Sustainable energy solutions for the residences of Stellenbosch University

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

The research objective of this assignment is to investigate technological options for sustainable energy solutions in the residences of Stellenbosch University. Conventional energy systems are contributing towards the degradation of global environmental sustainability. An alternative energy future exists if sustainable energy solutions, via renewable energy or energy efficiency, are adopted but these solutions await the political will and institutional governance to be implemented. A niche group of universities are modelling themselves around the sustainable energy agenda. As institutional spaces of learning, research and breeding grounds for new ways of thinking, universities stand poised to engage future leaders with local solutions to global energy dilemmas.

It is argued that sustainable energy is necessary, it is possible and other universities are implementing it in various formats. The author of this thesis, a student at Stellenbosch University, was prompted to ask: what opportunities exist for Stellenbosch University to implement sustainable energy? The research objective focused on end use energy efficiency as means, out of all the technical options theoretically possible today, to implement sustainable energy solutions in the residences of Stellenbosch University. The focus of end use efficiency was specific to water heating, lighting and appliance use, for which technical solutions exist.

This exploratory research was conducted via a macro, secondary data analysis of the quantitative data which detailed the energy consumption of residences in kilowatt hours as well as a micro, case study to facilitate a qualitative and quantitative analysis of the behavioural and leadership dynamics involved with technological implementation.

The findings revealed that end use energy efficiency is a possible means for sustainable energy use within the residences of Stellenbosch University. However, the use of heat pump water heating technology in the majority of the residences and the omission of air conditioning in the residences results that the greatest potential for energy efficiency measures are not available. The centralised kitchen infrastructure requires highly rated equipment to deal with the swift throughput of meal times during the residences. The remaining focus areas of energy consumption, residential living, therefore, poses the greatest opportunity for end use energy efficiency. This posits residential lighting and appliance use as the focal point of the investigation.

The findings concluded recommended courses of action for the University, residential leaders and students. The holistic and integrated approach to the research objective, guided by systems thinking and ecological design, capacitates actors at three different levels to pro actively implement end use energy efficiency. A by product of the micro, case study was a tool which the new Green House Committee members can now use to identify key points of energy efficiency and energy conservation in their residences. The local solutions generated by this thesis significantly contributed towards taking the first step towards mitigating global, national and community problems. Sustainable energy solutions are necessary, available and being implemented in other universities. End use energy efficiency, as a means to sustainable energy, is necessary, available and possible to implement within the residences of Stellenbosch University.

Opsomming

Die navorsingsdoelstelling van hierdie tesis is om tegnologiese opsies vir volhoubare energie-oplossings vir die koshuise van die Universiteit Stellenbosch te ondersoek. Konvensionele energiestelsels dra tot die agteruitgang van globale omgewingsvolhoubaarheid by. Daar is wel ’n alternatiewe opsie vir die toekoms indien volhoubare energie-oplossings, deur hernubare energie of energiedoeltreffendheid, aanvaar word. Die implementering van hierdie oplossings is egter van politieke samewerking en institusionele beheer afhanklik. ’n Nisgroep universiteite is tans besig om hulle aktiwiteite op die agenda oor volhoubare energie te rig. As institusionele ruimtes van leer en navorsing en teelaardes vir nuwe denkwyses, staan universiteite gereed om toekomstige leiers met plaaslike oplossings tot die globale energiedilemmas in te span.

Dit word geargumenteer dat volhoubare energie nodig is, dat dit moontlik is, en dat ander universiteite dit in verskeie formate implementeer. Die outeur van hierdie tesis, ’n student aan die Universiteit Stellenbosch, vra na aanleiding hiervan: Watter geleenthede bestaan by die Universiteit Stellenbosch om volhoubare energie te implementeer? Die navorsingsdoelstelling fokus op eindgebruik-energiedoeltreffendheid as middel, uit al die tegniese moontlikhede wat vandag teoreties moontlik is, om volhoubare energie-oplossings in die koshuise van die Universiteit Stellenbosch te implementeer. Die fokus van eindgebruik-doeltreffendheid is spesifiek op waterverhitting, verligting en die gebruik van toestelle waarvoor tegniese oplossings reeds bestaan.

Hierdie ondersoek is uitgevoer deur ’n makro-, sekondêre analise van die kwantitatiewe data, wat die energieverbruik van huishoudings in kilowatt-uur uitdruk, asook ’n mikrogevallestudie ter ondersteuning van ’n kwalitatiewe en kwantitatiewe analise van die gedrags- en leierskapdinamika wat met die tegnologiese implementering verband hou.

Die bevindinge toon dat eindgebruik-energiedoeltreffendheid ’n moontlike oplossing is vir volhoubare energieverbruik in die koshuise van die Universiteit Stellenbosch. Die gebruik van hittepomp-verhittingstegnologie in die meerderheid koshuise en die afwesigheid van lugversorging in die koshuise beteken egter dat die grootste potensiaal vir maatreëls tot energiedoeltreffendheid nie beskikbaar is nie. Die gesentraliseerde kombuisinfrastruktuur vereis die voorste toerusting om die vinnige omset van maaltye by die koshuise te kan hanteer. Die oorblywende fokusarea van energieverbruik, naamlik huishoudelike gebruik, bied die grootste geleentheid vir eindgebruik-energiedoeltreffendheid. Verligting in wonings

en die gebruik van toestelle is die fokus van die ondersoek, maar die beperkinge van energiedoeltreffendheid in die konteks van die Universiteit Stellenbosch se koshuise word ook aan die lig gebring.

Die bevindinge lê die grondslag vir aanbevole handelswyses vir die Universiteit, residensiële leiers en studente. Die holistiese en geïntegreerde benadering tot die navorsingsdoelstelling op grond van stelseldenke en ekologiese ontwerp stel rolspelers op die drie vlakke in staat om eindgebruik-energiedoeltreffendheid proaktief te implementeer. ’n Neweproduk van die mikrogevallestudie is ’n instrument wat die nuwe Kweekhuiskomiteelede kan gebruik om strategiese punte van energiedoeltreffendheid en energiebewaring in hulle koshuise te identifiseer. Die plaaslike oplossings wat deur hierdie tesis gegenereer is, dra aansienlik by tot die eerste stap na die oplossing van globale, nasionale en gemeenskapsprobleme. Volhoubare energie-oplossings is noodsaaklik, beskikbaar en word in ander universiteite geïmplementeer. Eindgebruik-energiedoeltreffendheid, as ’n middel tot volhoubare energie, is noodsaaklik, beskikbaar, en kan in die koshuise van die Universiteit Stellenbosch geïmplementeer word.

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Chapter 1: Setting the context

1.1. Introduction

> 'Unequal access to modern energy is closely correlated with wider inequalities in opportunities for human development. Countries with low levels of access to modern energy systems figure prominently in the low human development group. Within countries, inequalities in access to modern energy services between rich and poor and urban and rural areas interact with wider inequalities in opportunity' (*Human Development Report*, 2007:45).

This statement explicates the foundational role of energy in the panacea for human development. The relationship between energy and human development began when humans first learnt how to use fire for cooking and heating and, through several revolutions, has culminated in the 21st century in a dependency in which modern living would cease to exist should we 'unplug' ourselves.

This critical role of energy warrants attention when evidence reveals that the current processes and consequences that supply us with energy[1] are proving to be environmentally unsustainable on a global, national and local scale (Aubrecht, 2006; Intergovernmental Panel on Climate Change (IPCC[2]), 2001; IPCC, 2007a,b,c,d). The greenhouse gases (GHG) emitted during power generation from fossil fuels are particularly under scrutiny as detrimental to humanity's environmental sustainability. Research by the IPCC concluded that warming of the environment is 'unequivocal' and that the greenhouse gases created from the world's power supply (electricity) are the primary anthropogenic forcing of climate change (IPCC, 2007d:2,5). This knowledge is amplified by suggestions that the optimal time frame in which we should decrease absolute global emissions lies within the next 50 years (Meinshausen,

[1] Energy, in this thesis, refers exclusively to electrical energy (i.e. electricity)

[2]The IPCC was formed in 1988, under the auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), to 'provide scientific technical and socio-economic information in a policy-relevant but policy neutral way to decision makers' (IPCC website, 2007). This organisation reviews the available peer reviewed and popular literature relating to climate change and, in negotiating processes with scientists, government officials and policy makers, compiles reports that present certain observations based on trends observed in the data. The First, Second, Third (TAR) and Fourth Assessment Reports (FAR) respectively were published in 1990, 1995, 2001 and 2007. Each Assessment Report is made up of Working Group Contribution Reports and concludes with a Synthesis Report. A Summary for Policy Makers (SPM) for each of these reports is available. (IPCC website, 2008)

2006 in *Stern Review*, 2006:200; *Stern Review*, 2006:193,206). The world's growing population and subsequent increase in demand for energy makes approaches to this problem more complex and exacerbates the issue of national energy security.

If conventional energy systems are proving to be environmentally unsustainable, the question to ask is: are there any alternatives for a sustainable energy future? Technologically, the answer is yes. Renewable energy systems allow for a sustainable energy future, in which energy efficiency is a technological aid. If, and how, these technological solutions can be implemented in our built environment is, however, governed by a complex and dynamic set of factors.

This complex global issue translates itself into the local context in this thesis, the research objective of which is to investigate what technological options exist for implementing sustainable energy solutions in the residences of Stellenbosch University, with particular emphasis on energy efficiency. The residences of Stellenbosch University were chosen as the focal point for two reasons. Firstly, universities should play a global role as examples of sustainable living and as living-learning environments. Secondly, Stellenbosch University's residences were open to investigation as a local space and were accessible to the author. Investigating what technological options exist for implementing sustainable energy solutions in the residences of Stellenbosch University is a local reaction towards the reality of the global and national energy context.

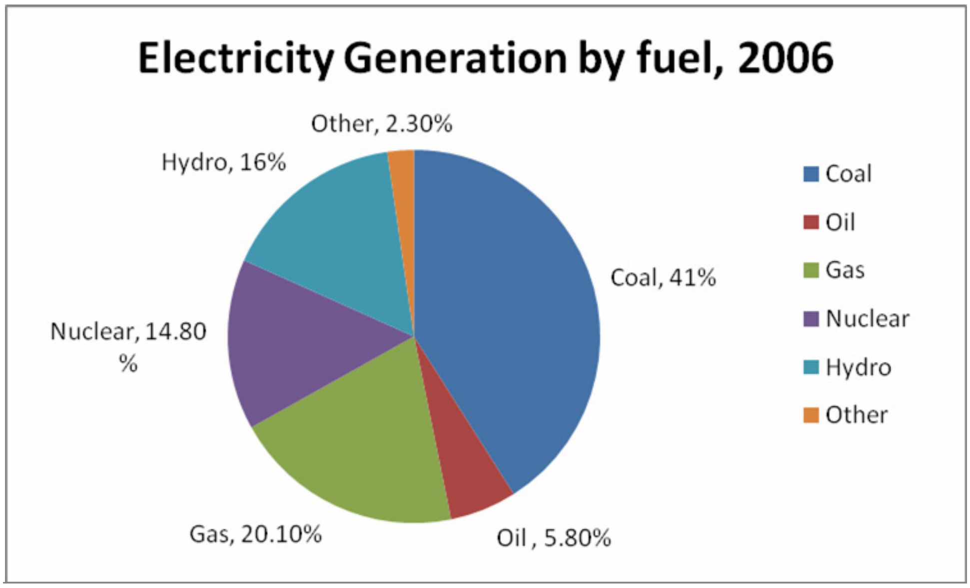
This introductory chapter provides the contextual background to the research objective. It begins with a review of the global and national energy context to identify the dominance of fossil fuel sources for electricity production. This is clearly established so that the research objective, which is particular to the national energy context, is justified. In other words, investigating what technological options exist for implementing sustainable energy solutions in the residences of Stellenbosch University is clearly a necessary research objective in light of the current and future carbon based energy context of South Africa. The literature review in the next chapter documents why the use of conventional energy systems is environmentally unsustainable (this argument is not explored in the introductory chapter). The research objective and the nuances of the aim of the research are thereafter clearly detailed and conceptual clarifications regarding energy and solutions paradigms are made.

The background to the research objective is detailed and this informs the significance of the study. Finally, a thesis 'road map' is provided to orient the reader as to how the documentation of this thesis is presented.

1.2. Global energy context

Global energy in 2006, in terms of electricity, was generated predominantly by fossil fuel sources, followed by nuclear, hydro and a 2.3% contribution from all the renewables (solar, wind, geothermal, combustible renewables and waste and heat) (International Energy Agency (IEA), 2008:24). The breakdown of the relative contribution of various fuel types towards global energy supply is represented below in Figure 1: Electricity generation by fuel (Redesigned from IEA, 2008:24).

Figure 1: Electricity generation by fuel, 2006 (Redesigned from IEA, 2008:24)



Coal is the dominant fuel source for current electricity generation. All the renewable energy technologies commercially available or those that are traditionally used (i.e. burning wood, cow dung) account for a fractional 2.3% of our electricity supply. These statistics for 2006 reflect the recent historical global trend in which fossil fuels significantly supply the majority of the world's electricity needs and renewable energy provides an insignificant source of electricity (German Advisory Council on Climate Change, 2003; World Energy Council, 2007).

World Population Prospects, The 2006 Revision (United Nations, 2007) predicts that the current population of 6.7 billion will increase to 9.8 billion by 2050. The most significant contribution to this is the increase from 5.4 billion in less developed regions to 7.9 billion while the population of developed regions is predicted to stay constant at approximately 1.2 billion.

The most recent *Human Development Report* (United Nations Development Programme, 2007), which focused on *Fighting Climate Change: Solidarity in a divided world,* details the annual consumption of energy per capita for 2004 in kilowatt hours (kWh), according to the following groupings (2007:305):

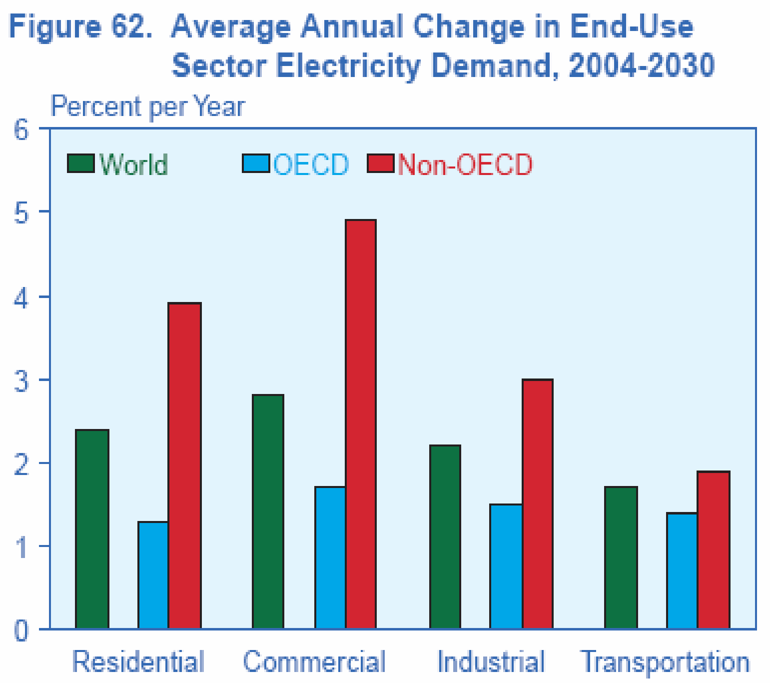
Table 1: *Human Development Report* annual energy consumption according to kWh/capita (2004)

Region	**2004 energy consumption in kWh/capita**
Least developed countries	119
Sub-Saharan Africa	478
South Asia	628
Developing countries	1 221
East Asia and the Pacific	1 599
Arab states	1 841
Latin America and the Caribbean	2 043
Central and Eastern Europe and the Commonwealth of Independent States (CIS)	4 539
Organisation for Economic Cooperation and Development (OECD)	8 795
High-income OECD	10 360

Reviewing these two sets of statistics simultaneously, it is clear that the populations that are increasing coincide with the populations that have the largest potential and desire to increase their energy consumption. Assuming that a lifestyle characteristic of countries belonging to the OECD is what people generally aspire towards, and that improved access to energy resources continues, the desired per capita jump from 1 222 kWh to 8 795 kWh will have a large impact on demand for energy resources.

A recent Energy Information Administration (EIA) projection confirms this hypothesis. In the 2007 *International Energy Outlook* (EIA, 2007:61), it was suggested that by 2030, the supply of electricity by non-OECD countries will grow at an annual growth rate which is three times larger than that of OECD countries. The predicted increase in end use demand is from the commercial, residential and industrial sectors of non OECD regions (EIA, 2007:62), as illustrated below in Figure 2: Average annual change in end-use sector electricity demand, 2004–2030 (EIA, 2007:62).

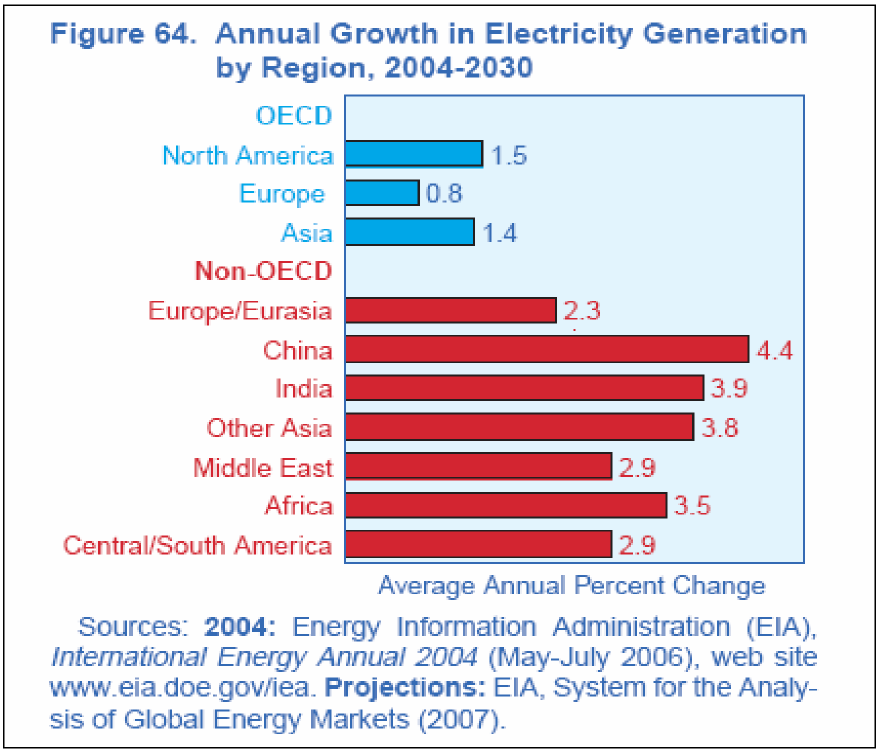
Figure 2: Average annual change in end-use sector electricity demand, 2004–2030 (EIA, 2007:62)



Sources: **2004:** Derived from Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

A breakdown of the expected growth in the supply of electricity also identifies the non OECD regions as the catalysts for the increase, as depicted below in Figure 3: Annual growth in electricity generation by region, 2004–2030.

Figure 3: Annual growth in electricity generation by region, 2004–2030 (EIA, 2007:62)



Global supply of electricity in 2004 at 16 424 billion kWh is, at an annual growth rate of 2.4%, expected to increase to 30 364 billion kWh in 2030, with non-OECD supply taking over in 2015 (EIA, 2007:61).

The IEA predicts the growth for the time period 2004–2030 will be supplied primarily by coal and natural gas (IEA, 2007:62). Although future resources and reserves of oil and gas are debatable, the remaining known resources and reserves of coal, and to some extent gas and oil, indicate a medium-term (approximately 100–200 years) presence of fossil fuels in the future global energy mix (Aubrecht, 2006:242; Global Advisory Council on Climate Change, 2003; InterAcademy Council, 2007:59; World Energy Council, 2007).

Are there any alternatives to the likely possibility that fossil fuels will dominate the global energy context? In addition, will these alternatives be able to supply the increase in demand for energy in a sustainable way? Renewable energy and, to a certain degree, energy efficiency are both alternative streams of technology with significant potential to place humanity on the path of a sustainable energy future.

Energy sources are examined according to their theoretical, conversion, technical, economic and sustainable potential (Teske et al, 2007:61; German Advisory Council on Climate Change, 2003:44). Theoretical potential refers to the amount of total energy theoretically available, regardless of whether the available technology is able to convert it or whether it is cost effective. Conversion potential refers to what is theoretically available multiplied by the conversion efficiency of the extraction technology, assuming the resource can be extracted in totality. Technical potential refers to the amount of energy that can be extracted with modern, available technology, taking conversion efficiencies into account. Economic potential refers to the amount of energy that can be extracted with modern, available technology at cost effective rates. Sustainable potential refers the amount of energy that can be extracted if environmental limits are accounted for.

Humanity's annual energy needs account for 0.1% of the theoretical potential of the sun's energy (Fink and Beaty, 2000:11–6). The technical potential of renewable energy, which could be extracted with the technology that is available today, equates to 5.9 times of current global energy demand (Teske, Zervos and Schafer, 2007:60). The calculated theoretical and technical potential of renewable energy sources (Aubrecht, 2006; German Advisory Council on Climate Change, 2003; Teske et al, 2007; World Energy Council, 2007) via the energy received by Earth from the Sun on a daily basis, and the subsequent wind, wave, geothermal and biomass power it generates, is capable of meeting our current energy demand and expected future energy demand.

The potential of energy efficiency, argued for since the oil crisis of the 1970's, 'represents an enormous and largely untapped resource' (Hirst, 1981:1). In particular, end use efficiency, which involves 'technologically providing more desired service per unit of delivered energy consumed is generally the largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services' (Lovins, 2005a:1).

This analysis of the global energy context reveals three related trends which are discussed in greater detail in the following sections of this introductory chapter and in sections of the literature review. In brief, though, three trajectories that will influence the dynamics of global energy demand are evident. Firstly, population is expected to increase in the future and the expected increase occurs predominantly in communities that would want improved access to electricity. Secondly, reserves of fossil fuels are able to meet this demand in the medium-term future and coal, possibly, in the long-term future. Lastly, the production of greenhouse gases associated with fossil fuel electricity generation, especially from coal, is potentially environmentally damaging. These three trajectories clearly point to a global energy future governed by conventional energy systems that generate undesirable environmental consequences. The three trajectories surfaced by the global context therefore brings us to a point where our future energy path stands at a crossroads: do we continue making use of conventional energy systems in light of the knowledge that it could threaten our environmental sustainability or do we search for alternative, sustainable, options?

1.3. National energy context

The South African energy context reflects the global scenario described above. South Africa relies on an energy mix that is dominated by coal. Approximately 90% of electricity needs are met by the combustion of coal at coal-fired power stations (Department of Minerals and Energy (DME), 2008; *Digest of South African Energy Statistics*, 2006:41). Nuclear, hydro and pumped storage power stations contribute to the remaining portion of the domestic energy mix (Power Engineering, 2007).

The recent instability in the supply of electricity in South Africa has been cause for concern. The '[current] reserve margin of 8–10%, which is below the global benchmark of 15%', (Department of Public Enterprises (DPE), 2007:6) is an indicator that South Africa's capacity does not have much flexibility for large growth in demand. Furthermore, future emissions controls will exacerbate the planning process when, after 2012, South Africa will be subjected to the terms of the Kyoto Protocol. Our 'dirty' status as electricity producers because of the prominent use of coal in the national energy mix implies that the measures will have to be taken seriously.

National power capacity is summarised in Table 2: Eskom power stations (Eskom 2007a; Eskom, 2008a; Eskom, 2008b; DPE, 2007; DPE, 2008; Smit, 2007) to identify the type of primary fuel that each power stations uses, its corresponding installed power capacity in megawatts (MW) and the number of years that a particular power station will exist in the energy mix. This summary reveals that the electricity used by end users in South Africa is characteristic of an energy mix that is heavily dominated by coal-fired power stations.

Table 2: Eskom power stations (Eskom 2007a; Eskom, 2008a; Eskom, 2008b; DPE, 2007; DPE, 2008; Smit, 2007)

Power station	**Rated output**	**No. of years in service (up to 2006)**	**No. of years of service left (including 2007)**	**Type of fuel source**
Acacia Power Station (outskirts of Cape Town, Western Cape)	171 MW (3 x 57 MW)	30	10	Gas
Arnot Power Station (50 km east of Middelburg, Mpumulanga)	2100 MW (6 x 350 MW)	31	9	Coal fired
Camden Power Station (close to Ermelo, Mpumulanga)	1600 MW (8 x 200 MW)	39	1	Coal fired
Duvha Power Station (15 km east of Witbank, Mpumulanga)	3 600 MW (6 x 600 MW)	22	18	Coal fired
Drakensberg Pumped Storage Scheme (close to Bergville, in the Drakensberg, KwaZulu-Natal)	1000 MW (4 x 250 MW)	25	15	Pumped storage
Gariep Hydroelectric Power Station (near Norvalspont, on the Gariep River banks, 300 m downstream from the Gariep Dam wall, Free State)	360 MW (4 x 90 MW)	36 (first two machines) 31 (other two machines		Hydro electric
Grootvlei Power Station (close to Balfour, Mpumulanga)	1 200 MW (6 x200 MW)	32	8	Coal fired
Hendrina Power Station (40 km south of Middelburg, Mpumulanga)	2 000 MW (10 x 200 MW)	30	10	Coal fired
Kendal Power Station (40 km south-west of Witbank, Mpumulanga)	4 116MW (6 x 686 MW)	13–14	26–27	Coal fired
Koeberg Power Station (near Melkbosstrand,25 km north-west of Cape Town, Western Cape)	1 800 MW (2 x 900 MW)	Unit 1 = 22, 5 years Unit 2 = 21, 5 years		Nuclear power
Komati Power Station (between Middleburg and Bethal, Mpumulanga)	1 000 MW (5 x 100 MW 4 x 125 MW)	40	0	Coal fired

Kriel Power Station (between Kriel and Ogies, Mpumulanga)	3 000 MW (6 x 500 MW)	27–28	13–12	Coal fired
Lethabo Power Station (between Vereeniging and Sasolburg, Free State)	3 708 MW (6 x 618 MW)	16	24	Coal fired
Majuba Power Station (between Volksrust and Amersfoort, Mpumulanga)	4 110 MW (3 x 665 MW dry-cooled units; 3 x 716 MW wet-cooled units)	5.75	34.35	Coal fired
Matimba Power Station (near Ellisras, Limpopo)	3 990 MW (6 x 665 MW)	14	26	Coal fired
Matla Power Station (30 km from Secunda, Mpumulanga)	3 600 MW (6 x 600 MW)	23.5	16,5	Coal fired
Palmiet Pumped Storage Scheme (near Grabouw, 2 km upstream of the Kogelberg Dam wall on the Palmiet River, Western Cape)	400 MW (2 x 200 MW)			Pumped storage
Port Rex Power Station (East London, Eastern Cape)	171 MW (3 x 57 MW)	26	14	Gas
Tutuka Power Station (between Standerton and Bethal, Mpumulanga)	3 654 MW (6 x 609 MW)	16.5	23.5	Coal fired
Vanderkloof Power Station (near Petrusville, under the Vanderkloof Dam, Northern Cape)	240 MW (2 x 120 MW)	30	10	Hydro electric
Ankerlig Power Station (near Atlantis, Western Cape)	588.68 MW (4 x147.17 MW)			Gas
Gourika Power Station (near Mossel Bay, Eastern Cape)	438.87 MW (3 x 146.29 MW)			Gas

The future activities of these 22 Eskom power stations are all aimed towards increasing the installed capacity of electricity to increase the reserve margins from the current 8% to 15% (DPE, 2007: 6) and to increase the current installed capacity of 40 GW to approximately 90

GW by 2025 (DPE, 2008; Power Engineering, 2007). Table 3 below shows that significant future investments are aimed at the return to service (RTS) of large coal-fired power stations, the building of new, large, coal-fired power stations, nuclear energy and a national energy efficiency drive.

Table 3: Summary of future activities planned for Eskom power stations (DPE, 2007; Smit, 2007)

Future activity	**Details**	**Type of fuel source**
Continuation of RTS of Camden	By 2009 Camden should be fully operational, adding 1 600 MW (DPE, 2007: 8)	Coal fired
Continuation of RTS of Grootvlei	The first unit of Grootvlei is planned for 2007 and the last for 2009, operating at 1 200 MW (DPE, 2007: 8)	Coal fired
Continuation of RTS of Komati	The first unit (Unit 9) of Komati is planned for commission in 2007 and the total operation for 2011 (1 000 MW) (DPE, 2007:8)	Coal fired
Upgrading Arnot Station	Technological improvements aim to add an extra 300 MW generating capacity by the power station by 2010 (DPE, 2007: 8)	Coal fired
Continuation of Open-Cycle Gas Turbine (OCGT) projects	5 additional units of 147, 17 MW at Ankerlig (Eskom, 2007c) 2 additional units of 146. 29 MW at Gourika, also referred to as the Gas 1 OCGT project (Eskom 3)	Gas
Coega Open-Cycle Gas Turbine (OCGT)	1 diesel-fired OCGT plant will be located in Coega in the Eastern Cape, with a capacity of about 330 MW, 1 in Avon on the north coast of KwaZulu-Natal, with generation capacity of about 750 MW. This is the first IPP project.(Van der Merwe, 2007: http://www.engineeringnews.co.za/article.php?a_id=115616)	Gas
Saldanha Open-Cycle Gas Turbine (OCGT)	Proposed for the future	Gas

Medupi Power Plant (Project Alpha)	Base load, coal-fired, dry-cooled power station in Lephalale, Limpopo Province, which will add 4 500-4 778 MW by 2011 and will make use of super-critical boilers to increase efficiency (DPE, 2007:9)	Coal fired
Project Hotel (Braamhoek/Ingula)	A pumped storage scheme, situated 23km northeast of Van Reenen, within the Little Drakensberg mountain range between the Free State and KwaZulu-Natal. Installed capacity of 1 332 MW (4 X 333MW) (DPE, 2007:9)	Pumped storage
Steelport Pumped Storage Scheme		Pumped storage
Closure of older power stations	Most conventional coal-fired power stations are estimated to reach their due date by 2015 (Table 2, above)	
Nuclear power plant planned	Eskom has announced its intention of supplying 20 GW of nuclear power by 2025, which equates to roughly 25% of total power capacity (Power Engineering, 2008; World Nuclear News, 2008)	Nuclear power
Renewable power stations being discussed	100 MW solar-concentrating tower power station (Eskom Annual Report, 2007) 100 MW wind-power station (*Eskom Annual Report*, 2007)	Solar energy Wind energy
Independent power producers	30% of new power plants for capacity generation should be supplied by independent power producers (Van der Merwe, 2007)	
Demand Side Management (DSM) and energy efficiency drive	Eskom plans to achieve a 3 000 MW saving by 2012 and a further 5 000 MW saving by 2025 via DSM and energy efficiency measures. They have also set a 10% energy savings target nationwide, achieved via energy efficiency.	

The information above clearly indicates that electricity supply in the South African context is, and will continue to be, dominated by fossil fuels and nuclear energy. National efforts at sustainable energy use are concerned with the voluntary and marginal targets set for energy efficiency and renewable energy. The 2005 *Energy Efficiency Strategy of South Africa* stipulates a voluntary target of ‘a final energy demand reduction of 12% by 2015’ (DME, 2005:12) and the *White Paper on Renewable Energy* (DME, 2003:i) has set a voluntary target of 10 000 GWh of energy from renewable sources by 2013.

The recent national carbon tax, described by Finance Minister Trevor Manuel in his budget vote speech and supported strongly by Martinus van Schalkwyk, Minister of Environmental Affairs, signals governmental commitment and the government's acknowledgement of the detrimental effects of current fossil fuel power generation (Ensor, 2008).

The recent *Long Term Mitigation Scenarios (LTMS)* (Scenario Building Team, 2007) commissioned by the Department of Environmental Affairs examined future prospects for combating climate change in South Africa and drew attention to the carbon-based dependency in the South African energy context. It investigated likely scenarios for South Africa in 2050 in terms of carbon emissions and what options exist for mitigation. The process concluded that 'if all countries, including high emitters in the developing world, adopted a Growth without Constraints [continue with current energy mixes dominated by fossil fuels] approach, climate change impacts in South Africa would be extensive' (Scenario Building Team, 2007:25).

However, in spite of these initiatives described above, the national energy context detailed in Table 2 mirrors the large carbon footprint of the global energy context. Future national initiatives detailed in Table 3 indicate that South Africa will further be embedding itself in a coal dependent energy scenario. The national and global energy context were explored in detail in this chapter to make explicit the trajectory upon which we are on: not only is our carbon footprint getting larger, but also, it is getting 'deeper'. As global citizens and as South Africans, the question arises of what we can do to instigate a change of direction from this eminent energy future. The research objective is located within the need to react towards the current global and national energy contexts in an attempt at finding local sustainable energy solutions.

1.4. Research objective

The global and national energy contexts detailed above affirm that, currently, energy is sourced primarily from fossil fuels. The alternative to this dominance of fossil fuels is reviewed in the next chapter of this thesis. The research objective aligns itself with the need for sustainable energy use within a global and national context and the ability of universities, as a space, to implement such approaches. This thesis explores the most appropriate technological solutions to implement sustainable energy, with special reference to energy efficiency, and studies the residences of Stellenbosch University to demonstrate the case. The research objective is embedded within two approaches: systems thinking (Clayton and Radcliffe, 1996:1-27; Gallopin, 2003), which is a way 'of thinking in terms of connectedness, relationships and context' (Gallopin, 2003:7) and ecological design (Van der Ryn and Cowan, 1996), which favours context specific solutions.

With regard to the research objective, sustainable refers to the understanding of sustainability within the context of the sustainable development discourse. As a contested concept, sustainability, in this thesis, encompasses the complex interaction between three elements. Firstly, an environmental sustainability which 'translates into holding waste emissions within the assimilative capacity of the environment without impairing it' (Goodland and Daly, 1996:1003). Secondly, a strong sense of sustainability that asserts that natural capital cannot be replaced or interchanged with other forms of capital and that 'any development path that leads to an overall reduction of the stocks of natural capital (or, especially, to a decline below the minimum) fails to be sustainable even if other forms of capital increase' (Gallopin, 2003:16). Thirdly, a sustainability approach that generates intergenerational and intra-generational equity (Hattingh, 2001) to meet present and future needs for a quality of life that is materially comfortable.

Energy is defined by the formal language of science as 'the capacity to do work' (Aubrecht, 2006:35). Different forms of energy exist (Aubrecht, 2006: Extension 3.5), such as mechanical, chemical, nuclear, thermal and electromagnetic. Energy in this thesis refers exclusively to electrical energy in the form of electricity. The words energy and electricity are used interchangeably throughout the thesis. Sustainable energy solutions for the residences of Stellenbosch University therefore do not consider transportation issues or issues surrounding the embodied energy of the materials used in the construction of the residences.

Solutions, in terms of semantic clarity, refers to the processes that need to be initiated within the university's' maintenance and policy structure to ensure sustainable energy use in the residences. This point to stress is that, by definition, sustainable approaches are holistic in nature and generally rely on process orientated manifestations as opposed to simply assuming that the installation of a technology, without regard for its context or future use, will be a solution. The foundations of systems thinking and ecological design which informs the concept of solutions for this thesis advocates local and context based solutions.

Sustainable energy systems refer to the myriad of energy efficiency and renewable energy technologies that can be deployed. However, they are embedded here within a holistic understanding of why they are needed. Building on the definitions of 'sustainable' and 'energy' stated above, this concept aligns itself with two definitions from the reviewed literature that the author felt provided a clear understanding of the type of actions that underpin sustainable energy systems.

The InterAcademy Council report, *Lighting the Way: Towards a Sustainable Future* (2007), defines sustainable energy as:

> 'Energy systems, technologies, and resources that are not only capable of supporting long-term economic and human development needs, but that do so in a manner compatible with (1) preserving the underlying integrity of essential natural systems, including averting catastrophic climate change; (2) extending basic energy services to the more than 2 billion people worldwide who currently lack access to modern forms of energy; and (3) reducing the security risks and potential for geopolitical conflict that could otherwise arise from an escalating competition for unevenly distributed oil and natural gas resources. In other words, the term 'sustainable' in this context encompasses a host of policy objectives beyond mere supply adequacy' (InterAcademy Council, 2007:1).

A local NGO, Sustainable Energy Africa (SEA), who have been working closely with local government to implement sustainable energy use at a city level, define a sustainable energy path by asking city leaders the following questions (Sustainable Energy Africa, 2007:11):

- 'Are we steadily moving away from dirtier fossil fuels?
- Are we promoting interim cleaner options such as natural gas?
- Are we promoting renewable energy 'low hanging fruit' such as solar water heaters?
- Are we pursuing energy efficiency aggressively in all sectors?
- Are we promoting passive solar / efficient design of buildings?
- Are we improving access to safer and healthier energy sources for the poor?

- Are we keeping the cost of energy affordable for the poor?
- Are we balancing these concerns with economic growth?'

Sustainable energy solutions are therefore a moral prerogative and the technologies to implement such solutions are available in commercial format. Sustainable energy solutions are located within the larger need for sustainable neighbourhoods (Swilling 2005) in which 'sustainable urban infrastructure as the basis for building sustainable neighbourhoods [is] the only long term hope for South Africa [and] should be the only option worth considering' (2005:51).

Universities could be responsible for educating minds about sustainable energy use and, as spaces of learning, could be living examples of sustainable energy use. As of 1 January 2005, a 'decade of Education for Sustainable Development' began. This resolution was passed by the United Nations and is being overseen by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Association of University Leaders for a Sustainable Future (USLF), 2008a). It is an international attempt at implementing the concept of sustainability in all areas of educational institutions owing to the need for heightened awareness of sustainable development. David Orr's question – why it is that 'the people who contribute most to exploiting poor communities and the Earth's ecosystems are those with BAs, MScs and PhDs and not the 'ignorant' poor from the South?' (Orr, 1994 in Martin and Jucker, 2005:21) – aptly captures the vital role educational institutions play in the story of sustainable living.

In 1990 the Tailloires Declaration was created in France (two South African universities were involved in the creation of this declaration). This document is 'the first official statement made by university administrators of a commitment to environmental sustainability in higher education .... [it] is a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities' (Clugston and Calder,1999; USLF, 2008b).

USLF (2008c) lists the names of the 375 universities that have signed the Tailloires Declaration, as of 3 June 2008. In South Africa the universities that are signatories are the Universities of Cape Town, Rhodes, Witwatersrand, Natal and Western Cape.

With regards to Stellenbosch University, Rector Professor Russel Botman expressed a commitment to sustainable neighbourhoods when he announced strategic support for the 'promotion of a sustainable environment' as one of the issues aligned with the aims of 'United Nations' focus areas (also known as the Millennium Development Goals) to improve the quality of life of people globally in the coming decade' (Botman, 2008:13).

This rhetorical commitment to sustainable development is not matched by institutional policy commitment or *de jeur* living conditions and culture on the Stellenbosch campus although research expertise and learning opportunities that focus on sustainable development are available among Stellenbosch University's course options. The present research objective is, therefore, an exploratory application of the argument for sustainable energy to a local context so as to contribute to finding local solutions to a global issue.

1.5. Clarification of concepts

Energy, the unit of measurement for this thesis, and the accompanying technological solutions for sustainable energy are defined in this section, often according to their scientific definitions. Understanding these concepts within a scientific discourse sometimes differs from understanding them from a layman's reality. The clarification is necessary to clearly define the technological parameters of the research. In addition, the concepts of climate change, systems thinking and ecological design are made clear.

1.5.1. Energy

Energy is based on the concept of work developed from Newton's first and second law of motion. Work 'done by any force is the product of the force and the distance moved in the direction of the force' (Aubrecht, 2006:33). Energy is defined as the 'capacity to do work' (Aubrecht, 2006:35; *McGraw-Hill Encyclopaedia of Energy*, 1981:252). Kinetic energy is derived from the concept of work and the International System of Units (SI) for work and energy is therefore the joule (J)[3]. However, many units of measurement for energy exist: British Thermal Unit (BTU), foot- pound, quad, calorie, ton of oil equivalent and ton of coal equivalent (Aubrecht, 2006: Extension 7).

[3] See Aubrecht, 2006: Extension 3.5, 'Deriving Kinetic Energy from Work'

For the purposes of this thesis, energy is defined in terms of power and, therefore, according to the unit of watt (W). Power is defined as the 'work done divided by the time needed to do the work' (Aubrecht, 2007, 41).

Power = Work /Time

= Joule/Second

= J/s

The J/s is also known as the watt (W). Therefore, a joule can also be a Ws. It is common practice to refer to the unit of energy as kWh. Costs per kWh, energy savings and equivalent carbon dioxide savings are quoted in kWh in the rhetoric of sustainable energy issues in practice and this thesis.

The conceptual distinction between power and energy is significant. Energy is the amount of 'fuel' you need to perform a service while power refers to how fast you perform the service, using the amount of 'fuel' in question. This conceptual difference also helps to understand that Demand Side Management (DSM) is not necessarily energy efficiency as it changes the time at which energy is used but does not automatically imply an overall energy saving, although it might.

Energy is governed by the Law of Conservation which postulates that energy can never be created or destroyed; it can only be converted. This implies that the amount of energy in the universe is constant, it does not fluctuate. Therefore, to say that energy is 'consumed' or 'used' is actually incorrect. When energy 'use' or 'consumption' are used in this thesis it is for convenience of understanding.

1.5.2. Energy efficiency

Energy efficiency refers to an improvement in the input/output ratio in terms of energy consumption or energy service experienced by an energy user: this occurs either when less energy is needed to perform a service without a decrease in the quality or quantity of the service or if the input can increase the quantity or quality of the service (Aubrecht, 2006:144; Hawkens, Lovins and Lovins, 1999; Lovins, 2005a:2; World Energy Council, 2006:3; World Energy Council, 2008:9).

Energy efficiency is defined by specific characteristics and conceptual distinctions. Amory Lovins, CEO of the Rocky Mountain Institute, who 'lately led the redesign of $30 billion worth of facilities in 29 sectors for radical energy and resource efficiency' (Rocky Mountain Institute, 2008: Rocky Mountain Institute website) and who coined the term 'negawatt' to describe energy efficiency, succinctly demarcates these distinctions, as summarised below (Lovins, 2005a,b).

- Energy efficiency should not be equated to energy conservation (saving) because, ideally, it does not involve simply doing without or doing with less: it involves doing more with less. A consequence of energy efficiency is that it saves energy, as is the consequence when you simply do not use the energy service. However, colloquially, individuals do use these terms interchangeably. In this thesis a distinction between the two is maintained.
- The terms load management and energy efficiency should not be confused: the former changes the time at which energy is used while the latter saves energy when an energy service is delivered.
- Energy services (e.g. your home is heated) should be redefined to incorporate cultural values, needs and customs. The point being made concerns cultural conceptual understanding of things like 'hot', 'cold' or 'speed' and how this influences the way in which different cultures want appliances to satisfy them.
- Energy efficiency applies when energy is converted. Five conversion stages in the life cycle of energy can be identified:
    - The conversion efficiency of extracting primary energy (the fuel source) from the natural reserve
    - The conversion efficiency of changing primary energy into secondary energy (electricity) at a power plant
    - The conversion efficiency of distributing secondary energy to end-use points
    - The conversion efficiency of distributing secondary energy at the end use points to energy services used by consumers (known as end use efficiency).
    - The conversion efficiency of 'converting delivered energy services into human welfare'

Generally, however, people take into account three main processes where energy conversion efficiency is important: at the power plant, the transmission and distribution of electricity, and end use (Lovins, 2005a; World Energy Council, 2006).

1.5.3. Renewable energy

Renewable energy refers to those primary fuel sources that are considered 'inexhaustible' (*Oxford Dictionary of Environment and Conservation*, 2008:378). They are considered 'inexhaustible' because all renewable energy originates from the electromagnetic radiation created via fusion inside the sun, a process that is expected to survive for countless years. This solar energy is further converted into wind energy, wave energy, tidal and oceanic energy, geothermal energy and bio energy. The calculated 'power rating' of the sun is 3.9 x 10^{26} W (Aubrecht, 2006:459). Global power demand is a minuscule fraction of this at an estimated 13 TW. Renewable energy sources have a role to play in sustainable energy solutions because, while producing power, they do not emit greenhouse gases, they can be used on a micro scale for individuals and on a deregulated basis, and they provide energy security in terms of independence of price volatility or geopolitical monopolies associated with finite resources (InterAcademy Council, 2007:91-92).

Global trends in renewable energy are concerned with creating economies of scale for the various technologies so that they are financially attractive against the cost of fossil fuels, support for mandatory and voluntary policy obligations, searching for efficient storage systems, tapping the potential of micro generation, deregulation and improving efficiencies of the technologies. (InterAcademy Council, 2007:91-111; Kammen, 2006; Renewable Energy Policy Network for the 21st Century (REN 21), 2006; World Energy Council, 2007: 14-19; Teske et al, 2007).

1.5.4. Conventional energy systems

This refers to the dominant energy sources that currently generate electricity. Fossil fuels (coal, oil and gas), nuclear energy and macro hydro collectively refer to conventional energy systems in this thesis.

1.5.5. Climate change

Climate change (Aubrecht, 2006:331-381; Lutgens and Tarbuck, 2001:367-388) refers to the geographical process whereby average climatic conditions change. Climate change has occurred throughout history and is regarded as an expected geographical phenomenon due to natural forcings (biological, geological and cosmological). However, the term is currently associated with the induced effect of anthropogenic forcings that have accelerated the rate of greenhouse gases in the atmosphere so as to stimulate global warming and therefore induce climate change.

1.5.6. Systems thinking

Systems thinking (Clayton and Radcliffe, 1996; Gallopin, 2003) is an approach to problem solving in sustainability that 'entails considering the various agents interacting in the world as systems' so that the interacting complexity of systems is acknowledged and reduced in an 'intelligent and sophisticated' way without being forced into 'one dimensional mapping' (Clayton and Radcliffe, 1996:12). With regard to the use of sustainable energy solutions for the residences of Stellenbosch University, systems thinking encourages 'the simultaneous consideration of the local and global dimensions and the way they interact' (Gallopin, 2003:5).

As an approach Clayton and Radcliffe (1996:7) highlight the strength of such an approach in relation to the use of context based, specific solutions, but this does not always generate, in return, one comprehensive 'meta solution' for a problem.

1.5.7. Ecological design

Ecological design is defined as 'any form of design that minimises environmentally destructive impacts by integrating itself with living processes' (Van der Ryn and Cowan, 1996:18). Although it is associated with the architectural movement (Birkeland, 2002: 26- 29; McDonough and Braungart, 1992; Roaf et al, 2003), the authors stress that it is a 'partnership with nature that is not bound to a particular design profession' (Van der Ryn and Cowan, 1996:18).

Ecological design as an approach to the built environment is founded on five principles (Van der Ryn and Cowan, 1996), which collectively support the use of sustainable energy.

Together with systems thinking, it informs the approach taken here in attempting to find sustainable energy solutions for the residences of Stellenbosch University. The five principles that contribute to an understanding of 'solutions' are as follows: firstly, solutions should grow from the local context and value regional knowledge; secondly, design choices should be informed by ecological accounting in which the social and environmental costs are included in the overall project cost analysis; thirdly, to design with nature and natural resource flows of the local context in mind; fourthly, to respect that everyone is a designer and that intuitive non-expert advice can contribute towards the design process; lastly, that nature should be made visible so as to remind us of our mutual dependence.

Ecological design questions the traditional power hierarchy associated with expert knowledge. Van der Ryn and Cowan (1996:147) argue that sustainability is a 'cultural process rather than an expert one' which redefines the traditional boundaries of knowledge and the knower for a more inclusive approach which demands that we should 'all acquire a basic competence in the shaping of our world'.

1.6. Background to thesis topic selection

My ecological footprint (Rees and Wackernagel, 1996) is 5.9 global hectares, according to the 2008 Earth Day Network ecological footprint calculator. Not only is this considerably higher than the average global ecological footprint for all humans of 1.5 of hectares (Wackernagel and Rees, 1996:54) but 3.3 planets would be needed if everyone lived like me. This raised the vexing paradox: if everyone strived to achieve my standard of living, the natural capacity of the Earth's resources would come under threat; yet my standard of living is generally considered by many to constitute the goal for a successful life. The question arose: whose 'right to life' should be considered? That of the planet or the rights of those in developing contexts? The immediate rights of humans now at the expense of future generations?

This numerical experience echoed my sentiments felt regarding natural resource limits when visiting the ancient Mayan temples in Guatemala and Angkor kingdom ruins in Cambodia during my travels. In both cases, environmental mismanagement was suspected as the primary reason for the eventual disintegration of these civilizations. The sense of place and history which was evoked while walking in these deserted ruins made me question whether they represented looking at a picture of the past, or a picture of the future.

The decision to complete an MPhil in Sustainable Development Management and Planning created a space in which ideas about resource management, sustainability and just development were explained, contested and redefined. The transdiciplinary focus on renewable and sustainable energy offered via the Centre for Renewable and Sustainable Energy (a South African National Energy Research Institute (SANERI) and Central Energy Fund (CEF) sponsored initiative), provided exposure to the technical solutions available to implement sustainable living, and, particularly, sustainable energy use.

Emerging from a theoretical context focused on sustainable energy and equipped with the technical language, I felt capacitated and compelled to do something that would implement sustainable energy solutions. Exposure to the sustainable development discourse revealed many case studies and examples of attempts at creating sustainable neighbourhoods. After evaluating different district options, such as the town of Stellenbosch, the city of Cape Town and the R310, the question came to mind of how my learning environment affirms and promotes the use of sustainable energy use. I asked: are universities, as spaces of learning and influence, doing anything to incorporate sustainable energy use into the built environment? A literature search revealed inspiring international stories in which students were taking ownership of their own campuses and directing campus initiatives towards sustainable development via partnerships with top management and conducting campus research that could inform appropriate decision making. The literature search also revealed that Stellenbosch University, and most South African universities, were not generating research by students about their own campuses in an effort to create a sustainable community or culture. Although the seed for this thesis topic was planted in my personal capacity to find real solutions for my immediate environment, the global and local energy context described above provided the subsequent justification for this thesis topic.

1.7. Significance of research

The research is significant for several reasons. The first three pertain to ideological alignment on a global, national and regional scale with the goal of environmental sustainability. Firstly, the research topic aligns itself with the global imperative of environmental sustainability and the global phenomenon of climate change, and with the role that sustainable energy plays as a solution in both these arenas. Secondly, it aligns itself on a national level with one of the medium 'wedges' (Commercial Energy Efficiency) identified in the *LTMS* (Scenario Building Team, 2007: annexure) as an option for South Africa to pursue to decrease carbon emissions. Thirdly, it aligns itself with local commitment towards sustainable development made by the Rector of Stellenbosch University. In addition, sustainable energy use is a solution to the looming prospect of significantly increased electricity penalties which could become a reality for the University (Campus News, 2008).

The remaining reasons pertain to the significance of the results generated by the research process. The findings detail a top down and bottom up approach towards identifying intervention points for end use energy efficiency within the residences. Significantly, a tool has been created which can now be used by members of the newly formed residential Green House Committee members (the House Committee is known on campus as the HK and referred to as this hereafter). The findings conclude that energy efficiency exists as an untapped source of potential within residences as a means towards sustainable energy use.

1.8. Thesis outline

Chapter 1 sets the context for the current global and national energy context by identifying the dominant dynamics involved in generating electricity. The research objective, i.e. investigating options for sustainable energy solutions for the residences of Stellenbosch University, is explained, as is the decision to focus upon end use energy efficiency as the technological focus for this thesis. It also introduces the conceptual foundation that informs the way in which findings to the research objective were sourced.

Chapter 2, the literature review, presents three arguments in reaction to the current energy context explained in the preceding chapter. The first is that sustainable energy is necessary; secondly, that technology to implement sustainable energy is available; and lastly, that universities in the international arena are investing in sustainable energy technologies. As a result of these three arguments, the question of what technological options exist for the residences of Stellenbosch University to implement sustainable energy solutions is raised.

Further, expressed interest in end use energy efficiency leads to a summary of technologies that are applicable to Stellenbosch University residences.

Chapter 3, which explains the research methodology, details the theoretical thought processes and practical logistics that were adopted in order to best approach the research objective. A secondary data analysis was performed on the primary data supplied by the US Energy Manager, which reflects the monthly energy consumption of the individual residences. The macro analysis that this quantitative data facilitated aided the research objective by establishing the context and therefore allowing key points of intervention to surface. However, the secondary data analysis did not allow for an investigation into the behavioural issues associated with residential consumption and it did not comply with the emphasis on a context based, local and particular approach to problem solving expressed within the systems thinking and ecological design foundations of the research objective. For these reasons, a micro analysis, in the form of a case study, was also conducted. The consequences for the research objective of a case study methodology are discussed.

Chapter 4 presents the findings from the macro, secondary data analysis. The context clearly exposed several trends and points of intervention that are presented, explained and discussed in terms of how they contribute towards the research objective.

The findings of the micro, case study analysis are presented in Chapter 5. The emergent processes in the critical case study informed the research objective by suggesting a process and creating a tool that can now be used by all residential leaders to investigate where best to implement end use energy efficiency within their residences. Several specific details for technological considerations were surfaced by the case study and they can be applied to other residences too.

The concluding chapter, Chapter 6, summarises the research journey and the research findings. The conclusion is that this thesis identifies key points of intervention in the implementation of sustainable energy solutions via a top down approach as well as a bottom up approach that capacitates residential leaders to identify opportunities for end use energy efficiency within their residences. The findings and conclusion of the thesis are discussed in relation to the literature review, and the resulting comparisons, significance of the research, opportunities for future scholarship and policy recommendations are offered as a platform for future dialogue on resource management by students for their own living spaces.

1.9. Chapter summary

The research objective, investigating options for implementing sustainable energy solutions for the residences of Stellenbosch University, was introduced. This thesis focuses particularly on the technologies of energy efficiency and case studies of the residence to explore the research objective. The research objective is an application of a global and national concern to a local context and documents the findings of this process.

This introductory chapter shows that the global and national energy context is governed by the predominant use of fossil fuel, in particular coal, to generate electricity. Demand for electricity is expected to increase in the future and the available reserves and resources of coal are expected to be able to meet this growing demand in the medium to short term future. However, the current and future supply of electricity via fossil fuels is environmentally unsustainable. What can be done to facilitate an emerging economy like South Africa on a path which allows for development but without the associated carbon intensity of our 'dirty' electricity? The research objective positions itself as a local attempt towards finding sustainable solutions for this national energy, and global, dilemma.

Upon identifying what characterises the current global and national energy context in this chapter, Chapter 2 positions this context within the discourse of sustainable development and the subsequent literature review details the effect of conventional energy systems on the environment and details the end use energy efficiency options which can be implemented to negate these harmful environmental effects.

The significance of the research objective can capacitate residential leaders and top management with local sustainable energy solutions to direct Stellenbosch University on a path of sustainable living. This thesis is the first of its kind on campus and is an example in which the interlinkages between actions by local communities can proactively be part of the process towards solving the global and national energy dilemmas described above.

Chapter 2: Literature review

2.1. Introduction

The literature review is founded on the discourse of sustainable development. From this foundation three golden threads are extracted. The first relates to the argument for sustainable living and the significant role that sustainable energy use has within the context of sustainable living. The second argument is that the technology for sustainable energy use is available, identified within the broad realms of energy efficiency and renewable energy. Thirdly, examples of sustainable energy use amongst predominantly American universities are presented to illustrate the ways in which other universities are implementing sustainable energy in the operations and maintenance of their campus. These three golden threads are woven together to argue respectively, in this thesis, that sustainable energy use is necessary, that the technology available to implement it is available and that other universities are already using it. What technological options then exist for sustainable energy solutions as regards to the residences of Stellenbosch University?

