EFFECTIVE IMPLEMENTATION OF ENERGY EFFICIENCY IN THE SOUTH AFRICAN RESIDENTIAL SECTOR

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Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science in Engineering at the University of Cape Town. It has not been submitted before for any degree or examination at any other university.

Signature of Author . . . .

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Abstract

This thesis concerns the effective implementation of energy efficiency initiatives in the South African residential sector. Energy efficiency will help South Africa meet some of its socio-economic goals whilst protecting the environment and using resources effectively. In light of the recent blackouts, South Africa has stepped up its energy efficiency initiatives in order to delay the need for new generation capacity.

Although it seems rational to expect all the “engineering” savings from efficiency initiatives, often human behavioural responses tend to offset the beneficial effects of efficiency initiatives. Such behavioural changes are called the rebound effects. It is therefore imperative to anticipate the rebound effect when carrying out efficiency initiatives to improve energy planning and also to implement measures aimed at mitigating the rebound effect.

Energy modelling using LEAP was carried out for the South African residential electricity sector. A number of scenarios were parameterised to explore the potential impacts of energy efficiency in the residential sector over the period from 2001 until the year 2030. Scenarios which contained some rebound were also parameterised and the impact of tariff increments and awareness campaigns to mitigate rebound was also illustrated. Policy measures were then suggested from the findings of the LEAP model.

The results from the LEAP modelling suggest that reducing residential electricity demand by 10% in 2030 will require high penetration rates of efficient appliances and in order to mitigate the rebound effect, efficiency initiatives should be carried out in conjunction with awareness campaigns and price interventions.

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Abbreviations

DME: Department of Minerals and Energy

OECD: Organisation for Economic Co-operation and Development

DSM: Demand Side Management

LEAP: Long-range Energy Alternatives Planning System

EEDSM: Eskoms Energy Efficiency and Demand Side Management programme

NEP: National Electrification Programme

GEAR: Growth, Employment and Redistribution

RDP: Reconstruction and Development Programme

ASGISA: Accelerated and Shared Growth Initiative for South Africa

GHG: Green House Gases

CFL: Compact fluorescent lamp

NERSA: National Energy Regulator of South Africa

OCGT: Open Cycle Gas Turbine

CDM: Clean Development Mechanism

ADMD: After Diversity Maximum Demand

DOE: Designated Operation Entity

VER: Verified Emission Reductions

SWH: Solar Water Heaters

DWA: Department of Water Affairs

RHE: Rural High-income Electrified

RLE: Rural Low-income Electrified

RLN: Rural Low-income Not electrified

UHE: Urban High-income Electrified

ULE: Urban Low-income Electrified

ULN: Urban low-income Not electrified

1 INTRODUCTION

The cost of coal and electricity in South Africa has been historically low. As a consequence energy has been taken for granted and energy consumption is higher than it should be (DME, 2005). The government aspires for more energy sustainability and this requires not only considering the supply side of energy but also the way energy is used. For sustainable development, less energy should be used to produce the same amount of goods or services. Therefore the government has set energy efficiency targets through its 2005 Energy Efficiency Strategy (DME, 2005). Energy efficiency helps decouple energy growth from common drivers like GDP and population growth. For example, it is commonly assumed that a combination of structural change and energy efficiency improvements have allowed OECD countries to decouple GDP growth from the growth in primary energy consumption (Geller, et al., 2006).

On 25 January 2008 the government announced the National Electricity Emergency Programme to deal with the electricity supply problem. Energy efficiency is an integral part of the National Electricity Emergency Programme. Energy efficiency can be used to reduce demand, increasing power capacity and the reserve margin. Implementing energy efficiency initiatives can be thought of as adding a virtual power plant. The national electricity utility Eskom through its DSM and energy efficiency initiatives is aiming to curb residential demand by 10% from a projected baseline according to the Energy Efficiency Strategy (DME, 2005).

