste through double siding. The environmental committee initiated a change in July whereby all printers that have the double sided function have this as the default (it was found that not all printers have this function)*
- *Energy use of computers for staff and students was assessed, including the need to leave them on at night. A plan to reduce energy used by computers is to be devised and implemented. All SoAD Domain PCs now shut down at 12.30am every night although staff are asked to leave computers on for security updates*
- *Public transport and walking routes to the faculty are to be displayed in the main atrium. Bus and train timetables are*

[28] Wilks Andrew, Victoria University of Wellington, *Faculty of Architecture and Design GHG Emissions Reduction Plan Progress Update*, Internal Report, November 2008

available by reception. A walking map is available for travel between different campuses

- *Currently the University provides free 10-trip bus tickets to staff and students for travel between campuses*
- *A compulsory faculty wide first year environmental course is starting in 2009. Sustainable education is being introduced into studios and appropriate electives*
- *Staff and student research contributing to reducing or analysing the faculty's GHG emissions it is to be encouraged through awards and competitions. Students involved in ARCH222 have had various assignments around this topic.*
- *The library is to be utilised for displays about climate change design resources that deal with environmental design*
- *Atrium louvers are to be operated for natural ventilation and the opportunity for using fresh air to cool the building overnight is to be assessed.*

2.3 Problems with Carbon Neutrality in SoAD

The internationally recognized carbon neutral status in SoAD was short lived as it was not extended after 2007. SoAD's Dean and Deputy Pro Vice Chancellor Gordon Holden stated that the decision to get re-certified was difficult.

> *We deeply regret that we cannot proceed on the path that we had entered. However, the cost to renew CarboNZero status is beyond what can be supported in the current environment of reduced government funding and rising costs for the university… It's a very tough time and, as committed as we are, we can't afford the certification.*[29]

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[29] Fowler Nina, Salient; The student magazine of Victoria University of Wellington, *Carbon Neutral Victoria?* 20 July 2009, <http://www.salient.org.nz/features/carbon-neutral-victoria> [accessed 09 November 2009]

According to *Salient* the VUW student magazine, the estimated cost of doing this for another 18 months was approximately $28,000, made up of $12,000 for measurement, auditing and registration by Landcare Research and an estimated $16,000 for carbon credits. Due to the National Government funding cuts and no more free Meridian carbon credit support, the Dean was not able to financially justify the cost of carbon neutral status at SoAD. According to the Environmental Faculty Manager Andrew Wilks,[30]

> *This cost is not one that the university is willing to pay… The university has decided against purchasing carbon offsets due to the current financial pressures facing the university. Purchasing carbon offsets remains an option for the university but not in the near future. While official carbon neutral certification is off the cards, the university is making steady emissions reduction progress.*[31]

The financial reason for discontinuing carbon neutral status seem at variance the savings gained by the university from energy efficiency measures (such as lighting upgrades, efficiency of heating, ventilation and improving air conditioning plant) which have been initiated across the university faculties and are estimated to have already saved the university $139,000 per year. The figure for re-certifying SoAD is $28,000. Surely the savings gained from energy efficiency measures minus the capital costs could pay for re-certification? An aspect of concern is that no one has been allocated to ensure these GHG emission reduction plans are efficiently implemented at the Te Aro campus. All persons involved already have an existing role in the School and their jobs are not necessarily directly related to ensuring the GHG reduction plan is implemented. Due to staff absence through research leave and the plan being very specific to the faculty, there is an absence of university micro management so no one is available to take full responsibility for this plan. For monitoring and reporting emissions reduction, a faculty administration person was to be dedicated to maintaining the 2008

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[30] Ibid.
[31] Ibid.

inventory in conjunction with Andrew Wilks (VUW FM) and Mark Shaw (SoAD FM). This team was to determine the most appropriate monitoring and data collection procedure by July 2008. Emissions reductions for 2008 and emissions issues were to be reported in the 2009 Faculty GHG Emission Reduction Plan and the 2009 GHG Report. With turnover in administrative staff, this person has not been allocated.[32] The change of head of school also determined whether certain schemes were approved or not. For example in the SoAD's GHG Emissions Reduction Plan Progress Update November 2008 report it states that due to the change of head of school the plans for the faculty to establish a GHG emissions reduction sub-committee to report back at faculty meetings and provide briefings for the Wigan Street additional 2 floors to be 5-6 green star rated were all abolished.

Having no specific micro management of the GHG reduction plan could very easily lead to the plan being abandoned. Therefore there should be a case for a proper environmental management position in SoAD to implement the emission saving strategies efficiently (See Chapter 10 for the financial case for a hiring an operations manager). Chapter 3 talks about how minimally these emission reduction plans have been implemented, the lack of accurate data collection, the inconsistent review of the performance of the SoAD and the need for consistent analysis of the emissions reduction plan.
The issue of GHG emission reduction is an inevitable one and is something that the university may not be able to disregard in the future. The sooner the issue is embraced, the easier it will be in the future and SoAD will also reap the benefits from the savings made each year. SoAD should not see carbon neutrality as a costly venture but as a savings exercise.

[32] Wilks, Andrew, Victoria University of Wellington, *Faculty of Architecture and Design GHG Emissions Reduction Plan Progress Update*, Internal Report, November 2008

2.4 Problems with Carbon Offsetting schemes

The existence of offset schemes is a direct reflection of the capitalist driven agenda of compensating everything with money. The typical response when faced with a crisis is to let someone else deal with the problem. Offsets do not provide incentives for individuals and institutions to greatly change consumption patterns or other social, economic and political structures significantly but instead give people an 'easy way out.' Offsetting creates a diversion from the actions required to deal with the challenge of emissions reduction. [33] *'The Carbon Neutral Myth, offset indulgences for your climate sins'* by Carbon Trade Watch states clearly,

> *Offset schemes are shifting the focus of action about climate change onto lifestyles, detracting from the local participation and movement building that is critical to the realisation of genuine social change... Instead of acknowledging the uncomfortable but necessary truth that we cannot responsibly persist with our current lifestyles, climate conscious people are being encouraged to believe that with offset schemes they can continue as they were, as long as they pay money to absolve themselves of their responsibility to the climate.* [34]

There is also criticism of the broad assumptions made about the emissions avoided as a result of renewable energy projects and tree planting. It is not straightforward to calculate accurately how much GHG is emitted through a certain activity/action and hence how much extra CO_2, for instance, there would have been in the atmosphere if the project did not exist.[35] It is also complex to measure the CO_2 that has been hypothetically neutralised as this is based on *'future value*

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[33] Smith Kevin, *The Carbon Neutral Myth, Offset Indulgences for your Climate Sins,* (Transnational Institute, The Netherlands, February 2007), p.6 <http://www.carbontradewatch.org/pubs/carbon_neutral_myth.pdf> [accessed 16 March 2009]
[34] Ibid, p.7, 9

[35] Ibid, p.19

accounting' where carbon savings expected to be made in the future are counted as savings made in the present.[36] There are heavy doubts as to the validity of the scientific basis of offsetting, showing that it is not possible to compare absorption of atmospheric CO_2 by trees with the fossil CO_2 emitted from burning fossil fuels. There are problems with the temporary carbon storage in plantations and the inadequate understanding of the carbon cycle does not allow accurate calculation of how much CO_2 is being absorbed by the trees.[37]

2.5 Conclusion

The sponsorship agreement between SoAD and Meridian Energy for carbon offsets in 2007 was that they were free and temporary. This dependency on sponsorship was what led to the discontinuation of the carbon neutral certification. It is clear that the main drive behind the institution's desire to be carbon neutral is the pressure to address the threat of climate change. For an academic institution that researches and teaches about sustainability it seems hypocritical to not put it into practice. The reliance on carbon offsetting does not seem to address the problems associated with carbon offsets neither does it address the broader issues such as New Zealand's excessive consumption per capita, resource depletion, unequal resource distribution and heavy dependence on foreign fossil fuels. What VUW fails to realize is that reducing consumption will cost nothing to implement and will generate savings for the school. There seems to be a great reliance on, and preoccupation with, carbon offsets to promote sustainability rather than reduction as a method. Some progress has been made in implementing the GHG Emissions Reduction Plan, but much still needs to be done as the reduction goals are very small and more effort has gone into discussing whether they are feasible rather than implementing schemes and

[36] Ibid, p.24
[37] Ibid, p.19

systems that can easily reduce emissions. It is also critical to note the absence of proper management within the faculty as this is vital to the success of carrying out a GHG emissions plan.

3.0 Carbon footprinting / auditing of SoAD

This chapter presents the operational consumption data for SoAD that was analysed and calculated under the carboNZero energy audit for 2007. Landcare Research converted each category of consumption to carbon dioxide equivalent emissions in order to calculate how the offsets for the School to be considered a carbon neutral faculty. To establish an understanding of SoAD's consumption pattern, the last three years has been considered to see if there are any inconsistencies or recognisable areas of growth and to see what areas are the major emission sources for the university. Looking at the data will help determine the biggest contributing factors to emissions. The intention of this chapter is to find out the state of the school with regard to its consumption and emissions and whether there has been any improvement since the carbon neutral certification.

3.1 Background information on Te Aro Campus - SoAD

Figure 3:1: Wigan Building facing Wigan St, taken by the author on May 2009

Figure 3:2: Vivian Building facing Vivian St, taken by the author on May 2009

Te Aro campus is located in Wellington CBD between Vivian and Wigan St and consists of the School of Architecture (architecture, building science, landscape architecture, interior architecture and building management programmes) and the School of Design (digital media and industrial design programmes). There are two buildings in Te Aro campus, the main building facing Vivian St, which covers a significant portion of the campus with a total floor area of 10,323m^2, has four levels and the smaller building facing Wigan St covering 2,844m^2 has five levels. Total floor area therefore equals 13,167m^2. These buildings have lecture theatres, design studios, computer suites, library, workshops, offices and an exhibition space in the main atrium.

The Faculty has no student parking facilities. A limited number (25) staff parking facilities are available at the Te Aro campus for $400/yr per park.[38] These costs below market costs. For example Wilson Parking (at a heavily discounted price) in Willis St near SoAD costs $120 per month (including GST)[39] making in $1440 per year for unreserved parking. The average number of staff forced to park off

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[38] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report p.28 http://www.victoria.ac.nz/fm/services/docs/Vic%20Commute%20Travel%20Plan%20-%20Public.pdf [accessed 12 March 2009]

[39] Wilson Parking Promotional Poster wellington@wilsonparking.co.nz for 31 April 2009

campus is ten per day.[40] The pay and display parking around the campus ranges from $3 to $4 an hour.[41]

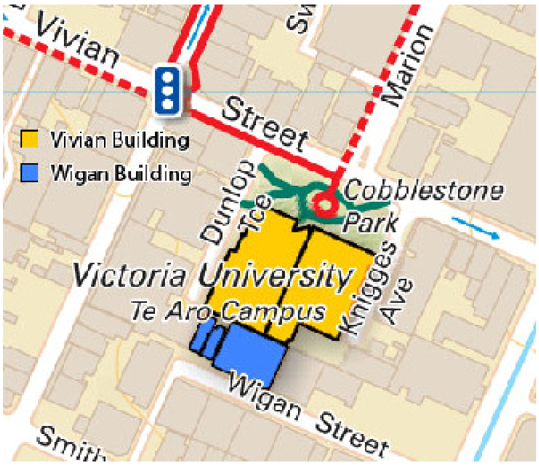

Figure 3:3: Map of Te Aro campus - Yellow is Vivian St Building and Blue is Wigan St Building (North point upwards)

Student and Staff numbers for Te Aro campus

The number of staff members has been quite steady in the past three years, averaging 100.[42] The number of different types of staff members fluctuates but not significantly, and according to the staff telephone directory for the SoAD in 2008 and 2009, there were:

Type of staff	2008	2009
Academic staff (part time & full time)	68	60
Librarians (part time & full time)	8	8
Technicians (part time & full time)	15	17

[40] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report p.28 http://www.victoria.ac.nz/fm/services/docs/Vic%20Commute%20Travel%20Plan%20-%20Public.pdf [accessed 12 March 2009]
[41] Wellington City Council, November 2006, <http://www.wellington.govt.nz/services/parking/pdfs/2006-11centralparkingmap.pdf> [accessed 02 March 2009]
[42] Chea Sou, Faculty of Architecture and Design, Victoria University of Wellington, personal communication, 05 March 2009

Administration	11	13
TOTALS	**102**	**98**

Table 3:1: Total number and staff breakdown[43]

It is important to include part time staff as part of the head count as it is likely that they will consume almost as much as a full time staff member in terms of resources, commuting to work and energy use. Despite the shorter time period they occupy the building, these part time staff have their own office (shared or individual) and working part time tends to maximise their activities during the limited hours they have. Therefore a figure of 100 staff is a reasonable average to use.

The number of equivalent full time students (EFTS) has increased over the past three years. From 2006 to 2007 the number of full time students enrolled in SoAD increased by approximately 8% and by 11% the following year and is expected to increase in the future.

EFTS (Equivalent Full time students)	2006	2007	2008
Total number of students	1149	**1244**	1378

Table 3:2: Total EFTS for the past 3 years[44]

Building occupation hours for Te Aro campus

The campus is in use all year round but most intensively during the traditional academic period of late February to October. The summer school period is the least busy term. The building is occupied for various hours during the day and at different times of the year. The table below indicates a general understanding of the various opening and closing hours for SoAD for the year 2009 and this can also be

[43] Faculty of Architecture and Design, Victoria University of Wellington, Staff telephone directory for 2008 and 2009

[44] Chea Sou, Faculty of Architecture and Design, Victoria University of Wellington, personal communication, 05 March 2009

applied to previous years.

Trimester 1 & 2 : 2 Mar - 12 Apr, 27 Apr - 1 Jul, 13 Jul - 23 Aug, 7 Sep- 15 Nov 09

Opening Hours	**Mon to Thu**	**Fri**	**Sat**	**Sun**
Arch & Design Library	08:30 - 22:30	08:30 - 18:30	13:00 - 17:30	13:00 - 20:30
Studio opening hours	07:30 - 23:30	07:30 - 23:30	09:00 - 23:30	09:00 - 23:30
Office hours	08:30 - 17:00	08:30 - 17:00	Closed	Closed

Table 3:3: Opening hours for various parts of the building. Tri 1 & 2[45]

- During Mid trimester & Mid year breaks library closes an hour earlier Mon - Fri (13 Apr - 26 Apr, 2 Jul - 12 Jul, 24 Aug - 6 Sep)
- Library is closed on statutory and most public holidays
- Post graduate students (excluding Honors students) and staff have 24 hour access

Trimester 3: 16 Nov - 23 Dec, 5 Jan - 28 Feb 2009

Opening Hours	**Mon, Tue**	**Wed, Thu**	**Fri**	**Sat**	**Sun**
Arch & Design Library	08:30 - 17:30	08:30 - 18:30	13:00 - 17:00	Closed	13:00 - 17:00
Studio opening hours	07:30 - 22:00	07:30 - 22:00	07:30 - 22:00	Closed	13:00 - 22:00
Office hours	08:30 - 17:00	08:30 - 17:00	08:30 - 17:00	Closed	Closed

Table 3:4: Opening hours for various parts of the building. Trimester 3[46]

45 Victoria University of Wellington <http://www.victoria.ac.nz/architecture/facilities/access-hours.aspx>, http://www.victoria.ac.nz/library/contact/hours.aspx [accessed 01 March 2009]

46 Ibid.

- Office hours may be shorter during trimester 3

3.2 CarboNZero audit for the base year 2007

The carboNZero programme is an internationally renowned greenhouse gas emissions measurement, reduction and certification system offering voluntary mitigation strategies through the use of credible and verified offsets or carbon credits.[47] SoAD has been certified by offsetting the carbon emissions from various operational building activities for the period of 01/01/2007 to 31/12/2007. This certification was valid until 31/03/09.[48]

Excluding electricity as part of the emission offset needs
At present electricity is not included in the emissions to be offset because electricity is supplied to the faculty by Meridian Energy which is certified carbon zero as it is considered to be generated with renewable technology. Despite this, electricity use here has been calculated and converted to carbon emissions data to consider increasing electricity use efficiency and reducing consumption as an important part of a GHG emissions reduction plan.[49]

3.2.1 The results from carboNZero GHG emissions profile 07

All GHG emissions were calculated using the carboNZero programme calculation tools. The pie graph below shows the operational GHG emissions for SoAD for the various different

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[47] CarboNZero, *Summary of carboNZero Certification,* <http://carbonzero.co.nz/documents/disclosure_vuw_2007.pdf> [accessed 03 March 2009] p.3
[48] Ibid. p.4
[49] Faculty of Architecture and Design, Victoria University of Wellington, *Greenhouse Gas Reduction Plan*, May 2008, <http://www.victoria.ac.nz/home/about/publications/2008_GHG_emission_reduction_plan_-_FoAD.pdf> [accessed 13 February 2009] p.4

emissions sources. The combined total emissions for 2007 were 664 tonnes carbon dioxide equivalents (CO_2e) including electricity.[50]

Emission Sources	**Tonnes (CO_2e)**
Direct (Scope 1) Emissions:	
Gas (Boilers in Buildings)	136.77
Gas (BBQ / Workshop)	0.20
Diesel (Faculty Van)	0.67
TOTAL	**137.64**
Indirect (Scope 2) Emissions:	
Electricity	327.53
TOTAL	**327.53**
Indirect (Scope 3) Emissions:	
Diesel (Field Trips)	0.25
Taxis	1.52
International Flights	82.61
Domestic Flights	4.80
Waste to landfill	109
TOTAL	**197.87**
TOTAL OPERATIONAL EMISSIONS (incl. electricity)	**663.03**
TOTAL OPERATIONAL EMISSIONS (not including electricity)	**335.5**

Table 3:5: Emissions sources and figures for SoAD[51]

[50] Ibid. p.4
[51] Ibid. p.4

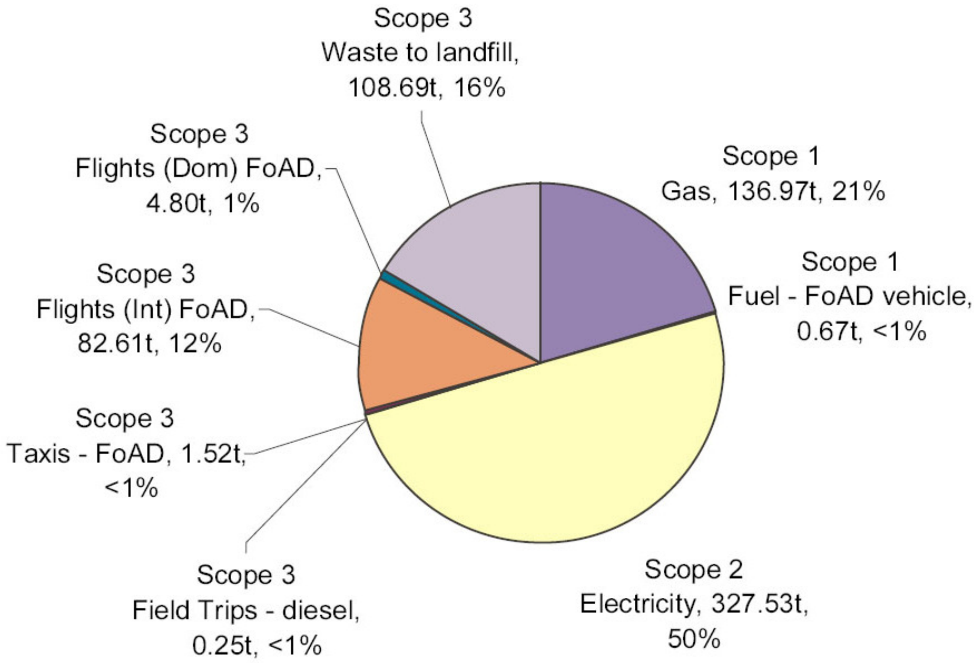

Figure 3:4: GHG emissions (tonnes CO_2e) by emissions source for SoAD[52]

The emissions categories were divided into three groups:

***Scope 1** represents direct GHG emissions from sources that are owned or controlled by the SoAD (e.g. vehicle fleet fuel-use).*

***Scope 2** represents indirect GHG emissions from the generation of purchased electricity consumed by the faculty.*

***Scope 3** represents indirect GHG emissions that occur as a consequence of the activities of the faculty, but occur from sources not owned or controlled by it. Inclusion of these is done on a case-by-case basis and they include road freight, shipping freight, business air travel, and staff commuting.*[53]

Total operational emissions not including electricity of 336 tonnes CO_2e has been offset with Verified Emission Reductions (VERs are

[52] Ibid. p.4
[53] Ibid. p.4

created by eligible projects for emissions reductions achieved up to the end of 2007) from Projects to Reduce Emissions (PRE) windfarm credits (PRE is a NZ government scheme for projects that are eligible under the Joint Implementation initiative of the Kyoto Protocol).[54]

	Tonnes CO_{2e}
SoAD Emission Inventory	663.03
Meridian supplied electricity	327.53
Unavoidable GHG emissions for offset	**335.50 (rounded to 336)**

Table 3:6: GHG Offsets required for carboNZero certification[55]

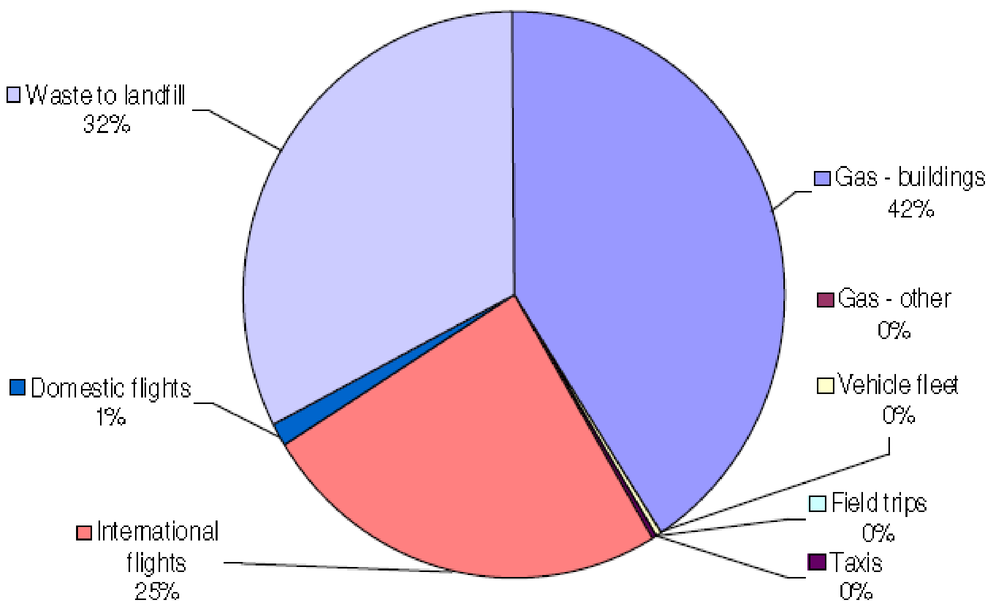

Figure 3:5: Percentage of Emissions (not including electricity)[56]

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[54] CarboNZero, *Summary of carboNZero Certification,* <http://carbonzero.co.nz/documents/disclosure_vuw_2007.pdf> [accessed 03 March 2009] p.3

[55] Faculty of Architecture and Design, Victoria University of Wellington, *Greenhouse Gas Reduction Plan*, May 2008, <http://www.victoria.ac.nz/home/about/publications/2008_GHG_emission_reduction_plan_-_FoAD.pdf> [accessed 13 February 2009] p.4

[56] Ibid. p.4

3.2.2 Excluded emissions from carboNZero audit

Transport by land – Commute to school (Scope 3)

In March 2007, Victoria University conducted a voluntary travel survey which indicated how staff and students commute to school and work. Although the results were allocated on a campus basis the low survey participation rate of staff and students and statistical uncertainties have led to an insufficient data sample and hence this was excluded from the 2007 GHG inventory that was compiled by carboNZero for the SoAD.[57] The survey did supply important data to formulate a VUW Travel Plan.

Food / Catering (Scope 3)

SoAD regularly hold conferences, exhibitions, ceremonies and other events that involve catering companies providing finger food and drinks to the public. Although this may not be a direct emission by the school it is an activity carried out during and as part of the operation of the school and therefore should be accounted for in Scope 3 emissions. Another Scope 3 emission factor would be the food (usually lunch) consumed by students and staff during school hours.

Goods purchased (Scope 3)

Office consumables, magazines, books, electronics, chairs, tables, and other miscellaneous items that are necessary for the operation of SoAD should be considered under Scope 3 emissions.

3.3 VUW and SoAD's consumption patterns from 2006 to 2008

The last three years have been considered here to see if there are any changes in the consumption pattern and any recognisable growth or decline in the different consumption sectors. This data is

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[57] CarboNZero, *Summary of carboNZero Certification,* <http://carbonzero.co.nz/documents/disclosure_vuw_2007.pdf> [accessed 03 March 2009] p.2

generally for the whole of VUW therefore calculating the approximate SoAD portion may be inaccurate and differ from the carboNZero calculations. There seem to be two different data sets for consumption at SoAD, one from VUW FM and the other from carboNZero data. To look at consumption in the years before and after the base year of 2007, this research had to rely on VUW general data.

Electricity Use

Based on records from the VUW FM (environmental)[58], the following chart shows electricity use for both buildings. It should be noted 2007 data varies slightly from the carboNZero calculations.

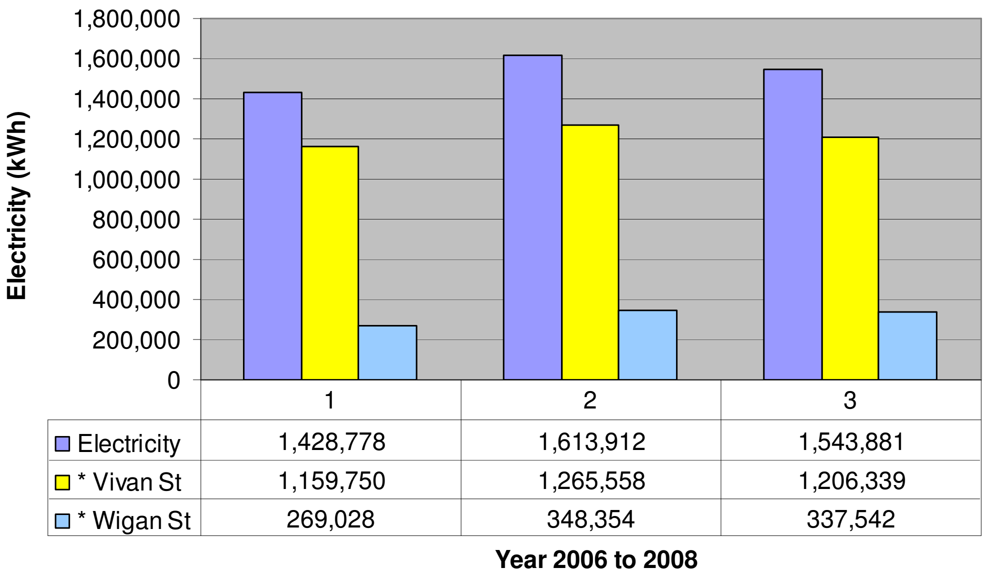


Figure 3:6: Total electricity consumption for Te Aro for 2006 to 2008[59]

Electricity consumption rose for both buildings between 2006 and 2007 by 13%, although it dropped slightly in 2008 by 4%, probably due to the energy efficient measures being implemented. The graph below shows the CO_{2e} emissions for total electricity consumption and

[58] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)
[59] Ibid.

the pattern corresponds to electricity use.

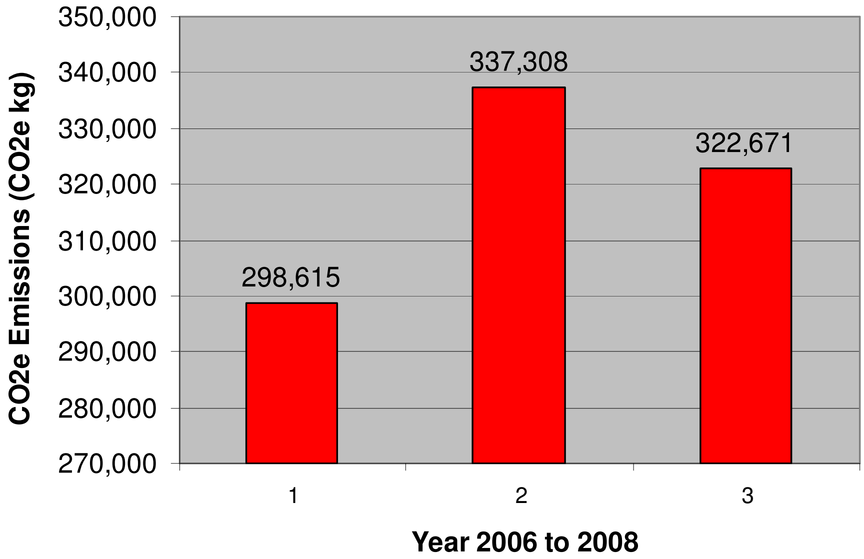
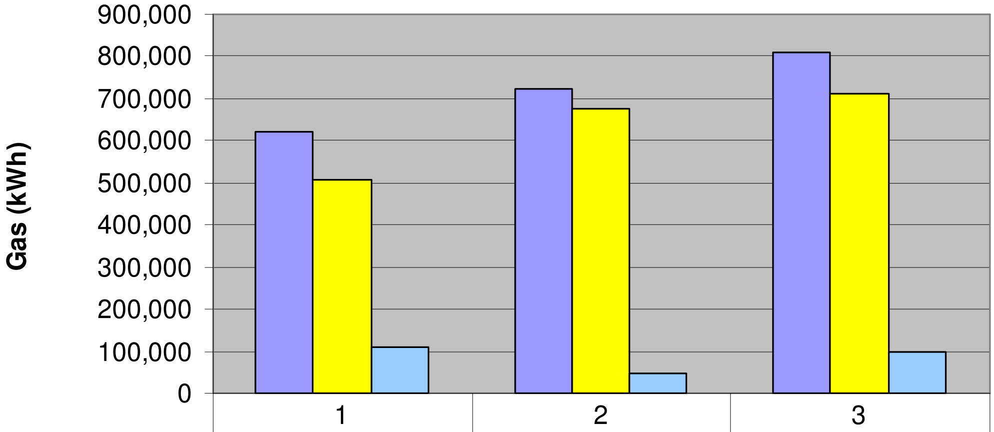


Figure 3:7: CO_2e emissions for total electricity consumption (CF = 0.209) (Notice CarboNZero 2007 figures give 327.53t CO_2e for total electricity consumption emissions which is a slight variance with the VUW figure of 337.31t CO_2e for 2007).

VUW used a conversion factor (CF) of 0.209 for electricity consumption in 2006 and 2007 and a CF value of 0.165 for 2008. For consistency in calculation the general CF value of 0.209 was used instead for 2008. Also this CF value seemed to be closer to the carboNZero calculation which uses CF = 0.203. It is not clear why the 2008 CF value was changed, but the information states that the factors are from Ministry of Environment, Guidance for voluntary GHG reporting. Again, the lack of consistency in calculating the data should be noted.

Gas Use

Gas is used purely for space heating with active use during winter months and very little or no use during summer months.



	1	2	3
Gas	619,206	724,453	809,554
* Vivan St	508,529	675,752	711,342
* Wigan St	110,677	48,701	98,212

Year 2006 to 2008

Figure 3:8: Total gas consumption for Te Aro campus 2006 - 2008[60]

Vivian building gas use has increased steadily from 2006 to 2007, first by 16% and then 11% the following year. In the Wigan building use decreased from 2006 to 2007 by 56% but then doubled in 2008. This suggests here may have been inaccurate reading of the gas meter or a fault during 2007.

[60] Ibid.

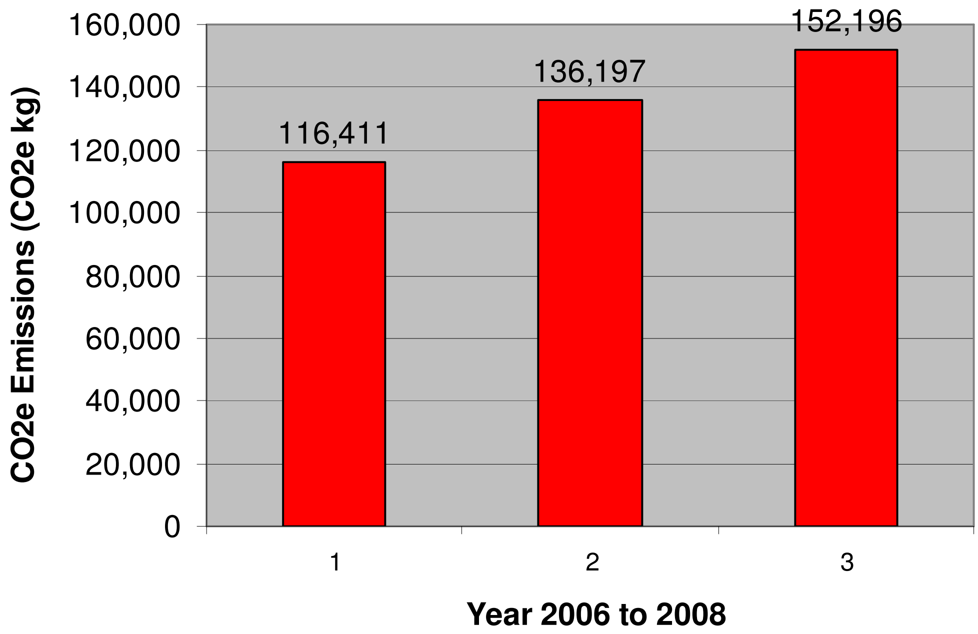


Figure 3:9: Total CO_2e emissions for gas consumption (CF = 0.188)

Again, the gas consumption increase corresponds with CO_2e emissions increase. (CarboNZero figure for 2007 is 136.77t CO_2e which varies only slightly with the VUW records of 136.20t CO_2e). VUW used a conversion factor (CF) of 0.188 for gas consumption in 2006 and 2007 and a CF value of 0.194 for 2008. For consistency in calculation the general CF value of 0.188 was used instead for 2008. Also this CF value seemed to be the same value as the carboNZero calculation which used CF = 0.188.

Transport by air

The funded business trips by air were recorded for the whole university and not by separate campus for the years 2006 to 2008. These figures are not indicative as to whether travel was for conferences, marketing, administration, or other purposes. However the figures do indicate how many flights were taken as part of the university's business. However, these figures may be an underestimate because only funded staff flights were recorded. Many staff paid for their own trips and hence it is assumed that staff flights used in the carboNZero calculation was an underestimate).

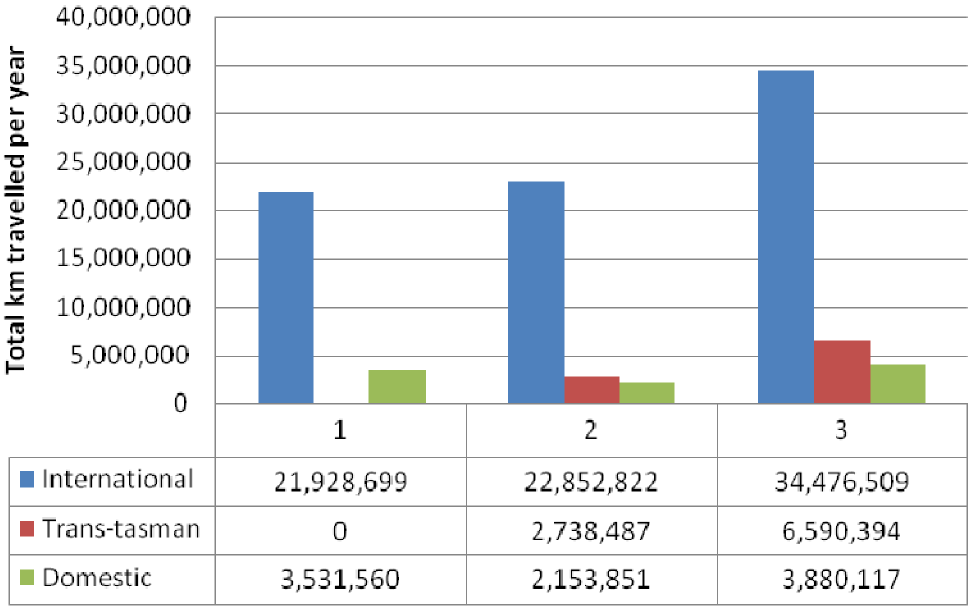


Figure 3:10: Total funded business trips by air (VUW) from Year 2006 - 2008[61]

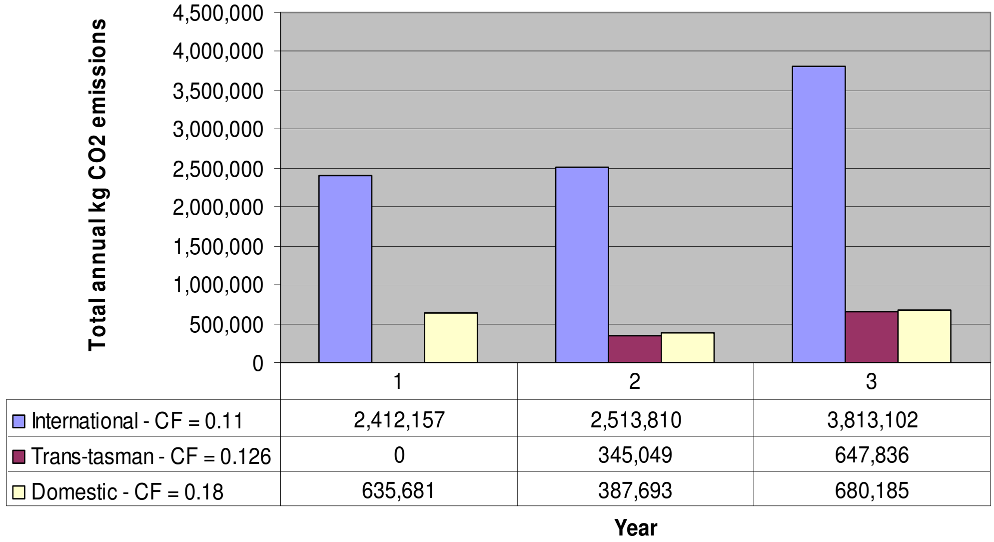


Figure 3:11: CO_2 emissions for total funded business trips by air (VUW) from Year 2006 - 2008[62]

From the graph it is very clear that total air flights increased dramatically by 62%for the university from 2007 to 2008. From 2007 to 2008 international flights increased by 60% and domestic by 80%.

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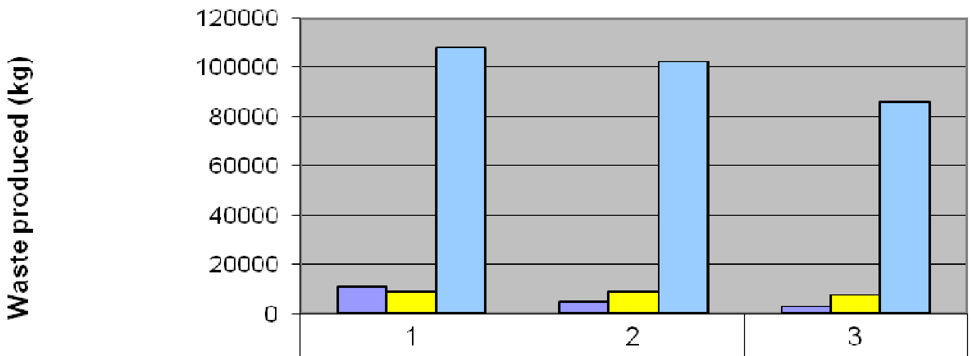
[61] Ibid.
[62] Ibid.

A possible cause for this increase could be the introduction of the PBRF[63] system with its significant focus on research outputs from staff. Staff have to show they are fulfilling the obligation to research which results in increasing pressure to attend conferences, especially international conferences. However, it is equally likely that the increase could be for marketing or administrative purposes. Regardless, it is interesting to note the sudden increase in the number of flights taken.

As there is uncertainty about the distribution of flights between different campuses in VUW the figures can only be used as a general indication of the ratio of international to domestic flights and the increase in flights taken over the three years. There is also conflict between the conversion factor for the VUW calculations and those of carboNZero (See chapter 8 on Transport by air), so it is unclear how to generate accurate emission data for staff business flights.

Waste

There was a separate record of waste for each campus and Figure 3:12 shows VUW's record, which seems to conflict with carboNZero data (See chapter 9, Waste Use).



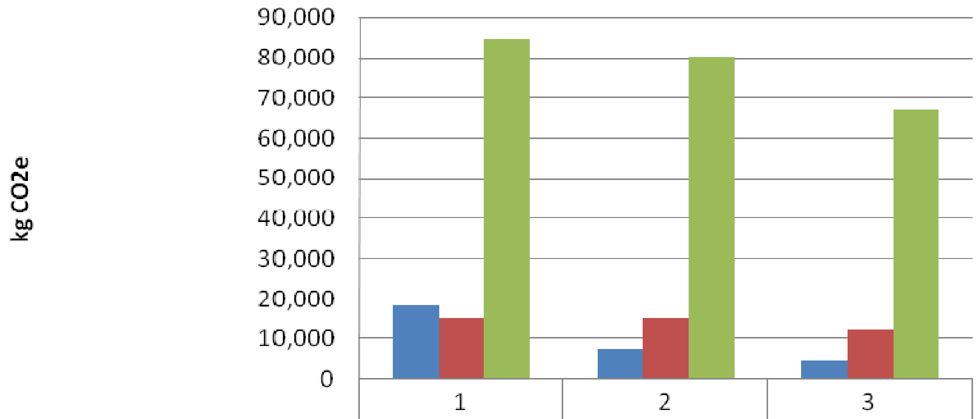
	1	2	3
Mixed Recycling Glass/Cans/Plastic	10900	4512	2713
Recycling Paper	9000	9010	7440
Total Waste to landfill	108295	102681	85965

Year 2006 to 2008

[63] Vale Brenda, Faculty of Architecture and Design, Victoria University of Wellington, personal communication, 12 March 2009

Figure 3:12: Total waste produced at Te Aro campus

The amount of waste going to landfill each year is decreasing. From 2007 to 2008 there was a 15% decrease and from 2006 to 2007 a 5% decrease in waste generated. Mixed recycling (glass, cans and plastic) has also decreased by 59% from 2006 to 2007 and by 40% from 2007 to 2008. Paper recycling also decreased by 17% from 2007 to 2008. However, the carboNZero data for waste (See Waste Chapter 9 for details) is 108,690 kg CO_2 which is slightly different to that provided by VUW (see Figure 3:13 below).



	1	2	3
CO2e Emissions for mixed Recycling Glass/Cans/Plastic (CF= 1.69 from carboNZero)	18,421	7,625	4,585
CO2e Emissions for recycling Paper (CF = 1.69 from carboNZero)	15,210	15,227	12,574
CO2e Emissions for waste to landfill - Conversion factor = 0.78	84,470	80,091	67,053

Figure 3:13: kg CO_2e for total waste produced from Year 2006 - 2008

VUW's 2007 CO_2 emissions are 102,943 kg CO_2 which is below the carboNZero figure (despite using the same CF).

Paper use

The chart below gives a record of total paper usage at VUW.

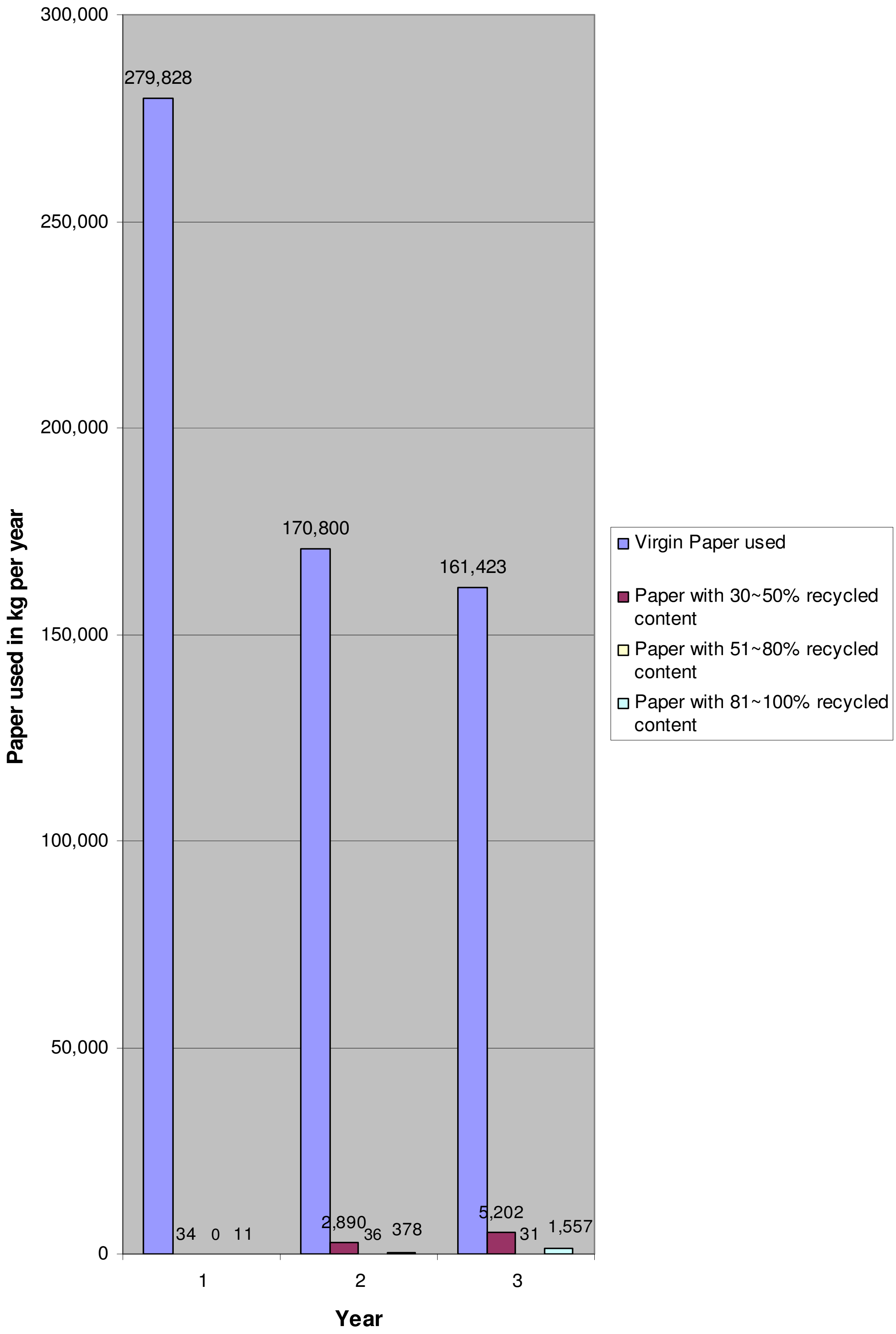


Figure 3:14: Total paper use for VUW from Year 2006 - 2008

The graph indicates the reduction in the use of virgin paper and the increase in the use of paper with recycled content. Regardless, the overall paper usage has dropped from 2006 to 2007 by 35% and from 2007 to 2008 by 7%. This is probably due to the increase in double sided printing implemented by VUW FM.

3.4 Including electricity and transport to school emissions

When trying to focus on the 'big things' that makes a significant impact on the overall SoAD emissions, it is clear that electricity, gas, transport by air (domestic and international combined) and waste to landfill become the biggest factors that make up the emissions. Focussing on factors that contribute 10% or more of overall emissions, it seems unreasonable to exclude the impact of electricity in the overall emissions, even though the electricity is coming from Meridian (considered renewable energy source), and to not include transport to work emissions because the sample size was too small.

Case to include electricity as part of emissions that need to be reduced

According to the Meridian Annual report for the year ending June 2008[64]:

> *In the last financial year, 63 percent of electricity for sale to consumers*
> *was generated using renewable resources…Meridian's contribution to total New Zealand electricity generation was approximately 30 percent of the country's supply.*

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[64] Meridian Energy, "Annual Report for the year ending 30 June 2008", <http://www.meridianenergy.co.nz/NR/rdonlyres/8F26402C-29FB-4A3F-AC3A-6F130BA7EF1D/24430/MeridianAnnualReportJune2008.pdf> [accessed 12 April 2009] p.13

Also renewable electricity generation in New Zealand makes up 66% of total with the majority generated from hydro, although, this percentage has increased since 2002 due to installation of more wind turbines, It is, therefore, not accurate to claim that purchasing electricity from Meridian will be carboNZero.

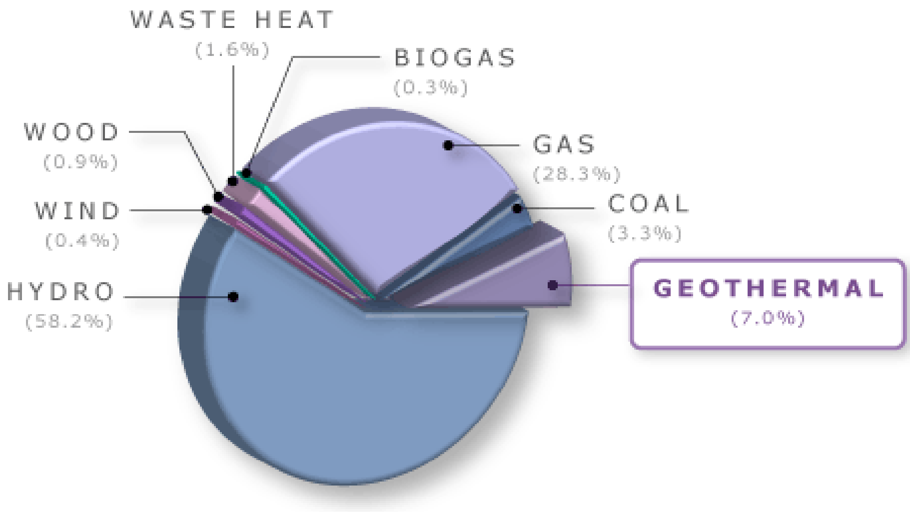

Figure 3:15: Source of electricity generation in NZ, 2002[65]

Hydro 58.2% + Wind 0.4% + Geothermal 7.0%
= Total 66% of renewable energy production

Case to include transport to work as part of emissions that need to be reduced

Staff and student commuting are also considered to be a potentially large source of emissions. The results from the VUW travel survey in 2007 indicate that a high percentage of staff and students that commute to Victoria University live within walking distance of the

[65] Carol Stewart. "Geothermal energy", Te Ara - the Encyclopedia of New Zealand, updated 02 Mar 2009, http://www.TeAra.govt.nz/en/geothermal-energy/3/4 [accessed 14 April 2009]

campus (Wellington City) or live within the Wellington region as indicated in Figure 3:16 below.[66]

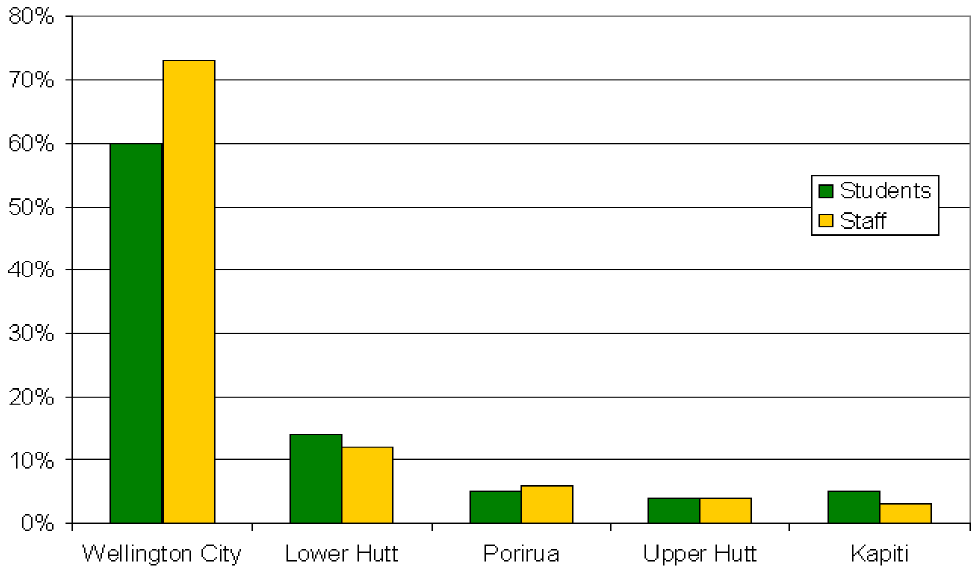

Figure 3:16: Staff and Student home locations for VUW[67]

The overall mode split for staff and students in VUW is shown in Figure 3:17 and for Te Aro campus in Figures 3:18 and 3:19.