2.2. The need for sustainable development

Sustainable development was formally defined as '[meeting] the needs of the present without compromising the ability of future generations to meet their own needs' in 1987 in the Brundtland Report, *Our Common Future,* more formally known as the World Commission on Environment and Development (WCED) (Oxford Dictionary of Environment and Conservation, 2008:491; WCED, 1987:8 in Dresner, 2002:1,31; WCED in Rogers, Jalal and Boyd, 2006; WCED in Sachs, 1999:76). This canonical definition

> '...set in motion what many now argue are the three mutually reinforcing and critical aims of sustainable development: the improvement of human well being; more equitable distribution of resource use benefits across and within societies; and development that ensures ecological integrity over intergenerational timescales' (Sneddon, Howarth and Norgaard, 2001:255–256).

The need for sustainable development is embedded within two realisations: Firstly, that there are limits to our consumption of the Earth's natural resources and that environmental sustainability is significant (Dresner, 2002; Hattingh, 2001; Goodland and Daly, 1996; Pezzoli, 1997; Rogers et al, 2006). Secondly, that the mantra of progress, championed by modernity, did not produce the intended effects of liberation and equality for everyone (Dresner, 2002; Hattingh, 2001, Sneddon et al, 2001; Stiglitz, 2002) and sustainable development was, therefore, a 'call for [a] redirection of the enlightenment project' (Sneddon et al, 2001:254). The ideas of a limit to growth and the concern for environmental sustainability are discussed below as it is of relevance to understanding the importance of sustainable energy use while the philosophical post modern critique of development is not reviewed in this literature review.

The idea of a limit to growth gained recognition in 1798 with the Malthusian theory of population which argued that exponential population growth would outstrip linear food production. Although the Malthusian theory was criticised, the subsequent work of John Muir, Aldo Leopald, Edward Mishan and Rachel Carson brought to attention the interconnection between humans and nature and the need to control our consumption of natural resources in order to maintain ecological equilibrium. The relationship between population and the capacity of the earth's resources to satisfy the populace was analysed in 1972 in the report *Limits to Growth* (Meadows et al, 1972) published by a group of scientists from MIT known as the Club of Rome. In the same year, the Stockholm Conference on the Human Environment, the first of a series of United Nations conferences about the environment and development, took place. This laid the foundation for the WCED and the seminal 1992 United Nations Conference on Environment and Development (UNCED), known as the Earth Summit, and the subsequent 'Rio Cluster of UN Proceedings' which affirmed the idea of sustainable development on the policy map.

The Brundtland definition quoted above symbolised the acknowledgement of a space in which a mutual dialogue between two natural resource discourses could be communicated: the growing ecocentric concern for the finiteness of the Earth's natural resources and the anthropocentric concern that developing countries have more equitable and improved access to natural resources to improve their quality of life (Bartelmus, 1994:8; Dresner, 2002:1; Hattingh, 2001:2; Pezzoli, 1997:550–553; Sachs, 1999:75–78; Rogers et al, 2005:22; Sneddon et al, 2006:254).

An ecocentric orientation towards sustainable development supports a strong, narrow and deep notion of sustainability that advocates environmental concern as its primary focus for the intrinsic value associated with looking after the Earth (Hattingh, 2001:9,11-12; Gallopin, 2003: 14; Mebratu, 1998:511). The Deep Ecology Movement (Deval, 2001; Naess in Deval, 2001; Macy and Young Brown, 1998), Eco Theology (Macy and Young Brown, 1998:49-52; Mebratu, 1998:508:509) and Eco Feminism (Mies and Shiva, 1993; Macy and Young Brown, 1998:48; Mebratu, 1998:506) all echo the need to re evaluate our relationship to and the power hierarchies with nature so as to appreciate nature as a source which informs our happiness and quality of life without commodifying or exploiting the Earth.

An anthropocentric orientation towards sustainable development questions the consequences for justice and human rights of all people if natural resources are protected irrespective of the needs of the developing nations (Hattingh, 2001:9,11–12; Gallopin, 2003: 14; Mebratu, 1998:511) .The Human Development paradigm (Wise, 2001:48-49, ul Haq, 1995), Ecological Governance and Sustainable Livelihoods paradigms (Chambers, 1992; Norberg-Hodge, 2000; Sachs, 2002:7; World Resources Institute, 2002:2-29), Eco Socialism (Pepper, 1993 in Mebratu, 1998:507–508) and an Ecological Space paradigm (McLaren, 2003; Wackernagel and Rees, 1996) all question how power hierarchies distribute natural resources amongst nations. The argument is that, located within the need to rethink our consumption patterns of natural resources, distribution trajectories should not perpetuate the current situation which allows one-fifth of the world to enjoy four-fifths of the world's processed natural resources (*Human Development Report*, 1998:2) but should instead espouse the 'Egalitarian Principle' (Sachs, 2002:37) which stipulates that every human has an equal right to the Earth's natural resources.

This dialogue between ecocentric and anthropocentric notions of sustainable development has generated several contesting, vague or disputed voices and raised concerns as to whether or not sustainable development is even a concept to be taken seriously (Dresner, 2001:63-74; Gallopin, 2003:7; Hartwick and Peet, 2003:210; Pezzoli, 1997; Mebratu, 1998:494,503; Rogers et al, 2005:22; Sachs, 1999:72–89; Sneddon et al, 2006). This semantic elusiveness is because

> '... what renders [the discourses] deeply different, however, is the way in which they understand *finiteness* [italics added]: either they emphasise the finiteness of

development in the global space and disregard its finiteness in terms of time, or they emphasis the finiteness of development with regard to time and consider irrelevant its finiteness in terms of global space' (Sachs, 1999:78–89).

Ecological finiteness is noted within contemporary ecological reporting (Bartelmus, 1994; Flavin, 2001; Goodland and Daly, 1996) and the sustainable agricultural debates where evidence of biodiversity loss and the decaying state of different ecosystems is apparent. The Millennium Ecosystem Assessment (2005:27) claims that our environmental services face possible future degradation while the Living Planet Index (2006:4) claims that humanity's ecological footprint is 25% bigger than the Earth can provide for and that the health of our biodiversity has been degraded by 30%. The United Nations *Global Environmental Outlook* report concluded, after reviewing the state of land resources, forests, biodiversity, freshwater, coastal and marine life, the atmosphere, urban areas and disasters, that 'in many areas, the state of the environment is much more fragile and degraded that it was in 1972' (2002:9). The question has been raised: are we heading for an 'ecocide'- 'will people 'inadvertently [destroy] the environmental resources on which their societies [depend]?' (Diamond, 2005: 6).

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) – an organisation 'with a multi stakeholder bureau co-sponsored by the Food and Agricultural Organization of the United Nations (FAO), the Global Environment Facility (GEF), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank and World Health Organization (WHO) released a report, which was overseen by expert authors, governmental officials and industry leaders via a two-round peer review process and was approved by the governments of 57 countries'. It identifies findings that are a response to the increasingly detrimental effects on environmental sustainability induced by modern agricultural practices. The 'emphasis on increasing yields and productivity has in some cases had negative consequences on environmental sustainability' in terms of, as the report concludes, land degradation, water exploitation, salinization, eutrophication, water pollution, loss of biodiversity and greenhouse gas emissions from fertilizers (IAASTD, Global Summary for Policy Makers, 2008).

This issue of finiteness to development has recently been compounded by knowledge disseminated by the debates concerning peak oil production and climate change. These two issues have generated renewed popular environmental awareness which is currently enjoying the attention of the media. Recent documentaries such as *An Inconvenient Truth* and *The 11th Hour* as well as accessible literature such as *Heat* (2006) by George Monbiot, *Half Gone* (2005) by Jeremy Leggett and *Collapse* (2005) by Jared Diamond are creating awareness of pertinent environmental issues. Living 'green' does, currently, not belong to the marginalised domain of 'tree huggers' and 'hippies' but seems to be a factor that has recently captured the imagination of mass society.

The peak oil debate, which predicts when our production of crude oil will peak and at what point we will be consuming oil at a higher rate than that at which we discover it, has been contentious owing to the complexities of the raw data and prediction modelling used (Association for the Study of Peak Oil and Gas, 2008: http://www.peakoil.net/; Aubrecht, 2006:214-241 ; Campbell, 2002; Energy Watch Group, 2007; Ivanhoe, 1995; Kammen, 2006; Lovins, Datta, Bustnes, Koomey and Glasgow, 2005; Post Carbon Institute, 2004). What is significant about the peak oil debate for this thesis is not whether or not production of oil has peaked or that only a small percentage of electricity needs are met by burning oil, but that the debate has placed the spotlight on humanity's vulnerable dependency on a natural resource and how the looming horizon of finiteness of a non renewable natural resource threatens future development. The current reality of high oil prices has had a ripple effect on the global economy and disposable income of consumers and contributed towards geopolitical instability. Regardless of whether or not the trend of escalating oil prices will continue or will stabilise like the 1970's oil crisis, this phenomenon has clearly exposed the long term unsustainability of planning based on a finite resource.

The peak oil debate is the prelude to the eventual limit of conventional energy sources such as coal, gas and uranium. Conventional energy systems ensure the possibility of the globalised, technologically dependent 'network society' (Castells, 1996) that characterises 'modern' living and the current concept of progress. However, as a natural resource, fossil fuels are proving to be a sustainability issue in terms of their long term availability, economic feasibility and their contribution to greenhouse gases in the atmosphere – a global commons. The green house gas emissions of an individual living in Ethiopia are not equal to the green house gas emissions of someone living in USA, but the individual living in Ethiopia will still be affected by the harmful consequences of excess GHG's in the atmosphere. This simple example illustrates that that if conventional energy systems are proving to be environmentally unsustainable for everyone, not just those using them, the issues of a limit and justice, defined in the literature review above, arise: energy is an important sustainability issue. This is detailed in the following section.

The sustainable development literature provides a wakeup call for reviewing our future development as a species with two issues in mind: the environmental consequences of our actions and the equality of power hierarchies that govern the distribution of our environmental resources. Sustainable development thus incorporates 'an ethic' and 'challenges us to make moral choices' for inter-generational justice, intra-generational justice, environmental protection and respect for life (Hattingh, 2001:7). The conclusion to this section is that sustainable development is necessary because, as a dialogue, it acknowledges that there are limits to how we use natural resources and that there are issues of equality with regard to how we distribute our resources and who is involved in the decision making process. Sustainable development provides the space in which these limits and issues can be engaged with.

2.3. The need for sustainable energy

Sustainable energy use was defined in the introductory chapter as an approach to generating electricity that espouses a strong sense of environmental sustainability and honours intergenerational and intragenerational rights. Sustainable energy use is necessary for three important reasons. The first relates to the long term benefit to energy security of such an approach, the second is the positive effect for our current environmental sustainability; and the final reason is the potential to mitigate poverty by allowing more equitable access to energy sources which can then perform services that aid sanitation, education, entrepreneurship and improved material quality of life. It is the second reason, pertaining to environmental concerns, that is the focus of this thesis. The other two issues are therefore not examined as extensively further.

As stated in Chapter 1, current global energy needs are met primarily by fossil fuels, nuclear power and hydro power (IEA, 2008:24). Within this context, fossil fuels and in particular coal, contribute approximately three fourths of the energy sources that generate electricity for world demand. Fossil fuels are non renewable resources.

Fossil fuels will eventually be depleted. In addition, different countries have different energy mixes in terms of their natural reserves of oil, coal or gas. These natural resources are not evenly and fairly spread between different nations. In terms of resource availability, fossil fuels are not a sustainable energy solution for our power needs in the long term because they are finite and non renewable. Although you can use conventional energy sources sustainably, via optimising energy efficiency and designing the built environment to not waste the consumption of fossil fuels unnecessarily, in a strict sense of the word, they are not sustainable. This first reason therefore has a long term goal of energy security in mind. Future energy mixes of nations will include a greater portion of power created via harnessing renewable energy sources, along with their fossil fuel or nuclear contributions, so that the inherent long term unsustainability associated with the finiteness of a natural resource is not an issue of concern.

The second reason, emerging from the climate change discourse, pertains to the current question of environmental sustainability associated with the carbon emissions generated when burning fossil fuel sources to create power. Evidence surfacing from the debate around climate change shows that the emissions produced from the burning of fossil fuels to generate electrical energy are a significant proportion of the total greenhouse gases emitted (IPCC, 2007d; *Stern Review*, 2006). When this information is coupled with evidence that there is a limit to the amount of greenhouse gases that the atmosphere and natural ecosystems can absorb (IPCC,2007a,b,c,d; *Stern Review*, 2006) the use of fossil fuels to generate electrical energy becomes a sustainability issue because it implies that a limit to our use of fossil fuels to generate electrical energy is in order. The degree of this limit and who has to limit the use of their fossil fuel consumption resonates with the issues of environmental sustainability and the question of power hierarchies involved in the distribution of resources, as identified in the sustainable development literature review.

The findings of the IPCC are considered credible due to the process by which the data is reviewed: many scientists, government officials and policy makers, of different nationality and academic ideology, assess the peer reviewed and popular literature available. The IPCC considers itself a 'scientific body' that provides information that is 'based on scientific evidence and reflects existing viewpoints within the scientific community. The comprehensiveness of the scientific content is achieved through contributions from experts in all regions of the world and all relevant disciplines including, where appropriately documented, industry literature and traditional practices, and a two stage review process by experts and governments'. Climate change sceptics (Lomborg, 2002) exist but the 17 years of cautious investigation by the IPCC warrants respect for the long term and meticulous research process that, with each assessment report, has thoroughly covered one building block after another so that the latest report is founded on a solid foundation of knowledge. Although the sceptics' arguments deserve to be noted, the balance of information is in favour of the IPCC.

The IPCC concluded in Synthesis Report of the FAR in 2007 that, with regard to observed changes in the climate and their effects, 'warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level' and that 'observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature' (IPCC, 2007d:2).

It is the suggested cause of this warming that has been contentious. The IPCC argues that the rise in global temperatures is most likely caused by anthropogenic (human induced) forcings and that it is unlikely that the rise in temperatures in recent years is attributable to natural forcings only. This claim, put forward in the TAR and with more evidence in the FAR, is that 'global atmospheric concentrations of carbon dioxide ($CO_{2)}$, methane (CH_4) and nitrous oxide (N_2O) have increased markedly. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica)' (IPCC, 2007d:5).

The contributing factors for the anthropogenic warming due to global GHG's are attributed to several factors, detailed in Figures 4, 5 and 6 below. The graphs reflect the estimations that the largest contributing factor to anthropogenic forcings of the increase in global GHG's concerns the use of fossil fuels and, within that context, the use of fossil fuels to generate power (IPCC, 2007d:5; *Stern Review*, 2006:169, 173).

Figure 4: Historical and projected GHG emission by sector (*Stern Review*, 2006:169)

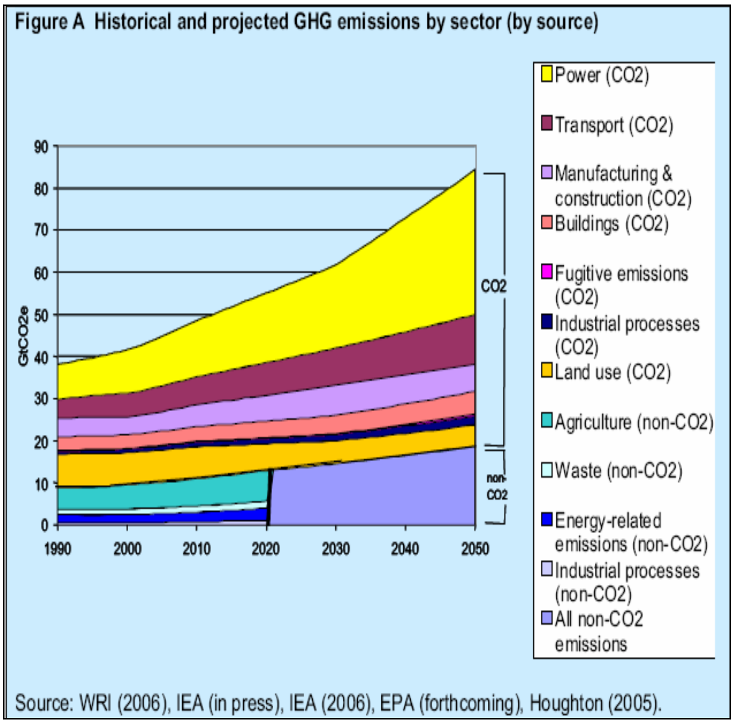


Figure 5: GHG emissions in 2000, by source (*Stern Review*, 2006:173)

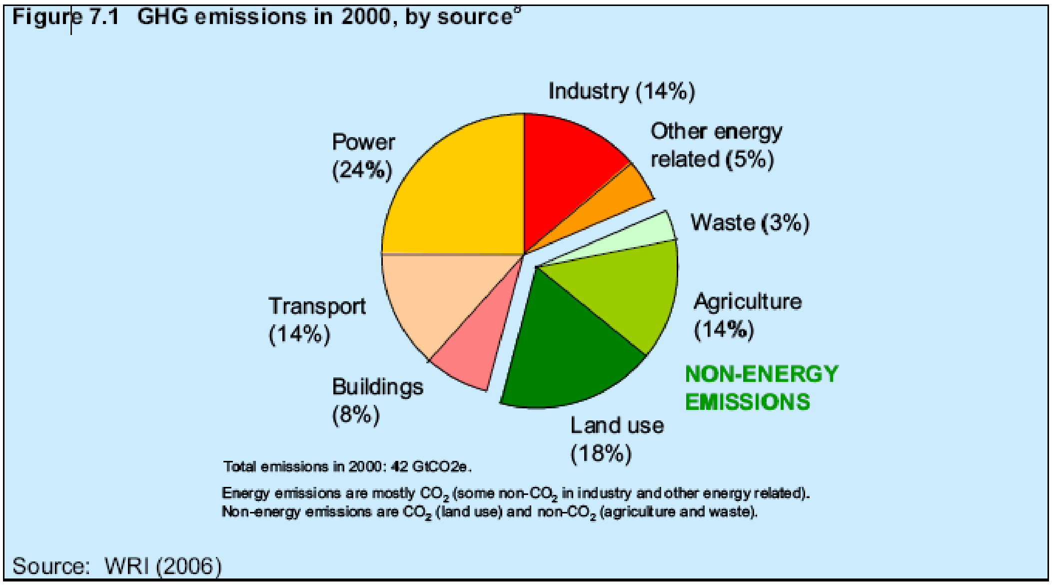
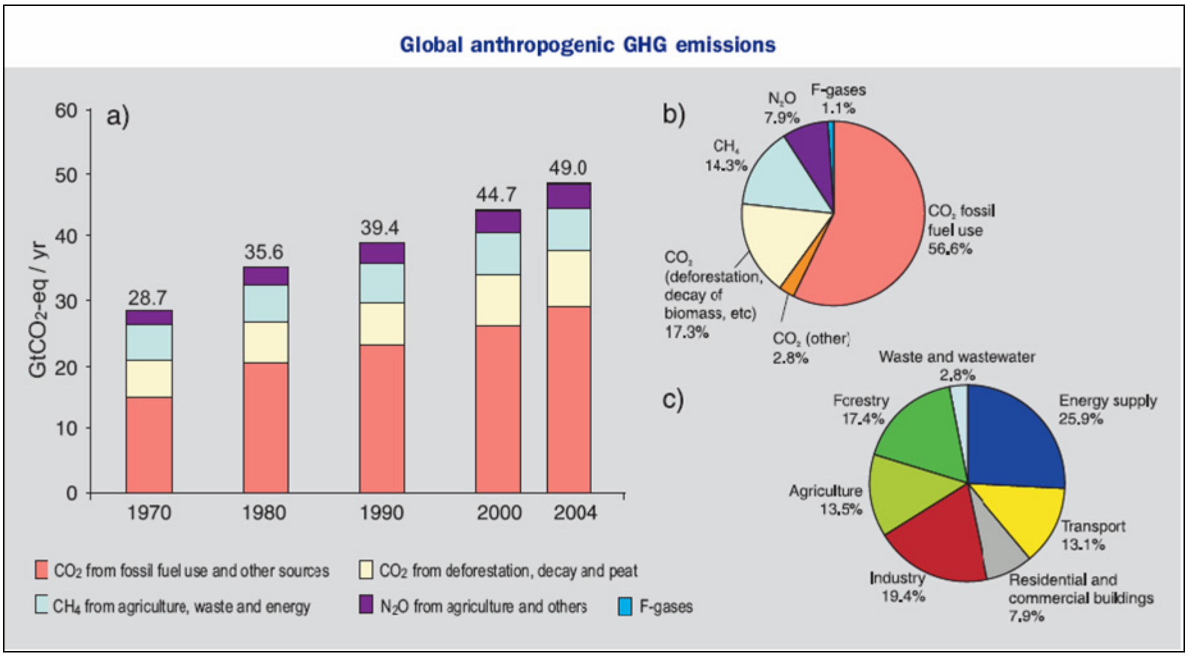


Figure 6: Global anthropogenic GHG emissions (IPCC, 2007d:5)

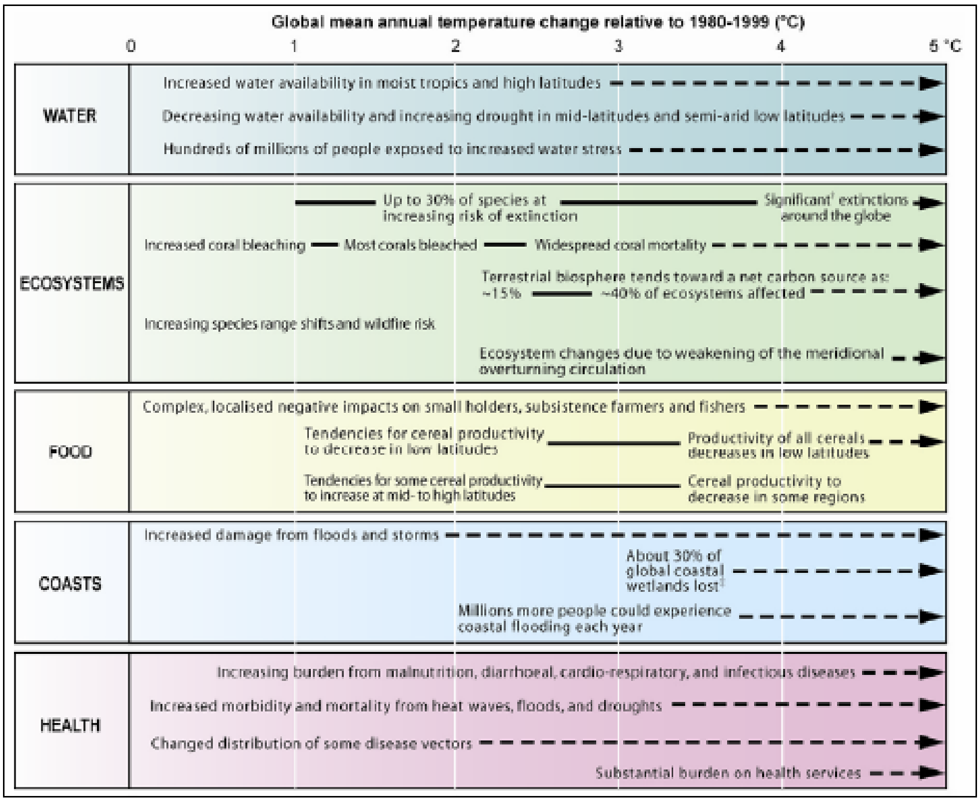


The effect of burning fossil fuels is the release of carbon dioxide, sulphur dioxide emissions (Sox), nitrogen dioxide emissions (NOx) and methane, collectively referred to as greenhouse gases. Greenhouse gases affect the global temperature. Changes in global temperature have consequences for the state of the environment. It has been concluded that a 2 °C or greater increase in global temperatures will induce significant changes in climatic conditions (Teske et al, 2007:7 11; *Stern Review*, 2006:80,148). Figure 7: Summary of effects of a change in average temperature on the environment (IPCC 2007b:14) on the next page details the expected changes to accompany a change in temperature.

The pertinent issue that has evolved from the research done by the IPCC concerns a time scale: at what point in time do we need to start decreasing greenhouse gases (peak stabilisation), and at what rate, to deter a corresponding change in temperature?

Recent measurements of carbon dioxide concentration indicate levels of approximately 380 parts per million (ppm) (*Stern Review*, 2006:3). Carbon dioxide equivalent levels, which reflect GHG concentration, are estimated at 430 ppm and to be increasing at a rate of 2.3 ppm

Figure 7: Summary of effects of a change in average temperature on the environment (IPCC 2007b:14)



each year[4] (*Stern Review*, 2006: 3–4). The *Stern Review*'s observation of an increasing population and energy demand along with the fact that 'the stocks of hydrocarbons that are profitable to extract (under current policies) are more than enough to take the world to levels of CO_2 concentrations well beyond 750ppm' (*Stern Review*, 2006: 169,179[5]) highlights the future relationship between environmental sustainability and conventional energy systems.

Figure 8 is a succinct summary within the climate change literature of the various scenario predictions which stipulate, for various carbon dioxide equivalent stabilization[6] levels, what the probability will be for exceeding a 2 °C increase in global temperature.

[4] As quoted in the *Stern Review* from 'The 1980–2004 average, based on data provided by Prof. K Shine and Dr L Gohar, Dept. of Meteorology, University of Reading. (2006:3).

[5] Assuming that an increase in GDP (Gross Domestic Product) is driven by fossil fuel, intensive energy processes.

[6] The critical point at which 'annual emissions be brought down to the level that balances the Earth's natural capacity to remove greenhouse gases from the atmosphere"' (*Stern Review*, 2006:194).

Figure 8: Predicted probability of exceeding the 2 °C threshold and the corresponding CO_2 equivalent level (*Stern Review*, 2006:295)

Stabilisation Level (CO_2e)	Maximum	Hadley Centre Ensemble	IPCC TAR 2001 Ensemble	Minimum
Probability of exceeding 2°C (relative to pre-industrial levels)				
400	57%	33%	13%	8%
450	78%	78%	38%	26%
500	96%	96%	61%	48%
550	99%	99%	77%	63%
650	100%	100%	92%	82%
750	100%	100%	97%	90%

In addition to the effect on climate change of generating electricity from fossil fuels, utilities contribute in other ways towards unsustainable resource management (Aubrecht, 2006: 245-293). Fossil fuel power stations generate waste heat, use large amounts of water and produce combustion effects over and above those that are related to climate change. In most coal and oil fired power stations, waste heat is dissipated into the atmosphere via wet or dry cooling towers. The use of the more energy and water intensive, but more efficient and cheaper, wet cooling towers can cause fog in the local area or, in some recorded cases, influence local weather. When the waste heat is rejected to an aquatic system, it dissolves the oxygen content of water (which is bad for the cleansing ability of water) and stimulates changes in the aquatic ecosystems. Coal fired power stations need water for cooling and generating heat in large volumes. Lastly, the emissions created during the combustion of fossil fuels also generate air pollution, a serious health concern, and the presence of acid rain.

The details of the information above are relevant to the debate concerning sustainable energy because they provide the scientific justification that the waste products from fossil fuel sources are threatening our environmental sustainability. The conclusion for this section is that sustainable energy is necessary to ensure the environmental sustainability of a global commons – the atmosphere. It provides an alternative to make use of energy sources which are not associated with the simultaneous production of greenhouse gases or specified polluting effects. Technologically, this is achieved via energy efficiency and the use of renewable energy. Energy efficiency offers one set of means to solve this by decreasing the amount of fossil fuel primary energy needed as much as possible. Furthermore, it is a measure that is actually commercially and technically available to cope with the reality of a carbon based future. Renewable energy offers a means to solve this problem by generating power that does not emit greenhouse gases. These two technological avenues are discussed in the following section below.

2.4. Technological avenues for achieving sustainable energy

Sustainable energy solutions can be achieved via a myriad institutional, policy, financial and behavioural instruments. Technologically, they can be implemented via two broad routes: energy efficiency and renewable energy. Both of these routes are governed by different technological, economic, policy and social factors that are tailored to meet the energy needs and potential of a demarcated geographical location. The implementation of energy efficiency and renewable energy can be regarded as the physical manifestation or technical paradigm of the ideological paradigm of sustainable development and sustainable energy, described above. However, how energy efficiency and renewable energy are implemented to achieve sustainable energy generation is dependent on the complexity of interacting technological, economic, policy, institutional and cultural factors which are context specific. Implementing sustainable energy in an existing building in Johannesburg will differ from the choices made to retrofit an existing building in London for the same purpose.

This thesis would, ideally, have reviewed all the energy efficiency and renewable energy technologies available to the residences of Stellenbosch University. Energy efficiency, in comparison with renewable energy, is regarded as the 'low hanging fruit' (Anderson, 2006) of sustainable energy because it is deemed to be the 'closest fruit to pick' in terms of economic and technical feasibility. Due to the case study methodology of the research and the participatory process, energy efficiency emerged as the most feasible route to pursue and the subsequent literature therefore deals with it exclusively. Figure 9 below represents all the energy efficiency and renewable energy options that are theoretically possible towards sustainable energy solutions for the residences of Stellenbosch University. It reflects what is commercially and technically available now; research into the many options that seem plausible but are still categorised as 'research' are not included, for example, hydrogen fuel cells, second generation biofuels, nanotechnology, tidal energy, ocean thermal energy conversion and salinity gradients.

Figure 9: Theoretical options of energy efficiency and renewable energy technologies that are available commercially to implement sustainable energy solutions in the residences of Stellenbosch University (Aubrecht, 2006; InterAcademy Council, 2007; Kammen, 2006, LTMS, 2007; Pacalal and Socolow, 2004; REN 21, 2006)

RENEWABLE ENERGY

*Solar Power
Solar PV:
Crystalline
Polycrystalline
Thin film
Solar thermal
Solar water heaters
Parabolic trough
Parabolic dish
Central receiver trough
Linear Fresnel reflectors
*Wind Power
Horizontal axis wind turbine (Macro)
Horizontal axis wind turbine (Micro)
*Hydro Power
Dam construction
Natural river flow
Micro Hydro
*Geothermal
*Wave Power
*Biofuels

ENERGYEFFICIENCY

*Improving conversion efficiencies of power generation
Renewables
Coal:
Integrated gasification combined cycles
Supercritical and ultrasupercritical power plants
Fluidised bed combustion
Pressurised pulverised coal combustion
Combined heat and power (cogeneration)
Gas :
Combined cycle gas turbines
Oil

*Improve conversion efficiencies during transmission and distribution of electricity

*Ensuring ecological design, that influences end use need for certain energy services
Passive heating and cooling
Insulation
Thermal conductivity of construction materials
Building envelope

*Improve conversion efficiencies during end use of energy when delivering energy services

2.5. Energy efficiency

Energy efficiency refers to an improvement in the input/output ratio in terms of energy consumption/energy service experienced by an energy user. It occurs when less energy is needed to perform a service without a decrease in the quality or quantity of the service or when the input can increase the quantity or quality of the service (Aubrecht, 2006:144; Hawkens et al, 1999; Lovins, 2005a:2; World Energy Council, 2006:3; World Energy Council, 2008:9).

Energy efficiency is important for sustainable energy use due to the estimated potential in terms of energy savings it can allow (Aubrecht, 2006:144-169; Hawkens et al, 1999; IEA, 2008; InterAcademy Council, 2007; IPCC, 2007c:19; Lovins, 2005a, Lovins, 2005b; Pacalal and Socolow, 2004: 969; *Stern Review*, 2006:219; Teske et al, 2007:78; World Energy Council, 2008).

The most recent IEA report, *Energy Efficiency Policy Recommendations: In support of the G8 action plan* stated that

> 'energy efficiency policies have already proved to deliver significant energy savings. The recent IEA publication *Energy Use in the New Millennium* (IEA, 2007) found that improvements in energy efficiency in 14 major economies from 1990 had reduced energy demand in 2004 by 14% compared to that which would have taken place if the efficiency improvements had not occurred.....For example, the IEA document *Cool Appliances* (IEA, 2003) identified that current energy efficiency policies only exploit about one third of the cost-effective energy savings potential from improving the efficiency of household appliances. In *Light's Labour's Lost* (IEA, 2006), a global cost-effective lighting energy savings potential of 38% was found' (IEA, 2008:7-8).

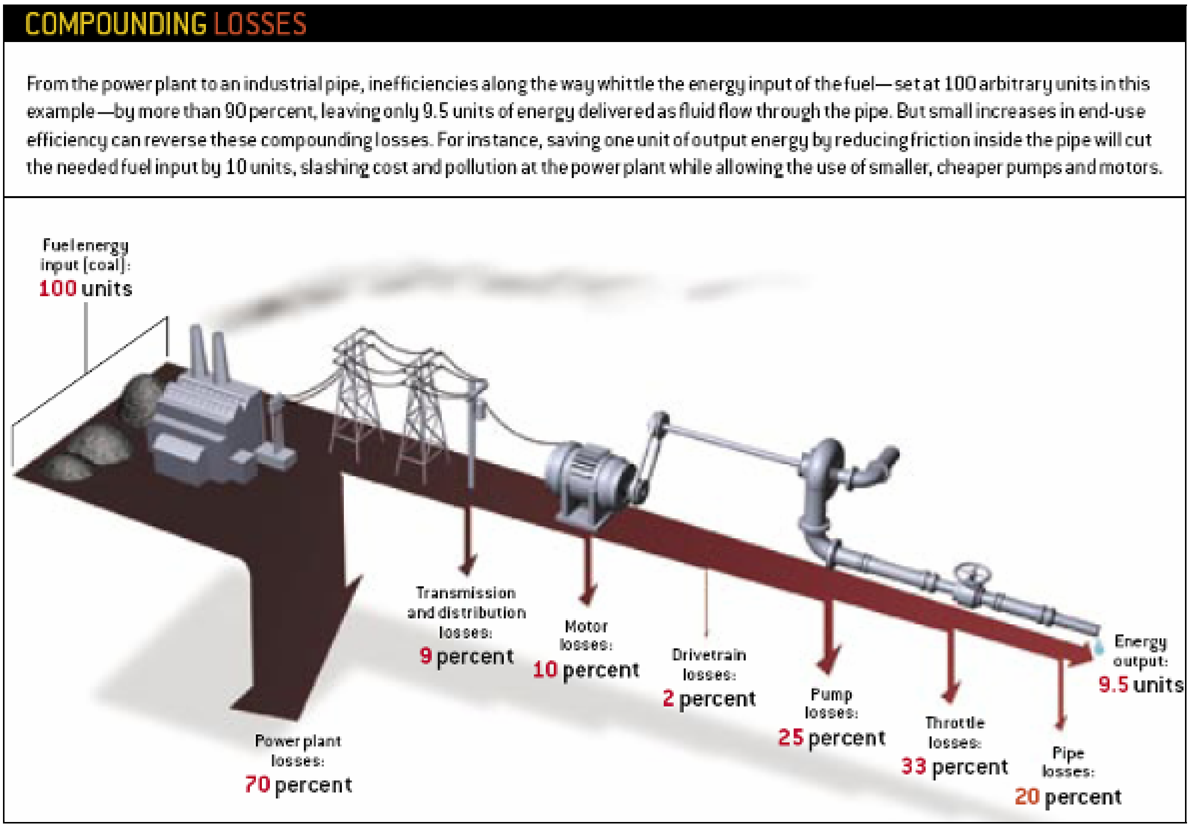
A recent InterAcademy report, *Lighting the way: towards a sustainable energy future*, reiterated that 'efficiency improvements that reduce the amount of energy required to deliver a given product or provide a given service can play a major role in reducing the negative externalities associated with current modes of energy production' (InterAcademy Council, 2007:19).

The World Energy Council, in response to questions as to the actual potential of energy savings for energy efficiency, concluded in the report *Energy Efficiencies: pipe dream or reality?* 'the opportunities for enhanced energy efficiencies throughout the world are a reality, not a pipe-dream. Important gains in efficiencies have already been achieved but much more can be done with the tools at our disposal' (World Energy Council, 2006:11).

The possibility of realising the potential energy savings deployed by energy efficiency depends on multiple factors. Barriers to implementing energy efficiency have been identified, usually associated with incorrect costing models, differences in economic and engineering understanding and diminishing or expanding returns on energy efficiency investment (IEA, 2008; InterAcademy Council, 2007:28-30; Lovins, 2005a; Lovins 2005b; World Energy Council, 2006).

This thesis focuses exclusively on end use conversion efficiency in order to generate sustainable energy solutions for the residences of Stellenbosch University. It has been argued that end use efficiency holds the greatest potential for energy efficiency (InterAcademy Council, 2007; Lovins, 2005b; World Energy Council, 2006:11). The debate contemplates whether the potential for the greatest energy saving can occur upstream (closer to the power plant) or downstream (closer to the end user). Figure 10, based on typical energy conversion losses which are weighted in comparable units, is used to illustrate the advantage of rather targeting end use energy efficiency, downstream, as opposed to upstream .

Figure 10: Compounding losses to end use energy (Lovins, 2005b:76)



An initial 100 units of primary fuel source results in 9.5 units of electricity, available to perform an energy service. From this, the conclusion is, that for every 10 units of primary fuel source (for example, coal), approximately 1 unit of electricity is created. The argument, therefore, is that by saving one unit of electricity via energy efficiency downstream at the end-use, 10 units of primary energy are also saved upstream. This large saving with regards to the physical fuel source (coal, gas or oil) has positive consequences for environmental sustainability in terms of decreased carbon emissions and natural resource management.

Alternatively argued, if you save 1 unit upstream, at the power plant, you save 1 unit of primary fuel. Compare this to the one unit of energy saved downstream which results in 10 units of saved primary fuel. This simple example affirms how losses are compounded along the energy chain and to 'save the most primary energy and the most capital cost, therefore, efficiency efforts should start all the way downstream' (Lovins, 2005b:25).

The emphasis on end use efficiency places the spotlight on the space in which sectors in society actually use electrical appliances: the built environment. These options are discussed in the next section.

Another argument in favour of energy efficiency for sustainable energy use is that it makes economic sense (Lovins, 2005a). The initial capital investment required to implement energy efficient technology allows for future savings in electricity that 'pay back' the initial capital cost over a certain number of years and thereafter allow for financial savings. Payback periods between 2 to 5 years are deemed acceptable by commercial investors.

However, adopting energy efficiency to achieve sustainable energy means has been questioned (Figge and Hahn, 2004:173-179; Korhonen, 2008). Korhonen identifies eight challenges to 'eco-efficiency' (efficiency of all resources) and succinctly summarises the limitations of adopting energy efficiency for sustainable energy solutions. The first criticism is that energy efficiency encourages dematerialisation when in actual fact efforts should be focused on substitution. The logic is that efficiency simply allows us to use less harmful flows but does not encourage the use of alternative flows that would negate the entire use of the harmful flows. However, the need for a transition period where energy efficiency can play a role is acknowledged. Secondly, the neoclassical, modernist economic foundations which inform the concept of energy efficiency are highlighted as the breeding ground for a culture which favours efficiency convenience and an unwillingness to change paradigms –'EE [Energy Efficiency] prefers to promote fuel efficient air travel, instead of considering alternatives to meet the needs of resting, holidays, and free time' (Korhonen, 2008:1334). Thirdly, the numerical denotation of efficiency cannot account for the social issues involved and therefore excludes important qualitative issues pertinent to sustainability. In addition, any attempt to incorporate the social and ecological dimensions into an energy efficiency number is disregarded on the grounds that certain resources are infinite and therefore have no price while reducing the complexity of others to a number is not feasible. The fourth critical observation is that the system boundaries of where the efficiency is being applied need to be made clear otherwise its effect cannot actually be determined. Fifthly, it is argued that efficiency has been sold as a universal prerogative without considering local social and cultural issues which has created a technocratic dogma devoid of context sensitivity. The sixth critique relates once again to the logic of efficiency: improving efficiency is a 'downstream activity, efforts should be maintained at the highest point 'upstream' so as to target the root cause of the resource problem. The seventh reason is a critique on the tendency for most organisations to favour incremental changes as opposed to radical paradigm shifts which the author suggests is fuelled by investment security. Efficiency is viewed as a' blind alley' investment wise because it does build a long term platform for sustainable technology.

The eighth and final reason is significant as it proposes that eco efficiency actually achieves what it intends to stop: increased consumption of the natural resource. This is referred to as Jevons Paradox (Jevons, 1990 in Korhonen, 2008; Mayumi et al, 1998) or the rebound effect (Berkhout et al, 2000; Korhonen, 2008) or the Khazzoom- Brookes Postulate (Saunders, 1992). Jevons paradox pertains to the notion that an increase in resource efficiency actually stimulates an increased demand for the natural resource because of human addiction to comfort. Examples in which increases in efficiency in agricultural production, refrigerators and car mileage echo an increase in overall increase in resource use are cited (Muyami et al, 1998). The rebound effect is used in energy conservation debate. Berkhout et al (2000) explain that an increase in energy efficiency can stimulate increased consumption in three ways: increased efficiency can actually make the energy service cheaper, thereby increasing demand for it; greater purchasing power due to electricity bill savings could stimulate spending on other energy using appliances and lastly, these changes are accompanied by changes in electricity demanding production facilities to accommodate for increased demand of the products.

The critique of energy efficiency is valid if framed as being the only solution to sustainable energy solutions. Energy efficiency, alone, cannot suffice as the sustainable energy solution for humanity. Ultimately, sustainable energy solutions require the use of renewable energy to meet all our energy demands. However, until such time when economic and political drivers successfully integrate renewable energy into the energy context, what can aid the process? Energy efficiency, with its accessible and user friendly, technology plays a capacitating and significant role in the transition towards a sustainable energy future. It is the 'least-cost strategy that can immediately have an impact. In the context of climate change, implementing energy efficiency buys governments time while they configure their economies for a low-carbon future' (IEA, 2008:5). Energy efficiency is the first step towards a sustainable energy future and, as the 'low hanging fruit', allows institutions who do not yet have the investment or policy drive to implement renewable energy, to act and do that which can contribute towards environmental sustainability.

2.6. Energy efficiency for residential and commercial buildings

Energy efficient buildings can contribute significantly towards minimising levels of global greenhouse gas emissions (Teske et al, 2007: 80; IPCC, 2007c:19; Pacalal and Socolow, 2004: 969). The Working Group III contribution to the Fourth Assessment Report (FAR) stated, with 'high agreement' and 'much evidence' that by focusing on energy efficient design for buildings, the opportunity to 'considerably reduce CO_2 emissions with net economic benefit' existed (IPCC, 2007c:19). Achieving end use energy efficiency in buildings is therefore an appropriate approach towards finding sustainable energy for the residences of Stellenbosch University.

Residential and commercial buildings in South Africa are not regulated by mandatory energy efficiency standards. However, two significant recent developments to introduce standards have taken place in 2008. The creation of a rating system, designed especially for a South African context, is now available and building owners can voluntarily submit their built environment to be rated by accredited Green Star officials, facilitated by the Green Building Council of South Africa (GBSCA) (GBSCA, 2008). Furthermore, the recent South African National Standards (SANS) 204, for energy efficiency in buildings, was published in 2008 in an attempt to significantly improve energy efficiency within the built environment of South Africa (Naidoo, 2008; Standards South Africa, 2008).

2.6.1. Conducting an energy audit

The first step in implementing end-use energy efficiency in a building is to conduct an energy audit of a building. An energy audit is a process that identifies energy consumption trends within a building so that the possible points for improved energy efficiency can be located. The degree of complexity in an energy audit is variable: a general walk-through energy audit can be performed by anyone whereas more technical and complicated energy audits are performed by trained professionals (Blumstein and Kuhn, 2006:277-294; Capacity Building for Energy Efficiency and Renewable Energy (CaBEERE) and DME, 2005; City of Cape Town, 2008; Energy Star, 2008; Omer, 2008: personal communication; U.S Department of Energy, 2005; Sustainable Energy Africa[7], 2007; Sustainable Energy Africa and AMATHEMBA Environmental Management Consulting, 2008).

A formal definition of an energy audit is 'the practise of surveying a facility to identify opportunities for increasing the efficiency of energy use' (Blumstein and Kuhn, 2006:277). Many examples of energy audits, in varying degrees of detail and applicability to either residential, commercial or industrial buildings exist (Eskom, 2003; Washington State University, 2008). Although the principles of energy efficiency are universal, it is important to be aware of the geographical context of the referenced literature sources as there is a discrepancy between technological solutions suggested in 'developed' contexts and suggested 'developing' contexts. For this reason, this thesis explicitly uses locally sourced references regarding implementing energy efficiency, which are based on local energy needs, energy infrastructures, measuring systems and appropriate energy efficient technology.

The basic tenet of any energy audit, regardless of the degree of complexity, is to determine the estimated relative contribution towards total energy consumption of respective electrical services. This is done by the following four steps:

1. Identify the electrical appliance
2. Determine its power rating from the product label or available power rating averages in kW

7 Sustainable Energy Africa is a Cape Town based NGO which has been involved in creating awareness, building capacity, facilitating 'technical know-how', publishing accessible information, influencing local government and provincial policy regarding sustainable energy use in South Africa.

3. Estimate a daily, weekly and monthly time period for which this appliance will be switched on in hours (the time period is chosen by the client; in this thesis monthly estimates are used).
4. Determine the monthly energy usage multiplying the kW power rating determined in Step 2 by the estimated time period in hours determined in Step 3 to deduce the energy consumption in kWh (Energy = Power X Time).

After this basic audit is performed, the degree of detail increases to examine the hot water system, consider load management issues (peak power, load profiles and power factors), include thermal conductivity calculations of the building materials, determine the passive solar considerations, identify the leaks in the building envelope, identify the insulation status of the ceiling and piping and determine the fuel sources of the electricity. Industrial energy audits require specialised expertise to examine the unique energy consumption patterns that are particular to the industrial process and machinery in question.

By reviewing the relative contribution of appliances or sectors (water heating, space heating and cooling, lighting, kitchen, laundry, study, entertainment etc) to total energy consumption as well as the comparison between power ratings and time usages, key areas for intervention can be identified.

Energy use differs for residential, commercial and industrial buildings. The energy consumption of the residences of Stellenbosch University is, in most cases, represented by three components of energy use: water heating, kitchen usage, and remaining energy consumption referred to as 'residential'. This breakdown provides a helpful categorisation tool and will inform the technological considerations that were sourced from the *Energy Efficiency Manual* (Wulfinghoff, 1999), a definitive and renowned book for users attempting to improve energy efficiency.

2.6.2. Water heating

Heating water requires a significant portion of the total energy use of a building (Wulfinghoff, 1999:457), with residential estimates of approximately 30-40%, commercial estimates less while industrial hot water needs are often larger. The *Energy Efficiency Manual* has a list of 'measures' (Wulfinghoff, 1999:439-503) rated according to cost potential savings, energy savings and ease of retrofit, which promote energy efficient water heating that are tabulated below . These measures are listed below to emphasise the multiple options for energy efficiency as well as the importance of an intimate knowledge about your context.

Table 4: Reproduction of *Energy Efficiency Manual* measures to improve energy efficiency of water heating systems (Wulfinghoff, 1999:439–503)

Technological focus	Detailed Measures
Reducing service water consumption:	• Repair water fixtures regularly • Install efficient wash basin fixtures • Install efficient shower heads • Install shower valves that allows easy control of temperature and flow rate • Provide instructions for efficient use of water in showers and lavatories • Install efficient toilets • Install efficient urinals or improve existing urinals
Water heating systems	• Minimize the hot water temperature o Use low temperature detergents • Install a separate high temperature water heater for high temperature applications • Install water heaters that have the lowest energy cost and highest efficiency • Install supplemental insulation on water heaters • Install automatic flue dampers on fuel fired water heaters • Clean and adjust the combustion systems of fuel fired water heaters periodically • Clean out scale from water heaters periodically • Exploit interruptible or storage rates for electric water heating • Control electric water heating to reduce demand charges
Service water pumping	• In facilities that have their own service water pumps, configure the system to minimize pump energy consumption o Use multiple pressurization pumps o Install gravity tanks or pressurized storage tanks • Design hot water recirculation to minimize pump energy • Trim pump impellers to eliminate excess system pressure • Install power switching that prevents unnecessary operation of spare pumps • Install pump motors that have the highest economical efficiency

A consideration that was omitted from this list in the *Energy Efficiency Manual* was the use of a heat pump to heat water. A heat pump is a device that can heat your water needs based on the thermodynamic principles of a heat engine operating in reverse (Aubrecht, 2006:116,160, Extension 9.6; Fink and Beaty, 2000:21-98).

Heat engines, such as the Stirling cycle and the modern day Rankine cycle, Otto cycle (petrol car) and diesel cycles (diesel car), operate on the principle of the First Law of Thermodynamics. Heat moves spontaneously from a heat reservoir at temperature T1 to a heat reservoir with temperature T2, where T1>T2. A device is placed in the path of this spontaneous heat flow which then converts this heat into work. The heat engine is the device that converts heat to work.

A heat pump is a device that intercepts this spontaneous flow of heat from a hotter system to a colder system so as to reverse the direction of the heat flow for cooling purposes, as evident in refrigeration and air conditioning systems. Instances when heat needs to be moved from a colder system to a hotter system are, in principle, impossible according to the Second Law of Thermodynamics. However, a heat pump is able to do this with the input of work done on the system (made possible from an electrical input). The result therefore is that energy is extracted from the colder heat reservoir, work is done on the system and 'the original heat plus the additional work [are exhausted] to the high temperature reservoir' (Aubrecht, 2006:116). The energy received at the warmer heat reservoir is 'more' as it has been compounded by the additional input of work. This translates to one unit of work input generating more than one unit of work output.

The pertinent result for energy efficiency is that an 'electric heat pump is more efficient than resistive electric heating' (for example, a geyser) (Aubrecht, 2006:116) although, when referring to the efficiency of a heat pump, the concept of a Coefficient of Performance (COP) should be used. In an electric geyser, the thermal energy required to heat the water is derived solely from electricity. In a heat pump, the thermal energy required to heat the water is derived from electricity *and* the low energy heat reservoir which, in practice is either the outside temperature of air or water. Because ambient water and air temperature are always above zero in absolute temperature (0Kelvin or -273 °C), they contain large amounts of thermal energy. This outside thermal energy is moved by the electricity (via a pump and compressor) and the outside thermal energy plus the work done is exhausted to heat the water. One can observe that the electricity used in the heat pump is not solely responsible for generating the output and, in comparison to an electric geyser, makes it more efficient.

Due to the use of heat reservoirs (temperature differentials) in the functioning of a heat pump, the changes in daily ambient temperature and humidity will have an influence on the COP of a heat pump. In practice, most heat pumps have a COP of 3. This implies that if the pump is rated at 30 kW, for every 30 kW of electric power it consumes it will generate 90 kW of heated water. An electric geyser would require 90 kW of electric energy to perform the same energy service.

2.6.3. Lighting

Lighting, in commercial buildings, 'typically accounts for 20% to 50% of total energy consumption' (Wulfinghoff, 1999:1017). The *Energy Efficiency Manual* provides comprehensive and detailed 'measures' for energy efficiency lighting (Wulfinghoff, 1999:1017–1157 and 1425–1484):

> 'Experience suggests that aggressive lighting energy conservation can reduce average lighting energy consumption by a factor of three to ten compared to conventional practise, while providing good visual quality. In contrast, most contemporary lighting conservation programs reduce energy consumption by less than half. This says that there is plenty of room for improvement over present practise' (Wulfinghoff, 1999:1017).

Light is created when electrons fall from one a higher energy level to a lower energy level by losing energy. This loss of energy is done via emitting a photon, or a particle of light. The amount of energy this photon contains influences its wavelength which, if it falls within a certain range, can be seen by humans. When electrons change their energy levels in a state in which molecules are isolated (like gases) 'the photons are emitted at a limited number of precise wavelengths', but if the electrons change their energy level in a state where they are tightly packed and colliding with other electrons, like a solid, 'the wavelengths of light emitted ... are distributed in a broad, continuous statistical pattern' (Wulfinghoff, 1999:1449–1450).

Technically, if a light source is efficient, the output of wavelengths from the energy input should produce as many photons in the visible range as possible. This explains why incandescent bulbs are not efficient – the majority of their wavelengths are in the infrared range, which is invisible to the human eye.

Fluorescent lighting is deemed more efficient because, due to the gaseous state, the efficacy of the light improves. In other words, for every electrical input, you see more light from a fluorescent than from an incandescent bulb because more of the fluorescent wavelengths fall within the visible spectrum.

Fluorescent lightning, however, needs ballasts. Ballasts regulate the current from the lamp (Fink and Beaty, 2000:26-31,32; Wulfinghoff, 1999:1469). Two types of ballasts exist: magnetic (an improved hybrid magnetic is now available) and electronic. 'The efficiency of electronic components gives electronic ballasts inherently higher efficiencies than magnetic ballasts..... The best electronic ballasts consume about one fourth as much energy as older magnetic ballasts' (Wulfinghoff, 1999:1059). Furthermore, electronic ballasts also contribute towards improved efficiency of the lamp itself. With regard to magnetic ballasts, the modern versions (referred to as hybrids) are more energy efficient than the older versions. When they are combined with lower rated bulbs, they can sometimes be as efficient as electronic ballasts.

Efficient lighting consists of optimising bulbs, fixtures, light control and light path. When reviewing the options for lighting, a task orientation approach should be adopted so that each fixture is dealt with individually and visual quality and not only energy efficiency is ensured. Visual quality is examined via illumination intensity (lux) and how it affects task efficiency, levels of comfort, how the light is distributed (is it 'spotty'?), how lighting angles cause shadows and background lighting is used, the presence of glare or veiling reflections, and colour rendering (Wulfinghoff,1999:1427-1438).

Table 5: Comparison of bulbs (Wulfinghoff, 1999:1440-1441)

Lighting quality	**Con Incandescent**	**Halogen Incandescent**	**Con Fluorescent**	**Compact Fluorescent**
Lumen output(lumen)	10–50 000	300–40 000	900–12 000	250–1 800
Lumen degradation(% of initial lumens)	15–40	8–15	8–25	15–20
Service life(hours)	750–4000	2000–6000	7000–20 000	10 000
Efficacy(lumens/watt)	7–22	14–22	30–90	25–70 (incl. ballast losses)
Ballast energy consumption (% of rated wattage)	None	None	5 (high quality) – 20 (low quality)	10 (electronic)–20 (magnetic ballasts)
Dimming ability	Unlimited	Unlimited	Requires special dimming ballasts	Units with integral ballasts cannot be dimmed

Colour Rendering Index	100	100	50-95	60-85
Starting temperature	No limit	No limit	10–15 °C	-29–0 °C
Effect of temperature .on light output	Minimal	Minimal	Serious loss of light output above and below optimum lamp temperature (about 100 °F)	Serious loss of light output above and below optimum lamp temperature (about 100 °F)

Table 6: Reproduction of *Energy Efficiency Manual* measures to improve energy efficiency of lighting (Wulfinghoff, 1999:1021–1157)

Technological focus	Detailed measure
Lamps and fixtures, incandescent	• Eliminate excessive lighting by reducing the total lamp wattage in each activity area. • Substitute higher efficiency lamps in existing fixtures. o Screw in fluorescent o Tungsten halogen • Substitute lamps that minimize light trapping and or improve light distribution. • Modify existing fixtures to reduce light trapping and or improve light distribution. o In fixtures with shades that absorb light, modify or eliminate the shades o Install reflective inserts in fixtures that have absorptive internal baffles or surfaces o For task lighting, install focussing lamps on flexible extensions. • Replace incandescent fixtures with fluorescent or HID fixtures • Modify or replace incandescent exit signs with fluorescent or LED light sources • Install dimmers
Lamps and fixtures, fluorescent	• Eliminate excessive lighting by removing lamps and disconnecting or removing their ballasts. o To remove single tubes from 2-tube ballasts, substitute dummy lamps o To remove single tubes where 2-tube ballasts are installed, substitute single tube ballasts o To remove single tubes from groups of fixtures, rewire the ballasts between fixtures • Where fixtures have been delamped, disconnect or remove the ballasts. • Replace fluorescent lamps with high efficiency or reduced wattage types • Replace ballasts with high-efficiency or reduced wattage types, or upgrade ballasts and lamps together. • Install current limiters • Install fluorescent dimming equipment • Consider retrofit reflectors for fluorescent fixtures
Lighting controls, manual	• Install effective placards at lighting controls • Use security forces, watch engineers, or other regularly assigned personnel to keep unnecessary lights turned off. • Install all single pole toggle switches so that the toggle is down when the switch is off • Replace rheostat dimmers with efficient electronic dimmers • Where fixtures are not easily visible from the switch locations, install telltale lights. • Draw attention to switches that should be used in preference to others. • In applications where fixtures may be operated improperly by unauthorized personnel, use key switches.