The Rebound Effect is defined as the proportion of energy efficiency savings that are lost to additional usage of efficient energy technologies, reversion to inefficient technology, or increased consumption of other energy services (Davis, 2008). If the rebound effect is sufficiently large it may undermine the rationale for policy measures to encourage energy efficiency. It is therefore important to anticipate the level of degradation of energy savings due to the rebound effect and to implement measures aimed at rebound effect mitigation.

1.1 Background to report

In the third week of January 2008, major blackouts occurred throughout South Africa dramatically undermining South Africa’s reputation of having cheap reliable electricity. Instead of only building new power plants, research into the final uses of electrical energy was conducted and opportunities to save energy were recognised. Energy efficiency initiatives and DSM have small lead times and are often cheaper than supply side options. Therefore strategies designed to encourage consumers to improve energy efficiency and use alternative energy sources were drawn. Although the crisis seems to be averted for now due to the recent economic meltdown, South Africa still faces the potential of an energy crisis with Eskom facing a lack of funds for new build projects and with demand having reverted to 2008 levels. Therefore energy conservation is still essential.

Although it seems logical to expect that the electricity demand reduction for a specific final energy service would have a 1 to 1 correlation with improved efficiency, often consumers of electricity become complacent and find other ways of using that energy to increase comfort levels. This phenomenon is called the rebound effect. The rebound effect is when an efficiency initiative leads to increased usage of an energy service meaning that actual gains will be less than expected technical gains and in the extreme case will lead to even greater demand for the energy service commodity with the efficiency initiatives than without them.

Without proper implementation, energy efficiency initiatives might fail, resulting in a waning of confidence for current and future programs. It is therefore important for policy makers to consider rebound when setting a platform for energy efficiency so as to account for lower than anticipated savings and find ways of mitigating rebound. Considering rebound when formulating energy efficiency policy is in fact recommended in a handbook on energy efficiency programme evaluation methodology (SRCI, 2001).

Sections 1.2 to 1.5 are summaries of what is covered in more detail later in the report.

1.2 Objectives of report

The main objectives of this project are to explore how different factors affect the South African residential electricity demand and to investigate the impacts of measures that could potentially be included in energy efficiency strategies and policies. The particular emphasis is on energy efficiency and the direct rebound effect.

Objectives:

- Give a literature review on energy matters and energy efficiency measures in South Africa especially in the residential electricity sector.
- Give a literature review of the rebound effect and explore mitigative measures.
- Model residential electricity demand using LEAP so as to illustrate:
  - maximum possible energy efficiency gains from a baseline scenario
  - potential losses due to direct rebound.
  - the potential effects of measures such as raised awareness and tariff increments which can be implemented concurrently with efficiency initiatives.
- Suggest potential policy measures from the baseline studies and the model results.

Potential uses of the report outcomes:

- Can be used to gain a better understanding of overall energy matters pertaining to South Africa and also to gain an understanding of electricity use in the residential sector.
- Can be used to inform the public of ways of reducing electricity consumption.
- Can also be used to advocate for energy efficiency and also to show potential impacts of the rebound effect.
- Can be used for planning of future efficiency programmes.

1.3 Methodology

Using information from existing reports, statistics and information obtained from organisations, companies and persons involved in the energy sector a LEAP model previously compiled by (Haw, et al., 2007) is updated and scenarios based on different energy efficiency technologies, tariff increments and raised awareness are constructed. Using empirical evidence of the rebound effect from other studies, scenarios analysing the impacts of rebound are also constructed. Assumptions used in developing the model will be stated and will be accompanied with relevant justification.