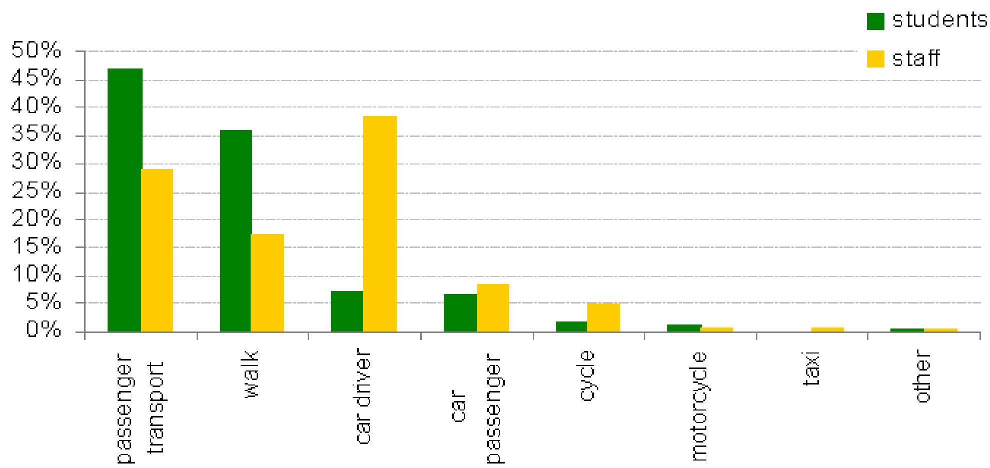

Figure 3:17: Mode split results for VUW, March 2007[68]

[66] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report p.6

[67] Ibid. p.6

[68] Ibid. p.7

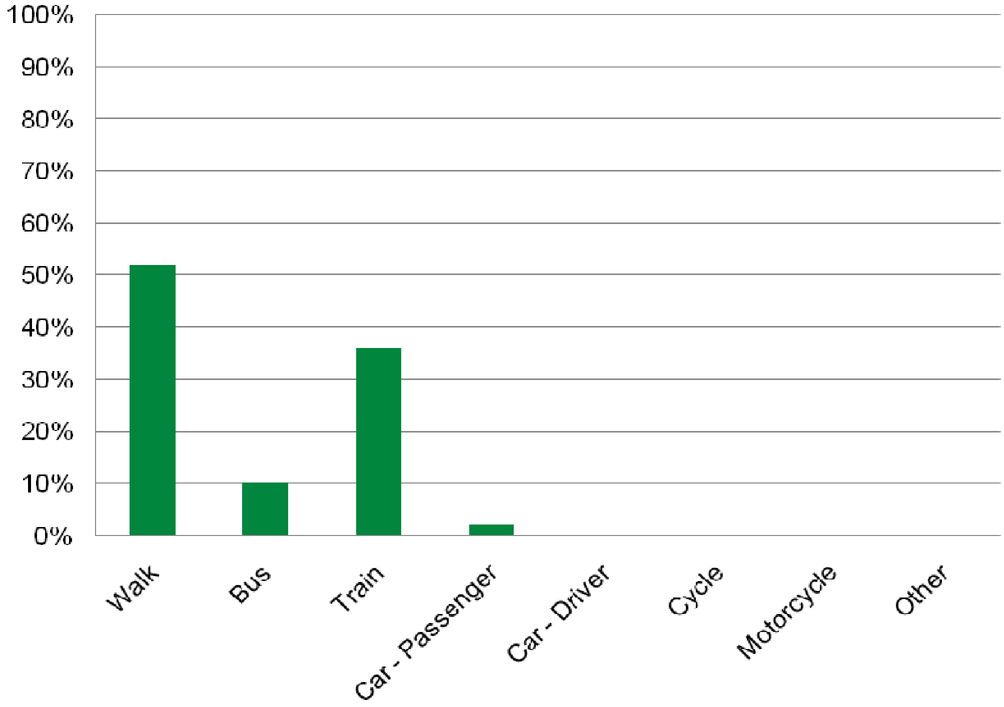

Figure 3:18: Student mode split for Te Aro campus, March 2007[69]

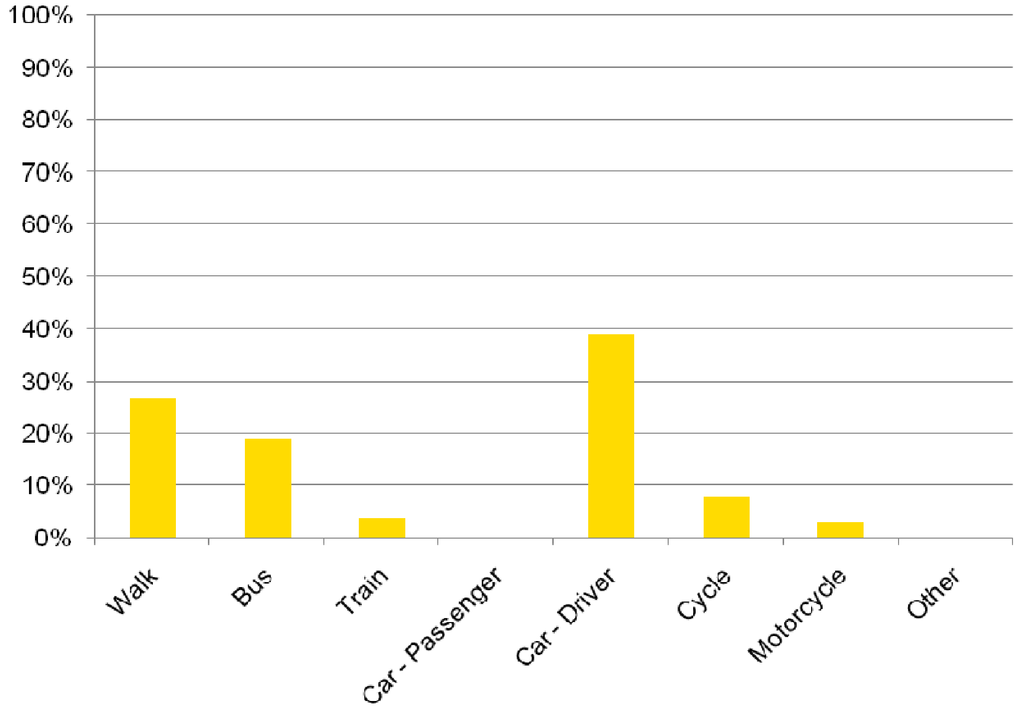

Figure 3:19: Staff mode split for Te Aro campus, March 2007[70]

[69] Ibid. p.7
[70] Ibid. p.8

The travel survey revealed a mode split in which students showed a good use of the public transport network and minimal use of commuting by car, possibly due to lack of car parks and the high expense associated with maintaining a car. Staff on the contrary have a high number of car commuters and there are no apparent incentives to change this.

From the records of the VUW Travel Survey 2007, approximate figures can be calculated for Te Aro to see how realistic these are.

Given data from Travel Survey 2007	Calculation of km/day
1244 Students total = 1,655,531 km/yr (1 student = 1331 km/yr)	37 weeks in Trimester 1 & 2 = 259 days = 5.1km/day/student (2.5km one way)
100 Staff total = 271,878 km/yr (1 staff = 2719 km/yr)	42 weeks in Trimester 1, 2 & 3a = 294 days = 9.2km/day/staff (4.6km one way)

Table 3:7: Calculation of staff and students commute km per day in Te Aro campus[71]

This figure seems quite realistic. Staff mostly drive so it would be easier to live further away from school and students usually tend to flat closer to the Wellington CBD allowing them to take the bus to school.

Despite the small sample size (and unreliability in statistical terms), it could have beeen used as a general indication and included in the carboNZero 2007 audit. Since it is a significant operational activity for the school it should be included to see whether transport by land

[71] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (7 May 2009), Re: *SoAD carboNZero 08* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

makes a contribution to the overall emissions.

Final 'Big things' – Energy, Transport and Waste

The final large items that need to be reduced are energy (electricity and gas), waste (landfill and recyclables) and transport emissions (air and land). Chapters 7-9 will therefore focus on reducing these factors.

3.5 Conclusion

It is clear that VUW and SoAD need to reduce their carbon footprints drastically in the critical areas of energy, transport and waste in order to promote themselves as truly carbon neutral in the future. Even if the university decides to continue purchasing carbon credits to offset emissions, the emissions need to be as low as possible for this to be affordable.

There is a lack of coherence and consistency in the data gathered and a further breakdown of data would be desirable. Data should be more specific to each faculty to show different use and consumption patterns, and other factors need to be considered such as food purchased and consumed and other purchased items. At what point is it acceptable to say the school is carbon neutral? How many factors does the school need to consider when considering carbon neutrality?

4.0 Ecological footprinting of SoAD's activities

The previous chapters have shown that SoAD's biggest contributors to GHG emissions are energy, waste and transport. However, CO_2 footprinting poses a difficulty when trying to grasp the impact of an activity due to the impalpable nature of the gases concerned. This has led to more straight-forward, and visual measurements, such as Wackernagel and Ree's Ecological Footprint (EF)[72]. This attempts to calculate humanity's demand on nature in specific, understandable terms, using official government statistics. This land based measurement of human consumption takes into consideration the five main areas of resource consumption; food, housing, transportation, consumer goods and miscellaneous services. The purpose of ecological footprinting is to understand the impact of the operational activities of the school that have not been addressed in the carboNZero 2007 calculation, such as food, and to see what sort of impact the EF calculation has with respect to land based measurement. This measurement can be compared with the carboNZero data to see if there are any new insights into the impacts that might be considered important to reduce.

4.1 Ecological footprint (EF) of New Zealand and the world

Wakernagel and Rees define EF as:

> *Ecological footprinting is a measure of human demand on the Earth's ecosystems. It compares human demand with planet Earth's ecological capacity to regenerate. It represents the amount of biologically productive land and sea area needed to regenerate the resources a human population consumes and to absorb and render*

[72] Wackernagel Mathis and Rees William, *Ecological Footprint, Reducing Human impact on earth,* (New Society Publishers 1996)

harmless the corresponding waste. Using this assessment, it is possible to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody lived a given lifestyle.[73]

It is measured in global hectares (gha) which is a standardized hectare of land able to produce resources and absorb waste at world average levels. The 2008 Living Planet Report from the World Wildlife Fund (WWF) is a global survey that showed (based on 2005 calculations) current resource use is 2.7 gha per person which is 0.6 gha above the biocapacity of the planet (See Figure 4:1). This overshoot is further explored in Table 4:1, where the over consumption of high-income countries is clearly indicated.

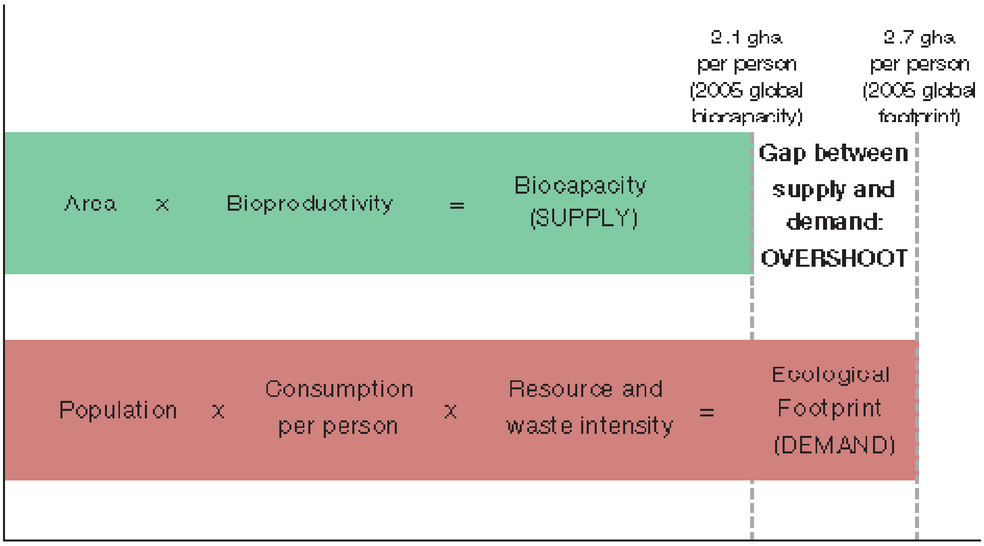

Figure 4:1: Footprint and Biocapacity factors that determine overshoot[74]

Country / Region	Population (millions)	Total Ecological Footprint
WORLD	**6,476**	**2.7**

[73] WWF, *Living Planet Report 2008*, <http://www.footprintnetwork.org/download.php?id=505> [accessed 15 May 2009] p.14
[74] Ibid. p.23

High-income countries	972	6.4
Middle-income countries	3,098	2.2
Low-income countries	2,371	1.0

Table 4:1: Ecological Footprint 2005 (global hectares per person)[75]

Country / Region	Total Biocapacity (gha/person)	Ecological reserve or deficit (-) (gha/person)
WORLD	**2.1**	**-0.6**
High-income countries	3.7	-2.7
Middle-income countries	2.2	0.0
Low-income countries	0.9	-0.1

Table 4:2: Biocapacity 2005 (global hectares per person) [76]

The report indicates that responsibility lies with the wealthy nations to eliminate the world's ecological debt (overshoot) but it also critically points out the inequitable consumption of the earth's finite resources by a small number of people. Per capita footprints of high-income countries are over their biocapacity by 2.7gha per person (= 3.7gha - 6.4gha) and above the world's total biocapacity by 4.3 gha per person (= 2.1gha - 6.4gha). Meanwhile the EFs of middle-income countries are within their biocapacity and those of low-income countries only just outside it and both are very near or within the fair share of the total biocapacity of the world.

In order for the global ecological overshoot to be eliminated, the world needs to reduce its average footprint by **22%** (= (2.7gha - 2.1gha) / 2.7gha x100) to be within its total biocapacity. However this seems like an unfair target as this would mean that the developing nations (middle and low income countries) cannot develop as this would then lead to an overshoot. Predominantly the countries in the

[75] Ibid. p.32
[76] Ibid. p.32

lower income sector are under developed in terms of basic human needs such as access to food, water, health care, education and housing and they need to develop and increase their footprint, as they are not consuming their fair earth's share. This would lead to more dramatic reduction of footprint for high income countries. For the high-income countries to be within their biocapacity they need to reduce their footprint by **73%** (= (6.4gha – 3.7gha) / 3.7gha x 100).

How bad is NZ? Land based measurement of environmental impact

According to WWF's Living Planet report New Zealand's per capita ecological footprint is the sixth largest in the world due to the related emissions from imported goods and services and the increasing consumption. The report also indicates that,

> *Humans are now exceeding the planet's regenerative capacity by about 30 percent. If demand keeps growing at the same rate, the equivalent of two planets would be required in the mid-2030s to sustain current lifestyles - or 3.5 planets if everyone on Earth used resources at the same pace as New Zealanders."*[77]

Main reasons behind NZ's emissions are the transport and energy generation sectors. According to Energy Efficiency and Conservation Authority reports, New Zealand has one of the largest figures of car ownership with a corresponding long distance travelled in those cars, second only to the US.[78]

New Zealand's Ecological Footprint

New Zealand has an enormous bio capacity which is almost twice its footprint and also it is blessed with high yielding land for grazing and

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[77] Xinhua, China Daily, "New Zealand's ecological footprint among world's highest: survey," 29 October 2008, <http://www.chinadaily.com.cn/world/2008-10/29/content_7154606.htm> [accessed 27 May 2009]

[78] Ibid.

growing crops[79] and good climatic conditions for growing food. This means it can have a less energy intensive agriculture and horticulture industry.

Country / Region	Population (millions)	Total Ecological Footprint
New Zealand	4.0	7.7

Table 4:3: Ecological Footprint of New Zealand 2005 (global hectares per person)[80]

Country / Region	Total Biocapacity (gha/person)	Ecological reserve or deficit (-) (gha/person)
New Zealand	14.1	+6.4

Table 4:4: Biocapacity of New Zealand 2005 (global hectares per person)[81]

Despite New Zealand being within its own biocapacity, the earth functions as a whole planet not as a series of individual countries. Therefore NZ is responsible for its high per capita consumption and its EF that is nearly 4 times the world's biocapacity. For NZ to be within the global biocapacity of 2.1 gha, it has to reduce its EF by **73%**. This reduction will only keep it within the global biocapacity and does not take into consideration the provision for poorer nations to develop. So this goal is perhaps not enough. There is a problem in all this in that global population is growing, so the per capita available biocapacity is getting smaller every day.

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[79] Global Footprint Network, Research and Standards Department, *Calculation Methodology for the National Footprint Accounts,* 2008 Edition, 16 December 2008, <http://www.footprintnetwork.org/download.php?id=508> [accessed 25 May 2009] p.4

[80] WWF, *Living Planet Report 2008*, <http://www.footprintnetwork.org/download.php?id=505> [accessed 15 May 2009] p.36

[81] Ibid. p.37

It is clear that the fewer people there are, the greater the biocapacity available and also that the current global ecological footprint is largely influenced by the high-income nations, which include New Zealand. So although there is the population issue, the more important issue is the high consumption of a small number of people.

4.2 Criterion for EF Calculation for SoAD

Australian EF Calculator

The Environmental Protection Authority (EPA) in Victoria, Australia provides a specific EF Calculator for Schools[82]. The EPA is run by the State Government of Victoria which suggests the calculator is reliable. It is used here with the intention of identifying the environmental impact of everyday operational activities for the school. It is also designed to be used as an incentive to encourage progress and improve existing environments to be more sustainable. It considers the five main sources of consumption; food, building, transportation, consumer goods and miscellaneous services.

Data for the year 2007 is used for this calculation to be consistent with the SoAD carboNZero 2007 calculations.

Limitations in using EPA EF calculator

The limitation of this calculator is that it is based on the Australian system. Certain answers are required in Australian dollars, so there are some inaccuracies from converting NZ dollar to AUS dollar as values are rounded. Also the exchange rate is unreliable as it changes constantly (current exchange rate: $1 NZ equals to $1.29

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[82] State Government of Victoria, EPA Victoria, *Ecological Footprint Measuring our impact on the environment,* <http://www.epa.vic.gov.au/ecologicalfootprint/about/howitworks.asp> [accessed 16 May 2009]

AUS).[83] There are various factors that may differ from the NZ situation (such as yield factors) and this limitation should also be addressed as it will affect the accuracy. Therefore this calculator will only be used as a general guideline, and not necessarily an accurate reflection of SoAD's consumption.

Due to poor record keeping and difficulty in accessing SoAD's various records, various assumptions and approximations have had to be made. Certain factors have a broad range (such as for catering which varies quite dramatically from year to year). In this case a minimum value has been calculated and then a maximum value to see if the changes make a significant contribution to the overall footprint.

It should be born in mind that this ecological footprint calculation is for SoAD activity only and does not take into consideration an individual's consumption outside the school.

Calculating Lunch – the hypothetical presence of a school Canteen

A significant section of the EF calculator involves food. Due to the absence of a canteen in SoAD, this would change the EF scenario dramatically as food is critical to total EF. In order for the EF of SoAD to be more accurate, the impact of staff and students consuming lunch during the school's opening hours will be considered.

The EPA calculator cannot take into consideration the amount of imported food purchased and so is unable to incorporate food miles into the calculation. The calculator asks for the $AUS spent on different categories of food. Since the food prices in Australia are similar to those of NZ, the $NZ figures will be directly translated into Australian dollars.

In order to calculate the approximate value of an average lunch for each student and staff member, the usual daily median energy intake must be known for the different age and gender classes involved as each would require a different amount of food. A background paper

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[83] XE, "The world's Favourite Currency and Foreign Exchange Site", <www.xe.com> [accessed 20 May 2009]

"*Food and Nutrition guidelines for Healthy Adults*"[84] from the Ministry of Health NZ states that males and females aged 19-24 years have the highest median energy intake. Energy intake decreases gradually as a person gets older. From the study it was concluded that there was no clear difference in energy intake between different socioeconomic groups.[85]

Considering the majority of the students in SoAD consist of 19-24 year olds, a different energy intake value was used from that of staff members.

Age Group/Gender	Usual daily median energy intake kJ/day	Usual daily median energy (kJ) intake per meal (daily intake / 3)
19-24 y.o. Male	13,037 (3,104 kcal/day)	4346 (1,035 kcal/day)
19-24 y.o. Female	8,783 (2,091 kcal/day)	2928 (697 kcal/day)
Adult Male (staff)	11,631 (2,769 kcal/day)	3877 (923 kcal/day)
Adult Female (staff)	7701 (1,834 kcal.day)	2567 (611 kcal/day)

Table 4:5: Usual daily median energy and per meal intake for staff and students[86]

Using these kJ averages, a typical lunch can be generated to satisfy the four different dietary requirements. To do this various type of foods have been chosen and added up to be close to the

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[84] Ministry of Health, *Food and Nutrition Guidelines for Healthy Adults: A background paper*, (October 2003) http://www.moh.govt.nz/moh.nsf/0/07BC6DBE764FDABBCC256DDB006D9AB4/$File/foodandnutritionguidelines-adults.pdf [accessed 28 May 2009] p.9

[85] Ibid. p.9

[86] Ibid. p.19

recommended kJ/meal intake for lunch. A typical "kiwi" packed lunch diet was chosen which included products that were imported from overseas.

The EPA EF calculator (see Appendix 4) requires the data in $AUS for the totals for the different food categories.

To satisfy the different dietary requirements between genders, it is assumed that the ratio of female to male students in SoAD is 50/50 and the same assumption will be applied to the staff.

The results are shown below. For cost calculations, certain foods have been bought in bulk then apportioned into single servings, explaining the low cost of these items. The total kJ intake per meal was kept within 40kJ of the recommended energy intake.

RDI = 4346 kJ per meal	**Student Male**	**622 students**	
Type of food	***Total weight***	***Total cost***	***Total energy content***
Confectionary			
Chocolate bar x1 Chips x1	25g 45g	$0.67 / each $1.00 / pack	589 kJ 970 kJ
Fruit and Vegetables			
Apple x1	100g	$0.30 / each	200 kJ
Bakery Products			
Bread (Brown) x4 slices	126g	$0.40 / 4 slices	1134 kJ
Dairy Products			
Butter (spread)	5g	$0.04	152 kJ
Other food products			
Marmite	10g	$0.20	82 kJ
Meat products or Fish			
Tuna (Can)	136g (2 servings)	$3.08	966 kJ

Soft drinks / other			
Lipton Ice Tea	250mL	$0.67	292 kJ
TOTAL		**= $6.36 NZ**	**= 4386 kJ** (+40kJ above RDI)

Table 4:6: Average male student's lunch

RDI = 2928 kJ per meal	**Student Female**	**622 students**	
Type of food	***Total weight***	***Total cost***	***Total energy content***
Confectionary			
Chocolate bar x1 Chips x1	25g 45g	$0.67 / each $1.00 / pack	589 kJ 970 kJ
Fruit and Vegetables			
Apple x1	100g	$0.30 / each	200 kJ
Bakery Products			
Bread (White x2 slices	63g	$0.20 / 2 slices	630 kJ
Dairy Products			
Butter (spread)	5g	$0.04	152 kJ
Other food products			
Marmite	10g	$0.20	82 kJ
Soft drinks / other			
Lipton Ice Tea	250mL	$0.67	292 kJ
TOTAL		**= $3.08 NZ**	**=2916 kJ** (-12 kJ below RDI)

Table 4:7: Average female student's lunch

RDI = 3877 kJ per meal	Staff Male	50 staff	
Type of food	***Total weight***	***Total cost***	***Total energy content***
Confectionary			
Chocolate bar x1 Chips x1	25g 45g	$0.67 / each $1.00 / pack	589 kJ 970 kJ
Fruit and Vegetables			
Apple x1 Banana x1	100g 168g	$0.30 / each $0.55	200 kJ 571 kJ
Bakery Products			
Bread (White) x2 slices	63g	$0.20 / 2 slices	630 kJ
Dairy Products			
Butter (spread)	5g	$0.04	152 kJ
Meat products or Fish			
Tuna (Can)	68g (1 serving)	$1.54	483 kJ
Soft drinks / other			
Lipton Ice Tea	250mL	$0.67	292 kJ
TOTAL		**= $4.97 NZ**	**=3887 kJ** (+10kJ above RDI)

Table 4:8: Average male staff member's lunch

RDI = 2567 kJ per meal	Staff female	50 staff	
Type of food	***Total weight***	***Total cost***	***Total energy content***

Confectionary			
Chips x1	45g	$1.00 / pack	970 kJ
Fruit and Vegetables			
Apple x1 Banana x1	100g 168g	$0.30 / each $0.55	200 kJ 571 kJ
Bakery Products			
Bread (Brown x2 slices)	63g	$0.20 / 2 slices	567 kJ
Dairy Products			
Butter (spread)	5g	$0.04	152 kJ
Other food products			
Marmite	10g	$0.20	82 kJ
TOTAL		**= $2.29 NZ**	**=2542 kJ** (-25 kJ below RDI)

Table 4:9: Average female staff member's lunch

It is interesting to note that due to the lower energy requirement for females, tuna could only be incorporated into the male student and staff members' sandwiches therefore reducing the meat/fish intake for females and resulting in lower costs. Certain products with high energy content like a chocolate bar had to be replaced with lower energy intensive food such as a banana for female staff (see table 4:9) to be within the recommended energy intake. Also the brown bread had slightly lower energy content so this was used instead of white bread (the white bread will also lack necessary dietary fibre).
The majority of the food was produced within NZ (mainly Auckland), but the tuna came from Thailand, bananas from Philippines and Lipton Ice Tea from Australia.
The price of these selected food products was sourced from the local *New World* Supermarket in Te Aro, Wellington in June 2009.

4.3 Results and analysis from EPA EF calculator

The information required for the EPA, EF calculator [87] is listed in appendix 1. Data for 2007 for SoAD consumption was used. Since Australia and New Zealand have a similar pricing for many products and services with respect to each country's own currency, NZ dollars will be used directly as if they were Australian dollars for information required in dollars.

Results

Using the EPA EF Calculator, the total annual Ecological Footprint for Victoria University School of Architecture and Design is: **2,026 global hectares**. This is equivalent to 2,628 football fields. The average Ecological Footprint per person in SoAD is: **1.51 global hectares**. This figure is within the global bio-capacity. However this footprint is only for the operation of the school (it excludes activities outside the school) and therefore emphasises the need to reduce the school's operational activities.

Total Footprint Areas by Impact Activity (gha)

ACTIVITY	***Energy Land***	***Cropping Land***	***Grazing Land***	***Forest Land***	**Occupied Land**	**TOTAL**
Food	541.65	119.33	618.88	2.114 3	40.371	**1322.5**
Energy & Water	240.62	0	0	0	0.3680	**241.01**
Goods	98.210	2.8668	3.8748	3.669	125.90	**192.82**
Building	126.04	2.2617	6.5472	0.759	24.232	**159.85**
Travel to & from school	29.482	0	0	0	2.0593	**31.539**

[87] State Government of Victoria, EPA Victoria, Ecological Footprint Measuring our impact on the environment, *School Calculator,* <http://www.epa.vic.gov.au/ecologicalfootprint/calculators/school/schoolDetails.asp> [accessed 03 June 2009]

Travel Excursions	28.473	0	0	0	0.2631	**28.736**
Recycling & Waste	8.2936	0	0	-10.21	2.1444	**0.2167**
Travel Fleet	0.4079	0.0049	0.0152	0.001	0.0695	**0.4985**

Table 4:10: Rank of highest total footprint areas by impact activity to lowest

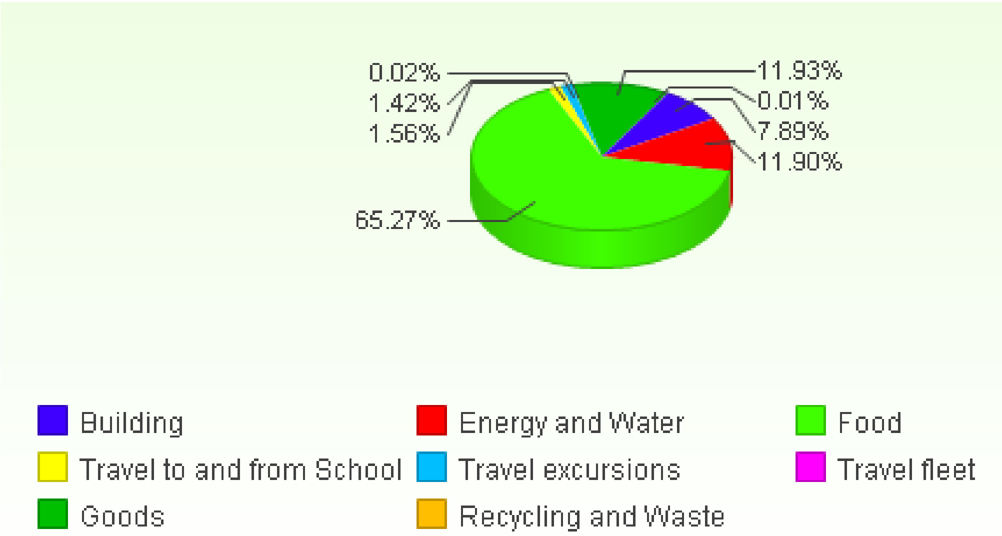

Figure 4:2: Percentage distribution of different activities

From the results generated by the EPA EF Calculator it seems very clear that food is the single most significant factor that determines the ecological footprint of the school. However, this was not even considered for the carboNZero calculation. Other factors such as goods, energy and water are the next biggest contributors.

Each activity is looked at more closely below.

Building

Building	Ecological footprint	Percentage
Build & maintenance	159.15 gha	99.56%

Occupation of site	0.7033 gha	0.44%

Table 4:11: Building related footprints

This indicates the importance of maintaining the building so it will have a long life.

Utilities

Utilities	Ecological footprint	Percentage
Electricity use per year	589.72	57.85%
Supply of 'green' electricity consumption	-389.2	38.18%
Gas use per year	40.266	3.95%
Water use during the year	0.2422	0.02%

Table 4:12: Utilities related footprints

The result puts the focus on electricity use despite purchasing carbon zero energy from Meridian. The electricity figures should be regarded with caution because of Australia's different generating mix compared with NZ. Surprisingly, gas consumption is insignificant in the footprint compared to the carboNZero data, which raises a question about the Australian conditions for gas usage. However water use is insignificant for both calculations (carboNZero and EPA EF calculations) even though Australia has problems with water shortages.

Food & Drink

Food & drink	Ecological footprint
Meat	1051.6
Dairy	3.5246
Fruit & vegetables	27.735
Oils & fats	0
Flour & cereal foods	0

Bakery products	31.170
Confectionery	114.31
Other food products	41.127
Soft drinks & other beverages	50.210
Beer for catering	1.1661
Wine & spirits for catering	0.3205
Soft drinks & other beverages for catering	0.4237
External catering	0.8788

Table 4:13: Food and drink footprint

The analysis above clearly indicates the impact of eating meat (in this case fish) as part of a regular meal. Highly processed foods, such as confectionary, come next in rank. Even though tuna was only served to the males, it still resulted in a huge impact on the overall footprint area.

Travel to and from school

Travel to and from school	Ecological footprint	Percentage
Car	9.5744	30.36%
School Bus	0	0%
Public Transport	21.964	69.64%
Walking/Cycling	0	0%

Table 4:14: Commute to work footprint

The results indicate that public transport is used predominantly.

Travel excursions

Travel excursions	Ecological footprint	Percentage
Car	0.9653	3.36%
Train (long distance)	0	0
Train (short distance)	0	0

Bus	0.0101	0.04%
Boat	0	0
Domestic air travel	1.6988	5.91%
International air travel	26.062	90.69%
Walk/Ride	0	0

Table 4:15: Travel Excursion footprint

Surprisingly air travel is less than 1% of the overall footprint, which is very different from the carboNZero calculations. This is due to the inclusion of food and commuting to work (not considered in the carboNZero calculations due to unreliable data) which greatly affects the overall ranking. International air travel was the greatest factor of impact.

Travel fleet

Travel fleet	Ecological footprint	Percentage
Manufacturing	0.373	74.82%
Total Fuel Bill per year	0.1255	25.18%

Table 4:16: Travel Fleet footprint

This factor is so small it does not seem to impact on the overall footprint at all.

Goods

Goods	Ecological footprint	Percentage
Copy Paper	13.150	5.44%
External Publications	3.645	1.51%
Subscriptions	82.467	34.11%
Journals	81.681	33.79%

Computers and Printers	59.718	24.70%
Stationary for Staff	0.5467	0.23%
Stationary for Students	0.5467	0.23%

Table 4:17: Goods footprint

The goods make 12% of the overall footprint. Journals, subscriptions and computers and printers make the biggest contribution. It indicates the need for better record keeping of goods purchased and thinking about the impact of journals and subscriptions.

Recycling and Waste

Recycling and waste	Ecological footprint	Percentage
Recycling Paper	-13.16	49.58%
Recycling Aluminium	0	0
Recycling Mingled Glass/Plastic/Steel	0	0
Organic Waste	0	0
General Waste	13.381	50.42%

Table 4:18: Recycling and waste footprint

Again, waste becomes an insignificant factor in EF calculations compared to the carboNZero calculations, making up less than 1% of the overall footprint.

4.4 Conclusion

The importance of diet when it comes to determining the overall ecological footprint should not be overlooked. The exclusion of food in the carboNZero calculation could have altered the percentage distribution. This gives a strong argument to consider food as part of the factors that need to be reduced. Goods purchased were also excluded from the carboNZero calculations although EF analysis shows a recognisable impact. Exclusion of food and goods as part of emission factors questions the validity of the 2007 carboNZero calculations and SoAD's carbon neutral status at that time.

However, due to the limitations presented by this EF calculator, there are some questions about the validity of the results and it should therefore be used as a general guideline only and not as a reason to ignore factors like waste reduction. Food was a hypothetical calculation and therefore requires a real survey of the students and staff in SoAD for a more accurate assessment.

5.0 Case studies of carbon neutral and sustainable campuses

The previous chapters looking at SoAD's business-as-usual (BAU) approach to achieving carbon neutrality by direct reliance on carbon offsets lead to the question of whether this is a common practice for universities around the globe, and what other universities have done to achieve an emissions reduction. It is important to understand the relative performance of SoAD when compared to policies and decisions of other schools. This will ensure that carbon neutrality is carried out in a progressive and non-illusory manner.

The findings of this chapter also analyse the differences and similarities between two current approaches to sustainability in universities (the carbon neutral campus and the sustainable campus) as they both try to achieve a low-carbon and sustainable future. There is further examination of the extent to which these approaches affect the behaviour of the users and the built environment. Looking at these case studies, it is possible to analyse different solutions that could be implemented in SoAD.

5.1 Carbon Neutral campus

It is becoming popular for universities all around the world to strive for sustainability. This has become a powerful marketing tool with organizations dedicated to certifying and verifying their sustainable status or intentions. For example in the USA, *over 500 universities and colleges have signed a pledge to be carbon neutral. In the UK, several universities have signed up to a government funded independent company called 'The Carbon Trust' that helps organizations and institutions reduce their climate impact*.[88]

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[88] Kodikara, Tushara, Salient, The student magazine of Victoria University of Wellington, *Why Victoria University should become carbon neutral,* 12 May 2008, <http://www.salient.org.nz/features/why-victoria-university-should-become-carbon-neutral> [accessed 09 May 2009]

GreenReportCard.org is the first website *to provide in-depth sustainability profiles for hundreds of colleges in all 50 U.S. states and in Canada. The information is based on extensive research conducted for the College Sustainability Report Card*[89] *which stated that two out of three colleges improved their efforts at going 'green.'Here are some numbers from the 2009 report:*

- *70% buy food from local farms*
- *64% serve fair trade coffee*
- *59% have high-performance green building standards for new buildings*
- *45% have cut carbon emissions*
- *42% use hybrid or electric vehicles, and*
- *37% buy renewable energy - with 30% producing some of their own, using wind or solar generators.*[90]

Table 5:1 below lists the universities in the United States, Canada and United Kingdom that are aiming to be carbon neutral in the future and that have already achieved carbon neutral status.

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[89] Sustainable Endowments Institute, The College Sustainability Report Card, <http://www.greenreportcard.org/about> [accessed 12 June 2009]
[90] Ford, Carin, Higher Ed Morning, "Green report card: How did your college do?" May 16 2009, <http://www.higheredmorning.com/green-report-card-how-did-your-college-do> [accessed 04 June 2009]

Name of university & location	Carbon Neutral Status	What are they doing? Building VS Behaviour	What are they aiming for? Goals & Targets	Offsets Y/N?
College of Atlantic, Maine USA[91] [92] [93]	19/12/2007 1st university in US to achieve carbon neutral status	• Obtaining all electricity from low impact hydroelectric generation therefore reducing GHG emissions by 22% • Comprehensive energy audit • Extensive energy efficiency retrofit in all buildings • Flexible work plans for staff to work at home • Promote carpooling and biking	• Reduce 2010 per student carbon emissions by 50% from 1990 emissions • Commit to 100 percent reliance on renewable energy sources for all uses (not just electricity) by 2015	Yes Offset for 2,488 tons of carbon emissions from 01/10/06 to 21/12/07 The Climate Trust Project: Optimization of traffic signals and traffic flow to reduce time cars spend idling at traffic lights.

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[91] College of Atlantic, Carbon Net Zero Timeline, <http://www.coa.edu/html/carbonnetzerotimeline.htm> [accessed 12 June 2009]
[92] College of Atlantic, “Net zero FAQ,” <http://www.coa.edu/html/netzerofaq.htm> [accessed 12 June 2009]
[93] Green Progress, *College of the Atlantic Becomes First Carbon-Neutral Campus,* <http://www.greenprogress.com/environment_article.php?id=1451> [accessed, 12 June 2009]

		• Replace incandescent light bulbs.		
Maharishi University of Management Fairfield, Iowa, USA[94]	Aiming for carbon neutrality in the future	• Retrofitting the whole campus with geothermal technology for heating and cooling buildings • Electricity for geothermal heat pumps will be provided by solar panels and wind turbines • Hire a sustainability co-ordinator • Implement daylighting technologies • High performance fixtures and appliances • Solar hot water • Reconstruct native prairie on campus for better water retention in	• 44% savings in energy costs through the geothermal system • Signed climate agreement which requires completion of an emissions inventory within 2 years and sets target date for becoming carbon neutral, and taking immediate steps to reduce GHG emissions from short term actions. Including sustainability in the curriculum is also required, together with making the action plan,	No

[94] Maharishi University of Management, *University Sustainability Initiative, Geothermal Technology to foster Carbon-Neutral Campus,* <https://www.mum.edu/news/geothermal.html> [accessed, 12 June 2009]

		the soil • Vermicomposting project • Self sufficient food production	inventory and progress report publicly available	
Southern New Hampshire University New England, USA[95][96]	Carbon neutral within 2 years	• University will receive 17,500 renewable energy credits per year which translates into 13,125 t of CO_2 per year, while the remaining credits will be used to invest in carbon offsetting projects that have not yet been determined • Planning to build 2 new LEED certified buildings • President vehicle is hybrid • Investigating the use of geothermal	• Signed the American College & University Presidents Climate Change Commitment which entails institutions pursue climate neutrality. Initiating detailed inventory of all GHG emissions, setting goals/targets, making sustainability part of the curriculum, tracking progress, and establishing policies to offset all air travel. • LEED silver rating for all new	Yes Renewable energy hedge with PPM energy which guarantees fixed price of renewable energy for the next 15 years. Remaining credits will be used to offset the 11,400t of CO_2 the university is projected to use per year

[95] South New Hampshire University Communications Office, *SNHU Goes Carbon-Neutral,* 19 May 2007, <http://jweinsteinlaw.com/pdfs/SNHU.pdf> [accessed 12 June 2009]
[96] South New Hampshire University Communications Office, *SNHU Goes Carbon-Neutral,* 19 May 2007, <http://www.snhu.edu/6886.asp> [accessed 12 June 2009]

		energy • Give up bottled water • Free bike rental program • Recycling paper, cans, and glass	buildings • Purchase Energy Star appliances • Make inventory available to the public • Purchase at least 15% of electricity from renewables • Waste minimization plan.	
Middlebury College Vermont USA[97] [98] [99]	Carboon Neutral by 2016	• Biomass plant, which will be powered by wood chips to meet 50% of heating, 20% of electricity and reduce carbon emissions by 40%.	• Staff and students to reduce the college's carbon emissions to 8% below 1990 levels by 2012 • Institutions to reduce GHG to	Yes • Forest sequestration Offsets • Offset purchased for air flights for students

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[97] Middlebury College, "Carbon Neutrality at Middlebury College:" *A Compilation of Potential Objectives and Strategies to Minimize Campus Climate Impact*, 19 June 2003, <http://community.middlebury.edu/~cneutral/es010_report.pdf> [accessed 13 June 2009]
[98] Middlebury College, <http://www.middlebury.edu/about/pubaff/news_releases/2007/pubaff_633141333185905594.htm> [accessed 13 June 2009]
[99] New England Comcast Network (NECN), <http://www.necn.com/Boston/SciTech/2009/03/12/VT-college-to-be-carbon/1236890613.html> [accessed 13 June 2009]

		• Energy-saving contests among the residence halls • A campaign to reduce the average temperature of buildings on campus by 2 degrees • Policy to increase the use of public transportation to and from campus • Operational adjustments such as energy efficient lighting and facility upgrades	10% below 1990 levels by 2012 • Signed the American College and University Presidents Climate Change Commitment which entails institutions to pursue climate neutrality	on study abroad program
St Andrew's University UK[100]	Carbon Neutral for energy by 2012	• Water saving schemes to reduce water use by 20% • All new building and refurbishment projects to achieve BREEAM excellent standard or equivalent	• Achieve and maintain zero waste to landfill from 2010 onwards • Reduce single occupancy car use to less than 45% by 2010	No Will be carbon neutral with energy use and renewable energy generation planned to

[100] People and Planet, "St Andrews - the First 'Carbon Neutral' University?" <http://peopleandplanet.org/navid2009> [accessed 13 June 2009]

		• Bike to work scheme for staff • Carrying out a behavioural change study into energy saving incentives • Establishing ongoing management offsetting projects that have not yet been decided and managing carbon impacts on an ongoing basis	• Develop solutions that reduce travel and transport impacts • Solar panels and a range of mini wind turbines on the roofs of university buildings • A biomass boiler to burn woodchips and elephant grass to generate electricity • Wind turbines at the university's main campus and off site	meet demand
Butte College[101][102][103][104]	Carbon Neutral by	• Solar PVs producing electricity on site and in a 4 acre field totalling 2.7 million	• Signed the The American	No

[101] CleanTech, "Butte College Is Now the Largest Solar Campus in California," <http://www.azocleantech.com/Details.asp?newsID=4834> [accessed 15 June 2009]
[102] Mechanical Web directory, "Butte College Now the Largest Solar Campus in California", 8 March, 2009 <http://www.mechdir.com/press/catalog/1273/index.html> [accessed 15 June 2009]
[103] PR Newswire, "Butte College Now the Largest Solar Campus in California," <http://news.prnewswire.com/ViewContent.aspx?ACCT=109&STORY=/www/story/03-04-2009/0004983212&EDATE> [accessed 15 June 2009]

California, USA	2015	kWh/yr • More than 25% of total energy use is provided by solar energy • Carpooling service with over 300 parking preference carpool spaces • Several existing buildings are LEED certified using the existing building criteria • "Green classes" in credited sustainability courses and workshops • Provides 1200 students with own bus transportation (rural campus) • Annual College operations achieve 75%-93% waste stream recycled • Napkins made from recycled paper • Paper plates made from sugar cane -	College & University Presidents Climate Commitment. This is a pledge to take a leadership role in addressing global warming. College agreed to develop a long range plan that will reduce and neutralize GHG emissions on all campuses • Covered parking with solar panels • Aim to meet 50% of total energy use with solar by 2009 • Planning to add hybrids to the list of vehicles allowed to park	

[104] The Free Library by Farlex, "Butte College Now Largest Solar Campus in California," <http://www.thefreelibrary.com/BUTTE+COLLEGE+NOW+LARGEST+SOLAR+CAMPUS+IN+CALIFORNIA.-a0196036624> [accessed 15 June 2009]

		100% compostable • Food Services composting project • Bookstore offers selected titles through e-books and electronic format • Student based sustainability group and clubs	in preferred parking areas	
Johns Hopkins University Homewood campus[105]	Fully carbon neutral by 2015	• Reduce carbon-intensive electricity use by investing in renewable electricity • Pursue on-campus opportunities to install renewable energy sources to generate electricity. • Support local renewable electricity producers by engaging in long-term purchase of power contracts and	• Decrease electricity consumption 20% by 2015. • Decrease non renewable energy and fossil fuel consumption by a minimum of 5% per year, or 40% total by 2015	Yes Offset by supporting renewable electricity resources in the local community

[105] Johns Hopkins University, *Responsible Energy Policy,* <http://www.jhu.edu/heat/Documents/Responsible%20Energy%20Policy%202015.pdf> [accessed 15 June 2009]

		energy hedge contracts • Encourage sustainable transport		
Morken Center for Learning and Technology at Pacific Lutheran University (PLU)[106][107][108][109] Washington, USA	Carbon Neutral by 2020	• This building uses 45% less energy than the code, with help from natural daylighting, high efficiency artificial lighting, and a closed loop geothermal heating and cooling system • Gold level certification by LEED • 2-year commitment to purchase energy from renewable sources, and nearly 20% of the university's energy is from renewables	• Build all buildings to LEED silver or better certification • Recycle 80% of campus wastes by 2010 • Reduce water consumption by 20% by 2011 • Reduce energy consumption by 25% by 2011 • Signed the American College & University Presidents Climate Change Commitment	Does not state

[106] Better Bricks, *Carbon Neutral and Net Zero, The Case for Net Zero Energy Buildings,* **<**http://www.betterbricks.com/DetailPage.aspx?Id=947> [accessed 16 June 2009]
[107] Pacific Lutheran University, *UC Morken powered by wind turbines*, 11 January 2008, <http://news.plu.edu/node/2289> [accessed 16 June 2009]
[108] Pacific Lutheran University, *PLU leads way to green future*, 05 January 2007, <http://news.plu.edu/node/1434> [accessed 16 June 2009]
[109] Pacific Lutheran University, *Sustainability at PLU*, <http://www.plu.edu/~sustain/> [accessed 16 June 2009]

		• Nearly 50% of the faculty and staff opted to boost recycling rate		
Cornell University[110][111][112] Ithaca, USA	Time frame for carbon neutrality has yet to be set	• Carshare and Vanpool services • All incoming students have option of a free bus pass • Solar panels installed to provide lighting to bus shelters and clock tower • Green building policy that requires all new construction and renovations over $5 million to attain LEED Silver rating and be 30%	• Combined Heat-and-Power Plant to be completed in 2010 to provide 80% of the electricity needed for campus. By switching fuel sources from coal to natural gas, and producing heat and electricity together, the facility will reduce Cornell's total carbon emissions by 20%	Yes Reaching thousands of homeowners through programs that can help families turn their homes into efficient, healthy, green energy producers. Supporting wind turbines and solar panels that power buildings and lab

[110] Cornell University, Cornell Sustainable Campus, "Our Strategy," <http://www.sustainablecampus.cornell.edu/cap/ourstrategy.cfm#carbonoffsets> [accessed 16 June 2009]

[111], The sustainable Campus, *Colleges & Universities - Transitioning to a More Sustainable Campus*, <http://www.sustainablecampus.org/universities.html> [accessed 16 June 2009]

[112] Cornell University, Cornell Sustainable Campus, "Climate Action Plan," <http://www.sustainablecampus.cornell.edu/cap/climateactionplan.cfm> [accessed 16 June 2009]

		more energy efficient than national ASHRAE standards • Replacement and upgrade of the central campus chilled water system with a more environmentally sound design that conserves energy and utilizes cold waters of a nearby lake, a renewable resource	• Pledging support for the American College & University Presidents Climate Commitment • By 2010 Cornell aims to drop well below their 1990 carbon emission levels	instruments that help students and researchers monitor GHG emissions

Table 5:1: Universities aiming for Carbon Neutrality - 9 case studies

It is interesting to note that these *carbon neutral universities* have similar aims and plans. There is an importance placed on comprehensive monitoring and auditing of operational activities to ensure accuracy of data which for buying offsets or ensuring that carbon emissions targets are met. Noticeably, the use of renewable energy is popular either as a form of carbon offset or to provide electricity for the university. This purchasing of green energy is particularly useful for marketing each university's support for carbon neutrality as it i supports the producers of renewable energy and strengthens the market for such technology. However the preoccupation with energy reduction is also clear; this saves the university money and helps to promote low carbon intentions. Standard measures to increase energy efficiency are similar throughout the various universities, such as phasing out incandescent lighting, maximising BMS use, purchasing energy efficient appliances and equipment and maximising daylighting. Low cost procedures are implemented first, such as simple behavioural changes like encouraging staff and students to turn off unused appliances, and encouraging car pooling, cycling and working from home. How these schemes are implemented is not always elaborated. For example Southern New Hampshire University provides free bicycle hire which can be an incentive to lower car use, but whether this is true has not been stated. Nevertheless there are incentives for non-measurable reduction policies such as establishing student groups to help the campus become more sustainable.

The big investments are for the long term and more consideration is given to these. Costly schemes such as building high level LEED or BREEAM certified buildings or installing on-site renewable energy generation form some of the ways in which universities are attempting to lower their carbon footprints. However this only relates to buildings for the future and there is also an emphasis in retrofitting existing buildings to be more energy efficient.

The emphasis on energy reduction tends to ignore the importance of transport and waste issues. Because these factors are seen as being outside the university's control, little has been done to reduce their associated GHG emissions. Also the difficulty associated with keeping accurate records of aspects such as staff and student commuting, the amount of recyclable waste and waste to landfill and air travel by staff may hinder emissions reduction progress. However, the carbon neutral focussed universities in general have a policy of showcasing GHG inventory plans of all emission sources and progress to the public. Universities such as Cornell, Southern New Hampshire and Butte College have signed a pledge with the American College and University Presidents Climate Commitment (ACUPCC) which commits each campus to taking steps to move towards climate neutrality. "*The pledge seeks to address the university's impact on the climate by reducing and offsetting greenhouse gas emissions in campus operations, and working with the faculty to integrate sustainability into the curriculum and research*."[113] ACUPCC requires the university to send in a detailed analysis of its annual greenhouse gas inventory and this and research reports from all the schools are to be displayed publicly online.[114]

Buying carbon credits seems to be the next choice to offset unavoidable emissions after energy consumption reduction. Various types of offsetting projects are chosen from within each university's local area, ranging from forestation projects to supporting renewable technology. Some universities are more dependent on offsets to achieve their carbon neutrality, like SoAD, while others resort to it as the inevitable final part of reaching the goal.

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[113] Presidents' Climate Commitment, American College & University Presidents' Climate Commitment, <http://www.presidentsclimatecommitment.org/html/commitment.php> [accessed 05 June 2009]
[114] Ibid.

The time period for achieving carbon neutral status differs between universities, however most universities aim to achieve it before 2020. The initial carbon emission reduction goals of universities also all differ, ranging from 20% to 50% and even dependence on offsets varies as some universities have not specified how they will deal with unavoidable emissions. Many universities state they will achieve carbon neutrality only in the area of energy.

5.2 Sustainable campus and comparison between the two campuses

The definition of a sustainable campus is vaguer than a carbon neutral one because issues of sustainability do not necessarily deal with quantifiable performance. Aspects of being a sustainable campus can include enhancing the well being of people, through such things as improving air quality and thermal comfort, to restoring and protecting ecological systems, to buying fair trade products. As defined by the International Institute for Sustainable Development, school and campus policies for sustainable development should *"aim to create a healthy, ecological, economic and socially responsible living and learning environment for all students and staff, and to make the school or campus a model of best practice for the community where it is located."*[115]

Table 5:2 is a list of universities that are committed to transforming their campuses to be sustainable by adhering to the sustainable principles stated above.