Lighting controls, automatic	• Where lighting is needed on a repetitive schedule, use timeclock control. o To combine time switching with daylighting, use astronomical timeclocks • Control exterior lighting with photocontrols • Install interior photocontrols to exploit daylighting • Where the need for lighting is determined by the presence of people, use personnel sensor switching • Where lighting can be turned off after a fixed interval, install timed turnoff switches. • If a door remains open when lighting is needed, use door switches.
Lighting layout	• Make the surfaces of the space highly reflective • Lay out lighting using the task lighting principle o Disconnect or remove fixtures where they are not needed o Relocate and reorient fixtures to improve energy efficiency and visual quality o Replace fixtures and improve fixture installations that waste light • Install fixtures or combinations of fixtures that provide efficient lighting for all modes of space usage • Install a separate control circuit for each lighting element that operates on a distinct schedule o Where light fixtures are needed in a predictable variety of patterns, install programmable switches • Install lighting controls at visible, accessible locations. o Provide localized control of ceiling fixtures by installing pullcord switches.
Fixture maintenance and marking	• Clean fixtures and lamps at appropriate intervals • Replace darkened diffusers • In fixtures where the type or number of lamps may vary, mark the fixtures to indicate the proper type of lamp
Lamps and fixtures, HID. {High Intensity Discharge) and LP.S.Low Pressure Sodium]	• Install the most efficient HID lamps, ballasts and fixtures o For lowest retrofit cost, replace mercury vapour lamps with metal halide or high-pressure sodium lamps that do not require ballast replacement. o Install HID dimming equipment o Inappropriate applications, substitute fluorescent for HID lighting

2.6.4. Appliances

Energy use by appliances can be defined scientifically (Aubrecht, 2006:41): Energy = Power x Time = W x S or = kW x hour. The power rating and time period for which the appliance is on are two variables that affect overall energy consumption. A decrease in either variable is directly proportional to a decrease in the overall energy consumption of the appliance. With regard to the average power ratings of appliances, a local power rating and average time period chart was sourced (Figure 11) so that the relevant appliances and energy services could be evaluated (Smart Living Handbook, 2007:47). Other similar lists and examples exist (Aubrecht, 2006:137).

Figure 11: Average power ratings and time period for South African households (*Smart Living Handbook*, 2007:47)

Appliance	Power use (watts)	Ave hrs/ day in use	Appliance	Power use (watts)	Ave hrs/ day in use
Lighting			Refrigeration		
Incandescent bulb (40W)	40	5	Freezer (chest)	105	4
Incandescent bulb (60W)	60	5	Fridge with freezer	158	5
Incandescent bulb (100W)	100	5	Fridge – no freezer	250	2
CFL (12W)	12	5	Home maintenance		
CFL (18W)	18	5	Dishwasher	2 500	0,9
CFL (20W)	20	5	Vacuum cleaner	1 000	0,5
Security (120W)	120	0,3	Laundry		
Cooking			Iron	980	0,4
Coffee machine	670	0,5	Iron (steam)	1 235	0,8
Electric stove	3 000	2	Washing machine	3 000	0,75/load
Frying pan	1 250	0,4	Tumble dryer	3 300	0,5/load
Hotplate – large	2 400	0,3	Music, entertainment, home office equipment and other		
Hotplate – small	1 275	0,2	Burglar alarm	10	24
Kettle	1 900	0,3	Cell phone charger	9	2
Microwave oven	1 230	0,8	Compact disc player	9	0,4
Toaster	1 010	0,3	Computer	134	1,5
Snackwich	1 200	0,3	Cordless phone	2	15
Food processor	166	0,2	Fax machine	45	13,6
Geyser			Hair drier	647	0,1
Geyser (electric)	2600	4,4	Radio	12	3
Geyser (solar with electric backup)	2600	1.7	M-Net decoder	28	12,1

Another factor to consider is how appliances are managed by customers. Multiple credible international and local sites regarding energy efficiency and conservation information regarding appliances, which can be easily accessed by consumers, are available. For example, the US Energy Star programme (http://www.energystar.gov/) has successfully used a rating system that now provides consumers with the products' energy efficiency and energy benefits. Locally, South African utility Eskom (http://www.eskom.co.za/live/content.php?Category_ID=568) and local government, the City of Cape Town, (http://www.capetown.gov.za/en/EnvironmentalResourceManagement/tips/Pages/EnergySavi ngTips.aspx) offer advice to optimise the energy efficiency of appliances, although several measures are concerned with energy conservation as well.

Recent investigations into the impact of standby options of appliances have refocused attention on the effect of product design on the energy consumption. The standby function on an appliance refers to the ability of an appliance to draw a small amount of power even if it has been switched off. Research shows, cumulatively, this amounts to a large amount of wasted energy and power (IEA, 2007; Lebot, Meier and Anglade, 2000). Lebot et al (2000) summarised the findings of several investigations of standby power consumption in OECD households and calculated that 'standby power is responsible for about 2% of OECD countries total electricity consumption and the related power generation generates almost 1% of their carbon emissions' (Lebot et al, 2000:1).

The conclusion of the preceding three sections clearly document and explain technological interventions that could be implemented as sustainable energy solutions in the residences of Stellenbosch University.

2.7. Sustainable energy solutions for universities: case studies

Precedent studies of universities that have implemented sustainable energy practices, pertaining to both renewable energy and energy efficiency, are detailed below. They reflect an American context as the widest variety and most organised representation of sustainable energy efforts is available from universities of this particular context. It is important to note that sustainable energy efforts are part of a greater sustainability drive at the universities and a substantial part of efforts are aimed at creating research groups or influencing the education curriculum. These case studies focus on the operations of a university (i.e. how it functions) and not on course content or research initiatives. Furthermore, the emphasis on residential context refines the literature search. Case study examples have identified 17 possible courses of action to implement sustainable energy in a residence of a university (Environmental Protection Agency, 2008: http://www.epa.gov/greenpower/toplists/top10ed.htm ; Harvard Green Campus Initiative, 2008: http://www.greencampus.harvard.edu/hpbs/links.php#EnergyEfficientLighting; Petersen, 2005) These separate courses of action are generally executed in an integrated or parallel fashion. The first six courses are strategically orientated whereas the remaining eleven courses of action involve the implementation of technical solutions to evaluate, report back and decrease consumption of fossil fuel sources. They are:

Strategic actions towards implementing sustainable energy in the residences of universities:

1. Organised social groups and information sharing networks
2. Top leadership commitment
3. Policy commitment
4. Climate change strategies
5. Projects, campaigns and programmes to raise awareness
6. Student activism and research

Technical actions towards implementing sustainable energy in the residences of universities:

7. Energy consumption reporting (Bath University, UK; Bard College, USA; Pennsylvania State University, USA; Middlebury College, USA; Mount Allison University, USA; Tulane University, USA; University of Colorado at Boulder, USA; University of Pennsylvania, USA;)
8. Energy Auditing of buildings (Pennsylvania State University, USA)
9. Retrofitting buildings (State University of New York at Buffalo, USA; University of South Carolina, USA; Yale University, USA)
10. Ensuring that new buildings are based on ecologically designed architecture (University of Columbia, Canada)
11. Energy saving/ climate change competitions (Oberlin College, USA; University of Vermont, USA)
12. Feedback systems (Oberlin College, USA)
13. Providing appliance and lighting information (Iowa State University, USA)
14. Bulb exchange (Tufts University, USA; University of Pennsylvania, USA)
15. Generating renewable energy on campus (California State University's Hayward campus; Oberlin College, USA; St. Olaf College)
16. Generating renewable energy off campus
17. Purchasing green energy (Oberlin College, USA; University of Pennsylvania, New York University, Oregon State University, California State University System, University of

California, Santa Cruz, Texas A&M University System, Northwestern University, Western Washington University, University of Utah)

Energy efficiency for residences, and related university buildings, relates to bulb retrofits and providing appliance and lighting information. A light retrofit at Tufts University (Tufts Office of Sustainability website: http://www.tufts.edu/tie/tci/LightingControls.htm) in 2001, which focused on installing motion sensors for public spaces and exchanging incandescent bulbs for CFL's, saved the university '876,024 kWh's and $91,930, with the longest payback period for a retrofit of 3.6 years'.

Brown University has also focused on energy efficient drives on campus that encompassed broader arenas than just lighting. Initiatives to convert from oil to gas, improve insulation and replace steam traps have allowed for savings that the Energy Manager from the Facilities Department estimates, at the current price of electricity, saved the University $10. 8 million and a cumulative 90 million kWh's over the past 10 years (Martinez, 2007).

A modern and comprehensive case study in point is Oberlin College in the US, where dormitory (residential) energy consumption has been a key issue on campus and therefore aligns itself with the use of sustainable energy and the unit of analysis of this thesis. Oberlin College has incorporated a novel approach towards implementing sustainable energy that could be replicated in Stellenbosch University residences. Firstly, a feedback system (available online at http://www.oberlin.edu/dormenergy/), referred to as the Campus Resource Monitoring System, can be accessed by anyone on the internet. This feedback system is in real time. In other words, as you view the digital screen, the current energy consumption at that moment is relayed. This digital interface was created to provide students with 'easily interpretable real-time feedback on electricity and water consumption and on the financial and environmental impact of this consumption [to motivate and empower] students to conserve [resources] (Campus Resource Monitoring System website, 2008: http://www.oberlin.edu/dormenergy/news.htm). This 'dashboard' is accessed so as to compare the different dormitories in terms of 4 comparisons: per person consumption, relative consumption, environmental or economic costs and the kitchen and dining room power consumptions.

Each one of these comparisons is measured with the unit of power, in terms of average watts (W) per student, and this rating in each four of these comparisons is available for the last hour, day and month in question. The four comparisons are very user friendly. Viewers can translate the power consumption into various 'student friendly currencies', ranging from vegetarian or meat burgers to the number of hybrid vehicles or equivalent amounts of sulphur dioxide emissions. Meters that detail the cumulative energy (kWh) usage at the time point of 'this' hour, day, week and month are also available for each residence. This data is based on readings which are taken every 20 seconds from energy and water meters which are then sent to a central server that feeds the dashboard.

Installing the Campus Resource Monitoring System was intended to investigate the effect of a feedback system of influencing student residential behaviour towards energy saving (which could be implemented via energy efficiency). According to the website and argued in a published article, the 'dorm Energy Competition, successfully demonstrated that low-cost resource use feedback systems motivate students to exhibit substantial short term reductions in energy and water use in dormitories' (Oberlin College, 2008; Petersen et al, 2007).

The technology of the feedback system could be viewed conceptually as an energy efficient technology, but the strategies adopted in the residences of Oberlin College, which were informed by the feedback system, were aimed more at energy conservation than energy efficiency. They focused on switching lights off in rooms that were not occupied, making use of natural light during the day, switching computers screens or hard drives off when not in use and showering for a shorter time (Petersen et al, 2007:29). The post competition survey revealed that students felt that certain actions could be sustained after the competition (i.e. switching off unnecessary lights) while others not but the majority would continue using the energy conservation strategies that has been espoused both on campus and outside of campus (Petersen et al, 2007:29).

In addition, Oberlin College is also an example of energy awareness with regard to its Student Experiment in Ecological Design (SEED) house. Students have conjured up their own creative methods at saving energy: a picture of a Senator, whose strict climate change policies they support, was pasted above the shower to promote shorter showers. Fridge sharing and using extra blankets were two other energy saving tactics used.

Oberlin College purchases approximately 50% of its energy needs from renewable sources, mainly hydro and recovered landfill gas (Oberlin College, 2008; Petersen, 2005). This is done via a purchasing agreement with a local electricity supplier, Oberlin Municipal Light and

Power System (OMLPS), which in turn purchases electricity via Amp Ohio, a conglomeration of utilities that generate and purchase electricity. In terms of on site renewable energy generation, a160 kW Solar PV installation exists at the Adam Joseph Lewis Centre for Environmental Studies building which supplies approximately 1.5% of campus electricity needs. Oberlin College also makes use of cogeneration from heating plants in which steam supplies approximately 5–10% of campus electricity needs.

The examples of universities that are implementing sustainable energy in the United States are embedded within a larger higher education drive to integrate sustainability into the curriculum and learning environment. Large scale environmental audits of the campus, strong student cultures which demand sustainability, student research and policy action plans characterise these broad based approaches to implementing sustainability within the built environment of a university. These pertain to investigating the resources and materials flows across the campus and not only energy: from recycling computers to using locally produced food and determining the number of polystyrene coffee cups being used every day by students. Organisations such as the Association for the Advancement of Sustainability in Higher Education (http://www.aashe.org/index.php), the National Wildlife Federation Campus Ecology department (http://www.nwf.org/campusecology/), the US Partnership for Education for Sustainable Development (http://www.uspartnership.org/main/view_archive/1), Second Nature: Education for Sustainability (http://www.secondnature.org/) and the Climate Challenge Organisation (http://www.climatechallenge.org/) generate motivation that has been successfully translated into the institutional organisation and policy arenas of universities with regards to sustainability. Furthermore, the numerous regional, state and national programs or standard rating programmes that specialise in either energy efficiency (for example, the Energy Star system) green building (the LEED building rating) and renewable energy(for example, the EPA's Green Power Partnership) provide accessible technical help to consumers and policy makers.

South African research on initiatives to implement sustainable energy within the residences on campus, or even the educational and administrative buildings, is limited. However, a recent article (McGregor, 2008) states that the recent power cuts prompted a Higher Education for South Africa (HESA) organised meeting amongst several institutions to 'brain storm' options for dealing with the power crisis. The article documents initiatives by the University of the Witwatersrand (Wits) and the University of Pretoria (Tuks). Wits is planning to perform energy audits of all their buildings to inform its electricity usage profile. The suggested strategies focus on awareness campaigns, energy efficient lighting, reducing the time of heating water and demand side management initiatives. Tuks has identified three major energy saving actions for campus. The first relates to a lighting retrofit of all the buildings (sponsored by Eskom) which, in two years time, should decrease the electricity demand from lighting by an estimated 35% - 50%. The second action concerns hot water load management via the demand side management and hot water load control sensors. The final action, with a long term view in mind, concerns using solar water heaters to heat residential water use (Four buildings are being retrofitted this year, another six are planned for next year).

This HESA meeting, held on the 11 February 2008, as a reaction to the then power crisis in South Africa, and not particularly on sustainable energy, highlighted the need for energy solutions for universities. The summarised attempts of participating universities were focused mainly on options for standby power (generators), load control and plans for building according to more green principles (HESA Sector Meeting on the Power Supply Situation, 2008). A review of the energy reports sent by UCT, Wits, Central University of Technology in the Free State, Nelson Mandela Metropolitan University, University of Limpopo and University of Venda revealed that technological efforts at energy management were focused more on securing supply (and therefore purchasing generators) and load management than energy efficiency or renewable energy.

One case study of a lighting retrofit of a South African university library illustrates the potential benefits of implementing energy efficiency for a university. The University of Kwazulu Natal, in association with Bonesa, the South African Efficient Lighting Initiative (ELI-RSA), conducted a lighting retrofit in the EG Malherbe Library in 2003 (Energy Research Institute, 2003; Nicol, date unspecified). The lighting retrofit, which cost the university R806 727, allowed for a saving on electricity costs of R219 254 per annum, which allowed for the investment to be repaid in 3.6 years (and 1.8 years with 50 % Eskom DSM funding) (Nicol, date unspecified). This also translated into environmental savings as the decrease in electricity demand directly allowed for decreased carbon dioxide, sulphur dioxide, nitrogen dioxide and particulate matter waste emissions as well as avoided water usage (Nicol, date unspecified). A consequence of the decrease in heat and energy within the library also facilitated a decreased need for air conditioning (Energy Research Institute, 2003). Lastly, students took note of the improved lighting conditions (Energy Research Institute, 2003). This case study reveals financial, environmental and social benefits of an appropriately applied energy efficient retrofit and hints to the possibilities that exist for all South African universities.

The review of the selected case studies above therefore provides a platform to imagine what could be possible for the residences of Stellenbosch University. These examples were made explicit to provide stories from other contexts, with respect to their different environments, that could inspire or guide local solutions. Stellenbosch University could be reinvented by locating itself within a sustainable agenda.

2.8. Chapter summary

The literature review revealed an unfolding narrative. Sustainable development is a global challenge because current growth trends perpetuate negative consequences for the global environment and notion of equality. It is necessary that future development is sustainable to maintain the resource base upon which we exist and the right of every human's share of the global commons. Energy is a significant resource dynamic for a sustainable future because carbon dioxide emissions from electricity generation are the largest contributing factor towards anthropogenic induced climate change. Furthermore, the calculated time scales involved in climate change indicate an urgent call to action. A transition towards sustainable energy use is thus 'one of the central challenges humankind faces in this century' (InterAcademy Council, 2007: xvii).

Sustainable energy can be implemented via a myriad of technological avenues. Energy efficiency, a demand side solution, is considered the 'low hanging fruit' in relation to other options because it is commercially available and, generally, does not require a total transformation of systems operations. Individuals and organisations can implement it now. In addition, energy efficiency can allow for financial savings due to decreased energy consumption. The literature revealed an argument that favours end use energy efficiency specifically, based on the idea of compounding efficiency losses during energy conversions.

Limits to energy efficiency as well as unintended consequences of energy efficiency were noted but these do not suffice to argue that energy efficiency is irrelevant, only that it cannot be the singular solution towards a sustainable energy future. However, as an aid that capacitates immediate action, energy efficiency, and particularly end use energy efficiency, is a significant technological avenue in the transition towards a sustainable energy future.

The commercially available technologies to implement end use energy efficiency were detailed so that the range of possible options for residences of Stellenbosch University are made explicit to indicate how end use energy efficiency can facilitate sustainable energy use. These included energy efficient options for water heating systems, lighting and appliance use as these are relevant to the unit of analysis for this thesis.

Sustainable energy use is becoming an agenda for certain universities. Examples of different types of actions to transform current energy use within the operation on campus were provided as space in which to imagine what possibilities could be relevant and inspiring for the context of the residences of Stellenbosch University.

In conclusion, the literature review revealed an argument which explains why sustainable energy is necessary, details the technologies that indicate sustainable energy use is possible and provides examples of international universities which are implementing sustainable energy. These three golden threads are woven together to ask: what technological options exist for Stellenbosch University? Equipped with this 'tool box' of why and how energy efficiency can aid this process, the research journey applies the different tools to the context of the residences of Stellenbosch University as the research objective.

Chapter 3: Research methodology

3.1. Introduction

Chapter 3 describes the particular research methodology, research design and research processes that inform this thesis. Based upon the systems thinking and ecological design foundations, the exploratory nature of the research objective is guided by quantitative and qualitative paradigms so as to ensure solutions that are not informed by the 'one dimensional mapping' of a singular approach (Clayton and Radcliffe, 1996:12). Instead, a systems approach to sustainability views the interaction of different systems according to a 'multidimensional framework' (Clayton and Radcliffe, 1996:12). In addition, both systems thinking and ecological design espouse searching for local, context sensitive solutions. This is why a secondary data analysis of energy consumption was required to set the context for the research objective and why a case study informed a context dependent search for end use energy efficiency options for residences. The motivational reasons for the decisions made as well as their advantages and limitations are presented below.

3.2. Research methodology

The methodological approach to the real life problem, which has been defined as a research problem in this thesis, is described according to the Three Worlds Framework, as suggested by the social science research methodologist Mouton in the book *Understanding Social Research* (1996 in Mouton, 2001:137) and Babbie and Mouton (2008:1-67) and resonates with Karl Poppers' idea of Three Worlds of Knowledge (Phillips, 1982).

The philosophy of science, which affects social research, dissects how society has chosen to validate 'truth' (Babbie and Mouton, 2008:1–68; Phillips, 1982). The meta science positions of positivism, phenomenology, critical theory and the contemporary discourses of modernism and post modernism have, respectively, informed the epistemological (theory of knowledge) and ontological (the theory of reality) assumptions of research methodological approaches. These underlying assumptions inform and mould the findings of a research objective and for this reason are made explicit in this chapter.

The Three Worlds Framework is a tool that allows for the 'analytical distinction' (Mouton, 2001:142; Babbie and Mouton, 2008) between different levels of scientific enquiry in our daily lives. World 1, the world of everyday life and lay knowledge, is concerned with pragmatic knowledge production which deals with problems that appear in our daily lives. World 2, the world of science and scientific research, is concerned with epistemological knowledge production which searches for 'truths', via scientific scrutiny, within the patterns and specific experiences of our daily lives. World 3, the world of meta-science, is concerned with the critical knowledge production that analyses our scientific findings from World 2, and reflects on its ethical implications and philosophical foundations – this world is generally regarded as the realm that 'searches for the truth'.

The research problem in this thesis, investigating sustainable energy solutions for the residences of Stellenbosch University, is located within World 2, the world of science and scientific research. It involves subjecting a real life problem to scientific scrutiny so that an 'answer' can be found or, as Mouton describes it (2001:138), '[selecting a phenomenon from] World 1 ... [and making it into an object] of inquiry'.

The methodological paradigms that govern World 2 in terms of social research are identified as quantitative, qualitative and participatory paradigms and are, respectively, linked with positivism, phenomenological and critical theory metatheories (Babbie and Mouton, 2008:47-68). Each methodological paradigm is governed by an historical narrative of its own and diverging movements within the paradigm with vast volumes of literature dedicated to them. The explanations below are summaries of the conceptual foundations. In particular, the ontological assumptions of object and subject within each approach influences how being or reality is perceived while the epistemological assumptions influence how knowledge is generated to provide evidence for the research objective.

A quantitative methodological paradigm focuses on 'assigning numbers to perceived qualities of things' (Babbie and Mouton, 2008) and generally involves surveys and statistical analyses in an attempt that 'a natural science of society [can] only be value-neutral if subjectivity and prejudice [are] disciplined by the dispassionate and systematic application of statistical techniques' (Babbie and Mouton, 2008:53). The focus on various forms of counting and empirical evidence is to statistically validate certain generalisations (Holliday, 2002:6).

A qualitative paradigm acknowledges the influence of a researcher's subjectivity and questions the possibility of objective value neutral knowledge. Qualitative research 'attempts always to study human action from the insiders perspective' (Babbie and Mouton, 2008:53) and generally involves interviewing, observation and studying personal documents so that the researcher is focused on 'getting [his or her] hands dirty in real research'. The focus is on exploring the context and relationships so as to suggest hypotheses or discover what emerges (Holliday, 2002:6).

The participatory action research methodological paradigm 'involves a much closer relationship than that which is usual between the researcher and the researched' (Babbie and Mouton, 2008:58) because of the 'necessity to involve those persons who are the supposed beneficiaries of research in the entire research process' (Babbie and Mouton, 2008:58). The participatory methodological paradigm has evolved to question the traditional assumptions underlying the power hierarchies between the researcher and the researched and to promote the value of maximum engagement, participation and doing (as opposed to only researching).

The first element that affected the choice of research methodology for this thesis was the question of scale. Should this research problem be investigated by taking an objective, macro stance and reviewing the numerical data of the energy consumption of the residences to make suggestions based upon quantitative data? Or should the research objective be approached subjectively by getting involved with residences, on a grassroots, micro level to allow the intimate platform of personal interaction as qualitative data for suggested solutions? The question concerning a micro versus macro scale (and therefore a quantitative vs. qualitative paradigm) was concerned with whether suggestions generated by the research on one scale (i.e macro) would actually be applicable to the context of the other (i.e micro).

The systems thinking and ecological design paradigms that inform the working definition of 'sustainable energy solutions' in this thesis, echo concerns about the disjuncture between scales and argue for an acknowledgement of the context in which solutions are to be implemented. In addition, both discourses highlight the need to acknowledge complexity by approaching problem solving in a holistic manner that does not reduce a context to one sided 'fixes'. Therefore, a combination of a macro and a micro view was taken and two parallel research journeys were embarked upon, accompanied by the respective quantitative and qualitative methodological research approaches. Elements of a participatory action methodological approach were also adopted at times when the qualitative research became highly interactive, but the degree of participation was not as consistently prominent as recent Participatory Action Research (PAR) advocates stress it should be. The PAR approach is therefore not used as a framework for the research objective.

The first research journey concerns a macro view of the historical and present energy profiles of the residences in the unit of measurement of kWh and involved a largely quantitative paradigm. It involves processing the monthly energy consumption entries as recorded by the US Energy Manager to determine an energy profile for the residences on campus. This processed data then needs to be analysed to see if any trends or patterns emerge.

The second research journey concerns moving the research magnifying glass over a case study to better understand the context and reality in which sustainable energy solutions for residences can actually be implemented. This entailed a micro view and quantitative and qualitative paradigms. The expressed desire for context based solutions entailed that the residential context in which the suggested solutions were to be taken place were considered so as to avoid the application of inappropriate technology.

The simultaneous use of quantitative and qualitative paradigms to investigate the research objective upholds the holistic approach to finding solutions, as defined in the introductory chapter.

3.3. Research design

Research design is 'the blueprint of how you intend conducting the research' (Babbie and Mouton, 2008:74). The purpose of this research is exploratory as it entails asking: what are the best sustainable solutions for the residences of Stellenbosch University? (Babbie and Mouton, 2008:79; Van der Merwe, 1996:287). Elements of descriptive and explanatory research are used as well when describing and explaining the energy profiles of the residences. The research objective involves examining a new area of research in the context of the residences of Stellenbosch University. Babbie and Mouton summarise the purposes of exploratory research as an attempt to:

'Satisfy the researcher's curiosity and desire for better understanding

Test the feasibility of undertaking a more extensive study

Develop methods to be employed in any subsequent study

Explicate the central concepts and constructs of a study

Determine priorities for future research

Develop new hypotheses about an existing phenomenon'

In addition, exploratory studies usually use in-depth interviews, case studies, literature reviews and informants to lead to insight and comprehension. This is valuable as it allows for primary research in which new data is generated but the drawback is that many exploratory research projects do not reach a conclusive answer to their stated problem statement but instead 'point the way to an answer' (Babbie and Mouton, 2008:80).

The unit of analysis is the residence and, particularly, the energy consumption of the residences in kWh. This unit of analysis is, in terms of the quantitative paradigm, examined for a longitudinal time period between 2003 and 2007 whereas the qualitative paradigm is a cross sectional study for the period February 2008 through to October 2008.

The quantitative, macro research process is governed by a secondary data analysis (SDA) (Mouton, 2001:164-165) research design. The empirical, numerical primary data supplied by the US Energy Manager is explored for descriptive and explanatory purposes so as to identify and explain energy trends, patterns and comparisons within the residences of Stellenbosch University. An SDA research design is helpful as it is not necessary to spend time and resources on gathering the primary data, but this fact also informs its primary limitation: unknown errors in primary data recording and the objective of collecting the primary data could influence the results of the processed secondary data. For this reason, the use of SDA calls for explicit and detailed explanation of the data's origin and possible errors.

The qualitative, micro research process is governed by a case study research design (Babbie and Mouton, 2008:280-283; Flyvberg, 2001; Holliday, 2002:18; Mouton, 2001:149–150; Yin, 2003). The use of this research design aligns itself with the systems thinking and ecological design approaches to sustainability because it breeds context based solutions that acknowledge the interaction of systems.

The case study research design 'has a distinct advantage when a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control' (Yin, 2003:9). However, this is not a limiting definition and the exploratory 'what' of the objective of this thesis is considered viable for a case study research design. A broader definition (Yin, 2003:13) explains this as 'an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and the context are not clearly evident'.

Case studies research design offers advantages for the research process, provided it is correctly matched with the research objective. It 'arises from the desire to understand complex social phenomenon' and 'allows investigators to retain the holistic and meaningful characteristics of real life events' (Yin, 2003:2). Flyvbjerg argues for the 'power of examples' (2001:66-87), based on an Aristotelian appreciation for the knowledge derived from case studies, in order to propel the social sciences on a significant path. The context-dependent, practical and intimate knowledge generated from case studies is insightful and sheds new light on the unit of analysis.

However, case study methodology has been criticized (Babbie and Mouton, 2008:280; Flyvbjerg, 2001:66; Mouton, 2001:150; Yin, 2003:10-11) for several reasons. The most prominent reason usually is that case studies are dismissed because general theories cannot be deduced from them and they are, on these grounds, scientifically useless. This, in turn, is based on the assumption that general theories are more valuable than specific, localised knowledge. Another reason is that case studies are often viewed as useful only in the beginning stages of a research process, the exploratory phase, and cannot be used when the research becomes more serious. The bias of the researcher and the close bond between the case study and the researcher are also grounds for concern. Lastly, issues concerning the quality of data collected and the lack of rigour associated with case studies has been noted.

Although a case study facilitates the need for context dependent, localised solutions stipulated by the research objective, the question arises as to whether a single case study or multiple case studies will be able to direct the research objective. In other words, how will one or several case studies generate sustainable solutions for all of the residences of Stellenbosch University?

By advocating the importance of case studies in the scientific development of the social sciences, Flyvbjerg (2001:71-81) highlights that case studies do have larger 'generalising' value. Firstly, case studies can have a critical impact on a general theory when, for example, they subject a claim successfully to Poppers' notion of falsification and thereby refute the hypothesis. Secondly, the point that generalisation is a form of knowledge production should not be equated with generalisation being the only form of credible knowledge production. It is argued that actually ‘one can generalise on the basis of a single case, and the case study may be central to scientific development via generalisation as supplement or alternative to other methods. But formal generalisation is overvalued as a source of scientific development, whereas the power of the good example is underestimated’ (Flyvbjerg, 2001:77).

The theoretical framework described above presents the research methodologies and designs that were suited to expose the context in which energy efficient options, as a means towards sustainable energy, were used. An SDA research design was used for a macro view in which the quantitative context of energy consumption was investigated to pursue the research objective. The case study research design was used for a micro view in which the qualitative context, as well as quantitative concerns, was investigated to pursue the research objective.

3.4. The research process

The research methodology process described below details how the research process was conducted and explains why the decisions which influenced what needed to be done to best approach the research objective were made. This involves identifying the data sources from which certain research decisions are justified as well as the data used to generate the findings of the thesis.

The macro and micro processes have been explained by drawing the analytical distinction between qualitative, quantitative and participatory methodological paradigms above. However, this is merely an analytical distinction which has been exercised for the clarity purposes involved in writing a thesis. The research process of this thesis was not a static, orchestrated experience which generated data in the organised fashion below but a dynamic, emergent process which constantly required the interaction of quantitative and qualitative data. The procedures for collecting and processing data for the macro and micro views as well as the participation of the residences in the 2008 US Energy Challenge are separated and presented below.

Table 7: Overview of data collection and processing required for the research process

1.	Collection and processing of quantitative data for the macro view: energy consumption of the residences
2.	Collection and processing of quantitative and qualitative data for the micro view: selecting the case study
3.	Collection and processing of quantitative data and qualitative for the micro view: Processes in the case study • Investigating reasons for the 2007 US Energy Challenge • General walk-through energy audit • Energy survey • Allocating the Eskom prize money on energy efficiency
4.	• Collection and processing of quantitative and qualitative data

3.4.1. Energy consumption of residences

The collection and processing of the quantitative data regarding the energy consumption of the residences was done in order to generate five sets of quantitative information:

- A breakdown of the monthly energy consumption in kWh according to residential use, kitchen use and water heating use and other, where applicable, for the chosen residences for the time period 2003 to 2007

⇩

- The monthly energy consumption in kWh of the chosen residences for the time period 2003 to 2007

⇩

- A breakdown of the annual energy consumption in kWh according to residential use, kitchen use and water heating use for the chosen residences for the time period 2003 to 2007

⇩

- The annual energy consumption in kWh of the chosen residences for the time period 2003 to 2007

⇩

- The annual kWh/student energy consumption of each residence for the time period 2003 to 2007

These five sets of data were generated for two reasons. The first concerns the need for this data to contribute to the research inquiry whereas the second is an attempt to lay a foundation upon which future residence leaders can inform themselves to make decisions about sustainable energy choices.

Compiling the energy data into accessible tables identifying monthly and annual totals, the residential breakdown and energy consumption per student allows for a digital canvas on which all ‘like apples’ can be compared so that patterns, trends and anomalies in the energy consumption of the residences can be investigated. In order to suggest the most appropriate interventions to stimulate sustainable energy solutions for the residences, the energy context needs to be identified and the use of this quantitative data was therefore necessary to set the context of actual energy consumption. In addition, this data was necessary to decide which residences to select for several case studies.

With regard to the second reason, the detailed documentation of the energy profiles of residences will now be made available in an accessible format to students when this thesis is housed in the Stellenbosch University JS Gericke Library. This allows for interested individuals to construct an ‘energy history’ of their residences and identify which factors contribute towards their overall energy consumption so as to better understand which technological and behavioural interventions to implement in their residence. For example, a resident of Majuba would, after finding out that the warm water he uses is heated by a heat pump and not by a geyser, not waste his time with looking at blanket insulation options or timers but instead look at the kitchen or residential use to implement energy efficiency. Likewise, a student at Monica could, comparatively, deduce that their energy use per student was ranked as the worst of the ladies residences and investigate why this was so.

These five sets of generated quantitative information, as well as their subsequent evaluation, were made possible by collecting and processing data from several different sources. The quantitative data, their sources, and the method in which they were communicated are detailed in Table 8 below.

Table 8: Details of sources for the quantitative data and method of communication

Quantitative data	**Contact source**	**Method of data communication to researcher**
List of residences of the university	Betty Preller, Manager of Student Residence Services Marie Hendrikse, Student Administration	Personal conversation
Gender of the residences	Betty Preller, Manager of Student Residence Services	‘US Kampus’ guide flyer

Official capacity of each residence (2003–2007)	Betty Preller, Manager of Student Residence Services Marie Hendrikse, Student Administration Diane Whitmore, Office Assistant Manager at Academia	Personal conversation
Surface area of each residence (2007)	Francois Swart, Manager of Facilities Information, Facilities Management offices	Personal conversation and emailed database
Water heating system of each residence	Dolf Krige, US Energy Manager[8], Maintenance and Operations	Personal communication and emailed explanation
Type of kitchen used in each residence	Betty Preller, Manager of Student Residence Services Kevin Matthews, architect, Facilities Management Offices	Personal communication Telephonic conversation
Monthly and annual energy consumption in kWh for each residence	Dolf Krige, US Energy Manager, Maintenance and Operations	Emailed primary data from Maintenance and Operations database which had to be processed
Breakdown of monthly and annual energy consumption in kWh into residential use, water heating use and kitchen use for each residence	Dolf Krige, US Energy Manager, Maintenance and Operations	Emailed primary data from Maintenance and Operations database which had to be processed

The residences under review in this thesis constitute 28 residences[9] on Stellenbosch Campus. Of the residences on the official residence list, obtained from Student Administration (Preller, 2008: personal communication), Crozierhof, Waldenhof and Hombre were omitted. Crozierhof and Waldenhof are used by the university for visiting guests and Hombre was a male residence which was converted to the female residence Sonop (Preller, 2008: personal communication). The Tygerburg residences were not included in this investigation in an effort to maintain the focus on one location so that different geographical, climatic or environmental variables would not have to be considered. The final list of residences is summarised in Table 9: Residences of Stellenbosch University included for the research investigation.

[8] A new SU Energy Manager has subsequently been appointed.

[9] Student Houses were considered and investigated but not included so as to maintain uniformity of the unit of analysis.

Table 9: Residences of Stellenbosch University included for the research investigation

Female Residences	Male Residences	Mixed gender residences
Erica	Eendrag	Academia[10]
Harmonie	Helderberg	Concordia
Heemsteede	Helshoogte	Golfields
Huistenbosch	Huis Marais	Huis de Villliers
Irene	Dagbreek	Huis MacDonald
Lydia	Huis Visser	Lobelia
Minerva	Majuba	Metanoia
Nemesia	Simonsberg	
Nerina	Wilgenhof	
Serruria		
Sonop		

Dolf Krige explained that energy use in residences can be classified according to many different criteria (Krige, 2008: personal communication). Significant variables that influence the difference in energy consumption pertain to differences in:

- number of students
- surface area or size of the residential building
- room infrastructure in the residences
- gender types
- type of water heating technology used
- type of kitchen configuration

In addition, factors that can influence the thermal mass of a building and, therefore, its ability to radiate and conduct heat or cold, will also influence energy use in residences (Krige, 2008: email communication). One would then need to consider the construction materials,

[10] Academia, formally, is not a residence of Stellenbosch University. It is owned by Ciphon and the University is currently in a 20 year lease contract with Ciphon. However, Academia has the largest official capacity of all the residences as well as the largest overall energy consumption. Its relative significance in size and energy consumption on campus warrants its inclusion for future decision making considerations.

insulation, type of roof/ceiling, orientation and shading of the residential building (Krige, 2008: email communication).

It was decided to limit the research investigation to three specific variables because this corresponds with the quantitative data supplied by the US Energy Manager and with an effective categorisation system in terms of the appliance use that affects ends use electricity consumption within the residences. The primary data obtained from the US Energy Manager concerning residential energy consumption is, in most cases, broken down into three sub totals, which collectively equate to total energy use. An energy reading for the centralised kitchen provides one subtotal. An energy reading for the water heating provides the second subtotal. However, when residences share a heat pump, their individual water heating energy use is not metered. Instead, the single reading that reflects the water heating consumption of two residences is divided proportionate to the residences' official capacity. For example, residence A and B share a heat pump and their respective official capacities are 60 students and 40 students. The monthly water heating reading measures 20 000 kWh for the heat pump. Residence A's water heating energy subtotal for the monthly will then be calculated as 12 000 kWh (20 000 x 60/100) and residence B's energy subtotal for the month will be 8 000 (20 000 x 40/100) kWh. Lastly, a reading for all the residential activities excluding the kitchen and water heating provides the third subtotal. This categorisation is available for all the female and male residences but not for the mixed residences. The mixed residences espouse individual and miscellaneous breakdowns and this discovery influences the level of investigation which one can pursue due to a lack of detail within the quantitative data.

It was decided to use two of these factors, the hot water consumption and kitchen configuration, as well as the gender of the residences, to create clusters of similar residences. Gender was considered as the energy behaviour of males could possibly be different to that of females. The three variables decided upon for comparative investigations of the residential energy profiles were, therefore, differences in gender, type of water heating technology used and type of kitchen configuration. These are summarised in Table 10: Differences in the variables used to investigate energy consumption of residences.

Table 10: Differences in the variables used to investigate energy consumption of residences

Gender (Hendrikse,2008:Personal Communication; Preller, 2008:Personal Communication)	**Water Heating System** (Krige, 2008: Personal Communication)	**Kitchen configuration** **(**Preller, 2008:Personal Communication; Matthews, 2008:Personal Communication)
Female Male Mixed (female and male)	Heat pump (individual or shared) Geysers (multiple) Multiple geysers each use electrical elements to heat water Central storage tank (This makes use of a large electrical element to heat the water in one central location.)	Preparation and serving of food for residence via one central kitchen Preparation and serving of food for residence and the preparation of food for another residence via one central kitchen Serving of food for residence via one central kitchen (preparation of food done elsewhere) Preparation and serving of food for residence via one central kitchen and a cafeteria Kitchenettes(multiple) Kitchenettes and serving of food for residence via one central kitchen

The process of collecting the above data involved scheduling appointments with the relevant individuals at Admin A, Maintenance and Operations, and the Facilities Management departments. The structured, linear representation of the findings does not map the oscillating, time consuming and tedious reality of the actual experience. It also does not map the patience and helpfulness of the mentioned individuals who were prepared to aid in this research process.

The processing of this quantitative data was done in Microsoft Excel. In particular, creating one database that contained the monthly total, annual total and breakdown of energy consumption in kWh for each residence was a large data processing task of the thesis. For each of the 28 residences, the *relevant* residential, kitchen and hot water (where applicable) energy consumption amounts for each of the 12 months in years 2003, 2004, 2005, 2006 and 2007 was extracted and organised into one database from 25 folders containing the primary data (provided by the US Energy Manager). The annual totals were then derived from these monthly database sets. Microsoft Excel processing advice was sought from the Statistical

Consultation Department at Stellenbosch University, under the assistance of Professor D.G Nel.

3.4.2. Selecting the case study

Deciding which residence to select as a case study was a process within the research journey. It explicitly stated that this would form part of the research process in the submitted thesis proposal. The emergent characteristics that resulted in selecting Lydia Residence as the case study are examined below and, thereafter, the research processes within Lydia Residence are explained.

Selecting Lydia Residence was the emergent product of three parallel tasks undertaken when the practical research began in February 2008. The three tasks are presented below and their written separation might give the impression of a linear process in which one task followed the other. In practise, they occurred simultaneously and the respective results had to be coordinated. Firstly, the quantitative data had to be processed and, according to the selection criteria explained below, several case study residences were planned on being selected. Secondly, the credibility of performing an energy audit, as a non engineer, had to be established. Lastly, the context of Stellenbosch University had to be explored for any viable examples of sustainable living and, possibly, sustainable energy use. The outcomes of these three tasks culminated in presenting Lydia Residence as the best choice for a case study for this thesis. These three tasks, in the order used above, are discussed in more detail below.

Initially, an objective, positivist and empirical approach, based on the quantitative data generated by the macro research process, was decided upon to select several case study residences. Based upon the three selected variables and their corresponding quantitative energy consumption, it was decided to create clusters of similar residences. Ideally, two to five clusters, each with the same gender, water heating systems and kitchen configuration would evolve from this organising of the data. Thereafter, one case study from each cluster could be selected so that several and not all the 28, residences on the list could represent the campus as a whole and, logistically, make it possible to study them physically. However, by using the specific three factors mentioned, 11 groups of clusters emerged. The results of this exercise are summarised below in Table 11.

Table 11: Creating clusters from the residences based on similarities in gender, water heating systems and kitchen configuration

No of cluster	**Gender**	**Water heating system**	**Kitchen configuration**	**Residences**
1.	Female	Heat pump	Preparation and serving of food to the specified residence	Erica Irene Nemesia Serruria Sonop
2.	Female	Heat pump	Preparation and serving of food to the specified residence and preparation of food for another residence	Harmonie Huis Ten Bosch Minerva
3..	Female	Heat pump	Serving of food to residence(preparation of food done at another residence)	Heemstede Lydia Monica Nerina
4.	Male	Heat pump	Preparation and serving of food to specified residence	Eendrag Helderberg Helshoogte Huis Marais Huis Visser Wilgenhof
5.	Male	Heat pump	Preparation and serving of food to specified residence and preparation of food for another residence	Dagbreek Simonsberg
6.	Male	Heat pump	Serving of food to residence(preparation of food done at another residence)	Majuba
7.	Mixed	Geysers	Kitchenettes	Academia Huis MacDonald Lobelia
8.	Mixed	Central storage tank	Kitchenettes	Concordia
9.	Mixed	Geysers	Kitchenettes and serving kitchen	Goldfields
10.	Mixed	Heat pump	Kitchenettes	Huis De Villiers
11.	Mixed	Geysers	Preparation and serving of food to specified residence and cafeteria	Metanoia

To physically audit eleven residences with the hope of gaining an intimate and personal feel necessary for a micro case study, in the time span available for the thesis, was logistically not feasible. Therefore, it was decided to theoretically compare these clusters against any trends or anomalies noticed within the kWh/student of the respective clusters' energy consumption and identify key interventions points to promote sustainable energy use amongst the residences.

While the processing of the quantitative data was taking place, local awareness and practise of sustainable energy on Stellenbosch campus was investigated. Personal discussions and contact meetings with individuals who were involved in promoting and practising sustainable living on campus were conducted and an award ceremony for the 2007 US Energy Challenge evolved as a significant event to attend for research purposes.

This award ceremony was hosted by the Environmental Affairs Portfolio of the SRC and the prize sponsors, Eskom (Energy Challenge Award Ceremony, 2008). The award ceremony was attended so that the winning residence could be used as a starting point for the investigation to identify and investigate the factors that had possibly influenced the residences' energy winning.

At the Energy Challenge Award Ceremony, Michael Leslie, the SRC member in charge of Community Development and Environmental Affairs, introduced me to Lydia Willems, the house mother of Lydia Residence before the event began. Upon meeting Willems it became clear that she, as an individual, was passionate about implementing changes on campus that would stimulate sustainable behaviour. During the award ceremony she gave a presentation, in her private capacity, to the few students who attended the event, about the need for sustainable living. The prize ceremony later that evening revealed that Lydia Residence had won the Energy Challenge. I approached Willems after the event about my intention to investigate the winning residence and she was very enthusiastic about working together to examine the energy profile of Lydia Residence.

An introductory interview with Lydia Willems was conducted (Willems, 2008: Introductory interview) with the intention of establishing a relationship with her. Willems was an individual who came across as enthusiastic about sustainable issues, holds a leadership position with a residential organisational structure and had actually been involved in implementing energy efficiency in Lydia Residence. This combination created a local knowledge node that could be accessed for the thesis as it would contribute towards informing an understanding of implementing sustainable energy solutions amongst the residences of Stellenbosch University. In essence, Lydia Residence and Willems, as a story, told a historical narrative of the research objective and for this reason would be a source to investigate and document, regardless of whether or not Lydia Residence was used as a case study for the micro research process.

Willems could offer insightful guidance with regards to understanding the context in which sustainable energy solutions for the residences of Stellenbosch University need to be implemented. An individuals' story was recognised and this narrative is woven into the research findings to document and distribute to the larger research community. Willems' story is explicitly subjective and is informed by her particular history and current context. This in not objective knowledge but one person's opinion and it is not presented as 'the' voice of implementing sustainable energy solutions amongst residences but as 'a' voice. This is in line with making use of local, 'indigenous' knowledge and the use of 'know how' that results from personal experience.

During this time, the technical expertise required to credibly perform an energy audit of a building was also being investigated. The available literature suggests that a lay person can indeed perform a general energy audit of a building (Omer, 2008: personal communication) and local energy audit experts (Grobler, 2008: telephonic communication; Nicol, 2008: telephonic communication) acquiesced to this. However, details about the electronic infrastructure of a building (Nicol, 2008: telephonic communication) and specialised mechanical equipment would require professional knowledge to be accurately investigated. Opting for a prudent approach, it was decided to seek technical assistance with regards to the energy audit so as to secure the technical credibility of the process.

Commercial energy audits can cost between R15 000 and R 70 000, depending on the size of the building. This was financially unfeasible and compounded by the fact that, at the time, several residences were being considered for energy audits. A search of an energy auditor who would offer the technical services for free or in exchange for something was embarked upon. The Centre for Renewable and Sustainable Energy Studies (CRSES) was approached for technical assistance with regard to an energy audit in exchange for promotional marketing for the CRSES. However, the Director of the Centre, Professor Wikus van Niekerk, pointed out that this type of marketing was not ideal and suggested that the Electrical Engineering Department be contacted as they conduct audits for a fee or to approach the owner of the building - the University - as they are the beneficiary of an energy audit (Van Niekerk, 2008: email communication).

At the same time, Lodine Redelinghuys, an Energy Services Manager at Eskom's Distribution Department, whom I had met at the 2007 US Energy Challenge award ceremony, was also approached. She responded that Eskom could offer an engineer to assist with an energy audit of Lydia Residence with the hope of later measuring the energy consumption once the suggested changes from the Eskom prize money of R5 000 had been installed (Redelinghuys, 2008: email communication). An opportunity which provided the technical credibility without having to find financing for it presented itself. The three tasks explained overhead, which took place during January and February 2008, met at the following crossroads and culminated in the final decision to select Lydia Residence as the case study:

- No clear meta system to objectively select a manageable number of case studies to physically audit evolved. The case studies would have to be subjectively selected because of their anomalies or unique energy characteristics.
- The residence that won the 2007 US Energy Challenge would be used as a starting point for investigation. This was done to isolate and document the contributing factors, if any, towards energy efficiency espoused by the residence to contribute towards the larger knowledge pool available to all residences to implement energy efficiency within the residences.
- While acquainting myself with Willems it had become clear that the winning residence was a living example of an individual in a leadership position with commitment to and experience of implementing sustainable energy solutions in the context of the unit of analysis in this thesis, the residence.
- An attempt to secure a credible energy auditor without the commercial price was initiated.
- Eskom proposed that they were willing to supply an energy auditor, free of charge, and for Lydia Residence, in exchange for identifying key areas of intervention for

energy efficiency within the residences, which aligned well with the research objective.

Lydia Residence therefore presented itself with three valuable resources for the research objective: an energy auditor for free, a living example of implementing energy efficiency within a residence of Stellenbosch University, and a very enthusiastic and willing individual in a leadership position within a residential infrastructure who understood the ideology of sustainable energy solutions. Practically, ideologically and logistically, Lydia Residence emerged as an ideal case study.

The way forward was, therefore, based on a single case, holistic research design (Yin, 2003:39-55). It is single case as only one residence and not multiple residences are being reviewed and it is holistic as there is one unit of analysis. 'Overall, the single case design is eminently justifiable' (Yin, 2003:45) if the case represents the critical testing of existing theory; is a rare or unique circumstance; is a typical representative case; is revelatory because it is the first case that allows investigation into a topic; or is longitudinal and allows a 'before' and 'after' comparison. Lydia Residence's winning of the energy challenge as a starting point of investigation is revelatory in the context of the unit of analysis as never before has anyone accessed the data and performed a study on the 'most energy efficient' residence on the Stellenbosch campus. For the research objective, the case study serves as a critical case study which will 'confirm, challenge or extend' (Yin, 2004:40) the argument summarised in the literature review.

3.4.3. Processes with the case study residence

Four activities or processes were undertaken in order to identify the key areas for intervention in Lydia Residence to implement energy efficiency. The first was to investigate reasons why Lydia Residence won the 2007 US Energy Challenge. Research on Lydia Residence was conducted with the organisational assistance and ideological support of Willems. Throughout the year, a relationship developed between Willems and myself, via personal and email communication, in which ideas and thoughts were exchanged. These thoughts and ideas have been documented to make explicit a dialogue of change. This documentation, as mentioned earlier, is presented in an explicitly subjective manner and with the acknowledgement that both Willems and I discussed ideas with a particular agenda: wanting to see how sustainable energy solutions can be implemented in the residences of Stellenbosch University.

The second process was a general walk-through energy audit of Lydia Residence, conducted on 11 March 2008. Riyaad Omer, a mechanical engineer and Energy Services Manager at Eskom who performs energy audits as part of his daily working schedule and I performed this audit. We were accompanied by a member of the Lydia Residence HK.

The general walk-through energy audit of Lydia Residence was characterised by three key activities, based upon Omer's guidance and two case study examples (Eskom, 2003; Washington State University). Firstly, any structural features which could influence energy consumption were noted. Secondly, a light audit was performed according to the details in Table 12 and ballast details were noted. Lastly, an appliance audit was performed according to the details in Table 13. Two private rooms were also viewed. The three processes rely on observational accounting and auditing and were thus aided by photographic evidence.

Table 12: Guidelines for conducting a light audit

Room/Area	**Type of lighting**	**Quantity of lighting**	**Power rating of light (W)**	**Estimated time span that lighting is left on(hours)**

Table 13: Guidelines for conducting an appliance audit

Room/Area	**Appliance**	**No of appliances**	**Power rating of appliance(W)**	**Estimated time span that appliance is left on (hours)**

With regard to the time span for which the appliance or lighting was left on, we had to ask those around us, senior members, members of the HK and Willems about estimated time uses of lights and appliances. This ad hoc procedure jeopardises the accuracy of the timing amounts presented in the findings. For example, how would anyone know, for certain, how long the passage lights are kept on for? One of the nightly duties of the HK is to switch off the lights at 23:00 but this is not to say that they will not be switched on again and left on. The kitchen staff were able to provide more accurate daily averages of time intervals for the lights and appliances used in the dining room and serving kitchen as the kitchen is opened and closed at three specific times each day. We could therefore estimate very general and most likely cases and the specified time intervals in the findings are therefore no claim to accurately measured time periods.

Access to the girls' private rooms was not allowed and we therefore only saw two individual ladies students' rooms. A profile of the typical lighting and appliance products used was not deduced from the general walk through energy audit due to lack of access. The lack of access to students' rooms gave birth, however, to the idea of an energy survey to determine the typical profile of a student room in Lydia Residence.

The energy survey also created the opportunity to investigate what type of behavior, with regards to appliance use, showering habits, eating habits and clothes washing habits by the students of Lydia Residence, could possibly be influencing the energy profile of Lydia Residence.

The unit of measurement in this thesis for evaluating energy consumption is kWh. The energy survey was, therefore, not an attempt to establish numerical data but instead to investigate perceptions about personal energy use.

A questionnaire for the survey was designed, with input from Willems and Omer. Survey methodology (Babbie and Mouton, 2008:229-267; Mouton, 2001:152-153) emphasises that the effect of a survey depends on its sensitivity to the context and participants. The historical popularity of using surveys by social scientists has allowed common errors to be thoroughly identified and documented. When conducting a survey one should try and avoid ambiguity, double barreled questions, negative items, long items, irrelevant questions and bias. Be aware of the respondents' language, competency to answer the question and willingness to complete the survey. With regards to the actual format of the survey, make sure it is clear, well laid out and the order of questions is logical. Very clear instructions on how to answer the question (for example, tick the box or cross the circle) are necessary to avoid confusion. Structure and present contingency and matrix questions so that they do not lead to confusion. Ideally, a survey should be pre tested so that any possible misunderstandings can be noticed and changed. The following 13 questions below constitute the Energy Survey which was handed out on 16 April 2008 amongst the students of Lydia Residence at the house meeting. A technical explanation for why each question was asked is included (in italics).

Figure 12: Questionnaire designed for Lydia Residence energy survey

Dear Lydia resident

Lydia Energy Survey (1 – 13): Please would you kindly complete this questionnaire. It will aid in the research which is investigating why Lydia won the energy efficiency award for the month of August 2007 from Eskom. Please be honest and understand that the answers are both anonymous and that this questionnaire will in no way be used to come and investigate your room. In attempting to find energy efficient solutions, your honesty will aid in highlighting key areas for improvement.

Lydia Food provider Survey (14 -18): Please complete even if you never eat a meal.

1. Please tick and fill in the table below.
   PLEASE TICK FOR YES AND DRAW A CROSS FOR NO

Do you use this appliance in your room?	Do you share this with your roommate?	For how many hours, approximately, would you put this appliance on **in one day**?	
Kettle			
Toaster			
Study Lamp			
Summer Fan			
Winter blow heater			
Element heater			
Laptop			
PC			
Fridge			
Hairdryer			
Cell phone charger			
Warming blanket			
Radio			
OTHER?			