1.4 Scope and limitations of report

This report is limited to the analysis of the use of electricity in the South African residential sector and also energy efficiency and fuel switching initiatives the government may introduce through policy. The types of initiatives under study are:

- Efficient lighting
- Solar Water Heating
- Geyser Blankets

The potential direct rebound effects of the above stated initiatives are analysed and interventions that can help sustain effective implementation of energy efficiency and fuel switching initiatives are investigated. The interventions under investigation are tariff increments and awareness campaigns. The LEAP modelling tool is used to illustrate factors that affect residential electricity demand. The LEAP model has a forecast horizon spanning from 2001 to 2030. A detailed description of the LEAP modelling tool will be given in chapter 5

1.5 Report Outline

Chapter 2 describes the background to the South African energy sector in general to highlight some of the main issues in the energy sector that ultimately influence implementation of energy efficiency and DSM initiatives. A brief literature review of the residential energy sector will be presented and some drivers for electricity consumption in the residential area will be reviewed followed by an analysis of energy efficiency in the South African context.

Chapter 3 explores energy efficiency in the South African context and reviews key policy documents on energy efficiency. The main energy efficiency programs being carried out in South Africa will also be reviewed and methods of promoting energy efficiency will be highlighted.

Chapter 4 reviews literature on the rebound effect and investigates surveys taken in South Africa related to residential energy efficiency and the rebound effect. The purpose of this chapter is to show the legitimacy of the rebound theory and to emphasise the consequences of disregarding it when carrying out DSM or energy efficiency initiatives for the purposes of reducing energy consumption. Rebound estimates were quoted from literature.

Chapter 5 describes the methodology used for constructing the LEAP model used to illustrate energy savings from various energy efficiency initiatives and to illustrate the potential impact of the direct rebound effect and also to illustrate energy savings when efficiency programmes are initiated concurrently with awareness campaigns and tariff increments.

Chapter 6 concludes the report. Limitations and suggestions for future work are given followed by policy recommendations aimed at effective implementation of energy efficiency initiatives. Finally a conclusion is given which highlights the main findings of the report.

2 THE SOUTH AFRICAN ENERGY SECTOR

This chapter explores the current energy sustainability challenges faced by South Africa as a country with a dual economy[1]. Energy sustainability involves using energy to meet socio-economic goals whilst protecting the environment and using resources effectively. Many of these sustainability challenges have to be tackled concurrently as they are dependent on each other. Therefore the best solutions will be able to cater for all aspects of sustainable development with minimal resource input and high developmental impact. The challenges will be presented as motivation for the promotion of energy efficiency. Also the residential sector will be reviewed to highlight some of the drivers of electricity consumption which were used in modelling residential electricity consumption.

The remainder of this chapter will explore the South African energy sector. A brief analysis of the primary energy sector will be given with an emphasis on coal as it is used to produce more than 90% of the country's electricity. Graphs to compare final energy use of different sectors will be presented to give a brief description of the South African energy sector. Detailed descriptions of the electricity sector and the residential energy sector are then given and a discussion of energy efficiency in the South African context concludes the chapter.

2.1 Introduction

Historically, South Africa has had an abundant and relatively cheap coal and electricity supply. This encouraged investment in high energy intensive industries. Since the price of energy was very low, there was very little incentive for industry or households to invest in efficiency initiatives as the potential cost benefits would not be realised.

Compared with developed countries, the South African economy uses a lot of energy for every Rand of value added. In 2006 South Africa had the 42nd biggest GDP in the world but

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[1]Dual economy refers to gap between the wealth-creating, developed formal economy, and the poor, underdeveloped, largely unemployed sector. Therefore sustainable development will aim to support continued growth of the first economy and develop the second economy by increasing access to services to enable development.

was the world's 21st largest consumer of energy (DME, 2008b). This is due to the nature of the major contributors to GDP in South Africa which are the Iron and Steel and Chemical and Petrochemical Industries, followed by the mining and pulp and paper industries (DME, 2005). In fact, industry as a whole consumes approximately 40% of the total electricity generated (DME, 1998).