[115] International Institute for Sustainable Development, "Sustainable School and Campus Policies", <http://www.iisd.org/leaders/policybank/> [accessed 13 June 2009]

Name of university & location	Rating schemes?	What are they doing? Building VS Behaviour	What are they aiming for? Goals & Targets
University of California (UC), Berkeley, USA[116]	• LEED silver for new buildings • Existing building improvement • LEED credits for water	• Conduct GHG inventory, report emissions, energy plan • Initiate Energy Star Purchasing Standards • Track paper purchasing • Plant drought tolerant plants, increase native plantation • Perform campus wide water audit • Reduce the impervious area • Incorporate life cycle analysis into analysis of buildings/create LCA assessment tool (Taken into account when buying building materials)	• Conduct lighting audit and retrofits • Improve energy management systems BMS • Develop a clean energy strategic implementation plan (10 MW goal) • Real time energy feedback • Install water efficient fixtures in existing building • Expand composting, improve compost collection • Post occupancy studies • Pilot greywater project in a new or

[116] University of California Berkeley, "Sustainability", <http://sustainability.berkeley.edu/assessment.html> [accessed 15 June 2009]

		• Establish a recycled paper quota for purchase • Purchase alternative fuel vehicles in compliance with Energy Policy Act • Conversion of campus vehicles to run on biodiesel • Provide at least one local produce and organic option in dining commons / campus restaurants • Create incentives to promote public transit or cleaner fuel consumption (parking is cheaper for people who carpool). Pursue introduction of rideshare projects • Become a certified organic processor/retailer • Increase the use of biodegradable packaging • Use sustainable methods in exotic weeds	substantially renovated building • Zero waste buildings [Policy to divert 50% of waste, but regularly achieving over 75%] • Transition to paperless and electronic procedures • Establish organized recycling standards for major events • UC will consider the total cost of ownership including purchase, operating, maintenance and disposal in purchasing • Prioritize the purchase of reusable and recyclable materials with minimal packaging • Increase the % of ZEV vehicles by 50%

		abatement • List sustainability courses for students	
University of British Columbia (UBC), Canada[117]	Evaluate mechanisms to certify new institutional buildings under LEED	• ECOTrek is a program involved in rebuilding and retrofitting the infrastructure of nearly 300 core buildings which makes the emissions 25% below 2000 levels on a square metre basis • Construction of geo-exchange heating and cooling system using groundwater as an energy source • As of 2006, U-Pass program has reduced overall automobile levels by 22% below 1997 levels despite a 28% growth in population since then • Canada's first university in-vessel composter	• Phase 1 of UBC aims to renovate ten buildings between 2005-2010, extending the life of more than 36,000m2 of buildings by 40 years or longer • UBC's Food Services department is continually evaluating and reviewing its criteria for sourcing food that is local, sustainably harvested, raised humanely, and features environmentally preferable packaging • The target is to transform UBC from a car dependent commuter campus into a more compact and intensified, environmentally

[117] University of British Columbia, "Sustainability Office", <http://www.sustain.ubc.ca/> [accessed 15 June 2009]

		• No longer uses any pesticides for cosmetic purposes on the campus grounds. Employs more seasonal gardeners for weeding, and is trying out a product that uses steam to control weeds • Use of certified green cleaning products • Purchase of coffee which is 100% organic, shade grown and fair trade. Certified and purchasing policies implemented for seven seafood categories • Over 50% of households are connected to the campus with 68% of the University Town households having one or more members who work or study on campus • Increased student engagement in sustainability is reflected in students signing the Sustainability Pledge, obliging them to	friendly, live-work community with better amenities for students, faculty, staff and residents • Make new institutional buildings 25% more efficient (on average) than the Model National Energy Code • Develop strategies to increase government and granting agency's funding for research in sustainability • Convert at least 10% of UBC vehicle fleet to super ultra low emission vehicle standard by 2010 • Divert 55% of annual operational waste from the landfill by 2010 • Reduce water consumption in institutional and ancillary buildings by 40% from year 2000 levels

		use the knowledge they gain at UBC to improve the sustainability of the communities in which they live, work and learn • Social, Ecological, Economic Development Studies, brings together students, faculty, and staff to address sustainability issues • More than 400 courses related to sustainability across its twelve faculties and over 400 research projects addressing some aspect of sustainability	• Reduce non-renewable energy consumption in institutional buildings by 30% from 2000 levels • Reduce volume of paper purchased per capita by 20% from 2000 by 2010
University of Toronto, Canada[118] [119] [120]	LEED silver certification in the library and information	• U-Pass bus card that allows unlimited ridership for all full-time and graduate students • Online carpool rideshare program allocated parking	

118 University of Toronto <http://www.utm.utoronto.ca/index.php?id=1553> [accessed 15 June 2009]
119 University of Toronto <http://eratos.erin.utoronto.ca/conway/ecofootprint/CSAFmainpage.html> [accessed 15 June 2009]
120 University of Toronto <http://www.utm.utoronto.ca/index.php?id=green> [accessed 15 June 2009]

	complex	• On campus there is a dedicated bike/pedestrian road, ample bike racks, free bike hire for 24 hours, free bicycle repair facility, and map showing closest bike shops • Hybrid/Efficient Vehicle Parking Rebate. 50% discount • Naturalization projects on the campus by planting trees, flowers, shrubs and grass • Created a new position of Environmental Affairs Officer, whose main goals are to improve transportation options, waste management practices, "green" purchasing practices and energy efficiency, and to help the students become more eco-conscious and environmentally aware • Completed an Ecological Footprint, sustainability audit and energy/GHG inventory for the campus • Photovoltaic solar array on the exterior wall of the South Building	

		• Visitor's cart retrofitted with two solar panel modules to run entirely on solar power to charge the batteries • Various organisation dedicated to improving the 'greening' of campus and the community • Solid Oxide Fuel Cell facility is the installation of solid oxide fuel cells in the student residences to provide electricity, hot water, and space heating • Large volume stormwater management pond to be installed on the campus to retain and settle all campus storm runoff	
University of Canterbury[121][122], Christchurch, NZ	Greenstar NZ Certification of new buildings	• There is a sustainability community made up of students and staff who share an interest in sustainability issues • A carpooling scheme for staff and students that rewards carpoolers with priority parking around	Adhering to green building design principles in their new buildings. • Long life span (100 years +) • Utilise thermal mass

121 University of Canterbury, *Recycling and waste minimisation*, <http://www.sustain.canterbury.ac.nz/waste/index.shtml> [accessed 25 June 2009]
122 University of Canterbury, *Sustainable Building Design*, <http://www.sustain.canterbury.ac.nz/consenergy/buildings.shtml#biol> [accessed 25 June 2009]

		campus[123] • A calculator compare the cost and time differences of various modes of transport for students and staff • Many sustainability-related academic courses available in all disciplines with many academic staff involved in sustainability research • Community Garden using organic gardening methods provides free food for students suffering financial hardship and, increases interaction amongst staff and students. It hosts educational workshops on self-sufficiency, home composting, and organic growing. It provides a means for composting some of the University's landscaping and food waste.[124] • Annual competition and workshop programme	• Double glazing (lowE, argon filled) to all exterior windows • Increase insulation in walls and ceiling • Exterior solar shading to the North-East facing windows to reduce the direct sunlight entering the building • Energy efficient light fittings • Using BMS (Building Management System) on various HVAC systems for optimum use • Roof future proofed for photovoltaics • Efficient water fixtures • Rainwater harvesting, greywater reuse,

[123] University of Canterbury, *Transport*, <http://www.sustain.canterbury.ac.nz/transport/index.shtml> [accessed 25 June 2009]

[124] University of Canterbury, *Okeover Community Garden*, <http://www.sustain.canterbury.ac.nz/comm_garden/index.shtml> [accessed 25 June 2009]

		running throughout to helping students save money and become more eco-friendly in their living accommodation • Cafés in campus are currently trialling food containers made from recycled materials. They offer a discount for customers who bring their own cups. Staff encouraged to rinse dishes in cold water. Selling only fair trade, organic coffee and tea. Vegetarian options available with low levels of fat and chemical components. • A new building for the New Zealand ICT Innovation Institute (NZi3) has recently been completed with a five-star New Zealand Green Building Council rating, the first for an educational building in New Zealand.	• Use of acrylic/waterbased paints to surfaces • Low formaldehyde emitting MDF for joinery units and use of low VOC finishes • Rubber flooring to research laboratories to reduce future maintenance • Carpet tiles to reduce wastage and allow for partial replacement without the need for full replacement • Maximise daylighting • Provide interpretative and educational features in the atrium that explain the sustainability principles of the building

Table 5:2: Universities aiming for Sustainability - 4 case studies

It is clear that more universities are striving to be a sustainable campus than a carbon neutral campus, perhaps due to the fact that this does not require a measurable outcome. Each university can have its own set of goals and targets to follow. This means that these goals can either make a significant contribution to reducing environmental impact or very little. Since the targets that are set are not necessarily measured in carbon or other equivalent measure, there is no way of knowing how the campus is performing. Therefore it is also harder to make comparisons between universities as they each have differing outcomes. There is no mention of purchasing carbon offsets to become a sustainable campus, as overall performance is not necessarily based on GHG measures.
Energy reduction is not the main issue with sustainable campuses. However, this goal seems to achieve more than the carbon neutral campuses as it encompasses broader issues and gives almost equal importance to other factors such as transport, waste, food, pollution control, student community involvement and increasing bio diversity. For example, more focus is given to reducing water consumption than for a campus aiming to be carbon neutral. Improvements such as better stormwater management, purchasing fair trade coffee, banning pesticides, use of green cleaning products, encouraging students to sign the sustainability pledge (to ensure behavioural change), decreasing impervious paving, xeriscaping, planting trees within the campus, providing locally produced organic food and avoid purchasing unsustainable fish in campus restaurants are all strategies not explored in the carbon neutral campus. There also seems to be an emphasis on building new LEED certified buildings (or equivalent rating schemes) or retrofitting existing buildings to high LEED standards.

Preoccupation with behavioural change in the sustainable campus is clear and some reports have calculated ecological footprint, which deals with the campus's consumption with respect to land use. This method of calculating the consumption considers transport, food, waste and lifestyle options and so coincides with the intention of being a sustainable campus. The importance of education and community involvement is more evident, strongly encouraged, and promoted in the sustainable campus. It seems as if students are taking responsibility into their own hands by signing sustainability pledges and being actively involved in a wide variety of volunteering programs and groups.

Despite the importance of monitoring, reporting emissions and making an energy plan and GHG inventory, these aspects are not as extensive as in the carbon neutral campuses. The sustainable campus goals are more qualitative in approach, being addressed in words rather than in numerical, quantitative performance goals. However, this leaves the problem of knowing when a sustainable campus is truly reducing environmental impact.

5.3 Conclusion

Looking at these case studies and their approach, it is possible to analyse different solutions for reducing GHG emissions which can also be considered for SoAD's own GHG reduction plan to move it forward from its BAU stance.

There seems to be no general consensus on the exact date or reduction target that a carbon neutral campus needs to set. It is difficult to state whether any of these campuses are actually carbon neutral and only a very few universities have claimed this status. Essentially, all campuses should be able to be carbon neutral if they rely heavily on carbon offsets like SoAD, but the expense of purchasing carbon offsets does not seem to be financially attractive, especially without achieving savings to first reduce carbon emissions. The role of offsets tends to play a more important role in a carbon neutral campus for cancelling any remaining emissions. The sustainable campus universities rely on LEED/BREEAM equivalent certified rating schemes to judge the specific performance of their buildings. However, these are only certifications of design intentions and are never a measure of the performance of the building in use.

The findings show that the preoccupation of a carbon neutral campus with its operational impacts means it tends to ignore the promotion of behavioural change. On the other hand, these campuses are more inclined to implement energy efficiency methods first. Sustainable campuses are more focussed on behavioural aspects that reduce environmental impact. However the question remains, what happens when all these simple schemes are met or become the norm? What then is the next step?

There are more similarities than differences between these two approaches to campuses and their goals do coincide with each other. The difference is the emphasis placed on certain aspects.

A sustainable campus still aims to be carbon neutral and a carbon neutral campus tries to incorporate sustainability principles into emissions reduction plans. So essentially they are the all trying to do the same thing and be leaders in sustainability by minimising impact, maximising efficiency, and making sure there is a future for the next generation by addressing the critical problems of today.

It may be a good idea to recommend a convergence of these two models for universities striving to be more sustainable in the future.

6.0 Reduction Targets for Energy, Transport and Waste

From the carboNZero 2007 audit of SoAD it was clear that electricity was the highest emitter despite the fact that it was excluded from the emissions to be offset. The second highest emission source was gas use, then waste to landfill and then flights (domestic and international). The ecological footprint analysis showed the impact of food and goods purchased for SoAD. However this will not be included in this thesis as there is no accurate data on which to base a carboNZero calculation. What the study did indicate is that f food and goods purchased should be incorporated in future footprint calculations for SoAD,. However the commute to work emissions will be incorporated into the carboNZero audit as the sample data was found to be sufficiently accurate.
Any other emission factors below 10% will not be considered (such as taxis, faculty van and BBQ gas). Water was not a significant emission contributor and was also not considered.

Reduction Goals 25%, 50% and 90%

The following sets out the reasons for the percentage reduction goals in this thesis.

The Kyoto Protocol: 25% minimum reduction

According to the Ministry of Environment,

> *New Zealand is committed to The Kyoto Protocol to reduce its greenhouse gas emissions back to 1990 levels between 2008 and 2012. The latest greenhouse gas inventory shows that New Zealand's emissions are increasing, with emissions in 2005 about 25 per cent higher than they were in 1990. If nothing is done to reduce emissions, New Zealand could be 30 per cent over the*

target by 2012.[125]

NZ Green Building Council: 50% reduction

The NZGBC has suggested a 50% energy use reduction target in New Zealand through its Green Star rating tool. Green Star was launched in 2007 and rates the 'sustainability' of new and refurbished office buildings. It is a conditional requirement for obtaining a NZ Green Star that the base building design achieves an energy use figure of 120 kWh/m²/yr or less using the modelling method in NZS 4243/4218.[126] If applied to SoAD this results in a **47% reduction** from the current 227 kWh/m²/yr.

For example the first 5 Green Star building in NZ is the Department of Conservation (DOC) building which is modelled to use 101kWh/m²/yr.[127]

New Zealand: 90% maximum reduction

The highest reduction percentage guideline was based on the World Wildlife Fund (WWF) report stating that the NZ government needs to commit to reducing GHG emissions by more than 80 percent from 2005 levels, by 2050 (NZ has the sixth largest EF in the world[128]). While New Zealand contributes only 0.2% of global emissions, the

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[125] Ministry for the Environment, "The Kyoto Protocol", 20 March 2008, <http://www.mfe.govt.nz/issues/climate/international/kyoto-protocol.html> [accessed 05 July 2009]

[126] Fernandez, Nicolas Perez, 'The influence of construction materials on life-cycle energy use and carbon dioxide emissions of medium size commercial buildings', (Ph.D Thesis, Victoria University of Wellington, July 2008), p.64 <http://researcharchive.vuw.ac.nz/bitstream/handle/10063/653/thesis.pdf?sequence=1> [accessed 02 July 2009]

[127] Ministry for the Environment, *Sustainable Building Case Study: Conservation House*, June 2007, <http://www.mfe.govt.nz/publications/sus-dev/case-study-conservation-house-jun07/case-study-conservation-house-jun07.pdf> [accessed 17 July 2009] p.7

[128] Xinhua, China Daily, "New Zealand Ecological Footprint among world's highest: survey", 29 October 2008, <http://www.chinadaily.com.cn/world/2008-10/29/content_7154606.htm> [accessed 27 May 2009]

per-capita rate is very high in global terms.[129] Another study by George Monbiot called *'Heat, How to stop the planet from burning,'* claims that in order to keep the earth within critical temperature by minimising carbon dioxide (CO_2) concentration in the atmosphere the wealthy nations need to cut emissions by an average of 90% by 2030 given their status of being heavy emitters.[130] Therefore 90% reduction has been set as the target for this study.

6.1 Conclusion

It is clear that currently there is no consensus as to what reduction target should be achieved, as all are voluntary. This poses a problem as voluntary targets mean that there is no incentive for anyone to make reductions, which may well be achieved at an economic loss. A 25% reduction is suggested as the minimum requirement although it is clear that NZ's responsibility lies in a 90% reduction, a target which might seem unrealistic at present.

The following chapters will show what SoAD needs to do to achieve the three reduction goals set in this chapter.

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[129] Ministry for the Environment, *Questions and Answers on New Zealand's 2020 emissions reduction target*, 10 August 2009, <http://www.mfe.govt.nz/issues/climate/emissions-target-2020/questions-answers.html>[accessed 15 September 2009]

[130] Monbiot George, *Heat, How to stop the planet from burning*, (London: Allen Lane 2006), p.16

7.0 Energy Reduction Plan

This chapter will explore how to reduce the energy component of SoAD's emissions in order to reach the three targets set in chapter 6. Energy use is largely related to the building operation and the occupants' behaviour. As SoAD has unique hours of operation and its specific activities differ from other commercial offices or institutional facilities, its energy consumption patterns need to be analysed carefully. Reduction schemes to save energy will have financial paybacks and will help the school prepare itself for the critical times ahead.

7.1 Electricity Use

Electricity use is a significant source of emissions (as high as 50% of the total emissions of the faculty). This chapter analyses the four major contributors to electricity use; computers, lighting, space heating, and ventilation/air conditioning. The difference in electricity savings between low cost behavioural changes and high cost technologies is explored.

This investigation also addresses the option of electricity generation for the school and whether this is viable as a long term investment. This analysis will help the school weigh the options between implementing reduction in electricity use and renewable electricity generation (or a combination of both) to see which methods can help the school achieve carbon neutrality most effectively.

The carboNZero 2007 data for electricity and gas (Table 7:1) will form the base energy use to be reduced.

Electricity	1,613,471 kWh/yr
Gas	726,301 kWh/yr
Total	**2,339,772 kWh/yr**

Table 7:1: CarboNZero 2007 energy consumption data[131]

To have a general understanding of the various electricity end-uses for the two buildings, data collected from previous energy audits was used to formulate an approximate electricity end use for 2007. This is because there is no electricity end use data for 2007 available. Tables 7:2 and 7:3 include the total annual electricity consumption for the year of the energy audits and the percentage electricity end use distribution for each building. Despite the differing periods of the audits, these two figures were combined to give a final overall electricity end use distribution for the whole building. To make these figures appropriate for the year 2007, changes such as the increase in the number of computers (for details see 7.2 Equipment/Computer Use) have been incorporated to reflect the current electricity use.

2005 Wigan Building Energy Audit		
Floor area:	2,844m²	22% of total area
Total Electric Energy:	223,146 kWh/yr	
Lift	1%	2231.5 kWh/yr
Lighting	47%	104878.6 kWh/yr
HVAC	28%	62480.9 kWh/yr
Equipment / Computers	8%	17851.7 kWh/yr
Electric Heating	14%	31240.4 kWh/yr
DHW	2%	4462.9 kWh/yr
Total	**100%**	**223,146 kWh/yr**

Table 7:2: Annual electricity consumption by end use in Wigan Building for the year ending 30th of June 2005[132] (excludes gas for space heating)

[131] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)
[132] Cook, David, Energy Solutions Ltd, Victoria University of Wellington, *Wigan Building, Draft Energy Audit Technical Report,* 15 December 2005, p.27

2003 Vivian Building Energy Audit		
Floor area:	10,323m²	78% of total area
Total Electric Energy:	1,054,040 kWh/yr	
Lift	1%	10540.4 kWh/yr
Lighting	56%	590262.4 kWh/yr
HVAC	31%	326752.4 kWh/yr
Equipment / Computers	12%	126484.8 kWh/yr
Total	**100%**	**1,054,040 kWh/yr**

Table 7:3: Distribution of electricity consumption by end use from Vivian Building energy audit of July 2003[133] (excludes gas for space heating)

In 2003 the total number of PCs in the Vivian building was 185 (with a mixture of CRT and LCD monitors).[134] The Wigan building housed 59 computers, including 9 laptops (with a mixture of CRT and LCD monitors) in 2005.[135] In 2009 there were over 500 computers (laptop and desktop, all with LCD monitors)[136] in SoAD, so the number of computers has approximately doubled since 2003-2005. This change is reflected in the table below where the kWh/yr for equipment has been increased by a factor of two to generate a new percentage distribution of different electricity end uses.

Combined 2003 and 2005 Vivian & Wigan Buidling data				
Total Electric Energy:	1,277,186 kWh/yr	$13{,}167m^2$	**Accommodate increase in PCs for 2007**	
			x 2 Equipment	**New %**

[133] Energy Solutions Ltd, Victoria University of Wellington, *School of Architecture and Design Draft Energy Audit Report,* 14 May 2004, p.4
[134] Ibid. p.16
[135] Cook, David, Energy Solutions Ltd, Victoria University of Wellington, *Wigan Building, Draft Energy Audit Technical Report,* 15 December 2005, p.22
[136] Ryu Soo, Victoria University of Wellington, Personal count on 12 August 2009

Lift	12771.9 kWh/yr	1.0 %		1%
Lighting	695141 kWh/yr	54.4 %		49%
HVAC	389233.3 kWh/yr	30.5 %		27%
Equipment/ Computers	144336.5 kWh/yr	11.3 %	288,673 kWh/yr	20%
Electric Heating	31240.4 kWh/yr	2.4 %		2%
DHW	4462.9 kWh/yr	0.3 %		1%
Total W+V	**1,277,186 kWh/yr**	**100%**	**1,421,522 kWh/yr**	**100%**

Table 7:4: Distribution of electricity consumption by end use in Vivian and Wigan Buildings combined

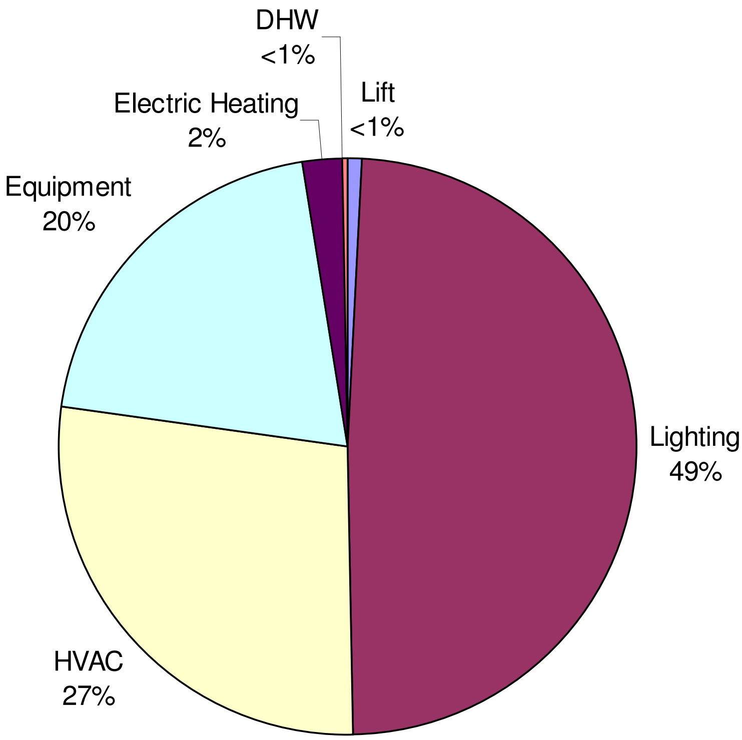

Figure 7:1: Updated and combined Vivian + Wigan building energy end use distribution

From these graphs it is noted that electric heating is only for the Wigan Building extension (gas is used for space heating and to warm the incoming air for both buildings). The equipment category mainly represents computer use. Other equipment being workshop machines, printers and microwaves only represents a very small fraction of equipment use and will therefore be omitted from further discussion as it is not a significant contributor to energy consumption. Although these energy distribution figures were produced 4-5 years ago, the percentage distribution of electricity end use is reasonably similar from year to year (except for the increase in computer numbers).[137]

Electricity use for DHW (Domestic Hot Water), lifts and the small amount of electric heating is also considered too small for it to be part of the reduction in use discussions that follow.
Applying the new electricity end use distribution (Figure 7:1) to the 2007 electricity figure results in the following kWh/yr. The focus for reduction will be the significant contributors, which are lighting, HVAC and Equipment / Computers.

Lift	16,135 kWh/yr
Lighting	**790,601 kWh/yr**
HVAC	**435,637 kWh/yr**
Equipment	**322,694 kWh/yr**
Electric Heating	32,269 kWh/yr
DHW	16,135 kWh/yr
Total	**1,613,471 kWh/yr**

Table 7:5: New electricity end use distribution figures for reduction

Number of hours of operation for different times of the day and year

Energy uses change with the time of the day. These are set out in

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137 Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (20 August 2009), *RE: SoAD carboNZero 08* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

Figure 7:2. Below in Table 7:6 the hours of each type of opening for the whole year are estimated.

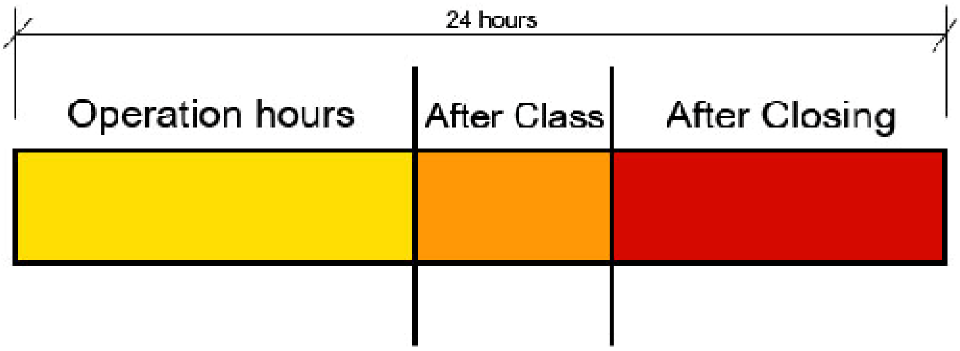

Figure 7:2: Illustration of the three different types of building use

Typically (Trimester 1 and 2) ‘operation hours’ are between 7:30am and 5:30pm when classes finish. The ‘After class’ period is from 5:30pm till the closing time of 11:30pm, when all undergraduate students are required to leave the building. After 11:30pm the building is officially closed, except for post graduates and staff members who have 24 hour access.

From observation it is noted that peak usage of the building is from midday till late afternoon. After 5:30pm as lectures finish and many of the staff members leave, it is observed that students also leave, although some come back later in the evening. Therefore this period is labelled “after class hours” as it seems to be a consistent pattern throughout the trimesters. Due to this variation, certain spaces are closed earlier than others, for example most staff offices are closed around 5pm while studios are open till 11:30pm.

Trimesters 1 and 2 have the same opening and closing times but trimester 3 (summer months) is different as the opening hours are reduced as student numbers decrease dramatically. Tables 7:6 and 7:7 in Appendix 7 show the opening hours in greater detail.

Total area of all spaces in level 3 as a representative model of the whole building

In order to investigate how the existing building could be changed to be carbon neutral, the next step is to work out the approximate floor areas of all spaces. These were taken off the drawings supplied by the university and are set out in Table 7:8. Because of the complexity of the task, only Level 3 was investigated in detail and used to represent the whole building.

The way SoAD occupies both Vivian and Wigan buildings is complex because both have been converted from other uses. There are five levels in Wigan Street and four in Vivian Street (including a basement floor) and these are connected at three points. Level 3 was chosen for its arrangement of spaces which is repeated on Level 2, being a mix of offices, labs, services, and studios. It is also the level immediately under the roof in Vivian Street, so heat loss calculations for this level (See chapter 7.5 on Space heating - Gas) will account for the loss through the roof to the outside. If these results are applied to the remainder of the building they will be an over estimate rather than an under estimate.
Table 7:8 in Appendix 7 shows the square metres for each space in detail. Figure 7:3 gives the plan of level 3. (The numbers correspond to the room space allocations in Figure 7:3)

Figure 7:3: Plan of Level 3 showing spaces and room numbers

7.2 Equipment - Computer Use

To reduce the computer energy use various reduction strategies will be explored. Currently equipment / computer use represents 20% of total electricity, as shown in Table 7:9.

Computer %	Total electricity	kWh/yr	200/500 PCs (40%)
20%	1,613,471 kWh/yr	322,694	**129,078 kWh/yr**

Table 7:9: Total kWh/yr for computer use for Level 3 only

To calculate the computer energy use for level 3, the number of computers housed there was counted (200 PCs) and their energy use taken pro rata from that used by all 500 computers.

However this is only an approximate value for Level 3 computer use. Level 1, Level 4, and Level G have a different density of computer use compared to Levels 2 and 3. There is also a small percentage of laptops (Desktop Macs are assumed to be similar to PCs) used in SoAD but because the number is relatively small it is assumed for this exercise that all computers are desktop PCs.

Below are the current SoAD desktop computer models and their specifications:

- Dell Intel ® Core ™ 2 Duo CPU E6750 @ 2.66GHz, 3.25GB of RAM (19 inch monitor)
- Dell Intel ® Core ™ 2 CPU 6600 @ 2.40GHz, 2GB of RAM (19 inch monitor)
- Dell Intel ® Core ™ 2 Quad CPU, Q 6600 @ 2.40GHz, 3.25GB of RAM (19 inch monitor)

To find out the approximate power consumption of these computers two studies have been consulted.[138][139] The following specification in Table 7:10 is the closest to the SoAD desktops. However, the average power rating between the two studies will be taken to arrive at more accurate power consumption for the desktop computers.

Make & Model	**Basic Specifications**	**Off** (plugged in)	**Boot** (peak)	**Moderate Use** (range)	**Sleep**	**Battery Charging** (power on)
Dell OptiPlex 745 w /19-inch	Core 2 Duo, 2.0 GB RAM, 100 GB/7200 RPM hard drive,	1W	145W	111 – 133W	2W	N/A

[138] University of Pennsylvania, “Information Systems and Computing, Approximate Desktop, Notebook, & Netbook Power Usage”, 10 July 2009, <http://www.upenn.edu/computing/provider/docs/hardware/powerusage.html> [accessed 12 July 2009]

[139] Michael BlueJay, “How much electricity do computers use?” October 2009 <http://michaelbluejay.com/electricity/computers.html> [accessed 12 October 2009]

Dell LCD (purchased mid 2006)	UltraSharp 1907FPV display					

Table 7:10: Approximate desktop power usage in Watts[140]

Further investigation revealed a slightly wider range of power usages, as shown in Table 7:11.

Computers	
Desktop Computer	60-250 watts
Sleep / standby	1 - 6 watts
Monitors	
Typical 17" LCD	35 watts
Screen saver (any image on screen)	same as above
Sleeping monitor (dark screen)	0-15 watts

Table 7:11: Typical desktop computer uses[141]

Combining the two sets of figures an average rating in Watts was established.

- From Table 7:10: (111W+133W)/2 = **122W** for a desktop (PC + monitor)
- From Table 7:11: (60W+250W)/2 + (15W+35W)/2 = **180W** for a desktop (PC + monitor)

[140] University of Pennsylvania, “Information Systems and Computing, Approximate Desktop, Notebook, & Netbook Power Usage”, 10 July 2009, <http://www.upenn.edu/computing/provider/docs/hardware/powerusage.html> [accessed 12 July 2009]

[141] Michael BlueJay, “How much electricity do computers use?” October 2009 <http://michaelbluejay.com/electricity/computers.html> [accessed 12 October 2009]

- Averaging the two figures = (122+180)/2 = **150W for average PC**

Since architecture and design students tend to use demanding programs (visual and graphic software) this will result in higher energy use, therefore a power rating of 150W would seem to be a reasonable approximation.

The settings for the SoAD PCs have the following power saving options. This setting is fixed and cannot be changed by the students or staff. Only the time when monitors automatically turn off can be altered. Why the simple procedure of setting computers to go into sleep mode has not been implemented is an interesting question, as it would cost nothing.

- Turn off monitors – Every 20 minutes (can be changed)
- Turn off hard disks – Never (fixed)
- System standby – Never (fixed)

Because the monitors turn off after 20 minutes it makes sense to use the average of 15W (sleeping monitor) and 35W (monitor on) from the Table 7:11 figures. It is important to note that this figure is for a smaller monitor of 17 inches.

Power consumption for computers that have been left on when not in use (therefore having a lower power consumption) would probably be around **75W**, calculated from (60W + 15W) = **75W** (from Table 7:11).

Calculation of Computer Energy Load

The number of computers available per room was recorded for level 3, differentiating between staff and student computer use (see Table 7:12). It is found from observation that students tend to have more intensive use of programs with higher energy consumption than staff, such as 3D modelling software and visual graphic software. Staff members tend to use less intensive programs such as Microsoft Word, Powerpoint and access to internet for administrative and research purposes.

The calculation below is based on personal observation made on June 9th 2009 between 5 - 7pm. Student occupancy of every room / space was recorded for computer use. The observation time was during the exam study period, a time considered one of the least busy in the trimester. The results are shown in Table 7:12.

Different areas/rooms LEVEL 3	**Computer Count**	**Occupancy: No. of students**	**% of PCs in use**
VIVIAN BUILDING			
22 Staff Offices	25	N/A	N/A
Design Computer Lab **320**	4	1	25%
Arch Computer Lab **317**	16	2	12%
Arch Computer Lab **319**	41	7	17%
Design Computer Lab **322**	40	12	30%
Vivian Studio **301**	20	2 (80% on PC)	8%
Vivian Studio **303**	8	15 (50% on PC)	93%
Vivian Studio **323/333**	10	7 (80% on PC)	56%
Seminar / Teaching space **308+318**	2	N/A	N/A
WIGAN BUILDING			
Wigan Studio **301**	29	13 (60% on PC)	26%
Wigan Seminar **302 + 303**	5	N/A	N/A
TOTAL (or average)	**200**		**34%**
Total Staff + Other Computers	**32**		
Total Student Computers	**168**		

Table 7:12: Computer count and % use

From the results above, it is clear that computer use is low (under 50%) during the least busy period (exam study period), which is straight after the final design project hand in period. During the

previous two weeks before final hand in for design presentations, the occupancy level is very much higher. On average, from various observations throughout the year during normal periods, the occupancy level is around 50% throughout the year.
What the observations show is that during the least busy period many computers are left on without being used, and it seems a waste of energy to open an entire computer lab with its air conditioning and lighting use for a very low occupancy rate.

7.2.1 25% reduction scheme

Only low cost methods will be considered to achieve the 25% reduction in energy use. The two options are as follows;

1) Be efficient by carefully planning computer resources for maximum occupancy;
2) Reduce school opening hours.

How this could be achieved is set out in Figure 7:4 and the details are discussed below.

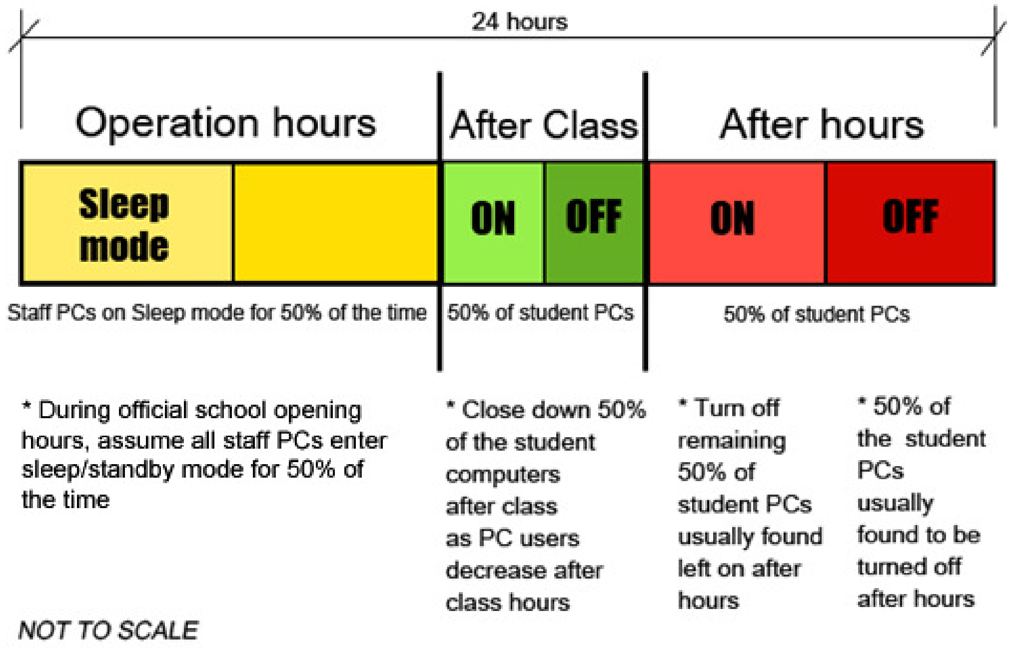

Figure 7:4: Illustration of how 25% energy savings can be made

Solution 1: ***Switch off 50% of PCs currently left on overnight***

From numerous observations throughout the year, approximately 50% of the PCs are left on overnight. This seems to be a common practice. Despite energy saving campaigns from students it seems to be almost a 'habit' to leave the computer on. Also the VUW CarboNZero Progress Report November 2008 stated that all the PCs in the SoAD domain will automatically switch off at 12:30am, but from observation this has not happened. This is due to students not logging off. These computers will not switch off as they are read as "active" computers.

To reduce this unnecessary use, the BMS scheduling should be altered to turn a designated proportion of all computers off after 11:30pm regardless so that "active" computers go into sleep mode. To calculate the savings, half the student computers were considered to be "turned off" and 50% left "on." The results of these actions are shown in Appendix 2, Table 7:13.

The total kWh/yr saved by closing down 50% of PCs currently left on overnight is 13,753 kWh/yr

Turning off the selected studios and labs as shown in Table 7:13 would be the equivalent of turning off 50% of the student computers (84 PCs) on level 3. 75W (0.075kW) was used as the power consumption for computers left inactive throughout the night, that is during the after closure period of 2,183 hours for trimester 1 and 2.

Equation: ***(No. of student PCs) x 0.075 kW x 2183 hours = _____ kWh/yr***

Adding all the potential savings from turning off half the PCs at night, equals **13,753kWh/yr** which is **11% savings in total computer use**.

Solution 2: ***Close down 50% of PCs after class hours***

It is found from numerous observations throughout the year that students using the computer labs decrease in number after class hours (which is after the official timetabled lectures/studio sessions). Therefore closing down 50% of the computers that are usually available during this period would be a way to save energy. As computer labs come with swipe card access, these can be changed to be inaccessible after 5:30pm and closed down automatically through BMS scheduling or by the operations manager. During busy times (i.e. before final project hand in period) these labs can be opened, depending on the demand. This emphasizes the importance of having an operations manager watching over the demands and scheduling appropriate opening and closing of the computer labs. The effects of this action are shown in Appendix 2, Table 7:14.

The total kWh/yr saved by closing down 50% of PCs in after-class hours is 15,762 kWh/yr

The suggested closing of Arch Computer Lab 317, Design Computer Lab 322, Vivian studios 301 and 303 from 5:30pm till the official closing period of 11:30pm in trimesters 1 and 2 (weekdays and weekends) would result in the following savings.

= (Close down 84/168 student PCs in total) x 0.15kW x (1110 hrs + 444 hrs)

The potential savings from closing down 50% of student PCs in the after class period equals **15,762kWh/yr** which is **12% savings in total computer use**.

However, restricting computer use during these hours could lead to more concentrated use during the day which in turn would increase energy consumption. This also results in many students needing to depend on using their own computers at home. Since the electricity used at home is paid for by the student, it could lead to more sensible and efficient use of computers rather than students using school computers for non-academic purposes (such as playing games, checking emails and viewing videos online). However it could be a way of shifting the power consumption problem in a way that reduces the SoAD's capacity to control and shape the energy being used and does not necessarily guarantee that electricity will be used sensibly.

Solution 3: *Sleep mode after 20 minutes of inactivity for staff computers*

Tables 7:10 and 7:11 show the reduced power consumption of computers when they are switched to sleep mode after a specified period of inactivity. During sleep mode only 2W-6W are consumed resulting in an average of 4W. From Energy Star's website, it is found that activating system standby or hibernate settings in desktop PCs in commercial situations can cut electricity use by PCs roughly by half.[142]

A case study from the University of Wisconsin-Oshkosh (UW Oshkosh) looked at computer labs where the PCs were kept powered 24 hours a day to accommodate students and nightly software updates. They placed 485 computers into a low-power "sleep" since they had already set computer *monitors* to go to sleep after 20 minutes. UW Oshkosh decided to look into activating *computer* sleep settings. UW Oshkosh set the system standby idle timer to 20 minutes on each computer. As a result, their computers, which normally used around 60 to 70 watts of power, entered a low-power mode using around 2 to 3 watts, after 20 minutes of inactivity. They found that activating sleep settings cut computer energy use by 75%.[143]

This investigation takes the less optimistic saving of a 50% reduction from changing the sleep mode setting, and assumes this change is implemented on all staff but not student PCs. There are 32 staff PCs (plus other PCs available in seminar rooms) in level 3 with a total power draw of 4800W. If the computers were set to go to sleep after 20mins of inactivity during operation hours on weekdays (trimester 1 and 2 – 7:30am to 5:30pm) this results in:

= 32 x 0.15kW x (2960hrs-1110hrs) * 50% = **4440 kWh/yr savings**

The accumulated savings from the three main actions are summarised in Table 7:15.

Total low cost scheme savings:

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[142] Energy Star, "Activating power management features in enterprises", <http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_enterprises> [accessed 18 July 2009]

[143] Energy Star, *Computers, on 24/7, awaiting updates but wasting energy*? <http://www.energystar.gov/ia/products/power_mgt/UofWisc_CPM_casestudy.pdf> [accessed 02 July 2009] p.4

Savings	kWh/yr saved
Switch off 50% student PCs currently left on at night (Tri 1 & 2)	**13,753**
Switch off 50% student PCs after class hours (Tri 1 & 2)	**15,762**
Switch staff PCs to go into sleep mode (Tri 1 & 2: operation hours)	**4,440**
TOTAL savings of 129,078 kWh/yr	**33,955**

Table 7:15: Total low cost method savings kWh/yr

A **26% reduction** (33,955/129,078 kWh/yr x100) is achieved through implementing the three reduction schemes in Table 7:15, thereby satisfying the Kyoto Protocol requirement.

There are other ways of achieving 25% savings as listed below:

- Closing down the school early (reducing the school's opening hours)
- Converting PCs to laptops (laptops use less energy than PCs)
- Putting more SoAD PCs in sleep mode
- Switching off more computers during trimester 3 (summer school period)

7.2.2 50% reduction scheme

To attain a 50% reduction in energy consumption more drastic measures need to be considered. There are several options to achieve this target each of which are discussed in more detail below.

1) **Low cost method:** Put all the PCs into sleep mode

2) **High cost method:** Convert most of the PCs to lap**tops (laptops hav**e a greater than 50% energy savings over desktops).

1) Low cost method

Over the year the school is open for 3686 hours from Monday to Friday and an additional 1148 hours during weekends.
If 200 computers were all set to sleep mode, hibernating after 20 minutes of inactivity, it would simply reduce electricity consumption for computers by 50%.

Put all student PCs in sleep mode after 20 mins of inactivity during trimester 1 and 2 *opening hours* (7:30am – 11:30pm) – weekdays and weekends.

- There are 168 student PCs x (2960 hrs + 1073 hrs) x 0.15kW x 50%
  = **50,816 kWh/yr**

Put all staff PCs in sleep mode after 20 mins of inactivity during trimester 1 and 2 *operation hours* (7:30am - close at 5:30pm) – weekdays and weekends.

- 32 staff PCs x (1850 hrs + 629 hrs) x 0.15kW x 50%
  = **5,949 kWh/yr**.

Put all staff PCs in sleep mode after 20 mins of inactivity during trimester 3 *operation hours* – weekday and weekends (during this period staff are still at work while most students are on holiday)

- 32 staff PCs x (643.8 hrs) x 0.15W x 50%
  = 1,545 kWh/yr

Put all student PCs in sleep mode after 20 mins of inactivity during trimester 3 opening hours – weekday and weekend (assume 50% of the PCs are switched off during summer months).

- (168 student PCs x 50%) x 801.3 hrs x 0.15 x 50%
  = 5,048 kWh/yr

The combined total savings become:

50,816 + 5,949 + 1,545 + 5,048 = **63,358 kWh/yr → 49% reduction**

2) High cost method

Laptops are known to be more energy efficient than desktop PCs. Research shown below in Table 7:16 reveals that if SoAD was to replace the current desktop specification with a laptop equivalent (i.e. the first Apple MacBook Pro with 2 GB RAM, 100GB hard drive) there would be a 79% reduction in energy use (32W average/150W) and if the replacement was a higher specification model (i.e. the second Apple MacBook Pro with 4 GB of RAM, 250GB hard drive) it would result in a 62% saving in energy (56.5W average/150W). The monitor size will also be smaller in laptops.

Make & Model	**Basic Specifications**	**Off** (plugged in)	**Boot** (peak)	**Moderate Use** (range)	**Sleep**	**Battery Charging** (powered on)
Apple MacBook Pro 15-inch	2.16 GHz Core Duo, **2.0 GB RAM**, **100 GB**/7200 RPM hard drive, Mac OS 10.4.9	1W	59W	26 – 38W (**32 W** average)	2W	76W
Apple MacBook Pro 15-inch	2.5 GHz Core 2 Duo, **4.0 GB RAM**, **250 GB**/5400 RPM hard drive, Mac OS 10.5.6	1W	52W	55 – 58W (**56.5 W** average)	1W	41W

Table 7:16: Approximate Notebook Power Usage in Watts[144]

To achieve 50% reduction, all 32 **staff** PCs needs be replaced with the equivalent laptop (2 GB RAM, 100GB hard drive). This would result in 13% savings.

- 32 computers x 32W average= **1024W** (laptops with current specification)

As **students** require a higher specification (4 GB RAM, 250GB hard drive), 121 PCs need to be replaced with 4 GB RAM laptops to achieve a combined 50% savings in energy.

- 47 desktop computers x 150W = **7050W** (unconverted PCs)
- 121 laptops x 56.5W = **6836.5W** (laptops with higher specification)

Total existing PC power consumption for level 3 = (150W x 200 PCs) = **30,000W**

Reduction calculation = (30000W – 7050W) – 6836.5W – 1024W = 15,090W

= 15,090W / 30000W x 100

→ **50% reduction**

As laptops come with energy efficient set ups and are easier to set to sleep mode, switching to laptops will not only use less energy but will automatically put an energy conserving system in place. As laptops have the advantage of being portable, this could be an attractive option for students and staff, as they can also work from home. This might also reduce transportation energy for coming to school. This

144 University of Pennsylvania, "Information Systems and Computing, Approximate Desktop, Notebook, & Netbook Power Usage", 10 July 2009, <http://www.upenn.edu/computing/provider/docs/hardware/powerusage.html> [accessed 12 July 2009]

strategy also means the school could be closed earlier as students would still be able to work on their projects at home with the equipment available. Leasing out laptops to students (the option of getting personal laptops is available for post graduate students which they can take home for work) could be a helpful option for those who are struggling financially to acquire a computer of their own (laptops are more expensive than desktops). To ensure that these laptops are controlled properly and maintained, it makes sense to employ a person who can oversee all these matters and ensure that the scheme is running smoothly.

7.2.3 90% reduction scheme

To achieve 90% reduction in energy consumption, it is necessary to switch both staff and student PCs to laptops with current specification (2GB RAM).

- 32 computers x 32W = **1024W** for change to laptops
- 168 computers x 32W = **5376W** for change to laptops

Combined saving of **79%** = ((30,000W - 1024W – 5376W) / 30000W x100)

To save a further 11%, would require reducing computer (laptop) use, or more simply, SoAD would need to reduce the number of computers available for use.

32 computers x 32W = **1024W** for laptops
61 computers x 32W = **1952W** for laptops

Reduction calculation: 30,000W – 1024W – 1952W = 26,992W
= 26,992/30,000W x 100 → **90% reduction**

By reducing the student computers to **61 computers** (eliminating 107 computers – 63% reduction) 90% reduction can be achieved.

7.2.4 Guidelines for saving computer electricity use

- Switch **off** computers and monitors when not in use (i.e. switch off after hours and make sure computers in some areas are completely off to eliminate standby energy consumption)
- Efficient time/resource/space management and BMS scheduling are essential – (this also saves lighting and HVAC load) – the aim is maximum occupancy during opening hours
- Enable the energy saving settings for all computers (sleep mode or turning off after 15-20 mins of inactivity)
- Convert PCs to laptops (make sure laptops are Energy Star accredited and made of recyclable/recycled materials)

7.2.5 Conclusion

The 25% reduction in energy is the easiest task to achieve. It is clear that setting PCs to sleep mode is the biggest saver of energy and is also the easiest action to implement. This is a simple behavioural change by being efficient and reducing wasteful energy use. Most importantly it costs nothing to implement, and can be achieved immediately.

To achieve 90% reduction involves higher cost and a significant reduction in the school's activity. Since SoAD currently replaces 25% of the computers (which are currently on a 4 year lease) every year[145] it would be better to begin the change to laptops immediately. However it is necessary to consider the footprint of having new

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[145] Shaw Mark (Faculty Manager for SoAD), (mark.shaw@vuw.ac.nz), (13 May 2009), *RE: SoAD – computers and printers* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

computers (see ecological footprint calculations page) as they produce e-waste and embodied energy is consumed during their production. This is something that requires further investigation. However, certain electronics are now recyclable and producers, such as Apple, are taking life cycle analysis into consideration. These issues should guide the choice of the type of laptop whether leased or purchased by SoAD. It is important to note that changing to higher specification laptop models would result in fewer energy savings than a laptop with a lower performance specification.

7.3 Lighting Use

Lighting makes up the largest part of SoAD's energy use. According to the Draft energy audit report for 2004,[146] when the building was refurbished in the early 1990s its lighting fixtures were updated to be modern and reasonably efficient. Artificial lighting is used during the day in computer labs, toilets and studio spaces as they have little or no access to daylight. Spaces that have access to daylight are staff offices, the atrium and parts of the studios facing the window. From personal observation on numerous occasions more than half the lights are left on after hours. Studios, toilets, kitchenette, atrium, circulation spaces such as corridors and staircase have lights switched on while lights in staff offices, seminar rooms and computer labs are generally switched off after closing hours. The latter are spaces where the users have more sense of being responsible for switching lights off after use.

Light switches in studios are difficult to locate and, from experience, turning off 100% of the studio lights seemed impossible. According to the carboNZero 2007 GHG reduction plan, staff members have complained about the difficulty of locating light switches. The switches for circulation lights are placed in three places on level 3 for

[146] Energy Solutions Ltd, Victoria University of Wellington, *School of Architecture and Design Draft Energy Audit Report,* 14 May 2004, p.15

Vivian Building and when used turn off the whole building's circulation paths therefore leaving the occupant in complete darkness. This applies to other levels as well. Wigan Building light switches for the studios and circulation spaces are not locatable and therefore the lights remain on at all times. Therefore most circulation lights are generally on even after closing hours. Lighting currently represents 49% of total electricity use. The estimated kWh/yr breakdown for level 3 is shown in Table 7:17.

Lighting %	Total electricity	Lighting kWh/yr	Level 3 (23.7% of total lighting)[147]
49%	1,613,471 kWh/yr	790,601	**187,372 kWh/yr**

Table 7:17: Total kWh/yr for lighting electricity use for Level 3

The same reduction targets will be applied to lighting to reduce its energy demand by 25%, 50% and 90%.

Types of lighting

There are three main types of lighting used in SoAD. The majority of the spaces (studios, labs and offices) are lit by T8 fluorescent tubes 1500mm in length. The smaller lighting fixtures are compact fluorescent and metal halide lamps which are mainly used to light the smaller spaces and corridors. Table 7:18 gives the wattage and other data for the different types of lighting fixtures:

Type of lighting / Description	Lamp (W)	Ballast /control gear (W)	Total Wattage (W)	Mean Lumens	Colour Temp. (K)	Average Life (hrs)
T8	18[148]	9	27	1000	4000	8,000 –

[147] There are 4 floor levels in the Vivian Building and 5 in Wigan. The Total floor area for level 3 is 3114m². The total floor area of SoAD is 13,167m². Therefore level 3 is 23.7% of the total floor area.

Fluorescent 600mm (Fl)						10,000
T8 Fluorescent 1200mm (Fl)	36[149]	10	46	2200	4000	8,000 – 10,000
T8 Fluorescent 1500mm (Fl)	58[150]	14	72	3300 – 4600[151]	4000	8,000 – 10,000
Halogen Metal Halide (MH)	35	70[152]	105	?	3000 / 4200	9000
Compact Fluorescent (CF)	18	1	19	?	2700 / 4000 [153]	10,000

Table 7:18: Wattage for different lighting fixtures

Lighting Count

In order to investigate the total energy use for lighting, the lighting wattage demand figures in Appendix 3, Table 7:19 are used to calculate the total wattage for all the lighting in that specific space. This data will be used to calculate the kWh per year reduction needed to achieve the three targets.

42,905W was the total wattage of all installed lighting on level 3.

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[148] Cook, David, Energy Solutions Ltd, Victoria University of Wellington, *Wigan Building, Draft Energy Audit Technical Report,* 15 December 2005, Appendix C2
[149] Ibid.
[150] Ibid.
[151] Edirectory, "White fluorescent lighting tube," <http://www.edirectory.co.uk/pf/880/mia/d/sylvania+1500mm+standard+slim+58w+white+fluorescent+lighting+tube+f58w+135/pid/8457963> [accessed 23 July 2009]
[152] Toplightco, "Metal Halide Lamps," <http://www.toplightco.com/acatalog/Wholesale_Lighting_CDM_T_35_Watt_G8_5_Metal_Halide_Lamps_922.html> [accessed 23 July 2009]
[153] Toplightco, "Compact Fluorescent Lamp," <http://www.toplightco.com/acatalog/Wholesale_Lighting_TC_D_G24d_2_Compact_Fluorescent_Lamp_18_watts_915.html> [accessed 23 July 2009]

Lighting level

To see if the lighting standard at SoAD meets the recommended minimum lighting levels, an illuminance (lux) reading was taken throughout the various parts of level 3 on Monday 08/06/09 between 3-4pm in the afternoon with the use of a digital light meter. This time period was selected as being at the end of the time when daylight would usually still form the only lighting for at least some parts of the building. Towards the middle of the day there would be more daylight available in the same locations. Another measurement was also taken after sun down (after 7 pm) to understand the lighting levels without daylight. There were three types of lit spaces – one lit only by daylight, one only by electric lighting and the third a combination of both.

Below are the recommended lighting levels for different purposes from AS/NZS1680.