This question was intended to establish a 'student room profile' for a typical student of Lydia Residence to determine what types of appliances were generally being used in the rooms and which appliances were being used the most.

2. If you have a computer, what screen do you have?

   LCD

   OLD PLASMA SCREEN

Question 2 was asked based on the energy efficiency debate between plasma and LCD (Liquid Crystal Display) screens. Digital screens (LCD and plasma) have begun to replace cathode tube rays (CRT) screens recently and the digital versions are more energy efficient than the older CRT models (Ecos Consulting, 2008; Energy Star, 2008b; Raskin, 2007). With regards to the choice between LCD or Plasma screens, LCD screens are generally considered more energy efficient. Plasma screens require light illumination for each pixel whereas LCD screens make use of a constant light source in the background and the pixels act so as to block out the light to form an image (Raskin, 2007). The constant, steady flow of light in the LCD generally (depending on the degree of solid background colour of the screen) demands less power than the continuous switching on an off needed for the individuals pixels in a Plasma screen.

3. Do you usually switch your computer/laptop off when you are finished with it or do you leave it on or put it in standby mode?

   SWITCH IT OFF

   LEAVE IT ON

   STANDBY

This question, based on the recent findings that standby power cumulatively contributes towards a significant energy consumption, was therefore asked to investigate behavioural *patterns with regards to laptop and computer use, especially since many students possess them.*

4. When you switch an appliance off do you

   MAKE USE OF THE OFF BUTTON ON THE APPLIANCE

   SWITCH OFF THE SWITCH AT THE PLUG

   PHYSICALLY UNPLUG THE APPLIANCE AT THE SOCKET

This question was asked to test to what limits students would go to switch an appliance off.

5. Do you find the light provided by the main light in your room sufficient (i.e. You would not need the additional lighting of a desk lamp?

   YES

   NO

During the walk through energy audit of Lydia Residence, a few students complained that the ceiling lighting in the rooms, which had been replaced with CFL bulbs, did not suffice in terms of brightness for studying purposes. This question was posed to a broader audience to confirm or dispute this complaint.

6. a) Do you know what light bulbs are being used for your study/desk lamp?

   YES

   NO

Question 6a was intended to investigate the level of awareness amongst the students of Lydia Residence with regards to knowing which type of light bulb they had purchased.

   b) If you do, is the light bulb in your study desk lamp a :

   CFL

INCANDESCENT

HALOGEN

Question 6b was used to scrutinise the answer given in 6a and to confirm who really does know which light bulb exists in their study/ desk lamp.

7. How many times a day do you shower ?

   ONCE

   TWICE

   THREE TIMES

This question was posed to generate bathing trends, which make use of warm water, which could affect the energy consumption.

8. How long do you usually shower for?

   5 MINUTES

   10 MINUTES

   15 MINUTES

   20 MINUTES

   25 MINUTES

   30 MINUTES

   35 MINUTES

Question 8 was posed to contribute towards investigating bathing trends within Lydia Residence.

9. What time of the day do you usually shower ?

   05:00-06:00

   06:00-07:00

   07:00-08:00

Question 9 was asked to establish bathing peaks within Lydia Residence.

10. What do you use the kitchenettes for?

    PREPARE SNACKS

    PREPARE MAIN MEALS

    MICROWAVING FOR HEATING

    MAKING TOAST

    PLUGGING IN MY OWN GRILL OR FRYING PAN TO PREPARE FOOD

Question 10 was posed to determine which appliances within the kitchenettes are actually being used by the students of Lydia Residence.

11 . Would you make use of a low flow shower head, knowing that it saves energy and water, but also knowing that the effect of the shower will not be as powerful?

    YES

    NO

    INDIFFERENT

Question 11 was intended to test the attitudes towards accepting an energy saving technology even if it did affect the quality of the experience.

12. Do you always switch the lights to your room off when you leave?

YES

NO

USUALLY

SOMETIMES

DO NOT KNOW

This question was asked to determine the students' perceptions of their energy saving behaviour.

13. Do you make use of the washing machines and tumble dryers?

WASHING MACHINE ONLY

WASHING MACHINE & TUMBLE DRYER

TUMBLE DRYER EVERY TIME

TUMBLE DRYER SOMETIMES

THE WASHING LINES (SUN DRYING)

DON'T USE THE FACILITIES AT ALL

Tumble dryers and washing machines are appliances which have a high power rating, due to their heating functions. The industrial tumble dryers in Lydia Residence are rated between 4 and 5.2 kW while the washing machines are rated at 0.6 kW. This question was posed to determine how often these appliances are used.

This questionnaire was distributed to students on arrival at the House Meeting of the Lydia Residence on 16 April 2008. Willems gave a talk about environmental issues and the reasons for conducting the energy survey were explained. A chance for questions or misunderstandings with regards to the questions was posed to the audience. The only question which was asked regarded a clarification of what the differences between a CFL, incandescent and halogen light (re: Question 6a) were. I explained that a CFL referred to energy saving bulbs, incandescent bulbs were the traditional bulbs which gave a warm, yellow light while halogens usually emitted a very bright, white light. The students of Lydia Residence were given a chance to complete the questionnaire while I was there and then proceeded to hand them in. The completed questionnaires were collected by myself that evening.

Allocating the Eskom prize money on energy efficiency in Lydia Residence was the fourth and final process conducted with Lydia Residence. Lydia Residence was awarded R10 000 from Eskom as the winning residence of the 2007 US Energy Challenge with the agreement that R5 000 of the prize money had to be spent on energy efficiency. Attempting to distribute the R 5000 on energy efficiency within Lydia Residence was a source of inquiry that aligned itself with the research objective and could therefore contribute towards finding energy efficient solutions that were possible with meagre funds. The relative energy savings on annual energy consumption as well as the payback periods for several technological options were calculated so as to generate indicators for decision makers.

3.4.4. Participation

The participation with the Environmental Affairs subcommittee, via Micheal Leslie, the SRC member for the Community Development and Environmental Affairs Portfolio, for the reason of assisting with the 2008 US Energy Challenge, contributed to generating knowledge regarding contextual solutions. This interaction, which emerged as a process from the research investigation and was not a premeditated requisite of the research journey, contributed towards informing the research results.

My personal interaction and participation with the SRC and the subsequent HK orientation for the 2008 US Energy Challenge and for the 2009 HK Green portfolios' was an unexpected consequence of the process but it generated insights which can contribute towards the research objective. It was therefore not governed by any controlled, pre planned methodology.

3.5. Limitations of the research methodology, design and process

The quality of data is subject to possible shortcomings and these need to be highlighted. The research methodology and process of this particular research journey was marked by several limitations and these are explained in this section.

Firstly, the inherent limitations of the chosen research designs exist. The SDA depends on the accuracy of the metering done by other individuals and by the relevant individuals accuracy in relaying information to the researcher as well as the lack of human error on the researchers behalf when processing the quantitative data. The single case study approach has been critiqued on several grounds but its applicability to the research objective is necessary and the 'inability' of a case study to inform generalisations was contested when the findings revealed that, due to the diversity in variables, generalisations would most likely not be helpful for the research objective.

Secondly, the logistical feasibility involved of studying a residence was underestimated. It added a dimension of complexity to the research process which was more significant than anticipated. Residences are governed by certain rules and, not being a resident of Lydia Residence, the researcher was not excused from the protocols that govern residential behaviour for non - residents. Coordinating meetings with the pertinent individuals, residential gatherings and technical viewings or installations within Lydia Residence required organisational skills on my behalf that maximised the time available to complete the research.

The third limitation concerns the available primary data which was used. If residences share a heat pump or kitchen, the energy meter reads the combined energy use and their relative portions are determined by allocating values according to their relative official capacity and not their real use. Because official capacity was used, the actual number of students was neglected. For larger residences this will not make a large difference to their energy/student rating but for the smaller residence it is significant factor affecting the intensity of their kWh/student rating.

Fourthly, limitations regarding the four processes with Lydia Residence can be summarised in Table 14. They were focused upon the logistics of implementing processes within a residence and wrongly assuming a certain level of technical awareness amongst the students.

Table 14. Limitations of processes with the case study residence

Process with case study residence	**Noted limitation**
Relationship with Lydia Willems	No significant error. The subjective bias of the subject has been acknowledged.
Energy Audit	Inability to accurately predict the time periods. Several appliances did not have power ratings on the labels. Could not identify power ratings of appliances and lights in rooms.
Energy Survey	A better description of the technologies or visual representation (pictures) should have been provided in the survey to explain CFL, halogen, incandescent, LCD, plasma screen, low flow showerhead The awareness regarding how the variables of power and time affect energy use should have been investigated Could not identify power ratings of appliances and lights in rooms.
Allocating the Eskom prize money towards energy efficiency	Lack of rigorously accurate data to calculate energy savings and payback periods; general estimates used

3.6. Chapter Summary

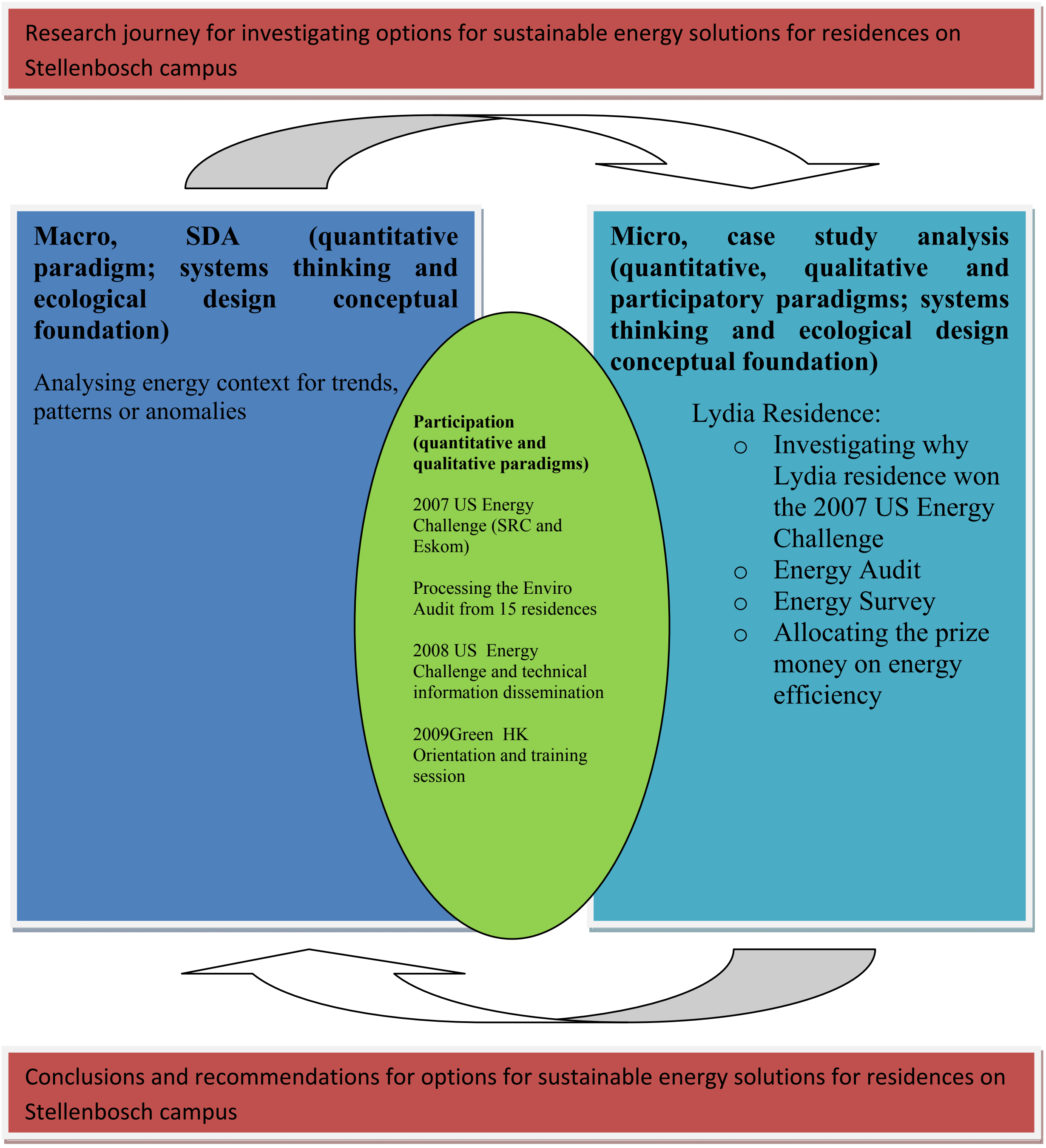
In summary, the research methodology, design and process was described in this chapter. Quantitative and qualitative methodological paradigms have informed the ontological and epistemological assumptions of the research objective. The subsequent 'macro' and 'micro' processes are respectively reflected by SDA and a holistic, single, case study research design as useful strategies to guide the exploratory nature of the research objective.

The macro, SDA, informed primarily by quantitative data sourced from the relevant individuals within the institutional structure of Stellenbosch University, aids the research objective by establishing the context. Without knowing what influences residential energy consumption, sustainable energy solutions cannot be suggested. The macro process therefore provides the first step of the research objective: it helps to identify where sustainable energy solutions need to be implemented.

The micro, holistic, single, case study with Lydia Residence, informed by qualitative and quantitative paradigms, is necessary to move the argument forward for three important reasons. Firstly, a case study allows for an intimate interaction with the behavioural trends of residential living - the quantitative data cannot capture the complexities involved in behavioural dynamics. Secondly, the technological focus on energy efficiency requires an understanding of the built environment in which retrofits are going to take place: the unit of analysis has to be able to accommodate new technology. Lastly, Lydia residence is particularly relevant as a case study because they are the first residence to win the US Energy Challenge (by a significant margin) and espouse leadership behavioural dynamics which have been very committed to sustainable living. The subsequent processes with Lydia Residence all analysed options of energy efficient technology which aided the research objective by suggesting what should be implemented.

The findings of the quantitative data from the macro, SDA are presented in the following chapter (Chapter 4) and the findings from the micro case study are presented in Chapter 5. Figure 13, on the next page, is a summarised schematic representation of the journey (research methodology, design and process) planned to investigate the research objective of this thesis.

Figure 13: Schematic representation of research methodology, design and process



Chapter 4: General findings of the macro secondary data analysis

4.1. Introduction

The general findings presented below aid the research objective by establishing the context. The context referred to here is the energy consumption of the respective residences. Establishing a context reveals patterns, trends and anomalies so that broad areas of intervention can be identified. The findings, therefore, point to the direction where technological solutions should be implemented whereas the findings of the next chapter suggest which technological solutions suggested in the literature review should be applied.

A significant finding was that the context is characterised by diversity in the variables that influence energy consumption. Creating sustainable energy solutions for a diversity of variables implies that solutions will have to be tailor made for each residence. Due to differences in water heating technology and kitchen configuration, there is no 'one size fits all' solution for the research objective. This realisation navigated the research process on an altered course: sustainable energy solutions for the residences of Stellenbosch University will refer to an approach, or process, in which specific solutions for each residence are identified, as opposed to one technological 'magic bullet' that passes through them all.

The context was analysed according to annual and average energy consumption per student (kWh/student). Clear trends and points of intervention became apparent. This analysis revealed that the mixed residences, which make use of element heating and kitchenette systems, consume the most energy per student, followed by the male residences, which make use of heat pump water heating technology and centralised kitchens. The female residences, which make use of heat pump water heating technology and centralised kitchens, consume the least energy per student.

The analysis, therefore, suggests that male behavioural habits, element heating and kitchenette systems contribute to increasing energy consumption amongst residences of Stellenbosch University.

This chapter presents the general findings of the quantitative data processed from the variables identified in Table 10 (Chapter 3, section 3.4.1). The data is organised into three broad areas (in sections 4.2, 4.3 and 4.4) via several comparative tables. Section 4.1 documents the official capacity, kitchen configuration, water heating technology and total surface area, respectively, of each residence. Two significant findings stem from this section: the diversity of variables that influence energy consumption and the discovery of heat pump technology as the most prominent water heating technology. Section 4.2 is concerned with total annual energy consumption and a sector breakdown of residential, kitchen and hot water usage, measured in kWh, for each residence. The energy ratios of kWh/m² and kWh/student are presented in section 4.3. The data presented above is now also available to interested residential leaders who wish to know their residential energy profile better for effective decision making. The energy consumption per student ratios (kWh/student) provide the basis for the energy analysis that follows[11]. The energy analysis documents the trends that highlight certain behavioural tactics which need to be investigated via a case study. Finally, an investigation into heat pumps affirms that they are energy efficient and financially feasible for the context.

4.2. Presentation of variables affecting energy consumption of residences

The four tables presented below reflect four different variables for each residence: official capacity, kitchen system, water heating system and surface area. This data was initially needed to select a case study and it provided the criteria against which energy consumption was evaluated. By revealing a variety of differences with regards to the variables, especially within the kitchen configuration and water heating technology, the four tables also signal a significant turning point in the research objective.

The variables presented below are broad sets of distinctions: their particular complexities were not detailed and could possibly bring another level of complications to the fore. This indicates that residences do not consume electricity in the kitchen, bathrooms and residential living spaces in exactly the same way. Therefore, there is not going to be one solution for all the kitchen or water heating systems and recommendations will need to take male behaviour into account while other suggestions will have to take female behaviour into account. Technological suggestions will have to be adapted to each residence or groups of similar

[11] It was decided to evaluate comparative residential consumption according to one ratio (kWh/student and not kWh/m²) to ensure a consistent evaluation throughout the thesis.

residences. This is significant as it implies that the research objective – investigating sustainable energy options for the residences of Stellenbosch University – will be met by an approach or paradigm that can be adapted to inform decision making as opposed to a list of suggested technological renovations.

Two important observations further evolve from the variables presented in the four tables below. The first is that the female and male residences have the same water heating technology (heat pump, either shared or individual) and central kitchen systems (of which three varieties exist) while the mixed residences have element heating systems (the exception being Huis de Villiers which makes use of a heat pump) and kitchenette kitchen systems (the exception being Metanoia which makes use of a central kitchen and a cafeteria, as well as Goldfields which makes use of a serving kitchen too).

The second observation is that heat pumps are used in many of the residences. As stated in Chapter 2, the literature review, the COP of heats pumps translates to successful efficiencies. The data reflected in Table 17: Comparison of residential water heating systems technologies, 2007 clearly indicates that the water heating technology of the residences is dominated by an energy efficient technology, a decision backed by top management. However, the most recently built residence, Metanoia, makes use of traditional geysers to heat water.

In conclusion, the presentation of the variables informed the research objective with three insights. Firstly, sustainable energy solutions will need to consider the reality that the residences have different technologies governing their kitchen and water heating needs. This variance suggests that sustainable energy solutions would be better suited as a strategy that can be adjusted accordingly as opposed to a definitive plan that will not be flexible for individual contexts.

Secondly, all male and female residences as well as one mixed residence use heat pumps. A sustainable energy solution for the water heating technology, in the case of the relevant residences, already exists. Thirdly, the single sex residences make use of centralised systems for their hot water and kitchen needs whereas the mixed residences rely on decentralised systems for their hot water and kitchen needs. This is important for the research objective as it influences the degree of control over influencing behaviour and identifying which appliance should be focused upon.

Table 15: Comparison of residential student official capacity, in numbers of persons, 2003–2007

Residence	Official Capacity[12]				
	2003	2004	2005	2006	2007
Erica	193	193	193	193	193
Harmonie	161	160	160	160	160
Heemstede	229	228	229	229	229
Huistenbosch	168	168	171	168	168
Irene	164	164	164	164	164
Lydia	182	185	185	183	183
Minerva	231	264	264	264	264
Monica	134	134	134	134	134
Nemesia	193	192	193	192	192
Nerina	231	260	260	260	260
Serruria	193	193	193	193	193
Sonop	262	263	270	263	263
Eendrag	263	263	279	263	263
Helderberg	327	327	330	330	330
Helshoogte	326	270	323	326	326
Huis Marais	117	117	120	117	117
John Murray-huis (Dagbreek)	368	368	368	380	380
Huis Visser	117	117	122	117	117
Majuba	151	151	162	151	151
Simonsberg	272	272	279	272	272
Wilgenhof	189	189	189	189	189
Academia	552	672	792	792	792
Concordia	200	200	200	200	200
Goldfields	152	152	154	154	154
Huis de Villiers	160	166	166	166	166
Huis MacDonald	51	51	51	51	51
Lobelia	60	60	60	60	60
Metanoia	0	0	495	495	496

[12] Official capacity refers to the stated capacity according to Student Administration. In reality, the actual capacity could be slightly less or more.

Table 16: Comparison of residential kitchen systems, 2007

Residence	Kitchen System
Erica	Preparation and serving (Tienie Louw :Erica, Nemesia, Serruria)
Harmonie	Preparation (Harmonie + Monica)
Heemstede	Serving (Huis Ten Bosch+Heemstede)
Huistenbosch	Preparation (Huis Ten Bosch+ Heemstede)
Irene	Preparation and serving
Lydia	Serving (Minerva+Lydia+Nerina)
Minerva	Preparation (Minerva + Lydia+Nerina)
Monica	Serving (Harmonie + Monica)
Nemesia	Preparation and serving(Tienie Louw :Erica, Nemesia, Serruria)
Nerina	Serving(Minerva+Lydia+Nerina)
Serruria	Preparation and serving(Tienie Louw :Erica, Nemesia, Serruria)
Sonop	Preparation and serving
Eendrag	Preparation and serving
Helderberg	Preparation and serving
Helshoogte	Preparation and serving
Huis Marais	Share preparation and serving (Huis Marais+Huis Visser
John Murray-huis (Dagbreek)	Preparation (Dagbreek + Majuba)
Huis Visser	Share preparation and serving (Huis Marais+Huis Visser
Majuba	Serving (Dagbreek+Majuba)
Simonsberg	Preparation (Simonsberg + Goldfields)
Wilgenhof	Preparation and serving
Academia	Kitchenettes
Concordia	Kitchenettes
Goldfields	Kitchenettes and serving kitchen (Simonsberg+Goldfields)
Huis de Villiers	Kitchenettes
Huis MacDonald	Kitchenettes
Lobelia	Kitchenettes
Metanoia	Preparation and serving and cafeteria

Key

Preparation and serving	One central kitchen used to prepare and serve food to residence by a contractor
Preparation	One central kitchen used to prepare and serve food to residence and food prepared for another residence by a contractor
Serving	One central kitchen used to serve food to residence, food is prepared elsewhere by a contractor
Kitchenettes	Several small kitchenettes which students use to prepare food themselves
Kitchenettes and serving kitchen	Several small kitchenettes which students use to prepare food themselves and one central kitchen used to serve food to residence, food is prepared elsewhere

Preparation and serving and cafeteria	One central kitchen used to prepare and serve food to residence by a contractor and a 'ready to eat' cafeteria

Table 17: Comparison of residential water heating technologies, 2007

Residence	Water heating technology
Erica	Heat pump:Erica/Nemesia/Serruria
Harmonie	Heat pump
Heemstede	Heat pump
Huistenbosch	Heat pump:Lydia/Huis Ten Bosch
Irene	Heat pump
Lydia	Heat pump:Lydia/Huis Ten Bosch
Minerva	Heat pump:Nerina/Minerva
Monica	Heat pump
Nemesia	Heat pump:Erica/Nemesia/Serruria
Nerina	Heat pump:Nerina/Minerva
Serruria	Heat pump:Erica/Nemesia/Serruria
Sonop	Heat pump
Eendrag	Heat pump: Eendrag/Helshoogte
Helderberg	Heat pump
Helshoogte	Heat pump: Eendrag/Helshoogte
Huis Marais	Heat pump:Dagbreek/Huis Marais/Huis Visser
John Murray-huis (Dagbreek)	Heat pump:Dagbreek/Huis Marais/Huis Visser
Huis Visser	Heat pump:Dagbreek/Huis Marais/Huis Visser
Majuba	Heat pump
Simonsberg	Heat pump
Wilgenhof	Heat pump
Academia	Geysers
Concordia	Central storage tanks
Goldfields	Geysers
Huis de Villiers	Heat pump
Huis MacDonald	Geysers
Lobelia	Geysers
Metanoia	Geysers

Table 18: Comparison of residential surface area, in square metres, 2007

Residence	Total m²
Erica	4084
Harmonie	4589
Heemstede	5392
Huistenbosch	3065
Irene	5097
Lydia	5384
Minerva	6272
Monica	3804
Nemesia	4084
Nerina	6912
Serruria	4084
Sonop	4513
Eendrag	10412
Helderberg	6832
Helshoogte	11362
Huis Marais	2787
John Murray-huis (Dagbreek)	12616
Huis Visser	2771
Majuba	4771
Simonsberg	8563
Wilgenhof	5560
Academia	22926
Concordia	5650
Goldfields	2391
Huis de Villiers	5423
Huis MacDonald	2033
Lobelia	1817
Metanoia	14817

4.3. Presentation of the energy consumption of residences

Five sets of data were identified in Chapter 3 (section 3.4.1) as an objective of the findings from the quantitative data of the macro view. Two of these data sets are included in Appendix A (monthly energy consumption of residences), two below (annual energy consumption of residences) and the last one (energy consumption per student in each residence) is included in the following section dealing with energy ratios. The data sets included as Appendix A are a breakdown of monthly energy consumption in kWh according to residential use, kitchen use, water heating use, and other, where applicable, for the chosen residences for the time period 2003 to 2007 and the subsequent total monthly energy consumption in kWh of the chosen residences for the time period 2003 to 2007.

A breakdown of the annual energy consumption in kWh according to residential use, kitchen use and water heating use for the chosen residences for the time period 2003 to 2007 is presented in tables 19, 20 and 21. The three tables reflect female, male and mixed gender consumption patterns, respectively.

Table 19: Female residences annual energy consumption in kWh according to residential use, kitchen use and water heating use, 2003-2007

Female residence	**Total annual consumption of energy in kWh**				
	2003	2004	2005	2006	2007
Erica					
Residential	197815	172864	152335	128617	165199
Tienie Louw kitchen(pro rata with Nemesia and Serruria)	86766	75102	80182	76403	79617
Hot water (pro rata with Nemesia and Serruria)	69974	70522	71737	73927	77310
Total annual	**354554**	**318489**	**304254**	**278947**	**322126**
Harmonie					
Residential	137585	131666	148192	124349	129391
Kitchen	103889	86525	101154	91643	102861
Hot water	73956	63605	60478	56168	61590
Total annual	**315430**	**281796**	**309824**	**272160**	**293842**
Heemstede					
Residential	146406	137795	162596	161689	162364
Kitchen	25389	23959	28876	22793	30706
Hot water	67683	61756	62227	57395	61180
Heemstede Anneks	28605	34646	28945	27393	25925
Total annual	**268083**	**258156**	**282644**	**269270**	**280175**
Huistenbosch					
Residential	139678	136904	141105	176773	214116
Kitchen	104859	100837	109181	40748	78567
Hot water (pro rata with Lydia)	83962	79146	71415	69499	76119
Total annual	**328499**	**316887**	**321701**	**287020**	**368802**

Irene					
Residential	137335	117220	118640	107267	110757
Kitchen	78631	75312	79961	76401	81144
Hot water	67935	67402	63752	56484	56937
Total annual	**283901**	**259934**	**262353**	**240152**	**248838**
Lydia					
Residential	130763	130705	151728	116243	118394
Kitchen	43329	43968	46489	41950	42286
Hot water(pro rata with Huistenbosch)	90958	87155	77261	75705	82915
Total annual	**265050**	**261828**	**275478**	**233898**	**243595**
Minerva					
Residential	167378	181738	215568	186130	199705
Kitchen	144336	133196	175605	161766	156411
Hot water(pro rata with Nerina)	76758	72035	74736	74334	80582
Total annual	**388472**	**386969**	**465909**	**422230**	**436698**
Monica					
Residential	163873	171730	175426	163356	179265
Kitchen	52678	57553	49519	43059	44037
Hot water	52285	54894	55228	54769	58428
Total annual	**268836**	**284177**	**280173**	**261184**	**281730**
Nemesia					
Residential	171934	163508	188567	166722	163374
Tienie Louw kitchen(pro rata with Erica and Serruria)	86766	74713	80182	76007	79204
Hot water(pro rata with Erica and Serruria	69974	70157	71737	73544	76910
Total annual	**328673**	**308378**	**340486**	**316273**	**319488**
Nerina					
Residential	169526	181979	182187	170857	175396
Kitchen	87980	104277	93092	90443	75689
Hot water (pro rata with Minerva)	76758	70943	73603	73208	79361
Total annual	**334264**	**357199**	**348882**	**334508**	**330446**
Serruria					
Residential	173467	171237	194184	173176	175690
Tienie Louw kitchen (pro rata with Erica and Nemesia)	86766	75102	80182	76403	79617
Hot water (pro rata with Erica and Nemesia)	69974	70522	71737	73927	77310
Total annual	**330206**	**316862**	**346103**	**323506**	**332617**

Sonop					
Residential	238894	231468	248473	240124	244766
Kitchen	106108	106292	106116	108096	126827
Hot water	110240	106970	99931	96442	102947
Total annual	**455242**	**444730**	**454520**	**444662**	**474540**

Table 20: Male residences annual energy consumption in kWh according to residential use, kitchen use and water heating use, 2003 - 2007

Male residence	**Total annual consumption of energy in kWh**				
	2003	2004	2005	2006	2007
Eendrag					
Residential	224121	221676	250758	249591	162506
Kitchen	210112	190316	189572	202239	185406
Hot water(pro rata with Helshoogte)	124482	130057	117894	113050	100208
Total annual	**558715**	**542049**	**558224**	**564880**	**448120**
Helderberg					
Residential	254030	262668	276499	245238	251874
Kitchen	149297	145881	155531	136680	145279
Hot water	140741	149157	130407	144488	146186
Total annual	**544068**	**557706**	**562437**	**526406**	**543339**
Helshoogte					
Residential	524727	524776	539440	484188	525545
Kitchen	117031	119860	115605	109462	104753
Hot water(pro rata with Eendrag)	154300	133519	136486	140130	124212
Total annual	**796058**	**778155**	**791531**	**733780**	**754510**
Huis Marais					
Residential	122090	102902	115811	128776	129989
Kitchen	60564	62058	63398	31755	75583
Hot water(pro rata with Dagbreek and Huis Visser)	53417	50204	52109	51720	53859
Total annual	**236070**	**215164**	**231318**	**212251**	**259431**
Dagbreek					
East wing residential	187074	165779	188568	171364	185026
West wing residential	123527	93287	110507	118526	103267
Kitchen	200250	225452	249337	244700	208337
Washing room	24927	21866	24406	28389	60348
Hot water(pro rata with Huis Marais and Huis Visser)	168012	157906	159801	167979	174928
Total annual	**703790**	**664290**	**732619**	**730958**	**731906**

Huis Visser					
Residential	108407	119867	141095	131523	125408
Kitchen	60564	62058	64455	31755	75583
Hot water(pro rata with Dagbreek and Huis Marais)	53417	50204	52978	51720	53859
Total annual	**222387**	**232129**	**258527**	**214998**	**254850**
Majuba					
Residential	176612	178001	157256	159588	161423
Kitchen	42145	42239	40724	40682	41873
Hot water	108050	105644	88636	90235	100192
Total annual	**326807**	**325884**	**286616**	**290505**	**303488**
Simonsberg					
Residential	277096	295105	315276	310971	326653
Kitchen	179123	179100	164103	168074	151637
Hot water	175619	160310	149431	139697	140713
Total annual	**631838**	**634515**	**628810**	**618742**	**619003**
Wilgenhof					
Residential	217332	212713	220141	225059	214776
Kitchen	148688	143459	140000	149332	153160
Hot water	84849	91949	90109	100784	98648
Wilgenhof IWH Woonstel	15357	15258	14113	13942	13938
Total annual	**466226**	**463379**	**464363**	**489117**	**480522**

Table 21: Selected mixed residences annual energy consumption in kWh according to residential use, kitchen use and water heating use, 2003-2007

Mixed residence	**Total annual kWh**				
	2003	2004	2005	2006	2007
Academia					
Academia sub 1	536735	533272	1025256	902967	974878
Academia sub2	853976	1220395	1407375	1315005	1337832
Total annual	**1390711**	**1753667**	**2432631**	**2217972**	**2312710**
Concordia					
Residential and Kitchen	245375	247889	277234	265147	282725
Hot water	317423	325195	322013	295779	296837
Total annual	**562798**	**573084**	**599247**	**560926**	**579562**
Goldfields					
Residential	209113	203541	206760	199486	185081

Entertainment/Dining hall	8372	8731	8432	6969	8128
Kitchen	21433	22452	25732	22038	22298
Caltex 1	17359	17934	16800	19355	21395
Caltex 2	22042	23298	24761	20461	22034
Heidehof (I W H Goldfields)	20784	18051	17656	18683	22156
Nagenoeg	20833	23383	24882	21643	22367
Toekoms	29998	35001	25809	27618	30073
Total annual	**349934**	**352391**	**350832**	**336253**	**333532**
Huis de Villiers					
Residential and Kitchen	293057	276089	303967	290982	306156
Hot water	90440	104160	96360	84760	91120
Total annual	**383497**	**380249**	**400327**	**375742**	**397276**
Huis MacDonald					
Residential, Kitchen and Hot water	204381	207496	199450	213659	182930
Inwonende Hoof: Huis MacDonald	13869	13618	15309	16297	16362
Total annual	**218250**	**221114**	**214759**	**229956**	**199292**
Lobelia					
Residential, Kitchen and Hot water	160200	162100	154500	173300	189300
Total annual	**160200**	**162100**	**154500**	**173300**	**189300**
Metanoia					
Residential and Hot water			161324	996844	1013200
Kitchen			9633	168722	171172
Metanoia Inwonende Hoof				10579	9517
Total annual			**170957**	**1176145**	**1193889**

The total annual energy consumption in kWh of the chosen residences for 2003 to 2007, summarised from Table 19, 20 and 21 above is consolidated and reflected in Table 22 below.

Table 22: Summary of residential total annual energy consumption in kWh, 2003 - 2007

Residence	**Total annual energy consumption in kWh**				
	2003	2004	2005	2006	2007
Erica	354554	318489	304254	278947	322126
Harmonie	315430	281796	309824	272160	293842
Heemstede	268083	258156	282644	269270	280175
Huis ten bosch	328499	316887	321701	287020	368802
Irene	283901	259934	262353	240152	248838
Lydia	265050	261828	275478	233898	243595

Minerva	388472	386969	465909	422230	436698
Monica	268836	284177	280173	261184	281730
Nemesia	328673	308378	340486	316273	319488
Nerina	334264	357199	348882	334508	330446
Serruria	330206	316862	346103	323506	332617
Sonop	455242	444730	454520	444662	474540
Eendrag	558715	542049	558224	564880	448120
Helderberg	544068	557706	562437	526406	543339
Helshoogte	796058	778155	791531	733780	754510
Huis Marais	236070	215164	231318	212251	259431
Dagbreek	703790	664290	732619	730958	731906
Huis Visser	222387	232129	258527	214998	254850
Majuba	326807	325884	286616	290505	303488
Simonsberg	631838	634515	628810	618742	619003
Wilgenhof	466226	463379	464363	489117	480522
Academia	1390711	1753667	2432631	2217972	2312710
Concordia	562798	573084	599247	560926	579562
Goldfields	349934	352391	350832	336253	333532
Huis de Villiers	383497	380249	400327	375742	397276
Huis MacDonald	218250	221114	214759	229956	199292
Lobelia	160200	162100	154500	173300	189300
Metanoia			170957	1176145	1193889
Total	**11472560**	**11651280**	**12830025**	**13135740**	**13533627**
Percentage increase relative to previous year		**1.56%**	**10.12%**	**2.38%**	**3.03%**

The sum of the individual residences annual consumption detailed in Table 22 indicates an increasing trend in energy consumption amongst the residences, which were reviewed annually from 2003. The 10.12% increase in 2005 can be explained by the increased capacity of the new residence Metanoia (495 students) and the addition to Academia (120 students).

The breakdowns according to the energy metering supplied by the US Energy Manager for the female and male residences reveals that the largest proportion of energy use is attributable to residential use while the remainder is generally shared between kitchen and water heating electricity needs (Table19 and 20). The available energy metering for the mixed residences does not allow for such an analysis (Table 21). However, the breakdown available from two mixed residences are a case in point. Huis de Villiers reflects similar relative proportions (24%) to that of the female and male residences in its water heating needs whereas Concordia, the only other mixed residence for which there is a water heating energy reading, reflects relative water heating needs of 54%. Huis de Villiers makes use of a heat pump whereas Concordia uses element heating (central storage tanks). This comparison is significant because it suggests that element heating uses more energy than a heat pump, In this case, the element heating uses almost double the amount of energy of that of the heat pump. If this comparison is applied linearly to the mixed residence context, it suggests that a 30% energy saving is possibly being negated by using element water heating technology as opposed to heat pumps.

4.4. Presentation of energy ratios

The size of a residence (in terms of its physical size and capacity) influences its total annual energy consumption. A residence that occupies a large space is likely to need more electricity in total than a residence that needs electricity to light and provide energy services to a smaller space. Similarly, a residence with a large number of students is likely to consume more energy than one with fewer students. To account for difference attributable to the size of a residence, energy consumption was calculated in relation to surface area (size) and number of students (capacity), as presented, respectively, in table 23 and 24. The total annual energy consumption per student (kWh/student) was used to inform the comparative energy analysis in the section that follows.

Table 23: Comparison of residences annual total energy consumption per square metre of surface area, in kWh/m², 2007

Residence	TOTAL GSM m²,2007	KWh,2007	kWh/ m²
Erica	4084	322126	79
Harmonie	4589	293842	64
Heemstede	5392	280175	52
Huistenbosch	3065	368802	120
Irene	5097	248838	49
Lydia	5384	243595	45
Minerva	6272	436698	70
Monica	3804	281730	74
Nemesia	4084	319488	78
Nerina	6912	330446	48

Serruria	4084	332617	81
Sonop	4513	474540	105
Eendrag	10412	448120	43
Helderberg	6832	543339	80
Helshoogte	11362	754510	66
Huis Marais	2787	259431	93
John Murray-huis (Dagbreek)	12616	731906	58
Huis Visser	2771	254850	92
Majuba	4771	303488	64
Simonsberg	8563	619003	72
Wilgenhof	5560	480522	86
Academia	22926	2312710	101
Concordia	5650	579562	103
Goldfields	2391	333532	139
Huis de Villiers	5423	397276	73
Huis MacDonald	2033	199292	98
Lobelia	1817	189300	104
Metanoia	14817	1193889	81

Table 24: Comparison of total annual energy consumption in kWh/student, 2003–2007

Residence	**Total annual energy consumption in kWh/student**				
	2003	**2004**	**2005**	**2006**	**2007**
Erica	1837	1650	1576	1445	1669
Harmonie	1959	1761	1936	1701	1837
Heemstede	1171	1132	1234	1176	1223
Huistenbosch	1955	1886	1881	1708	2195
Irene	1731	1585	1600	1464	1517
Lydia	1456	1415	1489	1278	1331
Minerva	1682	1466	1765	1599	1654
Monica	2006	2121	2091	1949	2102
Nemesia	1703	1606	1764	1647	1664
Nerina	1447	1374	1342	1287	1271
Serruria	1711	1642	1793	1676	1723
Sonop	1738	1691	1683	1691	1804
Eendrag	2124	2061	2001	2148	1704
Helderberg	1664	1706	1704	1595	1646
Helshoogte	2442	2882	2451	2251	2314
Huis Marais	2018	1839	1928	1814	2217

John Murray-huis (Dagbreek)	1912	1805	1991	1924	1926
Huis Visser	1901	1984	2119	1838	2178
Majuba	2164	2158	1769	1924	2010
Simonsberg	2323	2333	2254	2275	2276
Wilgenhof	2467	2452	2457	2588	2542
Academia	2519	2610	3072	2800	2920
Concordia	2814	2865	2996	2805	2898
Goldfields	2302	2318	2278	2183	2166
Huis de Villiers	2397	2291	2412	2264	2393
Huis MacDonald	4279	4336	4211	4509	3908
Lobelia	2670	2702	2575	2888	3155
Metanoia	0	0	345	2376	2407

4.5. Energy analysis

The data above (Table 15 -17,19 – 22,24) was collected so that the energy consumption per student of each residence (kWh/student) could be compared against the three variables of gender, hot water heating technology and kitchen configuration. The comparative results revealed clear patterns explicated below.

This section analyses the energy consumption per student from three angles. The first evaluates trends in energy consumption per student from 2003 to 2007. Figure 14 to 18 below represent the annual energy consumption (in kWh) per student for each of the 28 residences in ascending order from the lowest to the highest energy consumption per student for 2003 to 2007. These five figures allow a comparative review of trends concerning energy use within the 28 residences listed. The second is an analysis of the energy consumption (in kWh) per student according to the 11 clusters identified in Table 11 in Chapter 3 to investigate whether the same energy trends repeat themselves or not. Thirdly, a statistical analysis measures the relationship between the numerical energy consumption per student rating of each residence and the three variables.

4.5.1. Comparative energy consumption per student

The five figures below compare the annual energy consumption per student of the 28 residences reviewed in this thesis against each other. These trends are made explicit because, if they consistently appear over a 5 year period, they suggest a structural feature unique to that residence that is influencing energy consumption which deserves further investigation.

The most energy intensive residence is consistently, for the period 2003-2007, Huis MacDonald. Huis MacDonald uses geysers to heat water and students prepare food in kitchenettes. However, the energy consumption per student ratio could be influenced by capacity. Huis MacDonald has an official capacity of only 61 students. This small capacity means that the error for discrepancy between actual capacity and official capacity is more sensitive than for a residence with a large capacity such as Dagbreek, which has 380 students.

The second, third and fourth most energy intensive residences across the period of 2003-2007 also follow a pattern: Lobelia, Concordia and Academia (the exception being Helshoogte in 2004 which, after Huis MacDonald, was the second most energy intensive residence). Lobelia, Concordia and Academia are all characterised by mixed gender, kitchenette configuration and electrical resistive heating.

Figure 14: Comparative residential energy consumption according to kWh/student:2003

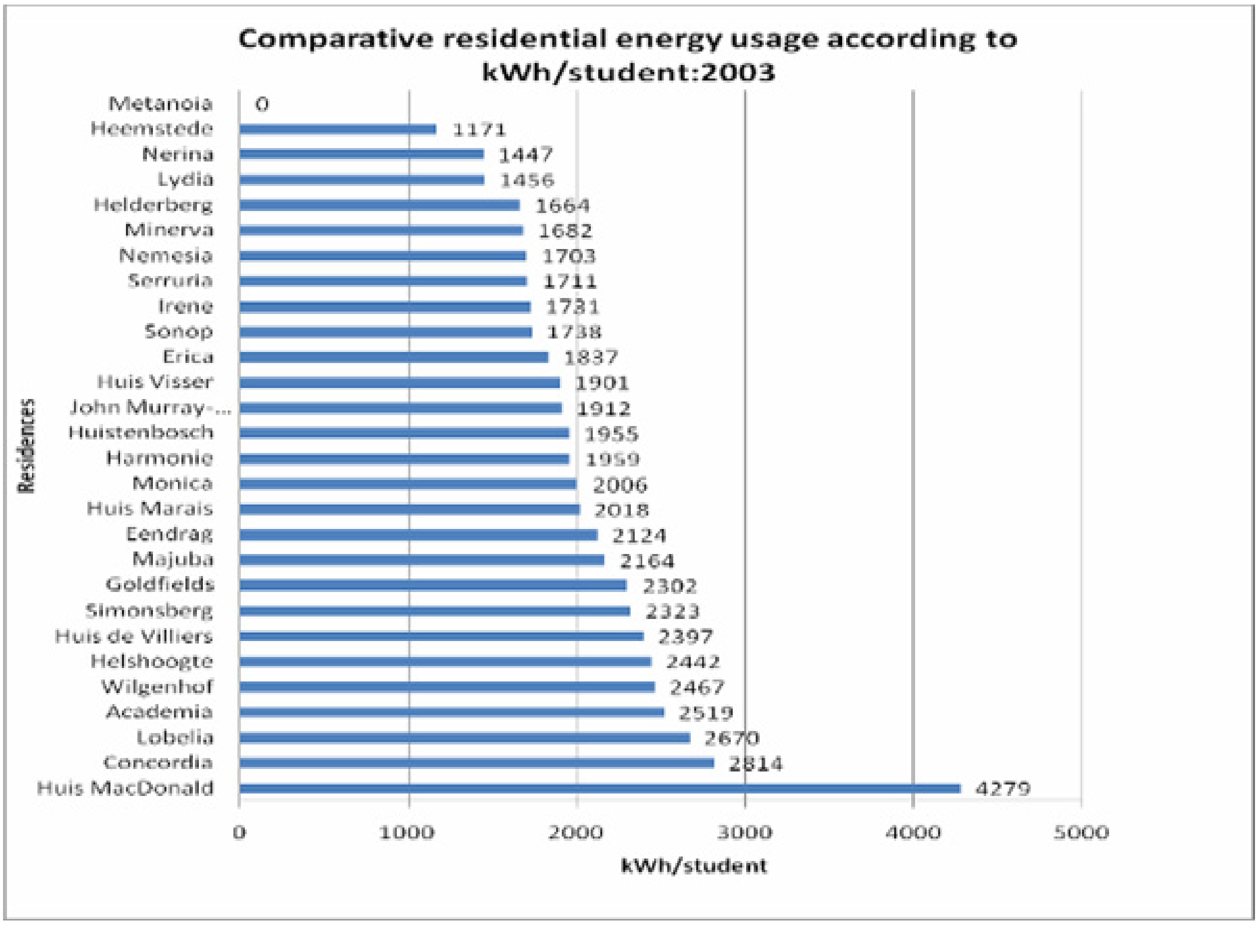


Figure 15: Comparative residential energy consumption according to kWh/student:2004

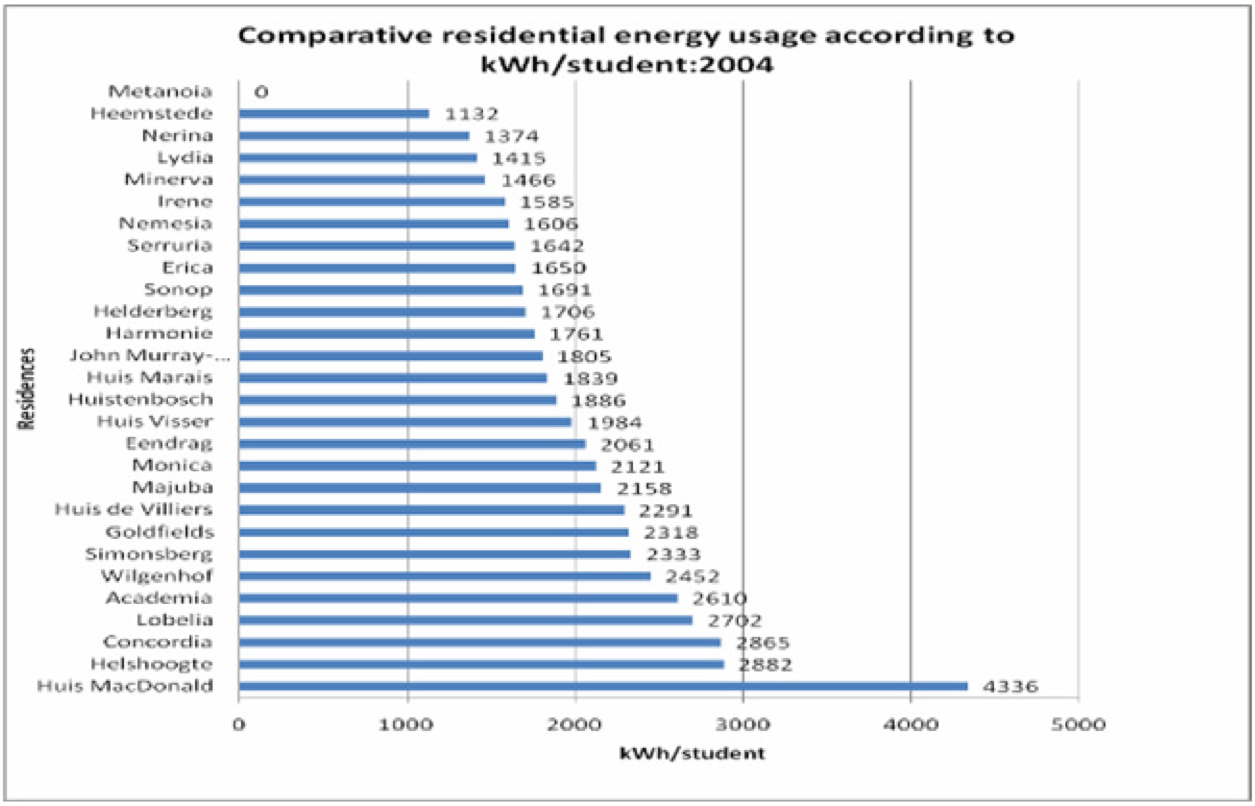


Figure 16: Comparative residential energy consumption according to kWh/student:2005

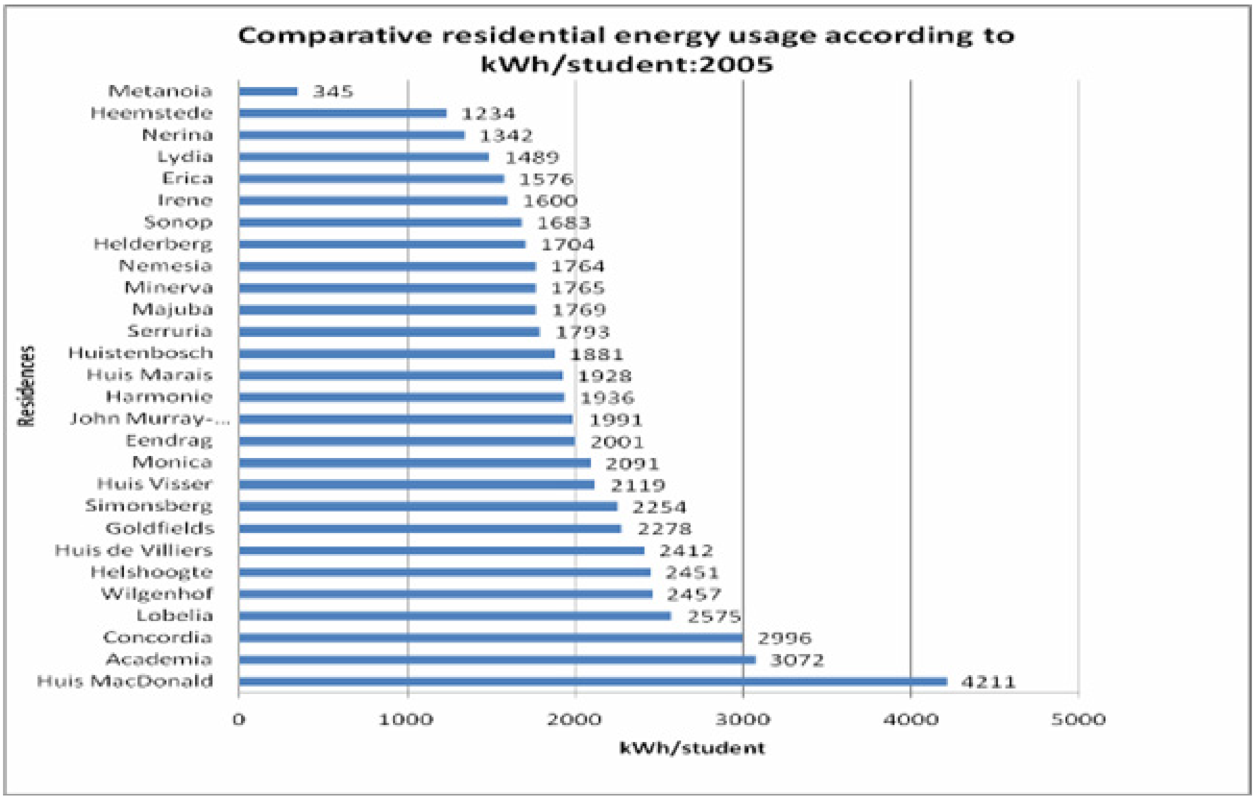


Figure 17: Comparative residential energy consumption according to kWh/student:2006

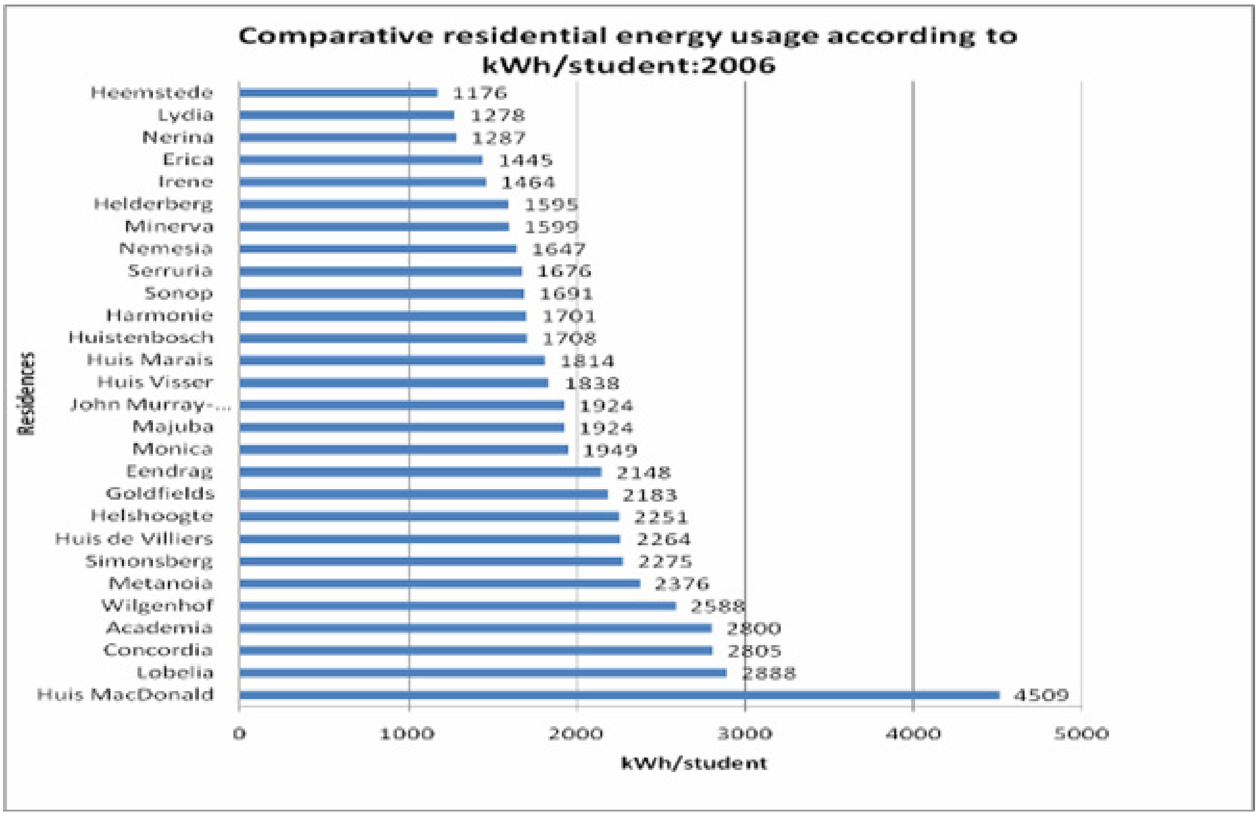
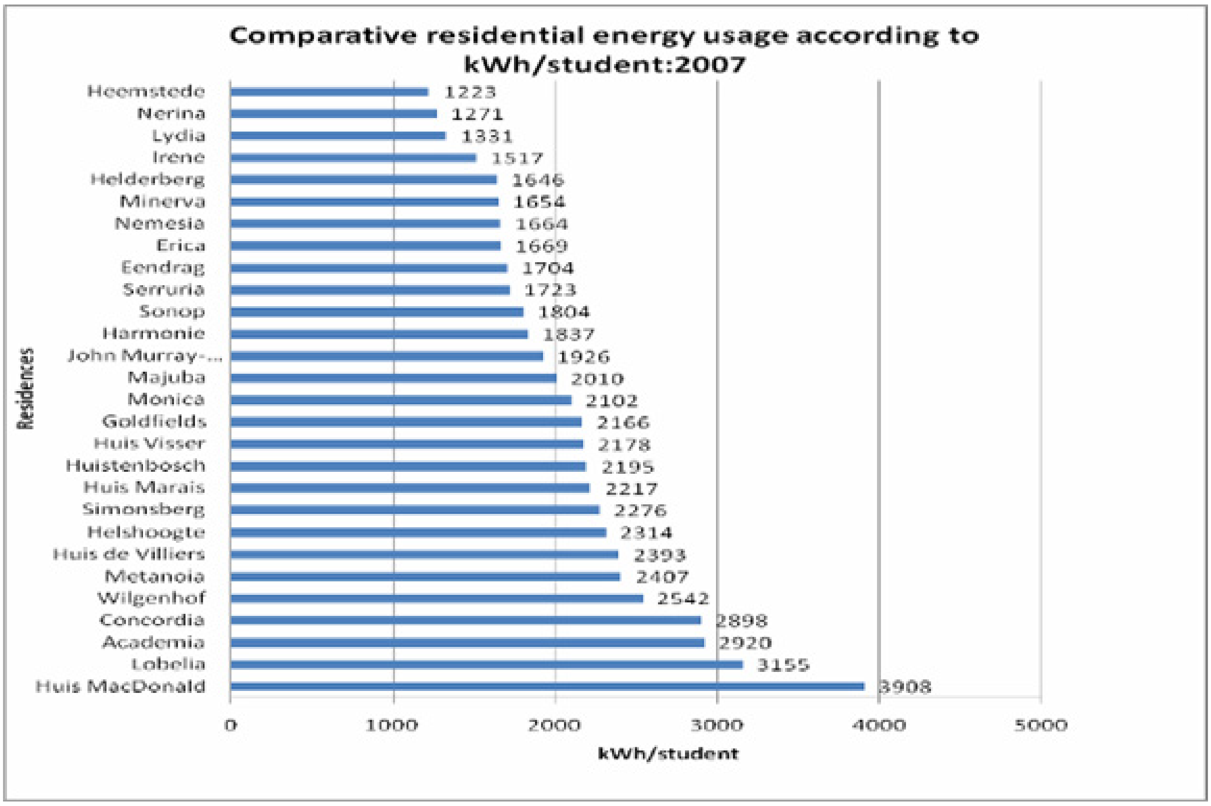


Figure 18: Comparative residential energy consumption according to kWh/student:2007



The three residences that use the least energy per student – Heemstede, Nerina, Lydia – also follow a consistent pattern. They are all female residences, make use of heat pumps for water heating and their kitchens are all serving kitchens only. Monica has the same profile as Heemstede, Nerina and Lydia. However, for the period 2003–2006, Monica is the most energy intensive female residence and is second to Huistenbosch in 2007 even though the residence espouses the same characteristics as the residences that have the lowest energy consumption per student.