2.2 Coal

The South African primary energy mix is dominated by coal. The coal reserves have approximately 121 billion tonnes of coal ore, of which about 55 billion tonnes are classified as economically recoverable reserves (DME, 1998). About 245 million tonnes of Anthracite and Bituminous coal are produced annually (IEA, 2007). South Africa currently accounts for 92% of the coal consumed on the African continent (EIA, 2009). South Africa's large coal reserves supply over 77% of the country's primary energy (DME , 2010). Coal exports also bring in a lot of foreign currency. The total value of coal extracted, was almost R36 billion in 2005. South Africa is the 6th largest exporter of coal (Haw, et al., 2007). About 21 percent of the run-of-mine coal produced is exported, and 21 percent is used locally (excluding power-station coal). The rest is not saleable and is discarded (DME , 2010). The graph below shows the uses of coal in South Africa.

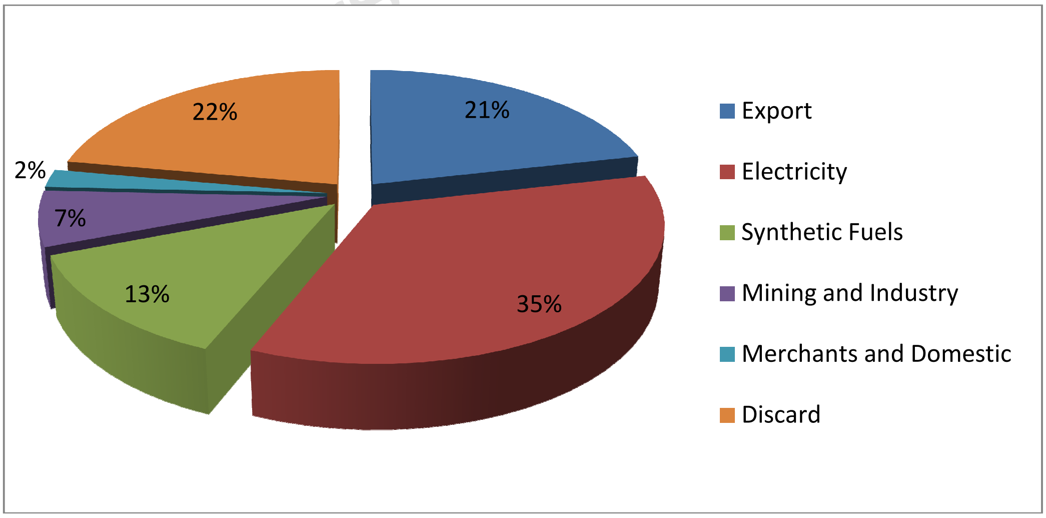

Figure 2.1: Coal use in South Africa 2004.

Source: (Haw, et al., 2007); (Prevost, et al., 2005)

The total primary[2] energy supply was 5,240,908TJ and the total final[3] energy consumed was 2,717,860TJ in 2004. The following graphs show the shares of primary fuels used in South Africa and the shares of final energy use by energy carrier.