Min. recommended illuminance	Characteristics and examples
40 lux	Corridors, Walkways
80 lux	Interiors used intermittently; changing rooms, storage areas, loading bays, stairs, toilets
160 lux	Activities only needing coarse detail; staff canteens, entrance halls
240 lux	Continuously occupied areas with occasional visual tasks such as reading, writing, typing; enquiry desks, libraries
320 lux	Routine office tasks of reading, writing, typing, enquiry desks, libraries
600 lux	Drawing boards, town planning and enquiry counters dedicated to viewing paper plans

Table 7:20: Recommended lighting levels for different purposes from AS/NZS1680[154]

Figure 7:5 below shows the lighting level measurements taken at different places on level 3. The light meter was read in between light fixtures to avoid high level readings and positioned approximately 1m (table height) above ground level. Note that not all the spaces could be measured due to inaccessibility. Level 3 will be used here as representative of the lighting use for all levels. There should not be a great problem in doing this as the lighting plan for all levels is, from observation, reasonably consistent.

For detailed light level measurements on level 3 at day and night times see Appendix 3, Table 7:21.

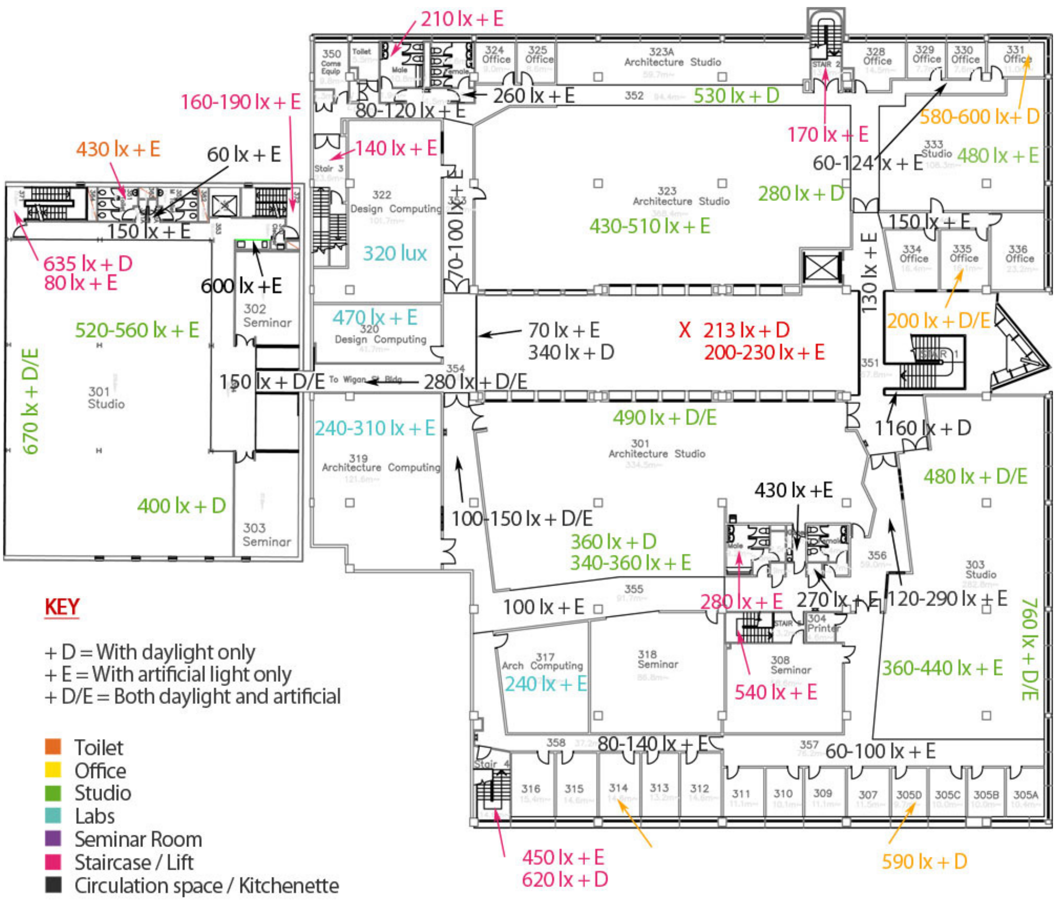

Figure 7:5: Different light meter readings on level 3

[154] Adelaide City Council, "Green Building Fact Sheets", *Energy Efficient Lighting,* http://www.adelaidecitycouncil.com/adccwr/publications/guides_factsheets/energy_efficient_lighting_fact_sheet.pdf> [accessed 21 July 2009] p.2

Below follows a discussion of ways of achieving the various levels of reduction required for carbon neutrality.

7.3.1 25% reduction scheme

Reduction achieved by de-lamping and installing lower wattage lamps

The measured lighting level (in lux) for spaces in level 3 can be compared to the recommended lighting level to see if it is sufficient or excessive. The reduction in current lighting level to its appropriate task lighting level can then be transferred to a reduction in wattage for lighting.

This can be achieved through de-lamping, installing lower wattage tubes or using dimmers, and this is set out in Table 7:22 in Appendix 3.

The total wattage reduction after de-lamping and installing lower wattage lamps is 13,837W.

From the measurements, the majority of the level 3 spaces were over-lit according to the recommended illuminance value. So if SoAD de-lamped and installed lower wattage lamps to meet the recommended illuminance, it would save approximately **32%** of its energy use derived from lighting (13,837W / 42,905W x 100). This is a low cost method and can even save money as de-lamping would result in spare lamps, and purchasing lower wattage lamps in the future would mean the school would spend less money on energy for lighting.

7.3.2 50% reduction scheme

It was found from the previous exercise that a 32% reduction can be easily achieved by reducing wattage and de-lamping. To achieve 50%, a different approach was taken. Assuming an unchanged status quo (de-lamping has not occurred in this exercise) these are the following suggested schemes to reduce lighting use by 50%.

Solution 1: *Turn off remainder of lights left on during after hours*
From numerous observations it is obvious that it is common practice to leave the lights switched on even after the building has officially closed. Only post graduate students and staff have 24 hour access and few make use of this privilege. Hence the estimated savings from turning these lights off is explored in Appendix 3, Table 7:23.

The total estimated savings from turning remaining lights off after-hours is 31,026kWh.

From this calculation it appears that approximately **16%** of lighting energy can be saved by simply turning off the lights left on after hours (31,026kWh/187,372kWh x 100).

Solution 2: *Close off 45% of the areas after class hours*
In the computer energy savings calculation, it was noted that SoAD could close down 50% of the computers (and therefore the corresponding spaces as well) after class hours (from 5:30pm till 11:30pm) as the occupancy rate drops to half during this time. The lights in these spaces should also be turned off. However to reach the 50% reduction in lighting energy more spaces need to be closed with the lights turned off. This means that more studios need to be closed as they are larger spaces with more lighting. Vivian Studio 323/333 and 301 could be closed and instead Vivian Studio 303 opened as this is a smaller space. Wigan studios also needed to be closed. Table 7:24 in Appendix 3 calculates how much lighting energy the school would save from turning off the lights to spaces

that will have been closed to reduce computer use by 50% after class hours, plus the additional studio spaces.

Total savings for switching off the areas closed off after class hours are 34,126kWh

It is found that **18%** of lighting energy (34,126/187,372kWh x 100) can be saved by closing down Arch computer labs 317 and 319, Vivian studios 310 and 323/333 and Wigan Studio, (($52m^2+121.6m^2+334.5m^2+536.4m^2+378.9m^2$) / $3114m^2$ x 100) between 5:30pm and 11:30pm in Trimester 1 and 2 (Mon-Sun) which is 45% of the total floor space of level 3.

Solution 3: ***Close down 54% of the student service part of buildings during Trimester 3 opening hours***

During trimester 3 (summer school period), the student numbers decrease dramatically and the building gets used mainly by staff members and a small number of students. Therefore it makes sense to restrict the spaces that are accessible and plan the use of these efficiently. This method prevents a large space being open to be used by small number of students therefore wasting a lot of lighting energy. Table 7:25 in Appendix 3 shows the savings from turning off the lights to spaces that otherwise would have been on.

Total savings for closing down 54% of student spaces during trimester 3 are 20,308kWh

It is found that **10%** (20,308kWh/187,372kWh x 100) of lighting energy use can be saved from closing Wigan studio 301, Vivian studios 303, 323, 333, design computer labs 320, 322 and architecture computer lab 317. Closing down 54% of the total level 3 floor area is required to achieve 10% lighting energy savings (52 m^2+121.6 m^2+334.5 m^2+282.8 m^2+536.4 m^2+378.9 m^2)/3114 m^2 x 100).

Solution 4: ***Install motion sensors in corridors, staircases and toilets to turn lights off after 10 inactive minutes***

From observation, most of the time lights are left on in intermittently used spaces, such as toilets and corridors, despite the absence of users throughout the whole year. If these lights were fitted with motion sensors so that they turned off automatically after 10 minutes of inactivity, the expected annual energy savings are calculated in Appendix 7, Table 7:26. These intermittent spaces always have electric lighting because of the lack of natural daylight.

Estimated savings from installing motion sensors in intermittent spaces are 12,523kWh.

Past research has shown that use of occupancy sensors for control of lighting can save up to 30% of the electrical energy used for lighting. Experiments conducted have shown that about 5% more energy can be saved by using smart occupancy sensor as compared to non-adapting fixed time delay sensors.[155]

Since these lights are left on most of the time, even after closing, and as mentioned earlier staff and security guards find turning them off difficult as this results in leaving the occupant in complete darkness, total opening hours for trimesters 1, 2 and 3 are used for the following calculation including after closing hours (2960+1073+362.5+45+363.8+30 = 4834.5 hrs/yr).

About **6%** (12,523kWh / 187,372kWh x 100) energy savings result from installing all the circulation and intermittent space lighting with motion sensors.

By combining the four schemes mentioned above, the reduction target of 50% lighting energy savings can be achieved.

[155] Vishal Garg and N. K. Bansal, 'Smart occupancy sensors to reduce energy consumption,' *Energy and Buildings,* 32 (2000), 81-87 (p.1)

Total low cost scheme savings:

Savings	kWh/yr saved
Turn 50% off remaining lights left after closing hours (Tri 1 & 2)	**31,026**
Close off 45% of the areas after class hours (Tri 1 & 2)	**34,126**
Close down 54% of the student service part of the building (Tri 3)	**20,308**
Install motion sensors in intermittent spaces (Tri 1, 2 & 3)	**12,523**
TOTAL lighting energy of 187,372 kWh/yr	**97,983**

Table 7:27: Total low cost method savings kWh/yr

97,983kWh / 187372kWh x 100 = **52%** lighting energy reduction therefore meeting the EUI target.

7.3.3 90% reduction scheme

To reduce the lighting energy load by 90%, one promising option is to invest in LED technology. LED technology differs from other lighting sources by directing light towards a particular direction compared with the usual omni-directional fluorescent tubes that require lighting fixtures to direct light towards where it is wanted. However, even with these reflectors there are losses.

Figure 7:6: LED fluorescent lighting tube[156]

To get a more accurate light output figure for T8 Fluorescent and LED equivalent taking into consideration the factors mentioned above, various tests have been performed and recorded. The website www.led-4-light.com states the following:

> *…the actual light utilization of a standard T8 fluorescent tube has been determined to be 65% on average. Our LED Tubes have a utilization efficiency of 95% due to their directional nature. This result in a 46% increase in Effective Lumens output when compared against a standard T8 Tube… It should be noted that many manufacturers only quote the initial lumens on their lamps. The initial lumens represents* [sic] *the light output of the lamp in the first 1000 hours or less of operation. Mean lumens is more representative of the light output after this initial 'burn in' period and can be 20% less than the initial lumen rating.*[157]

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[156] Supplier List, "LED Fluorescent Light," "<http://www.supplierlist.com/photo_images/204430/T5_LED_tubeT8_LED_tubeT10_LED_tubeLED_Fluorescent_Light.jpg> [accessed 05/01/10]

[157] LED-4-light, "Effective lumens measurement", <http://www.led-4-light.com/Effective%20Lumen%20Measurement.htm> [accessed 27 July 2009]

The comparison between the two is shown in Table 7:28.

Type of lighting / Description	Lamp (W)	Ballast /control gear (W)	Total Wattage (W)	Mean Lumens	Colour Temp. (K)	Average Life (hrs)
T8 Fluorescent 1500mm (Fl)	58	14	72	3300 – 4600[158]	4000	8,000 – 10,000
1500mm LED T8, Commercial Grade - 5000K	20	N/A	20	3360 (effective lumens)	3000 - 6500	50,000 (5+ years)

Table 7:28: Comparison of LED Fluorescent Tube Light with standard T8 fluorescent tube[159]

Comparing the specifications of a LED fluorescent tube light and a standard T8 fluorescent tube (Table 7:28), the advantages of LEDs seem obvious. The LED wattage power rating (and actual power consumption) is 72% lower, life span is 5 times longer, there is no requirement for a ballast or a starter which also consume energy, heat generation is lower, there is no presence of mercury and there are lower maintenance costs because of the long life. The LED tube can be placed directly into conventional T8 fluorescent brackets by removing the ballast and starter before replacement. [160] There is also no flickering, no UV emissions, and the lamp is vibration resistant. Despite previous notions that LED lighting colour is perceived as poor, new improved technology has shown that various colour

[158] Edirectory, “Fluorescent lighting tube,” <http://www.edirectory.co.uk/pf/880/mia/d/sylvania+1500mm+standard+slim+58w+white+fluorescent+lighting+tube+f58w+135/pid/8457963> [accessed 24 July 2009]
[159] LED-4-light, “Effective lumens measurement”, http://www.led-4-light.com/Effective%20Lumen%20Measurement.htm [accessed 27 July 2009]
[160] Traders City <http://www.traderscity.com/board/products-1/offers-to-sell-and-export-1/t8-led-tube-light-1500mm-72148/> [accessed 24 July 2009]

temperatures are possible and there are even warmer tones of white to emulate natural light.[161]

The only downside of LED lights is that they are at least ten times more expensive[162] [163] [164] than an equivalent fluorescent lamp. However the lifetime is five times longer, therefore reducing the price difference to half. In addition, there are lower maintenance costs and a reduced air conditioning load from the reduced heat from operation. To achieve a 90% reduction in lighting it is necessary to change all lights in SoAD to an LED equivalent. For example changing the majority of the fluorescent lamps to LED equivalents will save 73% of energy in use ((72W - 20W) / 72 x 100). Since the current lighting levels are higher than the recommended lighting level by 30%+ and the effective lumens of LEDs are similar to those of fluorescent tubes, replacing all the T8 fluorescent light tubes to LED equivalents and de-lamping to meet the appropriate lux levels would safely result in a 90% reduction.

The fact LEDs are expensive should lead to more care being taken with their application relative to the tasks in hand, thus avoiding excessive lighting levels and associated energy usage.

Additional endeavours to save energy

It will also be necessary to carry out an awareness campaign to get staff and students to act responsibly by turning off lights. This applies to places with no sensors such as staff offices, kitchens, the staff room and computer labs. Occupants of the school should also take responsibility for the carbon neutral vision by actively participating in energy saving schemes.

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[161] Photon Star, SmartWhite, *Intelligent Dynamic LED Luminaires,* <http://www.events.photonstarlighting.com/resources/ARC+2009+SmartWhite+Preview.pdf> [accessed 23 July 2009]

[162] Energy Super Store <http://www.energy-superstore.com/index.asp?PageAction=VIEWCATS&Category=167> [accessed 24 July 2009]

[163] Creative Lightings <http://www.creativelightings.com/LED-T8-Fluorescent-SMD-Tube-4-foot-288LED-18W-p/cl-smdt8-4-dw18w288.htm> [accessed 24 July 2009]

[164] LED Light <http://www.ledlight.com/t12-t8-led-tube-light-4foot-15-watt.aspx> [accessed 24 July 2009]

This has been attempted in the previous carboNZero 2007 GHG emissions plan where “Save energy - turn lights off” stickers have been placed on light switches in labs, toilets, and offices to remind occupants and by holding energy saving awareness meetings. However this has proven to be unsuccessful as repeatedly rooms have been found with the lights on. Unless the values of the staff and students are changed, these behavioural changes will not happen. This could be implemented through education, training, awareness campaigns and staff adhering to the school’s carbon neutral policy. However, it might be a good idea to have additional occupancy sensors in certain places despite the small savings that result, to reduce the lighting energy consumption immediately. The fact the lights turn themselves off will be a reminder of the need to be vigilant about turning off unused lights. Also enhancing the light switch locations and installing timers on circulation lights could encourage the occupants to turn lights off more easily and frequently, and also not discourage those who are active about saving energy.
It is also noted that cleaners do not clean the light fittings and many have a significant dust accumulation. Cleaning light fitting regularly could help save energy as maximum brightness will be achieved.

7.3.4 Guidelines for saving lighting electricity use

- Turn off lights that are not in use especially after hours
- Maximise daylighting by programming activities when daylight is available
- Have appropriate light levels for different spaces to prevent over-lighting spaces
- Install motion sensors in spaces that are used intermittently (i.e. corridors, staircases, toilets)
- Maximise occupancy to prevent turning on all the lights for few people
- Control lighting in smaller sections to prevent the whole space being lit for one person

- Have light switches that are easily accessible and well planned
- Invest in LED technology which lasts longer and is more efficient

7.3.5 Conclusion

It seems that reducing lighting levels currently in excess of requirement, and reducing usage is the only way to save energy in a low cost manner. Both are easy to implement and will save the school money in the long run. It is possible to replace the existing lights with LEDs to achieve both 25% and 50% reduction targets; however this would be a significant investment which the school would need to consider carefully. This reiterates the idea that to save significant amounts of energy either usage can be drastically cut or there can be investment in new technology. It seems to be a good idea to implement behavioural changes to achieve up to 50% of the savings and think about investing in better technology to achieve the 90% reduction.

7.4 HVAC (Ventilation and Air Conditioning) Use

According to the Energy Solutions Ltd's SoAD's Draft Energy Audit Report in 2004, the main body of the building (Vivian) has no air conditioning (except in the labs and enclosed theatres) and cooling is achieved by ventilation with outside air by the Air Handling Units (AHUs). Currently the school's cooling system is based on a chiller on the roof. This supplies chilled water to a nearby air handler. The system which is used to cool fresh air has the advantage of being able to use outside air as a source of cooling without having to run the chiller as long as the outside air is not too warm. The roof mounted air handler supplies fresh air that has been cooled as required to two supply ducts that extend down to level 0. On each level in Wigan, two branch ducts supply conditioned air to the floor. This supplied air is only partially treated. From each floor exhaust air is extracted to a common duct which has fans mounted on the roof. There is a small amount of air conditioning (chiller use) in summer periods to cool the overall spaces based on observation made in the Wigan Building Draft Energy Audit Technical Report in 2005.

There are 13 split air conditioning systems around the building which are situated in rooms with high heat load such as computer labs and lecture theatres and it is unlikely they are ever called on to heat (probably due to their location which is central therefore highly insulated from heat loss to the outside). External units are mainly on the roof. Lecture theatre air conditioning is controlled by the presenter and occupancy sensors are in place. All other air conditioning is currently on the main BMS schedule and therefore runs for 104 hours / week. (Air conditioners and AHUs are enabled for the period 07.00 – 23.00hrs Mon-Fri and 08.00hrs – 20.00hrs over the weekend all year round) After hours they can be activated by use of wall dial type selectors used to choose duration to extend the air conditioning by up to 6 hours.

There appear to be no holiday schedules and exceptions to normal operation for quiet periods do not appear to be part of the normal operating procedures.

Complaints of overheating tended to be in offices facing north or smaller studio areas rather than the large open areas. Windows are available to be opened to increase ventilation.

There are three cooling and ventilation systems according to different purposes:

- Extract fans (kitchens and toilets, workshop)
- Chillers (For cooling outside incoming air– air conditioning)
- Air Handling units (Ventilation purpose)

The heating component in HVAC is ignored here as the air is heated by gas.

These reports are based on 2004-2005 data therefore there will be some differences with actual current results.

Here is the percentage distribution for HVAC from the total electricity consumption.

(H)VAC %	Total electricity	27% kWh/yr	Level 3 (23.7%)[165]
27%	1,613,471 kWh/yr	435,637	**103,246 kWh/yr**

Table 7:29: HVAC energy load for level 3

According to the energy draft audit report for the Wigan and Vivian buildings back in 2003-2005[166] [167]a percentage distribution of the three different end-uses of energy for the HVAC component is shown in table 7:30 and figure 7:7.

[165] This % figure was calculated from the previous lighting chapter

[166] Cook, David, Energy Solutions Ltd, Victoria University of Wellington, *Wigan Building, Draft Energy Audit Technical Report,* 15 December 2005, Appendix C1,

[167] Energy Solutions Ltd, Victoria University of Wellington, *School of Architecture and Design Draft Energy Audit Report,* 14 May 2004, p.14,18

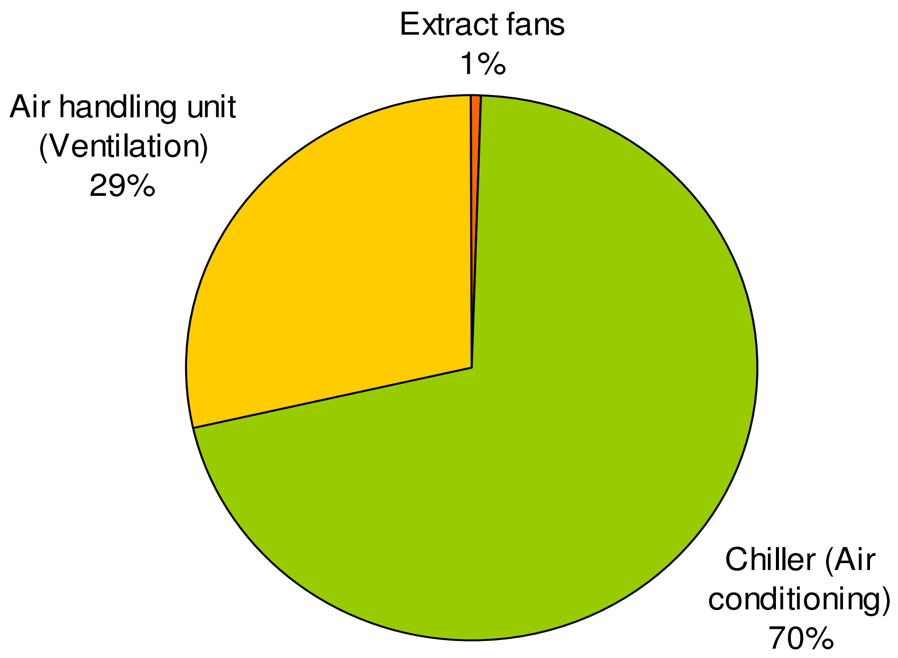

Figure 7:7: AHU, Chiller, Extract fans consumption percentage distribution[168]

Level 3 (23.7%)[169]	Chiller Load (70%)	Air Handling Unit Load (29%)
103,246 kWh/yr	72,272 kWh/yr	29,941 kWh/yr

Table 7:30: Chiller and Air Handling Unit Load

Extract fan energy consumption will be omitted as it only represents 1% of the HVAC consumption. It is considered too small to be considered.

The same reduction targets of 25%, 50% and 90% will also be applied here to consider various solutions.

[168] These percentages are calibrated from combining the Vivian and Wigan building data from each Draft Energy Audit Report
[169] This figure was calculated from previous lighting chapter

7.4.1 25% reduction scheme

Solution 1: ***Close down 50% of air conditioned spaces after class hours in trimester 1 and 2***

Savings can be achieved by turning off air conditioning in 50% of the computer labs closed after class hours in Trimesters 1 & 2 (equivalent to shutting down two labs in level 3).

36 hours in a week is the total air conditioning operation hours during the after class period of 5pm-11pm Mon-Fri, and 5pm-8pm Sat-Sun. Half of these labs can be shut down after class hours like the previous proposal of shutting down 50% of the computers (see Chapter 7.2 Equipment - Computer Use).

104 hours of total air conditioning operation per week x **37 weeks** in trimester 1 & 2 = **3848 hrs** (total air conditioner operation hours for trimester 1 and 2). In trimester 3, air conditioner operation is 801 hours. So the total for annual operation hours is 3848+801 = **4649 hours/yr.** In Trimester 3 despitefew students using the building in the summer months the whole computer lab's air conditioning will be on to cater for these few people.

So, 36 hours x 37 weeks in trimester 1 & 2 = **1332 hours** of after class hours of air conditioning operation. 50% of the labs can be shut down during this period to save electricity.

1332hrs / 4649 hrs x 100 = **28% of air conditioning hours could be reduced in a year.**

28% of 72,272 kWh/yr = 20,236 kWh/yr air conditioning load during the after-class period (assuming each computer lab has similar cooling load).

Since 50% of the labs are proposed to be closed, 20,236 /2 = **10,118 kWh/yr** will be saved from closing off 50% of computer labs in trimester 1 and 2.

This is a **10% overall HVAC saving** (10,118/103,246 kWh/yr x 100) from shutting down 50% of the computer labs during trimester 1 & 2 after class hours.

Solution 2: *Close off 100% of labs in Trimester 3*

There are 801 hours of air conditioning operation in computer labs during trimester 3. Since computers are available in studios, students can still have access to them, therefore closing down 100% of computer labs is viable when few students are present. The studios are open spaces which can achieve cooling in summer via natural ventilation through operable windows. The over-heating issue is not prominent in these spaces.

Despite the small number of students, even if there is only one student per lab, the air conditioning will be on to cater for that one person.

So, 801 hours / 4649 hours/yr = **17%** of cooling hours eliminated.
17% of 72,272 kWh/yr = 12,286 kWh/yr
12,286 / 103,246 = **11% overall HVAC savings** from shutting down all computer labs in Trimester 3

Solution 3: *Reduce the minimum position of the fresh air dampers during the heating season in winter.*

Overheating is a problem in summer and since the chillers are not used to cool spaces other than lecture theatres or computer labs (such as studios) the cooling system used in these is by employing fresh air. To facilitate this, fresh air dampers have been set at a minimum of 50% all year.[170] This 50% minimum fresh air damper

[170] *Fresh air is provided by two variable air handling units (AHUs) on the roof. It is distributed through ducts to each level of the building. The duct pressure is set to 450 Pa and the fresh air dampers are set to a minimum 50% supply air / cooling at 0.5 degrees and atrium cooling at 18 degrees.* (Energy Solutions SoAD Draft Energy Report)

regime is likely to be a requirement for about three months during summer. However, outside that period it is thought that too much fresh air is brought into the building that needs to be warmed up before it is distributed around the building. (This proposal will also incur gas savings from having less fresh air to heat)

The concentration of CO_2 in a space is used as an indicator of air quality. CO_2 measurements were taken from various parts of the building (in 2004-2005) which confirm that the ventilation rate is high. CO_2 readings were in the range of 430-650ppm (with damper set at 50%).[171] For most applications readings of 800-1000ppm are more than adequate. (See Table 7:30 below)

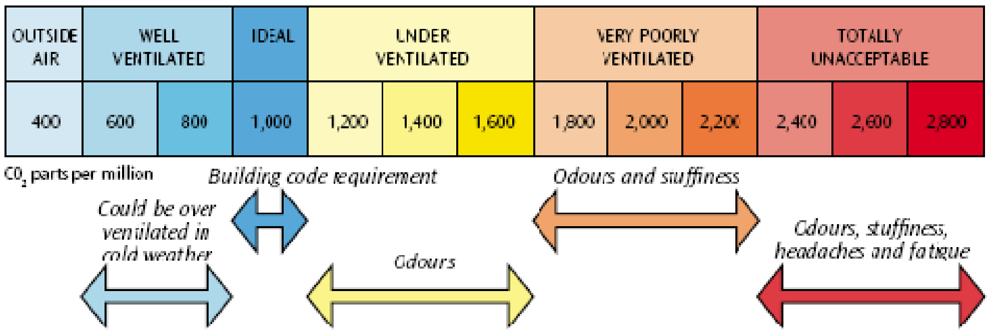

Figure 7:8: Carbon Dioxide as an indicator of classroom ventilation from BRANZ[172]

Since the ventilation rate is excessive for SoAD, it would be possible to set the dampers from 50% to a lower percentage (i.e. 10%) to achieve 1000 parts per million of CO_2.

Ventilation energy load is **29,941 kWh/yr** to maintain 430-650ppm (approximately 500ppm on average). By adjusting the damper setting

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[171] Energy Solutions Ltd, Victoria University of Wellington, *School of Architecture and Design Draft Energy Audit Report,* 14 May 2004, p.14

[172] BRANZ Ltd for Ministry of Education, *Designing Quality Learning Spaces: Ventilation & Indoor Air Quality,* <http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/PrimarySecondary/SchoolOpsPropertyManagement/VentilationIndoorAirQualityGuide.pdf> [accessed 14 June 2009] p.16

to achieve the ideal carbon dioxide ventilation requirement from the Building Code of 1000ppm, the school can reduce its AHU load.
Only 3 months of cooling is required at 50% damper setting (500ppm on average) during the mid November to mid February period (trimester 3).
So for 75% of the time (9 months out of 12 months) the CO_2 level can be 1000ppm which will be a reduction of 50% in the AHU energy use.
75% of 29,941 kWh/yr = **22,456 kWh/yr** which will be the equivalent of 9 months of the year on ventilation at approximately 500ppm.
To reduce the ventilation rate to achieve 1000ppm during 9 months of the year means that:

50% of 22,456 kWh/yr = **11,228 kWh/yr** can be saved.
This is a reduction of **11%** from the total HVAC load. (11,228/103,246 kWh/yr x 100)

Total low cost scheme savings:

Savings	**kWh/yr saved**
Close down 50% of air-conditioned spaces after class in trimester 1 & 2	**10,118**
Shut down all PC labs in Trimester 3	**12,286**
Reduce ventilation rate from 500ppm to 1000ppm	**11,228**
TOTAL HVAC energy of 103,246 kWh/yr	**33,632**

Table 7:31: Total low cost method savings kWh/yr

These measures achieve a combined total of 33% of savings, meeting the 25% reduction target.

7.4.2 50% reduction scheme

Solution: ***Change desktop PCs to laptops to reduce heat input into computer labs***

As the computer labs are located in the centre of the building which is well insulated from the exterior temperature, they will remain at a stable internal temperature throughout the year. However labs will require air conditioning throughout the year as there are heating loads from the occupants and PCs. They will particularly get warm during winter months as it is the busiest time, resulting in high heat output from computers and the occupants using them. However there is a possibility of switching to laptops which will have a lower heat output than the current desktop PCs. Desktop PCs are approximately more than twice the size of laptops (due to less efficient design) with more than twice the resulting heating load. The heating load of a PC is dependent on its power use. From the computer chapter it was found that laptop energy use is 65%-79% lower than that of desktop PCs depending on the specification. In the event that all SoAD desktops are converted to laptops, the heating load will diminish as the heat output of laptops will be significantly smaller. As the occupancy rating of the labs is irregular throughout the day, week and year, it is more complicated to take into consideration the heat output of the occupants.

Currently the temperatures in the labs are between 19-21 degrees (measured with a thermometer on the first week of July 2009 with people and air conditioning in place).

Converting desktop PCs to laptops (same specification) with79% reduction in power rating reduces the heat input. Therefore the air conditioning load is reduced by 79% of 72,272 kWh/yr = 57,095 kWh/yr

57,095/103,246 kWh/yr x 100 = **55% reduction in air conditioning load**

7.4.3 90% reduction scheme

Solution: ***Reduce / eliminate the active air conditioning time to the minimum that is reasonable through passive cooling methods and changing the level of cooling requirement perceived by occupants***

Another alternative is retrofitting the building so that it needs no active cooling system. Since mean temperature in Wellington during the hottest month (January) is 17 degrees Celsius[173] it is not necessarily critical to provide air conditioning. Also, during summer periods there are hardly any students, and during Trimesters 1 and 2, the outside temperature range is temperate so that it seems unnecessary to have air conditioning altogether. Since there is in any case more fresh air intake in summer, to eliminate air conditioning altogether seems reasonable.

Since the 1980s when there was a boom in the use of air conditioning, it became the norm or fashion to have air conditioning in all commercial spaces. This led to spaces that were over-cooled and often resulted in internal temperatures that made the occupants uncomfortable. This excessive perception of the requirement of cooling still prevails today where people became so accustomed to a narrow band of temperature thanks to the modern technology of active cooling and heating. In reality, human bodies are much more adaptable and capable of withstanding much larger temperature ranges.[174]

Therefore it seems reasonable to eliminate air conditioning since the outside temperature (especially in Wellington) is not extreme and as long as there is adequate fresh air intake, it does not seem like a

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[173] Maclean Chris, ' Te Ara - the Encyclopedia of New Zealand, "Wellington region - Facts and figures'", updated 20 November 2009 <http://www.TeAra.govt.nz/en/wellington-region/17> [accessed 27 July 2009]

[174] Heschong Lisa, *Thermal Delight in Architecture*, (The MIT Press; First edition, 1979) pp.20-30

difficult challenge for occupants to "put up with" higher temperatures than usual.

There are also other adjustments that can be made to the building fabric to prevent heat gain.
The application of solar radiation films to windows, for example, minimises heat gain resulting in 77% reduction in heat gain with the continuing benefit of daylighting.[175] Additionally, the implementation of double glazing and increased insulation in the roofwould also reduce heat gain and help protect from solar radiation in summerwhile the manual ventilation option by opening windows is still available. In the summerthere is very little activity therefore a damper setting of 10% is still adequate for fresh air intake. The added retrofits (solar films, double glazing and increased insulation) may also aid in overheating problems in staff offices that predominantly face north. There is existing external solar shading 1.2m in width to block out harsh high angle solar radiation. However this is not present on level 2 – which seems necessary as staff in level 2 have expressed that there are overheating problems in office spaces.

70% in energy reduction can be made by eliminating air conditioning throughout the whole year (See figure 7:7 VAC pie chart)
11% in energy reduction can be made by reducing fresh air intake (500ppm to 1000ppm) during non-cooling periods (9 months – trimester 1 and 2)

That is only a combined total of **81%.** Even if the ventilation rate in summer was increased to give 1000ppm CO_2 (which would probably

[175] 3M, "Window Films", <http://solutions.3m.com/wps/portal/3M/en_US/WF/3MWindowFilms/> [accessed 02 August 2009]

cause some overheating) it would still only result in 85% reduction overall.

It seems like 90% reduction is not possible without compromising fresh air intake (which will not meet the current Building Code requirements).

Since air quality cannot be compromised, the need for renewable electricity generation to meet the cooling load becomes apparent.

Around **9%** of HVAC load still needs to be met via electricity generation:

HVAC demand is 435,637kWh/yr for the whole SoAD.

9% of 435,637kWh/yr = 39,207 kWh/yr needs to be generated.

Solar generation has the advantage of peaking at the same time as peak air-conditioning loads and SoAD has the roof space available. Therefore PVs will be chosen for this exercise.

There is approximately 3000m^2 of roof space available.

On average a 1kWp PV panel array is 10m^2, which can produce 1000kWh per year costing $10,000 (include installation).[176]

To meet 39,207kWh, it would require 40 PV arrays resulting in 400m^2 of space and costing $400,000.

7.4.4 Guidelines for saving ventilation and air conditioning electricity use

- Dress appropriately for season to reduce demand on cooling and heating
- Reduce damper settings to eliminate excessive fresh air intake
- Rely on natural ventilation

[176] See Section, *7.6.1 Solar Power* for calculation method

- Reduce excessive standards of air conditioning (perhaps some spaces do not even need it?)
- Plan rooms to ensure maximum use – Close down rooms that are not in use
- Use laptops which have less heat output than desktop PCs
- Think about renewable electricity generation for air conditioning if this is inevitable

7.4.5 Conclusion

It is interesting to note that lighting savings schemes seem to be in contradiction tocomputer and HVAC saving schemes. To achieve savings in lighting requires bigger spaces like the studios to be closed down (with fewer computers) while closing down the computer labs will save more computer and HVAC energy use as the computers are concentrated in a smaller space. SoAD needs to consider these factors and decide which energy savings are worthwhile at the end of the day.

In order to make sure that air conditioning is not used excessively it is important for someone (i.e. the operations manager) to spot check the temperatures in the conditioned rooms to ensure that overcooling is not occurring. It might even be a good idea to have sensors that are calibrated to turn off when a certain temperature has been reached. It is advisable for someone to re-analyse what is required at SoAD and reconfigure the BMS to provide an efficient cooling and ventilating scheme for different periods of the year (i.e. for holidays and quiet times)

7.5 Space Heating - Gas Use

SoAD’s space heating is currently provided by gas which is used to power boilers that heat the majority of the spaces in winter. In the Vivian building gas is used for heating hot water circulated to radiators and in the Wigan building gas is used to warm incoming air via an air handling unit.[177] [178]The schedule for this air-handling unit is 7:30am to 11:30pm Monday to Friday and 9:00am to 8:00pm on weekends. There has also been use of supplementary electric heaters in staff offices especially in the southern side of the Vivian Street building during winter months which would result in increased electricity usage. Staff that work late in the university and at weekends will be without heating and this may also increase supplementary electric heating.

It is cheaper to purchase gas than electricity, making it a better economic option. In the GHG Emissions Reduction Plan Progress Report (Nov 2009), VUW decided not to switch from gas heating to electricity due to the higher operational cost although electric heating would lower the emissions as electricity purchased by SoAD is from renewable sources and NZ's electricity generation is predominantly from renewables.

The recorded internal temperatures around the various parts of the building (mainly studios and computer labs on different levels) range from 19 to 22 degrees. The lowest temperatures of 14 - 16 degrees were recorded when the heating was turned off and the hottest recorded temperature was 24 degrees. All these temperatures were consistently measured using a thermometer every week during the month of July 2009.

The GHG Reduction Plan Progress Report (Nov 2008)[179] claims that the heating set-point for the terminal units has been lowered to 20 degrees as standard across Victoria University. However, on

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[177] Energy Solutions Ltd, Victoria University of Wellington, *School of Architecture and Design Draft Energy Audit Report,* 14 May 2004, p.13
[178] Cook, David, Energy Solutions Ltd, Victoria University of Wellington, *Wigan Building, Draft Energy Audit Technical Report,* 15 December 2005, p.9
[179] Wilks, Andrew, Victoria University of Wellington, *Faculty of Architecture and Design GHG Emissions Reduction Plan Progress Update*, Internal Report, November 2008

numerous occasions offices and studios were found to have higher temperatures than this, averaging 21-22 degrees.

Both Vivian and Wigan buildings are single glazed. The joinery is aluminium with no thermal breaks in the frames. The north and south façades have significant amounts of glazing which can aid heat gain and heat loss. The presence of a small atrium space in the Wigan building and a large atrium space in Vivian Street allows the warm heated air to escape (See figure 7:11, 7:12 and 7:13). Although the atrium is a good source of daylight it is also problematic as it draws warm air from other spaces.


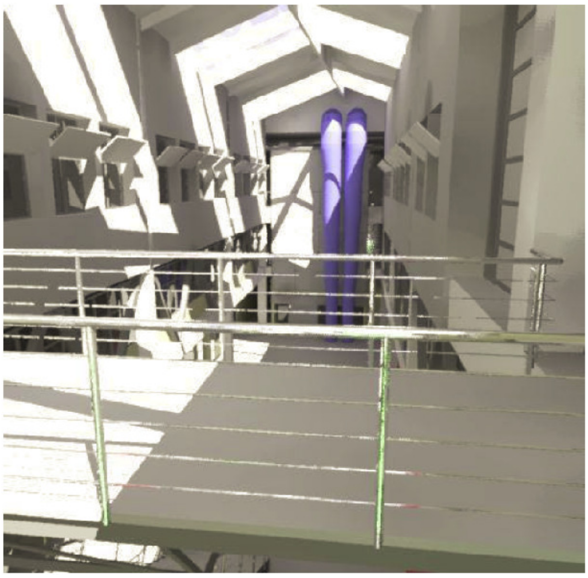

Figure 7:9 (Left): Exterior view of the north glazing on the atrium[180]
Figure 7:10 (Right): Radiance rendering of the atrium[181]

[180] Victoria University of Wellington, *Case Study 13, Schools of Architecture and Design, Wellington, Tertiary Education Institute, New Zealand,* <http://www.victoria.ac.nz/cbpr/documents/pdfs/task21-soa.pdf > [accessed 02 August 2009] p.1,3
[181] Ibid.p.1,3

Figure 7:11: (Left) Photograph of the atrium space – facing North[182]
Figure 7:12: (Right) Photograph of interior space of atrium facing towards Wigan Building (taken October 1995, 2pm)[183]

The open floor planning of the buildings means there is a lack of enclosed spaces to retain the heat. Existing doors that could help to enclose the spaces into smaller units are always left open (see figure 7:13). This makes it is easy for heat to escape to the atrium and thence through its single glazed roof. High floor to ceiling heights in offices become problematic in winter months as warm air rises to the ceiling, failing to provide heat to the occupants. Staff offices are also highly glazed with radiators placed beneath the windows.

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[182] Ibid.p.1,3
[183] Ibid.p.1,3

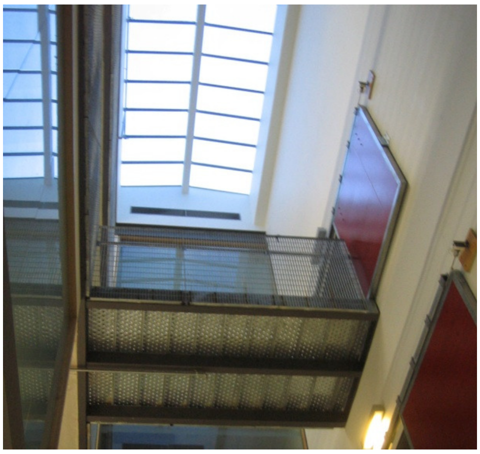

Figure 7:13 (Left): Studio doors left open to the atrium, taken by the author
Figure 7:14 (Right): Atrium in Wigan building looking up, taken by the author

The gas consumption for 2007 as calculated in the carboNZero audit was **726,301 kWh/yr**.

The three reduction targets (25%, 50% and 90%) will be applied to explore various ways of reducing gas use.

7.5.1 25% reduction scheme

Solution: *Reduce heating period to 5 months by eliminating heating in summer*

According to the gas invoices checked for carboNZero 2007 calculations, (See Table 7:32) there was no gas use during the summer months of January to April for the Wigan building (heating period of 9 months). It appears that the boiler was switched off. However in the Vivian building it appears that there was still a small gas consumption even during January, February and March when the internal temperature is warm enough to not require any active heating (heating period of 12 months). Evidence for this is the fact a corridor radiator in the Vivian building was on for March 25th at 8:30am on a day predicted to be warm and sunny. Such radiators should have been turned off completely or at least should turn off with their thermostat when the internal temperatures have reached a reasonable level. This is a sign that the heating period is not controlled or planned properly and that the boilers may be being used even when not necessary.

Because NZ has a temperate climate a 5 month heating period for the North Island is recommended as sufficient in BRANZ's ALF 3.1.1[184]. Through BMS scheduling, the following gas savings can be made by simply reducing the heating period.

Wigan Building Heating Period	**Totals (kWh)**
~~30/12/06 to 30/01/07~~	~~0.00~~
~~31/1/07 to 28/2/07~~	~~0.00~~
~~1/3/07 to 30/3/07~~	~~0.00~~
31/3/07 to 30/4/07	3,735.27
1/5/07 to 31/5/07	3,593.35
~~1/6/07 to 30/6/07~~	~~2,298.20~~
~~1/7/07 to 31/7/07~~	~~2,409.64~~
1/8/07 to 30/8/07	10,587.55
31/8/07 to 28/9/07	13,501.77
29/09/07 to 31/10/07	11,252.26
~~1/11/07 to 30/11/07~~	~~1,323.36~~
~~1/12/07 to 19/12/07~~	~~0.00~~
~~20/12/07 to 30/1/07~~	~~3.44~~
Total	**48,705**
Vivian Building Heating Period	**Totals (kWh)**
~~30/12/06 to 30/01/07~~	~~-1,640~~
~~31/1/07 to 28/2/07~~	~~2,698~~
~~1/3/07 to 30/3/07~~	~~2,374~~
~~31/3/07 to 30/4/07~~	~~24,077~~

[184] Stoecklein A. and Bassett M. "ALF3: The Annual Loss Factor Method, 3rd edition," (Version 3.1.1) Judgeford, Copyright (c) 2000, BRANZ

~~1/5/07 to 31/5/07~~	~~58,804~~
1/6/07 to 30/6/07	130,973
1/7/07 to 31/7/07	133,304
1/8/07 to 31/8/07	125,905
1/09/07 to 28/9/07	60,220
29/09/07 to 31/10/07	60,444
~~1/11/07 to 30/11/07~~	~~56,684~~
~~1/12/07 to 21/12/07~~	~~21,966~~
~~22/12/07 to 30/1/08~~	~~1,789~~
Total	**677,596**

Table 7:32: SoAD's carboNZero gas consumption records for 2007

Table 7:32 shows gas usage for heating during 5 months of the year and this yields the following savings.

Wigan Building

Eliminate heating during the lowest gas consumption months of November, December, January, February, March June and July

2298.20 + 2,409.64 + 1323.36 + 3.44 **= 6035 kWh saved per year**

Vivian Building

No heating in the following months

November, December, January, Feb, March, April and May

1789+21,966+56684+2374+2698+ (-1640) +24,077+58,804 (this is how it was calculated in carboNZero data)

= 166,751 kWh saved per year.

Therefore, (6035+166,751 kWh/yr) / 726,301(total gas use) kWh/yr =

24% gas is saved by reducing the heating period to 5 months

This means the revised gas consumption for the year is 726,301-166,751 = **559,550 kWh/yr.**

So, simply reducing the heating period to the recommended 5 months and also possibly eliminating unnecessary heating to some spaces (like the atrium or corridors), results in a total saving of 24%, which is close to the Kyoto Protocol target.

To further reduce heating demand, another possible way is to reduce heating in spaces that are intermittently used. From the total floor space of the building 11% does not necessarily need to be heated. These spaces are: (See figure 7:15)

- Corridor 351 = 77.2m²,
- Wigan Corridor 363 = 31.6m²,
- Atrium space = 260m² approx. (This is located in level 1, but for this exercise it is assumed to be located on level 3 as it passes through this level as well)

There is a total of 3,114m^2 in level 3.

= (77.2m^2+31.6m^2+260m^2) / 3114m_2 x 100) = **11% of unheated floor space**

Assuming that heating load is proportional to floor area, 11% of gas energy for 5 months (726,301 kWh/yr – 175,406 kWh/yr) = **60,598 kWh/yr** saving from eliminating heating in some spaces in the building.

This is an **8%** saving (60,598 kWh / 726,301 kWh x 100)

It is difficult to calculate the savings from reducing heating in these areas as the whole school is open for heat flow. However enclosing spaces into “heat cells” would appear to offer considerable heat savings.

7.5.2 50% reduction scheme

The World Health Organization (WHO) recommends a minimum indoor temperature of 18℃, and ideally 21℃ for babies or elderly people. The average daily indoor temperature in the winter for most New Zealand houses is just 16℃.[185] The average internal temperature in SoAD is 20 degrees or above (20 degrees being the standard for all VUW buildings).

Using the ALF (Annual Loss Factor) Version 3.1.1 software, it is possible to do a simple calculation of heat loss and gain. Offices are generally located at the periphery of the building with large areas of glazing and high floor to ceiling heights. A standard office was selected and modelled in four different peripheral locations (NW, NE, SE and SW – See Figure 7:15) to discover the heat gains and losses. By changing the parameters using ALF (such as increasing insulation, installing double glazing) possible savings can be ascertained. Because ALF is designed for residential spaces (up to 2 storeys high) there is a limitation in using this program and a level of inaccuracy when trying to apply it to SoAD . It can only be used as a very general indicator of the building's heat loss and heating demand. Obviously, there are spaces in the building that are not close to the windows and have a big floor space (like the studios) but for the purpose of this exercise these factors are ignored.

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185 Science Media Centre, *Cold houses and impact on health*, 18 June 2008, <http://www.sciencemediacentre.co.nz/2008/06/18/cold-houses-and-impact-on-health/> [accessed 04 August 2009]

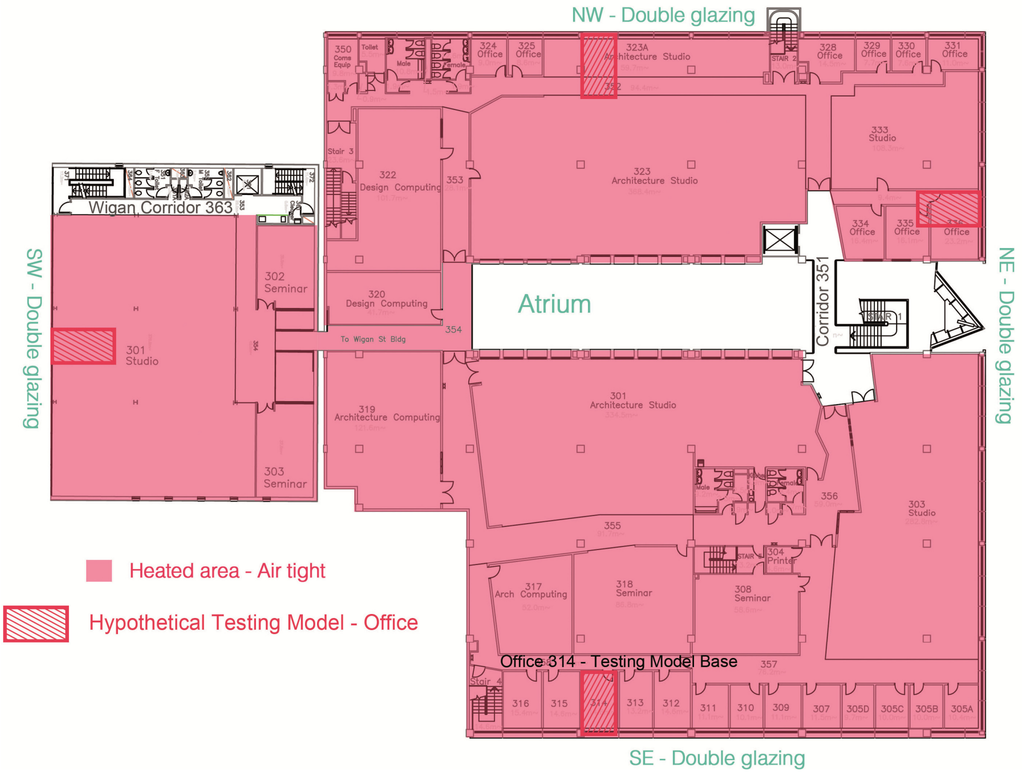


Figure 7:15: Level 3 plan of heated space and unheated space

As indicated by the red square above in figure 7:15, office 314 on the SE side is the test model for all four sides of the building (which will differ in solar gain). The parameters of the office are shown below in figures 7:16 and 7:17.

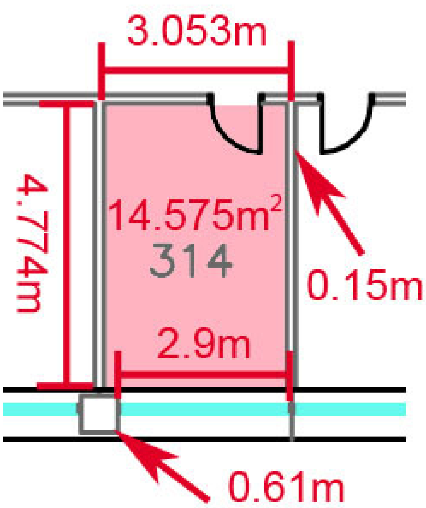


Figure 7:16: Level 3 standard model office plan on SE side

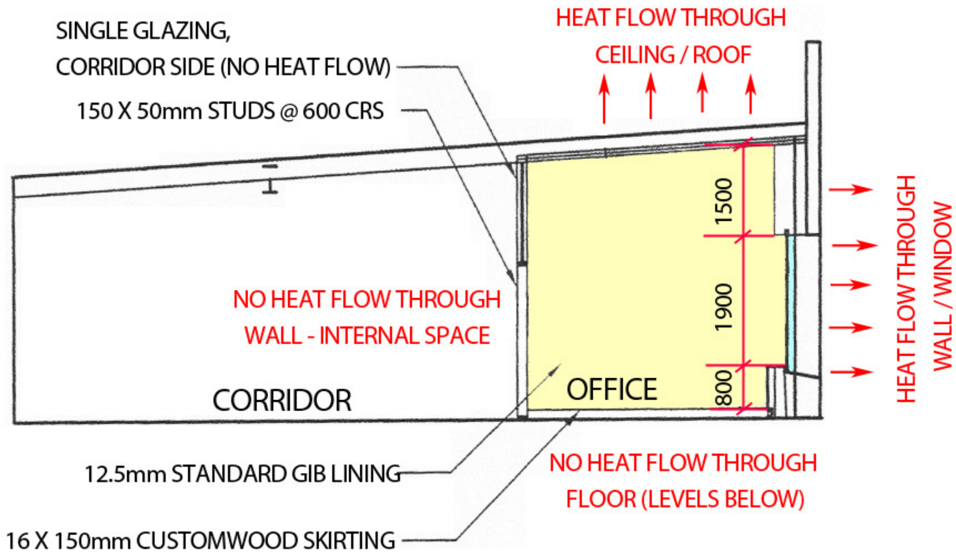


Figure 7:17: Level 3 standard model office section on SE side

Because the test office is located on level 3 (top level of the Vivian building) there will be heat flow through the ceiling, windows and the outside wall. There will be no or very little heat flow through both the internal walls and the floor. Level 2 and Level 1 will have no heat flow through ceiling and floor, so this calculation would be an overestimate of heat flow in the building rather than an underestimate.