The most energy intensive female residences – Monica, Huis Ten Bosch and Harmonie –also follow a pattern: The variables that they have in common are gender and heat pump water heating technology. Monica has only a serving kitchen while Huistenbosch and Harmonie have kitchens that prepare food for the residence and other residences as well.

Likewise, the three most energy intensive male residences – Wilgenhof, Helshoogte and Simonsberg –are the same in the period 2003-2007. All three make use of heat pump water heating technology and prepare and serve food in the residence while Simonsberg also prepares food for Goldfields. The least energy intensive male residence was consistently Helderberg. This residence also makes use of a heat pump and prepares and serves food from its own central kitchen.

Based upon the comparative information above, a general pattern emerges: the mixed residences that use element heating for their water and have kitchenettes consume more energy than the male residences that make use of heat pumps and centralised kitchens, which in turn consume more energy than the female residences that also make use of heat pumps and centralised kitchens. This generalisation was tested against the clusters and the average energy consumption per student for all the residences in each cluster for the period 2003–2007.

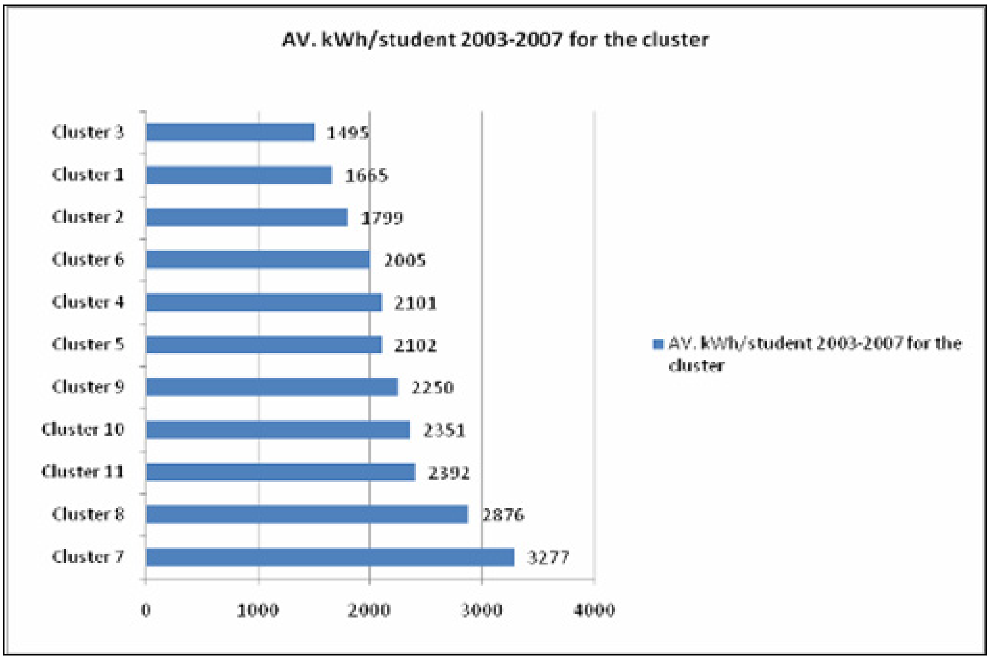
4.5.2. Comparative cluster analysis

An aggregated summary of the cluster data reveals clear patterns and confirms the general observations made from the comparative data in section 4.5.1. Eleven different clusters were identified in Table 11, Chapter 3. Table 25 and Figure 19 represent the energy consumption (in kWh) per student. The results are organised respectively in descending and ascending order. In Figure 19, the first three clusters – 3, 1 and 2 – on the graph are all female. The next three clusters – 6, 4 and 5 – are all male. They are followed by clusters 9, 10, 11, 8 and 7, which are all mixed residences. Judging the energy consumption per student according to gender, it follows that female residences use less energy per student than male residences, which in turn use less energy per student than mixed residences.

Table 25: Summary of the average kWh/student rating from 2003–2007 for each cluster, arranged in descending order

Cluster no.	Gender	Water heating technology	Kitchen configuration	AV. kWh/student 2003-2007
7	Mixed	Geysers	Kitchenettes	3277
8	Mixed	Central Storage tanks	Kitchenettes	2876
11	Mixed	Geysers	Preparation and serving kitchen and cafeteria	2392
10	Mixed	Heat Pump	Kitchenettes	2351
9	Mixed	Geysers	Kitchenettes and serving kitchen	2250
5	Male	Heat Pump	Preparation and Serving kitchen and Preparation for another res	2102
4	Male	Heat Pump	Preparation and serving kitchen	2101
6	Male	Heat Pump	Serving kitchen; food prepared at another res	2005
2	Female	Heat Pump	Preparation and serving kitchen and Preparation for another res	1799
1	Female	Heat Pump	Preparation and serving kitchen	1665
3	Female	Heat Pump	Serving kitchen; food prepared at another res	1495

Figure 19: Comparison of the average kWh/student for 2003–2007 for each cluster,



However, the kWh/student rating is dependent on other variables besides gender. This conclusion is not, therefore, an attempt to draw a deterministic relationship between gender and energy intensity although the distinction between female, male and mixed gender is important because it is accompanied by general similarities in water heating technology and kitchen configuration. The female and male residences make use of heat pumps and have large centralised kitchens and the mixed residences generally make use of element heating and generally have multiple kitchenettes. The examples above do not allow for the observation, for example, of a female residence with geyser water heating technology which could, possibly, yield a different relationship between gender and energy intensity.

The cluster analysis reveals how differences in kitchen configuration affect energy consumption per student. One would expect that the female and male residences with only serving kitchens have the least energy consumption per student, followed by those with a preparation and serving kitchen and that the residences with kitchens that prepare and serve food to the residence as well as prepare food for another residence have the highest energy consumption. The cluster results confirm this expectation. Both the female and male groupings reflect this order (see Table 25 and Figure 19; clusters 3, 1 and 2 for female residences and clusters 6, 4 and 5 for male residences). The similarity in female and male water heating technology allows for the kitchen to be an independent variable and the figures confirm the logical conclusion that the kitchens that prepare food for another residence will increase the kWh/student rating while the residences that only have serving kitchens use the least energy per student.

The averaged kWh/student rating for the mixed clusters do not reflect what one would expect as neatly as the female and male residence clusters. Cluster 9, which uses heat pump water heating technology and a kitchenette configuration, is more energy intensive than Cluster 10, which makes use of a geyser water heating technology and has a serving kitchen in addition to its kitchenette configuration. Cluster 9 is represented by Goldfields while Cluster 10 is represented by Huis de Villiers. Could it be that the serving kitchen of Goldfields provides the majority of the students with food and they do not make use of their individual kitchenettes as much as the other residences with kitchenette kitchen configurations? The top three energy intensive clusters, 11, 8 and 7, all make use of element heating. Note that cluster with the central kitchen – Cluster 11 (Metanoia) – is less energy intensive than those with the kitchenettes in this confined context.

However, the above analyses are based on the relative positioning of the residences against each other. If one has a look at the actual numbers, the variance in the numerical value of the energy consumption per student rating is not as clear. Is there really a relationship between the energy consumption per student and the variables chosen? A statistical analysis, based on a repeated measures analysis of variance (RM ANOVA), was selected to compare the relationship between the average annual energy consumption per student of each residence for the time period 2003–2007 against the three variables of gender, water heating technology and kitchen configuration (Nel, 2008b: Centre for Statistical Consultation).

4.5.3. Statistical variance

An analysis of variance (ANOVA) compares two or more population means (variables) for each subject to evaluate if there is equality or a significant difference by analysing the sample variance. A repeated measures (RM) ANOVA is used when, for each subject, the same variable is measured on more than one occasion. The energy consumption per student ratio was measured for 2003, 2004, 2005, 2006 and 2007 against the different genders, kitchen systems and water heating technologies.

The RM ANOVA revealed that energy use according to kWh/student has not had a significant variance over the time periods stipulated but does differ according to gender, type of kitchen configuration and water heating technology. With regard to gender, judged against energy use according to kWh/student, mixed residences promote the highest energy/student consumption followed by male residences and female residences, respectively. With regard to kitchen system configuration, judged against energy use according to kWh/student, kitchenettes promote the highest energy/student consumption, followed by preparation kitchens, preparation and service kitchens and service kitchens, respectively. With regard to water heating technology, judged against energy use according to kWh/student, geysers promote the highest energy/student consumption, followed by central storage tanks and heat pumps, respectively.

4.6. Heat Pump investigation

The second conclusion of the macro analysis concerns the dominance of heat pump technology to heat water in the residences. Investigation revealed two facts: heat pumps allow for energy savings and are financially feasible (Krige, 2008: electronic communication; Louw, 2008: telephonic communication).

The heat pumps were installed in 1980 (Krige, 2008: electronic communication). The names of three individuals who were involved in their installation were provided: Mervin Edwards, who worked at Maintenance and Operations at the time; Lawrence Louw, the engineer in charge of the heat pump and currently working at Tekniheat in Cape Town; and Willem Roos, who worked at the Planning Department of Stellenbosch University at the time. Roos (2008: telephonic conversation) apologised for not being able to remember any details concerning the decision to install heat pumps at the time.

Edwards (2008: telephonic conversation) confirmed that heat pumps were installed in 1980, to replace old and polluting oil fired boilers in the residences. The cost of heat pumps in 1980 would have to be compared against the cost of diesel and this ratio would also need to be compared to the cost comparison of an electrical unit against the cost of diesel. From his experience, Edwards advocated that heat pumps compared favourably against geysers in the categories of efficiency, cost savings, water temperature control, insulation control, maintenance and longevity. However, qualified technicians were needed to maintain heat pumps. He commented that Maintenance and Operations always fights for the best in terms of technology and efficiency whereas the Planning Department always opts for the lowest initial capital cost.

Louw (2008: telephonic conversation) reiterated that the decision to implement heat pumps was located in the need to change from the diesel fired boilers which were creating air pollution on campus and were costly to run because of the high price of diesel. Louw has been dealing with heat pumps for over 30 years and Tekniheat is a commercial company that specialises in selling heat pumps. Louw stressed that heat pumps have an average payback period of 3 years.

The following example (Krige, 2008: electronic communication; Louw, 2008: telephonic communication) illustrates the energy savings and financial feasibility of investing in a heat pump.

> The following assumptions are made:
> *For every 100 students, the cost of the heat pump is R 163 000.
> *The average student needs a 100 litres of water per day at a temperature of 50 °C

*The water coming in from the mains is approximately 15 °C and needs to be heated to 50 °C. It takes 1 kWh to heat 25 litres of water to 50 °C (based on the specific heat capacity of water at 4, 2 kJ/kg °C and Q= mcΔT).

Therefore, if each student needs 100 litres of water, each student needs 4 kWh per day to heat their water needs (assuming there are no losses).
100 students x 4 kWh each x 310 days = 124 000 kWh/year

If circulation losses of approximately 20% are factored in then you actually need 148 800 kWh/year for 100 students. At the quoted price of R0.229/ kWh (2008 prices; excluding vat) (Krige, 2008: electronic communication), this would cost the university

148 800 x R0.229 = R 34 075.20

A heat pump saves approximately 70% of this. Therefore, the kWh cost savings from heat pump =R 23 852.64. The university is charged for kWh rating and for a kilo Volt Ampere (kVA) rating. The University is charged R74.33 (excluding VAT) per kVA, once a month (Krige, 2008: electronic communication)

Assume that this heat pump draws 10 kVA (this is calculated by using the average diversified load of Lydia Residence as an example. Over the five year period, the heat pump for Lydia Residence, on average, demanded 20 kVA for 183 students. Therefore, for 100 students, one can assume an approximate load of 10 kVA). The power needs for this particular heat pump assume that you would need to heat at least 60 litres per student in 4 hours. For 100 students, this would mean you would have to heat up 6 000 litres in 4 hours.

If it takes 1 kWh to heat 25 litres, you need 240 kWh in 4 hours to heat 6 000 litres. You therefore need 60 kW (approximately equal to KVA) 'to be supplied by electrical elements. Due to diversity of different loads at the metering point, only about 62,5% of this load can be assumed, i.e. about 37,5 kVA' (Krige, 2008: email communication)

(37,5-10) x R74.33/kVA x 12 months = R 24 530

Therefore, the total kWh savings and kVA savings for one year would equate to:

R 23 852.64+ R 24 530= R 48 382.64

If the heat pump costs R 163 000, this would be paid back in 3.3 years.

The approximated example above illustrates that heat pumps are financially feasible investments in the context of the residences of Stellenbosch University. A payback period of 3.3 years is acceptable and thereafter the energy and financial savings accrue to the university.

There is a story within this decision by top management to install such energy efficient equipment that deserves to be investigated in the future. What dynamics and assumptions were present in 1980 that allowed such a decision to be made? What dynamics and assumptions were present recently when it was decided to install geysers in the most recently constructed residence, Metanoia? This comparison exposes the tension, expressed on numerous occasions by technicians and contractors during the research process, in which top management focuses on initial capital cost to inform decision making as opposed to reviewing the most energy efficient options which, although initially might be more expensive, hold long term energy savings and financial savings for the asset holder. Sustainable energy solutions for the residences of Stellenbosch University involve a long term view: decision making at a top management level cannot consider only initial capital cost if energy efficiency is going to be an option for the sustainable energy future of Stellenbosch University.

The assumption in the above example that a heat pump saves approximately 70% of the energy was questioned. Krige pointed out that, as a rough estimate, it was accurate for Lydia Residence. The calculations above concluded that approximately 148 800kWh/year/100 students is needed for the assumed water heating requirements. In reality, (and assuming the same water estimations as in the calculation) Lydia Residence used 82 798.86 kWh/year/183 students. For 100 students, Lydia Residence therefore required 45 245.3 kWh/year. If the theoretical water heating needs are calculated to be 148 800 kWh/year/100 students but the residence consumed only 45 245.3 kWh/year/ 100 students, a 70% savings on the 148 800 kWh/year/100 students can be deduced, thereby affirming the estimate.

This same calculation was applied to all remaining residences and the results are summarised below in Table 26. Note that Concordia, which uses element heating, uses more than the theoretical estimate while the residences which make use of a heat pump illustrate real savings of between 57% and 82%.

Table 26: Investigating the energy savings of heat pump technology by comparing the calculated theoretical 148 800 kWh/year/100 student against real consumption/year/100 students, 2003–2007

Residence	**Average official capacity**	**Average hot water (pro rata) consumption**	**Average hot water (pro rata) consumption per 100 students**	**Relative real savings**
Erica	193	72694	37665	75%
Harmonie	160	63159	39425	74%
Heemstede	229	62048	27119	82%
Huistenbosch	169	76028	45094	70%
Irene	164	62502	38111	74%
Lydia	184	82799	45097	70%
Minerva	257	75689	29405	80%
Monica	134	55121	41135	72%
Nemesia	192	72464	37663	75%
Nerina	254	74775	29416	80%
Serruria	193	72694	37665	75%
Sonop	264	103306	39101	74%
Eendrag	266	117138	44004	70%
Helderberg	329	142196	43247	71%
Helshoogte	314	137730	43835	71%
Huis Marais	118	52262	44440	70%
John Murray-huis (Dagbreek)	373	165725	44454	70%
Huis Visser	118	52436	44437	70%
Majuba	153	98551	64329	57%
Simonsberg	273	153154	56018	62%
Wilgenhof	189	93268	49348	67%
Academia	720	Data not available		
Concordia	200	311449	155725	-5%
Goldfields	153	Data not available		
Huis de Villiers	165	93368	56655	62%
Huis MacDonald	51	Data not available		
Lobelia	60	Data not available		
Metanoia	495	Data not available		

4.7. Conclusion

The general findings of the quantitative data from the macro view have been analysed above and three key conclusions, which can inform the research objective, are identified from the data. The first concerns the discovery of the diversity of variables that influence energy consumption in the residences of Stellenbosch University. The variance in factors that influence energy consumption was a finding of the research; it was not an assumption or known factor before the research process began. Furthermore, the individual complexity of each one of these variables was not investigated within the scope of this research journey and this would, therefore, add to the level of diversity involved in creating sustainable energy solutions. Appropriate energy efficient technology for the different water heating systems and kitchenette configurations as well as the relevant appliance and lighting profiles of different residences should, ideally, be specifically sourced for each context.

The second significant finding is that, within the differences in variables, consistent trends and patterns did emerge. Based on an analysis of the energy consumption per student (kWh/student), three different forms of analysis indicate that mixed residences, which make use of element heating and kitchenette configuration, use the most energy per student. Thereafter, male residences, that make use of heat pumps and centralised kitchens, consume the next most energy per student. Female residences, that make use of heat pumps and centralised kitchens, consume the least energy per student.

The third significant finding is the use of heat pumps as the dominant water heating technology in the residences. This discovery informed the research objective by shifting the focus away from water heating as an energy efficient technology was already being used. The anticipated focus of finding sustainable energy solutions for the residences of Stellenbosch University was originally going to be the water heating technology as this is often where large energy efficiency options exists. However, with the large number of heat pumps in existence, the expected focus of the research objective shifted.

Several conclusions for the research objective can be deduced from the findings of the macro, SDA. These pertain to the strategic interventions which should be made by the University to implement end use energy efficiency, as a means to sustainable energy solutions, within the residences.

The first intervention calls for the installation of accurate energy metering in all residences to improve on the differentiation of the energy metering according to residential, kitchen and water heating use. This conclusion is based on the primary data received from the US Energy Manager which reveals a lack of differentiation for various energy services. The female and male residences would therefore require energy metering which records actual hot water usage and not the proportionate allocation. The mixed residences would therefore require additional metering to account specifically for individual units or, ideally, individual kitchen, water usage and residential energy consumption. However, the decentralised configuration of living conditions (i.e. flats) in the mixed residences does pose a problem for obtaining differentiation of energy metering because of the lack of one central kitchen or water heating system. Once effective energy metering is installed, a feedback system can be considered so that energy consumption is relayed back to the residences.

The second intervention calls for detailed energy auditing of the individual residences. The findings revealed a complex energy context for the residences of Stellenbosch University in terms of number of variables which affect energy consumption. To best locate energy efficiency options, the unique and specific qualities of each residence should be considered. In particular, the energy auditing should be able to answer the following question:

- What appliance use or behaviour stimulates greater energy use amongst male residences?
- What is contributing towards Huis MacDonald having the highest energy consumption per student ratio amongst the residences?
- Why is Helderberg the least energy intensive male residence?
- Why does Monica, in spite of only having a serving kitchen, espouse the highest female energy consumption per student ratio?

The third intervention requires energy efficiency options relevant to the mixed residences. The findings suggest that the kitchenette configuration and electrical resistive (geysers and central storage tanks) water heating technology used in the mixed residences contribute to increased energy consumption. This is likely also influenced by the decentralised configuration that stimulates increased energy consumption. Future decision making for new residences need to consider that these two variables contribute towards greater energy usage.

The fourth intervention requires energy efficiency options relevant to the male and female residences. The use of heat pumps in all the male and female residences implies that a major energy efficiency option does not exist. For this reason, interventions from the University should be focuses upon the residential use and kitchen appliances. The energy data confirms that the residential sector is the greatest contributor towards total energy use in the male and female residences. This suggests that lighting and appliance behaviour are the largest target amongst the male and female residences.

The conclusion to this chapter therefore identifies four broad strategic areas of intervention for the University. Not only do they identify a checklist of where to target energy efficiency but lay the foundation for a process towards a sustainable energy future.

However, this general quantitative data does not capture the behavioural dynamics involved in the residences, which, for example, would explain why male residences espouse a predisposition towards more energy per student. Lastly, the general quantitative data also do not take into account what type of institutional context will incentivise, maintain or suggest energy efficiency options. The differences in the energy consumption of each residence can only be explained by examining the unique behavioural trends of that residence and the particular lighting and appliance details of that residence. Behavioural trends can only be revealed by examining the context intimately via a case study which allows for human interaction. In addition, the transformation of the research objective into an approach or strategy, as suggested below, needs to be tested on a residence and this also requires a case study. The case study also allows for the possibility of a micro view, as originally intended.

4.8. Chapter summary

This chapter presented the general quantitative data from the macro view. It describes the context for the research objective by presenting the energy consumption of the different residences. In addition, the quantitative data numerically describes the energy context of the residences of Stellenbosch University for interested others to pursue further investigation once this data is made available for access in the library. This data was analysed according to an energy consumption per student (kWh/student) ratio against the three chosen variables of gender, water heating technology and kitchen configuration to explain certain trends and patterns.

Apart from setting the context, the findings above informed the research objective via three significant discoveries. Firstly, the exposed diversity within the variables implies that sustainable energy solutions for the residences of Stellenbosch University will refer to an approach or process that can apply to each residence so that the unique variables are accounted for. Secondly, the context clearly exposed trends, and in doing so, demarcated male behaviour, element heating and kitchenette configuration as contributing factors towards increasing energy consumption. This informed the research objective by clearly identifying where the focus should be placed by top management and Maintenance and Operations for the future. Lastly, the unexpected discovery that all the female and male residences make use of heat pump water heating technology shifted the focus of targeting water heating for sustainable energy solutions. The technical expertise consulted vouches for the energy savings and financial feasibility of heat pump investments, which aligns with the theoretical arguments for energy efficiency located in the literature review. The consequence for the research objective was the shift of focus from water heating technology to lighting and appliance use within the residences. This, in turn, is influenced by behavioural tendencies.

The findings informed four concluding recommendations for interventions. The first relates to improved energy metering; the second is detailed energy audits of all the residences; the third intervention pertains to the applicable lighting, water heating and appliance technology for individual flatlets in the mixed residences; fourthly, targeting residential lighting and appliance use for the male and female residences.

Although the identified trends are explained in terms of water heating technology and kitchenette configuration, they do not explain the behavioural tendencies that drive the consumption. Understanding such behavioural trends can only be uncovered by examining residences as case studies. The following chapter, therefore, uses a case study so as to investigate and test what approach or strategy can be adopted by residences in order to generate sustainable energy solutions. What evolved from the case study findings was a process which the newly appointed Green HK members can now adopt to install energy efficiency within their residence. This research journey is detailed in the next chapter.

Chapter 5: Findings of the micro case study analysis

5.1. Introduction

The case study aids the research objective as it facilitated the development of a tool which can be deployed by all residential leaders to promote end use energy efficiency in their respective residences as a sustainable energy solution for the residences of Stellenbosch University. The various processes further identified several key areas in which raising awareness and implementing new technology that could promote energy efficiency are possible.

Arrangements with the former and current Environmental Affairs SRC members (Leslie, 2008: personal communication; Links, 2008: personal communication) have been negotiated so that this tool can inform the future approach of the newly formed Green HK. This tool forms part of a greater 'greening' initiative by the SRC and HK leaders in which residential environmental audits, participating in the US Energy Challenge and recycling attempts are being undertaken.

Lydia Residence was chosen as the case study subject for this research thesis, for reasons explained above in the research methodology section. The research methodology chapter outlined the data generating processes and this chapter presents and discusses the findings of these processes. Four processes with Lydia Residence (as identified in section 3.4, Table 7 and Figure 13), which focused on end use energy efficiency, were undertaken.

Each process contributed towards the research objective. The contribution of each respective process towards the research objective is detailed below and summarised in Table 27.

Table 27: Contribution of each process with Lydia Residence towards informing the research objective

Process	Contribution of process
Investigating why Lydia Residence won the 2007 US Energy Challenge	Used as a critical case study Revealed possible influence of leadership on behaviour as a sustainable energy solution and energy conservation strategy
Results of the general walk-through energy audit of	Identified a bottom up process for all residences which

Lydia Residence	can contribute towards end use energy efficiency Exposed key lighting and appliance issues
Results from the Lydia energy survey	Identified a bottom up process for all residences which can contribute towards end use energy efficiency
Allocating the Eskom prize money towards energy efficiency	Identified technologies relevant for residences, informed by the case study: • Bulb type and rating of desk lamp • Low flow or 'econo' showerheads • Use of most efficient fluorescent tubes • Ballasts retrofit • Old and inefficient technologies replaced • Standby mode of appliances

5.2. Investigating why Lydia Residence won the 2007 US Energy Challenge

Lydia Residence won the 2007 US Energy Challenge. The residences were evaluated in terms of their relative increase or decrease in energy use, according to the energy consumption per student for the month of August in 2007, to the average energy consumption per student for the month of August in the years from 2002 to 2006 (Fluri, 2008: personal communication). The 2007 US Energy Challenge was judged by Tom Fluri, a masters engineering student at Stellenbosch University, and Lodine Redelinghuys, an Eskom Distribution Energy Services manger. It was decided to exclude the kitchen energy usage of the residences in the 2007 US Energy Challenge because of differences in kitchen configuration. Residences such as Academia, Lobelia, Concordia, Huis de Villiers and Huis MacDonald were not able to extract their kitchen energy usage as the primary data does not allow for such categorisation. Furthermore, water heating amounts are allocated on a pro rata basis when residences share heat pumps because there is only one energy metering point for the heat pump. In other words, if residences share a heat pump, their individual consumption is allocated according to their official capacity.

The average energy consumption per student rating for Lydia Residence, based on residential and water heating energy consumption, for the month of August in the years 2002–2006, was 192 kWh/student. The energy consumption per student rating for Lydia Residence, based on residential and water heating energy consumption, in August 2007 was 154.6 kWh/student. Relatively, this equated to 19.5% savings on energy consumption per student in August 2007 (Fluri, 2008: electronic communication). This 19.5% saving placed Lydia Residence in first position in the challenge. The results of the 2007 US Energy Challenge are reflected below in Table 28: Results of 2007 US Energy Challenge (Fluri, 2008: electronic communication).

Table 28: Results of the 2007 US Energy Challenge (Fluri, 2008: electronic communication)

Rank	**Residence**	**2007 vs AVG(2002-2006) [%]**
1	Lydia	-19.5
2	Harmonie	-13.0
3	Irene	-11.8
4	Heemstede	-11.5
5	Huis MacDonald	-9.4
6	Serruria	-7.9
7	Goldfields	-7.4
8	Helshoogte	-6.7
9	Majuba	-6.6
10	Nerina	-6.5
11	Huis Francie van Zijl	-6.1
12	Nemesia	-5.9
13	Sonop	-5.5
14	Dagbreek	-4.7
15	Minerva	-4.6
16	Wilgenhof	-4.5
17	Concordia	-3.5
18	Meerhof	-2.2
19	Erica	-1.7
20	Simonsberg	-1.5
21	Monica	0.0
22	Helderberg	0.1
23	Huis Visser	0.5
24	Lobelia	0.7
25	Metanoia	1.1
26	Huis de Villiers	4.1
27	Huis Marais	4.7
28	Kerkenberg	4.8
29	Academia	7.3
30	Hippokrates	19.2
31	Huis Ten Bosch	25.5

What resulted in the 19.5% decrease in energy consumption per student in Lydia Residence? The first step towards answering this question involved reviewing the primary data which informed this relative ratio. A review of residential energy and water heating needs for the month of August in each of the relevant years revealed a 20% decrease in consumption in 2006 from the previous year, as presented below in Table 29. This drop occurred primarily in residential consumption; hot water consumption remained relatively stable.

Table 29: Energy consumption of Lydia Residence for August, 2003-2007, in respect of residential and water heating needs

Energy compartment	**Total energy consumption in kWh**				
	Aug 2003	**Aug 2004**	**Aug 2005**	**Aug 2006**	**Aug 2007**
Hot water (pro rata)	12172	11170	10674	10905	10928
Residential	26226	26355	26583	18606	17359
Total	**38398**	**37525**	**37257**	**29511**	**28287**

Before delving into possible options, the larger annual context of energy consumption by Lydia Residence was investigated to determine whether the pattern in August could possibly be part of a larger trend. The annual energy consumption of Lydia Residence is reflected below in Table 30.

Table 30: Annual energy consumption of Lydia Residence, 2003–2007, in respect of residential, water heating and kitchen needs

Energy compartment	**Total energy consumption in kWh**				
	2003	2004	2005	2006	2007
Hot water (pro rata)	90959	87155	77261	75705	82915
Residence	130763	130705	151728	116243	118394
Kitchen (pro rata)	43329	43968	46489	41950	42286
Total	**265051**	**261828**	**275478**	**233898**	**243595**

The data above reveals a decrease in total energy consumption in Lydia Residence between 2005 and 2006. The 41 580 kWh decrease in total energy consumption between 2005 and

2006 is summarised in Table 31: Breakdown of the decrease in energy consumption in Lydia Residence, 2005–2006.

Table 31: Breakdown of the decrease in energy consumption in Lydia Residence, 2005–2006

Residential energy use	kWh decrease in 2006
Hot Water (pro rata)	1556
Residential	35485
Kitchen (pro rata)	4539
Total annual energy consumption decrease	**41580**

With regards to the total decrease in 2006, 85% of it is attributed to a decrease in residential energy use, 11% is attributed to a decrease in the kitchen energy use and the remaining 4% is attributed to a decrease in the water heating usage. What happened with the residential energy use which allowed for the specified energy saving and a cost saving of R 8 126.06 (35 485 kWh @ R0.229/kWh (excluding VAT) (Krige, 2008: electronic communication) in 2006?

Investigations (Krige, 2008: electronic communication; Willems, 2008: personal communication) revealed that in 2006 two relevant structural adjustments took place in Lydia Residence. The first was that the ironing rooms were closed and in the course of 2006 were converted into mini kitchenettes. The use of ironing facilities and mini kitchenette facilities was, therefore, interrupted throughout 2006. Secondly, Lydia Residence took part in a voluntary bulb exchange programme sponsored by Eskom in which students were provided with free CFL light bulbs in exchange for their old incandescent bulbs.

The investigation above identifies residential energy consumption as the area that influenced the winning. It was, therefore, a technological (lighting or appliance related) or behavioural change in either or both common and private rooms that decreased energy consumption. Technologically, the energy efficient CFL bulbs and lack of access to kitchen appliances could have of affected the energy consumption but the evidence above does not conclusively suggest it. Could behavioural factors have contributed towards the decrease in energy consumption? This was alluded to at the 2007 US Energy Challenge prize giving when a correlation between the arrival of the resident house mother (a sustainable advocate) and a decrease in the residential energy consumption was observed. Behaviourally, the influence of a person in a leadership position who is consistently raising awareness about resource management could possibly have had an effect but this, once again, is a possible likelihood and not a definitive conclusion drawn from the evidence.

Willems was interviewed about behavioural trends that could account for the decrease in energy consumption in 2006 and August 2006. Willems became the house mother at Lydia Residence on 1 April 2005. She cited switching off unnecessary lights and the response to her constant nagging about switching off appliances as the only behavioural trends that could have noticeably impacted upon residential energy consumption. Since 2005, the following has been implemented in Lydia Residence under Willems' leadership:

- The residence participated in the Eskom CFL handout in 2006 (students could voluntarily exchange their incandescent bulbs for a CFL bulb sponsored by Eskom).
- A sponsored glass recycling dome was placed on the property of Lydia residence.
- A courtyard garden with lawn was removed and replaced with gravel aggregate and the intention of indigenous, local, water wise greenery.
- The plants in the inner courtyard of Lydia Residence were creating shade for the north facing wing of the residence. They were removed to promote passive heating and improved natural lighting conditions.
- First year students are taken on a nature outing to a local conservation park during their orientation week by Willems to remind them of the beautiful and accessible nature that surrounds their University.
- Willems has a talk to the first years during orientation week about what types of SABS approved appliances are allowed in the room and encourages energy saving advice with regard to switching these on only when they are being used.
- Willems continuously deplores the students to switch off lights within their private rooms and the communal spaces when they are not used.
- At the beginning of the orientation week Willems introduces the need for environmental awareness and resource conservation to new students of Lydia Residence.

- The HK regularly inspect rooms to make sure that only approved electrical equipment is used by students.

- Four kitchenettes were renovated to accommodate a toaster, microwave and ironing board. This was to accommodate for the *de jure* rules that state these appliances are not allowed in the rooms and to dissuade the *de facto* status that students in fact do have these appliances and don't want to be inconvenienced with making food in a kitchen which is not close to their room or could be in use as there is only one.

On numerous occasions Willems mentioned to me that, generally, her 'greening' efforts were met with a lack of enthusiasm. Students see it more as an effort and not as something they are personally inspired to do. Willems perceived students to often be annoyed by her ideas or attempts to implement them in Lydia Residence. Personal observation at two house meetings at Lydia Residence confirm this sentiment: the attention span of the students was visibly smaller when it came to issues of sustainable living than when issues such as the House Dance or 'Jool' (Carnival) committee were discussed.

My relationship with Willems throughout the year revealed that an eco theological paradigm informed her concept of sustainable living. She is a member of the organisation 'A Rocha' which is 'an international conservation organisation working to show God's love for all creation' (A Rocha International pamphlet). During one conversation, Willems commented that the Church could possibly have missed the message when it focused on man and God: as an institution, it needed to consider man *and nature* (as well as God). A Rocha is a network through which she, and others, can communicate with or celebrate God through their daily experience of nature. She and I discussed, in depth, how a connection with nature can positively influence a person's life. This enriched sense of spirituality, in turn, motivates a sustainable livelihood approach because of a deep respect for nature and what your relationship with nature symbolises.

This discussion led to the question of whether or not students from Stellenbosch University are apathetic and insular with regards to not wanting to interact with a broader community and the environment.

As a student of Stellenbosch, and a resident of Huis Ten Bosch for four years, I explained that I recognised those apathetic and insular features in myself during my undergraduate years. Stellenbosch University was compared to a 'bubble' in which interaction with the community or environment was, for the average student, not something to engage with. We questioned whether this was just the normal behaviour of all students across the world or a particular characteristic of South African or Stellenbosch students.

Willems used 'Jool' (Carnival) as a point of focus. Jool is conducted at the beginning of each year as part of the Stellenbosch orientation programme for new students and current students. Each year, large amounts of human, financial and material resources are invested in the making of the floats for 'Jool'. However, Willems questioned the themes that govern the aesthetics of the floats for 'Jool' as well as the value of spending so many resources on a float that is made from newly purchased materials each year and is then thrown away. What concepts of sustainable living do the themes and the process of 'Jool' introduce to new and current students? 'Jool' is aimed at collecting funds for Matie Community Service (MGD) and therefore does contribute positively towards the broader US and Stellenbosch community. Willems was therefore not arguing that the concept of 'Jool' was irrelevant or misguided. She in fact saw an opportunity within this process to direct student awareness towards sustainable living issues and was questioning why it had not been used yet.

These insights were not included in this thesis as an attempt at ecological evangelicalism, or to criticise Stellenbosch students or as a naive attempt to tell students, from the sideline, how they must have fun. Instead, they were included as a platform for dialogue about two issues on campus that are pertinent to sustainable energy use in the residences of Stellenbosch University and therefore pertinent to this thesis. The first concerns the opportunity that active religious student groups pose as potential nodes of motivation to inform behaviour that aligns itself with sustainable living (and therefore sustainable energy use). The second concerns the opportunity which combines fun campus initiatives with judgement or theme criteria that are informed by sustainable living.

In addition, the partnership with Willems brought to the surface the lack of institutional support, in terms of a designated Environmental Portfolio within the HK organisational structure for dealing with sustainable living and sustainable energy use in residences. During the process of researching this thesis, the Environmental Affairs portfolio of the SRC successfully set in motion procedures for a 'Green' HK portfolio in the residences. However, there is still no institutional capacity to legally oblige students to purchase energy efficient appliances or lighting (Stellenbosch University General Yearbook, 2008:181). The regulations stated in the General Yearbook relate to safety measures and meeting SABS approval. Willems explained that HK leaders already have so much on their portfolios that she understands how any sense of obligation is diluted because they must first do other things which they are bound to do before they can attend to issues of sustainable living.

In conclusion, the documentation above contains statements, particularly pertaining to that of student behaviour, that are generalisations and perceptions. The generalisations and perceptions have not been supported by empirical evidence. However, the ideas and opinions that are documented ask four important questions which are repeated here because, strategically, they could inform sustainable energy solutions for the residences of Stellenbosch University as institutional vehicles of change:

1. How can the student religious organisations be accessed so as to introduce or initiate sustainable living awareness and projects amongst students on Stellenbosch campus?

2. Could the process of float building during 'Jool' not be more resource aware so that sustainable resource use is highlighted? (For example, use recycled or re usable products or include sustainable energy use in the judgement criteria).
3. What steps are being taken to implement institutional capacity for leadership positions within the HK structure that focus exclusively on sustainable living in the residences of Stellenbosch University and capacitate leaders to legally enforce certain actions?
4. The behavioural dynamic of student apathy raises the question of whether sustainable energy solutions can rely on behavioural changes or should they rather be technologically motivated?

The information above informs the research objective by accessing local knowledge (Willems) to place issues relating to student culture and context into the frame of reference. It suggests that solutions will have to take the student culture of awareness into account. Four strategic avenues of accessing student culture surfaced from the investigation. Why Lydia Residence won the US Energy Challenge is still not clear. The findings allude to the impact of leadership motivating behaviour that espouses energy conservation as well as the technological implementation of CFL's. As a critical case study, however, Lydia residence does not conclusively reveal the factors which influenced a decreased residential energy consumption or promoted energy efficiency.

5.3. Results of the general walk-through energy audit of Lydia Residence

The results of the general walk through energy audit of Lydia Residence included structural features of the building, lighting details and appliance details. The results are displayed below in tables 32, 33, and 34 and the accompanying photographs. An analysis is provided thereafter.

Table 32: Record of structural features during the general walk through energy audit of Lydia Residence

Observation	Accompanying photographic evidence
Direction of Lydia: north to north north east	

<table>
<tr><td>ENERMAX loggers which log energy consumption.</td><td>
</td></tr>
<tr><td colspan="2">There is one plug socket in each room. Students usually use a five point plug extension cord in this socket. Of the five plug points on the extension cord, one is for the fridge and each student is allocated two plug sockets.</td></tr>
<tr><td>The showers did not make use of low flow showerheads. However, the plumbing and pressure configuration of the showers in Lydia Residence would not be optimal for low flow showerheads due to a lack of pressure.</td><td></td></tr>
</table>

<table>
<tr>
<td>Visiting two rooms, the following appliances were observed:

• Fridge
• CFL ceiling light
• Laptop/computer
• Desklamp
• Kettle
• Hairdryer
• Cellphone charger
• Fan heater
• Cooling fan
• Radio
• Warming blanket
• Element Heater
• (Discovered the use of a griller, which is not allowed)</td>
<td>
 
</td>
</tr>
</table>

The use of north facing balconies as drying spaces for clothes	  

	
Water heating technology is a heat pump shared with Huistenbosch. The heat pump which generates hot water for Lydia Residence and Huistenbosch was viewed with Omer and Krige. The following technical characteristics of this heat pump configuration were noted: *Two compressors and heat pumps *Two tanks, one with colder water and one with warmer water *Volume of each tank=7 200 l (7.2 m3) *Tanks are insulated with an inner lining *Rated thermal output of each heat pump=100 kW *Estimated cost of each heat pump= less than R 100 000 *Sensor activated so that when the temperature difference between the two tanks is out of sync the heat pump is switched on and heats the water *Average water temperate is heated to approximately 65 °C *Mains water comes in at approximately 15 °C *A small circulating pump is installed so that warm water is in the pipes in the morning Krige highlighted the benefits of managing heat pumps. Firstly, they have much lower rates of compressor burnouts compared to element failures in geysers. Secondly, heat pumps allow for better control over supply of hot water as they can heat a large volume of water in a relatively short time and then be switched off whereas geysers remain on all the time. The question was asked why timers and geyser blanket insulation options could not be installed to promote energy efficiency in the residences which used geysers. Krige and an associate from Maintenance responded that timers would not work because the showering schedules were not known and that experience with geyser insulation was proving to be problematic because the extra sweating and moisture was damaging the thermostat controls of the geysers.	 

Three types of space lighting are used within Lydia Residence and each type is described and illustrated with a photograph below. The first is a circular CFL, 16 W, ceiling light which is enclosed in plastic and is found in the passageways and bathrooms of the first and second floor. The second is double fluorescent tube fittings. The tubes are either 1, 2m (36 W or 40 W) or 1, 5 m (58 W or 65 W) and magnetic ballasts were identified on them. The tubular lighting features on the ground floor. The third type of lighting is incandescent light bulbs, which are used for the service station in the kitchen and a lamp in the small TV room. One CFL bulb was noted amongst the incandescent bulbs in the kitchen.

Figure 20: Circular fluorescent lighting in the communal areas of Lydia Residence

Figure 21: Tube fluorescent lighting in the communal areas of Lydia Residence

Figure 22: Incandescent lighting in the communal areas of Lydia Residence

During the audit, two students complained that the ceiling CFL lighting in their rooms did not provide adequate light for studying purposes and they resorted to their own lamps as the primary source of light in their rooms.

Table 33: Record of lighting details from the general walk-through energy audit of Lydia Residence

Room/Area	**Light fitting and power rating (W)**	**Quantity**	**Estimated time span in which lighting is left on (hours)**
Dining room (ground floor)	Double 36 W fluorescent	2	Not quantified
	Double 40 W fluorescent	5	Not quantified
	1 36 W and 1 40 W in double fitting	1	Not quantified
Passageway (ground floor)	Double 58 W fluorescent tube	2	Not quantified
Bathroom 1 (ground floor)	Double 65 W fluorescent tube	1	Not quantified
Bathroom 2 (ground floor)	Double 65 W fluorescent tube	1	Not quantified
Kitchen (ground floor)	Double 58 W fluorescent tube	8	Not quantified
Study centre (ground floor)	Double 40 W fluorescent tube	4	Not quantified
Washing room (ground floor)	Double fluorescent tube 58 W	2	Not quantified
TV room (ground floor)	Double 36 W fluorescent tube	4	Not quantified
	Double 40 W fluorescent tube	2	Not quantified
Argrief (ground floor)	Double 36 W fluorescent tube	2	Not quantified
Bloukamer (ground floor)	Double 40 W fluorescent tube	4	Not quantified
Ground floor passage and	2 D CFL 16 W	54	Not quantified

bathroom lights			
First floor passage and bathroom lights	2 D CFL 16 W	46	Not quantified
Second floor passage and lights	2 D CFL 16 W	44	Not quantified
Ground floor private rooms	2 D CFL 16 W	23	Not quantified
First floor private rooms	2 D CFL 16 W	40	Not quantified
Second floor private rooms	2 D CFL 16 W	43	Not quantified

Table 34: Record of appliance details from the general walk-through energy audit of Lydia Residence

Room/ Area	Appliance	No of appliances	Power rating of appliance (W)	Estimated time span in which appliance is left on (hours)
Dining Room	Toaster Large toaster Hydroboil Warming tray Warming counter Cooling counter	1 1 1 1 1 1	Not labelled Not labelled 2,4 kW 1,2 kW 6 kW Not labelled	 2,5 24 1,5 3 1
Kitchen	Fridges Deep freeze Steamer Urn	4 1 1 1	Not labelled Not labelled 3.1 kW 3 Kw	24 24 1.5 10
Washing room	Tumble dryer Tumble dryer Washing machine Card readers	2 1 3 7	4 000 5 200 600 Not labelled	
Small TV room	TV VCR Vending Machine Vending Machine	1 1 1 1	Not labelled 16 W 9 00 W Unable to reach	
Large TV room	TV VCR DVD MNET Decoder UPS system	1 1 1 1 1	Not labelled 16 W Not labelled Not labelled Not labelled	
Mini kitchen	Stove and oven Toaster Microwave	1 1 1	Not labelled 1 300 W 900 W	
Villa Kitchenette	Toaster Microwave	1 1	1 300 W 900 W	
Flat Kitchenette	Fridge and freezer Toaster Microwave Coffee machine Snackwich machine Kettle	1 1 1 1 2 1	Unable to reach 850 W 1 200 W 900 W 750 W/ 690 W 2 000 W	

	Hot plate Can opener Fan	1 1 1	2 000 W Not labelled 50 W	
First floor kitchenettes	Toaster Microwave Mini bar fridge Ironing board	2 2 1 2	1 300 W/800 W 1350 W Not labelled	
Second floor kitchenettes	Toaster Microwave Kettle Ironing board	1 2 1 2	800 W 1200 W/1350 W 2 200 W	
Front porch	Card reader Electronic door			

The general walk-through audit informed the research objective by exposing several key points of intervention for energy efficiency and contributed towards the research objective as a useful tool. Firstly, the high power rating of the kitchen equipment and serving equipment in the dining area stood out as a major area of investigation. Secondly, opportunities for improved energy efficiency for lighting in terms of ballasts and improved power ratings were revealed. The use of several older rated tubes, 40 W and 65 W, could be replaced with more efficient 36 W and 58 W fittings and magnetic ballasts could be replaced with energy efficient electronic ballasts. Thirdly, improved water wise showerheads could possibly be used in the bathrooms to improve the energy efficiency of water heating requirements. Fourthly, an old tumble dryer, rated at 5 200 W, was discovered. Modern equivalents are rated at 4 000 W. This indicated the use of old appliances which could be replaced with modern, more efficient power rated appliances. The last three points of intervention had clear replacement options; the equipment in the kitchen required further enquiry.

Kevin Matthews, an architect at the Facilities Management Department, was contacted to discuss the residential kitchens (2008: telephonic interview). Matthews had been involved in a review of sustainable energy opportunities within the residential kitchens at Stellenbosch University. Matthews explained that one attempt at sustainable energy has been to install tilting frying pans which operate on gas in several centralised kitchens in June 2007. Although this saves on electricity, gas refilling prices and maintenance considerations have added to expenses. Matthews stated that management is worried about the bottom line and sustainability takes second place to this. If the capital cost for an energy efficient option is higher than an alternative, it will most likely not be considered as an option. Matthews stressed the point that end use energy efficiency in the kitchens at Stellenbosch University needs to consider the timing schedule for meals. The allocated time slots in centralised kitchens calls for equipment that can cope with a high throughput in short time. This translates into high power ratings because food needs to be cooked or heated quickly and dishes have to be washed quickly. For example, the steamer with a booster rated at 3 kW, which is used to wash the dishes, is needed for health reasons to eradicate bacteria. In addition, if someone had to wash all the plates by hand, this person would have to be employed the entire day. With regards to the context of student living in Stellenbosch, the kitchens need to be able to cope with a high turnover of students within a short timespan, enabled by highly rated equipment.

5.4. Results from the Lydia energy survey

The idea for an energy survey was created during the walk through energy audit as it became apparent that access to private rooms would not be possible. Furthermore, suggestions for energy efficiency cannot be made unless the baseline situation is known: conducting an energy audit is the first step towards sustainable energy solutions for the residences as it demarcates the baseline context against which recommendations need to be made. The results from the Lydia energy survey served as a testing ground for developing a questionnaire that can be applied to all residences and, therefore, usefully informed a strategy or approach towards sustainable energy use. The survey revealed that, in future, awareness of appliance and lighting power ratings should be tested, as well as knowledge of the variables that influence energy consumption. In future, the questionnaire should explain different technologies with images or a clear description. Secondly, the responses to the questions, although unique to the context of Lydia, highlighted and affirmed key intervention areas for implementation that could be applicable to other residences too.

The questionnaire was completed by 139 students from Lydia Residence. Lydia Residence has an official capacity of 183 students (in 2008). Therefore, 75.9% of Lydia residents responded. The results below document these responses according to appliance use and bathing trends and the accompanying bar graphs which indicate the responses statistically (Nel, 2008a: Centre for Statistical Consultation) can be found in Appendix C.

5.4.1. Appliance use

The results from the questions relating to appliance use are described and analysed below. The results from Question 1 generated a profile of what the average student room in Lydia Residence looks like. The appliances most commonly used in the rooms of the respondents are recorded in Table 35 and the perceived time period for which students think they use these appliances is recorded in Table 36.

The appliance most commonly found in the rooms of Lydia Residence is a kettle. A kettle has a high power rating. They are generally rated at 2 kW in South Africa. Based on the Lydia energy survey results above, if the 115 respondents who indicated a time period for their kettle use, put a 2 kW kettle on for 0.38 hours (23minutes) a day, it equates to 2622 kWh per month. This is a function of:

Energy = Power x Time

= 2 kW x 0.38 hrs

= 0.76 kWh per student

115 students x 0.76 kWh/students/day x 30 days

= 2622 kWh/month

This statistical average calculated from the Lydia Energy Survey constitutes 24% of the 2003–2007 Lydia Residence total residential energy consumption average of 10 797 kWh/month. If these survey results accurately reflect real kettle use in Lydia Residence, this amounts to a significant portion of the monthly residential energy consumption. However, the statistical assumptions of time periods taken from the Lydia Energy Survey cannot be considered as a definite given for the time which a kettle is put on every day in Lydia Residence - the survey mapped perception of time and not actual recorded time. Instinct also questions the accuracy of students' perceptions of how long their kettle was used: does the average student put a kettle on for a total of 22 minutes each day?

By comparing Table 35 and Table 36 to each other, one can identify which appliances will most likely contribute towards significant energy consumption within the context. The summer fridges, summer blow fan, study lamp, laptop and PC surface as appliances that should be as energy efficient as possible and on which energy conservation tactics should be practiced in Lydia Residence. In addition, with regard to the 'switching off' trend, 10% physically unplug the appliance at the socket, 9% switch off the switch on the plug socket and 81% make use of the 'off' button that exists on the appliance (Figure 26) (Figure 26 to 31 are presented in Appendix C). The majority of respondents switch off an appliance by making use of the off button that is on the appliance.

Table 35: Appliance profile according to frequency of use (in percentage) as generated by Question 1 of the Lydia Residence energy survey

Appliance	Frequency of use in percentage
Kettle	93%
Fridge	88%
Cell phone charger	88%
Study lamp	83%
Hair dryer	70%
Summer fan	70%
Laptop	68%
Radio	33%
Winter blow fan	22%
PC	11%
Hair straightener	6 %
Element heater	4 %
Toaster	2%
Electric blanket	2%
GHD (not specified)	0.7%
Smoothie machine	0.7%
Tooth brush charger	0.7%

Table 36: Appliance profile according to estimated use (in hours per day) as generated by Question 1 of the Lydia Residence energy survey

Appliance	Average estimated use in hours per day
Tooth brush charger	24
Fridge	23.09
PC	7.79
Laptop	6.59
Summer blow fan	5.43
Study lamp	4.05
Radio	3.61

Winter blow fan	3.11
Element heater	2.83
Cell phone charger	1.74
Electric blanket	1.33
Smoothie machine	0.5
Hair straightener	0.42
Kettle	0.38
Toaster	0.35
GHD	0.33
Hair dryer	0.31

In addition to the room profile above, the following characteristics for computer use, lighting, kitchenette use and clothes washing prevail in Lydia Residence. The majority of the respondents who have a laptop or PC use an LCD screen (Figure 25). This is also influenced by the fact that 109 respondents make use of a laptop in their room while 15 respondents make use of a PC and laptops generally use an LCD screen. Of the respondents, 7% leave their laptop or PC on, 55% switch their laptop or PC off and 38% leave their laptop or PC on standby (Figure 25). The findings confirm that the majority of computer users are using the most efficient monitors although the 38 % of students who make use of the standby option present an opportunity for energy conservation awareness and education.

With regards to lighting, 77% of the respondents claimed that the current ceiling CFL is insufficient in the rooms (Figure 27). A few respondents emphasised this point with emotional additions to the answering space. With regard to energy efficient lighting, 62 respondents claimed to know what type of bulb is used in their study lamp in Question 6a (Figure 28), yet 74 respondents specified knowledge in Question 6b of the type of bulb that was being used (Figure 29). The response to Question 6b does indicate that 40% of Lydia Residence has an awareness of the type of bulb used in the lamps that they purchase. Of this 40%, the majority identified their bulbs as halogen or, following that, incandescent. The 15 respondents who claimed that they were making use of a CFL bulb indicate that 11% of Lydia Residence is supporting energy efficient lighting. The remaining 89%, those who use halogen and incandescent lighting, present a point of intervention for energy efficient light bulbs.

With regard to energy conservation, 61% of the respondents claim to always switch off their room lights when they leave the room, 35% claimed to usually do this, 3% believe that they sometimes switch the lights off when they leave a room, and 1% admit to not switching the lights off (Figure 30). If this perception about energy saving behaviour is in fact a reflection of real behaviour, energy saving awareness and behavior is successfully being encouraged in Lydia Residence.