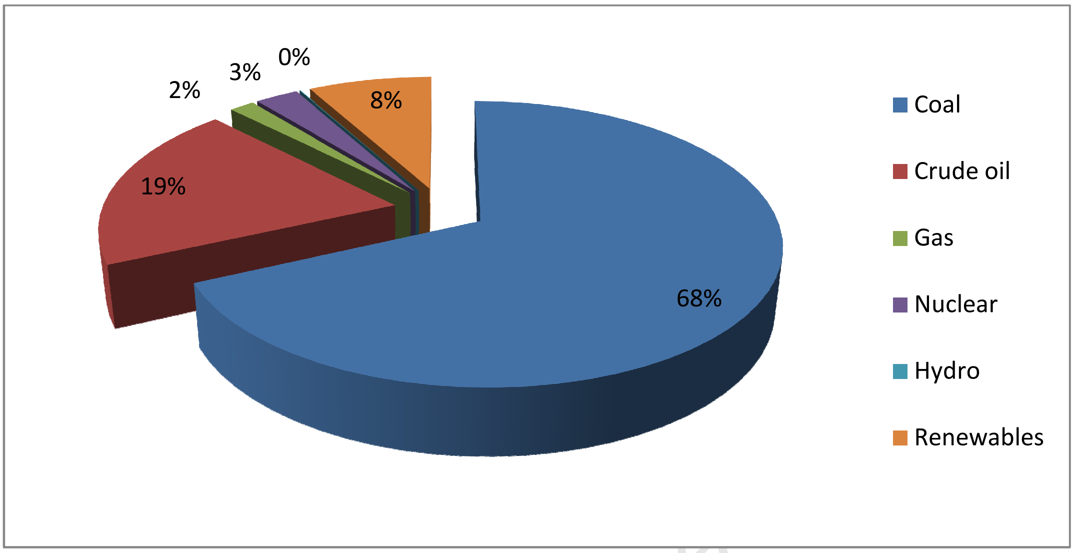

Figure 2.2: Primary Energy Supply in 2004

Source: (DME, 2006)

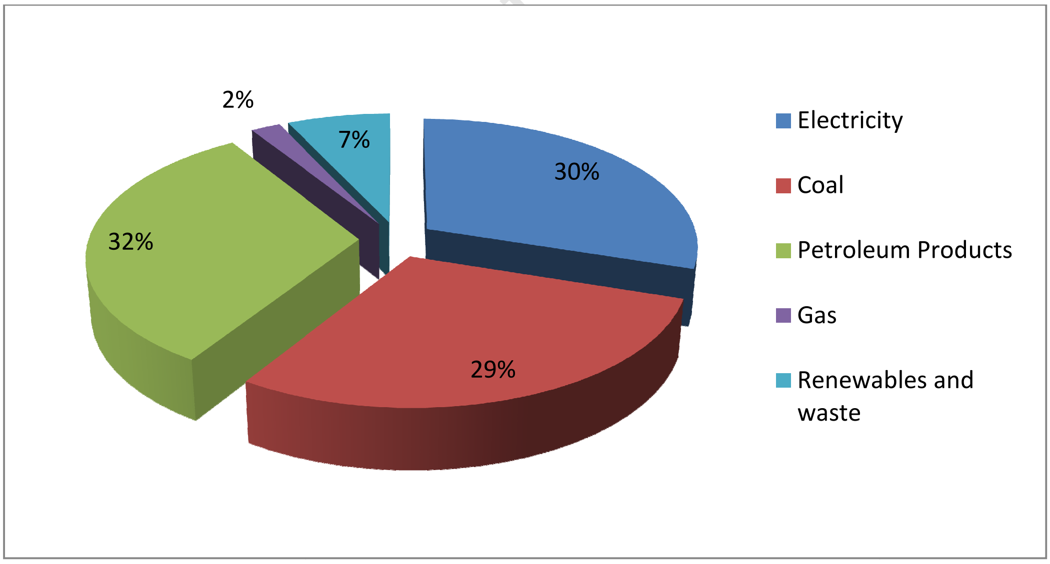

Figure 2.3: 2004 Final Energy Use by Carrier

Source: (DME, 2006)