For ALF modelling assumptions for this room see Appendix 4.

Heat Loss/Gain Result for current operating standard

Office	SE facing	NE facing	SW facing	NW facing
Floor Loss	**0 kWh/yr**	0 kWh/yr	0 kWh/yr	0 kWh/yr
Wall Loss	**315 kWh/yr**	315 kWh/yr	315 kWh/yr	315 kWh/yr
Window Loss	**790 kWh/yr**	790 kWh/yr	790 kWh/yr	790 kWh/yr
Roof Loss	**177 kWh/yr**	177 kWh/yr	177 kWh/yr	177 kWh/yr
Air leakage	**238 kWh/yr**	238 kWh/yr	238 kWh/yr	238 kWh/yr

Warm-up	**482 kWh/yr**	482 kWh/yr	482 kWh/yr	482 kWh/yr
Total load	**2003 kWh/yr**	2003 kWh/yr	2003 kWh/yr	2003 kWh/yr
Solar gain	**471 kWh/yr**	1076 kWh/yr	505 kWh/yr	1273 kWh/yr
Internal gain (1 occupant)	**543 kWh/yr**	543 kWh/yr	543 kWh/yr	543 kWh/yr
Total gain	**1013 kWh/yr**	1619 kWh/yr	1048 kWh/yr	1815 kWh/yr
Gain load ratio	**51%**	81%	52%	91%
Usefulness of gains	**70%**	59%	69%	55%
Useful gains	**707 kWh/yr**	949 kWh/yr	724 kWh/yr	1007 kWh/yr
Required heating energy	**1295 kWh/yr**	**1054 kWh/yr**	**1279 kWh/yr**	**996 kWh/yr**

Table 7:33: Heat gain/loss for four offices with different orientations

The only factor that differs is the solar gain which is dependent on orientation. This in turn, determines the useful gains. Required heating energy is therefore slightly different for each office.

50% reduction schemes

Taking the highest required heating energy of 1,295kWh, which is the office facing SE (the real office on which the modelling is based) an attempt is made to reduce its heating energy load by implementing various schemes.

Certain things are more worth doing than others as they save more energy, for instance increasing occupancy to two staff members per office saves very little energy compared to retrofitting windows with double glazing. So it may be worthwhile to spend extra on schemes that make the most difference.

Solution 1: ***Increase wall insulation from R1.07 to R1.7***

Currently the average wall R value is 1.07 (See appendix 7 for calculation). This needs to be increased to 1.7 in order for the combined savings total to reach 50%. This R value could be achieved with a slight loss of floor space but would require a capital outlay.

Thickness (mm)	Sheep Wool	Polyester	Cellulose (Macer. paper)	Mineral/Glass Fibre	Expanded Polystyrene
30 mm	0.5	0.5	0.5	0.6	0.7
40 mm	0.6	0.7	0.7	0.8	1.0
50 mm	0.8	0.8	0.9	1.0	1.2
60 mm	0.9	1.0	1.1	1.2	1.4
70 mm	1.1	1.2	1.3	1.3	1.7
75 mm	1.2	1.3	1.4	1.4	1.8
80 mm	1.2	1.3	1.5	1.5	1.9
90 mm	1.4	1.5	1.6	1.7	2.1
95 mm	1.5	1.6	1.7	1.8	2.3
100 mm	1.5	1.7	1.8	1.9	2.4
110 mm	1.7	1.8	2.0	2.1	2.6
120 mm	1.8	2.0	2.2	2.3	2.9
130 mm	2.0	2.2	2.4	2.5	3.1
140 mm	2.2	2.3	2.5	2.7	3.3
150 mm	2.4	2.5	2.7	2.9	3.6
200 mm	2.9	3.3	3.6	3.8	4.8
250 mm	3.6	4.2	4.5	4.8	6.0

Table 7:34: List of conservative R-values for selected insulation materials[186]

Solution 2: ***Change single glazed window to double glazing with argon filling and low emissivity coating – with wood/uPVC window frame***

Simply by changing the windows (see above) can save 43% of heating energy (See table 7:35) (and would also save on cooling

[186]Stoecklein A. and Bassett M. "ALF3: The Annual Loss Factor Method, 3rd edition," (Version 3.1.1) Judgeford, Copyright (c) 2000, BRANZ

load). Additional solutions could be to add thermal curtains or blinds to help reduce heat loss in winter and limit solar gains in summer, although these have not been calculated here.

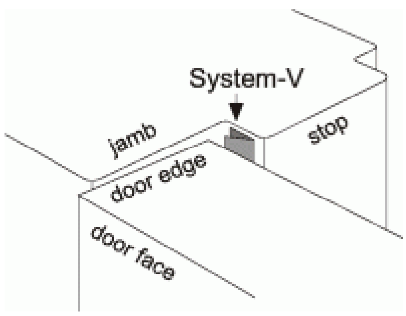
Solution 3: *Increase ceiling insulation from R1.9 to R4.8*

Currently there is 100mm of fibre glass insulation in the roof. Increasing the R value of the roof to 4.8 results in an increase in insulation thickness to 250mm. This would have to be attached to the underside of the ceiling. Even higher insulation is possible but would result in significant changes to the existing servicing on the ceiling and would be more expensive.

Solution 4: *Air tightness*

Airtightness can be achieved by the following methods.
To ensure that the heated space in Figure 7:15 is airtight, the doors need to be self-closing to lock in the "heat cells" and prevent heat from escaping to the atrium.

- **V-Seal weather/draught stopping**
  Door and window weather stripping reduces draughts, making spaces easier to heat. It stops heat loss through gaps in doors and windows. This can be achieved using a flexible, adhesive-backed vinyl strip that folds into a V shape to fill gaps from 1mm to 10mm. It is inexpensive ($50 NZ per 20m roll), easy to install, and will last a long time. [187]



[187] Community Energy Action Charitable Trust, "Community Energy Action Retail Shop", <http://www.cea.co.nz/retail-shop> [accessed 15 August 2009]

Figure 7:19: V-Seal weather/draught stopping seals[188]

- **Draught-stops for external doors (doors facing the atrium or to the outside)**

Sometimes doors do not hang in their frames squarely, or there is a gap between the bottom of the door and the floor. Draught stops for external doors prevent cooler outside air forcing its way inside. Draught excluders consist of a PVC carrier and a brush. This is a cheap way of making spaces air tight ($8 NZ per door seal strip). [189]

Figure 7:20: Typical Draught Excluder[190]

The combined saving schemes result in the following changes:

Office	SE facing	50% savings	Savings	Scheme
Floor Loss	0 kWh/yr	0 kWh/yr		
Wall Loss	**315 kWh/yr**	**279 kWh/yr**	**47 kWh/yr**	Increase insulation
Window Loss	**790 kWh/yr**	**224 kWh/yr**	**566 kWh/yr**	Double glazing
Roof Loss	**177**	**70 kWh/yr**	**107**	Increase

[188] Ibid.
[189] Ibid.
[190] Ibid.

	kWh/yr		kWh/yr	insulation
Air leakage	**238 kWh/yr**	**207 kWh/yr**	**31 kWh/yr**	Air tightness
Warm-up	482 kWh/yr	482 kWh/yr	482 kWh/yr	
Total load	2003 kWh/yr	1262 kWh/yr		
Solar gain	***471 kWh/yr***	***363 kWh/yr***	***108 kWh/yr***	Double glazing
Internal gain (1 occupant)	543 kWh/yr	543 kWh/yr	543 kWh/yr	
Total gain	**1013 kWh/yr**	**906 kWh/yr**		
Gain load ratio	**51%**	**72%**		
Usefulness of gains	**70%**	**69%**		
Useful gains	**707 kWh/yr**	**627 kWh/yr**		
Required heating energy	**1295 kWh/yr**	**635 kWh/yr**	**660 kWh/yr**	

Table 7:35: SE office 50% heat energy savings

(1295-660 kWh) /1295 kWh x 100 = **49% savings** from replacing windows (argon filled, low emissivity coating, thermally broken frames), increasing roof and wall insulation and making the building airtight.
From the savings column it is clear that double glazing and increasing roof insulation made the biggest savings.

7.5.3 90% reduction scheme (50% schemes as the base)

Solution 1: *Change the heating period to only morning and evening heating* (7:00am to 9:00am and 5:00pm to 11:00pm)
The heating schedule needs to be reduced from all day to just the morning and evening when the temperatures drop. Adequate insulation and double glazing should be sufficient to keep stable temperatures inside during the day.

Solution 2: *Change the ceiling height from 4m to 2.5m*
False ceilings in the offices would reduce the volume to be heated (the extra ceiling space could be used as storage space. A false ceiling is a dropped ceiling, fixed below the structure.

Solution 3: *Increase occupancy from one staff member to two*
Methods to increase office occupancy include encouraging more staff to work at home (this could be beneficial for staff that have young children), hot-desking by having staff share the office at different times of the day, and for offices that are reasonably spacious, two staff could work in the same office. However this could be transferring the heating problem somewhere else rather than dealing with it internally.
This internal heat gain is only representative for staff offices, but since during the winter month the school is busiest this would tend to happen with students clustered in other spaces such as studios. Again, certain spaces should be closed to ensure that each space is used at its maximum occupancy and these sorts of changes need to be made by an operations manager overseeing all the school's activities.

Solution 4: *Reduce heating level to 18 degrees*
Changing the heating level standard to 18 degrees meets the minimum standard set by the WHO. The presence of thermostats on radiators could ensure that these spaces are at this temperature. Currently, the temperature ranges significantly from space to space.

Solution 5: ***Increase wall insulation to R 4.8***

250mm of fibre glass is needed to achieve R 4.8 in the walls. This would need to be added in the interior, therefore reducing floor space.

The combined saving schemes result in the following changes:

Office	SE facing	90% savings	Savings	Scheme
Floor Loss	**0 kWh/yr**	**0 kWh/yr**		
Wall Loss	**315 kWh/yr**	**57 kWh/yr**	**258 kWh/yr**	Increase insulation
Window Loss	**790 kWh/yr**	**103 kWh/yr**	**687 kWh/yr**	Double glazing
Roof Loss	**177 kWh/yr**	**32 kWh/yr**	**145 kWh/yr**	Increase insulation
Air leakage	**238 kWh/yr**	**60 kWh/yr**	**178 kWh/yr**	Air tightness
Reduce volume	**482 kWh/yr**	**439 kWh/yr**	**43 kWh/yr**	False ceiling
Total load	**2003 kWh/yr**	**690 kWh/yr**		
Solar gain	***471 kWh/yr***	***244 kWh/yr***	***108 kWh/yr***	Double glazing
Internal gain	**543 kWh/yr** 1 occupant	**326 kWh/yr** 2 occupants	**217 kWh/yr** 1 occupant	Increase occupancy
Total gain	**1013 kWh/yr**	**570 kWh/yr**		
Gain load ratio	**51%**	**83%**		
Usefulness of gains	**70%**	**89%**		
Useful	**707**	**505 kWh/yr**		

gains	**kWh/yr**			
Required heating energy	**1295 kWh/yr**	**185 kWh/yr**	**1110 kWh/yr**	

Table 7:36: SE office 90% heat energy savings

1110 kWh /1295 kWh x 100 = **86% savings** can be made by reducing the heating schedule, heating level, ceiling height and increasing insulation and occupancy level.
From the savings column it is clear that double glazing and increasing insulation made the biggest savings.
This all that can achieved without compromising the heating standard of 18 degrees. Further increase in insulation makes very little difference. This would mean investing in renewable energy generation to meet the 90% reduction target (see renewable electricity generation chapter 7.6).

Other reduction methods

Ideally the school could install automated thermal shutters on the outside to reduce heat loss at night through windows (they could be used to prevent solar heat gain during summer). Alternatively the school could install thermally-lined curtains to minimise heat loss at night. This would be a more cost effective solution than double glazing.

As previously explored, 50% of the computer labs and studio spaces would be closed off after class hours. This would result in elimination of corresponding lighting and heating energy use. Therefore certain additional savings are expected from this proposal.

7.5.4 Guidelines for saving gas energy use

- Increase wall, floor and ceiling insulation
- Retrofit double glazed argon filled, low e coated windows in thermally broken frames
- Decrease heating levels and heating period
- Decrease ceiling height
- Increase air tightness
- Ensure heated spaces are differentiated from spaces that do not require heating
- Dress appropriately for the season
- Heat only during the critical winter months
- Avoid excessive ventilation in winter.

7.5.5 Conclusion

It seems clear that 25% of the savings could be achieved by eliminating excessive use. It is a surprise that heating is on in the summer, costing money.
Carefully considering different reduction options shows that a 50% reduction is still within reasonable limits. Heating demand is still within WHO recommendations although some monetary investments are required, such as double glazing which is expensive. No significant behavioural changes are required to meet a 50% reduction. However, a 90% reduction is much more difficult to meet. It comes to the point where conventional thermal comfort may not be available throughout the whole day. It should be noted that a well-designed building (i.e. with good insulation), should not require any active heating. Therefore, the suggested “sacrifices” SoAD occupants are expected to make to reduce the heating load by 90%

would have been unnecessary if the building had been designed to be zero energy to begin with. What the study does indicate is that SoAD's building is poorly designed with its excessively high ceiling height and large amount of single glazing. Walls and ceilings are insulated to the minimum standards, which is not adequate for the building to become zero in its heating load.

Again to achieve a 90%+ reduction in energy it seems best to explore renewable energy generation rather than spending the money to upgrade the building fabric.

7.6 Renewable electricity generation and savings comparison

Previous calculations and discussion showed the difficulty in achieving a 90% reduction in energy use, as this will involve high-cost investments such as switching to LED lighting and converting to laptops.

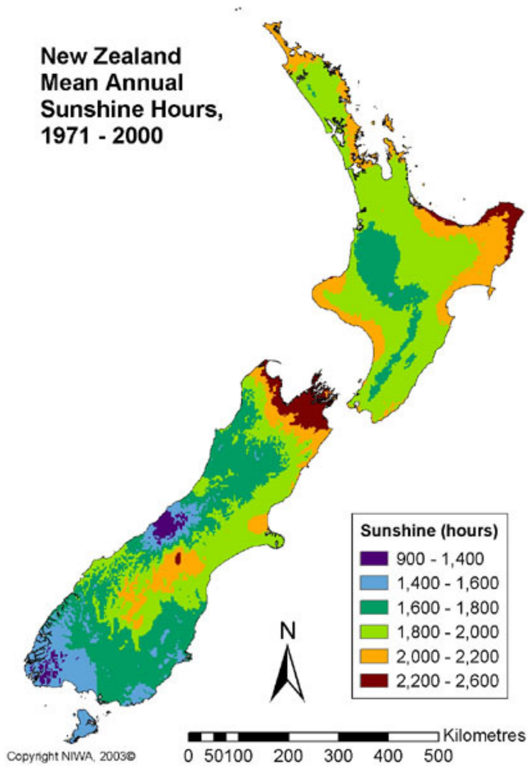
To ensure that SoAD activities are supported by carbon zero electricity the school should generate its electricity from an appropriate renewable source. If SoAD wants to keep its current activities without sacrificing energy use, this would seem to be the only option to guarantee carbon neutrality in energy use. The great advantage of generating electricity is that after the pay-back period, the school is guaranteed free electricity for the remaining life span of the electricity generator. Also any electricity savings SoAD makes (a 25% or 50% reduction) would be an added bonus as surplus electricity can be sold back to the main provider. Therefore it seems a wise choice to investigate renewable electricity generation.

This also addresses the broader issue of reducing reliance on non-renewable electricity. Renewable electricity provides certainty in electricity prices as the cost of renewable electricity is not affected by rising fossil fuel prices.[191] This could be a great opportunity for SoAD to be leaders in this field.

Two types of commercially viable renewable electricity generation option are explored below, through weighing cost, space and efficiency issues.

7.6.1 Solar power

Wellington receives 2000 sunshine hours on average, which is considered reasonably high in global terms. (Freiburg in Germany is known for its pioneering use of solar panels but only receives 1700 sunshine hours annually.)[192]



[191] New Zealand Wind Energy Association, *Electricity Supply and Wind Generation*, October 2008, <http://windenergy.org.nz/documents/factsheets/Electricity.pdf> [accessed 12 September 2009] p.1

[192] Emigrate NZ, New Zealand's Sunshine, *A place in New Zealand's Sunshine,* <http://www.emigratenz.org/NewZealandSunshine.html> [accessed 21 August 2009]

Figure 7:21: Map of NZ annual sunshine hours[193]

Electricity generation

Over a whole day, a well-located PV panel will typically generate between 2.5 and 5 times its rated power output. A PV array of between 8m² and 10m² can produce about 1kW of power when operating effectively.[194] A 1kWp (kilowatt peak) PV panel could produce between 2.5kWh (kilowatt hours) and 5kWh per day, or between 880kWh and 1750kWh per year.[195] Therefore a reasonable figure for PV panel performance in the North Island is approximately 1000 kWh per 1kW of PV panel.[196]

Cost

In 2008, PVs cost $9 – $13 per watt installed, making a 2 kW grid linked system cost between $18,000 and $26,000. These costs include cabling, metering apparatus, mountings and frames for panels, and any consents required.[197] The cost of generating one unit (kWh) of electricity from a solar panel is calculated to be around 50c/kWh to 70c/kWh, although this can vary considerably. The cost of installation and related equipment, such as an inverter and battery bank, for a 1 kW stand-alone power system can be between $20,000

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[193] Mullan Brett, Tait Andrew and Thompson Craig. Te Ara - the Encyclopedia of New Zealand, "Climate", updated 2 March 2009, http://www.TeAra.govt.nz/en/climate/1/3 [accessed 02 September 2009]
[194] Right House, "Solar Panels" <http://www.righthouse.co.nz/products/generation/solar> [accessed 12 September 2009]
[195] EECA Energy Wise, "Solar electricity generation (photovoltaics)," <http://www.energywise.govt.nz/how-to-be-energy-efficient/generating-renewable-energy-at-home/solar-electricity-generation> [accessed 12 September 2009]
[196] Vale Robert, Victoria University of Wellington, personal communication based on a monitored whole house installation on Waiheke Island, 12 September 2009
[197] LEVEL, The authority of Sustainable Buildings, "Photovoltaic systems", <http://www.level.org.nz/energy/renewable-electricity-generation/photovoltaic-systems/> [accessed 21 September 2009]

to $35,000.[198]

Lifespan

PV panels have very low running costs, with no fuel inputs, no moving parts, very little maintenance beyond panel cleaning, and a long life expectancy as panels and frames last over 30 years, and inverters generally over 20 years. (Batteries for stand-alone systems have higher maintenance and renewal requirements.) Grid-connected photovoltaic systems may be able to export surplus electricity to the grid, by arrangement with an electricity retailer. In mid 2008 the best offer in New Zealand was a one-for-one buyback scheme by Meridian where the retailer pays the same rate as they charge for electricity taken from the grid. This figure includes the lines rental portion of the kWh/hr charge.[199]

For this exercise a system connected to the grid is assumed. At this stage the embodied energy of the PV system has not been considered.

Solar Power generation for SoAD

There is approximately 3000m² of roof space available over the Wigan and Vivian St buildings.

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198 EECA Energy Wise, “Solar electricity generation (photovoltaics),” <http://www.energywise.govt.nz/how-to-be-energy-efficient/generating-renewable-energy-at-home/solar-electricity-generation> [accessed 12 September 2009]

199 LEVEL, The authority of Sustainable Buildings, “Photovoltaic systems”, <http://www.level.org.nz/energy/renewable-electricity-generation/photovoltaic-systems/> [accessed 21 September 2009]

Figure 7:22: Aerial View of SoAD roof space[200]

This assessment assumes that the average 1kWp PV panel array is 10m², produces 1000kWh per year and costs $10,000, including installation.

The available roof area can contain approximately 300 such arrays producing 300,000kWh/yr and costing 3 million dollars. This is only 12% of the total energy demand of 2,339,772 kWh (electricity and gas) and does not even meet half the lighting demand for SoAD.

To provide 100% of SoAD's energy, 2,340 PV arrays are required, costing 23.4 million dollars and taking 23,400m² or 2.34ha of land, which is nearly eight times the size of SoAD's roof space.

To provide all electricity from solar (1,613,471 kWh) 1,614 PV arrays are required, costing 16.1 million dollars and taking 16,140m² or 1.61ha of land, more than five times SoAD's roof space.

This suggests a lot of money and land are required to meet SoAD's energy demand. Therefore only if the school first implemented the three target savings of 25%, 50% and 90% might it be sensible to try

[200] Google Earth 5.0, <http://earth.google.com> [accessed 29 September 2009]

and supply the remaining energy using PVs.

Energy Reduction	**Energy required**	**PV panels needed**	**Land requirement**	**Cost**
25% Reduction	1,754,829 kWh/yr	1,754	17,540m² / 1.8 ha	$ 17.5 million
50% Reduction	1,169,886 kWh/yr	1,170	11,700m² / 1.2 ha	$ 11.7 million
90% Reduction	233,977 kWh/yr	234	2340m2	$ 2.34 million

Table 7:37: The effect of different energy reduction strategies

Only by reducing SoAD's energy demand by 80-90% can the demand be met by PV panels on the roof.

Solar power energy generation by PVs is too expensive requiring high initial capital costs and unless drastic energy reductions are made a significant amount of land is required increasing the cost even more. If SoAD wants to be self sufficient with what it can produce on its roof it would need to reduce its energy use by 88%. Ironically peak energy is generated from PVs in summer when the school is least busy. Hence PVs do not seem to be the best option as the seasonal outputs are not synchronised with the SoAD's demand.

7.6.2 Wind power

New Zealand is a windy country and Wellington is known as a windy city (most wind farms in NZ are located close to Wellington or within the Wairarapa area to the north). A wind turbine in Wellington will produce electricity for about 90% of the time.[201]

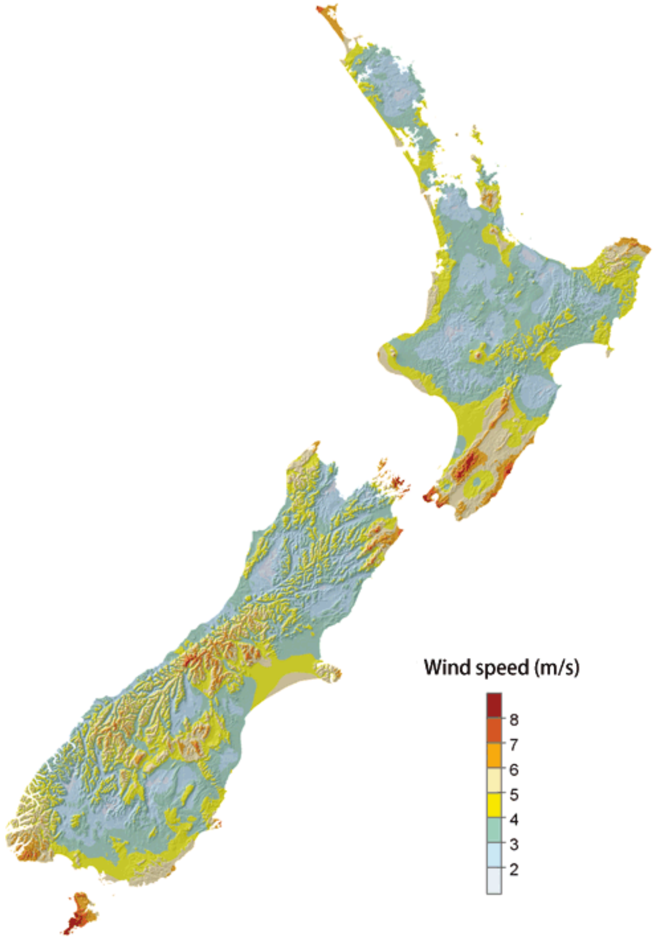

Figure 7:23: Average Wind speed in New Zealand [202]

New Zealand has consistently strong wind conditions compared with most countries, which makes wind power generation much more reliable. For example, the Brooklyn wind turbine is one of the best-performing turbines of its class in the world. Its capacity factor (the percentage of time it is expected to operate at its full potential) has averaged almost 48% over the past eight years, compared with an

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[201] New Zealand Wind Energy Association, *Electricity Supply and Wind Generation*, October 2008, <http://windenergy.org.nz/documents/factsheets/Electricity.pdf> [accessed 12 September 2009] p.2

[202] NIWA, <http://www.niwa.co.nz/__data/assets/image/0004/50539/renewable3_large.gif> [accessed 21 September 2009]

international average capacity of 23% for all wind farms globally. The Te Äpiti wind farm's capacity is around 45%, while Project West Wind on the southern west coast of Wellington is predicted to have a capacity factor around 47%, giving it the potential to be a world-leading wind farm. Project West Wind will be generating electricity for over 90% of the time.[203] The main limitation of wind generation is that electricity can only be produced when the wind is blowing. Therefore a reasonable range for the operating load factor of a wind generator is 20–50%.[204]

Location

This hypothetical wind turbine could be located somewhere near Wellington (off-site) especially near or in an existing wind farm such as the major wind farm under construction at West Wind. Because the location is really important for the efficiency of the wind turbine, it would be best if SoAD could either invest in one of the turbines that are being erected at West Wind, or commission one as part of the scheme, using the expertise of those involved. The purchase or lease of this land will add further cost to the wind turbine. According to Greenpeace's *'Yes2Wind'* project[205] a rough guideline for the required space for a wind turbine is 10,000 kW per 1,000,000 m², but only 2-3% of the land area would be occupied by the turbines and access tracks. The remainder can be used for other purposes, such as farming or as natural habitat. As 3% of 1,000,000m² is 30,000m², a 500 kW turbine (see Windflow 500 below) would need roughly 1,500m² or 0.15ha.

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203 Meridian Energy, "Facts about Wind," 2 May 2005, <http://www.meridianenergy.co.nz/NR/rdonlyres/AEB2EA1C-256F-4017-B7AC-9CBDCC24E39C/22487/Facts2babout2bWind2bmay2b2005.pdf> [accessed 28 September 2009]

204 Ministry of Economic Development, *New Zealand's Energy Outlook to 2030, September 2006* <http://www.med.govt.nz/upload/38641/eo-2006-final.pdf> [accessed 29 September 2009] p.97

205 Greenpeace NZ, Yes2Wind, <http://www.yes2wind.co.nz/faq1.5.19.php> [accessed 29 September 2009]

Lifespan

Current wind turbines generally have a lifespan of around 20 years, during which both the gearbox and generator may need replacement.[206]

WINDFLOW 500 – The two-bladed, 500 kW wind turbine

Windflow 500 is the only large scale wind turbine manufactured in New Zealand and Australia, and is considered a 'next generation wind turbine'. It incorporates technology and design features that can withstand strong wind conditions.

Figure 7:24: Photo of Windflow 500 with the two-blades spanning 33m

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[206] Windflow Technology Ltd 2006 - 2010, "Winds of Revolution" <http://www.windflow.co.nz/news/clippings/2004-2005/the-winds-of-revolution/?searchterm=lifespan> [accessed 30 September 2009]

Electricity generation

A 1MW turbine at West Wind at 41% capacity produces 3.6 million kWh/yr.[207] Therefore a 500 kW turbine will generate approximately 1.8 million kWh/yr. Looking at figure 7:25 below, it shows that a Windflow 500 at 40% capacity factor is consistent with West Wind performance figures as its annual energy output is also around 1.8 million kWh/yr.

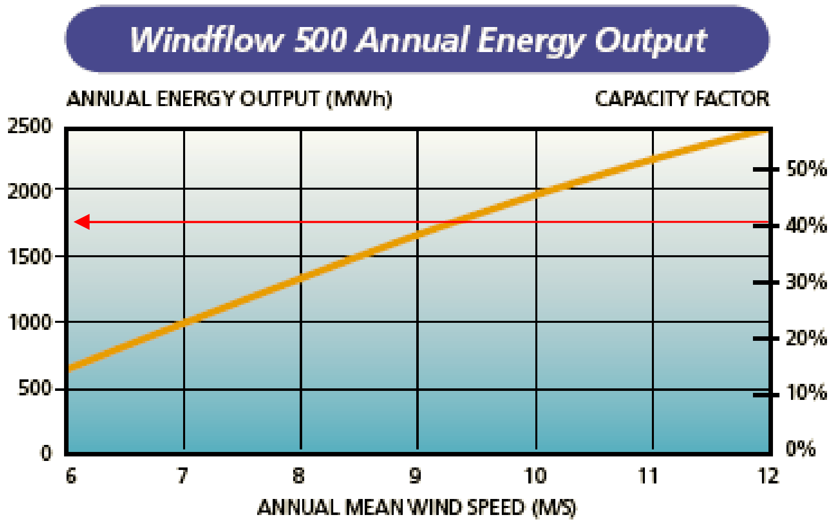

Figure 7:25: Windflow 500 Annual energy output[208]

Cost

One 500kW Windflow 500 two bladed turbine costs $1 million to buy and install.

Wind power electricity generation for SoAD

In 2007 SoAD used 1,613,471kWh electricity and 726,301kWh of gas, a total of 2,339,772kWh. A 500kW Windflow 500 turbine would only provide 76% of this energy demand. The rest (24%) needs to be

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[207] Hawkes Bay Wind Farm, "FAQ-Wind Farms" <www.hawkesbaywindfarm.net.nz/faq2.html> [accessed 30 September 2009]

[208] Windflow Technology Ltd**,** *Windflow 500, The next generation in Wind turbine design,* <http://www.windflow.co.nz/pdf-folder/misc/Windflow%20Brochure%20Mar%2007.pdf> [accessed 30 September 2009] p.2

either generated by another turbine or reduced through energy saving. If SoAD wants to be within the total annual energy generation of a Windflow 500 it would have to reduce its electricity use by at least 24% in order to be considered truly carbon zero. This reduction will automatically meet the Kyoto Protocol requirement. Since a 25% energy reduction is already part of SoAD's GHG emissions reduction plan and it can be achieved quite easily and at low cost by eliminating inefficient, wasteful use, this seems a better option than investing in another turbine.

According to the SoAD Draft energy report 2004, electricity costs 11.83c / kWh and natural gas 4.35c/kWh. This results in charges of $190,874 for electricity and $31,594 for gas totalling $222,468 per annum. This means that a 500kW wind turbine is the price of 4.5 years of SoAD's energy (excluding land cost).

Table 7:38 shows a hypothetical situation where the school invests in a 500kW turbine generating 1.8million kWh/yr; and makes a profit by reducing its energy consumption and selling the surplus electricity back to the retailer based on the one-for-one buyback scheme. The table also indicates the benefits of saving as much as possible as a 90% saving would result in a pay-back period of just over 5 years. This could be a valid financial incentive for the school to reduce its energy use.

Energy Reduction	Energy required after reduction	Extra energy (credit) from 1.8million kWh/yr	Credit in dollars / year (Using $11.83/kWh average for electricity)	Payback period with the extra surplus energy credit
25% Reduction	1,754,829 kWh/yr	45,171 kWh/yr	$5,344	187 years
50% Reduction	1,169,886 kWh/yr	630,114 kWh/yr	$74,542	13.4 years

90% Reduction	233,977 kWh/yr	1,566,023 kWh/yr	$185,261	5.4 years

Table 7:38: Energy reduction resulting in various energy credits

Reason for Choice

It seems that wind is an ideal option for SoAD despite the need for an off-site, windy location. It is cost effective as the pay-back period is reasonable. The turbine is made in NZ and generating electricity from the wind requires little space in comparison to solar panels.

7.7 Savings and comparisons

To put SoAD's consumption into a different perspective, a comparison study has been made to understand current demands. An important moral lesson can be learnt by converting SoAD's wastage into equivalent resources, vital for survival in developing countries.

Due to excessive, unsustainable consumption of earth's finite resources, the ecological capacity of the planet is under strain. As discussed in previous chapters, the unequal consumption of earth's resources poses moral implications and puts responsibility on the wealthy nations. The only "fair" way of reducing emissions is reducing what the wealthy nations are responsible for. This means that developing nations should be able to grow and be within their fair earthshare, which puts pressure on first world nations to cut demand drastically. Another pressing issue is the amount of wasteful energy usage in the first world nations as a result of negligence, inefficiency and unnecessary standards. This "abundance" in energy has been a luxury easily exploited by the first world that could mean a matter of life and death for many.

This comparison of how much land or carbon emissions could be saved is useful for students and staff to give a better understanding of the consequences of certain behaviours. Knowing that resources are valuable and scarce for other people around the world could instil humanitarian principles into sustainability as the essence of sustainability should not stop at being environmentally concerned.

From previous calculation it was found that SoAD spent approximately $223,000 on energy in 2007.

GHG emissions savings

To calculate total savings, carboNZero GHG emissions values were used and each reduction target was applied to the energy consumption in carbon emissions terms. As this is a lot harder to visualise, other forms of comparisons are explored below.

- 25% reduction in energy use prevents 116 tonnes of carbon annually from being released into the atmosphere.
- 50% reduction in energy use prevents 232 tonnes of carbon from being released into the atmosphere.
- 90% reduction in energy use prevents 418 tonnes of carbon from being released into the atmosphere.

Energy savings

To visualise what energy savings mean the kWh values for T8 fluorescent lamps (58 Watt) and computers (150W) are used.

- 25% reduction in electricity is equivalent to turning off 1000 T8 lamps running continuously for 6 months or turning off 100 PCs running continuously for 3 years.
- 50% reduction in electricity is equivalent to turning off T8 lamps running continuously for 1.3 years or turning off 100 PCs running continuously for over 6 years.

- 90% reduction in electricity is equivalent to turning off 1000 T8 lamps running continuously for 2.3 years or turning off 100 PCs running continuously for 11 years.

Land savings

To calculate this, the total annual electricity consumption in gha from the ecological footprint calculation in chapter 4 is used. From this, land savings can be calculated for each reduction target.

- 25% reduction in energy use is equivalent to saving 60 gha of land which is equivalent to 77 football fields.
- 50% reduction in energy use is equivalent to saving 120 gha of land which is equivalent to 154 football fields.
- 90% reduction in energy use is equivalent to saving 216 gha of land which is equivalent to 278 football fields.

What SoAD's saving mean to the third world

To calculate the meaning of the savings in the third world, the Oxfam Unwrapped website[209] was used to price actions that are vital for survival in poorer nations.

25% energy savings are equivalent to

- Providing 11,150 children with scarce school books ($50 for 10 school books)[210] that are essential to a child's learning. Currently, 80 million children remain out of primary school due to poverty.
- Planting 55,750 trees ($1 per tree)[211] that will furnish people in East Timor with food and many necessities such as shelter, medicine, clothing, tools, heat in the winter and shade in the summer.

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[209] Oxfam NZ, *Oxfam Unwrapped*, http://www.oxfamunwrapped.org.nz/ [accessed 01/10/09]
[210] Ibid.
[211] Oxfam NZ, *Oxfam Unwrapped*, *Product – Trees,* <http://www.oxfamunwrapped.org.nz/shopping.asp?action=product&catidback=103&id=56> [accessed 01/10/09]

50% energy savings are equivalent to

- Providing emergency shelter ($30 per shelter)[212] for 3,716 families forced to flee their homes as a result of conflict or natural disaster.

Figure 7:26: Emergency shelters for refugees[213]

- Providing 2,477 families with a goat ($45 per goat) which can eat weeds and household waste, and graze under supervision so crops and trees are not damaged. Goats fertilise crops with their manure and produce 7 litres of fresh milk per week. Goats to help rebuild livelihoods in Sudan and Ethiopia.[214]

90% energy savings are equivalent to

- Providing 133 water tanks ($1500 per tank)[215] for communities. Each tank provides clean, safe drinking water for 13,000 people

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[212] Oxfam NZ, *Oxfam Unwrapped*, *Product – Emergency Shelter* <http://www.oxfamunwrapped.org.nz/shopping.asp?action=product&catidback=101&id=71> [accessed 01/10/09]
[213] Ibid.
[214] Oxfam NZ, *Oxfam Unwrapped*, *Products – Goat,* http://www.oxfamunwrapped.org.nz/shopping.asp?action=product&catidback=102&id=47&i=last [accessed 01/10/09]
[215] Oxfam NZ, *Oxfam Unwrapped*, *Products – Water tank,* http://www.oxfamunwrapped.org.nz/shopping.asp?action=product&catidback=107&id=29&i=last [accessed 01/10/09]

- Providing 4,017 toilets ($50 per toilet).[216]. For a family of 5 this would mean 802 families benefit. In the Papua New Guinea Highlands, less than 10 percent of the population has access to adequate sanitation. The installation of one of these structures will prevent the spread of cholera and typhoid.

7.7.1 Guidelines for considering renewable electricity generation

- Have a detailed record of energy consumption and how it is used
- Analyse the micro environment to decide what sort of renewable electricity generation is appropriate
- Research into the different renewable electricity generation technology available
- Analyse the pay-back period
- Instil more energy-conscious behaviour by converting savings into positive benefits for others in order for occupants to be clear what they are wasting.

7.7.2 Conclusion

It is clear when considering renewable electricity generation that is solar is a difficult option. As discussed before, it requires a lot of land and its period of maximum generation period may not be synchronised with the operation of the facilities. Another issue not discussed in this chapter is the problem of embodied energy or the life cycle analysis of each technology. Solar hot water, for example, requires copper for the piping and there is a global shortage of copper, with most copper reserves being in Africa. There is not

[216] Oxfam NZ, *Oxfam Unwrapped*, *Products – Toilet* http://www.oxfamunwrapped.org.nz/shopping.asp?action=product&catidback=105&id=30&i=first [accessed 01/10/09]

enough copper in the world to meet the demand of solar panels became widespread.[217] There are benefits and disadvantages for both solar panels and wind power and what is necessary is to analyse which technologies are suitable for each location. It may be that the answer is neither, and there might be the need to explore other options such as biomass energy generation.

What is important is that a lot of energy is being wasted, and eventually this wastage will cost the school more money to keep up with demand. The most sensible thing SoAD can do is to eliminate unnecessary use of electricity so that only vital needs are met, possibly by renewable electricity generation. This study suggests that a 25% energy reduction is essential in SoAD for energy generation reasons, as wind generation technology can only meet 76% of SoAD's energy demand, for economic reasons to save the school money, and ethical reasons as the cost of this wastage translates to vital supplies in other countries.

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[217] Leonard Andrew, Salon, *Peak Copper? Forget about oil. Copper is getting pretty pricey, too*, 2 March 2006, <http://www.salon.com/tech/htww/2006/03/02/peak_copper/index.html> [accessed 05 January 2010]

8.0 Transport Reduction Plan

In the carboNZero 2007 faculty report, land and air transport accounted for 16% of total emissions, equal to the waste to landfill emissions. However, this does not take into consideration the transport emissions from commuting to and from the school. In this chapter, commuting transport emissions will be incorporated into the emissions reductions, despite the fact that the survey conducted for the Victoria University's Travel Plan 2007 was considered to be unreliable due to small sample size. However, this will give a general indication of how commuting to work emissions impact on the overall carbon footprint of the school. The chapter will be divided into two sections; transport by air and by land. Various solutions will be explored to reduce transport emissions by the three reduction targets set out previously.

The big things considered worth reducing are international flights and transport to work. Domestic flights will also be considered despite their small contribution to emissions, because it is believed that many staff flights are not paid for by the school.

8.1 Transport by air

The international flight calculation for carboNZero data did not consider the radiative forcing index (RFI) which is a numerical multiplier approved by the Intergovernmental Panel on Climate Change (IPCC) that takes into consideration the climate impacts of different pollutants which can be converted to carbon dioxide equivalents. RFI has been developed for effects like condensation trails from airplanes which only occur at altitudes above 9km. RFI is only applied to emissions over this threshold altitude, which may not be reached by some flights, typically those up to 400 kilometres long.[218] This means that RFI will not apply to domestic flights. The value for RFI calculation varies between 1.9. – 4.7. The company *Atmosfair* uses an RFI of 3 while the IPCC recommends a multiplier of 2.7. The carboNZero programme uses a multiplier of 1.9 which is lower than the IPCC recommendation.[219] The science behind this issue continues to be researched.

The RFI factor will be used to recalculate the carbon dioxide emissions for SoAD international flight emissions. These are shown in Table 8.1 below.

Type of flight	**Total dst (km)**	**CarboNZero 2007 data with CO_2 Conversion Factor**[220]	**With Radiative Forcing Index of 3 from Atmosfair**
International Flights	577,236	88,030 kg CO_2 (CF = 0.15)	197,970 kg CO_2
Domestic Flights	20,299	4,800 kg CO_2 (CF = 0.23)	4,800 kg CO_2
TOTAL	**597,535**	**92,830 kg CO_2**	**205,510 kg CO_2**

Table 8:1: New updated air travel CO_2emission figures[221]

The Atmosfair website provides an online calculator. By entering the destination, number of passengers and whether it is one way or return flight, (See Appendix 5 for airport codes) it automatically calculates the CO_2 emissions inclusive of RFI and allowing for take-off and landing. Using this, the total SoAD emissions from

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[218] Atmosfair, *The emissions calculator*, <http://www.atmosfair.de/index.php?id=415&L=3> [accessed 15 September 2009]

[219] Landcare Research, CarboNZero, *Frequently Asked Questions*, <http://www.carbonzero.co.nz/faq.asp#waste> [accessed 12 October 2009]

[220] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

[221] Atmosfair, *The emissions calculator*, <http://www.atmosfair.de/index.php?id=415&L=3> [accessed 15 September 2009]

international flights come to 197,970 kg CO_2. (The full list of the CO_2 emissions values are in Appendix 6)
The total CO_2 emissions are doubled by incorporating the RFI factor for international flights. What this shows is that the carboNZero calculations could be considered an underestimation.

Reduce air transport emissions

Reducing domestic air travel should not pose a difficulty as the time zones in New Zealand are all the same and physical presence in meetings and conferences may not be necessary at all times. Tele and video-conferencing is an existing technology that has not been fully utilised by the school although it was included in the GHG emissions reduction plan. Domestic flights are taken for meetings, conferences, research purposes and to transfer to an international flight.

Conferences held within New Zealand could easily be replaced by video and tele-conferencing technology. Laptops often have the additional benefits of having integrated webcams, and changing staff's desktop computers to laptops coincides with the proposal to reduce energy demand (see 7.2).
It is more difficult to reduce international flights as physical presence may be critical to research and video conferencing across different time zones in certain countries could pose a difficulty. It is also easier to form social connections by attending events than via internet forums.
It is important to note that, before air travel became the norm, academia existed and progressed. In the past, New Zealand was able to function normally and via rail and sea travel. Things still got done, albeit slower.

Reduce Domestic Flights

According to the carboNZero 2007 data domestic flights are predominantly from Wellington to Auckland with some to the South Island. It is assumed that out of 100 staff members only academic staff take flights for their research, meetings and attending conferences.

There are 64 academic staff based on 2008 and 2009 figures (see table 3:1).

20,299km / 64 staff = 317km per year per person. This is approximately equivalent to a single one way trip from Wellington to Christchurch (303km) per year per staff member, so domestic flights are relatively few in number.

Wellington (WEL) to Auckland (AKL) – 481km

There are two possible more sustainable alternatives for travel to Auckland.

Mode of Travel	One way travel time	One way cost (lowest)
Train[222]	12 hours	$49 – 89
Bus[223]	11 hours	$45 – 74
Air[224]	1 hour	$49 – 120+

Table 8:2: Different modes of travel Wellington to Auckland

There are clear disadvantages in taking more sustainable forms of transport. Currently travelling by air can be as cheap and is significantly faster. This poses disincentives for staff to travel using more sustainable transport. However, although the lowest fare prices were quoted, this requires advanced booking of at least a couple of weeks. Air fares become very expensive if booked at the last minute, which makes air travel less financially attractive.

All modes of travel (except part of the train ride, see below) require oil which is a non-renewable resource. However it may be easier to

[222] Rail New Zealand, <http://timetable.railnewzealand.com/> [accessed 01 October 2009]

[223] Intercity Coachlines <https://reservations.coachbookings.co.nz> [accessed 01 October 2009]

[224] Air New Zealand, <http://www.airnewzealand.co.nz> [accessed 01 October 2009]

convert diesel buses and trains to bio-diesel or electricity in the future than air travel.

Air NZ, other airlines, and InterCity coach services offer carbon credits to off-set the emissions generated from a trip. InterCity Group has also signed up to Landcare Research's carboNZero programme and will become carbon neutral by purchasing carbon credits through landfill, wind power and native forest regeneration projects.[225] As the main purpose of this research is to avoid reliance on offsets, these carbon credit schemes will not be considered here.. In contrast, the train service between Palmerston North and Te Rapa (Hamilton) is electric.[226] This reduces its carbon footprint as NZ electricity production is approximately 66% renewable. If the whole journey from Wellington to Auckland was electric the train could potentially be zero emission transport. This is, however, is a matter for national and local government, as has happened in Wellington, and is beyond the control of SoAD.

> *Greater Wellington Regional Council signed an agreement to purchase 70 new electric commuter trains with options to buy a further 13 two-car units at later dates, within the budget of $210 million. Track upgrades are scheduled to coincide with the arrival of the new trains from 2010 to run on all parts of the North Island's electrified rail network.*[227]

Staff will need at least 2 days for a return trip using the alternative sustainable transport options. A train journey has the advantage of greater comfort than a bus making it easier for staff to work during

[225] Intercity Coachlines, *InterCity Group Aims to Operate The World's First Carbon Neutral National Transport System,* <http://www.intercity.co.nz/about-us/mediarelease47.php> [accessed 01 October 2009]

[226] An History of Technological Innovation in NZ, *Main Line Railway Electrification,* <http://techhistory.co.nz/Electricity/rail_electrification.htm> [accessed 03 October 20009]

[227] Greater Wellington Regional Council, *Greater Wellington buys new electric commuter trains*, 13 November 2007, <http://www.gw.govt.nz/Greater-Wellington-buys-new-electric-commuter-trains/> [accessed 03 October 2009]

the journey. The university needs to consider the cost of longer staff travelling time if air travel footprint reduction is the goal.
There are other ways of travelling such as renting a fuel efficient or hybrid car, especially for several people travelling at the same time. This method will not explored here as it would take roughly the same time as going by train.

Wellington (WEL) to Christchurch (CHC) – 303km

To travel between islands is more complicated as the only alternative mode of transport is the ferry. Another land transport mode is then required to reach to Christchurch, making the journey inconvenient. Total travel time is at least 9 hours and the trip is more expensive compared to air travel. Fares are subject to change and are more expensive during busy periods.

Mode of Travel	One way travel time	One way cost (lowest)
Ferry: WEL to Picton[228]	3 hours	$53 + (dependent on time of year)
Train[229] from Picton	6 hours	$79+
Bus[230] from Picton	6 hours	$25+
Air	<1 hour	$49 - $120+

Table 8:3: Different mode of travel for WEL to CHC

To understand the different impact of these alternative transport options, various figures have been compiled and compared in Table 8:4. The first column gives the energy consumption for different modes of transport, including embodied energy of fuel but not

[228] Interislander, <http://www.interislander.co.nz/Booking/Select-Sailings.aspx> [accessed 01 October 2009]
[229] Rail New Zealand, <http://timetable.railnewzealand.com/> [accessed 01 October 2009]
[230] Intercity Coachlines <https://reservations.coachbookings.co.nz> [accessed 01 October 2009]

embodied energy of vehicles in MJ/passenger-km. The second and the third column give the energy consumption across different modes of transport as CO_2 emissions per kilometre. It is impossible to give accurate figures, as it depends on occupancy, the length of the journey, the age and type of vehicle and the speed. The figures below are compiled from a variety of sources and give an indication of how different modes of transport compare.

Mode of transport	**MJ / Passenger-km[231]**	**MJ/km to kg CO_2/km conversion[232]**	**Kg CO_2 per passenger km[233]**	**Kg CO_2 per passenger km[234]**
Cargo-passenger liner	0.015	**0.001** (diesel)	-	-
Electric commuter train (renewable)	0.59	**Zero emission**	-	-
Average Bus (diesel)	1.01 @ 20% occupancy	**0.096** (diesel)	0.0176 (Bus)	0.045 – 0.08 **(0.063)**
Trolley Buses (renewable electricity)	0.87	**Zero emission**	-	-
Diesel commuter train	0.74	**0.070** (diesel)	0.092	0.045 – 0.13 **(0.088)**

[231] Vale Robert and Brenda, *Time to eat the dog?: The Real Guide to Sustainable Living,* (Thames & Hudson 2009), p.122
[232] Australian Government, Department of the Environment, Water, Heritage and the Arts, <www.environment.gov.au/settlements/transport/comparison/pubs/2ch3.pdf> [accessed 05 October 2009] p.5
[233] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report, Appendix B, p.41
[234] Aviation Environment Federation (AEF), <www.aef.org.uk/downloads//Howdoesairtravelcompare.doc> [accessed 05 October 2009]

Driving – car 4 persons	0.92 (1.6 L)	**0.065**	(0.223) /4 = **0.056**	(0.25)/4 = **0.063**
Driving – car 1 person	3.19 (1.6 L)	**0.228** (petrol) 0.303 (diesel)	0.101 (for 1.5L hybrid) **0.223** (car driver – 3L diesel)	**0.1** - 0.13 (fuel efficient) **0.25 – 0.5** (large cars)
Air (below 500 miles – 805km)	2.69 - 4.36 (domestic)	-	-	**0.33 – 0.46** (RFI of 1.9)[235]
Air (Above 500 miles – 805km)	1.25 (Boeing 747 - international)	-	-	**0.21 – 0.33** (RFI of 1.9)
Ferry	7.25 (Lesson)	**0.689** (diesel)	0.0088	0.045 – 0.13

Table 8:4: Different modes of transport and their various coefficients

The first column shows energy use for modes of commuter travel in the US (including embodied energy of fuel) which is derived from actual passenger and fuel use data. Other data was gathered from various sources and certain selections were made by taking the medium range values. These MJ values were then converted to kg CO_2 by applying the coefficients calculated from table 8:5 (assuming that ships/ferries use fuel oil, and trains use diesel and motor vehicles use petrol). Transport powered by renewable electricity is considered zero emission.

Internal Combustion Engine vehicle	Energy (MJ/km)	GHG (kg/km)	1 MJ/km = X CO_2 kg/km
Petrol	2.42	0.172	0.0711

[235] AEF uses the RFI figure of 1.9 other than 3 which was used for Atmosfair earlier on in the chapter.

Natural Gas	2.42	0.128	
Diesel	1.89	0.131	0.0693
Fischer Tropsch Diesel	1.89	0.128	

Table 8:5: Energy use by and GHG emissions from internal combustion engine vehicles[236]

The figures from the third and the fourth columns represent different GHG emissions from various modes of transport. The third column is information compiled for the VUW Travel Plan. These figures did not consider RFI and the figure for the ferry seems low. Therefore another study by the Aviation Environment Federation (AEF) was consulted for the fourth column. This is a UK study which uses a 1.9 multiplier for the Radiative Forcing Index. This study was used as the representative for each transport mode's carbon emissions as the figures are reasonably consistent with other studies. The highlighted CO_2 kg figures (in yellow) will be used to calculate the savings by switching from a less to a more sustainable transport option. Despite the fact that much of Wellington's public transport system is electric, the figures for diesel vehicles will be used as these are present in the current transport mix and the electricity generated in NZ is not 100% renewable. So therefore this figure will be an overestimate of Wellington transport's actual impact.

In Table 8:4, the coefficient for ferries appears underestimated and another figure will be used (diesel figure)[237]. The ferry now becomes the worst mode of travelling by sea.

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236 Australian Government, Department of the Environment, Water, Heritage and the Arts, <www.environment.gov.au/settlements/transport/comparison/pubs/2ch3.pdf> [accessed 05 October 2009] p.5

237 Australian Government, Department of the Environment, Water, Heritage and the Arts, <www.environment.gov.au/settlements/transport/comparison/pubs/2ch3.pdf> [accessed 05 October 2009] p.5

However, travel in a cargo-passenger liner significantly reduces the energy per passenger compared to a ferry. This is because cargo-passenger liners carry large amounts of goods and passengers are only a small additional element. It may be that the Inter-islander ferry could be considered more like a cargo-passenger liner, as it carries freight vehicles as well as passengers, and this might make its per capita emissions for passengers lower. The value used in Table 8:4 is for passenger only ferries. This may lead to the conclusion that SoAD should minimise inter island travel by sea.

The following calculations will apply reduction goals of 25%, 50% and 90% to domestic and international flights separately.

8.2 Domestic flights Reduction

Below are the average CO_2 emissions per kilometre for different modes of transport from table 8:4:

- Bus average = 0.063 kg CO_2 / km
- Train average = 0.088 kg CO_2 / km
- Car average, driver = 0.25 kg CO_2 / km
- Airplane (above 805km) average = 0.27 kg CO_2 / km
- Airplane (below 805km) average = 0.395 kg CO_2 / km
- Ferry = 0.502 kg CO_2 / km

There is no replacement for air travel that offers the equivalent speed and convenience. Possible solutions are to replace carbon intensive travel with a less carbon intensive method or reduce travel by relying on more tele/video communication. Setting limits on air travel would lead staff to get the most work out of each visit and only travel when absolutely necessary. This will automatically promote tele/video conferencing method which has the advantage of no wasted travel time. It will also be cheaper for the university. Research travel can be rationed, like a sabbatical, so each staff member is allowed one overseas trip every couple of years. Currently, some staff members appear to be taking more air trips than others. Rationing would also ensure equality.