The use of cooking appliances can be accounted for in Table 37 below. The microwave is the most popular cooking activity and thus the most used appliance within the kitchenettes of Lydia Residence. The results suggest a moderate to low frequency of use of the kitchenettes and therefore not a significant area for intervention.

Table 37: Summary of cooking appliance use in Lydia Residence (generated by answers to Question 10 of the Lydia Residence energy survey)

Cooking activity	**No of respondents who answered yes to using kitchenette for the respective cooking activity**
Preparing snacks	17
Preparing main meal	19
Microwave cooking	100
Toast making	28
Grilling/frying	4

With regard to clothes washing trends, 37% of the respondents claim to not make use of the laundry services available within Lydia Residence. Approximately a quarter of the residents only use the washing machine and then dry their clothes in the sun while approximately a quarter of the residence use the tumble dryer along with the washing machine to clean their clothes. The results are summarised in Table 38. The results suggest that residents do try and make use of sun drying and that tumble dryers are not used excessively. The washing habits of residents can be improved to promote more sun drying but, as an area of intervention, they do not stand out significantly.

Table 38: Summary of clothes washing trends in Lydia Residence (generated by answers to Question 13 of the Lydia Residence energy survey)

Technique used	No of respondents who answered yes to making use of this technique
Washing machine only	43
Washing machine and tumble dryer	38
Tumble dryer every time	4
Tumble dryer sometimes	10
Drying lines on the balcony	41
Do not use clothes washing or drying equipment at Lydia Residence	51

5.4.2. Bathing trends

Of the 139 respondents, 79% claim to only shower once a day (Figure 33). The majority (91.3%) claim to only shower between 5 and 15 minutes (Figure 32). Within this bracket, the most popular showering time period is 10 minutes. As in the previous question, the responses reflect perceived behaviour and not quantitative measurements. A few students did comment additionally that the length of their shower depends on whether or not they wash their hair. The peak times for bathing could not be deduced due to the lack of clarity in the options of the survey.

53% of respondents answered that they would not prefer a low flow showerhead retrofit if the water pressure is decreased even if they knew it was contributing favourably towards environmental sustainability (Figure 31). Reasons cited generally pertained to the fact that less pressure would mean they would have to shower for longer when washing their hair.

5.4.3. Summary points of intervention

The results from the energy survey revealed areas of intervention for energy efficiency and energy conservation (switching off lights, using the sun to dry clothes, short showers). As a process, it contributed positively towards identifying what can be done within the residence as well as identifying which efforts would be wasted because they already exist in the residence. The results from Lydia Residence isolated the type of study lamp as a significant area of intervention for energy efficiency, followed by encouraging not using standby options on computers. In addition, and resonating with the literature review, the survey revealed a task lighting issue: energy efficient lighting must not be implemented at the expense of contextual needs. The response to the question of the low flow showerhead highlighted that alternatives to a low flow showerhead would have to be sought before energy efficient showerhead options are considered.

5.5. Allocating the Eskom prize money towards energy efficiency

Various negotiating processes and discussions (Willems, Malan, Leslie, Fluri, Omer, Overmeyer, 2008: personal communication) concluded that seven energy efficient and energy conservation technologies, summarised below, would be specifically viable for the context of Lydia Residence and possible within the given budget of R 5 000. These seven options are discussed below and analysed, where possible, in terms of relative energy savings and payback periods[13].

1. Fluorescent tube retrofit (suggested by the energy audit)
2. Ballast retrofit (suggested by the energy audit)
3. Ballast and fluorescent tube retrofit (suggested by the energy audit)
4. Change current shower heads to 'econo' showerhead (suggested by the energy audit and energy survey)
5. Change light bulbs used in study lamps (suggested by the energy survey)
6. Buy solar PV powered garden lights (suggested by the energy audit)
7. Buy new tumble dryer to replace old 5,2 kW tumble dryer (suggested by the energy audit)

A technical lighting consultant from Eagle Lighting was visited and the quoted prices for various lighting details are presented in Table 39 below.

[13] The payback periods calculated for the seven technological options are general and, in several cases, rely on assumptions made by the researcher due to a lack of available quantitative data. They are not rigorously scientific or highly detailed investigations. In addition, in certain cases, not one payback period but several periods were calculated with assumptions being based on 'best case', 'worse case' or 'middle path' scenarios so as to provide rough boundaries within which the actual payback period would fall. In incidences where general periods are given (for example, 15 – 20%), the most conservative estimate for that context is always selected for the calculation.

Table 39: Quoted prices from Eagle Lighting, 14 May 2008

Fitting	Quoted price
Single 1,2 m 36 W fluorescent tube	R 8.66
Double 1,2 m magnetic ballast	R165.00
Double 1,2 m electronic ballast	R179.00
Double 1,2 m retrofit with energy efficient tube and electronic ballast	R196.32
Single 1,5 m 58 W fluorescent tube	R10. 83
Double 1,5 m magnetic ballast	R172.00
Double 1,5 m electronic ballast	R299.00
Double 1,5 m retrofit with energy efficient tube and electronic ballast	R320.66
14 W CFL screw in or bayonet bulb	R28.95

5.5.1. Fluorescent tube retrofit for common lighting

The general walk-through energy audit identified 15 double 1, 2 m fittings with two 40 W tubes each and one double 1,2 m fitting with one 40 W tube (see Table 32). Therefore, thirty-one 40 W tubes could be replaced with 36 W tubes. Two double 1, 5 m fittings with 65 W tubes were also identified and this translates to replacing the 65 W tubes with four 58 W tubes.

The replacement of the fluorescent tubes mentioned above costs R311. 78 ([31@ R8.66] + [4@R10.83]). The cumulative power savings amounts to 152 W ([31@4 W] + [4@7W]). In the ideal savings scenario, these lights are left on for 24 hours a day and for 365 days in a year, generating energy savings of 1331.52 kWh/year (0.152 kW x 24 hours x 365 days). However, the lights are not left on for 24 hours a day, 365 days a year. Assume that the lights are used 300 days of the year[14], with the option of being left on average for a certain number of hours per day. The payback period as well as the annual relative energy savings on the average electricity (residential and kitchen) consumption of Lydia Residence of 173 171 kWh per annum is calculated below in Table 40.

[14] An assumption of 300 days is made by the researcher based on the notion that, of the official holiday time (approximately 106 days), most residences usually have visitors during holiday periods. In addition, there is not one residence that indicates zero energy consumption during the holiday time from the data. This is therefore an estimated probability.

Table 40: Payback periods for fluorescent tube retrofit

Assumed average time per day for which lights are on	Annual payback period	Relative average annual energy savings in percentage
1	Energy savings = Power x Time Energy savings = 0.152 kW x 1 hour x 300 days Annual energy savings = 45.6 kWh per year Financial savings = 45.6 kWh per year x R0.229/kWh Financial savings = R10.44 per year Payback period = R311.78/R 10.44 per year Payback period = 29.8 years	= Annual Energy savings x 100 Annual energy consumption = 45.6 kWh x 100 173 171 0.02%
4	Energy savings = Power x Time Energy savings = 0.152 kW x 4 hours x 300 days Annual energy savings = 182.4 kWh per year Financial savings = 182.4 kWh per year x R0.229/kWh Financial savings = R41.76per year Payback period = R311.78/R 41.76 per year Payback period = 7.4 years	= Annual Energy savings x 100 Annual energy consumption = 182.4Wh x 100 173 171 0.1%
8	Energy savings = Power x Time Energy savings = 0.152 kW x 8 hours x 300 days Annual energy savings = 364.8 kWh per year Financial savings = 364.8 kWh per year x R0.229/kWh Financial savings = R83.53per year Payback period = R311.78/R 83.53 per year Payback period = 3.7 years	= Annual Energy savings x 100 Annual energy consumption = 364.8 kWh x 100 173 171 0.21%
12	Energy savings = Power x Time Energy savings = 0.152 kW x 12 hours x 300 days Annual energy savings = 547.2 kWh per year Financial savings = 547.2 kWh per year x R0.229/kWh Financial savings = R125.30per year Payback period = R311.78/R 125.30 per year Payback period = 2.4 years	= Annual Energy savings x 100 Annual energy consumption = 547.2 kWh x 100 173 171 0.3%
16	Energy savings = Power x Time	= Annual Energy savings x 100

	Energy savings = 0.152 kW x 16 hours x 300 days Annual energy savings = 729.60 kWh per year Financial savings = 729.60 kWh per year x R0.229/kWh Financial savings = R167.07per year Payback period = R311.78/R 167.07 per year Payback period = 1.8 years	Annual energy consumption = 729.60 kWh x 100 173 171 0.42%

5.5.2. Ballast retrofit for common lighting

The energy audit reported that twenty four 1, 2 m fittings with magnetic ballasts exist and identified fourteen 1, 5 m fittings with magnetic ballasts. The total power capacity of the twenty four 1, 2 m fittings in Lydia Residence is 1 852 W (17 fluorescent tubes@36 W+31 fluorescent tubes@40W). The total power capacity of the fourteen 1, 5 m fittings in Lydia Residence is 1 652 W (24 fluorescent tubes@58 W + 4 fluorescent tubes@ 65W). The cost of replacing magnetic ballasts with electronic ballasts would equate to R 8 482.00 ([24@R179.00] + [14@R 299.00]). It is assumed that electronic ballasts fitted to the 1, 2m fitting save approximate 10-15% of energy and that electronic ballasts fitted to the 1, 5m fittings save approximately 15-20% (Gerswynn, 2009:electronic communication). In accordance with the fluorescent tube retrofit option discussed above (5.5.1), assume that the lights are left for the same hours a day, 300 days a year.

Table 41: Payback periods for an electronic ballast retrofit

Assumed average time per day lights are on	Annual payback period	Relative average annual energy savings in percentage
1	Energy = Power x Time 1,2 m energy = 1.852 kW x 1 hour x 300 days= 555.6 kWh ∴10% savings = 55.56 kWh 1,5 m energy = 1.652 kW x 1 hour x 300 days=495.6 kWh ∴ 15% savings =74.34 kWh Total annual energy savings = 129.9 kWh Financial savings = 129.9 kWh per year x R0.229/kWh Financial savings = R 29.74 per year	= Annual Energy savings x 100 Annual energy consumption = 129.9Wh x 100 173 171 0.07%

	Payback period = R 8 482.00 /R 29. 74 per year Payback period = 285 years	
4	Energy = Power x Time 1,2 m energy = 1.852 kW x 4 hours x 300 days= 2 222.4 kWh ∴10% savings = 222.24 kWh 1,5 m energy = 1.652 kW x 4 hours x 300 days=1 982.4 kWh ∴ 15% savings = 297.36 Total annual energy savings = 519.60 kWh Financial savings = 519.60 kWh per year x R0.229/kWh Financial savings = R 118.98 per year Payback period = R 8 482.00 /R 118.9 per year Payback period = 71 years	= Annual Energy savings x 100 Annual energy consumption =519.60 kWh x 100 173 171 0.3%
8	Energy = Power x Time 1,2 m energy = 1.852 kW x 8 hours x 300 days= 4 444.8 kWh ∴10% savings = 444. 48 kWh 1,5 m energy = 1.652 kW x 8 hours x 300 days=3 964.8 kWh ∴ 15% savings = 594.72 kWh Total annual energy savings = 1039.2 kWh Financial savings = 1039.2 kWh per year x R0.229/kWh Financial savings = R 237.97 per year Payback period = R 8 482.00 /R 237.97 per year Payback period = 35 years	= Annual Energy savings x 100 Annual energy consumption = 1 039.2kWh x 100 173 171 0.6%
12	Energy = Power x Time 1,2 m energy = 1.852 kW x 12 hours x 300 days=6 667.2 kWh ∴10% savings = 666.72 kWh 1,5 m energy = 1.652 kW x 12 hours x 300 days=5 947.2 kWh ∴ 15% savings = 892 kWh Total annual energy savings = 1 558.8 kWh Financial savings = 1 558.8 kWh per year x R0.229/kWh Financial savings = R 356. 96 per year Payback period = R 8 482.00 /R 356.96 per year Payback period = 23 years	= Annual Energy savings x 100 Annual energy consumption = 1 558.8 kWh x 100 173 171 0.9%
16	Energy = Power x Time 1,2 m energy = 1.852 kW x 16 hours x 300 days=8 889.6 kWh	= Annual Energy savings x 100 Annual energy consumption

	∴10% savings = 888.96 kWh 1,5 m energy = 1.652 kW x 16 hours x 300 days=7 929.6 kWh ∴ 15% savings = 1 189.44 kWh Total annual energy savings = 2 078.4 kWh Financial savings = 2 078.4 kWh per year x R0.229/kWh Financial savings = R 475.95 per year Payback period = R 8 482.00 /R per year Payback period = 17 years	= 2 078.4 kWh x 100 173 171 1.2 %

5.5.3. Fluorescent tube and ballast retrofit for common lighting

This retrofit entails a combination of changing the magnetic ballasts to electronic ballasts as well as replacing the relevant fluorescent tubes with more efficient models. Such a retrofit would cost R 8 793.78 (R 8 482.00 + R311. 78 ; detailed in section 5.5.1 and 5.5.2). The total annual energy savings consist of the energy savings from three amounts. The first is from using more efficient tubes (calculated in Table 40, section 5.5.1). The second is the 10% energy savings from retrofitting all 1, 2 m fittings with electronic ballasts. The total power capacity of 1,2 m fittings after being retrofitted with more efficient tubes, where necessary, is 1 728 W (48 fluorescent tubes@ 36 W each). The third is the 15% energy savings from retrofitting all the 1, 5 m fittings with electronic ballasts. The total power capacity of 1,5 m fittings after being retrofitted with more efficient, where necessary, is 1 624 W (28 fluorescent tubes@ 58 W each).

Table 42 : Payback periods for a fluorescent tube and electronic ballast retrofit

Assumed average time per day, lights on	**Annual payback period**	**Relative average annual energy savings in percentage**
1	Energy = Power x Time Fluorescent tube energy savings = 45.6 kWh 1,2 m energy = 1.728 kW x 1 hour x 300 days = 518.4 kWh ∴10% electronic ballast retrofit energy saving = 51.84 kWh 1,5 m energy = 1.624 kW x 1 hour x 300 days = 487.2 kWh ∴ 15% electronic ballast retrofit energy saving = 73.08 kWh	= Annual Energy savings x 100 Annual energy consumption = 170.52 kWh x 100 173 171 0.09%

	• Total annual energy savings = 170.52 kWh Financial savings = 170.52 kWh per year x R0.229/kWh Financial savings = R39.04 per year Payback period = R 8 793.78 /R39.04 per year Payback period =225 years	
4	Energy = Power x Time Fluorescent tube energy savings = 182.4 kWh 1,2 m energy = 1.728 kW x 4 hours x 300 days= 2 073.6 kWh ∴10% electronic ballast retrofit energy saving = 207.36 kWh 1,5 m energy = 1.624 kW x 4 hours x 300 days = 1 948.8 kWh ∴ 15% electronic ballast retrofit energy saving = 292.32 kWh • Total annual energy savings = 682.08 kWh Financial savings = 682.08 kWh per year x R0.229/kWh Financial savings = R 156.19 per year Payback period = R 8 793.78 /R 156.19 per year Payback period = 56 years	= Annual Energy savings x 100 Annual energy consumption =682.08 kWh x 100 173 171 0.39%
8	Energy = Power x Time Fluorescent tube energy savings = 364.8 kWh 1,2 m energy = 1.728 kW x 8 hours x 300 days= 4 147.2 kWh ∴10% electronic ballast retrofit energy saving = 414.72 kWh 1,5 m energy = 1.624 kW x 8 hours x 300 days = 3897. 6 kWh ∴ 15% electronic ballast retrofit energy saving = 584.64 kWh • Total annual energy savings = 1 364.16 kWh Financial savings = 1 364.16 kWh per year x R0.229/kWh Financial savings = R 312.39 per year Payback period = R 8 793.78 /R 312.39 per year Payback period = 28 years	= Annual Energy savings x 100 Annual energy consumption = 1 364.16 kWh x 100 173 171 0.7%
12	Energy = Power x Time Fluorescent tube energy savings = 547.2 1,2 m energy = 1.728 kW x 12 hours x 300 days = 6 6220.8 kWh ∴10% electronic ballast retrofit energy saving = 622.08 kWh 1,5 m energy = 1.624 kW x 12 hours x 300 days = 5 846.4 kWh ∴ 15% electronic ballast retrofit energy saving =876.96 kWh • Total annual energy savings = 2 046.24 kWh Financial savings = 2 046.24 kWh per year x R0.229/kWh Financial savings = R 468.58 per year Payback period = R 8 793.78 /R 468.58 per year	= Annual Energy savings x 100 Annual energy consumption = 2 046.24 kWh x 100 173 171 1.18 %

	Payback period =18 years	
16	Energy = Power x Time Fluorescent tube energy savings = 729.60 1,2 m energy = 1.728 kW x 16 hours x 300 days = 8 294.4 kWh ∴10% electronic ballast retrofit energy saving = 829.44 kWh 1,5 m energy = 1.624 kW x 16 hours x 300 days = 7 795.2 kWh ∴ 15% electronic ballast retrofit energy saving =1 169.28 kWh • Total annual energy savings = 2 728.32 kWh Financial savings = 2 728.32 kWh per year x R0.229/kWh Financial savings = R 624.78 per year Payback period = R 8 793.78 /R 624.78 per year Payback period =14 years	= Annual Energy savings x 100 Annual energy consumption = 2 728.32 kWh x 100 173 171 1.5 %

5.5.4. Change current showerheads to 'econo' showerheads

Based on information regarding the successful showerhead retrofit in Dagbreek, the same contractor was employed to examine the possibilities for Lydia Residence. The contractor was Deon Stone (2008: telephonic conversation, personal interview, technical installation) from Aqua Smart. He has installed multi flush systems prevalent on Stellenbosch campus and is passionate about saving water. Stone acquiesced to the fact that the shower configuration of Lydia did not suffice for low flow showerheads but he informed us though that he sold a unique showerhead which is not a low flow showerhead but is water saving (and therefore energy efficient), provided the showerhead is not set on the maximum pressure setting. These could be fitted to the showers in Lydia without a loss of pressure or 'shower quality'. Stone referred to this showerhead as an 'econo' shower head and quoted a price of R200.00 for each showerhead. The 'econo' works with older systems which do not accommodate for low flow pressure systems because it pushes the water through additional openings to increase the effect of pressure in the showerhead. Stone explained that, on average, the showerheads save approximately a third of the water used by normal showerheads, if they are not set on the maximum pressure setting. Assuming that all the water is hot water, this would translate to a third of the energy savings too. However, most people mix cold and hot water when bathing so the full water savings cannot directly be translated to energy savings as well.

There are 25 showers in Lydia Residence. At R 200.00 per showerhead, the total cost of replacing all 25 current showerhead with the ‘econo’ showerhead would amount to R 5000.

The average annual energy consumption for hot water in Lydia Residence over the five year period amounts to 82 799 kWh. Keep in mind that, due to the energy metering configuration, this is the proportionate amount and does not represent real energy consumption. If all the showerheads in Lydia were converted to ‘econo’ showerheads the payback period can be calculated. However, several assumptions need to be made explicit for this theoretical and general calculation. Firstly, the ‘econo’ showerheads are not set to maximum pressure. Secondly, students only use showers and not baths. Thirdly, for the estimated third (33.3%) of water savings, it is assumed that 1 quarter (8.32%), half (16.6%) and three quarters (25%) of this water is hot water so that three options are calculated to guide most likely behaviour. An annual energy savings of 8.32% on 82 799 kWh will conserve 6 889 kWh and result in financial savings of R 1 577.58 (6 889 kWh x R0.229 per kWh), allowing the investment to be paid back in 3.1 years. An annual energy savings of 16.6% on 82 799 kWh will conserve 13 745 kWh and result in financial savings of R 3 147.60 (13 745 kWh x R0.229 per kWh), allowing the investment to be paid back in 1.5 years. An annual energy savings of 25% on 82 799 kWh will conserve 20 700 kWh and result in financial savings of R 4 740.30 (20 700 kWh x R0.229 per kWh), allowing the investment to be paid back in 1.05 years.

5.5.5. Change light bulbs used in study lamps

Initially, a lamp exchange was considered. From the energy survey, lighting emerged as the arena which offered the most potential for energy saving. The survey revealed that 46% of the Lydia residents who answered the survey do know which type of bulb is used in the study lamps they own. Of these 46% of residents, 45% claim to make use of halogen bulbs, 35% claim to use incandescent bulbs and 20% make use of energy saving CFL bulbs. It is assumed that for the remaining 54% who did not know which bulb is being used for their study lamp, it is more likely that they would be using halogen or incandescent bulbs as these types are conventionally sold in shops. The survey results revealed that the use of halogen and incandescent light bulbs within the majority of students study lamps holds a large potential for energy savings if they could be replaced with energy saving CFL bulbs.

Based on the estimate that sufficient lighting for a study lamp equates to the quality of light emitted by a 50W halogen lamp, it was deduced that such a lamp produces light quality that is equivalent to 910 lumen (lm). A consultation of manufacturers' books indicated that a CFL which can produce approximately 900 lm equates to a 16 W conventional screw in or bayonet. A conventional CFL screw in or bayonet rated at 8W and 11W respectively produce 400 and 660 lm and are both available for R22.95 (However, OSRAM, the manufacturing company which Eagle Lighting deals with, does not accommodate for the manufacturing of a conventional 16 W CFL in South Africa; alternatively, a 14 W conventional screw in or bayonet produces approximately 800lm and is available in South Africa for R28.95 at retail stores. 18 W or 20 W CFL's are also available for sale in South Africa and they both produce more than the required 900 lm).

The possibility of using 'push in' CFL bulbs was considered as an alternative. These bulbs differ to the conventional screw in or bayonet bulbs in that the bulb cannot be fitted to a conventional lamp stand- they require a special fitting or, more usually a particular lamp stand, which allows them to be pushed in. An 11 W push in CFL produces approximately 900 lm of light. The stands that are needed for the 11 W push in CFL range between R150.00 - R200.00. Push in desk lamps rated at 9 W, and which emit a satisfactory quality of light, are also available on the market and are priced at approximately R79.00 (Northern Lights, Cape Town, 19 May 2008).

3 options therefore exist for 'retrofitting' the personal study or desk lamps owned by students. The first is purchasing a 14 W CFL bulb to replace the current incandescent bulbs. The second is purchasing an 11 W push in lamp for every resident. The third is purchasing a 9 W push in lamp for every resident.

In order to calculate the payback period of these three options, several assumptions need to be made explicit. Firstly, the feedback from Lydia Energy Survey is used for certain estimates. It is assumed that the lamps are used for 4 hours per day (Lydia Energy Survey, Question 1). It is assumed that the halogen lamps make use of 20 W bulbs and the incandescent lamps make use of 60 W bulbs in order to deduce the relative power savings when replaced with lower rated bulbs. The lamps making use of CFL bulbs are not retrofitted. Lastly, it is assumed the lamps are switched on 300 days in a year. Note that the payback periods in this example are calculated per student, as the lamps or bulbs belong to them.

Table 43: Payback periods for personal desk or study lamp purchases

Personal study or desk lamp retrofit option	Payback period per lamp, per student, for 20 W halogen lamp	Payback period per lamp, per student, for 60 W incandescent lamp
14 W CFL	Bayonette or screw in CFL'S can usually not fit into the halogen type lamps purchased by students.	Energy = Power x time Annual energy savings= 0.046 W x 4 hrs x 300 days Annual energy savings = 55.2 kWh Annual energy savings = 76% of average annual energy consumption per student [(55.2 kWh/0.06 kW x 4 hrs x 300 days) x 100] Annual financial 'savings' per student = 55.2 kWh x R0.229 per kWh Annual financial savings per student = R12.64 Payback period = R 28.95/ R12.64 per year Payback period = 2.2 years
Purchasing 11W push in lamp	Energy= Power x time Annual energy savings = 0.009 kW x 4 hrs x 300 days Annual energy savings = 10.8 kWh Annual energy savings = 45% of average annual energy consumption per student [(10.8 kWh/0.02 kW x 4 hrs x 300 days) x 100] Annual financial 'savings' per student = 108 kWh x R0.229 per kWh Annual financial savings per student = R2.47 Payback period = R 150/ R2.47 per year Payback period = 60 years	Energy= Power x time Annual energy savings = 0.049 W x 4 hrs x 300 days Annual energy savings = 58.8 kWh Annual energy savings = 81.6% of average annual energy consumption per student [(58.8 kWh/0.06 kW x 4 hrs x 300 days) x 100] Annual financial 'savings' per student = 58.8 kWh x R0.229 per kWh Annual financial savings per student = R13.46 Payback period = R 150/ R13.46 per year Payback period = 11 years
Purchasing 9 W push in lamp	Energy = Power x time Annual energy savings = 0.011 kW x 4 hrs x 300 days Annual energy savings = 13.2 kWh Annual energy savings = 55% of average annual energy consumption per student [(13.2 kWh/0.02 kW x 4 hrs x 300 days) x 100] Annual financial 'savings' per student = 13.2 kWh x R0.229 per kWh Annual financial savings per student = R3.02 Payback period = R 79/ R3.02 per year	Energy = Power x time Annual energy savings = 0.051 kW x 4 hrs x 300 days Annual energy savings = 61.2 kWh Annual energy savings = 85% of average annual energy consumption per student [(61.2 kWh/0.026kW x 4 hrs x 300 days) x 100] Annual financial 'savings' per student = 61.2 kWh x R0.229 per kWh Annual financial savings per student = R14.01 Payback period = R 79/ R14.01 per year

	Payback period = 26 years	Payback period = 5.6 years

The desk/study lamp exchange would depend upon the voluntary co operation of the students. The practical and political logistics of such an activity have been pointed out by those who live in Lydia as being problematic. The residential authorities have no legal grounds upon which to encourage or enforce such a retrofit. Furthermore, investing in lamps, which then become an asset which students have to take care of, could be an unwise investment of the money as there is no surety that the students will take care of a lamp which does not belong to them.

5.5.6. Buy solar PV garden lights

Willems suggested solar PV powered garden lights for the central courtyard. This would entail relative savings against the lights that would not need to be switched on. At the quoted rate of R120. 00 per solar garden light (model LS007, available at Bright Star Lighting, Cape Town) (Willems, 2008: personal communication), this purchase would be affordable within the budget and possibly play an educational role or promote awareness of sustainable energy use. With the R 5000, 41 solar garden lights can be purchased. This amount is unnecessary for the landscaping space requirements of Lydia Residence. At most, 20 solar garden lights would suffice. This installation would thus cost R 2 400. The product specifications for the LS 007 solar garden light indicate a power rating of 0.06 W for each solar garden light, with an average operating time span of 6 – 8 hours per day.

The payback period is therefore calculated as follows:

Annual energy savings = 20 x 0.00003 kW x 6 hours x 365 days

Annual energy savings = 1.314 kWh/year

Annual energy savings = 0.00075 % on average annual energy consumption (1.314 kWh per year/ 173171 kWh average energy consumption per year x 100)

Annual financial savings1.314 kWh @ R0.229 = R0.30

Payback period = R 2 400/ R0.30 per year

= 8000 years

5.5.7. Replace tumble dryer

A new 4 kW tumble dryer, to replace the old, 5.2 kW tumble dryer that is currently in the washing room, was suggested. This would allow for a 1.2 kW saving every time the tumble dryer is used. The following hypothetical scenarios were calculated to see what energy savings potential such an investment could stimulate for Lydia Residence. The replacement tumble dryer would cost approximately R 3 200.00 (Bezuidenhout, 2009: telephonic interview). Assuming the replacement tumble dryer operates for the same times as suggested in Table 43, 300 days in a year, the following annual payback periods can be deduced.

Table 44: Payback periods for a tumble dryer exchange

Assumed time of tumble dryer operation per day, 300 days per year	**Annual payback period for replacing the 5.2 kW tumble dryer with a 4 kW model**
10 minutes	Energy savings = Power x Time Energy savings = 1.2 kW x 0.1667 hr x 300 days Energy savings = 60 kWh/year Energy savings = 0.03% of average energy consumption (60 kWh per year/173 171 kWh average energy consumption per year) Annual financial savings = 60 kWh x R0.229 Annual financial savings = R13. 74 Annual payback period = R 3200/R13.74 Annual payback period = 232 years
1 hour	Energy savings = Power x Time Energy savings = 1.2 kW x 1 hr x 300 days Energy savings = 360 kWh/year Energy savings = 0.2% of average energy consumption (360 kWh per year/173 171 kWh average energy consumption per year) Annual financial savings = 360 kWh x R0.229 Annual financial savings = R82. 44 Annual payback period = R 3200/R82.44 Annual payback period = 38.8years
3 hours	Energy savings = Power x Time Energy savings = 1.2 kW x 3 hr x 300 days Energy savings = 1080 kWh/year Energy savings = 0.6% of average energy consumption (1 080 kWh per year/173 171 kWh

	average energy consumption per year) Annual financial savings = 1080 kWh x R0.229 Annual financial saving s = R247.32 Annual payback period = R 3200/R247.32 Annual payback period = 12.9 years
5 hours	Energy savings = Power x Time Energy savings = 1.2 kW x 5 hr x 300 days Energy savings = 1800 kWh/year Energy savings = 1.03% of average energy consumption (1 800 kWh per year/173 171 kWh average energy consumption per year) Annual financial savings = 1800 kWh x R0.229 Annual financial savings = R412.20 Annual payback period = R 3200/R412.20 Annual payback period = 7.7 years
10 hours	Energy savings = Power x Time Energy savings = 1.2 kW x 10 hr x 30 days Energy savings = 3600 kWh/year Energy savings = 2.07% of average energy consumption (3600 kWh per year/173 171 kWh average energy consumption per year) Annual financial saving s = 3600 kWh x R0.229 Annual financial savings = R824.40 Annual payback period = R 3200/R824.40 Annual payback period = 3.8 years

5.5.8. Points of intervention

This exercise was useful as it allowed for an intimate investigation of the effect that certain installations could induce. The estimated energy savings favour the ‘econo’ showerhead retrofit and the options relating to the personal study or desk lamp purchases as these espouse the most significant relative savings on annual energy consumption, which could translate into environmental benefits. The remaining retrofits suggest more modest savings between 0.00075% to 2.07%. The more modest estimated savings, in comparison to 8 - 85% savings of the showerhead and personal lamp retrofits, are however still significant if seen as a part of the national 10% energy saving target set by Eskom for their nationwide energy efficiency drive.

The estimated payback periods, often the actual, and in some cases the only, deciding factor for decision makers in practise, do, however, not favour many options. The most conservative estimate for the 'econo' showerhead' (8.32% energy saving, payback period of 3.1 years) and the CFL bulb exchange for a 60 W incandescent (76% energy savings, payback period of 2.2 years) are the most favourable conservative estimates. The remaining payback periods only become viable if the time spans become longer, which are often more unlikely in everyday residential living. This highlights the step in which decision makers will deem such technology as unnecessary as they do not make economic sense.

However, the findings also suggest a significant point. The estimated theoretical energy savings suggest that the impact of energy efficiency is marginal in Lydia Residence. Possibly, this reveals that Lydia Residence could be operating efficiently. This does not in any way delineate energy efficiency as obsolete for other residences on campus; it merely highlights the limits of energy efficiency within the context of Lydia Residence. The results for another residence could differ drastically.

5.6 A tool for residential leaders to implement end use energy efficiency

The processes described above culminated in the formation of a tool which the residential leaders can adopt in order to promote end use energy efficiency within the residences of Stellenbosch University. The case study methodology promotes a bottom up approach towards the research objective and the focus therefore was on what residential leaders could do to implement end use energy efficiency. The feedback from the 2008 US Energy Challenge (appendix) confirmed that attempts by leaders to implement energy efficiency were generally plagued by a lack of technical knowledge and were focused on unsustainable energy conservation tactics. The feedback and interaction with residential leaders clearly indicated that residential leaders need a guideline regarding technological issues involved in implementing end use energy efficiency. The processes with Lydia Residence sculpted this end product as the initial testing ground and it will most likely transform in the future when additional feedback from residential leaders further moulds its format. This tool is presented by Figure 23.

Figure 23: Tool for residential leaders to identify key areas for end use energy efficiency within their residence

Green leader,

Please fill in the following details. Preferably, supplement the findings with digital photographs.

1. **Complete** or **tick to indicate yes** for basic residential characteristics:

Checklist	Residential Details	Complete:
	Name of residence	
	Address of residence	
	Date of energy audit	
	Official capacity	students
	Surface area	m²
	Annual energy consumption	kWh
	Monthly average energy consumption	kWh/month
	Monthly energy consumption/student	monthly kWh/student
	Monthly energy consumption/m2	monthly kWh/m²
	Annual energy consumption/student	annual kWh/student
	Annual energy consumption/m2	annual kWh/m²
	Orientation of residence	North
		East
		South
		West
	Water heating technology	Heat pump
		Geysers
		Central storage tanks
	Kitchen configuration	Centralised kitchen: preparation and serving
		Centralised kitchen: serving
		Centralised kitchen: preparation, serving and preparation for another residence
		Kitchenettes
		Cafeteria
	Areas for sun drying	Yes
		No
	Low flow showerheads	Yes
		No
	Pressure system in showers that allows for low flow showerheads	Yes
		No

Common lighting Audit				
Type of light bulb and fixture	**Power rating (kW)**	**Quantity**	**Estimated time used (hrs)**	**Estimated energy (kW × Quantity × hrs)**
Fluorescent circle				
Fluorescent tube (single fitting)	36 W			
	40 W			
	58 W			
	65 W			
	__ W			
	__ W			
Fluorescent tube (double fitting)	36 W	(× 2)		
	40 W	(× 2)		
	58 W	(× 2)		
	65 W	(× 2)		
	__ W	(× 2)		
	__ W	(× 2)		
Incandescent bulb	60 W			
	100 W			
	__ W			
Compact fluorescent bulb	8 W			
	11 W			
	14 W			
	16 W			
	18 W			
	20 W			
	__ W			
	__ W			
Other	__ W			
	__ W			
	__ W			
	__ W			

Ballast audit for fluorescent lighting		
	Yes	**Quantity**
Magnetic ballast		
Electronic ballast		

Common appliance audit					
Area/Room	**Name of Appliance**	**Power rating (kW)**	**Quantity**	**Estimated time use (hrs)**	**Estimated energy (kW × Quantity × hrs)**
Kitchen		kW		hrs	kWh
Dining hall		kW		hrs	kWh
Washing room		kW		Hrs	kWh
TV room/s		kW		Hrs	kWh
Argrief/ Study rooms		kW		Hrs	kWh
Bar/social areas		kW		Hrs	kWh
Front portal		kW		Hrs	kWh
communal kitchenettes		kW		Hrs	kWh

Energy Survey

1.Please complete the following table.

Appliance	Do you use this appliance in your room? (Tick for yes, disregard if no)	How long do you use this appliance for, in **one day**?	How many days in a month do you use this appliance?
Kettle		minutes	
Toaster		minutes	
Study Lamp		hours	
Summer Fan		hours	
Winter blow heater		hours	
Element heater		hours	
Laptop		hours	
PC		hours	
Fridge		hours	
Hairdryer		minutes	
Cell phone charger		hours	
Warming blanket		hours	
Radio		hours	
Other?			

2. What variables below allow one to calculate an electrical appliances power consumption?

a)	Voltage/Time	
b)	Power x Time	
c)	Current x Time	
d)	None of the above	
e)	Do not know the answer	

3. When you buy a lamp, do you examine:

a)	The type of bulb used?	
b)	Whether it is energy saving?	
c)	The power rating of the bulb used?	
d)	The brightness of the lamp?	
e)	None of the above?	

4. When you buy an electrical appliance, do you examine:

a)	The power rating?	
b)	The voltage rating?	
c)	The SABS rating?	
d)	None of the above?	

5. If you have a computer, which computer screen do you have?

6. If you have a digital screen for your computer or laptop, is it a:

a)	LCD?	
b)	Plasma?	
c)	Not sure	

7. When you are finished working on your computer/ laptop do you:

a)	Switch it off?	
b)	Leave it on?	
c)	Put it on standby mode?	

8. When you switch an appliance off do you:

a)	Make use of the off button on the appliance?	
b)	Switch off the plug socket?	

c)	Physically unplug the appliance at the socket?	

9. Do you find the light provided by the main light in your room sufficient? (i.e. You would not need the additional lighting of a desk lamp)

a)	Yes?	
b)	No?	

10. Do you know what light bulb is being used for your study/desk lamp?

a)	Yes?	
b)	No?	

11. If you do know the light bulb used in your study/desk lamp, is it a :







12. When bathing, do you usually:

a)	Shower?	
b)	Run a bath?	

13. How many times a day do you shower or bath?

a)	Once?	
b)	Twice?	
c)	Three times a day?	

14. How long do you usually shower for?

a)	5 minutes?	
b)	10 minutes?	
c)	15 minutes?	
d)	30 minutes?	
e)	60 minutes?	

15. What time of the day do you usually shower or bath ?

a)	05:00-08:00	
b)	08:00-12:00	
c)	12:00- 17:00	

d)	17:00- 20:00	
e)	After 20:00	

16. What do you use the communal kitchenettes for?

a)	To prepare snacks?	
b)	To prepare food (chopping, basting etc) for main meals?	
c)	To use the microwave for heating food?	
d)	To make toast	
e)	To plug in your own grill or frying pan to cook food?	
f)	To use the oven to cook food?	

17. Would you make use of a low flow shower head, knowing that it saves energy and water, but also knowing that the effect of the shower will not be as powerful?

a)	Yes?	
b)	No?	
c)	Indifferent?	

19. Do you switch the lights off when you leave your room?

a)	Yes	
b)	No	
c)	Sometimes	

d)	Usually	
e)	Have not noticed	

.

20. Do you wash and dry your clothes at your residence, home or a Laundromat?

a)	Residence?	
b)	Home?	
c)	Laundromat?	

21. If you use the residential washing room, do you use the:

a)	washing machine?	
b)	tumble dryer sometimes?	
c)	tumble dryer every time?	
d)	The washing lines to dry your clothes in the sun?	

5.7. Conclusion

The value of the processes above were that it identified, for Lydia residence, which areas stand out as potential points of intervention to promote end use energy efficiency. The investigation into why Lydia Residence won the US Energy Challenge revealed a narrative which suggests that leadership, and how it influences individual behaviour, can be a part of sustainable energy solutions. Sustainable energy use requires a technological transition, both on the demand and supply side. However, it is not merely a techno fix: technically informed leadership is an imperative for the successful implementation of sustainable energy.

The energy audit and energy survey successfully informed a process which all residences can use to identify energy efficiency. The energy audit revealed common energy efficient lighting opportunities, the old tumble dryer and the kitchen appliances to be points of intervention while the energy survey revealed that the desk/study lamp and behavioural trends towards standby mode were areas of further intervention. This knowledge capacitated the residential leaders to select corresponding solutions accordingly, although the estimated energy savings and financial implications would be needed to finalise any decision making.

Exploring energy efficient options for Lydia Residence with the R 5000 prize money exposed a key process for residential leaders when evaluating end use energy efficiency options for their residences. By calculating 'back of the envelope' cost dynamics, residential leaders can evaluate which efforts will really be worth their while. By applying the hypothetical calculations, decision makers are empowered to act in ways that will actually contribute towards energy consumption.

The value of the micro case study revealed a process, not an end product, which can now be the first step for all residences. The diversity of variables established in the macro SDA concluded that the complex context needed tailored solutions. Endless lists of technological solutions for end use energy efficiency abound but one needs to perform an energy audit and energy survey of a building before the relevant comparative options can be identified. The findings of the micro case study conclude with a proposed process for residences to tailor make recommendations for end use energy efficiency within lighting and appliance use. Depending on the baseline context (i.e. what the residences uses), this could significantly or marginally contribute towards energy consumption.

5.8. Chapter summary

This chapter presented the findings of the case study, Lydia Residence. Four processes of investigation were conducted with Lydia residence and they indicated, as a process, the ability to generate a bottom approach which exposes points of intervention for end use energy efficiency. The processes highlighted that technological solutions are embedded within social contexts and the role that leadership plays in suggesting technological renovations is important. Furthermore, the micro case study highlighted the value of context based solutions. Although the technological retrofits considered here are very specific to Lydia Residence, the processes in which they were surfaced are not. An energy audit and survey as well as the subsequent hypothetical evaluation of different technologies can be conducted by any residence. Energy efficiency is a relative ratio: one can only calculate whether its effect is useful or not if one knows the baseline context against which proposed changes are being suggested. The micro case study, therefore, aids the essential first step in acquainting residential leaders with the baseline context of their residence. A significant conclusion drawn from this case study is the creation of a tool, moulded by the lessons learnt from Lydia Residence, which all residential leaders can now use themselves to implement end use energy efficiency, as means towards sustainable energy, within the residences of Stellenbosch University. It is being negotiated for implementation in 2009 (Links, 2008: personal communication).

Chapter 6: Summary and recommendations

6.1 Introduction

The findings of this thesis indicate that end use energy efficiency is one technological intervention that could be utilised as a sustainable energy solution for the residences of Stellenbosch University. The demand side approach towards the research objective capacitates university management, residential leaders and students to incrementally influence how energy services are used within residences. The research objective is therefore an explicit call for developing local reactions to the global transition towards sustainable energy use. Informed by the grassroots interaction with students and residential leaders, the concluding chapter provides the platform for a dialogue of change in the operations of Stellenbosch University by management and by students themselves. This thesis reflects the efforts of the author and a network of diverse and passionate individuals who have attempted to pragmatically and proactively find sustainable energy solutions for their own neighbourhood and in so doing added value to the local community. The suggested courses of action provide one blueprint, amongst many, for the "situation [that] demands a concerted effort by all of us to overcome old habits and display a new approach and different behaviour when it comes to electricity consumption' (Campus News, 2008) stated by the US Executive Director of Finance and Operations, Prof Leopoldt van Huyssteen.

The findings coincide with the "R35 million electricity shock!" (Campus News, 2008) due to 35% increase in electricity tariffs as well as the mandate of Eskom's Power Conservation Programme (PCP) that demands a 10% reduction of annual US electricity consumption (or face penalties of R10 million). Furthermore, Calumet Links , the newly elected SRC member for Environmental Affairs who has taken over from Mike Leslie, explained to me that several of the newly formed Green HK have been contacting him 'because they want to know what do in their residences' (Links, 2008: personal communication). The findings of this thesis thus significantly inform and contribute towards current concerns of top management as well as residential leadership. The potential to implement energy efficiency by the US, residential leaders and students, and begin a transition towards sustainable energy use, have been the product of this research journey.

This chapter summarises the quantitative and qualitative findings from the macro and micro research journeys and details how they informed the end product of the thesis. Based on the findings of this thesis, recommendations for the way forward towards sustainable energy use are presented. These findings are then discussed in relation to the literature review. It is argued that the interventions echo the argument from the literature review. In other words, sustainable energy solutions for the residences for Stellenbosch University, in the form of end use energy efficiency, are necessary and opportunities to implement them are identified in this thesis. Stellenbosch University can too become an example for sustainable energy use. Thereafter, the significance of this study is reiterated. The concluding recommendations provide clear opportunities for technological intervention for Stellenbosch University management, residential leaders and students in terms of implementing end use energy efficiency.

6.2. Summary of findings

The macro, SDA energy consumption for the residences revealed several findings that were important for establishing the context for the research objective. Firstly, the factors affecting energy consumption (water heating technology, kitchen configuration and behavioural trends) are diverse and this variance within the context therefore demands tailor made solutions which take the particular technologies of the residence into account. The second finding was the use of heat pumps for all the male and female residences to heat water. As explained in the literature review, the COP of a heat pump translates to energy efficiency. The contribution of water heating to the residential energy needs was thus lower than expected and the emphasis of technological solutions shifted from the water heating technology to residential lighting and appliance dynamics. Lastly, clear and consistent trends for the five year period evaluation of the quantitative data emerged. The energy consumption per student (kWh/student) indicated a trend amongst the residences of Stellenbosch University. Mixed residences, which make use of element heating and kitchenette configuration, consume the most energy per student. Male residences, which make use of heat pumps and centralised kitchens, use the next most energy per student. Female residences, which make use of heat pumps and centralised kitchens, use the least energy per student.

The macro, SDA thus laid down a conceptual map of trends concerning energy consumption in which key areas, identified above, can now be accessed for top down intervention. In summary, the findings of the macro SDA therefore identified the context and, in the process, three key considerations for future top down decision making when implementing sustainable energy solutions for the residences of Stellenbosch University.

The summary of the findings from the micro, case study analysis revealed three significant findings: suggestions for energy efficiency technologies for all residences, a tool for residential leaders to aid the new Green HK and behavioural dynamics related to leadership. The processes with Lydia Residence identified several energy efficient lighting and appliances as sustainable energy solutions for the residences of Stellenbosch University. The implementation of energy efficient lighting and appliances depends on whether they are in a common area (the University's responsibility) or a private room (the student's responsibility). The technologies relating to end use energy efficiency in common areas of the residences are listed below in Table 45. The implementation of these depends on suggestions from residential leaders, as generated by the tool detailed in Figure 23, and the subsequent approval by Maintenance and top management.

Table 45: End use energy efficiency in the common areas of the residences

1.	Most efficient fluorescent tube
2.	Converting magnetic ballasts to electronic ballasts
3.	Installing low flow or 'econo' showerheads
4.	Replace old appliances with more energy efficient models
5.	Subject electrical resistive heating to energy efficiency measures (insulation, temperature control and load management)

The technologies relating to end use energy efficiency in private rooms are listed below in Table 46. The implementation of these depends on the consumer choices that students make themselves and therefore would most likely be guided by mandatory policy (because the installation depends on consumers).

Table 46: End use energy efficiency in the private rooms

1.	The type of desk bulb used should be 9W or 11W CFL push in lamp or a 14-20 W CFL bulb only
2.	The most energy efficient appliances should be purchased
3.	LCD computer monitors should be favoured over CRT and plasma monitors
4.	Standby options should not be used

The findings of the case study informed the research objective by creating a tool which can be used by all residential leaders to identify key areas of intervention which are pertinent for their residences. This equips the leaders with a strategy and the suggested courses of action to suggest changes for energy efficiency. This tool was detailed in Figure 23 the preceding chapter.

In addition, the micro case study analysis also highlighted the role leadership plays in implementing energy efficiency within residences. The findings suggest Willems could possibly have stimulated an increased awareness of energy conservation and subsequently influenced behaviour. The role that religious organisations, 'Jool' and US institutional support could play in the future surfaced as three strategic considerations. These findings are significant because they highlighted that solutions to sustainable energy use cannot rely solely on techno fixes – effective technological interventions require an understanding of leadership and behavioural dynamics unique to the particular context.

Based on personal experience when presenting to residential leaders for the 2008 US Energy Challenge and 2009 Green HK Training, responses from the Environmental Audit administered by the Environmental SRC and feedback from residential leaders documenting their efforts during the 2008 US Energy challenge, the lack of technical knowledge regarding energy efficiency amongst residential leaders became prominent as well as a lack of understanding between energy conservation and energy efficiency. However, residential leaders displayed enthusiasm and commitment towards technical information that capacitates them to actually make changes in their own residences. The participation with the US Energy Challenge and the Environmental SRC member further highlighted no other incentive, besides a competitive motivation or moral prerogative, for students to implement energy efficiency within their residences or on campus. No financial or academic incentives accrue from practising sustainable energy for students. This has implications for behavioural dynamics as a strong ideological association or competitive mentality towards environmental behaviour needs to be considered to select the appropriate technology.

6.3. Recommended sustainable energy solutions for the residences of Stellenbosch University: the first seeds

The macro, SDA (governed by a quantitative paradigm and a systems thinking and ecological design conceptual foundation) was used to analyse the context for trends, patterns or anomalies. The findings of this process were that:

- The context of variables which influence energy consumption is complex and each residence needs to sculpt its own solution
- The dominant water heating technology is heat pumps (all female and male residences and one mixed residence have heat pumps)
- Mixed residences with electrical resistive water heating and kitchenette configuration use the most energy per student; male residences with heat pumps and centralised kitchens used the next most energy per student; female residences with heat pumps and centralised kitchens used the least energy per student.
- For male and female residences, data indicates that residential contribution is the greatest consumer of total energy. The primary data for the mixed residences does not exist for such an analysis.

The concluding recommendations, informed by the findings from the macro, SDA are a call to:

- Effective energy metering
- Detailed energy audits of all residential building
- Future decision making needs to seriously consider that electrical resistive water heating and kitchenette configuration contribute to increased energy consumption, which are unnecessary in light of the alternatives available.
- Target water heating, kitchenette systems and residential trends for mixed residences
- Target residential (lighting and appliances) trends for female and male residences

The micro, case study analysis (governed by a quantitative and qualitative paradigms as well as a systems thinking and ecological design conceptual foundation) entailed four processes with the case study, Lydia Residence. The findings of this process were:

- Leadership has a role in initiating, implementing and promoting sustainable energy use within the residence
- The emergence of a process which can be applied to all residential leaders in their approach to their own residence
- Appropriate technologies for residential contexts in terms of lighting and appliances
- A tool which can be part of a process to implement energy efficiency and sustainable energy within the residences

The findings of the micro case study focus informed the following concluding recommendations:

- A common lighting retrofit which replaces older inefficient bulbs with modern more efficient models and changes magnetic ballasts to electronic ballasts
- Retrofitting the bathrooms with low flow or 'econo' showerheads
- Drafting mandatory policy that regulates bulb wattage and type of desk/study lamp as well as restrictions on appliance models.
- Optimising management of current geysers and central storage tanks control (via temperature control, insulation and load management).
- Conducting an energy audit and energy survey, as suggested by the tool moulded by the case study with Lydia Residence (Figure 23), to identify key points of energy efficiency and energy conservation.
- Promote education and awareness within the residence concerning the variables that affect energy consumption (power rating and time span).
- Encourage the purchase of the lighting and appliances listed below until they become mandatory and can then be regulated by residential leaders.
- Purchasing of the following lamps:
  9W CFL push in lamp
  11 W CFL push in lamp
  14-20 W CFL screw in or bayonet bulb
- Purchase appliances with a comparative low wattage
- Make use of an LCD screen as opposed to a plasma or CRT screen for your computer
- Purchase products without a standby option (or don't make use of the option during the product life)

My participation (which was governed by a qualitative paradigm) involved working with a network of individuals on issues relating to sustainable energy use within the residences. I processed the results from the environmental audit (15 residences responded). Insights from international contexts and the Lydia case study were offered in a presentation to HK members before the 2008 US Energy Challenge by Omer and myself. I gave another presentation to the new Green HK members as an orientation session for 2009. We made a journal of the residential attempts at energy efficiency during the 2008 US Energy Challenge. The transfer of tacit understanding that flowed during this process resulted in the finding the following:

- A lack of technical knowledge amongst residential leaders
- Enthusiasm and a call for action by residential leaders
- A misunderstanding between energy efficiency and energy conservation

The concluding recommendations from the findings above focus on raising awareness and capacitating students and leaders with technical education. They are specifically aimed at

- Conducting an energy audit and energy survey, as suggested by the tool moulded by the case study with Lydia Residence (Figure 23), to identify key points of energy efficiency and energy conservation.
- Building upon the HK training conducted in 2008 to educate residential green leaders about the technical issues surrounding energy efficiency and sustainable energy dynamics.

The concluding recommendations listed above need to be implemented by different actors. University management, residential leaders all have a role to play in implementing end use energy efficiency as agents of demand side change towards a sustainable energy future although they will be dictated by different cost and institutional dynamics. The respective actions of each actor is detail below to clearly influence decision makers at different levels about technological solutions of end use energy efficiency.

Interventions by the University call for:

1. Effective energy metering
2. Energy audits of the residential building
3. Future decision making needs to seriously consider that electrical resistive water heating and kitchenette configuration contribute to increased energy consumption which are unnecessary in light of the alternatives available.
4. A common lighting retrofit which replaces older inefficient bulbs with modern more efficient models and changes magnetic ballasts to electronic ballasts
5. Retrofitting the bathrooms with low flow or water wise (for example, 'econo') showerheads.
6. Drafting mandatory policy that regulates bulb wattage and type of desk/study bulb as well as restrictions on appliance models.
7. Optimising management of current geysers and central storage tanks control (via temperature control, insulation and load management).

Interventions by residential leaders call for:

1. Conducting an energy audit and energy survey, as suggested by the tool moulded by the case study with Lydia Residence (Figure 23), to identify key points of energy efficiency and energy conservation.
2. Build upon the HK training conducted in 2008 to educate residential green leaders about the technical issues surrounding energy efficiency and sustainable energy dynamics.
3. Promote education and awareness within the residence concerning the variables which affect energy consumption (power rating and time span).
4. Encourage the purchase of the lighting and appliances listed below until they become mandatory and can then be regulated by residential leaders.

Intervention by students, as consumers, call for:

1. Purchasing of the following lamps:
    a. 9W CFL push in lamp
    b. 11 W CFL push in lamp
    c. 14-20 W CFL screw in or bayonet bulb
2. Purchase appliances with a comparative low wattage
3. Make use of an LCD screen as opposed to a plasma or CRT screen for your computer
4. Purchase products without a standby option (or don't make use of the option during the product life)

6.4. Interpretation of results in terms of the literature review

The research objective entailed the application of the argument presented in the literature review to a specific context, the residences of Stellenbosch University. This context was investigated for potential points of intervention to implement end use energy efficiency in the sectors of lighting, water heating and appliance use as a means towards sustainable energy use. As stated, a critical case study was used to challenge, confirm or contribute towards the argument (Yin, 2003:40).

The research findings revealed that the residences of Stellenbosch University are a space in which energy efficiency and strategic leadership initiatives can take place to begin the transition towards an '*econological* revolution that will test our technological abilities, our economic capacities and even our humanity' (Flavin, 2001:14) and sustainable energy use (Aubrecht, 2006:144-169; Goodland and Daly, 1996:1009; Hawkens et al, 1999; IEA, 2008; InterAcademy Council, 2007; IPCC, 2007c:19; Lovins, 2005a, Lovins, 2005b; Pacalal and Socolow, 2004: 969; *Stern Review*, 2006:219; Teske et al, 2007:78; World Energy Council, 2008).

The general walk through energy audit with Lydia Residence suggested that such a process is essential in establishing a baseline context and identifying general points of technological intervention and in this way supports the literature review. It deviates from the literature review by failing to reveal the nuances of energy consumption. Unless an energy audit of a residence can include an evaluation of each private room, it fails to capture the lighting and appliance details of the students. The general walk through energy audit suggested by the literature review also does not capture the behavioural dynamics which influence energy consumption. Furthermore, a general walk through audit cannot account for the estimated time periods which communal lighting or appliances are left on for. Without accurate estimations of time periods though, an accurate energy analysis is not possible.

The suggestions for energy efficient lighting (bulbs and ballasts) generated by the processes with the case study reflect the technical suggestions in the literature review from the *Energy Efficiency Manual* (Wulfinghoff, 1999). The suggested energy efficient retrofits can stimulate sustainable energy use. With regard to the literature, the emphasis on task design was also evident in the case study as lighting requirements needs to consider the context. It is no use suggesting the lowest wattage CFLs if they are not bright enough for studying needs. The case study therefore helped illuminate the specific wattage that would be suitable for studying purposes: a 16 W CFL bayonet or screw in bulb and an 11W CFL 'push in' lamp.

The investigation of heat pumps confirmed the stated energy efficiency of the literature review. However, the findings that most residences use heat pumps also meant that the greatest potential for energy efficiency had already been achieved.