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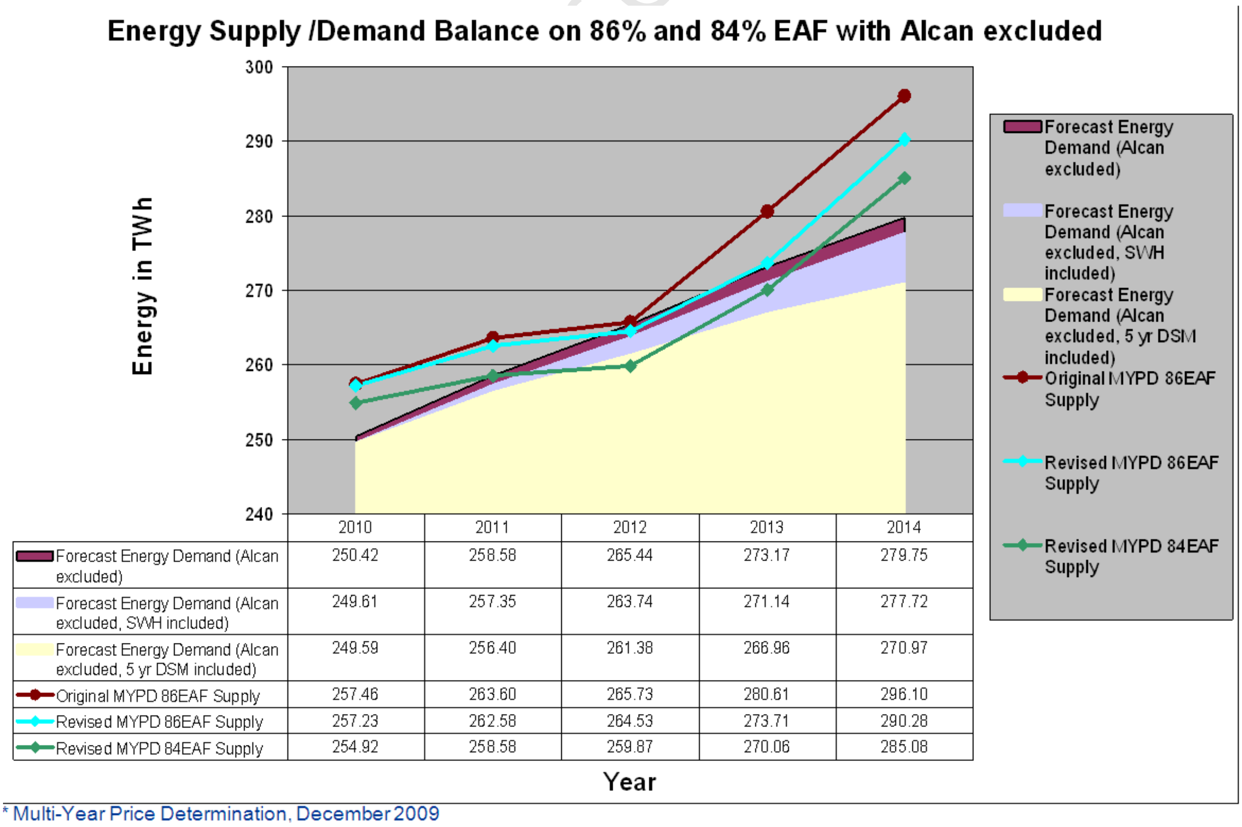
[2] Primary energy is energy contained in raw fuels found in nature.

[3] Final energy is energy contained in fuels that have undergone a conversion process.

2.3 Electricity

The South African electricity supply system was under severe pressure recently as generation capacity could not meet peak demand. DSM was used to shift the load and reduce peak demand. Eskom built peaking power stations and Eskom is now confident that they have the capacity to meet the peak demand but energy reserves are low (Visagie, 2010). Although there is a current 5TWh annual energy surplus, the system remains “tight”. It is therefore important to ensure that the 5TWh buffer be maintained and planned for into the future (Visagie, 2010). Although Eskom is confident it can meet the variable peak demand because of its plant mix, it should be noted that the use of OCGT’s to meet the peak demand is expensive.

Below is a graph showing the energy supply and demand balance. It is important to note how the green curve (Revised MYPD supply) will have inadequate energy supplies to meet any of the projected demands and also the importance placed on solar water heating initiatives to reduce consumption.