Also, with the current PBRF focus on research outputs, more credit could be given to publishing in journals rather than attending conferences.

8.2.1 25% reduction scheme

- 0.088 kg CO_2 / 0.395 kg CO_2 x 100 = 22%

This is a saving of **78%** for switching from air to train travel

The following flight records are taken from SoAD records for 01/01/07 to 31/12/07 from the carboNZero 2007 data (to convert km to CO_2 kg equivalent a CF factor of 0.23 was used in the VUW Travel Plan). For details of the domestic flights see Appendix 6, Table 8:6.

(14 one way trips x 481.2km) x 78% / 20,299km = 26%

For a 26% reduction in domestic air flight emissions

14 trips (or 7 return trips) from AKL to WEL should be taken by train

OR

(11 x 481.2km) /20,299km = 26%

11 one way trips should be replaced with tele-video conferencing

8.2.2 50% reduction scheme

For details for the domestic flights to achieve a 50% emissions reduction see Appendix 6, Table 8:7.

(27 one way trips x 481.2km) x 78% / 20,299km = 54%

For a 54% reduction in domestic air flight emissions

27 trips (or 13 return trips + one way) from AKL to WEL should be taken by train.
OR
(22 x 481.2km) /20,299km = 52%
22 one way trips (or 11 return trips) should be replaced with tele-video conferencing

8.2.3 90% reduction scheme

For details for the domestic flights taken to reduce emissions by 90% see Appendix 6, Table 8:8.

(37 one way trips x 481.2km) /20,299km x 100 = 92%
37 one way trips from AKL to WEL (or 18 return trips) should be replaced with tele-video conferencing
OR
Eliminate 24 one way (12 return) trips to Auckland → Saving of 11,549km
Eliminate all travel to South Island → Saving of 1,532km
15 one way trips (7 return + one way) from AKL to WEL taken by train
(15 x 481.2km) x 78% / 20,299km = Saving of 5,630km
Total: (5630+1532+11549)/20,299km x 100 = 92%
Together these give a 92% reduction

8.3 International air travel reduction

A conference entitled *Sustainable Theory / Theorizing Sustainability* was held in SoAD on 4th of September 2009 over a period of two days predominantly for academics from Australia and New Zealand. This event could have easily have been executed using video conferencing technology as the event was a series of lectures for an

audience of 30-50 people with Powerpoint presentations. Anywhere, apart from Perth, within Australia will not have a great difference in time zones making real time video conferencing much easier.
In 2007, recorded international flights totalled 577,236 km a year for 64 academic staff resulting in 9,019km per person. This is roughly a one way trip to Hong Kong (9,143km) per year or Wellington to Sydney return twice a year (2,232km one way).
The simple calculation below of the annual km reduction required per staff member to meet the reduction targets, indicates that reducing international air travel by up to 90% only allows for a domestic flight per year, or an international trip every 4+ years.

- 25% = 6764km – 3 trips to Sydney return (or a one way trip to Los Angeles or return trip every 2 years)
- 50% = 4510km – 1 trip to Sydney return (or a return trip every 3 years to Los Angeles)
- 90% = 910km – Auckland to Wellington return trip

Currently there is an unequal distribution of flights taken by staff. Introducing a rationing system where each staff member has a flight 'credit' can guarantee that the emissions will be within a certain set limit, and be more equitable.

8.3.1 25% reduction scheme

Since Australia is close to New Zealand and Asian countries like Hong Kong, Singapore and Australia speak English events in these countries could be held online.
The calculated savings are recorded in Appendix 6, table 8:9 using a RFI of 3. Emissions came to a total of 197.97 tonnes of CO_2, which was cut to 142.52 tonnes of CO_2 after cutting flights to Australia and Asia.

142.52t CO_2 / 197.97t CO_2 x 100 = 72%

This is a 28% reduction
Australian and Asian events can be catered for by video/tele conferencing to achieve the 25% reduction target.

8.3.2 50% reduction scheme

- Air plane (Boeing 747) average = 1.25 MJ/ passenger km
- Cargo-passenger liner = 0.015 MJ/passenger km

0.015MJ/passenger km / 1.25 MJ/passenger km x 100
= **99% energy reduction going from air flights to cargo-passenger liner**

From UK to Australia takes 30 days by cargo-passenger liner[238] so for the Asia Pacific rim a journey would take no more than 2 weeks. This calls for staff to be away longer when they travel, although during this time they can still work as internet access is available on the ship. However, there are no regular timetables and the places on such ships are limited. Trade routes to Asia and the Pacific should be frequent from New Zealand and advanced booking is essential. The full costs of boarding on such a ship should not be much more (within 25%)[239] than an air fare to these destinations.

Converting air flights to Asia-Pacific destinations to cargo passenger liner travel results in 83.75t CO_2 – See Appendix 6 table 8:10 for details.

83.75t CO_2 / 197.97t CO_2 = 42%
This is a 58% reduction

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[238] Vale Robert and Brenda, *Time to eat the dog?: The Real Guide to Sustainable Living,* (Thames & Hudson 2009), p.121
[239] Vale Robert, Victoria University of Wellington, personal communication, 26 October 2009

Travel to Australasia and parts of USA can be replaced by cargo-passenger liner travel which would still allow staff to travel abroad rather than reducing the number of international trips.

Staff also have the choice to utilise web/video technology or simply reduce travel.

8.3.3 90% reduction scheme

Selecting all the major routes that could potentially be trade routes for cargo liners to replace air travel results in 18.88t CO_2 – See Appendix 6 table 8:11 for details.

18.88t CO_2 / 197.97 = 9.5%

This is a 90.5% reduction

All major trade routes to Australia, Asia, America and London need to be replaced with passenger cargo liners as main form of travel. Staff have the choice to travel this way, use web technology or reducing travel.

The only way of reducing emissions from air travel is to replace flights with cargo-passenger liners with their limited availability. Such journeys will also take longer and could be more expensive, especially for longer distances. It indicates that there is no current alternative technology to air travel and that in order to embrace a sustainable future, air travel is something that needs to be reduced. On the upside, the internet is a great resource with increasing popularity and web-interaction can still meet the need for social connection via internet forums and chat rooms. In the digital age, the internet will play a critical communications role especially during the post oil era.

8.4 Transport by land

Transport by land data

Using the survey data provided by Andrew Wilks (Environmental Manager for VUW), approximate Te Aro campus transport to/from work figures were calculated. The survey only indicated the percentage of staff and students taking a particular mode of transport. It did not indicate how far away from the school each student or staff member lived. Therefore an approximate per person km value is used to calculate total km travelled for each mode of transport per person km/year. Then, each transport total km is converted to CO_2 emissions by multiplying by the appropriate conversion factor from table 8:4. Using these conversion factors will give different results from the VUW Travel Plan.

Obviously, the more popular the transport system the bigger its total carbon emission will be. The balance of the kms is from walking and cycling which do not emit any GHG.

Mode of transport and its overall percentage	**Distance travelled**	**CO_2 Conversion Factor**	**Kg CO_2 per passenger km**
1244 Students total – 1,655,531 km/yr (1 student = 1330.8 km/yr)			
10% of students took the Bus - 125	165,553 km	0.063	10,430 kg CO_2
36% of the students took the Train - 445	595,991 km	0.088	52,447 kg CO_2
TOTAL	**761,544 km**		**62,877 kg CO_2**
100 Staff total – 271,878 km/yr (1 staff = 2718.8 km/yr)			

19% of staff took the bus – 19	51,657km	0.063[240]	3,254 kg CO_2
3% of staff took the train – 3	8,156km	0.088[241]	717 kg CO_2
39% of staff are car drivers - 39	106,032km	0.25[242]	26,508 kg CO_2
2% of staff are motorcyclist - 2	5,438km	0.1[243]	544 kg CO_2
TOTAL	**171,283 km**		**31,023 kg CO_2**
GRAND TOTAL:	**932,827 km**		**93,900 kg CO_2**

Table 8:12: Total emissions from transport modes (excluding walking, cycling and car passenger km)

According to the Travel Survey, very few students used the car to travel to school. Predominantly students took public transport or walked or cycled, probably due to financial reasons. Maintaining a car is expensive and many students live around the Wellington CBD allowing them to walk or cycle. In contrast, the main form of transport of the staff was private vehicle. This may be due to the cheap parking fees.

Currently the car parking fee for staff is $295/yr to hunt for parking and a reserved park costs $590/yr. These figures remain below market costs. The average number of staff forced to park off campus daily is ten.[244] The pay and display parking around the campus costs from $3 to $4 an hour to $10 for the whole day. A train fare to Khandallah is $4 one way, which is $8 a day x 5 days a week x 49 weeks resulting in $1960 per year.[245] This provides no financial

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240 Assume for normal diesel buses
241 Assume normal diesel trains
242 Value for single driver
243 Motorcyclist will be considered as a fuel efficient car
244 Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report, p.28
245 Metlink, Greater Wellington's public transport network <http://www.metlink.org.nz/> [accessed 10 October 2009]

incentives for staff to travel by sustainable mode of transport. However, there are small savings from taking buses and trains as shown below,[246]

- A bus trip from Wainuiomata to Wellington, using a 10-trip ticket, is still $1.30 less than it would cost to drive based on full car running costs.
- A bus or train trip from Upper Hutt to Wellington, at the new 10-trip price, will cost $6.40, compared to $9 in a car.
- A train trip from Paraparaumu to Wellington, using a 10-trip ticket, will cost $8 from 1 September, compared to $13.60 in a car.
- A train trip to Masterton, using a 10-trip ticket, will cost $12 compared to $26.93 in a car.

A GPS bus timetabling system installed in the school would be desirable, while improving existing bus shelters and a more frequent timetable for buses and trains in the Wellington region would further encourage a change to public transport. However this is outside SoAD's control.
There are various methods to reduce staff car emissions. First, all staff could change their car to the most fuel efficient available. However this method is costly and involves consumption of energy for making these new cars, so this option will not be explored.
Staff could carpool, but this option is complicated as it poses the difficulties of not only finding other staff members living in the similar vicinity but also with similar time schedules. However this option may be attractive to some staff members who may need to carry a lot of stuff back home and it is more convenient than waiting for a bus or train. Carpooling has the same CO_2 emissions per km per person as public transport. According to the Travel Survey 2007, staff and students stated that the predominant motivator for car-pooling would be the ability to find other people to carpool with.

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[246] Greater Wellington Regional Council, *Fare increases: Q&As,* <http://www.gw.govt.nz/Fare-increases-Q-As> [accessed 19 October 2009]

Students		Staff	
Help finding people	42%	Help finding people	35%
Info about savings	22%	Info about savings	27%
Reserved car parks	21%	Reserved car parks	21%
Guaranteed ride home	15%	Guaranteed ride home	17%

Table 8:13: Motivators for car-pooling – VUW Travel Survey 2007[247]

Providing reserved car parks for carpoolers, guaranteeing a ride home, and information on savings should all be provided to encourage car pooling.

Currently in the Wellington area the majority of buses are fuelled by diesel, but GOWellington (see figure 8:1 below) has 65 electric trolleybuses within Wellington city. If all buses were trolley buses, Wellington area buses could potentially be zero emission. Official figures show that 90% of the population of Greater Wellington lives within 500m of public transport.[248]

The Regional Council's Regional Public Transport Plan notes Wellington has:

- A rail network with 147 carriages, serving 53 stations
- A bus network with 470 buses (including trolleybuses) serving around 2,800 stops on around 108 routes
- Two harbour ferries
- A five-station Cable Car.

[247] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report, p.23
[248] Greater Wellington Regional Council, *Regional Passenger Transport Plan 2007*, <http://www.gw.govt.nz/story_images/4396_RegionalPassenge_s8753.pdf> [accessed 15 October 2009]

Figure 8:1: Photo of GO Wellington trolley bus[249]

The majority of routes operate all day every day, some only operate during peak hours on weekdays, or only during the day, or do not operate at weekends. Evening and weekend services are usually operated by diesel buses.[250] Figure 8:2 displays the routes that the trolley buses serve.

249 Wikipedia, <http://en.wikipedia.org/wiki/File:WellingtonNewTrolleybus.jpg> [accessed 30 October 2009]

250 GO Wellington, <http://www.gowellingtonbus.co.nz/index.php> [accessed 30 October 2009]

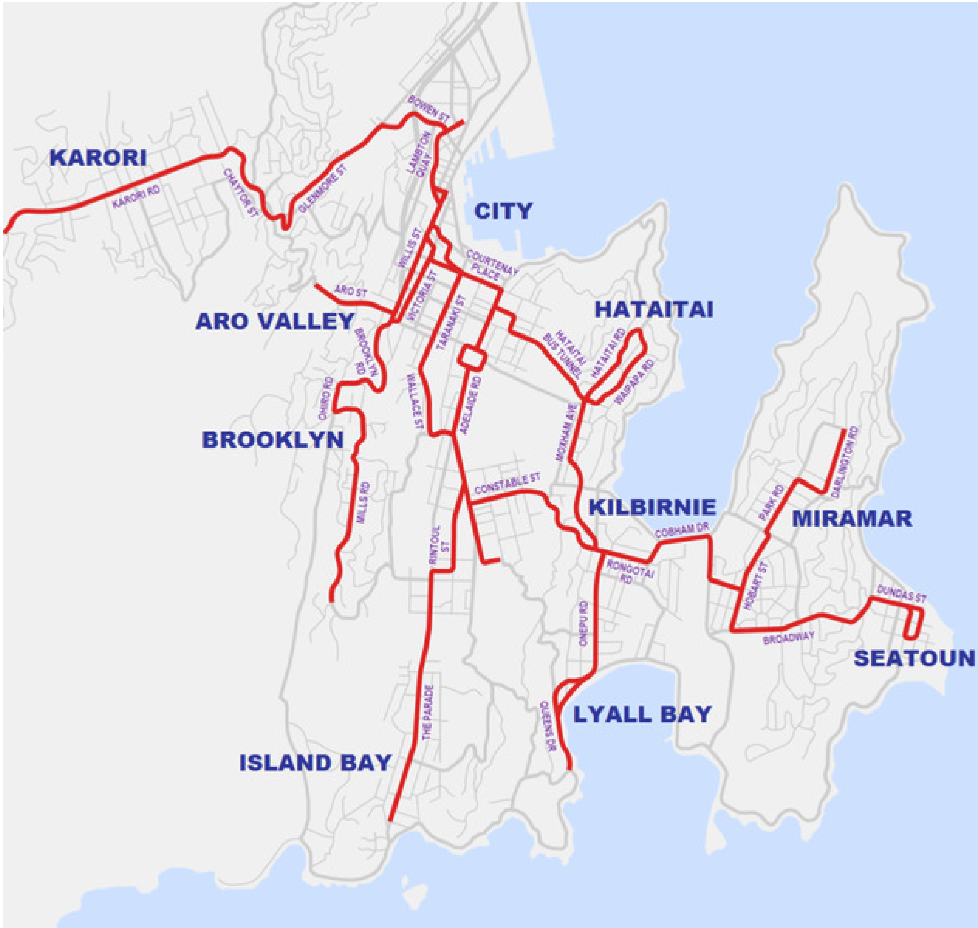

Figure 8:2: Map of the routes of GO Wellington trolley buses[251]

The VUW Travel Plan survey 2007 indicated that over 70% of staff members live in the Wellington City area. Therefore, 70% of the staff should be able to switch to buses to get work and the remaining 30% who live further away (for example, Lower Hutt or Porirua) should be able to take the train (see figure 8:3). Most of the Wellington trains are electric. [252]

[251] Wikipedia, <http://en.wikipedia.org/wiki/File:WellingtonTrolleybusRoutes.png> [accessed 02 November 2009]

[252] Lonely Planet, *Wellington, Getting there and around*, <http://www.lonelyplanet.com/new-zealand/wellington/transport/getting-around> [accessed 03 November 2009]

Figure 8:3: Map of the Wellington Rail Network[253]

8.4.1 25% reduction scheme

Using the data from table 8:4 and assuming that each staff member drives a medium car;

- Switching from medium car to train will result in: 0.088kg CO_2 / 0.25kg CO_2 x 100 = 35% → **65% savings**
- Switching from medium car to bus (or carpool with 4 people) will result in: 0.063kg CO_2 / 0.25kg CO_2 x 100 = 25% → **75% savings**

This is not taking into consideration that Wellington has electric trolley buses and trains, so these will be underestimates. If all the Wellington transport system was electric run on wind power, it would be zero emission.

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253 Wikipedia, <http://en.wikipedia.org/wiki/File:WellingtonRailNetwork.png> [accessed 02 November 2009]

Applying these percentage savings will result in the following:

Buses replace cars for the 70% of staff who live within Wellington metropolitan area and the 30% who live farther away need to carpool (4 people per car).

Distance travelled by staff by driving a car (solo)	**Total Kg CO_2 per passenger km**	**70% of staff on buses, 30% of staff carpooling (106,032 km x 0.063)**	**Savings**
106,032km	26,508 kg CO_2	= 6680 kg CO_2	26,508 – 6680 = **19,828 kg CO_2**

Table 8:14: 25% reduction scheme by switching staff car driving to public transport

Currently 19 staff takes the bus to work (3,254 kg CO_2) but this needs to be replaced with a zero emission form of transport such as walking or cycling, especially for those within 5 - 6km of school). Alternatively, if these staff members use the electric trolley buses (which are potentially carbon zero) this would achieve the same saving.

Savings are 19,828 kg CO_2 + 3,254 kg CO_2 / 93,900 kg CO_2 x 100 = **25%**

Staff who drive cars to work switch to public transport (buses) and carpool in a car of 4 and existing bus riders walk or cycle to work or use trolley buses running on renewable electricity.

Making the staff car parking spaces more expensive and using this car parking area to house bicycles would provide incentives to cycle to work or use public transport.

8.4.2 50% reduction scheme

There are several options to achieve a 50% reduction in emissions. The biggest emissions are from students taking trains. If half the students taking the train cycled to school a further 25% saving in emissions would result. Also if the trains ran on renewable energy emissions would be reduced. Figure 8:4 is a map of the Wellington City suburbs. The furthest away is Tawa approximately 15km from the CBD.

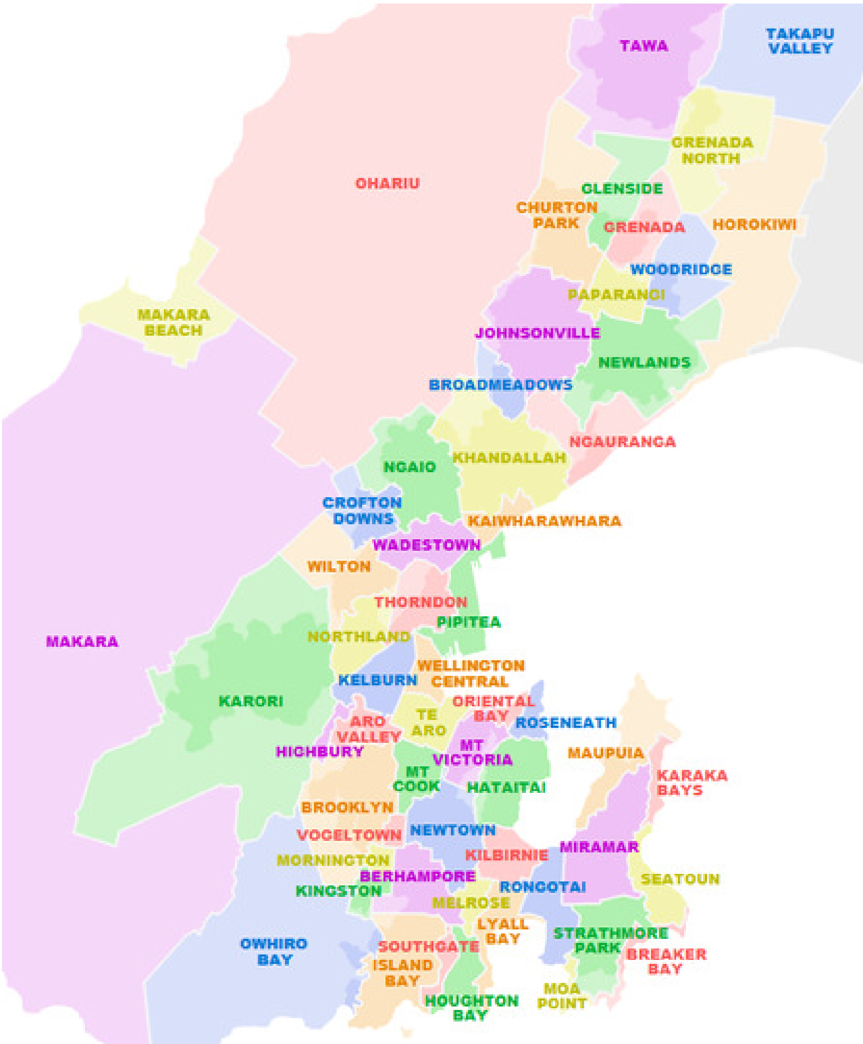

Figure 8:4: Wellington City suburbs[254]

[254]<http://pic.srv104.wapedia.mobi/thumb/8a8614543/en/max/720/900/WellingtonSuburbsMap.png?format=jpg,png,gif> [accessed 15 November 2009]

Option 1: ***Get students to cycle more***

Students who live within 5km of the CBD could cycle to school; if they would otherwise catch the train or the bus this would eliminate emissions. However, Wellington terrain is very hilly and with the windy weather, cycling may be weather dependent form of transport. In addition the roads are narrow and not designed for cyclists, posing safety issues. The travel plan shows that 60% of students live in the Wellington City region within 15km of the Wellington CBD. According to the VUW travel plan survey, very few staff and students choose to cycle to the University and show little enthusiasm for taking up cycling for the reasons mentioned above. However, the key motivators which would attract more cyclists are:

Students		**Staff**	
Cycle parking	24%	Safer routes	29%
Safe Routes	24%	Considerate drivers	20%
Considerate drivers	15%	Shower facilities	16%
Info on routes	13%	Cycle parking	15%

Table 8:15: Motivations for cycling from the VUW Travel Plan 2007[255]

According to research done by the Transportation Research Board of the National Academies, apart from home the most frequent trip destination for cyclists was work. Figure 8:5 indicates that the younger the age group the more trips made on bicycles per day. Considering that SoAD's student population predominantly ranges from 18-24 years, this study indicates that students are capable of 2 trips per day, over a 5-7 miles return trip = 8-11km (so approximately 5km one way)[256]. Therefore, any student living within 5km of the

[255] Wilks Andrew, Victoria University of Wellington, *Travel Plan, VIC Commute*, 30 September 2008, Internal Report, p.14

[256] Shafizadeh, K, Niemeier, D, 'Bicycle journey-to-work: Travel behaviour characteristics and spatial attributes' *Transportation research record*, 1578 (1997). pp.84-90

school should be able to cycle there comfortably. It could take longer than taking a bus, although during peak hours this may not necessarily be the case. Additionally any students living within 2km could walk. There is not enough accurate data to indicate exactly where students live and what form of transport they are taking which leads to a further investigation into this matter.

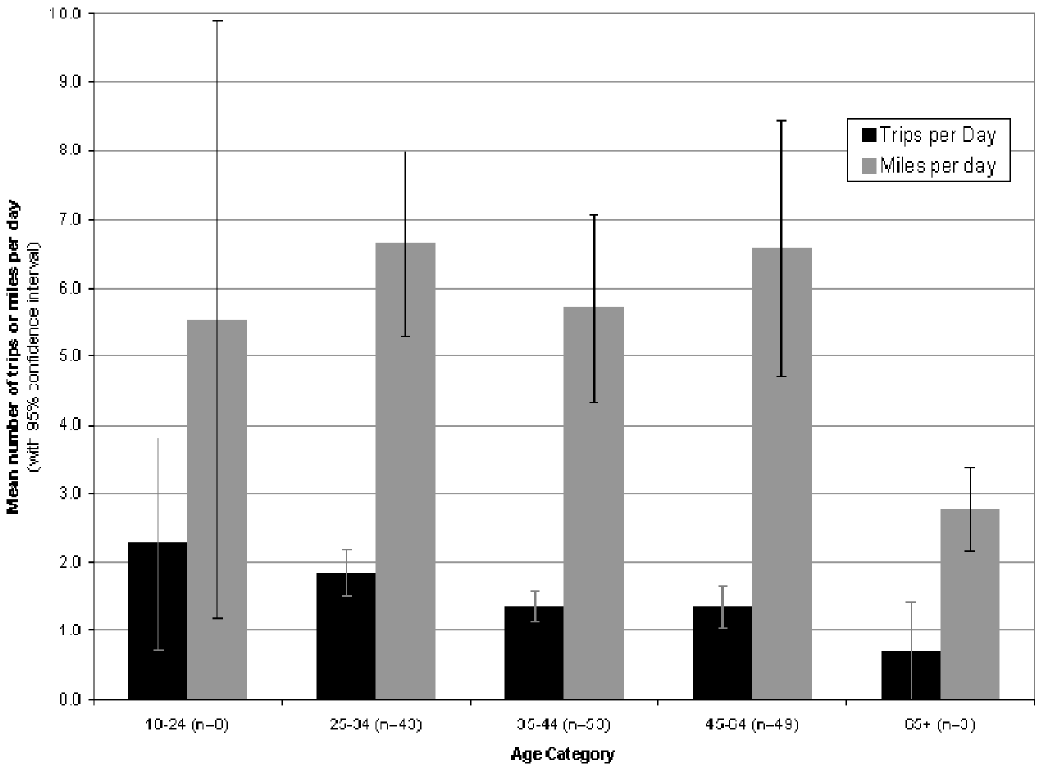

Figure 8:5: Mean number of trips and miles per day, by age on bicycles[257]

In chapter 5, it was shown that the University of Toronto in Canada had schemes to promote cycling and carpooling by implementing an online carpool rideshare program, allocated parking on campus for car-poolers, a dedicated bike/pedestrian road, ample bike racks, free bike hire for 24 hours, free bicycle repair facility and 50% discount for parking a hybrid or efficient vehicle. This policy could also be adopted by SoAD.

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[257] Ibid.

25% (staff taking bus/carpool) + 28% = **53% overall savings**

Option 2: *Reduce the number of commuting times to school*

Reducing the number of commutes is the easiest and cheapest action to implement. With better timetabling of lectures the school could maximise the lessons and lectures for each student in as few days a week as possible. This scheme could be aligned with closing down studios to save electricity. Students normally come to school for classes unless there is an important hand-in. From conversations students see no problem coming into school less than now. Currently a full time student needs to come into school on average 4 days out of 7. Lectures could also be recorded and uploaded online synchronised with the corresponding Powerpoint. This technology is available but not utilised. The advantage of this method is that students have access to the lectures at all times making attendance unnecessary. Questions can be answered via email and forwarded to everyone. Students would only need to come into school to attend tutorials for and presentations. Even assignment submissions can be done digitally, thus also saving paper.

So if students only needed to come in 2 days out of 4 days would reduce commuting time by 50%.

62,877 kg CO_2 x 50% / 93,900 kg CO_2 x 100 = 33% savings overall in combination with staff savings would result in 25%+33% = **58% overall savings**

In the digital age this generation of students have experienced a great change in social networking where digital space is utilised as a viable and active form of social interaction. There should not be much difficulty with changing from old style of teaching to the new by embracing the digital media.

8.4.3 90% reduction scheme

A 90% reduction is virtually impossible by simply replacing existing travel with a less carbon intensive means of transport unless everyone moves close to school and decides to walk or cycle. The only way is to come into university less frequently than now, which would change the way the school is run.
The solutions may lie in the hands of Wellington City Council and the government. Choosing the right government is critical for improving the transport sector in Wellington City.

Option 1: ***Make the public transport all electric***
If all the trains and buses were electric then all the transport in the Wellington region could potentially be zero emission if run wholly on renewables. These issues are beyond the control of the school, however since Wellington City holds a carbon neutral vision[258], this is an investment worth considering.

Option 2: ***Reduce the number of commuting times to school or move closer to the city***
If on average staff and students who do not walk or cycle come to school 4 times a week, reducing this number to 1 would give a 75% transport emissions saving. The students who live in the vicinity of the school would have more access as their transport emissions are zero. This may provide an incentive for people to live close to their work. To achieve a 90% reduction more people need to live close enough to be able to cycle or walk to school.

All staff live within cycling or walking distance of the school. This results in a saving of **31,023 kg CO_2 per year.**

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[258] Wellington City Council, "News – Features", *Council Agrees to Carbon Neutral Vision*
08 June 2007, <http://www.wellington.govt.nz/news/display-item.php?id=2937>
[accessed 02 February 2009]

All students who take the train switch to carbon zero transport (cycle or walk). This results in a saving of **52,447kg CO_2 per year.**

31,023 + 52,447 / 93,900 x 100 = **90% savings**

8.5 Guidelines to reduce transport emissions

- Maximise the use of web/tele conferencing technologies to avoid flying
- Consider taking slower forms of transport in place of air travel
- Reduce unnecessary air travel and plan travel to efficient with time and work
- Live close to work / school
- Walk and cycle more
- Share rides with other passengers
- Make more use of electric vehicles
- Ration staff flying
- Vote for a government that will invest in public transport

8.6 Conclusion

The possible solutions to reduce the carbon footprint of transport were explored. Finance seems to play a role in determining whether a more sustainable mode of transport is selected. Students already use more sustainable forms of transport than staff, so to reduce their footprint further, more carbon zero transportation such as cycling or walking is needed. (But this issue is more complicated as the food to fuel the cycling or walking can change the impact of the emissions) There seem to be no incentives for students and staff to switch to more sustainable modes of transport as parking fees for staff are cheaper than taking buses, and cycling is deemed to be unsafe on current roads. SoAD needs to provide the necessary incentives, although certain measures, such as converting all Wellington City's buses to be electric and improving roads to be cycle-friendly, are beyond SoAD's control.

Other options exist. For example, car sharing between 4 staff could result in a similar footprint to taking the bus.

SoAD already has existing systems utilising web technology which could replace the need for physical presence in lectures or conferences.

What this chapter emphasises is that in a world where a 90% reduction in carbon emissions is required, things are going to be different and things will take more time. Voting for the right government is critical as transport issues are part of a bigger problem outside SoAD's control.

9.0 Waste Reduction Plan

In the carboNZero 2007 report, waste to landfill accounted for 108.69t CO_2, making 16% of total GHG emissions for SoAD. This was based on the number of bins of waste in 2007. However, there was no method of knowing the composition of the waste, to see what was going to landfill and what was sent for recycling. Currently, there is no form of waste audit to measure the different types of waste produced. This re-emphasises the need for an operations manager to undertake waste audits so that any waste reduction plan can be as efficient and effective as possible. Note that the 'waste' category for carboNZero does not include sewage waste.

Below is the record from carboNZero for the total wastes produced by the school in 2007.

Compostable - Food organics / Garden waste (kg)	**Recyclable -** Paper/Plastics (kg)
67516.2	**35488.8**
65.5%	34.5%

Table 9:1: SoAD waste in kgs by type[259]

	Tonnes (CO_2e)	**Emission Factor**
Compostable	48.59	0.72
Paper & plastic	60.10	1.69
TOTAL	**108.69**	

Table 9:2: SoAD waste in tonnes CO_2e with the respective emission factors[260]

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[259] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)
[260] Ibid.

According to the carboNZero data, there are significant uncertainties in this estimation of GHG emissions from waste to landfill for SoAD. Core uncertainties occur in the following areas:

- *Estimation of refuse mass through assumptions that bins are full when emptied*
- *Assumptions as to the mix of compostable versus paper/cardboard/wood in the waste stream*
- *Assumptions of waste density to allow for estimation of waste on a mass rather than volume basis*
- *Assumption that all waste will go to landfill and that these wastes to landfill will generate GHG emissions* [261]

This simplified categorisation of waste poses problems. 'Recyclables' only indicates paper and plastic, excluding steel, aluminium, and glass that are in the waste stream and that could be recycled. 'Food and garden waste' represents compostable waste, however there should not be any garden waste generated in SoAD.
Despite the higher compostable waste percentage from the carboNZero data, it seems unlikely that this is an accurate assessment of the amount of waste produced in each category, because SoAD's main waste is paper. A waste audit in 2008 of Rutherford House (Pipetea Campus at Victoria University) estimated 26.2% compostable waste and 61.5% recyclable waste.[262] This is reasonably consistent with office and commercial waste distribution in the UK[263] (See figure 9:1) where recyclable waste including all paper, glass, cans and plastic equals 72% and compostable waste equals 21%.

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[261] Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)
[262] Ibid.
[263] Waste Online, "Waste at work information sheet," October 2004, <http://www.wasteonline.org.uk/resources/InformationSheets/WasteAtWork.htm> [accessed 02 December 2009]

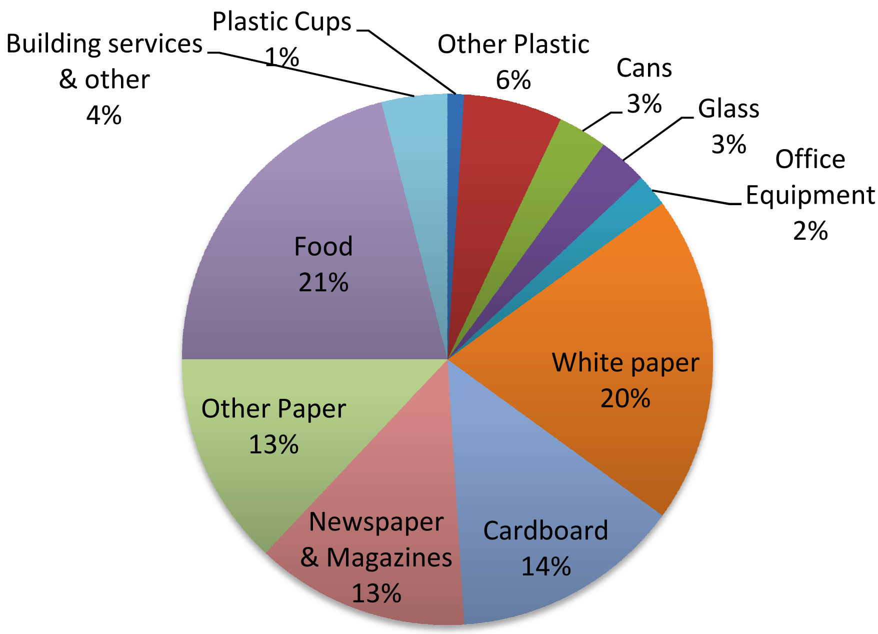

Figure 9:1: Office/Commercial waste distribution in UK, assumed to be by weight[264]

Currently in SoAD the 'compostable' bins go to landfill and due to negligent behaviour, include many recyclable wastes (such as cans, paper, and glass bottles). The compostable wastes in these bins are not sorted from the recyclable wastes. Therefore it can be concluded that all compostable waste is going to landfill and contributing to total SoAD GHG emissions. According to the Ministry of the Environment's waste data for NZ, many recyclable wastes do end up in NZ landfills as shown in figure 9:2. (These figures change from year to year depending on the situation)

[264] Ibid.

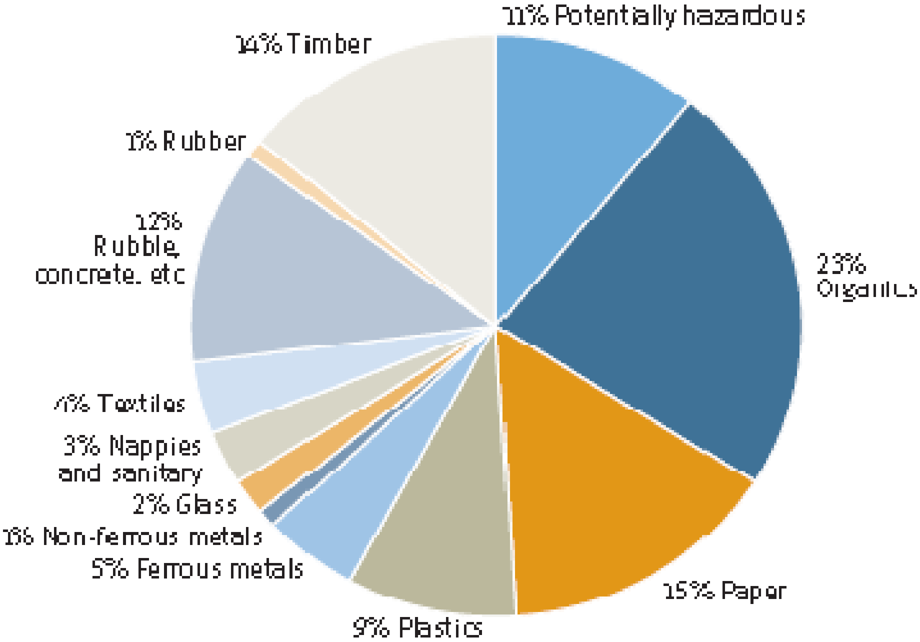

Figure 9:2: Estimates of the composition of waste disposed of to landfills, 2004[265]

Despite the presence in SoAD of recycling bins, there is still negligent behaviour by students and staff members in sorting out rubbish. One possible reason could be that users are not certain about which recyclables are actually recyclable. Table 9:3 shows the labels found on the school bins around SoAD.

Glass bottles / Jars	**Paper + cardboard**	**Non-Recyclables**
Grade 1,2 plastic Aluminium cans Tin cans Steel cans	Newspapers, office paper, advertising circulars, magazines, envelops, corrugated cardboard, egg cartons, pizza boxes	Polystyrene, lightbulbs, batteries, plastic bags, plastic wrap, grade 3-7 plastic, aluminium foil, all other waste

Table 9:3: Three different waste bins labels found at SoAD

[265] Ministry for the Environment, "Chapter 4 Indicator Specifications," <http://www.mfe.govt.nz/publications/ser/technical-guide-new-zealand-environmental-indicators/html/page4-4.html> [accessed 10 December 2009]

Figure 9:3: Three type of bins present in SoAD

Note that the non-recyclable bins allow disposal of batteries, lightbulbs (containing mercury if fluorescent) and other materials that should be collected separately as they are toxic for the environment if not disposed of properly. Additionally some of these materials can be recycled separately.

It was found on numerous occasions that in the paper recycling bins there were bound documents with plastic spiral-bindings and covers. These non-recyclable elements will contaminate the whole bin and should have been removed. It is likely that a contaminated bin will be discarded to landfill as sorting these elements out will require extensive manual labour. This contamination is also prominent in the recyclable bins. Non-recyclable materials are found in the recyclable bins such as grade 3-7 plastics, which are the most common (most people do not check or know that some plastics cannot be recycled), and numerous cork/plastic/metal lids from drink bottles. Unless these bins are manually sorted to ensure there are no unwanted materials it would be likely that these bins will get discarded to landfill. This emphasises the need for people to sort their rubbish and dispose of it properly into the correct bins. Alternatively, the government needs to improve the waste industry so that sorting can occur regardless of people’s negligence. However, manual sorting will cost money and labour. This is why developing countries with cheaper minimum wages are able to afford manual sorting of rubbish, as happens in Brazil and China.[266]

Currently SoAD's GHG emission reduction plan for waste is to recycle as much as possible. There are some efforts to reduce and reuse but these seem not to be active in the current system. It seems likely the main actions were to install recycling bins and have the public printers (not all) set on default double sided printing. There are guidelines about reducing and reusing paper however there are no strong incentives other than relying on the goodwill of students and staff. Currently, the system is designed to make it less convenient to do the right thing.

Recycling Situation in NZ

In the event that everyone behaves well and sorts out the rubbish in the right category, what happens to these recyclable wastes? Canterbury University has carried out research into where NZ waste gets distributed.[267]

> ***Paper and box-board/thin cardboard – Not recyclable in NZ***
> *Paper is sorted by colour and grade and baled in Christchurch before being shipped overseas. There, it is de-inked (currently, New Zealand does not have equipment to remove printing inks from the paper) and made into newspapers and other recycled paper grades.*
>
> ***Corrugated cardboard – Recyclable in NZ***
> *Cardboard is baled and sent either to Kinleith in the North Island or else overseas for remaking into cardboard boxes.*
>
> ***Glass bottles and jars – Recyclable in NZ (Only in Auckland)***
> *Glass is sorted by colour then crushed and screened at Meta NZ for use locally in: sandblasting; water filtration; asphalt and concrete additives; artwork; landscaping; glass flooring and glass tile*

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[266] David C. Wilson, Costas Velis, Chris Cheeseman, 'Role of informal sector recycling in waste management in developing countries', *Habitat International* 30 (2006) 797–808 p.798

[267] University of Canterbury, *"Sustainability," What happens to the items we recycle?* <http://www.sustain.canterbury.ac.nz/waste/recycle_what_happens_to_it.shtml> [accessed 15 December 2009]

production. Surplus glass is sent to Auckland for recycling into new bottles and jars.

However, Wellington City council may no longer take responsibility for glass recycling because it is uneconomic to send it to the recycling factory in Auckland due to transport costs.[268] It is understood the council would consider other options to get rid of glass, including burying it at the tip or grinding it into a powder for use in sealing the city's roads.[269]

Aluminium and steel cans – Not recyclable in NZ (Sent to Australia and Japan)
Cans are sorted and baled locally then exported overseas. Aluminium is recycled into a range of products including drink cans, while steel cans are recycled into items like fencing wire and reinforcing bars.

Plastic no. 1 bottles (PET) – Not recyclable in NZ (Sent to China)
Plastic no. 1 (mostly soft drink bottles) is sorted by colour and baled for export, mainly to China for recycling into fibre such as carpets and polar fleece. Plastics from New Zealand were supposed to be shipped to a processing plant in Hong Kong, where they were cleaned and heat-moulded, before being shipped to buyers elsewhere in China where they were sorted and processed by hand - a practice that raised health concerns.

Plastic no. 2 bottles (HDPE) – Recyclable in NZ
Plastic no. 2 (e.g. plastic milk bottles) is sorted and baled locally, and sent to the North Island for manufacturing into products like recycling bins, ducting, and irrigation pipes.

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268 Ministry for the Environment, *Waste generation and disposal in New Zealand*, <http://www.mfe.govt.nz/publications/ser/ser1997/html/chapter3.5.html> [accessed 16 December 2009]

269 The Dominion Post, *Wellington's council rethinks recycling*, 26 September 2008, <http://www.stuff.co.nz/dominion-post/news/wellington/645565> [accessed 17 December 2009]

Expanded polystyrene – Not recyclable in NZ
This type of plastic is compacted or melted into blocks and then shipped overseas for remanufacturing into new products such as bathroom fittings.

Batteries – Not recyclable in NZ (Sent to Korea)
Batteries are collected by a contractor and exported to the Kobar battery recycling facility in South Korea. Batteries are dismantled into their component parts and put through a distillation and furnacing process to recover the metals. Recovered cadmium is reused by battery manufacturers. Because it is uneconomic to separate the iron and nickel, this is melted down into ferro-nickel ingots which are used by the stainless steel industry. Plastic and cell casings are on sold to special recyclers. Kobar has been authorised and approved by the Korean government as an environmentally sound company.

Toner and ink cartridges – Not recyclable in NZ
The used toner cartridges are taken away by Ricoh and either remanufactured or, if unsuitable for remanufacture, are stripped into their component parts and sent for recycling or reuse.[270]

Difficulty of waste recycling in a capitalist society

The market for recycling waste is dependent on the global economy. Recyclable materials such as paper, plastic and metal are internationally traded commodities. The market for these goods is unstable and most of the times they are unprofitable as prices for plastics and paper in particular are low. Due to the global economic recession, prices of recycled materials have dropped causing a crash in the recycling business. This resulted in recycled materials sitting inside warehouses ready to be thrown back into the landfill.[271] Due to the small recyclable waste production in NZ, most of the wastes are

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[270] University of Canterbury, *"Sustainability," What happens to the items we recycle?* <http://www.sustain.canterbury.ac.nz/waste/recycle_what_happens_to_it.shtml> [accessed 15 December 2009]
[271] Barnett Sarah, New Zealand Listener, *Going to Waste*, April 18-24 2009, <http://www.listener.co.nz/issue/3597/columnists/13155/going_to_waste.html> [accessed 15 December 2009]

subject to international trade which makes recycling in NZ heavily dependent on international market prices. The irony of waste production is that it is a by-product of economic activity which is dependent on the endless cycle of production and consumption of resources which is not sustainable. Due to this, the waste stream in NZ will continue to reflect this cycle in future.[272]

The success of waste recycling is dependent on a continual supply of recycled materials and these materials being sold. The demand is driven by costs and is influenced by the following factors:

- *The prices of new raw materials and energy*
- *The economic activity where the materials are processed and used*
- *Whether recyclable materials are raw or processed*
- *The quality of the recyclable material (e.g. sorted and cleaned)*
- *Transport availability and costs.* [273]

For example, paper forms a large percentage of the total waste stream and over a third of it can be easily recycled. There are markets for clean office paper and newspapers which can be recycled five times before the fibres ultimately fail. These recycled papers are used to make cardboard trays, paper board and recycled stationary.[274] However, there is no market for 'mixed paper waste' (glossy magazines and 'junk mail') because of the costs of removing the impurities in it.[275] This indicates that the current system is not geared up for environmentally sound schemes. Economic factors

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[272] Ministry of the Environment, “Solid Waste Composition”, Environmental Report Card, July 2009, <http://www.mfe.govt.nz/environmental-reporting/report-cards/waste-composition/2009/waste-composition.pdf> [accessed 17 December 2009], p.19
[273] Ibid p.19
[274] Ministry for the Environment, “Waste generation and disposal in New Zealand” <http://www.mfe.govt.nz/publications/ser/ser1997/html/chapter3.5.html> [accessed 17 December 2009]
[275] Ibid.

prevent these resources from being recycled and economic factors also encourage the use of these materials that will all contribute to landfill.

Reduce, Reuse then Recycle

For the reasons stated above, SoAD should try to reduce waste as much as possible as a first point of emissions reduction, then reuse the waste materials and rely on recycling as a last resort for reducing GHG emissions from the total wastes generated.

Table 9:4 is a reflection of the percentage of recyclable wastes being recycled in NZ. By using these statistics a more realistic recycling situation for SoAD's waste can be predicted. Since SoAD does recycle some of its waste, it is inaccurate to claim that all wastes end up in the landfill stream therefore contributing to the GHG emissions.

Waste types	Actual recovered recyclables from total waste generated (%)	Potential recyclables that can be technically recoverable from total waste (%)
Paper	65%	75%
Plastic	5%	55%
Metal	81%	85%
Glass	35%	85%
Organic	23%	85%
Subtotal	51%	80%

Table 9:4: Recyclable material quantities from commercial waste[276]

Despite the high recoverable percentages for recyclable wastes, in practice the full recycling potential has not been reached. This is mainly due to much of the waste ending up in landfills for the reasons

[276] Ministry for the Environment, *Table 30: Recyclable material quantities,* <http://www.mfe.govt.nz/publications/waste/recycling-cost-benefit-analysis-apr07/html/table-30.html> [accessed 17 December 2009]

mentioned previously. Recycling waste is a voluntary activity and many commercial businesses do not bother. For example organic waste has a potential of 85% recovery, however only 23% has been recovered. Paper and metal have the highest percentages of actual recovery and plastic the lowest of only 55%. This emphasizes the need to reduce plastics consumption in NZ.

According to the Environmental Benefits of Recycling Report by WRAP (Waste and Resource Action Programme) in the UK,[277] recycling has a lower environmental impact than the alternatives of incineration or landfill, with energy consumption being a crucial factor (note that the UK and NZ have different energy generation mixes). Recycling was the most beneficial out of the environmental impact categories included in the studies.

New updated waste figures

Due to the inaccurate and unclear waste audit for SoAD, more accurate waste generation can be estimated based on the % distribution of office waste in the UK (see figure 9:1). Using the SoAD total of 103,005 kgs of waste generated in 2007, each waste category would be:

Food (kg)	**Cans** (kg)	**Other paper** (kg)	**Other waste**[278] (kg)	**Glass** (kg)	**Cardboard** (kg)	**White paper** (kg)	**Newspapers & Magazines** (kg)	**Other plastic** (kg)
SoAD waste % distribution based on UK commercial office								
21,631	3,090	13,391	7,210	3,090	14,421	20,601	13,391	6,180

[277] Waste & Resources Action Programme, *Environmental Benefits of Recycling, An international review of life cycle comparisons for key materials in the UK recycling sector*, May 2006, <http://www.wrap.org.uk/applications/publications/publication_details.rm?id=698&publication=2838&programme=wrap> [accessed 17 December 2009], p.114

[278] This includes e-waste from figure 9:1, however all e-waste gets sent back to the equipment leasers, whereas construction waste and plastic cups go to landfill. This will be a waste to landfill figure.

21%	3%	13%	7%	3%	14%	20%	13%	6%

Table 9:5: Waste make up in kg

By grouping the different waste categories into four main groups, the total waste before recycling comprises the following:

Food / compostable (kg)	**All forms of Paper** (kg)	**All forms of recyclables** (kg)	**Other waste to landfill** (kg)
21,631	61,804	12,361	7,210
21%	60%	12%	7%

Table 9:6: Four different groups of waste in kgs

Currently all the food waste is going to landfill as there are no separate bins for this, and only paper, cans, and glass are going to the recycling station although most will also end up in landfill due to "soiling" of the bins and the current economic recession making recyclable materials hard to sell.
The percentages for the actual recovered recyclables in NZ can be applied to the figures in table 9:5 to create table 9:7 below.

Food (kg) 23%	**Cans** (kg) 81%	**Other paper** (kg) 65%	**Other waste** (kg) 0%	**Glass** (kg) 35%	**Cardboard** (kg) 65%	**White paper** (kg) 65%	**Newspapers & Magazines** (kg) 65%	**Other plastic** (kg) 5%
Actual recovered recyclables from total generated in NZ								
4,975	2,503	8,704	0	1,082	9,374	13,391	8,704	309

Table 9:7: Actual recovered waste to be recycled in kgs

Adding the landfill waste and deducting the recoverable recycled waste equals 58,938kgs in total (which includes the recyclable materials sent to landfill) resulting in the conclusion that more than half of SoAD's waste is ending up in landfills. (See table 9:8 below)

	Food / compostable (kg)	**All forms of Paper** (kg)	**All forms of recyclables (cans, glass, plastics)** (kg)	**Other waste to landfill** (kg)	**TOTAL (kg)**
To landfill - 57%	21,631	21,631	8,467	7,210	**58,938**
To recycle - 43%	0	40,173	3,894	0	**44,067**

Table 9:8: Landfill waste and Recycled waste in kgs

To calculate the kg CO_2 emissions related to the different categories of waste, the Ministry for the Environment emissions conversion factor was used for compostable, paper, and other waste going to landfill (See table 9:10). The recyclables waste conversion factor was used from the carboNZero data for paper and plastics.

	Emission Factor land filled waste (without gas recovery) – See table 10	**Total Waste to landfill emissions (deduct recyclables)** (kg CO_2e) – See Table 7	**Actual recovered recyclables diverted from landfill (kg CO_2)** – See table 7
Compostable	0.945[279]	20,441	0
Paper	**2.52**[280]	54,510	101,236

[279] Ministry for the Environment, *Chapter 3 Emission factors and methods 2008*, <http://www.mfe.govt.nz/publications/climate/guidance-greenhouse-gas-reporting-sept09/html/page2.html> [accessed 19 December 2009]

Recyclables	**1.69**[281]	14,309	6,581
Other (office waste)	1.55[282]	11,176	0
TOTAL		**100,436**	**107,817**

Table 9:9: Waste make up in tonnes CO_2e emissions from landfill

The 107,817 kg CO_2e would be avoided by diverting the recyclable waste from going to landfill. However the calculation of GHG emissions savings from recycling becomes a complex issue it is necessary to analyse the life cycle of a recycled waste product as any new input of materials, transportation, water and any chemicals released from recycling process need to be taken into consideration. Many studies in this area come from the US which derives more of its electricity from coal than NZ. Also since NZ recyclable wastes are exported overseas the associated transport emissions overseas need to be compared with waste recycled in NZ to see which is more beneficial. This is an issue that requires further study and that will not be discussed in this thesis.

For the purpose of this exercise and to simplify the calculations, the assumption is made that recycling waste will stop GHG emissions from landfills. This means that more than half of the GHG emissions savings can be achieved from recycling at the current rate found in NZ.

40%+ overall reduction from landfill gas recovery

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280 Ibid.

281 Wilks Andrew, (Andrew.wilks@vuw.ac.nz), (29 January 2009), *RE: energy report for school of architecture and design* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

* From carboNZero data for plastics and paper; this figure will be considered as recyclable materials

282 Ministry for the Environment, *Chapter 3 Emission factors and methods 2008*, <http://www.mfe.govt.nz/publications/climate/guidance-greenhouse-gas-reporting-sept09/html/page2.html> [accessed 19 December 2009]

There is a way of saving GHG emissions generated by landfill through landfill gas recovery systems. According to the Ministry for the Environment, around 40%+ of GHG emissions can be saved in this way. This can be beneficial as it can generate electricity at the same time as reducing emissions. However the irony is that it depends on waste materials being constantly generated in order for it to work. This solution is outside SoAD's control and therefore will not be explored further here.