The appliance suggestions from the literature review provided average power ratings. However, the case study revealed that consumers lack an awareness of the variables which influence energy consumption (power and time) and the knowledge to review power ratings before purchasing appliances. This is also due to a lack of familiarity with what different power ratings mean. In other words, residents are not aware that a kettle uses 2000 W while a fan uses 50 W and this lack of quantitative knowledge or a 'feel for the numbers' breeds consumer ignorance. The case study therefore extends the literature review by suggesting that a level of consumer awareness or education is necessary before energy efficient appliances are actively chosen.

Of the 17 actions identified within the literature review which demarcate what residences in the United States are doing to implement sustainable energy solutions, the research objective made use of 7 of these, as stated below:

1. Organised social groups and information sharing networks
2. Student activism and research
3. Energy auditing of buildings
4. Retrofitting buildings
5. Energy saving competitions
6. Providing appliance and lighting information
7. Bulb exchange

These can all be implemented on a larger scale and contribute, directly or indirectly, towards a sustainable energy future for the residences of Stellenbosch University. However, the findings did not deal with the purchasing of 'clean' energy which is becoming popular amongst universities in US or the onsite or off site generation of renewable energy. In addition, the findings also did not deal directly with policy and institutional commitment towards sustainable energy use on campus.

The residential context also echoed the observation stated in the literature review that many efforts at an end use scale are focused on energy conservation and not energy efficiency (Lovins, 2005a). My personal participation with the residences for the 2008 US Energy Challenge indicated that residential leaders resorted to energy saving measures in an attempt at being proactive and further lacked the basic technical understanding of what influenced energy consumption and what energy efficiency really was.

This thesis also illustrated that case studies can inform generalisations (Flyvberg, 2001; Yin, 2001). The processes with Lydia Residence informed a tool which can now be used by all residences. Furthermore, the recommend technological suggestions can be applied to other residences too.

Lastly, the findings highlighted the value and importance of a systems thinking (Clayton and Radcliffe, 1996; Gallopin, 2001) and ecological design (Van der Ryn and Cowan, 1996) approach towards solutions. The need for context dependent solutions was evident in the macro and micro analyses when sculpting what and where energy efficient technology should be implemented. The research engaged with local 'know how' as a problem solving approach which is explicitly holistic and also appreciates the particular, as opposed to only general information.

6.5. Prospects for future scholarship

The exploratory nature of this thesis, and the fact that precedent studies do not exist, exposed gaps and uncertainties as well as opportunities for future research. The exploratory and ground breaking nature of the research, as predicted, did not produce a definitive end result but it revealed which areas need greater research to aid the transition towards a sustainable energy future on campus.

Firstly, the institutional capacity of Maintenance to accommodate the suggested changes by residential leaders needs to be investigated. If information is to be generated from a bottom up approach by the residential leaders, the logistics of a working relationship between Maintenance and the residential leadership will have to be established.

Secondly, the focus on end use energy efficiency is only one of the options which residences can pursue for a sustainable energy future. The various technological alternatives, stated in Chapter 2 (Figure 9), are respectively governed by a complexity of policy, economic and technical dynamics which creates a vast arena of potential research. This research study selected one of these approaches not as an attempt to claim it is the best or only approach but because it is considered the first step towards sustainable energy. In addition, this research study focused specifically on residences. Future studies could focus upon administrative buildings or educational facilities. For example, a study to investigate the feasibility of utilising solar water heaters for the residences could be conducted. Alternatively, the waste products of the kitchens could be investigated for its biogas potential. An economic assessment of purchasing green energy could be performed. Many instruments are utilised to implement sustainable energy use - this thesis made use of one of the technological possibilities.

A descriptive study which performs an energy audit of every residence is vital for quantitative data purposes so that hypothetical simulations can be modelled to evaluate the effect of changes on the overall energy consumption. Data concerning all the lighting, ballast and appliance information could allow for more accurate predictions of energy savings, cost savings and they payback periods of investments; influential factors for decision makers.

Behavioural attitudes of students from Stellenbosch University could be investigated from a psychology platform. The mindset or predisposition towards environmental moral justice and issues of sustainable living would need to be dissected to determine whether or not students from Stellenbosch University feel propelled to support sustainable living. Thereafter, the effect of motivational factors such as feedback systems in order to promote sustainable energy behaviour could be tested.

In addition, the trends identified in the comparative analysis of energy consumption could be investigated. For example, why do male residences to use more energy than female residences? Why does Monica residence espouse a similar energy consumption per student ratio to that of female residences which prepare food for other residences when Monica only has a serving kitchen?

Lastly, it is most likely that project proposals which detail the financial implications of investing in end use energy efficiency and other sustainable energy options will have to be completed before decision makers seriously consider the proposal of initial greater capital costs. The various funding schemes by universities and students, which are being practised in international contexts, to raise funds for investments in sustainable energy could possibly inform such a financial feasibility study.

6.6. Relevance of research study

It is argued that, for social science to matter, 'we must take up problems that matter to the local, national and global communities in which we live' (Flyvbjerg, 2001:166), a sentiment which this research objective resonates with. The findings of this research are a local solution to the global problem of a future climate change, detailed in the literature review. The findings are also a local solution to a national problem of inadequate energy supply, detailed in the introduction. Lastly, and most significantly, the findings are local solutions to the Stellenbosch community. The institutional need to decrease energy consumption due to increased costs and utility mandates can be achieved by the suggested technologies and processes. Furthermore, the crafted tool capacitates residential managers and Green HK members to take the first step towards energy efficiency, not only energy conservation. Arrangements with the SRC Environmental Affairs member and subcommittee (Links, 2008: personal meeting) as well as Eskom (Overmeyer, 2008: personal communication) cite future commitment to energy efficiency initiatives as detailed by this thesis in the future.

Notably, this is also the first research assignment conducted by a student from Stellenbosch University about the sustainable energy management of the residential environment. A recent thesis search on the library catalogue indicates that research by Stellenbosch students concerning any sustainable resource management of their learning environment is very limited. This research journey was thus a ground breaking exploration of imagining alternative realities for resource management within Stellenbosch University and stimulating a dialogue for sustainable neighbourhoods.

6.7. Conclusion

The global and national energy context described at the beginning of this research assignment are characterised primarily by fossil fuel use. The consequence of such a context is disturbing the ecological equilibrium of a space we all share: the atmosphere. Technical opportunities to direct our future on a sustainable energy future are available but await the political will and institutional governance to be implemented in a way which dominates the energy context. However, initiatives which are leading the way and pioneering alternative energy realities exist too. The literature review revealed that a niche group of universities were modelling themselves around the sustainable energy agenda. As institutional spaces of learning, research and breeding grounds for new ways of thinking, universities stand poised to educate the learners which occupy their spaces about an issue which is to have global implications for us all. As such, universities are spaces which can sculpt local solutions to a global problem.

The exploratory narrative of this research journey, woven from various golden threads within the literature, argues that sustainable energy is necessary, it is possible and other universities are implementing it in various formats. The author of this thesis, a student at Stellenbosch University, was prompted to ask: what opportunities exist for Stellenbosch University to implement sustainable energy? The research objective focused on end use energy efficiency as means, out of all the technical possibilities theoretically possible today, to implement sustainable energy solutions for the residences of Stellenbosch University. The focus of end use efficiency was specific to water heating, lighting and appliance use, for which technical solutions exist.

This is not an attempt at providing the final and absolute answer; it is part of an answer. Other options or strategies could be designed. However, framed according to the conceptual foundations of systems thinking and ecological design and the case study methodology, the contribution of this research assignment created context sensitive solutions.

The findings revealed that end use energy efficiency is a possible means for sustainable energy use within the residences of Stellenbosch University. However, the use of heat pump water heating technology in the majority of the residences and the omission of air conditioning in the residences results that the greatest potential for energy efficiency measures are not available. The centralised kitchen infrastructure requires highly rated equipment to deal with the swift throughput of meal times during the residences. The remaining focus areas of energy consumption, residential living, therefore, poses the greatest opportunity for end use energy efficiency. This posits residential lighting and appliance use as the focal point of the investigation within the context of the residences of Stellenbosch University.

The findings concluded recommended courses of action for the University, residential leaders and students. The holistic and integrated approach to the research objective, guided by systems thinking and ecological design, capacitates actors at three different levels to pro actively ‘be the change [they] want to see in the world’ (Ghandi) by implementing local solutions to global, national and community problems. Sustainable energy solutions are necessary, available and being implemented in other universities. End use energy efficiency, as a means to sustainable energy, is necessary, as the ‘low hanging fruit’ is available, and is possible to implement within the residences of Stellenbosch University.

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Appendices

Appendix A: Monthly energy consumption of residences

- A breakdown of the monthly energy consumption in kWh according to residential use, kitchen use and water heating use and other, where applicable, for the chosen residences for the time period 2003 to 2007

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- The monthly energy consumption in kWh of the chosen residences for the time period 2003 to 2007

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Table 47: Female residences monthly energy consumption, 2003 -2007

Female Residence	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Annual Total 2003
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**
Erica													
Residential	4804	4885	12135	14589	13722	21423	22806	18287	34657	20564	18192	11751	**197815**
Tinie Louw Kitchen(pro rata with Nemesia and Serruria)	4126	2512	7943	8555	7817	9553	7724	7986	9496	7189	8299	5566	**86766**
Hot water (pro rata with Nemesia and Serruria)	1511	1162	4420	5160	5025	7700	6939	6552	10900	7492	7969	5145	**69974**
Monthly Total	10441	8558	24497	28304	26564	38676	37468	32825	55052	35246	34460	22462	**354554**
Harmonie													
Residential	3002	3210	7984	9620	9329	14690	15493	16333	23226	12245	13396	9057	**137585**
Kitchen	6741	3219	8396	8591	7959	10480	10082	13100	10830	7451	10153	6887	**103889**
Hot water	2865	2341	4638	5137	5440	8103	7236	7173	10814	7452	7763	4994	**73956**
Monthly Total	12608	8770	21018	23348	22728	33273	32811	36606	44870	27148	31312	20938	**315430**
Heemstede													
Residential	3077	2831	10536	12197	11719	17463	15544	10906	24584	14029	14059	9461	**146406**
Kitchen	1002	623	1815	2220	2279	3004	2654	1581	3001	2399	2760	2051	**25389**
Hot water	1493	1089	4471	5387	5593	7645	6037	4767	10674	7104	8018	5405	**67683**
Heemstede Anneks	515	540	2010	2090	2247	3308	2927	2206	3626	3435	3392	2309	**28605**
Monthly Total	6087	5083	18832	21894	21838	31420	27162	19460	41885	26967	28229	19226	**268083**
Huistenbosch													
Residential	3699	3875	10006	11751	10178	15738	13776	10298	22631	13537	13960	10229	**139678**
Ktichen	6012	3195	8727	9857	9081	11912	8367	5561	12873	9018	10858	9398	**104859**
Hot water (pro rata with Lydia)	4170	3866	5422	6202	6237	8561	7520	7061	11235	8213	8792	6682	**83962**

Monthly Total	13881	10936	24155	27810	25496	36211	29663	22920	46739	30768	33610	26309	**328499**
Irene													
Residential	2611	3587	7684	10210	9780	16007	15279	11196	26427	14242	12692	7620	**137335**
Kitchen	5255	4510	7054	7400	6470	9135	5951	3734	9416	6307	8196	5203	**78631**
Hot water	3478	5478	4486	4522	4353	6527	5894	5296	9074	7248	6914	4665	**67935**
Monthly Total	11344	13575	19224	22132	20603	31669	27124	20226	44917	27797	27802	17488	**283901**
Lydia													
Residential	3125	3072	7831	9066	8678	13372	14859	11630	26226	13407	12074	7423	**130763**
Kitchen	2270	1659	3639	3883	3645	4720	3491	2468	5323	3722	4822	3687	**43329**
Hot water(Pro rata with Huistenbosch)	4517	4189	5873	6719	6756	9275	8147	7650	12172	8898	9524	7239	**90958**
Monthly Total	9912	8920	17343	19668	19079	27367	26497	21748	43721	26027	26420	18349	**265050**
Minerva													
Residential	3487	3922	11400	13388	12119	18241	17857	12067	29706	17413	17205	10573	**167378**
Kitchen	8904	5283	13079	13253	11576	16580	11337	7724	18246	12342	15417	10595	**144336**
Hot water(pro rata with Nerina)	3211	2739	5146	5887	5623	8659	6990	5850	11447	7807	8308	5095	**76758**
Monthly Total	15602	11944	29625	32528	29318	43480	36184	25641	59399	37562	40930	26263	**388472**
Monica													
Residential	7191	6319	11172	12868	12128	17636	16209	13506	24683	15438	15459	11264	**163873**
Kitchen	3495	2511	4434	4465	4386	5395	4464	3514	5935	4563	5296	4220	**52678**
Hot water	1904	1284	3285	3890	3882	5911	4908	4309	7720	5198	5802	4192	**52285**
Monthly Total	12590	10114	18891	21223	20396	28942	25581	21329	38338	25199	26557	19676	**268836**
Nemesia													
Residential	4805	4469	10640	12355	11267	16891	19520	19874	28340	16933	15811	11029	**171934**
Tienie Louw Kitchen(pro rata with Erica and Serruria)	4126	2512	7943	8555	7817	9553	7724	7986	9496	7189	8299	5566	**86766**
Hot water(pro rata with Erica and Serruria)	1511	1162	4420	5160	5025	7700	6939	6552	10900	7492	7969	5145	**69974**
Monthly Total	10442	8142	23002	26070	24109	34144	34182	34412	48735	31615	32079	21740	**328673**
Nerina													
Residential	3751	5033	12507	15418	14343	18636	16006	12159	26566	16823	17118	11166	**169526**
Kitchen	2569	2165	5407	6416	7300	8962	7290	6489	12240	9195	11136	8811	**87980**
Hot water (pro rata with Minerva)	3211	2739	5146	5887	5623	8659	6990	5850	11447	7807	8308	5095	**76758**
Monthly Total	9531	9937	23060	27721	27266	36257	30286	24498	50253	33825	36562	25072	**334264**

Serruria													
Residential	3174	3396	10884	12873	12012	19841	19377	15564	31751	17278	16670	10647	**173467**
Tienie Louw Kitchen (pro rata with Erica and Nemesia)	4126	2512	7943	8555	7817	9553	7724	7986	9496	7189	8299	5566	**86766**
Hot water (pro rata with Erica and Nemesia)	1511	1162	4420	5160	5025	7700	6939	6552	10900	7492	7969	5145	**69974**
Monthly Total	8811	7069	23246	26588	24854	37094	34039	30102	52146	31960	32938	21358	**330206**
Sonop													
Residential	8342	9589	18351	21562	18998	25683	23643	17377	34555	22128	22376	16290	**238894**
Kitchen	6703	5797	9901	9658	8772	11429	9685	5123	11967	8884	10866	7323	**106108**
Hot water	3597	3569	6834	7973	7914	12171	10810	8685	17278	10938	12425	8046	**110240**
Monthly Total	18642	18955	35086	39193	35684	49283	44138	31185	63800	41950	45667	31659	**455242**
	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	**Annual Total 2004**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**
Erica													
Residential	5610	5959	13235	15632	13964	19481	15784	16433	29382	15847	13255	8282	**172864**
Tinie Louw Kitchen(pro rata with Nemesia and Serruria)	983	2515	6933	7989	7633	9467	6178	4975	8996	6527	7748	5160	**75102**
Hot water (pro rata with Nemesia and Serruria)	2199	2033	4669	6394	5612	7651	5574	6277	9868	7336	8172	4739	**70522**
Monthly Total	8792	10507	24837	30015	27209	36598	27536	27685	48246	29710	29175	18181	**318489**
Harmonie													
Residential	2331	3011	9831	11615	10269	15192	11262	11766	22323	11886	13608	8572	**131666**
Kitchen	351	2850	8791	10229	6876	10443	6364	5554	11060	7756	9625	6626	**86525**
Hot water	261	1306	4474	6355	5220	7579	5722	6005	9104	6424	7049	4106	**63605**
Monthly Total	2943	7167	23096	28199	22365	33214	23348	23325	42487	26066	30282	19304	**281796**
Heemstede													
Residential	3599	4073	11161	11676	11106	16435	11221	13118	21063	13206	14672	6465	**137795**
Kitchen	181	1218	2095	2664	2026	2950	2157	1455	2848	2026	2548	1791	**23959**
Hot water	1988	1894	4060	5286	4559	6686	4819	5398	9211	6240	7558	4057	**61756**
Heemstede Anneks	515	1210	2250	2984	2566	2981	3434	2315	5083	3429	3930	3949	**34646**
Monthly Total	6283	8395	19566	22610	20257	29052	21631	22286	38205	24901	28708	16262	**258156**

Huistenbosch													
Residential	2668	4601	11084	13249	11096	16112	11559	10498	19847	12531	14547	9112	**136904**
Ktichen	2329	5702	9158	11394	7971	11495	7957	6280	12664	8257	10734	6896	**100837**
Hot water (pro rata with Lydia)	3421	3401	5672	7510	5975	8429	6782	6934	10143	7438	8283	5158	**79146**
Monthly Total	8418	13704	25914	32153	25042	36036	26298	23712	42654	28226	33564	21166	**316887**
Irene													
Residential	2581	2713	8396	10463	9069	12844	11582	14042	17881	9927	11155	6567	**117220**
Kitchen	1103	2028	6998	8177	5889	9320	6172	6852	9539	6236	8076	4922	**75312**
Hot water	2863	2237	3816	5224	4649	6337	5258	6902	10078	7352	8115	4571	**67402**
Monthly Total	6547	6978	19210	23864	19607	28501	23012	27796	37498	23515	27346	16060	**259934**
Lydia													
Residential	1724	2604	8355	10439	9356	14198	11604	13245	26355	12271	13098	7456	**130705**
Kitchen	1334	1429	3500	4387	3347	4610	3322	3447	6913	4039	4750	2890	**43968**
Hot water(Pro rata with Huistenbosch)	3768	3746	6245	8269	6579	9281	7469	7636	11170	8191	9122	5679	**87155**
Monthly Total	6826	7779	18100	23095	19282	28089	22395	24328	44438	24501	26970	16025	**261828**
Minerva													
Residential	1774	3861	13174	16420	14268	20222	14316	17123	32252	16855	19355	12118	**181738**
Kitchen	825	4284	13469	15477	13207	16251	9133	683	343	18193	27197	14134	**133196**
Hot water(pro rata with Nerina)	192	1287	5132	7322	6148	8359	6045	6819	10771	7400	8217	4342	**72035**
Monthly Total	2791	9432	31775	39219	33623	44832	29494	24625	43366	42448	54769	30594	**386969**
Monica													
Residential	5425	6677	12497	14455	12556	18549	15706	16794	25379	15820	16921	10951	**171730**
Kitchen	143	1631	4435	5452	4327	5777	3735	5951	11657	4671	5573	4201	**57553**
Hot water	230	1077	3678	5280	4294	6508	5154	5422	7967	5606	6175	3503	**54894**
Monthly Total	5798	9385	20610	25187	21177	30834	24595	28167	45003	26097	28669	18655	**284177**
Nemesia													
Residential	4278	5463	11387	13135	12738	17639	14688	15738	26607	15590	16542	9703	**163508**
Tienie Louw Kitchen(pro rata with Erica and Serruria)	978	2502	6897	7947	7593	9418	6146	4949	8949	6493	7708	5134	**74713**
Hot water(pro rata with Erica and Serruria)	2188	2023	4645	6361	5583	7611	5545	6245	9817	7298	8130	4714	**70157**
Monthly Total	7443	9987	22929	27443	25914	34668	26379	26931	45373	29381	32380	19550	**308378**

Nerina													
Residential	3148	4252	13360	17307	14823	21274	16229	16229	28914	17159	18072	11212	**181979**
Kitchen	2044	5130	10138	11465	10257	11882	8684	6955	11687	8517	10371	7147	**104277**
Hot water (pro rata with Minerva)	190	1268	5054	7211	6054	8233	5954	6716	10607	7288	8093	4276	**70943**
Monthly Total	5382	10650	28552	35983	31134	41389	30867	29900	51208	32964	36536	22635	**357199**
Serruria													
Residential	2531	4138	12288	14953	14179	19243	15680	16820	28231	15838	16645	10691	**171237**
Tienie Louw Kitchen (pro rata with Erica and Nemesia)	983	2515	6933	7989	7633	9467	6178	4975	8996	6527	7748	5160	**75102**
Hot water (pro rata with Erica and Nemesia)	2199	2033	4669	6394	5612	7651	5574	6277	9868	7336	8172	4739	**70522**
Monthly Total	5713	8686	23890	29336	27424	36360	27432	28072	47095	29701	32565	20590	**316862**
Sonop													
Residential	6494	7740	18852	21714	18967	24383	19629	20413	31123	20853	23630	17670	**231468**
Kitchen	569	2972	9540	10848	8038	11791	9951	9496	12706	9174	11126	10081	**106292**
Hot water	2115	2340	6982	9931	7831	11911	9952	11110	14786	10277	11911	7824	**106970**
Monthly Total	9178	13052	35374	42493	34836	48085	39532	41019	58615	40304	46667	35575	**444730**
	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	**Annual Total 2005**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**
Erica													
Residential	4053	4528	9568	10450	12667	18414	15976	12994	24766	13360	15695	9864	**152335**
Tinie Louw Kitchen(pro rata with Nemesia and Serruria)	1145	2920	6162	7966	7960	9416	6311	5774	10548	7139	8981	5859	**80182**
Hot water (pro rata with Nemesia and Serruria)	2368	2264	4618	4791	6106	8067	5996	5902	10252	7373	8566	5433	**71737**
Monthly Total	7566	9712	20348	23207	26734	35897	28283	24670	45566	27872	33242	21156	**304254**
Harmonie													
Residential	2387	2662	9164	9451	12276	16763	18736	17172	22209	12135	15405	9832	**148192**
Kitchen	2368	3127	8102	7549	9216	11065	11557	11164	11032	8179	10450	7345	**101154**
Hot water	1838	1729	4152	3716	5385	6775	5860	5772	8545	5774	6905	4027	**60478**
Monthly Total	6593	7518	21418	20716	26877	34603	36153	34108	41786	26088	32760	21204	**309824**
Heemstede													
Residential	1261	4098	11131	11914	15598	21087	14554	14277	26095	14885	17724	9972	**162596**

Kitchen	311	638	2032	1976	2631	3767	2817	2180	4044	2943	3454	2083	**28876**
Hot water	496	1638	4510	4234	6497	6842	5745	5659	9046	5926	7384	4250	**62227**
Heemstede Anneks	1620	350	1797	2142	1996	2558	3810	1404	3911	2958	3775	2624	**28945**
Monthly Total	3688	6724	19470	20266	26722	34254	26926	23520	43096	26712	32337	18929	**282644**
Huistenbosch													
Residential	1697	3431	10930	11582	13017	16427	14531	12610	20073	12262	15150	9395	**141105**
Ktichen	1209	3344	8139	9545	11404	12981	11073	10623	13368	9477	11109	6909	**109181**
Hot water (pro rata with Lydia)	661	1985	5069	5235	6544	8071	7154	6440	9867	6979	8221	5189	**71415**
Monthly Total	3567	8760	24138	26362	30965	37479	32758	29673	43308	28718	34480	21493	**321701**
Irene													
Residential	2007	2753	7337	7678	9557	13303	11307	9544	21490	13370	12897	7397	**118640**
Kitchen	258	2512	7352	7605	7714	9532	5771	4602	10468	9064	9405	5678	**79961**
Hot water	2382	2244	4319	4341	5041	6632	5733	5572	8853	7432	7073	4130	**63752**
Monthly Total	4647	7509	19008	19624	22312	29467	22811	19718	40811	29866	29375	17205	**262353**
Lydia													
Residential	2164	3130	9124	9737	11747	17684	17536	14481	26583	14144	16437	8961	**151728**
Kitchen	194	1169	3928	3721	4441	5441	4072	4272	6130	4095	5518	3508	**46489**
Hot water(Pro rata with Huistenbosch)	715	2147	5484	5664	7080	8732	7739	6968	10674	7550	8894	5614	**77261**
Monthly Total	3073	6446	18536	19122	23268	31857	29347	25721	43387	25789	30849	18083	**275478**
Minerva													
Residential	2136	5280	14602	16509	19391	27100	20139	14445	34744	20560	23613	17049	**215568**
Kitchen	2870	6960	14893	13206	16118	19880	14644	15051	21547	15718	18916	15802	**175605**
Hot water(pro rata with Nerina)	1695	1888	4571	4698	6660	8232	6162	6144	11834	8320	8615	5916	**74736**
Monthly Total	6701	14128	34066	34413	42169	55212	40945	35640	68125	44598	51144	38767	**465909**
Monica													
Residential	5334	6583	11998	13062	15396	20487	19152	14947	24453	14630	17482	11902	**175426**
Kitchen	132	954	4207	4293	4711	5516	5166	4554	5485	4555	5564	4382	**49519**
Hot water	466	1318	3458	3694	5072	6535	5882	5053	8125	5581	6294	3750	**55228**
Monthly Total	5932	8855	19663	21049	25179	32538	30200	24554	38063	24766	29340	20034	**280173**
Nemesia													
Residential	4742	5558	12477	13310	15341	21833	19000	15480	31868	16927	19858	12173	**188567**
Tienie Louw Kitchen(pro rata with Erica and Serruria)	1145	2920	6162	7966	7960	9416	6311	5774	10548	7139	8981	5859	**80182**

Hot water(pro rata with Erica and Serruria)	2368	2264	4618	4791	6106	8067	5996	5902	10252	7373	8566	5433	**71737**
Monthly Total	8255	10742	23257	26067	29408	39316	31307	27156	52668	31439	37405	23465	**340486**
Nerina													
Residential	3275	4777	14045	14094	16155	20781	17849	14956	27025	17314	20420	11496	**182187**
Kitchen	2493	4183	7757	8064	8876	10197	8718	8707	9447	7580	9248	7822	**93092**
Hot water (pro rata with Minerva)	1670	1860	4501	4627	6560	8108	6069	6050	11654	8194	8485	5826	**73603**
Monthly Total	7438	10820	26303	26785	31591	39086	32636	29713	48126	33088	38153	25144	**348882**
Serruria													
Residential	4661	6013	12017	13657	16055	23689	20527	17839	31985	16939	19304	11498	**194184**
Tienie Louw Kitchen (pro rata with Erica and Nemesia)	1145	2920	6162	7966	7960	9416	6311	5774	10548	7139	8981	5859	**80182**
Hot water (pro rata with Erica and Nemesia)	2368	2264	4618	4791	6106	8067	5996	5902	10252	7373	8566	5433	**71737**
Monthly Total	8174	11197	22797	26414	30122	41172	32834	29515	52785	31451	36851	22790	**346103**
Sonop													
Residential	8217	10323	19123	20028	21712	27486	23768	19726	33977	21300	25889	16924	**248473**
Kitchen	1644	6928	9321	8934	9955	12413	8000	7001	12861	9059	11598	8402	**106116**
Hot water	2504	3438	6021	6116	8960	11685	8809	7946	15105	10057	12151	7139	**99931**
Monthly Total	12365	20689	34465	35078	40627	51584	40577	34673	61943	40416	49638	32465	**454520**
	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	**Annual Total 2006**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**
Erica													
Residential	3601	3950	9328	11410	9694	17507	9931	10164	19365	11593	12882	9192	**128617**
Tinie Louw Kitchen(pro rata with Nemesia and Serruria)	787	3277	6914	8635	7839	9893	5983	3885	8945	6326	7826	6092	**76403**
Hot water (pro rata with Nemesia and Serruria)	3058	2750	4307	6084	5373	9129	5392	5361	10787	7082	8571	6033	**73927**
Monthly Total	7446	9978	20550	26129	22906	36529	21306	19410	39097	25000	29279	21317	**278947**
Harmonie													
Residential	3732	3627	9572	11334	9053	15207	10746	7641	19763	11241	13224	9209	**124349**
Kitchen	3297	3840	8063	9895	7283	11143	9044	3341	10480	7470	10070	7717	**91643**

Hot water	1942	1635	3340	4853	3978	7065	5046	3796	8168	5402	6456	4487	**56168**
Monthly Total	8971	9102	20975	26082	20314	33415	24836	14778	38411	24113	29750	21413	**272160**
Heemstede													
Residential	2894	6231	14338	16471	10805	22968	10728	11712	21350	15636	16741	11815	**161689**
Kitchen	209	883	1781	2194	1575	3118	1644	936	2869	2427	2667	2490	**22793**
Hot water	862	1413	4005	5718	4348	7561	3493	3458	8400	6349	6706	5082	**57395**
Heemstede Anneks	676	978	2242	2364	3614	2708	1722	901	4745	2539	2603	2301	**27393**
Monthly Total	4641	9505	22366	26747	20342	36355	17587	17007	37364	26951	28717	21688	**269270**
Huistenbosch													
Residential	2828	3654	10831	13373	11143	23688	13426	12750	26552	19895	22160	16473	**176773**
Ktichen	805	553	707	1050	360	3639	2501	2340	7602	6939	7357	6895	**40748**
Hot water (pro rata with Lydia)	2160	2384	4259	6303	5449	8704	5141	4997	10012	7058	7881	5152	**69499**
Monthly Total	5793	6591	15797	20726	16952	36031	21068	20087	44166	33892	37398	28520	**287020**
Irene													
Residential	1876	2799	7853	9304	7757	15876	7030	8036	17401	9951	11444	7940	**107267**
Kitchen	599	3117	6845	8837	6938	10122	4781	3526	9903	6434	8810	6489	**76401**
Hot water	151	1850	3651	4949	4804	7333	4296	4691	8085	5683	6475	4516	**56484**
Monthly Total	2626	7766	18349	23090	19499	33331	16107	16253	35389	22068	26729	18945	**240152**
Lydia													
Residential	2500	3646	9334	11268	8960	15083	7258	8150	18606	10896	12381	8161	**116243**
Kitchen	504	1857	3452	4818	3607	5099	2664	1690	5280	3920	5100	3959	**41950**
Hot water(Pro rata with Huistenbosch)	2352	2596	4639	6865	5936	9481	5601	5443	10905	7689	8585	5612	**75705**
Monthly Total	5356	8099	17425	22951	18503	29663	15523	15283	34791	22505	26066	17732	**233898**
Minerva													
Residential	5858	8298	15847	18577	15326	23953	11498	11560	27319	15304	18770	13820	**186130**
Kitchen	5553	11230	14599	17426	15356	20138	9788	6808	19657	13233	16221	11757	**161766**
Hot water(pro rata with Nerina)	3245	2595	4350	6661	5584	9326	5312	5330	10973	7054	8125	5778	**74334**
Monthly Total	14656	22123	34796	42664	36266	53417	26598	23698	57949	35591	43116	31355	**422230**
Monica													
Residential	5785	7581	12002	14555	13074	20962	12806	11553	22067	14885	16211	11875	**163356**
Kitchen	455	1194	4388	5204	3950	5519	3243	1211	5008	3903	4860	4124	**43059**
Hot water	422	1589	3206	5003	4103	7237	4189	4536	8128	5500	6413	4443	**54769**
Monthly Total	6662	10364	19596	24762	21127	33718	20238	17300	35203	24288	27484	20442	**261184**

Nemesia													
Residential	4982	5720	11853	14820	12943	23702	12173	12161	25115	14883	16585	11785	**166722**
Tienie Louw Kitchen(pro rata with Erica and Serruria)	783	3260	6878	8590	7799	9842	5952	3865	8898	6293	7785	6060	**76007**
Hot water(pro rata with Erica and Serruria)	3042	2736	4285	6052	5345	9081	5364	5333	10731	7045	8527	6002	**73544**
Monthly Total	8807	11717	23017	29462	26087	42626	23489	21359	44745	28221	32897	23847	**316273**
Nerina													
Residential	2721	4420	13650	17270	13389	22943	11876	11331	25824	15986	18847	12600	**170857**
Kitchen	4470	6190	7249	8496	8479	9801	6335	4656	9901	7861	10157	6848	**90443**
Hot water (pro rata with Minerva)	3196	2556	4285	6560	5500	9185	5231	5250	10807	6947	8001	5691	**73208**
Monthly Total	10387	13166	25184	32326	27368	41929	23442	21237	46532	30794	37005	25139	**334508**
Serruria													
Residential	6722	6699	12516	14857	13373	23571	13084	13477	24416	14967	17139	12355	**173176**
Tienie Louw Kitchen (pro rata with Erica and Nemesia)	787	3277	6914	8635	7839	9893	5983	3885	8945	6326	7826	6092	**76403**
Hot water (pro rata with Erica and Nemesia)	3058	2750	4307	6084	5373	9129	5392	5361	10787	7082	8571	6033	**73927**
Monthly Total	10567	12727	23738	29576	26585	42593	24459	22723	44148	28374	33536	24480	**323506**
Sonop													
Residential	7572	9379	19439	22495	19002	29209	17370	16926	32548	21991	25935	18258	**240124**
Kitchen	586	5237	10059	11013	8541	13716	8325	6097	12344	9336	12601	10241	**108096**
Hot water	1202	2543	5969	8701	6862	12457	8048	7050	14510	9784	11515	7801	**96442**
Monthly Total	9360	17159	35467	42209	34405	55382	33743	30073	59402	41111	50051	36300	**444662**
	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	**Annual Total 2007**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	**kWh**
Erica													
Residential	3702	4769	9526	10934	12573	23130	13610	16033	26090	16444	17012	11376	**165199**
Tinie Louw Kitchen(pro rata with Nemesia and Serruria)	1781	3318	6650	7637	7471	9151	5818	8522	9256	6699	8023	5291	**79617**
Hot water (pro rata with Nemesia and Serruria)	3526	3113	5003	6080	5567	8839	5320	7290	10834	7872	8375	5492	**77310**

Monthly Total	9009	11200	21179	24650	25611	41120	24748	31845	46180	31015	33410	22159	**322126**
Harmonie													
Residential	2655	3806	9944	11501	9367	15910	10147	15925	17882	11651	12283	8320	**129391**
Kitchen	2298	4406	8745	9676	7978	11614	7792	11500	12183	8276	10890	7503	**102861**
Hot water	2135	2235	3997	5020	4424	7129	4450	5845	8981	6088	6682	4604	**61590**
Monthly Total	7088	10447	22686	26197	21769	34653	22389	33270	39046	26015	29855	20427	**293842**
Heemstede													
Residential	5205	7667	13419	15516	12404	19951	14255	13893	21014	14208	14558	10274	**162364**
Kitchen	634	2081	2094	2708	2710	3383	2449	2965	3703	2486	3265	2228	**30706**
Hot water	2808	2561	4264	5226	5068	7401	4946	5667	7458	5388	6303	4090	**61180**
Heemstede Anneks	518	679	2008	2435	2803	2160	2430	2742	2807	2480	3163	1700	**25925**
Monthly Total	9165	12988	21785	25885	22985	32895	24080	25267	34982	24562	27289	18292	**280175**
Huistenbosch													
Residential	5966	10528	17401	19911	17356	25015	13819	17969	29802	18667	20694	16988	**214116**
Ktichen	4796	6375	6665	7487	7044	7585	5498	6363	7497	5756	7022	6479	**78567**
Hot water (pro rata with Lydia)	2772	2697	4840	6115	5930	8581	5784	7093	10033	7574	8200	6501	**76119**
Monthly Total	13534	19600	28906	33513	30330	41181	25101	31425	47332	31997	35916	29968	**368802**
Irene													
Residential	2899	4037	8127	9752	8018	15449	7869	9399	17726	10305	10467	6709	**110757**
Kitchen	3108	3607	7801	8420	6688	10488	4172	3945	10219	6967	9475	6254	**81144**
Hot water	2820	2492	4074	4809	4431	6064	3501	4073	8159	5893	6170	4451	**56937**
Monthly Total	8827	10136	20002	22981	19137	32001	15542	17417	36104	23165	26112	17414	**248838**
Lydia													
Residential	2463	3971	9716	11029	8975	15480	9196	9399	17359	10935	11937	7934	**118394**
Kitchen	1390	1782	4003	4617	3877	5248	2443	2055	4807	3627	4919	3518	**42286**
Hot water(Pro rata with Huistenbosch)	3019	2937	5272	6661	6459	9347	6300	7726	10928	8251	8932	7082	**82915**
Monthly Total	6872	8690	18991	22307	19311	30075	17939	19180	33094	22813	25788	18534	**243595**
Minerva													
Residential	2435	6415	16152	19195	16987	26489	12061	13715	28531	23420	20472	13833	**199705**
Kitchen	1910	8724	13663	15793	14642	18600	7770	8174	20933	17565	17348	11289	**156411**
Hot water(pro rata with Nerina)	2255	2753	5311	6240	6128	9689	5324	6352	11920	9290	9256	6063	**80582**
Monthly Total	6600	17892	35126	41228	37757	54778	25155	28241	61384	50275	47076	31185	**436698**
Monica													
Residential	6562	8247	12904	14992	13063	20635	15067	21260	23324	16124	15514	11573	**179265**

Kitchen	1059	2245	3883	4313	3799	4945	3471	3971	4874	3657	4486	3334	**44037**
Hot water	1954	2226	3678	4826	4340	6875	4598	5690	7994	5618	6223	4406	**58428**
Monthly Total	9575	12718	20465	24131	21202	32455	23136	30921	36192	25399	26223	19313	**281730**
Nemesia													
Residential	5091	5991	12064	14487	13028	20371	12178	14504	23861	15220	15869	10710	**163374**
Tienie Louw Kitchen(pro rata with Erica and Serruria)	1772	3301	6616	7597	7432	9104	5788	8478	9208	6665	7981	5263	**79204**
Hot water(pro rata with Erica and Serruria)	3508	3097	4977	6048	5538	8793	5292	7252	10778	7831	8332	5463	**76910**
Monthly Total	10371	12389	23657	28132	25998	38268	23258	30234	43847	29715	32182	21437	**319488**
Nerina													
Residential	2773	6415	15730	18418	14170	22559	11144	12694	24776	17031	18354	11332	**175396**
Kitchen	2186	5795	6991	7582	6312	8544	4436	4916	8798	6841	7654	5634	**75689**
Hot water (pro rata with Minerva)	2221	2712	5231	6146	6036	9542	5244	6255	11739	9150	9115	5971	**79361**
Monthly Total	7180	14922	27952	32146	26518	40645	20824	23865	45313	33022	35123	22937	**330446**
Serruria													
Residential	6375	7472	13175	15067	12903	21566	13491	16081	24927	16611	16589	11433	**175690**
Tienie Louw Kitchen (pro rata with Erica and Nemesia)	1781	3318	6650	7637	7471	9151	5818	8522	9256	6699	8023	5291	**79617**
Hot water (pro rata with Erica and Nemesia)	3526	3113	5003	6080	5567	8839	5320	7290	10834	7872	8375	5492	**77310**
Monthly Total	11682	13903	24828	28783	25941	39556	24629	31893	45017	31182	32987	22216	**332617**
Sonop													
Residential	8643	12037	20435	23366	19482	28927	20957	17920	31057	21816	23463	16663	**244766**
Kitchen	6844	8900	10965	12336	10096	14439	11774	7018	13447	9315	12801	8892	**126827**
Hot water	3969	3752	6959	8706	7372	12388	8464	7352	14475	10033	11741	7736	**102947**
Monthly Total	19456	24689	38359	44408	36950	55754	41195	32290	58979	41164	48005	33291	**474540**

Table 48: Male residences monthly energy consumption, 2003 -2007

Male residence	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Annual Total 2003
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Eendrag													
Residential	4072	4814	14394	18181	17404	25616	24392	17819	37052	22185	22975	15217	**224121**
Kitchen	9387	10318	15444	16781	18035	23382	17643	17123	26421	17959	22237	15382	**210112**
Hot water(pro rata with Helshoogte)	3437	3691	7055	8776	8914	14227	12712	9730	18846	12924	14272	9897	**124482**
Monthly Total	16896	18823	36893	43738	44353	63225	54747	44672	82319	53068	59484	40496	**558715**
Helderberg													
Residential	6009	6742	18814	23819	21381	28786	24392	18315	35948	24134	27052	18638	**254030**
Kitchen	7027	4463	14668	14905	13481	16907	11768	8693	17610	12804	16252	10719	**149297**
Hot water	4414	4403	8689	10300	10938	17635	13286	8653	21153	14867	15287	11116	**140741**
Monthly Total	17450	15608	42171	49024	45800	63328	49446	35661	74711	51805	58591	40473	**544068**
Helshoogte													
Residential	20768	19880	39211	48000	44400	54949	51087	35613	64839	48707	53694	43579	**524727**
Kitchen	4532	3892	9561	11000	9970	14094	10688	4650	15346	11198	12013	10087	**117031**
Hot water(pro rata with Eendrag)	4261	4576	8746	10878	11050	17635	15757	12060	23361	16019	17691	12267	**154300**
Monthly Total	29561	28348	57518	69878	65420	86678	77532	52323	103546	75924	83398	65933	**796058**
Huis Marais													
Residential	2626	3903	9155	15962	9546	12367	11193	9289	17765	10408	12022	7854	**122090**
Kitchen	2814	4579	5315	2808	4586	6393	4903	4089	8884	5610	6173	4413	**60564**
Hot water(pro rata with Dagbreek and Huis Visser)	1190	1453	3231	3879	3998	5986	5166	3996	7784	5935	6489	4309	**53417**
Monthly Total	6630	9935	17701	22649	18130	24746	21262	17374	34433	21952	24683	16576	**236070**
Dagbreek													
Eastwing residential	1506	1402	11391	15545	14155	20057	22060	14191	35479	20767	18882	11639	**187074**
Westwing residential	1745	2007	6647	8921	8320	13355	13165	22110	19117	11469	10019	6652	**123527**
Kitchen	9223	4777	22657	23648	22627	28951	18121	4978	10591	9732	27282	17663	**200250**
Washingroom	152	179	1844	2699	1683	3604	2591	809	3446	2121	3603	2196	**24927**
Hot water(pro rata with Huis Marais and Huis Visser)	3743	4569	10163	12200	12576	18829	16249	12570	24482	18667	20409	13554	**168012**

Monthly Total	16369	12934	52702	63013	59361	84796	72186	54658	93115	62756	80195	51704	**703790**
Huis Visser													
Residential	1604	2716	8568	10145	9489	12531	8992	6601	16228	10551	12493	8489	**108407**
Kitchen	2814	4579	5315	2808	4586	6393	4903	4089	8884	5610	6173	4413	**60564**
Hot water(pro rata with Dagbreek and Huis Marais)	1190	1453	3231	3879	3998	5986	5166	3996	7784	5935	6489	4309	**53417**
Monthly Total	5608	8748	17114	16832	18073	24910	19061	14686	32896	22095	25154	17211	**222387**
Majuba													
Residential	3427	2683	13729	17025	14927	19585	16254	12142	26435	16896	19122	14387	**176612**
Kitchen	1425	826	4006	4193	3717	4943	3018	2246	5439	3763	5107	3462	**42145**
Hot water	3667	3031	7012	8156	7940	11369	10354	8440	15689	11062	12798	8532	**108050**
Monthly Total	8519	6540	24747	29374	26584	35897	29626	22828	47563	31721	37027	26381	**326807**
Simonsberg													
Residential	7156	7057	17766	23364	21623	30594	28519	20853	44890	27893	27598	19783	**277096**
Kitchen	5950	3494	15894	16940	14930	20402	14810	13160	23566	16347	20109	13521	**179123**
Hot water	2680	2843	10653	12676	12767	21667	18221	12757	27392	18595	21330	14038	**175619**
Monthly Total	15786	13394	44313	52980	49320	72663	61550	46770	95848	62835	69037	47342	**631838**
Wilgenhof													
Residential	4340	4771	12665	18228	17730	25081	22349	16796	36032	22100	21757	15483	**217332**
Kitchen	5008	3420	13607	13866	14380	17761	11182	8677	19185	13907	16833	10862	**148688**
Hot water	1327	1294	4953	6369	6683	10009	8531	6267	13523	9207	10239	6447	**84849**
Wilgenhof resident manager	850	861	823	825	1026	1427	1647	1808	2044	1772	1350	924	**15357**
Monthly Total	11525	10346	32048	39288	39819	54278	43709	33548	70784	46986	50179	33716	**466226**
	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	**Annual Total 2004**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Eendrag													
Residential	3145	4559	16775	22859	18457	25159	19201	18645	31286	21041	24705	15844	**221676**
Kitchen	1510	4922	18162	21665	16201	24319	14327	13597	24043	16498	21435	13637	**190316**
Hot water(pro rata with Helshoogte)	3229	3743	8059	11527	11254	15000	11298	10752	18218	12939	15626	8412	**130057**
Monthly Total	7884	13224	42996	56051	45912	64478	44826	42994	73547	50478	61766	37893	**542049**
Helderberg													
Residential	6745	7925	21408	25536	21022	28799	22382	21639	35662	23681	28543	19326	**262668**

Kitchen	758	4380	15083	16736	14913	17871	10912	9341	18496	12696	15474	9221	**145881**
Hot water	7123	4888	8044	12120	12770	16157	12750	12931	20703	15428	16954	9289	**149157**
Monthly Total	14626	17193	44535	54392	48705	62827	46044	43911	74861	51805	60971	37836	**557706**
Helshoogte													
Residential	17962	23843	46098	51197	45213	56455	40506	38910	61504	46872	55111	41105	**524776**
Kitchen	2410	5245	9911	13225	12333	14670	9410	6923	15811	9662	13177	7083	**119860**
Hot water(pro rata with Eendrag)	3314	3842	8274	11833	11554	15400	11599	11038	18703	13284	16042	8636	**133519**
Monthly Total	23686	32930	64283	76255	69100	86525	61515	56871	96018	69818	84330	56824	**778155**
Huis Marais													
Residential	3008	3093	9140	11039	9421	12158	7043	7249	13030	8930	11970	6821	**102902**
Kitchen	1969	4283	5491	6315	4958	6880	4660	4006	7854	5094	6519	4032	**62058**
Hot water(pro rata with Dagbreek and Huis Visser)	1378	1513	3296	4608	3970	5609	3981	4374	7195	5126	5911	3243	**50204**
Monthly Total	6355	8889	17927	21961	18349	24647	15684	15628	28078	19150	24399	14096	**215164**
Dagbreek													
Eastwing residential	1314	1974	12059	16135	13406	19220	14623	13492	26976	15421	19315	11844	**165779**
Westwing residential	1153	1803	6717	7829	6777	10434	9581	9568	15811	8530	9290	5794	**93287**
Kitchen	938	6382	22651	25545	18090	26500	17119	13772	30124	20024	27320	16987	**225452**
Washingroom	180	5	1399	2868	1443	2533	1938	633	3829	1852	2933	2253	**21866**
Hot water(pro rata with Huis Marais and Huis Visser)	4334	4759	10368	14493	12487	17642	12522	13757	22630	16123	18591	10201	**157906**
Monthly Total	7919	14923	53194	66870	52203	76329	55783	51222	99370	61950	77449	47079	**664290**
Huis Visser													
Residential	3171	3999	9574	11852	9692	13566	9280	8727	16956	10873	13501	8676	**119867**
Kitchen	1969	4283	5491	6315	4958	6880	4660	4006	7854	5094	6519	4032	**62058**
Hot water(pro rata with Dagbreek and Huis Marais)	1378	1513	3296	4608	3970	5609	3981	4374	7195	5126	5911	3243	**50204**
Monthly Total	6518	9795	18361	22774	18620	26055	17921	17106	32004	21093	25930	15951	**232129**
Majuba													
Residential	3481	4959	15081	17526	15527	20565	14911	12906	23609	15637	20410	13389	**178001**
Kitchen	595	2521	4273	4723	3635	5114	2782	2236	5084	3840	4644	2792	**42239**

Hot water	3274	3919	7482	9858	9099	11344	8717	9072	15165	9845	11325	6544	**105644**
Monthly Total	7350	11399	26836	32107	28261	37023	26410	24214	43858	29322	36379	22725	**325884**
Simonsberg													
Residential	7406	8552	21469	25902	25374	32600	24877	26060	42908	26281	30690	22986	**295105**
Kitchen	541	4998	18371	20449	14770	21689	14307	14874	21006	13278	18673	16144	**179100**
Hot water	240	1673	9836	15146	13201	18418	13609	14174	24398	16547	19723	13345	**160310**
Monthly Total	8187	15223	49676	61497	53345	72707	52793	55108	88312	56106	69086	52475	**634515**
Wilgenhof													
Residential	5272	3778	14370	20992	18060	25110	18617	17654	30477	21295	22710	14378	**212713**
Kitchen	725	4025	13007	15276	14412	17408	11028	9661	19070	12768	16352	9727	**143459**
Hot water	168	986	5282	8378	7829	11241	7621	7916	14447	10975	11162	5944	**91949**
Wilgenhof resident manager	805	1069	791	1136	1277	1194	1820	1700	2098	1249	999	1120	**15258**
Monthly Total	6970	9858	33450	45782	41578	54953	39086	36931	66092	46287	51223	31169	**463379**
	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	**Annual Total 2005**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Eendrag													
Residential	3517	5193	18476	19470	22429	29548	23503	19356	39846	22991	27541	18888	**250758**
Kitchen	3824	6849	17085	16514	18257	21477	13247	12561	22695	16255	21247	19561	**189572**
Hot water(pro rata with Helshoogte)	727	2193	7298	7016	10285	13859	10749	9802	18373	12639	14963	9991	**117894**
Monthly Total	8068	14235	42859	43000	50971	64884	47499	41719	80914	51885	63751	48440	**558224**
Helderberg													
Residential	5099	6487	22262	23357	25708	32993	26043	22431	37056	25409	30078	19576	**276499**
Kitchen	995	4521	13597	12802	15356	18751	13494	14878	19727	13498	17714	10198	**155531**
Hot water	829	2852	8026	7934	11568	15897	12681	11454	19925	13360	16013	9868	**130407**
Monthly Total	6923	13860	43885	44093	52632	67641	52218	48763	76708	52267	63805	39642	**562437**
Helshoogte													
Residential	18114	24060	43970	46722	51165	58515	43976	43046	66978	48977	55305	38612	**539440**
Kitchen	553	2192	9883	9160	12159	14819	9445	10551	15304	10212	13137	8190	**115605**
Hot water(pro rata with Eendrag)	841	2539	8448	8123	11906	16044	12444	11348	21270	14633	17323	11566	**136486**
Monthly Total	19508	28791	62301	64005	75230	89378	65865	64945	103552	73822	85765	58368	**791531**

Huis Marais													
Residential	760	2735	9508	10419	11241	13723	10428	9775	16957	10639	12522	7104	**115811**
Kitchen	697	3894	5350	4825	6226	7214	4567	4051	8299	5542	7323	5409	**63398**
Hot water(pro rata with Dagbreek and Huis Visser)	1013	1325	3362	3421	4559	5975	4476	3911	7770	5779	6576	3943	**52109**
Monthly Total	2469	7954	18220	18665	22026	26912	19471	17737	33026	21960	26421	16456	**231318**
Dagbreek													
Eastwing residential	2853	2831	13133	15863	17328	22070	18519	13733	30149	19304	21293	11492	**188568**
Westwing residential	2238	2636	7790	8661	9729	12644	10767	8577	17161	11310	12167	6827	**110507**
Kitchen	960	7245	22658	24176	27144	29387	17868	17587	30623	25993	28096	17600	**249337**
Washingroom	135	103	1481	2572	1943	2904	2370	638	3493	2373	4106	2288	**24406**
Hot water(pro rata with Huis Marais and Huis Visser)	3105	4062	10311	10491	13980	18323	13725	11994	23828	17722	20166	12093	**159801**
Monthly Total	9291	16877	55373	61763	70124	85328	63249	52529	105254	76702	85828	50300	**732619**
Huis Visser													
Residential	1768	3128	11155	11826	13608	17955	11066	9826	20213	12832	17137	10581	**141095**
Kitchen	708	3959	5439	4906	6330	7335	4644	4119	8438	5634	7445	5499	**64455**
Hot water(pro rata with Dagbreek and Huis Marais)	1029	1347	3418	3478	4635	6075	4550	3976	7900	5875	6685	4009	**52978**
Monthly Total	3506	8434	20012	20210	24573	31364	20260	17921	36550	24341	31267	20089	**258527**
Majuba													
Residential	1966	2700	13696	14847	15367	17980	13201	12191	20914	14417	17902	12075	**157256**
Kitchen	82	826	3868	3529	4545	5215	3437	3352	5214	3609	4479	2568	**40724**
Hot water	774	1762	5618	5423	7614	10042	8209	7393	13429	9066	11205	8101	**88636**
Monthly Total	2822	5288	23182	23799	27526	33237	24847	22936	39557	27092	33586	22744	**286616**
Simonsberg													
Residential	9405	9675	22124	24594	28284	36612	28148	22743	47434	28616	35676	21965	**315276**
Kitchen	2142	10062	15850	14619	16607	19471	11198	9645	20011	14848	18916	10734	**164103**
Hot water	781	4283	8902	9595	13243	18816	12387	11145	22973	15623	20162	11521	**149431**
Monthly Total	12328	24020	46876	48808	58134	74899	51733	43533	90418	59087	74754	44220	**628810**
Wilgenhof													
Residential	3538	4140	15201	17307	21360	27351	19800	16945	33092	21858	24562	14987	**220141**
Kitchen	748	3723	12352	13370	14462	16421	10676	9542	18543	13658	16113	10392	**140000**

Hot water	449	1177	5590	6296	6510	10477	8158	7231	14759	10562	11983	6917	**90109**
Wilgenhof resident manager	923	564	843	980	903	1139	2009	1173	1573	1404	1428	1174	**14113**
Monthly Total	5658	9604	33986	37953	43235	55388	40643	34891	67967	47482	54086	33470	**464363**
	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	**Annual Total 2006**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Eendrag													
Residential	5250	7613	19079	24258	19995	33731	17598	14748	35876	23474	28682	19287	**249591**
Kitchen	7325	13534	17736	22476	16573	23211	12652	9115	23222	17101	22480	16814	**202239**
Hot water(pro rata with Helshoogte)	2168	3372	6244	9381	8007	15112	8744	7110	17754	11944	13889	9325	**113050**
Monthly Total	14743	24519	43059	56115	44575	72054	38994	30973	76852	52519	65051	45426	**564880**
Helderberg													
Residential	7556	8680	21778	26526	12245	32065	17251	15583	32728	22510	28037	20279	**245238**
Kitchen	1019	5020	12876	14751	12858	16946	9549	6819	17086	11915	15688	12153	**136680**
Hot water	4049	4183	8200	12195	11519	19399	11307	10207	20912	14255	16863	11399	**144488**
Monthly Total	12624	17883	42854	53472	36622	68410	38107	32609	70726	48680	60588	43831	**526406**
Helshoogte													
Residential	14884	22606	41034	47594	38515	57190	34418	33383	58044	43947	52298	40275	**484188**
Kitchen	1269	3396	11517	12370	8664	15001	6394	4700	14823	9755	12811	8762	**109462**
Hot water(pro rata with Eendrag)	2688	4180	7740	11628	9925	18731	10839	8814	22006	14805	17216	11558	**140130**
Monthly Total	18841	30182	60291	71592	57104	90922	51651	46897	94873	68507	82325	60595	**733780**
Huis Marais													
Residential	830	3530	11038	12943	9108	14846	7554	7868	19630	12929	16607	11893	**128776**
Kitchen	1744	2188	5255	6027	5438	6461	3225	0	0	0	0	1419	**31755**
Hot water(pro rata with Dagbreek and Huis Visser)	1276	1234	3123	4542	4150	6830	4250	3380	7515	5214	6067	4140	**51720**
Monthly Total	3850	6952	19415	23512	18696	28137	15029	11248	27145	18143	22674	17451	**212251**
Dagbreek													
Eastwing residential	2244	2624	14209	17882	14186	23135	12752	10376	24844	15864	20106	13142	**171364**
Westwing residential	1982	5201	8881	10521	8791	14784	8840	15379	15806	9977	11295	7069	**118526**
Kitchen	879	8594	22889	27741	23549	29343	18650	11140	30069	22257	29340	20249	**244700**
Washingroom	23	34	1652	1930	2341	1707	1164	159	12134	2835	2450	1960	**28389**

Hot water(pro rata with Huis Marais and Huis Visser)	4145	4008	10142	14751	13479	22182	13804	10979	24409	16933	19704	13445	**167979**
Monthly Total	9273	20461	57772	72825	62346	91151	55210	48033	107262	67866	82895	55865	**730958**
Huis Visser													
Residential	2544	3105	11532	14084	11295	17753	8627	6642	18138	12032	15409	10362	**131523**
Kitchen	1744	2188	5255	6027	5438	6461	3225	0	0	0	0	1419	**31755**
Hot water(pro rata with Dagbreek and Huis Marais)	1276	1234	3123	4542	4150	6830	4250	3380	7515	5214	6067	4140	**51720**
Monthly Total	5564	6527	19909	24653	20883	31044	16102	10022	25653	17246	21476	15920	**214998**
Majuba													
Residential	4276	4100	13944	16339	12967	19627	10132	9209	21341	15114	19163	13376	**159588**
Kitchen	168	968	3842	4727	4339	5484	2685	1548	5258	3674	4822	3167	**40682**
Hot water	3819	2968	4990	7376	7521	11137	6161	6027	13061	8807	10772	7596	**90235**
Monthly Total	8263	8036	22776	28442	24827	36248	18978	16784	39660	27595	34757	24139	**290505**
Simonsberg													
Residential	5394	7845	23248	29417	25090	43862	22529	19133	46400	29287	33296	25470	**310971**
Kitchen	1880	6288	16044	19066	16725	21242	10159	7603	19774	15631	18024	15638	**168074**
Hot water	633	2475	7688	12467	11293	20367	9462	7966	21834	14787	17728	12997	**139697**
Monthly Total	7907	16608	46980	60950	53108	85471	42150	34702	88008	59705	69048	54105	**618742**
Wilgenhof													
Residential	5265	5112	15434	21517	18090	32817	17727	16069	34115	21194	22495	15224	**225059**
Kitchen	3382	5450	13081	15883	13917	18266	9509	6232	19109	16091	17033	11379	**149332**
Hot water	2500	1629	5730	9229	8566	13799	7051	5720	14751	11923	12015	7871	**100784**
Wilgenhof resident manager	1290	585	760	980	1527	1049	1415	1166	1735	1190	1031	1214	**13942**
Monthly Total	12437	12776	35005	47609	42100	65931	35702	29187	69710	50398	52574	35688	**489117**
	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	**Annual Total 2007**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Eendrag													
Residential	3800	6849	22175	26084	21270	32510	16140	20342	10011	983	625	1717	**162506**
Kitchen	2861	8442	19475	20757	15699	22921	10978	17579	23259	14340	17176	11919	**185406**
Hot water(pro rata with Helshoogte)	2169	2349	7014	8711	8107	14105	8141	10262	13125	9365	9382	7478	**100208**
Monthly Total	8830	17640	48664	55552	45076	69536	35259	48183	46395	24688	27183	21114	**448120**

Helderberg													
Residential	1375	1963	23232	27361	22490	32269	18002	19419	34480	24546	27319	19418	**251874**
Kitchen	1393	5700	13921	15611	14427	17166	8259	11963	17754	13256	15094	10735	**145279**
Hot water	4883	4805	8872	10909	11007	17475	10020	13890	21337	15226	16245	11517	**146186**
Monthly Total	7651	12468	46025	53881	47924	66910	36281	45272	73571	53028	58658	41670	**543339**
Helshoogte													
Residential	14574	21123	46040	53491	42802	61344	39121	37235	63624	50559	53098	42534	**525545**
Kitchen	1042	3377	10110	11505	8614	13680	5380	7416	14664	8475	11468	9022	**104753**
Hot water(pro rata with Eendrag)	2689	2912	8694	10797	10048	17483	10092	12720	16270	11608	11629	9270	**124212**
Monthly Total	18305	27412	64844	75793	61464	92507	54593	57371	94558	70642	76195	60826	**754510**
Huis Marais													
Residential	2234	4278	11383	14550	10867	16565	8036	7734	17276	12090	15186	9790	**129989**
Kitchen	1882	2955	6547	7425	6235	8872	4584	6062	9395	6875	8735	6019	**75583**
Hot water(pro rata with Dagbreek and Huis Visser)	1658	1465	3476	4208	3924	6489	4401	4706	7632	5870	6257	3774	**53859**
Monthly Total	5774	8698	21405	26183	21026	31926	17021	18501	34303	24834	30177	19583	**259431**
Dagbreek													
Eastwing residential	2693	2951	16203	19201	15041	23726	17421	13496	25441	17473	19588	11792	**185026**
Westwing residential	1958	2331	7922	9802	8359	13061	9433	8414	14485	9550	10534	7418	**103267**
Kitchen	2194	7260	19363	22335	19968	24062	18617	13712	23775	20090	22896	14065	**208337**
Washingroom	63	111	4329	6300	7038	6060	4860	4836	8265	4704	9384	4398	**60348**
Hot water(pro rata with Huis Marais and Huis Visser)	5386	4757	11289	13668	12746	21075	14295	15283	24787	19064	20321	12258	**174928**
Monthly Total	12294	17410	59106	71306	63152	87984	64626	55741	96753	70881	82723	49931	**731906**
Huis Visser													
Residential	1501	3569	11808	13417	10579	16366	6786	8112	16747	12403	14567	9553	**125408**
Kitchen	1882	2955	6547	7425	6235	8872	4584	6062	9395	6875	8735	6019	**75583**
Hot water(pro rata with Dagbreek and Huis Marais)	1658	1465	3476	4208	3924	6489	4401	4706	7632	5870	6257	3774	**53859**
Monthly Total	5041	7989	21830	25050	20738	31727	15771	18879	33774	25147	29558	19346	**254850**

Majuba													
Residential	2184	4769	16256	18204	14130	20907	10696	10368	20332	14390	18083	11104	**161423**
Kitchen	58	1387	4011	4604	4355	5064	3076	2214	5196	3789	4861	3258	**41873**
Hot water	2637	3244	6828	8496	7906	13015	7481	8277	13873	9761	11242	7432	**100192**
Monthly Total	4879	9400	27095	31304	26391	38986	21253	20859	39401	27940	34186	21794	**303488**
Simonsberg													
Residential	9413	11445	25664	31237	26428	41208	24326	23847	45390	32515	32919	22261	**326653**
Kitchen	4308	6331	15497	15937	12891	18380	7211	7022	19832	15493	16606	12129	**151637**
Hot water	4369	3274	8839	10835	9956	18236	9363	9137	21570	16726	17243	11165	**140713**
Monthly Total	18090	21050	50000	58009	49275	77824	40900	40006	86792	64734	66768	45555	**619003**
Wilgenhof													
Residential	4825	5109	16222	20114	17671	27097	16606	15734	29461	20911	24685	16341	**214776**
Kitchen	803	4672	14239	15989	12883	18516	8949	15365	20090	13103	17083	11468	**153160**
Hot water	1461	1388	6487	8242	7959	13068	6239	7214	15437	10318	12429	8406	**98648**
Wilgenhof resident manager	1246	556	849	873	925	1139	1515	2031	1376	1085	226	2117	**13938**
Monthly Total	8335	11725	37797	45218	39438	59820	33309	40344	66364	45417	54423	38332	**480522**

Table 49:Mixed residences monthly energy consumption, 2003 – 2007

Mixed Residence	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Annual Total 2003
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Academia													
Academia sub 1	14170	15208	33211	39417	41017	59265	58029	54600	81964	57049	47873	34932	**536735**
Academia sub2	23204	30362	59858	72506	76171	106640	100208	74700	130475	70637	62077	47138	**853976**
Monthly total	37374	45570	93069	111923	117188	165905	158237	129300	212439	127686	109950	82070	**1390711**
Concordia													
Residential and Kitchen	9008	7415	11912	15504	17258	24625	30572	29284	38524	27996	18834	14443	**245375**
Hot water	16544	14195	17132	22138	26616	31724	30152	30504	36738	35933	31492	24255	**317423**
Monthly total	25552	21610	29044	37642	43874	56349	60724	59788	75262	63929	50326	38698	**562798**
Goldfields													
Residential	3758	6172	13632	18061	17476	24010	19994	16067	32509	21632	20703	15099	**209113**
Entertainment/Dining hall	202	233	581	628	661	892	836	791	918	839	1019	772	**8372**
Kitchen	121	130	2050	2247	1798	2679	2255	799	2577	2014	2768	1995	**21433**
Caltex 1	0	222	1216	1317	1354	2018	2176	986	2273	2063	2122	1612	**17359**
Caltex 2	296	307	1384	1800	1991	2669	2529	1221	2850	2554	2568	1873	**22042**
House manager	1747	217	1209	1266	1753	2251	2250	2698	2807	2361	1194	1031	**20784**
Nagenoeg	604	605	967	1406	1775	2676	3033	1923	1824	2550	1977	1493	**20833**
Toekoms	586	588	1404	1913	2006	3188	4048	1916	4867	3843	3506	2133	**29998**
Monthly total	7314	8474	22443	28638	28814	40383	37121	26401	50625	37856	35857	26008	**349934**
Huis De Villiers													
Residential and Kitchen	10527	11356	18660	22643	22263	28918	30287	29890	41099	29977	25565	21872	**293057**
Hot water	3600	3520	4880	5560	6400	8840	10400	9560	10520	10080	9920	7160	**90440**
Monthly total	14127	14876	23540	28203	28663	37758	40687	39450	51619	40057	35485	29032	**383497**
Huis MacDonald													
Residential, Kitchen and Hot water	8492	7103	11854	14876	15656	20805	22978	22030	28452	20167	17451	14517	**204381**
House manager	957	395	779	780	1044	1013	1508	2285	1862	1314	1043	889	**13869**
Monthly total	9449	7498	12633	15656	16700	21818	24486	24315	30314	21481	18494	15406	**218250**
Lobelia													
Residential, Kitchen and Hot water	7200	6200	8900	10800	17300	12000	14500	19800	18400	16700	17400	11000	**160200**
Monthly total	7200	6200	8900	10800	17300	12000	14500	19800	18400	16700	17400	11000	**160200**
Metanoia													
Residential and Hot water													
Kitchen													

	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	**Annual Total 2004**
House manager													
Monthly total													
	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	**Annual Total 2004**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Academia													
Academia sub 1	16926	19631	38184	47246	45949	58590	50289	52700	71860	49793	47278	34826	**533272**
Academia sub2	25548	31464	59097	94456	99760	130300	110943	135009	180192	130076	129207	94343	**1220395**
Monthly total	42474	51095	97281	141702	145709	188890	161232	187709	252052	179869	176485	129169	**1753667**
Concordia													
Residential and Kitchen	6371	6285	12994	16931	17970	24752	28270	31875	39334	27140	20499	15468	**247889**
Hot water	12378	11045	20846	28182	27506	33053	30715	32502	40108	35471	30824	22565	**325195**
Monthly total	18749	17330	33840	45113	45476	57805	58985	64377	79442	62611	51323	38033	**573084**
Goldfields													
Residential	3955	4948	14229	16861	17219	26073	15908	20461	26309	22642	22919	12017	**203541**
Entertainment/Dining hall	220	149	676	937	718	827	917	776	1110	765	762	874	**8731**
Kitchen	120	106	2147	2992	1861	2425	2601	1008	2937	1849	2460	1946	**22452**
Caltex 1	320	994	1270	1882	1612	1619	1807	1017	2662	1675	1575	1501	**17934**
Caltex 2	420	1344	1300	1981	1709	1874	2522	1574	4261	2370	2004	1939	**23298**
House manager	1220	843	969	1326	1144	1419	2330	1825	2596	1699	1204	1476	**18051**
Nagenoeg	625	679	1429	2211	2168	2395	3225	1472	3842	1833	1646	1858	**23383**
Toekoms	615	776	2088	2804	2301	3174	3945	2042	7171	4030	3156	2899	**35001**
Monthly total	7495	9839	24108	30994	28732	39806	33255	30175	50888	36863	35726	24510	**352391**
Huis De Villiers													
Residential and Kitchen	13220	11020	19501	22133	22216	28246	24609	30252	33192	27403	26136	18161	**276089**
Hot water	3440	5960	4560	8200	8200	8720	12000	9000	14520	10240	9320	10000	**104160**
Monthly total	16660	16980	24061	30333	30416	36966	36609	39252	47712	37643	35456	28161	**380249**
Huis MacDonald													
Residential, Kitchen and Hot water	8764	7280	13284	16975	17367	20826	21964	23308	25574	19598	17909	14647	**207496**
House manager	915	694	618	1018	757	795	1697	1730	2130	1278	870	1116	**13618**
Monthly total	9679	7974	13902	17993	18124	21621	23661	25038	27704	20876	18779	15763	**221114**
Lobelia													
Residential, Kitchen and Hot water	6700	7400	10300	17300	11500	18700	13400	21700	17400	15600	13100	9000	**162100**
Monthly total	6700	7400	10300	17300	11500	18700	13400	21700	17400	15600	13100	9000	**162100**

Metanoia													
Residential and Hot water													
Kitchen													
House manager													
Monthly total													
	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct -05	Nov-05	**Annual Total 2005**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Academia													
Academia sub 1	20941	35080	64677	69689	84395	115127	100209	94004	156162	104237	105996	74739	**1025256**
Academia sub2	45509	50068	83471	92174	113078	155676	136205	126893	214491	149777	139530	100503	**1407375**
Monthly total	66450	85148	148148	161863	197473	270803	236414	220897	370653	254014	245526	175242	**2432631**
Concordia													
Residential and Kitchen	6788	8149	15608	18127	21257	28556	32099	28561	42826	28259	26823	20181	**277234**
Hot water	9671	11301	19821	20231	27791	35059	32108	30204	39176	33911	35572	27168	**322013**
Monthly total	16459	19450	35429	38358	49048	63615	64207	58765	82002	62170	62395	47349	**599247**
Goldfields													
Residential	3395	7182	13661	12788	22435	25854	15142	19279	31366	22922	21382	11354	**206760**
Entertainment/Dining hall	372	201	636	729	601	905	875	1011	938	614	879	671	**8432**
Kitchen	91	476	2107	2585	1891	3080	2708	1335	3126	2103	3532	2698	**25732**
Caltex 1	172	450	1170	1131	945	1712	1881	1196	2308	2040	2243	1552	**16800**
Caltex 2	542	455	1243	1728	1307	2511	3178	1540	3887	2820	3149	2401	**24761**
House manager	1242	819	1107	1082	1104	1960	2635	1274	1826	1657	1569	1381	**17656**
Nagenoeg	614	341	1940	1681	1393	2431	3030	1830	3589	2621	3209	2203	**24882**
Toekoms	1139	550	1494	2078	1640	2612	2707	1497	3530	2983	3153	2426	**25809**
Monthly total	7567	10474	23358	23802	31316	41065	32156	28962	50570	37760	39116	24686	**350832**
Huis De Villiers													
Residential and Kitchen	10923	15855	19645	21731	25191	32162	30773	29850	38327	29855	27662	21993	**303967**
Hot water	7560	4320	7040	9640	6680	8040	9320	7440	9800	8000	10040	8480	**96360**
Monthly total	18483	20175	26685	31371	31871	40202	40093	37290	48127	37855	37702	30473	**400327**
Huis MacDonald													
Residential, Kitchen and Hot water	7756	7551	11684	13588	15553	19848	21480	20330	27223	19841	19517	15079	**199450**
House manager	921	577	764	924	715	1092	2064	1464	2492	1848	1157	1291	**15309**
Monthly total	8677	8128	12448	14512	16268	20940	23544	21794	29715	21689	20674	16370	**214759**
Lobelia													
Residential, Kitchen and Hot water	6000	7400	10300	13100	9600	21200	11900	21700	17500	13700	13100	9000	**154500**
Monthly total	6000	7400	10300	13100	9600	21200	11900	21700	17500	13700	13100	9000	**154500**

Metanoia													
Residential and Hot water							579	30420	45425	32739	29168	22993	**161324**
Kitchen							0	0	2726	2909	2719	1279	**9633**
House manager													
Monthly total							579	30420	48151	35648	31887	24272	**170957**
	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct -06	Nov-06	**Annual Total 2006**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Academia													
Academia sub 1	35801	40143	60435	74041	69003	117947	73763	67885	129068	85993	85578	63310	**902967**
Academia sub2	46806	53731	84535	104638	104799	165268	117042	111546	184943	128070	121642	91985	**1315005**
Monthly total	82607	93874	144970	178679	173802	283215	190805	179431	314011	214063	207220	155295	**2217972**
Concordia													
Residential and Kitchen	9684	9266	15867	20675	22767	34549	25237	30473	35680	23081	21554	16314	**265147**
Hot water	16129	14167	19053	27105	24850	36719	25812	26399	32265	26056	27205	20019	**295779**
Monthly total	25813	23433	34920	47780	47617	71268	51049	56872	67945	49137	48759	36333	**560926**
Goldfields													
Residential	4343	7751	15012	20821	12103	28196	14720	18084	25069	17387	22389	13611	**199486**
Entertainment/Dining hall	146	186	516	632	816	521	637	475	914	585	816	725	**6969**
Kitchen	561	590	2058	2354	2788	1987	1482	505	3173	1839	2435	2266	**22038**
Caltex 1	201	250	1202	1692	2360	2126	1689	551	3199	1866	2069	2150	**19355**
Caltex 2	507	365	1168	1727	2340	1829	1783	637	4116	2160	1947	1882	**20461**
House manager	0	0	0	0	0	6674	2085	2446	2907	1896	1361	1314	**18683**
Nagenoeg	628	500	1350	1680	2614	2249	2072	982	3453	2050	2139	1926	**21643**
Toekoms	753	558	1486	1957	2905	2661	2115	792	5820	3193	2832	2546	**27618**
Monthly total	7139	10200	22792	30863	25926	46243	26583	24472	48651	30976	35988	26420	**336253**
Huis De Villiers													
Residential and Kitchen	13240	18049	20368	22867	19375	34853	25579	27804	33450	26884	26887	21626	**290982**
Hot water	6000	3000	4560	6400	9440	6640	7600	5880	11160	8440	7880	7760	**84760**
Monthly total	19240	21049	24928	29267	28815	41493	33179	33684	44610	35324	34767	29386	**375742**
Huis MacDonald													
Residential, Kitchen and Hot water	8784	8057	11916	16306	17090	25160	21748	22487	26872	20622	19658	14959	**213659**
House manager	1217	811	823	954	1412	1462	1952	1489	2522	1417	1045	1193	**16297**
Monthly total	10001	8868	12739	17260	18502	26622	23700	23976	29394	22039	20703	16152	**229956**
Lobelia													
Residential, Kitchen and Hot water	6100	14200	10300	13100	12800	20000	11900	22000	21700	15200	17000	9000	**173300**
Monthly total	6100	14200	10300	13100	12800	20000	11900	22000	21700	15200	17000	9000	**173300**

Metanoia													
Residential and Hot water	25881	37589	66755	87530	79202	116993	76839	88868	130598	96850	110548	79191	**996844**
Kitchen	1264	7913	16805	18710	13858	19379	14416	12091	18675	14115	17673	13823	**168722**
House manager		0	0	0	0	0	5605	1401	1184	985	728	676	**10579**
Monthly total	27145	45502	83560	106240	93060	136372	96860	102360	150457	111950	128949	93690	**1176145**
	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	**Annual Total 2007**
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	
Academia													
Academia sub 1	29276	34068	65623	76000	73222	116288	83147	86571	148230	99524	94711	68218	**974878**
Academia sub2	42298	47118	90019	107138	102081	157017	119903	110323	186668	140198	130684	104385	**1337832**
Monthly total	71574	81186	155642	183138	175303	273305	203050	196894	334898	239722	225395	172603	**2312710**
Concordia													
Residential and Kitchen	6960	9002	16315	18069	19869	30599	32171	35835	39251	31356	24321	18977	**282725**
Hot water	9328	9039	18387	22739	24304	34254	27991	30525	34277	31452	30440	24101	**296837**
Monthly total	16288	18041	34702	40808	44173	64853	60162	66360	73528	62808	54761	43078	**579562**
Goldfields													
Residential	3157	5731	14049	17071	11194	28996	12618	7527	28523	22301	18479	15435	**185081**
Entertainment/Dining hall	333	317	632	888	1040	655	559	768	763	564	918	691	**8128**
Kitchen	62	644	2312	2808	2926	1981	1278	1503	2533	1473	3149	1629	**22298**
Caltex 1	470	281	1379	1783	2323	1971	1892	2026	3186	1816	2805	1463	**21395**
Caltex 2	515	361	1698	2241	2545	2034	1776	1717	2597	1930	2850	1770	**22034**
House manager	1130	932	990	1219	1681	1852	2947	4026	2819	1831	1680	1049	**22156**
Nagenoeg	778	593	1500	1913	2086	1756	1619	2480	3274	1967	2788	1613	**22367**
Toekoms	1133	674	2167	2795	3296	2778	2085	3083	3992	2311	3870	1889	**30073**
Monthly total	7578	9533	24727	30718	27091	42023	24774	23130	47687	34193	36539	25539	**333532**
Huis De Villiers													
Residential and Kitchen	12538	15499	21144	25144	21427	34307	30910	27664	38151	29930	25596	23846	**306156**
Hot water	5440	2360	5960	6280	10000	6360	8440	11720	8640	8160	10120	7640	**91120**
Monthly total	17978	17859	27104	31424	31427	40667	39350	39384	46791	38090	35716	31486	**397276**
Huis MacDonald													
Residential, Kitchen and Hot water	4953	5774	9408	14283	15199	19926	19612	20026	24370	19504	16056	13819	**182930**
House manager	1453	830	853	909	1664	821	2164	2452	1544	1071	1416	1185	**16362**
Monthly total	6406	6604	10261	15192	16863	20747	21776	22478	25914	20575	17472	15004	**199292**
Lobelia													
Residential, Kitchen and Hot water	1700	7200	8700	14200	12500	23100	16800	26600	19400	19100	40000	0	**189300**
Monthly total	1700	7200	8700	14200	12500	23100	16800	26600	19400	19100	40000	0	**189300**

Metanoia													
Residential and Hot water	33164	47804	82159	92127	78323	117418	65458	68001	132046	102977	110661	83062	**1013200**
Kitchen	3665	11523	16181	17201	13469	18414	9151	10490	19493	18387	18698	14500	**171172**
House manager	511	319	383	448	870	679	1169	1924	892	879	802	641	**9517**
Monthly total	37340	59646	98723	109776	92662	136511	75778	80415	152431	122243	130161	98203	**1193889**

Appendix B

Collection and processing of quantitative, qualitative and participatory data involved in my participation

My participation, as an active participant and not as a researcher, also generated insights which can contribute towards informing the possible solutions for sustainable energy use amongst the residences of Stellenbosch University.

The first observation concerns the grassroots level which is driving a search for a more sustainable campus. A formalised network, in order to promote knowledge sharing, would be essential to consolidate the efforts. Possibly, the Facebook group which has already been set up could be a temporary voice for this- it is student orientated and the digital format is appropriate technology for the context of modern communication. The search for sustainable solutions on campus is, at the time of writing, being driven by individual personalities and their respective ideological enthusiasm.

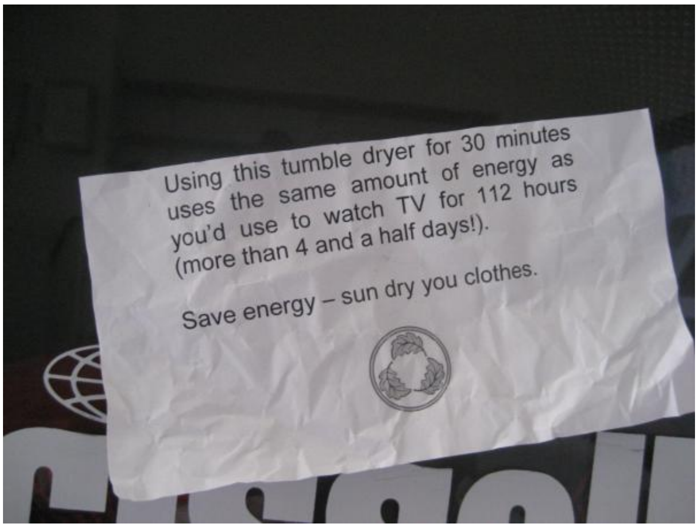
The experience with 2008 HK energy challenge revealed insights about the context too. Omer and I gave presentations concerning how to implement energy efficiency in the residences, in preparation for the 2008 US Energy Challenge (31 July, 2008). The meeting itself was marked by many questions from students and there was a keen interest for what the students themselves could do to implement energy efficiency. This sentiment was recognised again when Huis Ten Bosch asked me to do a presentation over lunch one day- the ladies of Huis Ten Bosch wanted to know what they could do now and with the resources they have available.

The residences were asked to forward photos and synopses of their residential attempts so that a journal of the 2008 US Energy Challenge could be compiled. Insightful comments included here were:

"Personally, I started shutting down my computer when leaving my room or going to bed instead of leaving it permanently on stand-by. This is directly because of the information session with ESKOM" (Huis Marais).

‘The symbol of the “green” project was a green dot, and it was placed on various crucial spots. The idea was that people would be reminded to save power and water by the seeing the dot’ (Eendrag).

In Huistenbosch, an energy list was created in which a first year engineering student of Huistenbosch went around the residence to calculate what the energy consequences of demanding certain energy services in Huis ten Bosch would equate to (some amounts were based on general averages as the power rating or time was not known). Below is an example of one this endeavour.



The conclusion from this is that the efforts were aimed at energy conservation and not energy efficiency. The enthusiasm is not matched with an understanding of the technical issues regarding energy efficiency. Most of the measures employed are not sustainable in the long term. However, this campaign is also meant primarily to raise awareness and, as Leslie pointed out from his experience this past year in the SRC, students generally respond best to a competitive element and to initiatives that are fun for spirit building in residences as opposed to slow, long term initiatives.

It was from this experience that the notion of a partnership between the green member of the residences and Maintenance and Operations should be formed- a bridge needs to be built so that the spirit and efforts of students are translated into technical changes in a safe way.

Appendix C: Graphical representation of the Lydia Residence energy survey results (Nel, 2008a: Center for Statistical Consultation)

Figure 24: Use of LCD screen vs. Plasma screen (results from question 2 of Lydia energy survey)

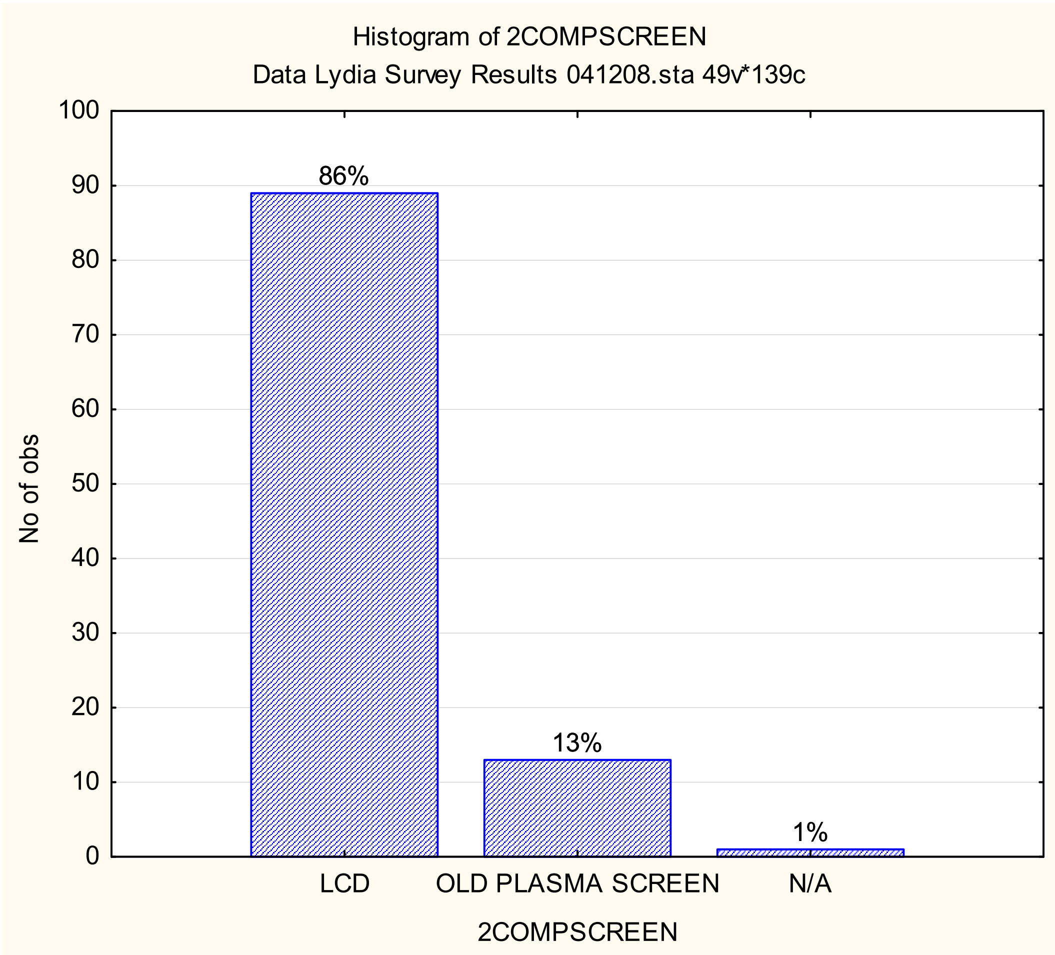


Figure 25: Switching off appliance trends (results from question 3 of Lydia energy survey)

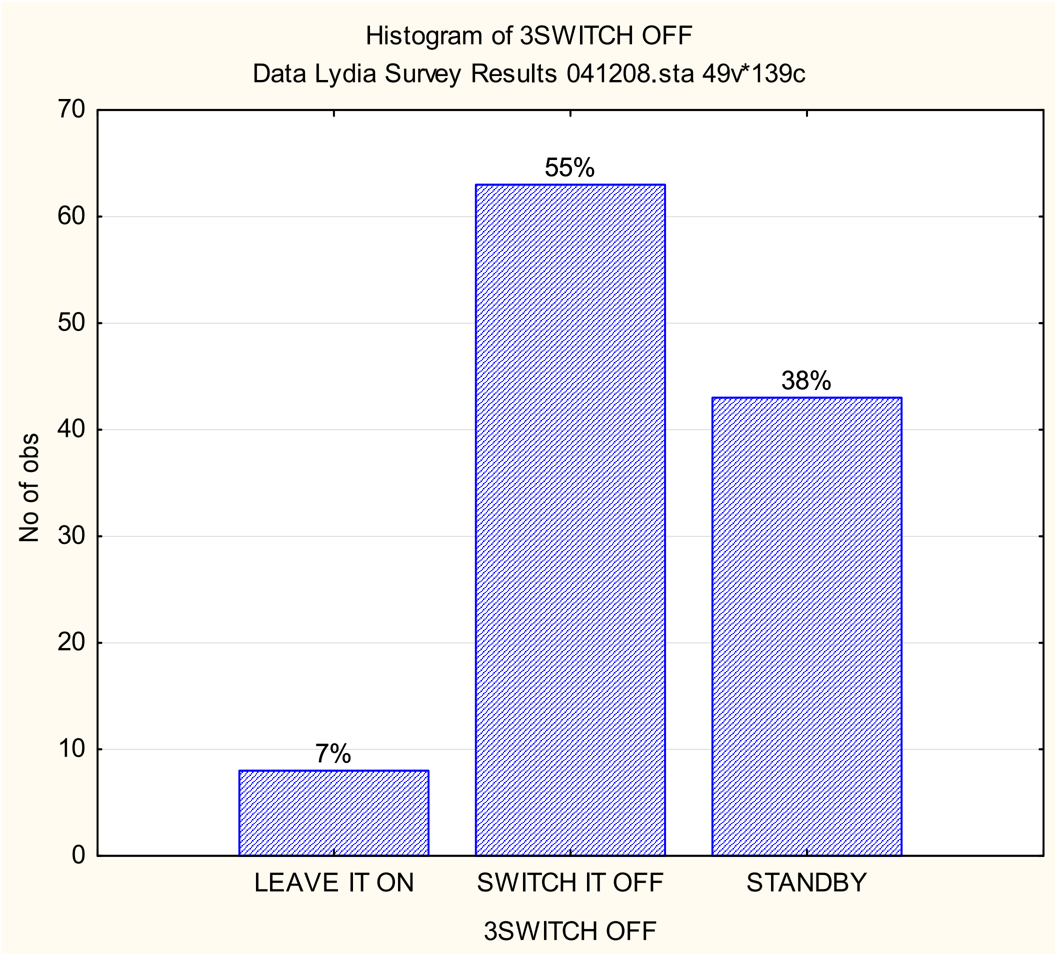


Figure 26: Switching off appliance trends (results from question 4 of Lydia energy survey)

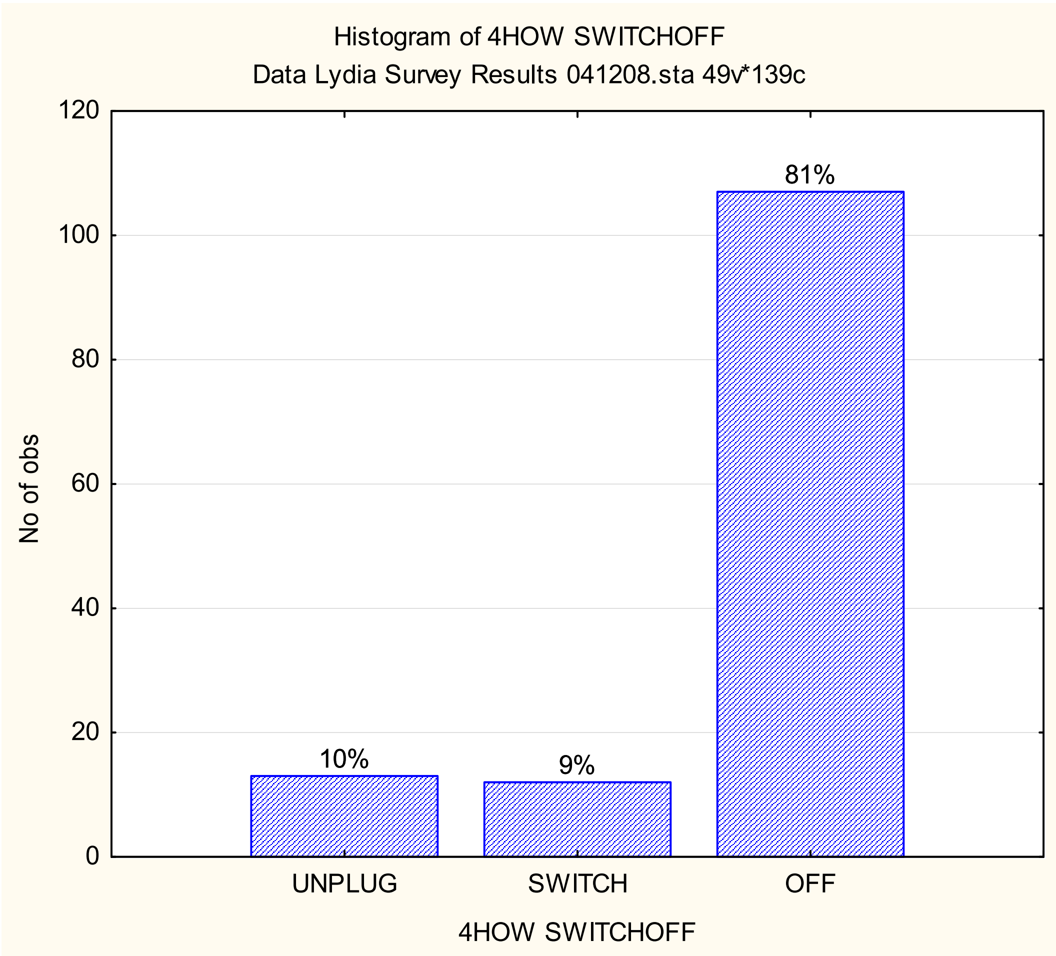


Figure 27: Investigating sufficiency of 2D CFL 16 W lighting for student needs (results from question 5 of Lydia energy survey)

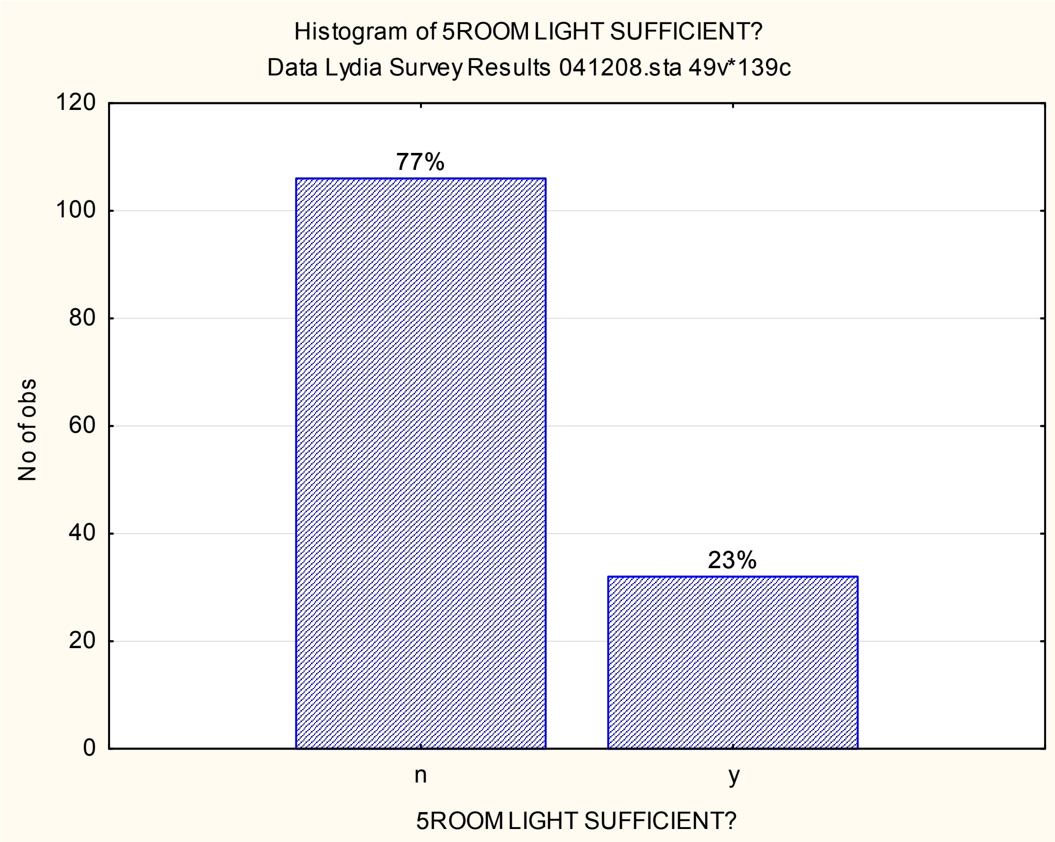


Figure 28: Investigating awareness of different light bulbs amongst students (results from question 6a of Lydia energy survey)

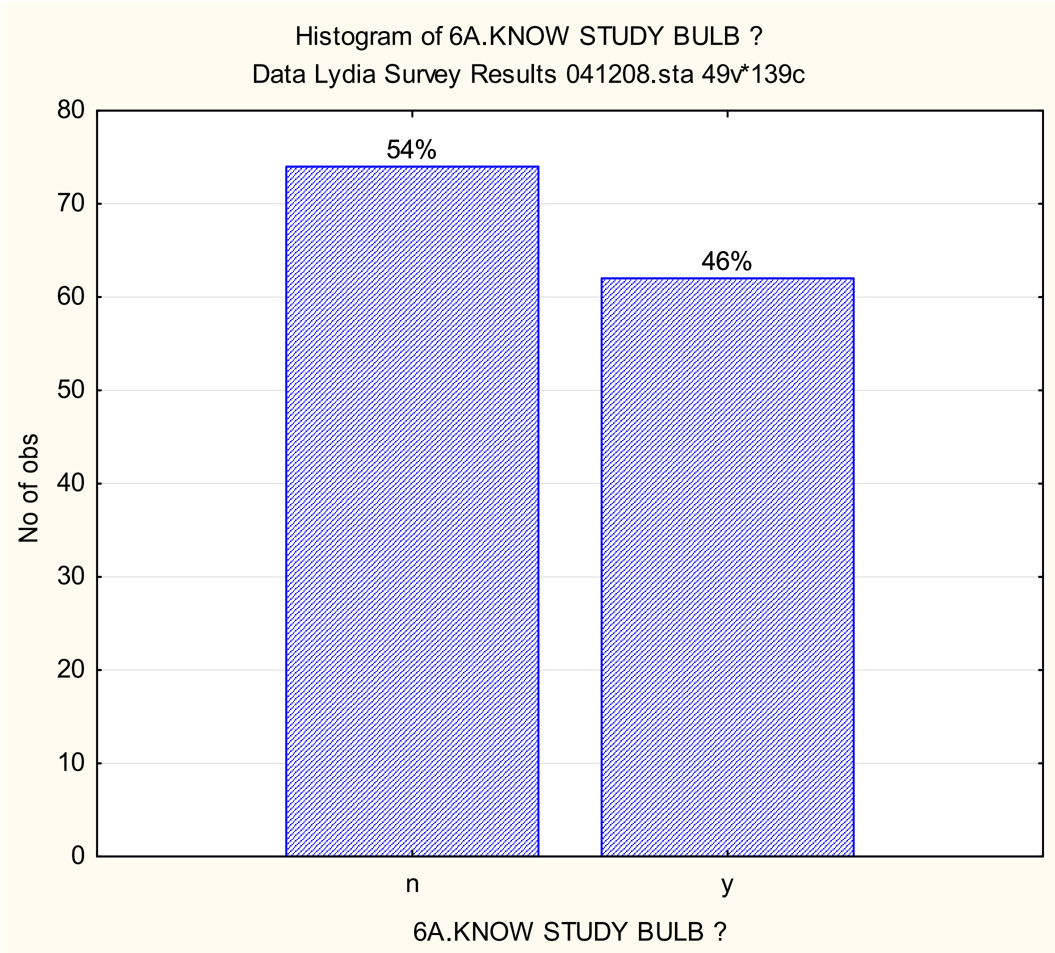


Figure 29: Investigating specific knowledge of individuals light bulb in desk/study lamp (results from question 6b of Lydia energy survey)

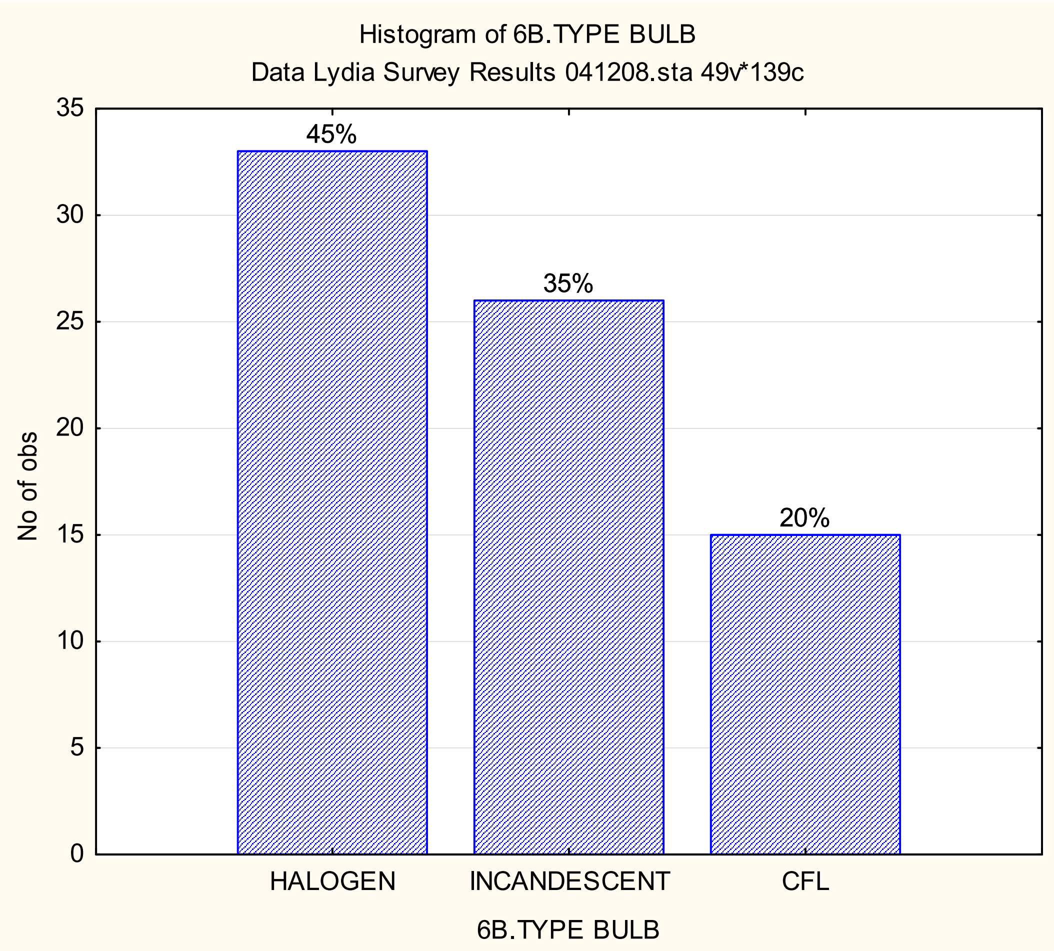


Figure 30: Investigating energy conservation lighting behavioral trends (results from question 12 of Lydia energy survey)

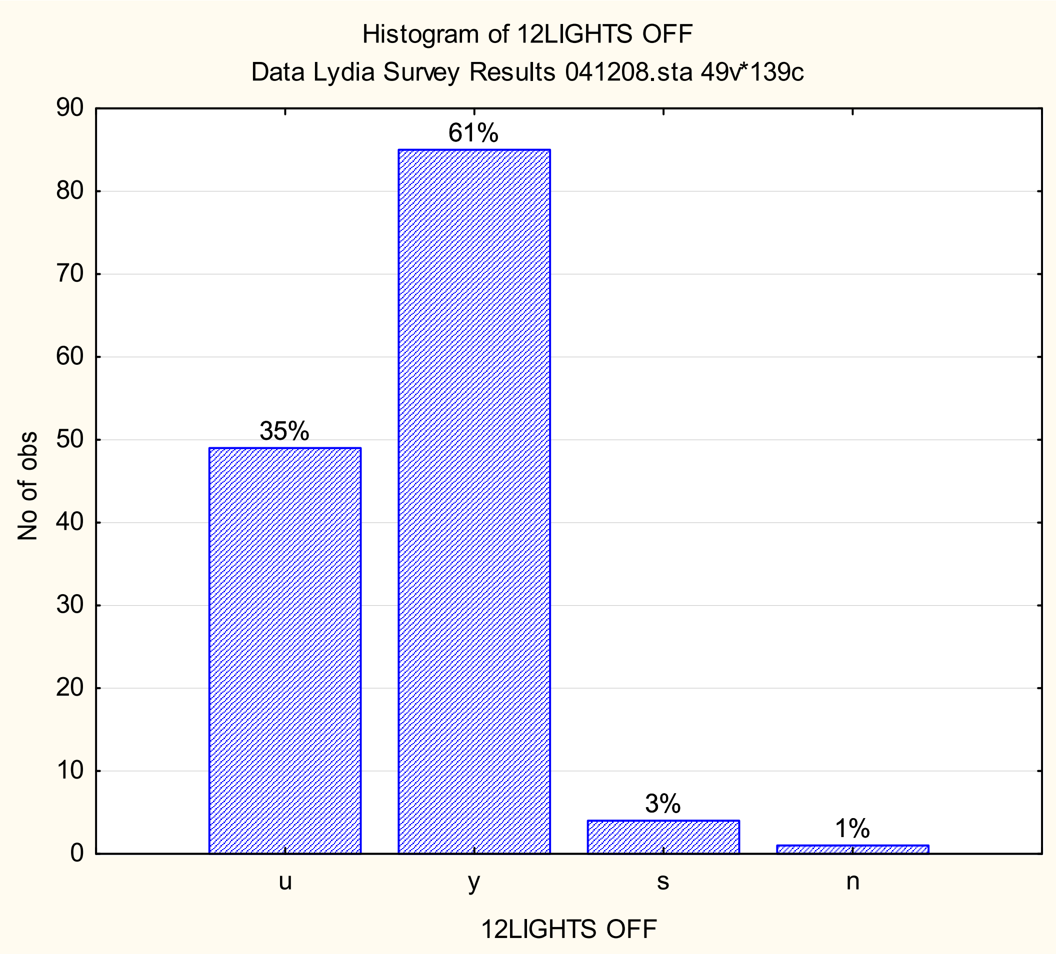


Figure 31: Investigating response to low flow showerhead (results from question 11 of Lydia energy survey)

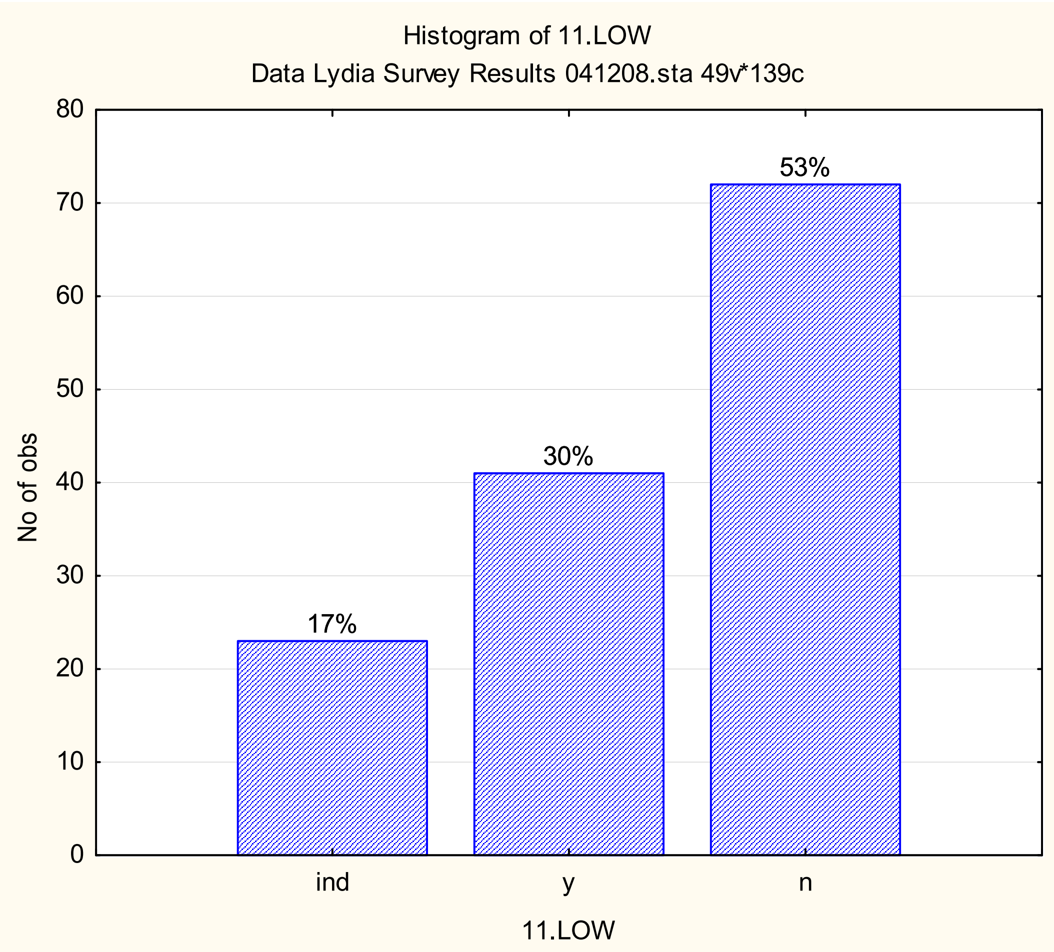


Figure 32: Perceived average bathing times (results from question 8 of Lydia energy survey)

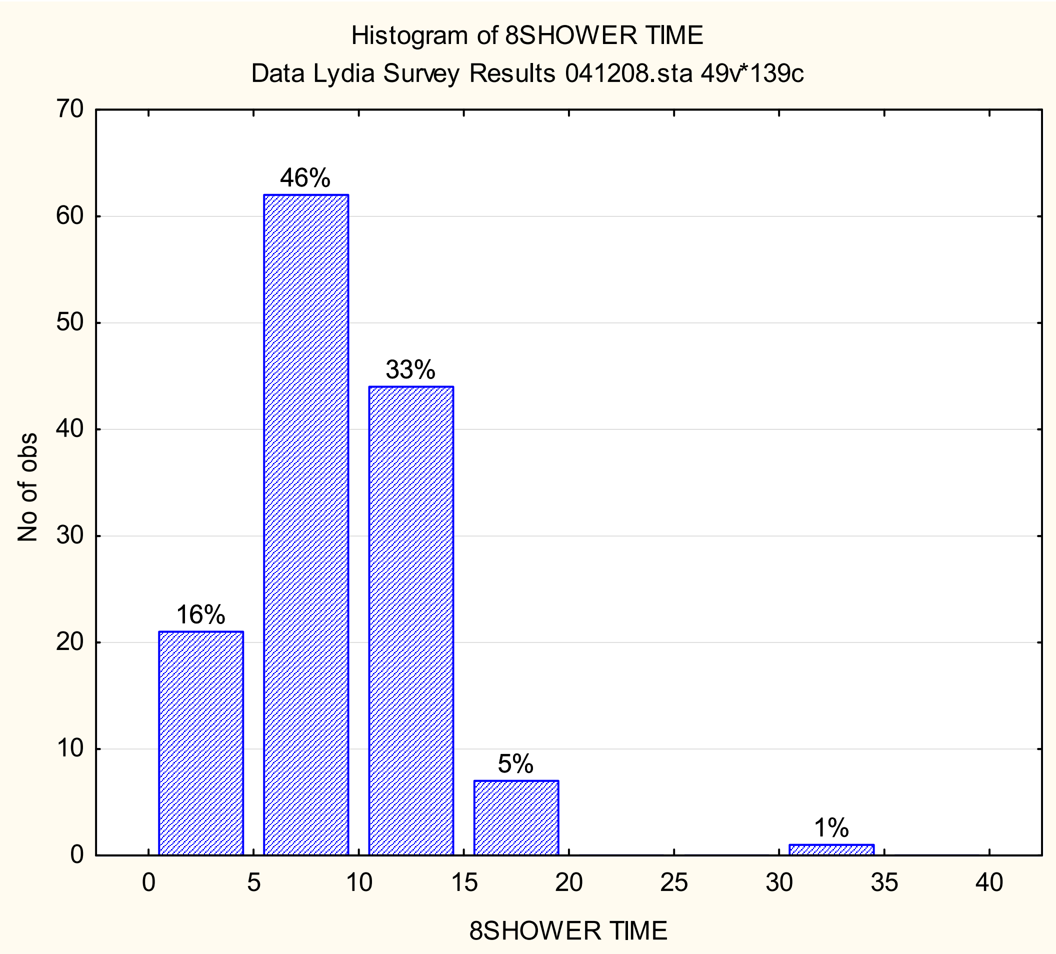


Figure 33: Number of times bath or shower in a day (results from question 8 of Lydia energy survey)