Emission source	**Data input unit**	**Emission Factor (Kgs CO_2e/unit)**		
Landfilled waste of known composition		**(without landfill gas recovery)**	**(with landfill gas recovery)**	**% savings from**
Paper and textiles	kg	2.520	1.45	44% savings
Garden and food	kg	0.945	0.545	42% savings
Landfilled waste – default values		**(without landfill gas recovery)**	**(with landfill gas recovery)**	
Mixed waste (national average)	kg	1.06	0.614	42% savings
Office waste	kg	1.55	0.893	42% savings

Table 9:10: Emission factors for waste to landfill – 2008[283]

The four main categories of waste (paper, recyclables, compostable and waste to landfill) will be reduced according to the three targets set earlier. Wastes that are recycled will be taken into consideration as such wastes decrease carbon emissions.

283 Ibid.

It is interesting to note that *incinerating 10,000 tons of waste creates 1 job, landfilling it creates 6 jobs, and recycling it creates 36 jobs.*[284]

9.1 Paper Use

Paper is by far the biggest consumption category of any commercial institution. Despite predictions of the "paperless office" after the invention of personal computers, this has turned out to be the contrary.[285] Paper use has increased dramatically in the last half of the 20th century rapidly increasing since the mid 1970's. Paper's advantages of being cheap, stable, portable, easy to archive and tangible makes it very popular in academia.

According to the Ministry for the Environment NZ uses about 48,000 tonnes of paper every year. Sanitary papers (such as paper tissues for kitchens and bathrooms) cannot be recycled. The negative impact of paper production does not stop at wastes going to landfill, but include air and water pollution, deforestation, and soil erosion.[286] One fifth of global harvesting of trees is from paper sourcing and accounts for 93% of all paper. This paper travels hundreds of kilometres from the forest to the consumer to be used as a communications tool and also for packaging.[287]

It is interesting to note that *75% of a tree harvested for paper does not wind up as a paper product.*[288]

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[284] ZeroWaste, New Zealand Trust, *Facts & Figures*, http://zerowaste.co.nz/default,72.sm [accessed 21 December 2009]
[285] Ministry for the Environment, *Paper products*, <http://www.mfe.govt.nz/issues/sustainable-industry/govt3/topic-areas/office-consumables/paper-products.html> [accessed 20 December 2009]
[286] Ibid.
[287] ZeroWaste, New Zealand Trust, *Facts about Paper*, http://zerowaste.co.nz/default,563.sm [accessed 21 December 2009]
[288] Ibid.

SoAD paper use

Chapter 3 showed that with each year VUW has increased the use of recycled content paper for printing and photocopying. However the amount of this is relatively small compared to overall usage. Demands have decreased slightly over the years. The School of Architecture in particular uses more paper than many other university departments due to the nature of its activities. A lot of cardboard is used to make models and big size printing for final presentation drawings means many test prints to ensure that the colour and resolution are as the student wants. Apart from printing documents for assignment hand-ins and lecture notes, SoAD have additional paper uses compared with other faculties.

Observation of paper use in SoAD:

- Virgin paper of 80gsm is used for all photocopying machines and printers. Some printers and photocopiers use higher gsm values –for example, the school letter head uses thicker paper
- Double sided printing is set as the main setting in library and studio computers. However this is not the case for lab computers and postgraduate studios
- Double sided in photocopiers is not set as the default and is not used much – probably because of not understanding the instructions
- Some printers still do not have a double sided printing option other than manual feeding
- Recycling paper bins usually placed next to every printer/photocopier
- Recycling paper bins present in most staff rooms
- Printing A4 costs 5c per page and A3 10c per page B/W and colour. Each postgraduate student has $100 worth of printing per month and free unlimited photocopying
- Staff appear to have no limits placed on their printing or photocopying
- A lot of misprints and uncollected prints are left next to printers and photocopiers

- Staff are unable to double side or re-use paper due to sharing printers in a network
- Mail communication is still considered more reliable than email. Therefore all formal communications are still done via mail.
- Lecture notes are printed and handed out and usually excess are printed
- Assignment hand-ins are mainly physical but digital hand-ins do exist and are increasing
- Some final year presentations are digital and some are not.

The total overall paper consumption of 61,803kg can be divided into the following categories from figure 9:1.

	White paper 33% (kg)	**Other paper 22%** (kg)	**Cardboard 23%** (kg)	**Newspapers & magazines 22%** (kg)	**TOTAL** (kg)	**Kg CO_2** CF = 2.52
Before deducting recycled paper	20,601	13,391	14,421	13,391	**=61,804**	**=155,746**
After deducting paper that went to recycling	7,210 (18,169 kg CO_2)	4,687	5,047	4,687	**=21,631**	**= 54,510**

Table 9:11: Different paper waste categories in kgs and its total emissions

Calculation of the School's virgin paper use using table 9:5 is as follows:

A ream (1 ream = 500 sheets) of 80gsm, A4 paper weighs approximately 2.5kg.[289] This means SoAD goes through 8,241 (=20,601kg / 2.5kg) reams of A4 per year. This is equivalent to 4,120,500 sheets (= 8,241 reams x 500 sheets) of A4 paper per year. This is approximately 3,066 sheets of A4 paper (or equivalent A3 and larger) per person per year (4,120,500 sheets / 1244+100 people). Actual usage will vary between students and staff and between different disciplines in SoAD.

9.1.1 25% reduction scheme

Solution 1: *Replace virgin paper with 100% recycled content paper*

It seems unnecessary to use virgin paper all the time, especially when recycled content paper can also have the same whiteness and quality. However, this will be at an added cost. The easiest way to reduce emissions is for SoAD to replace virgin paper with recycled content paper. Table 9:12 is a calculation of the expected savings:

[289] Wilfred, "Re: grams/square meter to pounds/ream," 10 May 2005, <http://www.onlineconversion.com/forum/forum_1118773419.htm> [accessed 28 December 2009]

Type of paper	Price	Availability	Kg CO_2 savings **(20,601kg used)** From: Papercalculator.org
Reflex Photocopy paper A4 White 80gsm 500 Pack (Virgin)	$5.99 per ream	Warehouse Stationary (NZ) – Australian made	**54,965kg CO_2 equiv** **Even if you used the 2.52 carbon emission factor from table 9:9, it would still result in 20,601kg x 2.52 = 51,915kg* CO_2 *which is similar to the above figure*[290]
Reflex Photocopy Paper A4 White 50% Recycled 80gsm 500 Pack	$9.96 per ream	Warehouse Stationary (NZ) – Australian made	**43,472kg CO_2 equiv. →** 21% savings from virgin paper
Reflex Photocopy Paper 100% Recycled A4 80gsm 500 Pack	$10.99 per ream	Warehouse Stationary (NZ) – Australian made	**31, 979 kg CO_2 equiv. →** 42% savings from virgin paper

Table 9:12: Emission savings from using recycled content paper[291]

Total paper emissions after deducting the paper recycled are 54,510kg CO_2 (see table 9:11). Changing SoAD's virgin paper use to 100% recycled paper would result in a 42% saving.

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[290] Ministry for the Environment, *Chapter 3 Emission factors and methods 2008*, <http://www.mfe.govt.nz/publications/climate/guidance-greenhouse-gas-reporting-sept09/html/page2.html> [accessed 19 December 2009]

[291] Warehouse Stationary, 'Photocopy paper', < http://www.warehousestationery.co.nz/is-bin/INTERSHOP.enfinity/WFS/WSL-B2C-Site/en_NZ/-/NZD/ViewStandardCatalog-ProductPaging?CatalogCategoryID=nrQKBTHBgmIAAAEdKE0MoH00&PageableID=s5YKAQIF.voAAAEmOtQVTMvF&PageableName=SubCategories&PageNumber=0&sort_attribute_1=&=&SecPageableID=tXcKAQIFYgwAAAEmiNQVTMvF&SecPageableName=Products&SecPageNumber=1> [accessed 31 December 2009]

* Reflex is certified by the international Forest Stewardship Council (FSC) Reflex Ultra White is also acid free

42% of 18,169kg CO_2 from white paper use = 7,631 kg CO_2.

→ **14% in overall paper savings** (7,631/54,510x100)

However, this only makes savings in kg CO_2 emissions not in kg of paper used. This is a not a REDUCE but a RECYCLING strategy. However, it is probably the easiest method to implement.

The 50% recycled content paper is similar in price to the 100% recycled paper and both guarantee whiteness and quality. As all papers considered are Australian made there is no difference in the footprint. It is important to note than even though this calculation is only for GHG emissions savings, reducing virgin paper use has other related savings. For example, according to the Zero Waste New Zealand Trust, for every one tonne of paper recycled:

- *31,780 litres of water are conserved*
- *2.5 barrels of oil are conserved*
- *4 cubic yards of landfill space is conserved and 4,100 kWh of electricity is saved*
- *Globally, the pulp and paper industry pumps 100,000 tonnes of acid rain producing sulphur dioxide into the air each year.*
- *Making paper from recycled materials results in 74% less air pollution and 35% less water pollution.*[292]

On a small scale, papers made out of non-wood sources are available. Examples include hemp, kenaf, agricultural residues (cereal straws, cotton linters, banana peels, coconut shells), and even denim scraps. *Many "agrifibers" yield more pulp-per-acre than forests or tree farms, and they require fewer pesticides and herbicides.*[293] However these non-wood papers are not readily commercially available in New Zealand therefore this option will not be explored.

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[292] ZeroWaste, New Zealand Trust, *Facts & Figures*, <http://zerowaste.co.nz/default,72.sm> [accessed 21 December 2009]

[293] ZeroWaste, New Zealand Trust, *Facts about Paper*, <http://zerowaste.co.nz/default,563.sm> [accessed 21 December 2009]

SoAD requires another 9% in GHG emissions reduction in order to reach the 25% reduction target after replacing all SoAD's virgin paper use with recycled content paper.

Solution 2: ***Replace newspaper and magazine subscriptions with online pdfs (REDUCE by REPLACING)***

Some newspaper and magazine subscriptions can now be accessed online in pdf formats. This is becoming more popular as these publications can easily be accessed online all around the world. For example the popular and internationally renowned architectural magazine from Germany "Detail"[294] allows subscribers to access previous and latest issues online as a pdf format. In addition, E-books are becoming more popular and this could grow with the new release of Apple's iPAD. If SoAD can maximise this option with international magazines, this will also cut emissions. However because these pdfs are easily available this may lead to students printing their own copies, increasing paper use. However these pdfs can be fixed so they cannot be printed. The issue of increased electricity use due to more computer use could be a problem but given the SoAD computers are already on all day it is better to use them to view the journals.

Newspapers & magazines after deducting recycled materials (kg)	**Kg C02 (CF = 2.52)**	**Replace 50% magazine subscriptions with online versions (kg CO_2)**
4,687	11,811	5,906

Table 9:13: Expected kg CO_2 savings from reducing magazine/newspaper subscriptions by 50%

5,906 kg CO_2 / 54,510 kg CO_2 x 100 = **11% overall paper savings**

[294] Detail Magazine, <www.detail.de/archive> [accessed 22 December 2009]

This results in a 25% saving in total. This is achieved by simply *replacing* the current usages with more efficient methods. However, further research is needed to compare the impacts of computer use and paper use. This issue will not be explored in this thesis.

9.1.2 50% reduction in total paper use

The easiest, quickest and cheapest way to reduce paper demand is simply to reduce all paper usage by 50% in each category. Cardboard is used for student models, presentation backing, assignment hand in folders, boxes for packaging, and filing. This can be reduced by putting more emphasis on digital models. Recycled cardboard can be used for draft exploration models. However the impact of using the computer in place of cardboard would need to be further researched. It could be that because of the renewable energy component in NZ electricity home computer use may be better than using paper, whether recycled or not, from overseas. Everything should be digital where possible. Examples of this are student grades sent by email, communicate via email rather than letters, filing on the computer instead of paper, double sided printing, printing two pages on one A4 side, only digital hand-ins and design presentations on computer screens. Also to further ensure that paper use is reduced by 50%, it is best to set a printing and photocopying monthly ration for each staff member and student. This will lead to more careful printing decision making and automatically make people be more efficient by getting the maximum printing out of their quota. Incentives to encourage this behaviour could be making the double sided printing option the same cost as printing single side and any leftover credit being claimed back for money or used for later months when needed. People who go over ration would need to purchase extra credit at high cost, although this might lead to wealthier students being able to buy more credits while poorer students cannot.

The "Other paper" category of waste is likely to be envelopes, advertising and packaging. The University should eliminate brochures and leaflets by putting most of the information on the web and restricting the number of printings of these hard copy materials.

- Currently the school uses 6 reams per person annully = approx 3000 sheets of paper per person per year (1 ream per 2 months)
- Reduce to 1500 sheets per person per year = 3 reams per person per year
- Reduction of 50% of *white paper* use results in **17% overall paper savings** (33% for white paper use /2)
- Reduction of 50% in *cardboard* use results in **12% overall paper savings** (23% for cardboard use /2)
- Reduction of 50% in *other paper* use results in **11% overall paper savings** (22% for other paper use /2)
- 11% savings can come from previous scheme to replace 50% of newspaper/magazine subscription by online pdfs.
- In total 11% + 17% + 12% + 11% = **51% reduction overall**

9.1.3 90% reduction in total paper use

A 90% reduction will be difficult to attain unless most of the paper use in each category is reduced dramatically. To achieve 90%, SoAD needs to eliminate most newspaper and magazine subscriptions, with online subscriptions the norm, eliminate the use of cardboard and miscellaneous paper as much as possible, and ideally have white paper use both reduced and converted to recycled paper only.

White paper	Other paper	Cardboard	Newspapers & magazines
~~33%~~ = 3% left	~~22%~~ = 2% left	~~23%~~ = 3% left	~~22%~~ = 2% left

Table 9:14: Required reduction from each paper category to achieve 90% reduction in emission savings

So 20% reduction in other paper, cardboard and magazines/newspapers category and 30% reduction in white paper would result in 90% reduction overall.

That means white paper use is 3% of 61,803kg = 1,854 kg per annum. This is equivalent to 742 reams per year which is 371,000 sheets per year. **This makes 276 sheets per person per year.** This means just over a half a ream per year per person is necessary to achieve a 90% reduction (this calculation excludes the CO_2 emissions savings from using recycled paper).

At the current rate of paper consumption, assuming no one double sides or prints two pages per sheet, 50% can be saved from double siding printing/ and photocopying and another 25% from printing two pages per sheet. This is already a 75% in reduction in paper use. All digital hand-ins, pdfs and e-books, online journals, lecture notes available online for students, all writing and editing of staff and student work on the computer and scanning digital copies instead of photocopying can save paper use. With this digital age, there is already a trend away from buying books to seeking information online.

Paper that cannot be double sided, like non- confidential can be reused by turning them into notebooks for note taking in lectures. All these schemes would be needed to achieve the 90% reduction, and will require effort.

This makes the point that without the active participation of students and staff in reducing waste, it will be very difficult to implement any reduction scheme effectively.

There is also the option of using composting bins for food compost as worms eat paper as well. This option will be explored in the food compost section below as paper is a vital ingredient for a good composting process.

9.2 Compostable waste / Food scraps

The next biggest emission factor is compostable waste, making up 21% of total waste after paper. Total compostable waste equals 21,631kg resulting in 20,411kg CO_2 of emissions. Currently all these compostable wastes are going to landfill.

Ideally, there should not be any food waste generated because in a sustainable society everyone will finish their food and not throw any away. Sustainability is about reducing waste, especially food waste. Figure 9:2 indicates that 23% of waste going to landfill is organics which includes food scraps that could have been eaten. This may be interlinked with the fact that the average New Zealander is over eating. According to statistics from a study conducted by AUT University's Professor of Nutrition Elaine Rush, New Zealanders are becoming overweight because people eat too much, rather than exercising too little as physical activity cannot fully compensate for consuming excess calories. A recent result from the study showed that:

> *New Zealanders were consuming between 350– 500 more calories a day than required. This means children would have to cut their intake by about 350 calories a day, which is equal to one can of fizzy drink and a small chocolate bar and adults 500 calories, which is the equivalent of a large burger. New Zealanders are over-eating and eating the wrong, energy dense foods which are full of calories, like white bread, full-fat milk and cuts of meat with a high fat content with high calories which leave people malnourished and hungry*.[295]

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[295] Rush Elaine, Auckland University of Technology, *Kiwis have been over-eating for three decades*, May 25, 2009, <http://www.aut.ac.nz/corp/newsrelease/?680> [accessed 22 December 2009]

According to the Ministry for Health, average New Zealanders (15 years old and older) are overweight by 30 to 40%.[296] This not only results in loss of life and diseases but puts strain on the health system.
This questions the state of the NZ diet and the behaviour of a throw-away society which is both unsustainable and unethical, given food is scarce is many countries. The sustainability.govt.nz website indicates that in 2008, a study in the United Kingdom[297] found that on average each person throws away 70kg of edible food a year. The study also showed that most of the food wasted was avoidable as 61% of food thrown away could have been eaten if it had been better managed (e.g. left over take-aways, food that had passed its expiry date). The study also found the top ten types of avoidable food waste were:

1. Potatoes
2. Bread Slices
3. Apples
4. Meat or fish mixed meals
5. World bread (e.g. naan, tortilla)
6. Vegetable mixed meals
7. Pasta mixed meals
8. Bread rolls/baguettes
9. Rice mixed meals
10. Mixed meals

The first point of reduction in food waste is to eliminate any leftover food, which means people should finish their food by only preparing what each person can eat. Only inedible waste, such as vegetable and fruit peelings, should be composted and returned to the soil as nutrients. Composting bins have become common practice for

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[296] Ministry of Health, *Food and Nutrition Guidelines for Healthy Adults: A background paper*, (October 2003) http://www.moh.govt.nz/moh.nsf/0/07BC6DBE764FDABBCC256DDB006D9AB4/$File/foodandnutritionguidelines-adults.pdf [accessed 28 January 2010] p.63
[297] Ministry for the Environment, Sustainability.govt.nz, *Food Waste*, <http://www.sustainability.govt.nz/rubbish/food-waste> [accessed 22 December 2009]

households but why not for academic institutions aiming to be carbon neutral? Chapter 5 already indicated various universities around the world that have embraced the idea of composting to reduce food waste going to landfill. Even in NZ, Canterbury University has a community garden so that food scraps are composted and used in the vegetable garden.[298]

Compost worms[299] will only eat certain kinds of food as indicated in table 9:15 below, therefore limiting the waste that can be composted.

Worms will eat - need	Worms won't eat – do not need
Paper: newspaper (shredded + wet), cardboard, soaked and ripped pizza boxes, paper, tissues, cardboard fast food packaging **Garden Waste:** compost, dead leaves, weeds, lawn clippings, peat moss, dirt **Food waste:** crushed egg shells, rolled oats, coconut fibre, waste from vegetable juicers, potato peelings, apple cores, pea pods, any vegetable or fruit scraps, tea leaves/bags, coffee grounds, **Other waste:** vacuum cleaner dust, carpet or underfelt, hair, composted animal manures, pencil sharpenings,	**Food waste:** No meat (raw or cooked), fish scraps, bones, fatty foods (cooking oil). It is best not to give them meat scraps or dairy products, as the compost bin is likely to become smelly and attract rats and mice. Worms do not particularly like acidic foods such as oranges, lemons, grapefruit, tomatoes and strong-smelling foods such as onions and garlic. **Other waste:** Chicken manure should be avoided because it is too strong.

Table 9:15: Waste that can be composted by worms and un-compostable wastes[300] [301]

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[298] University of Canterbury, "Okeover Community Garden," <http://www.sustain.canterbury.ac.nz/comm_garden/index.shtml> [accessed 22 December 2009]

[299] Tiger worms are the special composting worms that you need to convert organic waste into vermicast, an organic compost ideal for growing plants, trees and vegetables.

This means that ideally the school should not consume or waste meat as it cannot be composted. This coincides with reducing the food footprint as meat is a much more energy intensive food and yields a lot less per hectare than growing vegetables or fruit.[302]

SoAD throws away 21,631kg of food per year. Excluding public holidays, this equals approximately 60 kg per day. This means that for 1344 people = 0.045kg (45 grams) of food is thrown away per day, per person.

In order to compost a certain weight of food twice the amount of worms in weight are needed as a worm eats half its weight of food per day. According to a ground based worm farm, Central Wormworx in Cromwell in Central Otago, 1 hectare of land (10,000m²) can hold 40 million tiger worms[303] which is equivalent to 4,000 worms per sq metre. 1kg equals 4000 tigerworms.[304] A worm reproduces every 4 months and has a lifespan of a year or more.

1kg of worms = approx 4000 worms which requires 1sq metre of land.

To compost 60 kg of food per day need 120kg of worms = 480,000 worms = 120m² of land (this is not considering the increase in worm numbers due to breeding).

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9.2.1 25%, 50% and 90% reduction schemes

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300 Recycling Expert, "Composting", <http://www.recyclingexpert.co.uk/Composting.html> [accessed 22 December 2009]

301 Northland Regional Council, "For Schools, Worm Farming", <http://www.nrc.govt.nz/For-Schools/School-information-packs/Worm-farming/> [accessed 22 December 2009]

302 Ryu Wook, Market Gardner, personal communications, 24 December 2009

303 ZeroWaste, New Zealand Trust, *Examples of a ground-based worm farm*, <http://zerowaste.co.nz/default,660.sm> [accessed 1 January 2010]

304 What's on sale, "Product Details", *Compost Worms 1kg,* <http://www.whatsonsale.co.nz/product/53932.aspx> [accessed 08 December 2009]

Diverting food waste from going to landfill will reduce GHG emissions as anaerobic decomposing of waste emits methane which is worse than aerobic digestion (which emits carbon dioxide). Even organic food scraps take a long time to decompose in landfills due to lack of oxygen and sun to aid the decomposition process. Aerobic composting yields the beneficial by-product of compost that can provide nutrients back to the soil. A useful move would be for SoAD to have another bin for food scraps and organic waste. This would require a building manager to maintain these compost bins and ensure that the correct wastes are going to the worms. Table 9:16 below compares the amount of land required, the initial set up costs of composting bins and purchase of worms, and selling the compost created.

Compostable (kg)	**25% composted**	**50% composted**	**90% composted**
21,631	5408/ 360 = 15kg/day	10816/360 = 30kg/day	19468 = 54kg/day
How much land required? (this is not based on composting bins but ground-based worm farm)	15kg x 2 = 30kg → **30m²** **required** (30kg x 4000 = 120,000 worms required per day)	30kg x 2 = 60kg → **60m²** **required** (60kg x 4000 = 240,000 worms required per day)	54kg x 2 = 108kg → **108m²** **required** (108kg x 4000 = 432,000 worms required per day)
Sales of compost Assume 1kg = $1[305]	$ 5408/yr	$10,816/yr	$19,468/yr
How much to get started? $200 for 200L	Two compost boxes **= $400** for 8,000 starter	Three compost boxes **= $600** for 120,000 starter	Six compost boxes = **$1200** for 240,000

[305] Mitre 10, "Pea Straw Pelletized Mulch 10kg", <http://www.mitre10.co.nz/shop/gardening_supplies/seeds_bulbs_and_growing_media/pea_straw_pelletised_mulch_10kg_141914.cfm> [accessed 08 December 2009]

worm box with 4000 starter worms (which can breed to make 120,000 worms per year) One box can hold approx 8000 worms composting around 20L of food scraps per week.[306]	worms which will breed and make 240,000 worms /yr in total which can leave 160,000 worms for the year after (its full capacity of worms)	worms which will breed and make 360,000 worms /yr in total which can leave 240,000 worms for the year after (its full capacity of worms)	starter worms which will breed and make 720,000 worms /yr in total which can leave 480,000 worms for the year after (its full capacity of worms)
Land required for compost bins (0.75m x 0.68m and 0.63m high) Floor area of = $0.51m^2$, volume of $0.22m^3$	$0.51m^2$ x 2 = $1m^2$ +maintenance area of another $1m^2$ = **$2m^2$ total**	$0.51m^2$ x 3 = $1.5m^2$ +maintenance area of another $1.5m^2$ = **$3m^2$ total**	0.51m2 x 6 = $3m^2$ +maintenance area of another $3m^2$ = **$6m^2$ total**
Cost of collection[307] $20 for 240L bin which is $0.24m^3$. One compost bin is $0.22m^3$ and will compost approximately 15kgs of food per day.	Two compost bins (15kg x2) = Two 240L bins per day. $20 x 2 x 360days = **$14,400/yr**	Three compost bins (15kg x 3) = Three 240L bins per day. $20 x 3 x 360days = **$21,600/yr**	Six compost bins (15kg x 6) = Six 240L bins per day. $20 x 6 x 360days = **$43,200/yr**

Table 9:16: Comparison between land, compost bins, worm costs for different % reductions

[306] What's on sale, "Product Details"*, Lil' Pig Worm Farm 200L w/ 1kg Worms,* <http://www.whatsonsale.co.nz/product/44304.aspx> [accessed 08 December 2009]
[307] Darrell at Organic Management Ltd, <http://organicwastemanagement.co.nz/> personal communication, 11 December 2009

The great thing about these composting bins is that the worms will eat paper as well, so a blend of organic and paper waste would be ideal, which will lower paper waste for disposal in other ways but this in turn would increase total waste therefore requiring more bins and associated space. Location of these bins is crucial as they need to be away from direct sunlight. SoAD currently does not have spare land on site. However land can be utilised in the staff car parking area located below the canopy of the ground floor of the Vivian Building. Table 9:16 shows that composting bins were a better economic investment than having the rubbish taken away. It also shows that the investment can generate income for the school by selling the compost or it could be used for a community garden in SoAD if the space for this could be found.

9.3 Recyclable waste – Plastics, glass and aluminium

The recyclable red waste bins usually contain aluminium cans, glass bottles and plastic containers and bottles. These wastes are mostly containers for food and drinks. Due to the fast food culture these containers have a very short life and are disposed of after a single use. Studio life in SoAD results in late night work and many students end up relying on take away food. This increases the amount of plastic containers and bottles that could have been avoided if food were prepared and consumed at home. Figure 9:4 shows the three vending machines available in SoAD which contain the following snacks and drinks:

- Crisps
- Chocolate bars
- Cookies
- Lollies
- Water

- Soft drinks
- Energy water /drink

Figure 9:4: SoAD's only vending machines located on the ground floor

In 2007 SoAD disposed of 3,090 kg each of aluminium cans and glass bottles and 6,180kg of plastic bottles and containers. This is converted to number of bottles consumed per person per year below:

	Aluminium Can	**Plastic (PET) Bottle** (Assume all are Number 1 plastic)	**Glass Bottle**
500mL	0.0147kg[308]	0.036kg	0.267kg
750mL (wine bottle)	-	0.054kg[309]	0.4kg[310]
Per year	21,021 cans / yr	171,667	11,574 bottles/yr

308 The Aluminium Can Group, "Facts" <http://www.aluminium-cans.com.au/Facts.html> [accessed 10 December 2009]
309 Wine Anorak, *Wine in PET bottles: will plastic replace glass?* <http://www.wineanorak.com/wine_in_pet_bottles.htm> [accessed 11 December 2009]
310 Ibid.

	(= 0.0147 x 3,090kg/yr)	bottles/yr (= 0.036 x 6,180kg/yr)	(=0.267 x 3,090kg/yr)
Per year / per person (1344 students + staff)	16 cans / person	128 bottles / person	9 bottles / person

Table 9:17: Comparison between three different types of recyclable waste consumed per person per year

By weight the plastic is approximately one eighth of a glass bottle and an aluminium can is one ninth of a glass bottle. Each student and staff member goes through about three items out of aluminium cans, glass and plastic bottles each week.

To understand the different advantages and disadvantages of each recyclable waste table 9.18 sets out the different factors to consider in terms of the environment:

	Glass	**Plastics**	**Metals – Aluminium cans**
Availability	It is a reasonably renewable resource; there is plenty of it. Glass is also made from natural resources: silica sand and limestone. [311]	Not renewable as they need oil (petroleum) and natural gas to make them[312]	Not renewable –Aluminium is smelted from alumina, which is extracted from bauxite, mined in Queensland,

[311] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*, <http://good.net.nz/magazine/2/good-start/bottles-vs-cans> [accessed 23 December 2009]

[312] American Chemistry Council, "How is plastic made?" <http://www.americanchemistry.com/s_plastics/doc.asp?CID=1571&DID=5974> [accessed 22 December 2009]

			Australia[313]
Rate of recyclability (demand)	It can be recycled in NZ (but only in certain places). Production / disposal exceed recycling capacity. NZ recycles about 55% of glass containers.[314]	It cannot be recycled in NZ therefore requires a foreign market to purchase this waste and this is not always guaranteed as plastics are cheap to produce. Recycled plastic is about 40% more expensive than brand new material[315]	It cannot be recycled in NZ. However there is always a good market for aluminium. About 61% of NZ aluminium cans are recycled. Aluminium is worth the most when recycled[316]
Number of times it can be recycled	100% recyclable. Can be recycled indefinite number of times[317]	Loses its properties after being recycled several times[318]	100% recyclable. Can be recycled indefinite number of times[319]
Manufacturing impacts	Production is simpler and uses less electricity than	Manufacturing of plastics often creates large	Energy intensive. It takes a huge amount of

[313] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*
[314] Ibid.
[315] Wine Enabler, *Comparing the carbon footprint of plastic and glass wine bottles,* 2 December 2008, <http://wineenabler.com/comparing-the-carbon-footprint-of-plastic-and-glass-wine-bottles/> [accessed 23 December 2009]
[316]Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*,
[317] Recycle Arizona, "Recycling Plastic, Glass and Paper", <http://www.recyclearizona.net/recyclingmaterials.html> [accessed 22 December 2009]
[318] Ibid.
[319] Waste Online, *Metals - aluminium and steel recycling,* <http://www.wasteonline.org.uk/resources/InformationSheets/metals.htm> [accessed 22 December 2009]

	aluminium. Glass bottles made in New Zealand include around 60% recycled glass, one of the best ratios in the world (using recycled glass means the furnaces can run at lower temperatures).[320]	quantities of chemical pollutants[321]	energy to smelt aluminium; the Rio Tinto smelter at Tiwai Point in Bluff uses 15% of New Zealand's electricity.[322]
Mass (Transport)	0.267kg Glass bottles are the heaviest therefore require more fossil fuel to transport.	0.036kg Lighter material allowing more products to be shipped for given quantity of fuel than glass[323]	0.0147kg Lightest material allowing more products to be shipped for given quantity of fuel than glass[324]
Other use (other than its original use)	Aggregate in road and building materials, a substitute for sand at golf courses, even as a mulch	Five 2-litre PET bottles makes enough fibrefill for one jacket (or can be used as fill for sleeping	They are shredded, melted and made into components for cars, license

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[320] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*,
[321] Greenpeace, The poison plastic, <http://www.greenpeace.org/international/campaigns/toxics/polyvinyl-chloride/the-poison-plastic> [accessed 23 December 2009]
[322] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*]
[323] Wine Enabler, *Comparing the carbon footprint of plastic and glass wine bottles,* 2 December 2008,
[324] The Aluminium Can Group, "Facts" <http://www.aluminium-cans.com.au/Facts.html> [accessed 10 December 2009]

	under grapevines.[325]	bags), furniture.[326]	plates, aluminium foil.[327]
Percentage of energy saved by using recycled instead of raw materials in manufacture[328]	Glass 40%[329]	Plastic 70%[330]	Aluminium 95%[331] (75% when recycled back into aluminium beverage cans)[332] (Steel 60%)
New material Technology	-	Bio degradable plastics that will degrade in water, sunlight, or by bacteria: plastics made from plant extracts not oil[333]	**-**
Sorting / Collection		PVC bottles are hard to tell apart from PET bottles, but one stray PVC bottle in a melt of	It can be crushed to save space, comes in one material (no bottle caps and lids made with different

[325] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*,
[326] DesignBoom, *Recycling plastic bottles*, <http://www.designboom.com/eng/education/pet/recycling.html> [accessed 23 December 2009]
[327] Waste Online, Metals - aluminium and steel recycling,
[328] ZeroWaste, New Zealand Trust, *Facts & Figures*, <http://zerowaste.co.nz/default,72.sm> [accessed 21 December 2009]
[329] Ibid.
[330] Ibid.
[331] Ibid.
[332] Good; New Zealand's Guide to Sustainable Living, *Bottle VS Cans*
[333] ZeroWaste, New Zealand Trust, *Biodegradable Plastics*, <http://zerowaste.co.nz/default,475.sm> [accessed 21 December 2009]

		10,000 PET bottles can ruin the entire batch. Currently most recyclers are sorting plastics by hand (and in the third world) which are expensive and time consuming. Plastics also are bulky to collect.[334]	material), no need to remove additional paper/plastic labels, easy to sort[335]

Table 9:18: Comparison of pros and cons for each waste material

According to a Ministry for the Environment publication on Waste generation and disposal in New Zealand, various energy consumptions for making drink containers are recorded depending on the material used and the number of cycles (these figures include treatment but exclude transport which varies from place to place).

Container	Energy Use (kilojoules)	
Aluminium can, used once	7,500	
Glass beer bottle, used once	3,900	
Recycled aluminium can	2,700	
Recycled glass beer bottle	2,700	
Refillable glass bottle, used 10 times	640	

[334] DesignBoom, *Recycling plastic bottles*,
[335] The Aluminium Can Group, "Facts"

Table 9:19: Energy consumption per use for 350 ml drink containers[336]

The three major components of the carbon footprint of aluminium cans, plastic and glass wine bottles are:

(1) The manufacture of each type of bottle,
(2) The transportation of the bottle from the manufacturer to the consumer, and
(3) The disposal of the emptied can/bottle by the consumer.

Looking at the pros and cons of each material, **recycled aluminium** cans seem to be the best option. These have the second smallest energy consumption (other than reusing glass bottles 10 times), are more likely to be recycled due to high demand than any other material and are comparatively light which reduces transport emissions. However there is no way of knowing which cans are made of recycled aluminium.

In the case where all materials are used only once **plastic** becomes the best option even though it may have a higher energy input for manufacture than glass. Due to its lightness in weight its transportation emissions are significantly smaller and there is more potential for plastic waste to be exported overseas than glass for the same reason.

A simple, low cost way of reducing recyclable waste is simply not to consume anything that is not locally brewed, or contained in disposable containers (i.e. drink it at the pub or café) and drinking water rather than fizzy drinks.

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[336] Ministry for the Environment, *Waste generation and disposal in New Zealand,* <http://www.mfe.govt.nz/publications/ser/ser1997/html/chapter3.5.html> [accessed 21 December 2009]

Cans (kg)	**Glass** (kg)	**Other plastic** (kg)	**TOTAL**(kg)
3,090	3,090	6,180	12,360
25%	25%	50%	100%

Table 9:20: Recyclable materials related percentage

9.3.1 25% reduction scheme

A 25% reduction could easily be achieved by reducing all glass consumption because glass has a higher emission impact than plastic since it cannot be recycled in Wellington. This can be done by reusing glass bottles for storage of water and juice rather than using disposable cups. Instead of students buying mini glass juice bottles it would be better if they bought juice in bulk from the supermarket in plastic containers and transferred this to glass bottles which can be reused over and over again. Alternatively the school could have a canteen to provide freshly squeezed juice made from local fruit where students could have their glass bottles refilled for a fraction of the price.

Currently, certain juices are in glass bottles, as well as beer, ginger beer, coke and energy drinks. Ginger beer could be brewed at home, and energy and fizzy drinks should not be consumed as they are unhealthy.

9.3.2 50% reduction scheme

A 50% reduction could be met by reducing plastic bottle consumption, mainly for water, soft drinks and juice, by half by buying things in bulk for later distribution. .Wine and beer served during exhibitions could be from local wineries and breweries and also delivered in bulk in a refillable crate or two-litre plastic rigger. Even better would be for people to drink freshly squeezed juice or water, or go the local pubs in Cuba St for drinks served in glasses, thereby reducing the generation of more rubbish. There are

microbreweries and wineries all over New Zealand and near Wellington.
A 25-50% reduction would require minimising the consumption of soft drinks and energy drinks to reduce glass and plastic container use. These drinks are both energy intensive, contribute towards obesity and increase blood pressure.[337]

9.3.3 90% reduction scheme

Overall 50% of plastic waste and 20% of that from aluminium and glass needs to be eliminated to achieve a 90% reduction.
This eliminates virtually all shop bought drinks and relies on drinking water or home-made juice or ginger beer in refillable glass bottles. Having drinks at the place of production also helps reduce take-away packaging waste. These behavioural changes to achieve a 90% reduction require the active participation of all SoAD members in order for them to be successful. Having a school canteen to provide opportunities for this to happen could make things easier. This in turn would lead to an increase in organic waste from making fruit juice from local ingredients, but this could easily be composted. Another move would be to have easily accessible water fountains around the school that can be used to refill glass water bottles. These solutions or reduction schemes are healthier and cheaper options in the long run therefore there are other benefits than just environmental. However relying on the voluntary behaviour of SoAD members to guarantee emissions reductions might be difficult .This does indicate that in a sustainable institution this behavioural change is vital.
Below is a table quantifying the hypothetical consumption of these three different recyclable materials and the savings needed in order to meet the three reduction targets.

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[337] Ministry of Health, *Food and Nutrition Guidelines for Healthy Adults: A background paper*, (October 2003) http://www.moh.govt.nz/moh.nsf/0/07BC6DBE764FDABBCC256DDB006D9AB4/$File/foodandnutritionguidelines-adults.pdf [accessed 28 January 2010] p.52

	Aluminium Can	Plastic (PET) Bottle (Assume all are Number 1,2 plastic)	Glass Bottle
Per year	21,021 cans / yr	171,667 bottles/ yr	11,574 bottles / yr
Per year / per person (/1344)	16 cans / person	128 bottles / person	9 bottles / person
25% reduction (cans / bottles allowed per year)	15,766 cans/yr → 12 cans / person / yr	128,751 bottles/yr → 96 bottles / person / yr	8,681 bottles/yr → 7 bottles / person / yr
50% reduction (cans / bottles allowed per year)	10,511 cans/yr → 8 cans / person / yr	85,834 bottles/yr → 64 bottles / person / yr	5,787 bottles/yr → 5 bottles / person / yr
90% reduction (cans / bottles allowed per year)	2,103 cans/yr → 2 cans / person / yr	17,167 bottles/yr → 13 bottles / person /yr	1,158 bottles/yr → 1 bottle / person /yr

Table 9:21: Hypothetical bottle consumption of three different recyclable materials per person per year

So for 25% reduction each person is allowed about 2 cans or bottles per week [96 + 12 + 7 = 115 per year = about 2 a week], for a 50% reduction, less than 7 cans or bottles per month and for a 90% reduction, one bottle or can per month. This calculation is based on a total annual allowance that is the sum of the three categories of recyclable waste, and if every drink was consumed in plastic bottles this would allow a greater consumption.

9.4 Waste to landfill

Anything that cannot be put in the recyclable, paper or food compost bins should be placed in the rubbish bin. This can include the following wastes:

- Plastic wrappings (such as chip packets, pie wrappers and muesli bar wrappers)
- Plastic packaging and bags (including bubble wrap)
- Un-compostable food (such as meat, chewing gum)
- Plastic cutlery
- Unrecyclable paper and plastic (glossy magazines, flyers, sushi trays, grade 3-7 plastic)
- Plastic and paper cups (and plastic coffee lids)
- Paper towels and tissues
- Cigarette butts (10-12 years to decompose)[338]
- Other miscellaneous items

A lot of takeaway meals are consumed in SoAD as students spend many nights in the studio working on their projects. This leads to huge packaging waste, such as unrecyclable plastic containers, plastic bags, plastic cutlery, bamboo chopsticks, polyurethane containers, paper cups and plastic wrappers. It is not clear how much of this 'other waste' includes packaging waste, but this can all be eliminated by students eating in a restaurant thereby using ceramic plates and stainless steel cutlery which will be re-used, rather than take-aways in disposable packaging. Taking a 15 minute meal break should not pose any inconvenience to students even during busy periods. However, in places like McDonalds food already comes with various packaging therefore eating inside such a restaurant would make little difference in terms of waste reduction. Also in order to effectively reduce emissions from waste to landfill, un-compostable food such as meat and chewing gum should be avoided. As stated earlier, the average New Zealanders are over-eating, and the recommendations are for children to cut their daily intake by one can of fizzy drink and a small chocolate bar, and adults by a large burger. This will help reduce the waste to landfill emissions significantly as these types of foods usually come with packaging.

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[338] ZeroWaste, New Zealand Trust, *Facts & Figures*, <http://zerowaste.co.nz/default,72.sm> [accessed 21 December 2009]

Ideally, the school could operate a canteen serving cheap, healthy meals to students and staff using ingredients from local markets. Take away packaging can be eliminated as students can use the more convenient and cheaper canteen facility and if students bring their own plastic containers canteen food could be taken into the studios. However this canteen would be unlikely to be a profit making enterprise and the case for having it is environmental rather than financial.

Paper towels currently used in SoAD's toilets can be replaced with reusable cotton towels. The energy required to get these cotton towels hygienically washed and sanitized needs to be compared to using paper towels. This is something that would require further research and will not be explored further here.

The relatively large amount of cigarette butts generated in SoAD really touches on the more sensitive topic of smoking and whether this is something that should be tolerated. A society that markets and sells poison that eventually leads to death and that strains the health system indicates the present condition of how global society works and how much it is geared up to financial rewards, even at the cost of many lives. This 'free market' allows irrational behaviours to be tolerated and promoted for profit. In a society where each person values their own body there would be no smoking and its associated waste.

Waste to landfill is really a government problem and regulations are needed to ban materials that cannot be recycled, such as grade 3-7 plastics. Despite the available option of incinerating landfill wastes, NZ is able to generate its electricity from cleaner sources, such as hydro or wind, and therefore should focus on reducing waste and not burning it to generate electricity which will contribute to emissions. There is no way of quantifying the wastes to landfill as the various types of waste are different in volume and sizes. This is a section that needs to rely on the "good" behaviour of students and staff members and pushing the government for more stringent regulations on waste creation and minimising landfills.

9.5 Guidelines to reduce waste emissions

- Use paper with 100% recycled content (or even use non-wood based paper)
- Reduce demands first, reuse and then recycle as last resort
- Utilise computer technology instead of printing and subscribe to magazines online
- Be efficient with printing and photocopying material by utilising the double sided, two-page per sheet options
- Install composting bins and only consume food that can be composted
- Minimise food waste and unnecessary food consumption and eat healthily
- Re use glass and plastic bottles for drinks
- Drink locally produced juice or brew your own beer or drink plenty of tap water
- Minimise consumption of unhealthy soft drinks and energy drinks that are energy intensive to make and transport
- Buy in bulk to reduce packaging
- Try to avoid purchasing glass bottles as they have a higher carbon footprint for transport (but not to manufacture) and cannot be recycled in Wellington
- Choose aluminium cans over plastic bottles as these are more likely to be recycled
- Try to purchase items that are recyclable, such as number 1 and 2 grade plastic
- When eating out have food in the restaurant or café and avoid takeaways
- Do not smoke
- Vote for a government with tough actions on waste issue in NZ

9.6 Conclusion

It is apparent that the recycling industry is unreliable as it relies on the global economy and international buyers to sort NZ's waste. Waste is not necessarily a commodity that is recognised as an asset and this is clear in the current system that does not dispose of waste properly or reduce waste as much as possible. Current sustainable guides focus on recycling as one of the main solutions to reducing emissions associated with landfills. However it is very clear that this is"out of sight, out of mind" behaviour where the guilt is removed once the rubbish is in the bins, with the assumption it will end up where it should. There are hidden moral implications with recycling as it is usually third world countries that manually sort out the first world's waste problems exposing the workers to poor conditions and pay. Also a lot waste is quite literally wasted as food is thrown away or people overeat. Both actions cause more strain on the earth's capacity and use valuable resources that get discarded with all ending up in landfill. This is all apparent in SoAD's consumption patterns and unfortunately the key lies with the students and staff who need to take responsibility and be active in reducing the amount of waste produced. There are limits to what the school can control, though it could use 100% recycled paper.

The positive aspect of saving waste is that it saves the students and staff money, as less printing is cheaper. Minimising highly processed and overly packaged food usually results in better health due to a better diet. What this study indicates is that all the factors determining the school's sustainable credentials such as energy, transport and food are inter-related. Reducing paper use heavily depends on relying on the digital medium; however whether the impact of increased energy use is better or worse than using paper is uncertain.

Strong emphasis needs to be placed on auditing SoAD's waste production and ensuring that different wastes are sorted into their correct bins. There is a strong case for employment of an operations manager who can maintain composting bins and make sure that the waste operation in SoAD is running effectively and efficiently.

10.0 Ensuring carbon neutrality

10% offsets for SoAD

Even with a 90% reduction in emissions, this does not guarantee carbon 'neutrality' as SoAD will need to worry about the remaining 10%. Instead of resorting to purchasing carbon offsets from other companies, it may be wise for SoAD to deal with emissions reductions by asking staff and students to reduce emissions after they leave the building. This ensures that the behaviour changes of the staff and students are continued at home. This can be converted into measurable "offsets" by calculating the savings achieved by changing from the usual behaviour (i.e. such as savings gained from using more energy efficient light fixtures). This is something typical carbon offset programs do not offer.

This is the only way SoAD can become truly 'carbon neutral.'

Here are some suggestions that could be implemented in SoAD as viable carbon offset schemes:

Electricity

- Many students that flat may have incandescent light bulbs because these are cheap. SoAD could provide compact fluorescent light bulbs to gain energy savings.
- SoAD could provide staff with insulation for their hot water cylinder.

Gas

- Door 'snakes' could be provided to prevent heat loss in draughty accommodation
- Draft sealing measures could be taken in staff houses to prevent air infiltration and heat loss

Transport

- Staff who carpool with another staff can have car parking preference and/or discounts

- Bicycles to be leased to students who would usually take the bus to school

Waste

- Composting bins supplied to staff and those who already have one can pass the new one to another family member)
- Converting discarded A4 sheets into notebooks to be distributed to students and divert waste going to landfill.

10.1 Case for an Operations Manager

Previous chapters concluded the importance of the presence of a operations manager to ensure energy, transport and waste reductions were implemented in SoAD. Lack of such management in SoAD has resulted in poor auditing, lack of control and monitoring and hence the GHG reduction plan was not carried out with no one responsible to make sure the schemes were in place. There is a strong argument for having an operations manager and the finances could be explored by comparing the cost of hiring an operations manager with the cost of offsets.

According to the website *payscale.com's* survey, the role of General and Operations Managers is to:

> *"Plan, direct, or coordinate the operations of companies or public and private sector organizations. Duties and responsibilities include formulating policies, managing daily operations, and planning the use of materials and human resources, but are too diverse and general in nature to be classified in any one functional area of*

management or administration, such as personnel, purchasing, or administrative services."[339]

The minimum salary for such a role is $48,749 per annum but this does not include overheads for hiring this staff member, and providing an office and equipment.[340]

For managing SoAD, the tasks and requirements for the operations manager could include the following:

- Live close to school (within 30mins walking distance)
- Keep records of school's consumption and produce a report of the results, improvements, and patterns of consumption for each month
- Constantly keep up-to-date with new sustainability issues and technologies
- Ensuring that resources are used efficiently, for example closing computer labs during the least busy periods
- Organise meetings with staff and students to update them on the latest issues in sustainability and how they can meet reduction goals
- Organising meetings with cleaners, IT crew and FM to ensure that things are done in an efficient way
- Sort recycling with cleaners ensuring waste is minimised
- Implement saving schemes for computers with the IT technicians
- Implement lighting savings with security guards
- Implement paper reduction guidelines with administrative, library and academic staff
- Organising various campaigns and activities for the school to promote sustainability (i.e. competitions)
- Implement 10% SoAD offset scheme

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339 Payscale, *Salary Survey for Job: Operations Manager* (New Zealand), <http://www.payscale.com/research/NZ/Job=Operations_Manager/Salary> [accessed 02 January 2010]

340 Ibid.

- Compost waste management
- Undertake a building report to look at the case for investing in fabric improvements, such as double glazing and increasing ceiling insulation
- Set credits and rations for staff flights and deal with other transport issues.

To compare the cost of hiring an operations manager to buying carbon credits to offset SoAD's annual activities, a NZ company called *'Offset the Rest'* provides Gold Standard projects that provide carbon credits for purchasing. Their online calculator and any assessment that they undergo to calculate carbon footprint is in accordance with the highest internationally accepted standards and protocols.[341]

Table 10:1 below indicates the accumulative costs for offsetting each sector of SoAD's emissions.

Type	**Total annual quantity**	**Kg C02e**	**Accumulative carbon credit price**
Electricity	1,613,471 kWh	369,000.82	$ 15,774.79
Gas	726,301 kWh	156,009.45	$ 22,444.19
LPG	63 kg	187.11	$ 22,452.19
Bus (student + staff)	217,210 km	19,331.69	$ 23,278.62
Train (student + staff)	604,147 km	392,695.55	$ 40,066.35
Taxis	$ 18,114.01	2590.30	$ 40,177.09
Diesel - Fuel	348 L	382.80	$ 40,193.45
Car - Driver	106,032 km	25553.71	$ 41,269.51
Motorcycle	5,438 km	580.23	$ 41,294.31
International air	577,236km	100040.77	$ 45,571.06

[341] Offset the Rest, Living Carbon Neutral, *Calculate your footprint,* <http://www.offsettherest.com/carbon-credits-calculator.html#fs_home_energy> [accessed 03 January 2010]

flight			
Domestic air flight	20,299 km	3518.02	$ 45,721.45
Waste by weight (excluding recycling)	58,938 kg	110351.98	**$ 50,439.00**

Table 10:1: Cost of offsetting SoAD's annual emissions[342]

The total cost for offsetting SoAD's annual emissions is just over $50,000. This is the equivalent of hiring an operations manager who can ensure savings can be achieved at SoAD. The presence of an operations manager could lead to further financial savings which would pay overhead costs. SoAD needs to decide whether investing in carbon offsets, which do not require change in behaviour, is more important than hiring a personnel member who can ensure savings can be achieved and analyse what is most appropriate for the school.

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[342] Ibid.

11.0 Discussion

There are many reasons to be sustainable. A lot of the media presents the situation as hopeless or not worth dealing with as certain issues, like global warming, are not 'clear.' However, it is common sense to see that there is a rapidly growing population and demand, with increasing depletion of the eco-system and vital resources on which the well-being of humanity is dependent. People seem to address the environment or the planet as a separate entity and not something that is vital and integral to human survival. This is clearly reflected in the value systems of people and the slow reactions towards this issue. The problem, however, is a ticking bomb that cannot be ignored any further. It is impossible for everyone to have a good standard of living unless the wealthy share resources and reduce their consumption. This is not possible or realistic under the current economic system. Perhaps to be sustainable is to desire utopia. The problem with utopia is that it cannot exist and will only be a fictional ideal under the current capitalist system.

This chapter discusses the reasons why the current society and its systems do not work and why it needs to change.

11.1 Sustainability and capitalism

Through this research one thing has become very clear; it is that sustainability cannot operate in the current capitalist system which functions on the basis that people need to continue consuming endlessly with no regard for the environment. The current economic system is purely based on money which is not a realistic measure of the natural capital available. The current consumption patterns indicate that consumption is exceeding the regeneration of the planet, which is clearly indicated by the ecological footprint analysis.

Not only this, the increasing growing market of wealthy capitalist countries results in preventing developing nations from growing. Also, many sustainability measures are not implemented simply because they are not economic, such as purchasing solar panels, or in this case not extending the carbon neutral status of SoAD, and this indicates a huge flaw in a system that is not sustainable and does not encourage sustainability but thrives by doing the contrary.

11.2 Behavioural change and Future technological innovation

It was apparent in writing this thesis that behavioural changes are the simplest, cheapest ways of reducing consumption and hence emissions yet these are the most difficult to attain. This questions the fundamental value system of people in the 21st century, especially those who are in developed nations or those with material wealth. No matter how advanced the technological innovations are, if they are not affordable by the majority than they become an idle solution. If there is no demand for this kind of innovation then there is no improvement. Increasing efficiency also does not necessarily guarantee less consumption. For example the invention of computers predicted a paperless office which has proven to be the contrary. Cars are more efficient than 50 years ago, however the increased use of motor vehicles has outweighed their efficiency increase with consequences seen in rapid oil consumption and air pollution. Behavioural changes seem to be most successful when people do not have a choice, for instance consumption drops in an economic recession. Giving people the freedom to behave does not necessarily result in the most sustainable behaviour, such as recycling. One conclusion is that more control may be required from the government with more regulations, positive incentives and reward schemes for doing the right thing, and with careful implementation of restrictions and fines to discourage certain behaviours.

11.3 Health and sustainability

Eating highly processed food with artificial preservatives and flavourings with high energy content is bad for people's health. Overeating results in obesity which leads to an increase in health risks and even premature death. Not walking or exercising everyday is not good for health. This can be avoided by eating a healthy diet, not over eating and exercising regularly. It seems, therefore, that leading a healthy lifestyle is somewhat related to sustainability. Additional benefits come from consuming less, which means more money and living debt free. Needing less means having to work less and having extra time to enjoy life either by spending time with family and friends or keeping healthy and active by engaging in hobbies and other pleasurable activities. Being sustainable does not necessarily mean a reduced standard of living but involves improving the quality of life and at the same time helping to ensure that others who have nothing can have at least the bare minimum essential for a good quality of life.

11.4 Bigger picture versus Smaller picture

Many factors are outside SoAD's control. There is only so much an individual or an institution can do, for example with issues such as waste; despite an individual's best efforts to recycle the bigger picture means that this might not happen. This questions whether the importance rests with the bigger picture or individual choice. Given that people will choose more convenient actions rather than doing the right thing that is beneficial for everyone, perhaps the leaders should take more control in what people should and should not do. This places importance in voting for the right government. Such a government could pass a law that only allows recyclable materials to be used for packaging.

11.5 Nature of architecture schools and the profession

The nature of architectural education has changed from learning by apprenticeship to the creation of architecture schools. Architects also need to change according to the needs of the present. There should be a demand for architects that deal with more than superficial aesthetics. There has been, until very recently, no need for future architects to study sustainability as part of the professional course. Sustainability means that architects need to be more like building doctors by monitoring the building post construction, and not just leaving as soon as it is finished. Also architects need to improve and alter the existing building fabric instead of demolishing it and building new. Currently, architecture schools do not put emphasis on architects addressing social and environmental issues, but rather stress purely theoretical and aesthetic issues. The future of architects might become one of redundancy if they do not evolve with time.

11.6 Building Operation

This research has shown that the building does not need to change dramatically if there is a renewable form of electricity generation. Sustainability lies more with the operation of the building which goes beyond the 'architecture' of the building. It is useless to have a big zero energy house with one person living in it, and it is useless to have a zero energy house located so far away from work that the occupants are completely dependent on their motor vehicles. Perhaps there should be more emphasis on the operation of the building rather than the building itself.

11.7 Necessity and Luxury

As this research has indicated, life will still go on in a society where emissions are reduced by, although this would be a different society from now. Sustainability is about drawing a line between what are the necessary and important things and those that are excessive and unnecessary. Sustainability is a good tool to critique the way the current society operates and can provide a helpful guidelines that can lead to a more secure future.

Appendix 1: EPA Ecological Footprint parameters

These are the parameters entered into the EPA EF website to formulate the EF for SoAD for Chapter 4.

EPA Ecological Footprint Calculation factors

General School Information *(See Table 3:1, 3:2)*

- Student Numbers: **1244**
- Staff Numbers: **100 average**

Building Information *(See Chapter 3)*

- Total ground area of SoAD including grounds and buildings: **3458 m²**
  (Total floor are square metres for level 1)
- Total floor area of SoAD buildings: **13,167 m^2**
- Expected life of the buildings: Approx. **80 years**
  Any green design features of the building? - **No**
- Total annual electricity use – **1,613,471 kWh = 5,808,496 MJ** (carboNZero 2007 data)
- How much energy purchased from renewables? - **66% renewable energy generation in NZ** *(See Figure 3:15)*
- Total annual natural gas use: **726,301 kWh = 2,614,684 MJ** (carboNZero 2007 data)
- Total annual water use? **7,792 kL** (2007 VUW data)
- Are generators used to power your school? **No**

Catering

- Does your school have canteen facilities? – (**Hypothetical): Yes**

Type of food	***Number of***	***Number***	***Cost per***	***Total Costs***

	students	***of staff***	***one***	***per day x 5 days***
Confectionary				**$2211*5 = <u>$11055</u>**
Chocolate bar x1	1244 (M+F)	50 (F)	$0.67 / bar	$ 867 NZ
Chips x1	1244 (M+F)	100 (M+F)	$ 1.00 / pack	$ 1344 NZ
Fruit and Vegetables				**$ 458*5 = <u>$2290</u>**
Apple x1	1244 (M+F)	100 (M+F)	$0.30 each	$ 403 NZ
Banana x1	0	100 (M+F)	$0.55 each	$ 55 NZ
Bakery Products				**$ 393*5 = <u>$1965</u>**
Bread (Brown) slices	622 (Mx4)	50 (Fx2)	$0.10 / slice	$ 259 NZ
Bread (White) slices	622 (Fx2)	50 (Mx2)	$0.10 / slice	$ 134 NZ
Dairy Products				**$ 54*5 = <u>$270</u>**
Butter (spread)	1244 (M+F)	100 (M+F)	$0.04 / 5g	$ 54 NZ
Other food products				**$ 259*5 = <u>$1295</u>**
Marmite	1244 (M+F)	50 (F)	$0.20 / 10g	$ 259 NZ
Meat products or Fish				**$ 1993*5 = <u>$9965</u>**
Tuna (Can)	622 (M x2)	50 (Mx1)	$1.54 / serving	$ 1993 NZ
Soft drinks / other				**$ 867*5 = <u>$4335</u>**
Lipton Ice Tea	1244 (M+F)	50 (M)	$0.67 / serving	$ 867 NZ
TOTAL				**= $ 6235 NZ**

Table 4:10: Total cost of the food consumed by students and staff

Total amount spent on drinks and external catering per year[343]:

(a) Beer **$1500 average ($1000 - $2000 range)**
(b) Wine and spirits **$1500 average**
(c) Soft drinks & other non-alcoholic beverages **$1500**
(d) External Catering / Restaurants and café food **$1500**

Travel - To and From School *(See Table 3:7)*
Total distance travelled by staff and students for each of the following modes of transport for a single day

(a) Car (this will include motorcycle travel despite its lower fuel consumption) = 111470km /185days[344] **= 603 km**
(b) Public Transport (trains or buses) = 821,357 / 185 days km = **4440 km**
(c) Walking/Cycling = 994582km /185 days = **5376 km**

Travel – Excursions

- Have there been any excursions? **Yes** (carboNZero 2007 data)
- Total distances travelled by students and teachers on excursions/camps/trips per year – **610,552 km**

(a) Car = **12,160 km** (carboNZero 2007 data)
(Taxi included with CF=0.125, 2 persons in the car, (carboNZero 2007 data). (Rental cars are excluded)
(b) Train (long distance) = **0 km**
(c) Train/Tram (short distance) = **0 km**
(d) Bus = **524 km+332km =856km** (carboNZero 2007 data)
(e) Boat (e.g. Ferry) = **0 km**
(f) Domestic air travel = **20,299 km** (carboNZero 2007 data)

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343 Davey Natasha, Administrator for SoAD, Victoria University of Wellington, personal communication, 2 May 2009
344 37 weeks in trimester 1 and 2, so excluding travel to school on weekends, it is 5days x37= 185km in total

(g) International air travel = **577,236 km** (carboNZero 2007 data)

(h) Walk/Ride = **0 km** (unknown)

Travel - Fleet

- Does your school own/lease fleet vehicles? **Yes**

(a) Total kms travelled per year by staff for work related purposes = **1411 km/year** (caboNZero 2007 data)[345]

(b) Vehicle Type: Medium (9-15 litres)

(c) Number of vehicles: **1**

(d) % of total school use: **100%**

(e) Fuel type used: Diesel

(f) Fuel price per litre: $1 NZ

(g) % of travel with more than driver only: about 50%

Goods

(a) Copy paper used per year? **= 20,601kg[346]** (See Table 9:5)

(b) Average recycled content of all paper consumed? **= 2%** (VUW 2007 data average)

- Cost of printed materials and publications produced for your school by an external publisher per year? **$10,000[347]**
- Total amount spent on subscriptions to publications - **$105,000[348]**
- Total amount spent on printed books and journals for the school library per year **= $104,000[349]** assumption ($45k on journals, $59k on books)

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[345] Car show Room, Auto trader, <http://carshowroom.autotrader.com.au/forge/data_entry?tp=Prod&category=vehicle%20specifications&temp_type=detail&lifestyle=&omni_cust=Make/Model&bodystyle=&style_id=714953820090101> [accessed 2 May 2009]

[346] Wilfred, "Re: grams/square meter to pounds/ream," 10 May 2005, <http://www.onlineconversion.com/forum/forum_1118773419.htm> [accessed 28 December 2009]

***** One ream of paper (500 sheets) at 80 gsm is equivalent to approximately 2.5kg.

[347] Muir John, Librarian for SoAD, Victoria University of Wellington, personal communications, 5 July 2009

[348] Ibid.

- Total amount spent on computers and printer equipment in a year?
  = $312,500[350]
- Total amount spent on other stationary for staff per year
  = $1,500
- Total amount spent on other stationary supplies for students per year?
  = $1,500

Recycling and Waste

Total number of 240L bins that are filled per week?[351]

103005kg x1.04L = 107,125L per year.

447 of 240L bins (carboNZero 2007 data) = 447/52 = 8.6 per week

Waste Recycled (carboNZero 2007 data)

(a) Paper & cardboard = **34.5%** of total

(b) Aluminium = **0%** of total

(c) Co-mingled glass, plastic and steel = **0%** of total

Compost *(See Table 9:8 – These go to landfill)*

(d) Food & other organic waste = **0%** of total

Waste to Landfill *(See Table 9:8)*

(e) General waste to landfill = **65.5%** of total

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349 Ibid.

350 Shaw Mark. (Faculty Manager for SoAD), (mark.shaw@vuw.ac.nz), (13 May 2009), *RE: SoAD – computers and printers* [Personal email to Soo, Ryu], [online]. (soo.ryu@hotmail.com)

* 500 PCs, Macs and notebook – mostly PCs. ¼ replaced each year (125 PCs) at $2000 a year per desktop resulting in $250 per year per PC. 125 x 2000 = $**250,000** + ¼ of this for printers **= $312,500**

351 Fogt Robert, "Re: Kilgrams to liters," 22 September 2003, <http://www.onlineconversion.com/forum/forum_1064237591.htm> [accessed 28 December 2009]

* 0.96 kg/l means that 1 liter weighs 0.96 kilograms, or 1 kilogram is 1.04 liters

Appendix 2: Computer Use Reduction Calculations

Below is the timetable of opening and closing hours in more detail for the whole year.

	School opening hours	After class hours	After closing hours	Weekend opening hours
Timetable of total opening & closing times	Mon-Fri: 7:30am - 11:30pm = 16 hrs / day	Mon-Fri: 5:30pm - 11:30pm = 6 hrs / day Sat- Sun: Assume same = 12hrs/ weekend	Mon–Fri: 11:30pm - 7:30am = 8hrs / day Sat-Sun: 11:30pm - 9:00am = 9.5 hrs / day	Sat–Sun: 9:00am - 11:30pm =14.5 hrs / day
Trimester 1 & 2 37 weeks	= 16 hrs x 5 days x 37 weeks = 2960 hrs	= 1110 hrs = 444 hrs (weekend)	= 2183 hrs	= 1073 hrs

Table 7:6: Typical opening and closing hours for Trimesters 1 and 2 from March to November

	School opening hours	After class hours	After closing hours	Weekend opening hours
Timetable of total opening & closing times	Mon – Fri: 7:30am 10:00pm = 14.5 hrs / day	Mon – Fri: 5:30pm to 10:00pm = 4.5 hrs / day	Mon-Fri: 10:00pm-7:30am = 9.5 hrs / day Sat: Closed, Sun: 1pm-10pm (open)=39 hrs total	Sun only: (Sat closed) 1:00pm-10:00pm = 9 hrs / Sun
Trimester 3 (A) (5 weeks)	= 362.5 hrs	= 112.5 hrs	= 432.5 hrs	= 45 hrs
Open only during library	Mon/Tue/Fri: 8:30am – 5:00pm	Closed – N/A School usually closed 5pm–	Mon/Tue/Fri: 5:00pm - 8:30am Wed/Thu: 8pm -	Sun only: (Sat Closed) 1:00pm – 5:00pm

hours	Wed/Thu: till 8pm	8pm (depending on the day of the week)	8:30am	
Trimester 3 (B) 7.5 weeks	= 363.8 hrs	= 0 hrs	= 982.5 hrs	= 30 hrs
TOTAL	**= 3686 hrs**	**= 1667 hrs**	**= 3598 hrs**	**= 1148 hrs**

Table 7:7: Typical opening and closing hours for Trimester 3 (part A and part B) from November to February

Below is the table of sq metres for each space in level 3.

Different areas/rooms in Level 3	**Area (m^2)**	**Comments**
VIVIAN BUILDING		
x 22 Staff Offices	270.4	Vary in size and are usually for one staff member (Total combined floor area)
Design Computer Lab **320**	41.7	PCs only
Arch Computer Lab **317**	52	Scanner, photocopier, printer, PCs
Arch Computer Lab **319**	121.6	PCs only
Design Computer Lab **322**	101.7	PCs and one projector
Staircase **2**	13	Windows for daylight
Staircase **3**	23.6	No windows (No daylight)
Staircase **4**	14.5	Windows for daylight
Staircase **5**	13.2	No windows (No daylight)
Kitchenette (between **M1** & **F1**)	3.9	Microwave, mini fridge, hot water cylinder
Vivian Toilet **M1**	9.2	No windows (No daylight)
Vivian Toilet **M2**	10.8	Small windows
Vivian Toilet **F1**	8.4	No windows
Vivian Toilet **F2**	12.6	Small windows
Vivian Toilet Disabled **M/F**	5.5	Small windows
Corridor **351** (+ Staircase **1**)	77.2	Plenty of daylight from atrium
Corridor **352**	98.2	5 radiators

Corridor **353**	28.1	2 radiators
Corridor **354**	38.8	Faces atrium and connects to Wigan building
Corridor **355**	91.7	2 radiators
Corridor **356**	63.2	2 radiators
Corridor **357**	76.2	Daylight from windows
Corridor **358**	37.2	2 radiators
Vivian Studio 301	334.5	Daylight from atrium / skylight
Vivian Studio 303	282.8	Facing NE – lots of daylight
Vivian Studio **323/333**	536.4	Daylight from atrium / skylight
Seminar Rm **308+318**	145.4	Closed after class hours
Storage / Other **304/350**	22.5	Restricted access
WIGAN BUILDING		
Wigan Corridor **363**	31.6	Daylight from large glazed window
Wigan Corridor **364**	45.5	Daylight from small window
Wigan Studio **301**	378.9	SW facing windows – daylight
Wigan Seminar Rm **302 + 303**	71	Tutor's office/Seminar- closed after class hours
Wigan Toilet **M3**	7.1	Motion sensor
Wigan Toilet **F3**	7.1	Motion sensor
Wigan Staircase **6**	17.2	Timer light switch
Wigan Staircase **7**	11.4	Timer light switch
Other / Storage / Lift	9.8	Lift only suppose to be used for disabled/elderly
TOTAL (m^2)	**3114**	
Wigan Building Total (m^2)	579.6	
Vivian Building Total (m^2)	2534.3	
Wigan Building m^2 % of total	19%	Wigan building is approx. 1/5 totalfloor area

Table 7:8: Areas m^2 for each space

Below is the table of calculations for computer use reductions of 25%.

Different areas/rooms LEVEL 3	Switch off 50% of PCs left on overnight
	Trimester 1,2, Mon-Sun
VIVIAN BUILDING	**kWh/yr**
x 22 Staff Offices	Assume turned off
Design Computer Lab **320**	**655**
Arch Computer Lab **317**	Turned off after hours
Arch Computer Lab **319**	**6713**
Design Computer Lab **322**	Turned off after hours
Vivian Studio **301**	Turned off after hours
Vivian Studio **303**	Turned off after hours
Vivian Studio **323/333**	**1637**
Seminar **308+318**	Assume turned off
WIGAN BUILDING	
Wigan Studio **301**	**4748**
Wigan Seminar **302 + 303**	Assume turned off
TOTAL (kWh/yr)	**13,753**

Table 7:13: Result of turning off computers at night

Different areas/rooms LEVEL 3	Close down 50% of PCs in after class hours period
	Trimester 1,2, Mon-Sun
VIVIAN BUILDING	**kWh/yr**
x 22 Staff Offices	**N/A**
Design Computer Lab 320	**Open after class**
Arch Computer Lab 317	**Closed - 3108**
Arch Computer Lab 319	**Open after class**
Design Computer Lab 322	**Closed - 7104**
Vivian Studio 301	**Closed - 3774**
Vivian Studio 303	**Closed - 1776**
Vivian Studio 323/333	**Open after class**
Seminar 308+318	**N/A**
WIGAN BUILDING	
Wigan Studio 301	**Open after class**
Wigan Seminar 302 + 303	**N/A**

TOTAL (kWh/yr)	**15,762**

Table 7:14: Result of turning off 50% of PCs in after class hours

Appendix 3 – Lighting Use Reduction Calculations

Below is the table of calculations for installed lighting demand on level 3.

Different areas / rooms in Level 3	**No. of fittings**	**Lighting Type**	**Lamps per luminaire**	**Watts/luminaire incl. ballast & control gear(W)**	**Installed lighting (W)**
VIVIAN BUILDING					
x 22 Staff Offices	62	Fl: 1500mm	1	72	**4464**
Design Comp Labs 320	8	Fl: 1500mm	1	72	**576**
Arch Comp Labs 317	10	Fl: 1500mm	2	144	**1440**
Arch Comp Labs 319	12	Fl: 1500mm	3	216	**2592**
Design Comp Labs 322	16	Fl: 1500mm	1	72	**1152**
Staircase 1	2	Fl: 1500mm	2	144	**288**
Staircase 2	2	Fl: 1500mm	2	144	**288**
Staircase 3	2	Fl: 1500mm	2	144	**288**
Staircase 4	2	Fl: 1500mm	2	144	**288**
Staircase 5	2	Fl: 1500mm	2	144	**288**
Kitchenette	1	Fl: 1500mm	1	72	**72**
Vivian Toilet 1 (M/F)	4	Fl: 600mm	2	54	**216**
Vivian Toilet 2 (M/F) & disabled	5	Fl: 600mm	2	54	**270**
Corridor 351	3	Fl: 1500mm	1	72	**216**

(Atrium bridge)	11	MH	1	105	**1155**
Corridor 352	7	Fl: 1500mm	1	72	**504**
Stair 2 Door Light	2	MH	1	105	**210**
(Toilet entry space)	1	Fl: 600mm	2	54	**54**
Corridor 353	3	Fl: 1500mm	1	72	**216**
Corridor 354	3	Fl: 1500mm	1	72	**216**
To Wigan Building	3	CF	2	38	**114**
Corridor 355	4	MH	1	105	**420**
Corridor 355 b	1	Fl: 1500mm	1	72	**72**
Corridor 356	3	MH	1	105	**315**
Corridor 356 b	2	Fl: 1500mm	1	72	**144**
Kitchenette door	1	CF	1	19	**19**
Toilet entry space	1	Fl: 600mm	2	54	**54**
Corridor 357	4	Fl: 1500mm	1	72	**288**
Corridor 358	5	Fl: 1500mm	1	72	**360**
Vivian Studio 301	55	Fl: 1500mm	1	72	**3960**
Vivian Studio 303	47	Fl: 1500mm	1	72	**3384**
Vivian Studio 323/333	94	Fl: 1500mm	1	72	**6768**
Seminar 308+318	23	Fl: 1500mm	1	72	**1656**
Storage / Other	3	unknown	1	72	**216**
WIGAN BUILDING					
Wigan Studio	50	Fl: 1500mm	2	144	**7200**
Seminar 302 + 303	12	Fl:	2	144	**1728**

		1500mm			
Wigan Toilet	4	Fl: 1200mm	2	92	**368**
Wigan Toilet Entry	2	CF / 2D	1	19	**38**
Wigan Staircase 371	1	Fl: 1500mm	2	144	**144**
Wigan Staircase 372	1	Fl: 1500mm	2	144	**144**
Corridor 363	2	Fl: 1500mm	2	144	**288**
Kitchenette	1	Fl: 1500mm	2	144	**144**
Corridor 364	2	Fl: 1500mm	2	144	**288**
TOTAL	**475**				**42,905**

Table 7:19: Wattage for different lighting fixtures on Level 3

Below is the table of calculations for installed lighting demand at night and during the day for level 3.

Different areas/rooms in Level 3	Lux reading night time	Lux reading with daylight
VIVIAN BUILDING		
x 22 Staff Offices	340	600
Design Computer Labs 320	470	N/A
Arch Computer Labs 317	240	N/A
Arch Computer Labs 319	310	N/A
Design Computer Labs 322	320	N/A
Staircase 1	130	1160
Staircase 2	170	N/A
Staircase 3	140	N/A
Staircase 4	450	620
Staircase 5	540	N/A
Kitchenette	430	N/A
Vivian Toilet 1 (M/F)	280	N/A
Vivian Toilet 2 (M/F) + disabled	210	N/A

Corridor 351 Atrium bridge	150 130	1160 1160
Corridor 352 Door lighting for Stair 2 Toilet entry space	120 N/A 80	N/A N/A N/A
Corridor 353	70-100	N/A
Corridor 354 To Wigan St Building	270 70-280	360 340
Corridor 355	100-150 100-150	N/A N/A
Corridor 356	120-290 120-290	N/A N/A
Kitchenette door Toilet entry space	120 270	N/A N/A
Corridor 357	60-100	?
Corridor 358	80-140	N/A
Vivian Studio 301 Vivian Studio 303 Vivian Studio 323/333	340-360 360-480 430-510	360-490 760 280-530
Seminar 308+318	N/A	N/A
Storage / Other	N/A	N/A
WIGAN BUILDING		
Wigan Studio 301	520-560	400-670
Seminar 302 + 303	N/A	N/A
Wigan Toilet (M3/F3) Wigan Toilet Entries	430 50	N/A N/A
Wigan Staircase 371 Wigan Staircase 372	80 160-190	640 N/A
Corridor 363 Kitchenette Corridor 364	150 600 150	N/A N/A N/A

Table 7:21: Different light levels (lux) on level 3 at day and night

Below is the table of calculations for lighting use reductions of 25%.

Example calculation:

Design Computer Lab installed lighting = 576W

Lighting level as measured at night = 470lux

Recommended level = 240lux

Excess light level is 470-240= 230lux

This gives a potential percentage reduction possible of 230/470 x 100 = 49%

The potential reduction in watts is, therefore, 576 x 49/100 = ***282W***

Different areas / rooms in Level 3	Installed lighting (W)	Lux reading (night time)	Recommended lighting level (lx)	Excess light level (lx)	Wattage Reduction (W)
VIVIAN BUILDING					
x 22 Staff Offices	4464	340	240	100	**1313**
Design Computer Lab 320	*576*	*470*	*240*	*230*	***282***
Arch Computer Lab 317	1440	240	240	0	**0**
Arch Computer Lab 319	2592	310	240	70	**585**
Design Computer Lab 322	1152	320	240	80	**288**
Staircase 1	288	130	80	50	**111**
Staircase 2	288	170	80	90	**152**
Staircase 3	288	140	80	60	**123**
Staircase 4	288	450	80	370	**237**
Staircase 5	288	540	80	460	**245**
Kitchenette	72	430	160	270	**45**
Vivian Toilet 1 (M/F)	216	280	80	200	**154**
Vivian Toilet 2 (M/F) + disabled	270	210	80		**167**

				130	
Corridor 351	216	150	40	110	**158**
Atrium bridge	1155	130	40	90	**800**
Corridor 352	504	120	40	80	**336**
Door lighting for Stair 2	210	80	40	40	**105**
(Toilet entry space)	54	80	40	40	**27**
Corridor 353	216	70-100 (Av: **85**)	40	45	**114**
Corridor 354	216	270	40	230	**184**
To Wigan St Building Corridor	114	70-280 (Av: **175**)	40	135	**88**
Corridor 355	420	100-150	40	85	**286**
Corridor 355 b	72	100-150	40	85	**49**
Corridor 356	315	120-290 (Av: **205**)	40	165	**254**
Corridor 356 b	144	120-290 (Av: **205**)	40	165	**116**
Kitchenette door	19	120	40	80	**13**
Toilet entry space	54	270	40	230	**46**
Corridor 357	288	60-100 (Av: **80**)	40	40	**144**
Corridor 358	360	80-140 (Av: **110**)	40	70	**229**
Vivian Studio 301	3960	340-360 (Av: **350**)	320	30	**339**
Vivian Studio 303	3384	360-480 (Av: **420**)	320	100	**806**
Vivian Studio 323/333	6768	430-510 (Av: **470**)	320	150	**2160**
Seminar 308+318	1656	?	320	N/A	**N/A**
Storage / Other	216	?	40	N/A	**N/A**
WIGAN BUILDING					

Wigan Studio 301	7200	520-560 (Av: **540**)	320	220	**2933**
Seminar 302 + 303	1728	?	320	N/A	**N/A**
Wigan Toilet (M3/F3)	368	430	80	350	**334**
Wigan Toilet Entries	38	50	40	10	**8**
Wigan Staircase 371	144	80	80	0	**0**
Wigan Staircase 372	144	160-190 (Av: **175**)	80	95	**78**
Corridor 363	288	150	40	110	**211**
Kitchenette	144	600	160	440	**106**
Corridor 364	288	150	80	70	**211**
TOTAL	**42,905**				**13,837**

Table 7:22: Lighting levels for different spaces in level 3

Below is the table of calculations for lighting use reductions of 50%.

For example: *Vivian Studio 301 has 3.96 kW of installed lighting. In one year during trimester 1 and 2, after hours there are 2183 hours. From observation it is found that 50% of these lights are left on and the rest turned off.*
So, (50% x 3.96 kW) x 2183 hrs = ***4322 kWh of lighting energy that could be saved.***

Different areas/rooms in Level 3	**Installed lighting (kW)**	**Switch off the remaining 50% lights that are on after hours Trimester 1 & 2: Mon-Sun**
VIVIAN BUILDING		**Installed lighting (kW) x 2183 hours x 50% = ___ kWh/yr**
x 22 Staff Offices	4.464	Lights assumed to be turned off
Design Comp Labs 320	0.576	Lights assumed to be turned off

Arch Comp Labs 317	1.440	Lights assumed to be turned off
Arch Comp Labs 319	2.592	Lights assumed to be turned off
Design CompLabs 322	1.152	Lights assumed to be turned off
Staircase 1	0.288	**314**
Staircase 2	0.288	**314**
Staircase 3	0.288	**314**
Staircase 4	0.288	**314**
Staircase 5	0.288	**314**
Kitchenette	0.072	**79**
Vivian Toilet 1 (M/F)	0.216	**236**
Vivian Toilet 2 (M/F) + disabled	0.270	**295**
Corridor 351	0.216	**236**
Atrium bridge	1.155	**1261**
Corridor 352	0.504	**550**
Stair 2 door light	0.210	**229**
Toilet entry space	0.054	**59**
Corridor 353	0.216	**236**
Corridor 354	0.216	**236**
To Wigan Building Corridor	0.114	**124**
Corridor 355	0.420	**458**
Corridor 355 b	0.072	**79**
Corridor 356	0.315	**344**
Corridor 356 b	0.144	**157**
Kitchenette door	0.019	**21**
Toilet entry space	0.054	**59**
Corridor 357	0.288	**314**
Corridor 358	0.360	**393**
Vivian Studio 301	*3.960*	***4322***
Vivian Studio 303	3.384	**3694**
Vivian Studio 323/333	6.768	**7387**
Seminar 308+318	1.656	Lights assumed to be turned off
Storage / Other	0.216	Lights assumed to be turned off
WIGAN BUILDING		
Wigan Studio	7.200	**7859**
Seminar 302 + 303	1.728	Lights assumed to be turned off
Wigan Toilet	0.368	Sensor operated = Switched off

Wigan Toilet Entry	0.038	**41**
Wigan Staircase 371	0.144	**157**
Wigan Staircase 372	0.144	**157**
		Sensor operated = Switches off after
Corridor 363	0.288	time
Kitchenette	0.144	**157**
Corridor 364	0.288	**314**
TOTAL	**42.91**	**31,026**

Table 7:23: Estimated savings from turning the remaining lights off after hours

Different areas/rooms in Level 3	Installed Lighting (W)	Switch off the areas/rooms closed off after class hrs for computer use reduction Trimester 1,2, Mon-Sun:
VIVIAN BUILDING		= Installed lighting (kW) x (1110 hrs + 444 hrs)
x 22 Staff Offices	4.464	These are assumed to be turned off
Design Computer Lab 320	0.576	**Open**
Arch Computer Lab 317	1.440	**Closed: 2238**
Arch Computer Lab 319	2.592	**Closed: 4028**
Design Computer Lab 322	1.152	**Open**
Vivian Studio 301	3.960	**Closed: 6154**
Vivian Studio 303	3.384	**Open**
Vivian Studio 323/333	6.768	**Closed: 10517**
WIGAN		
Wigan Studio 301	7.200	**Closed: 11189**
TOTAL		**34,126**

Table 7:24: Estimated savings from turning off the lights in rooms after class hours

Different areas/rooms in Level 3	Installed	Close down the 54% of the student service part of building

	lighting (kW)	during Trimester 3 opening hours, Mon-Sun
VIVIAN BUILDING		= Installed lighting (kW) x 801.3 hrs
Design Computer Lab 320	0.576	**Open**
Arch Computer Lab 317	1.440	**Closed: 1154**
Arch Computer Lab 319	2.592	**Closed: 2077**
Design Computer Lab 322	1.152	**Open**
Vivian Studio 301	3.960	**Closed: 3173**
Vivian Studio 303	3.384	**Closed: 2712**
Vivian Studio 323/333	6.768	**Closed: 5423**
WIGAN		
Wigan Studio 301	7.200	**Closed: 5769**
TOTAL		**20,308**

Table 7:25: Estimated savings from turning off the lights in rooms after class hours

Different areas/rooms in Level 3	Installed lighting (kW)	Sensors to turn off after 10 inactive mins on corridors / circulation / staircase and toilets
VIVIAN BUILDING		= Installed lighting x 4834.3hrs x 35% (Tri 1 & 2 Mon-Sun, Tri 3 Mon-Sun)
Staircase 1	0.288	487
Staircase 2	0.288	487
Staircase 3	0.288	487
Staircase 4	0.288	487
Staircase 5	0.288	487
Kitchenette	0.072	122
Vivian Toilet 1	0.108	365
Vivian Toilet 2 + disabled	0.162	457
Corridor 351	0.216	365
(Atrium bridge)	1.155	1954
Corridor 352	0.504	853
Door light for Stair 2	0.210	355
(Toilet entry space)	0.054	91
Corridor 353	0.216	365

Corridor 354	0.216	365
To Wigan St Building	0.114	193
Corridor 355	0.420	711
Corridor 355 b	0.072	122
Corridor 356	0.315	533
Corridor 356 b	0.144	244
Kitchenette door	0.019	32
Toilet entry space	0.054	91
Corridor 357	0.288	487
Corridor 358	0.360	609
WIGAN		
Wigan Toilet (M3/F3)	0.368	Existing installed sensors
Wigan Toilet Entry	0.038	64
Wigan Staircase 371	0.144	244
Wigan Staircase 372	0.144	244
Corridor 363	0.288	487
Kitchenette	0.144	244
Corridor 364	0.288	487
TOTAL		**12,523**

Table 7:26: Estimated savings from installing motion sensors in intermittent spaces

Appendix 4: Gas Heating – ALF 3.1.1. Calculations

This section lists the modelling assumptions from ALF concerning the building design, climate and heating for the case study office in its current operating status. There are limits to certain options as they are fixed in the program.

ALF Modelling Assumptions for SE, NE, NW, SW facing office

Climate:

- **Location:** Wellington in the Lower North Island
- **Heating Season**: May to September (5 month heating period, which is standardised for ALF)
- **Annual Loss Factor**: 21.5
- **Wind Zone Factor**: 1.15
- **H1 Climate Location**: warm
- **Climate Zone**: 2 (Central to Lower North Island)

Building Design:

- **Total Floor Area:** 14.6 m^2
- **Number of Occupants:** 1 (usually one staff member per office)
- **Room Height:** average 4m

Heating:

- Heating Schedule : All Day Heating (7:00am - 11:00pm)
- Heating Level: 20℃

Slab Floor:

- **Floor Area:** 14.6 m^2 (refer to figure 6)
- **Perimeter Length:** 3.05 m (refer to figure 6)
- **External Wall Thickness:** 0.113 m (see figure 8)
- **Under Floor R-value:** 10 m^2℃/W

Floor R value (below) was high as possible (R = 10 m^2℃/W), as the floor heat losses will be small because level 3 would have minimum *floor heat loss due to floors below but the roof will have normal heat loss.*

- **Floor Covering R-value**: 10 m²°C/W
- **Total Slab Floor R-value**: 10 m²°C/W

For Zone 2, the BRANZ House Insulation Guide 2007 indicates the minimum R value for walls, floors and roofs in order for the building to comply with the NZ Building Code before 30/06/08.[352]

Zone 2 before 30/06/08 (R Values in compliance with NZS 4218:1996 Calculation Method)

- **Roof** = R1.9
- **Wall** = R 1.5
- **Floor** = R 1.3

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[352] Smarter Homes, *Your Guide to a smarter insulation*, <http://www.smarterhomes.org.nz/publications/your-guide-to-a-smarter-insulation/> [accessed 20 July 2009]

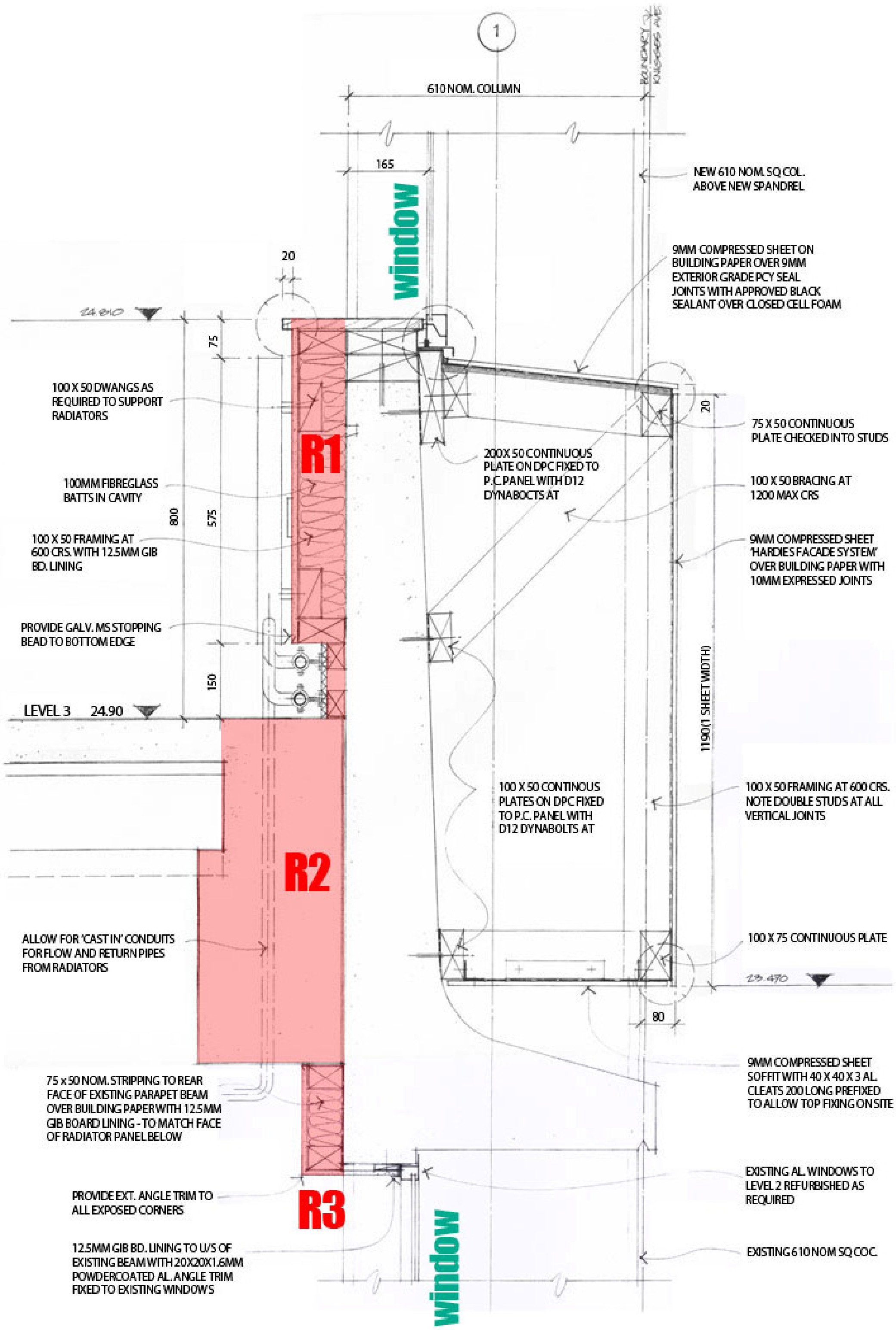

Figure 7:18: Construction detail section of wall / window

Walls:

- The Construction R-value is equal to the Insulation R-value

- Insulation R-value: 1.07 m²°C/W
- Construction R-value: 1.07 m²°C/W*

Wall A – R Value calculation:

R total / Area total (R1+R2+R3/A1+A2+A3) = R average

R1.28 x (3.05m x 0.4m) + R1.4 x (3.05 x 0.2m) + R1.9 x (3.05 x 0.8m)

R average = 1.07

Wall A details:

Length – 3.05m

Height – 4m

Net Area – 6.7m²

Window Area – (1.9m x 2.9m) = 5.51m

R Value – 1.07 m²°C/W

Wall B details:

Length – 4.77m

Height – 4m

Net Area – 19.1m²

Window Area – N/A

R Value – 6 m²°C/W

Wall C details:

Length – 4.77m

Height – 4m

Net Area – 19.1m²

Window Area – N/A

R Value – 6 m²°C/W

Wall D details:

Length – 3.05m

Height – 4m

Net Area – 12.2m²

Window Area – N/A

R Value – 6 m²°C/W

* R value of 6 was used for Walls B, C and D to represent internal walls. As these are internal heat loss will be minimal.

Roof details: [353]

- **Length** – 4.9m
- **Width** – 3.2m
- **Net Area** – 15.7m2
- **R Value** – 1.9 m²°C/W

Windows and Skylights:

- **Glass:** Single, clear
- **Frame:** Alumium frame (no thermal break)
- **R-value:** 0.15 m²°C/W
- **Solar Heat Gain Coefficient:** 70 %
- **Shading:** 30%
- **Window A =** Height – 1.9m, Width – 2.9m, Net Area – 5.5m²

Air Leakage:

Basic Airtightness: average

- The location-independent Air Leakage Rate is 0.50 ac/h.
- **Site Exposure**: medium (Semi) sheltered
- **Wind Zone Factor**: 1.15
- **Local Air Leakage Rate**: 0.58 ac/h

Thermal Mass:

- **Timber Floor:** 14.6 m², Carpet and underlay
- **Thermal Mass:** 0 kWh/°C

- **Concrete Floor:** 0 m², Without insulation

[353] Roof construction is differs between different parts of building and construction R values are hard to calculate, therefore the R values used comply with NZS 4218:1996.

- **Thermal Mass:** 0 kWh/℃
- **External Walls:** 6.7 m², Any internally lined construction
- **Thermal Mass:** 60 kWh/℃

- **Internal Walls:** 50.4 m², Timber or steel frame (44mm)
- **Thermal Mass:** 454 kWh/℃

- **Total Floor Area (used for Furniture and Ceiling):** 14.6 m² (4.5 Wh/m²℃ + 2.5 Wh/m²℃)
- **Thermal Mass:** 102 kWh/℃
- **Total Thermal Mass:** 827 kWh/℃
- **Effective Thermal Mass:** 21.9 W/℃

Appendix 5: Transport by air - Airport Codes[354]:

New Zealand:

AKL – Auckland

WEL – Wellington

CHC – Christchurch

BHE – Blenheim

Australia:

SYD – Sydney

MEL – Melbourne

BNE – Brisbane

Asia:

HKG – Hong Kong

PVG – Pu Dong, China

KIX – Osaka, Japan

CHC - China

SIN – Singapore

DAC – Dhaka, Bangladesh

America:

SFO – San Fransico, USA

LAX – Los Angeles, USA

ATL – Atlanta, USA

MSN – Madison, USA

ORD – Chicago, USA

SEA – Seattle, USA

HNL – Honolulu, Haiwaii

YYZ – Toronto, Canada

South America:

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[354] World Airport Codes, <http://www.world-airport-codes.com/> [accessed 09 August 2009]

EZE (BUE) Buenos Ares, Argentina

SJO – San Jose, Costa Rica

SCL – Santiago, Chile

Europe:

LHR – London

Appendix 6: Transport by air reduction calculations

Below is the table of calculations for transport by air (domestic) reductions of 25%, 50% and 90%.

From To	Count	km's	Total Km's
~~WLG AKL~~	~~24~~	~~481.2~~	~~11,549~~
AKL WLG	15	481.2	7,218
CHC WLG	2	302.5	605
WLG CHC	2	302.5	605
BHE WLG	2	80	161
WEL BHE	2	80	161
		Total	**20,299***

Table 8:6: Domestic Air flight records from SoAD – 25% reduction

From To	Count	km's	Total Km's
~~WLG AKL~~	~~24~~	~~481.2~~	~~11,549~~
~~AKL WLG~~	~~15~~	~~481.2~~	~~7,218~~
CHC WLG	2	302.5	605
WLG CHC	2	302.5	605
BHE WLG	2	80	161
WEL BHE	2	80	161
		Total	**20,299***

Table 8:7: Domestic Air flight records from SoAD – 50% reduction

From To	Count	km's	Total Km's
~~WLG AKL~~	~~24~~	~~481.2~~	~~11,549~~
~~AKL WLG~~	~~15~~	~~481.2~~	~~7,218~~
~~CHC WLG~~	~~2~~	~~302.5~~	~~605~~

~~WLG CHC~~	~~2~~	~~302.5~~	~~605~~
~~BHE WLG~~	~~2~~	~~80~~	~~161~~
~~WEL BHE~~	~~2~~	~~80~~	~~161~~
		Total	**20,299***

Table 8:8: Domestic Air flight records SoAD – 90% reduction

Below is the table of calculations for transport by air (international) reductions of 25%, 50% and 90%.

From To	Count	km's	Total Km's	t CO_2 RFI= 3	After Savings t CO_2
~~HKG AKL~~	~~3~~	~~9,143~~	~~27,428~~	~~9.69~~	0
~~AKL HKG~~	~~6~~	~~9,143~~	~~54,856~~	~~19.38~~	0
~~AKL PVG~~	~~2~~	~~9,336~~	~~18,672~~	~~6.22~~	0
~~AKL KIX~~	~~1~~	~~8,895~~	~~8,895~~	~~3.14~~	0
AKL LAX	2	10,454	20,909	7.540	7.54
LAX AKL	3	10,454	31,362	11.31	11.31
SFO AKL	4	10,475	41,901	15.12	15.12
AKL SFO	5	10,475	52,376	18.90	18.90
AKL LHR	2	18,355	36,710	13.98	13.98
LHR AKL	3	18,355	55,065	20.97	20.97
AKL EZE (BUE)	1	10,338	10,338	3.27	3.27
EZE AKL	1	10,338	10,338	3.27	3.27
LAX SYD	1	12,036	12,036	4.42	4.42
BNE LAX	1	11,510	11,510	4.21	4.21
CHC SIN	2	8,393	16,785	5.86	5.86
SIN CHC	2	8,393	16,785	5.86	5.86
SYD HNL	1	8,143	8,143	2.83	2.83
LHR SIN	1	10,881	10,881	3.94	3.94
SIN LHR	1	10,881	10,881	3.94	3.94
ATL SFO	1	3,441	3,441	0.94	0.94
LAX SJO	2	4,376	8,752	2.40	2.40
SJO LAX	2	4,376	8,752	2.40	2.40
HNL LAX	1	4,110	4,110	1.13	1.13

DAC SIN	2	2,882	5,765	1.54	1.54
SIN DAC	2	2,882	5,765	1.54	1.54
LAX YYZ	1	3,500	3,500	1.01	1.01
YYZ LAX	1	3,500	3,500	1.01	1.01
YYZ ATL	1	1,189	1,189	0.37	0.37
LAX SEA	2	1,535	3,071	0.90	0.90
EZE SCL	1	1,139	1,139	0.33	0.33
SCL EZE	1	1,139	1,139	0.33	0.33
ORD MSN	1	172	172	0.06	0.06
~~BNE SIN~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	0
~~SIN BNE~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	0
~~MEL WLG~~	~~1~~	~~2,594~~	~~2,594~~	~~0.69~~	0
~~MEL WLG~~	~~2~~	~~2,594~~	~~5,189~~	~~1.38~~	0
~~AKL SYD~~	~~3~~	~~2,163~~	~~6,489~~	~~1.74~~	0
~~SYD WLG~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	0
~~WLG SYD~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	0
~~AKL MEL~~	~~1~~	~~2,643~~	~~2,643~~	~~0.71~~	0
~~BNE WLG~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	0
~~WLG BNE~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	0
~~WLG MEL~~	~~3~~	~~2,594~~	~~7,782~~	~~2.07~~	0
~~BNE AKL~~	~~1~~	~~2,297~~	~~2,297~~	~~0.61~~	0
		Total	**577,236**	**197.97**	**142.52**

Table 8:9: International Air flight records from SoAD – 25% reduction

From To	**Count**	**km's**	**Total Km's**	**t CO_2 RFI= 3**	**After Savings t CO_2**
~~HKG AKL~~	~~3~~	~~9,143~~	~~27,428~~	~~9.69~~	~~0.097~~
~~AKL HKG~~	~~6~~	~~9,143~~	~~54,856~~	~~19.38~~	~~0.194~~
~~AKL PVG~~	~~2~~	~~9,336~~	~~18,672~~	~~6.22~~	~~0.062~~
~~AKL KIX~~	~~1~~	~~8,895~~	~~8,895~~	~~3.14~~	~~0.031~~
~~AKL LAX~~	~~2~~	~~10,454~~	~~20,909~~	~~7.540~~	~~0.075~~
~~LAX AKL~~	~~3~~	~~10,454~~	~~31,362~~	~~11.31~~	~~0.113~~
~~SFO AKL~~	~~4~~	~~10,475~~	~~41,901~~	~~15.12~~	~~0.151~~
~~AKL SFO~~	~~5~~	~~10,475~~	~~52,376~~	~~18.90~~	~~0.189~~

AKL LHR	2	18,355	36,710	13.98	13.98
LHR AKL	3	18,355	55,065	20.97	20.97
AKL EZE (BUE)	1	10,338	10,338	3.27	3.27
EZE AKL	1	10,338	10,338	3.27	3.27
LAX SYD	1	12,036	12,036	4.42	4.42
BNE LAX	1	11,510	11,510	4.21	4.21
~~CHC SIN~~	~~2~~	~~8,393~~	~~16,785~~	~~5.86~~	~~0.059~~
~~SIN CHC~~	~~2~~	~~8,393~~	~~16,785~~	~~5.86~~	~~0.059~~
SYD HNL	1	8,143	8,143	2.83	2.83
LHR SIN	1	10,881	10,881	3.94	3.94
SIN LHR	1	10,881	10,881	3.94	3.94
ATL SFO	1	3,441	3,441	0.94	0.94
LAX SJO	2	4,376	8,752	2.40	2.40
SJO LAX	2	4,376	8,752	2.40	2.40
HNL LAX	1	4,110	4,110	1.13	1.13
DAC SIN	2	2,882	5,765	1.54	1.54
SIN DAC	2	2,882	5,765	1.54	1.54
LAX YYZ	1	3,500	3,500	1.01	1.01
YYZ LAX	1	3,500	3,500	1.01	1.01
YYZ ATL	1	1,189	1,189	0.37	0.37
LAX SEA	2	1,535	3,071	0.90	0.90
EZE SCL	1	1,139	1,139	0.33	0.33
SCL EZE	1	1,139	1,139	0.33	0.33
ORD MSN	1	172	172	0.06	0.06
~~BNE SIN~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	~~0.020~~
~~SIN BNE~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	~~0.020~~
~~MEL WLG~~	~~3~~	~~2,594~~	~~7,782~~	~~2.07~~	~~0.021~~
~~WLG MEL~~	~~3~~	~~2,594~~	~~7,782~~	~~2.07~~	~~0.021~~
~~AKL SYD~~	~~3~~	~~2,163~~	~~6,489~~	~~1.74~~	~~0.017~~
~~SYD WLG~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	~~0.036~~
~~WLG SYD~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	~~0.036~~
~~AKL MEL~~	~~1~~	~~2,643~~	~~2,643~~	~~0.71~~	~~0.007~~
~~BNE WLG~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	~~0.007~~
~~WLG BNE~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	~~0.007~~
~~BNE AKL~~	~~1~~	~~2,297~~	~~2,297~~	~~0.61~~	~~0.006~~
		Total	**577,236**	**197.97**	**83.75**

Table 8:10: International Air flight records from SoAD – 50% reduction

From To	Count	km's	Total Km's	t CO_2 RFI= 3	After Savings t CO_2
~~HKG AKL~~	~~3~~	~~9,143~~	~~27,428~~	~~9.69~~	~~0.097~~
~~AKL HKG~~	~~6~~	~~9,143~~	~~54,856~~	~~19.38~~	~~0.194~~
~~AKL PVG~~	~~2~~	~~9,336~~	~~18,672~~	~~6.22~~	~~0.062~~
~~AKL KIX~~	~~1~~	~~8,895~~	~~8,895~~	~~3.14~~	~~0.031~~
~~AKL LAX~~	~~2~~	~~10,454~~	~~20,909~~	~~7.540~~	~~0.075~~
~~LAX AKL~~	~~3~~	~~10,454~~	~~31,362~~	~~11.31~~	~~0.113~~
~~SFO AKL~~	~~4~~	~~10,475~~	~~41,901~~	~~15.12~~	~~0.151~~
~~AKL SFO~~	~~5~~	~~10,475~~	~~52,376~~	~~18.90~~	~~0.189~~
~~AKL LHR~~	~~2~~	~~18,355~~	~~36,710~~	~~13.98~~	~~0.140~~
~~LHR AKL~~	~~3~~	~~18,355~~	~~55,065~~	~~20.97~~	~~0.210~~
~~AKL EZE (BUE)~~	~~1~~	~~10,338~~	~~10,338~~	~~3.27~~	~~0.033~~
~~EZE AKL~~	~~1~~	~~10,338~~	~~10,338~~	~~3.27~~	~~0.033~~
~~LAX SYD~~	~~1~~	~~12,036~~	~~12,036~~	~~4.42~~	~~0.044~~
~~BNE LAX~~	~~1~~	~~11,510~~	~~11,510~~	~~4.21~~	~~0.044~~
~~CHC SIN~~	~~2~~	~~8,393~~	~~16,785~~	~~5.86~~	~~0.059~~
~~SIN CHC~~	~~2~~	~~8,393~~	~~16,785~~	~~5.86~~	~~0.059~~
SYD HNL	1	8,143	8,143	**2.83**	**0.283**
~~LHR SIN~~	~~1~~	~~10,881~~	~~10,881~~	~~3.94~~	~~0.394~~
~~SIN LHR~~	~~1~~	~~10,881~~	~~10,881~~	~~3.94~~	~~0.394~~
ATL SFO	1	3,441	3,441	0.94	0.94
LAX SJO	2	4,376	8,752	2.40	2.40
SJO LAX	2	4,376	8,752	2.40	2.40
~~HNL LAX~~	~~1~~	~~4,110~~	~~4,110~~	~~1.13~~	~~0.113~~
DAC SIN	2	2,882	5,765	**1.54**	**0.154**
SIN DAC	2	2,882	5,765	**1.54**	**0.154**
LAX YYZ	1	3,500	3,500	1.01	1.01
YYZ LAX	1	3,500	3,500	1.01	1.01
YYZ ATL	1	1,189	1,189	0.37	0.37
LAX SEA	2	1,535	3,071	0.90	0.90

EZE SCL	1	1,139	1,139	0.33	0.33
SCL EZE	1	1,139	1,139	0.33	0.33
ORD MSN	1	172	172	0.06	0.06
~~BNE SIN~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	~~0.020~~
~~SIN BNE~~	~~1~~	~~6,133~~	~~6,133~~	~~1.99~~	~~0.020~~
~~MEL WLG~~	~~3~~	~~2,594~~	~~7,782~~	~~2.07~~	~~0.021~~
~~WLG MEL~~	~~3~~	~~2,594~~	~~7,782~~	~~2.07~~	~~0.021~~
~~AKL SYD~~	~~3~~	~~2,163~~	~~6,489~~	~~1.74~~	~~0.017~~
~~SYD WLG~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	~~0.036~~
~~WLG SYD~~	~~6~~	~~2,232~~	~~13,393~~	~~3.60~~	~~0.036~~
~~AKL MEL~~	~~1~~	~~2,643~~	~~2,643~~	~~0.71~~	~~0.007~~
~~BNE WLG~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	~~0.007~~
~~WLG BNE~~	~~1~~	~~2,512~~	~~2,512~~	~~0.67~~	~~0.007~~
~~BNE AKL~~	~~1~~	~~2,297~~	~~2,297~~	~~0.61~~	~~0.006~~
		Total	**577,236**	**197.97**	**18.88**

Table 8:11: International Air flight records from SoAD – 90% reduction

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