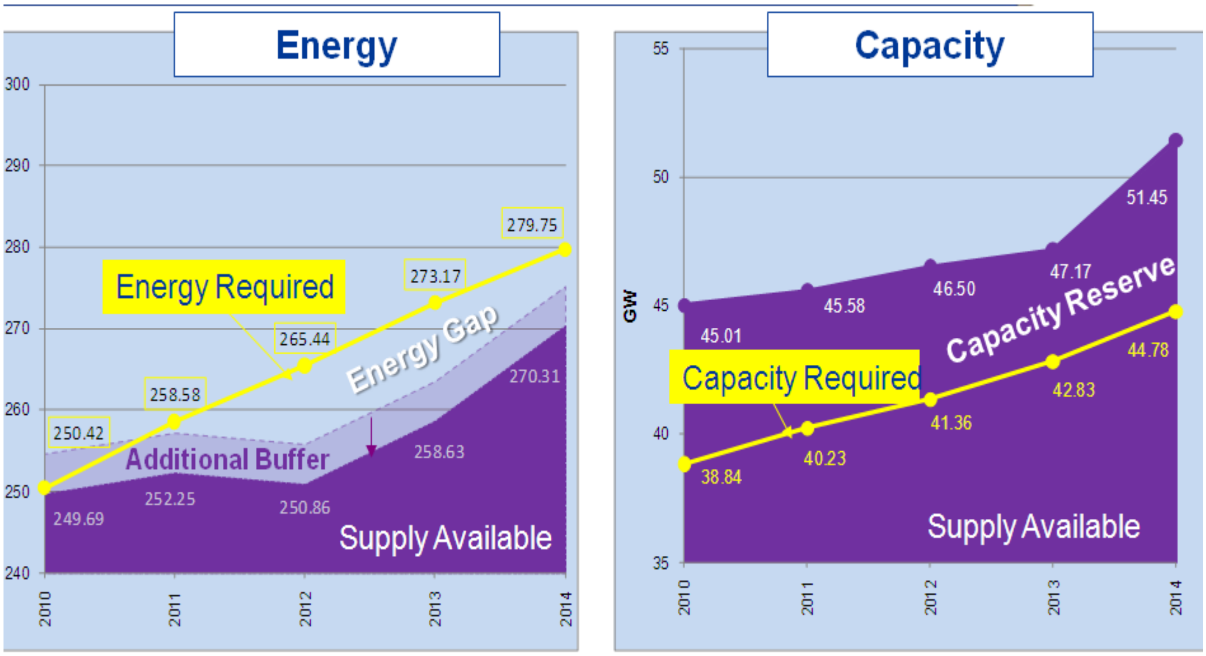


	2010	2011	2012	2013	2014
Forecast Energy Demand (Alcan excluded)	250.42	258.58	265.44	273.17	279.75
Forecast Energy Demand (Alcan excluded, SWH included)	249.61	257.35	263.74	271.14	277.72
Forecast Energy Demand (Alcan excluded, 5 yr DSM included)	249.59	256.40	261.38	266.96	270.97
Original MYPD 86EAF Supply	257.46	263.60	265.73	280.61	296.10
Revised MYPD 86EAF Supply	257.23	262.58	264.53	273.71	290.28
Revised MYPD 84EAF Supply	254.92	258.58	259.87	270.06	285.08

Figure 2.4: Graph showing electrical energy supply and demand from 2010 to 2014

Source: (Visagie, 2010)

The following graph shows the nature of the electricity crisis. The nature of the crisis (that is the lack of energy and not of power capacity) is an important factor when considering the rebound effect and will be explained in section 4.1.



	2010	2011	2012	2013	2014
Gap	-1.7%	0.5%	3.6%	3.5%	1.6%
+Buffer	0.3%	2.4%	5.5%	5.3%	3.4%

Initial Gap (Reserve)

2010	2011	2012	2013	2014
15.9%	13.3%	12.4%	10.1%	14.9%

Figure 2.5: Graph showing the nature of the problem; Energy and Capacity.

***Source:* (Visagie, 2010)**

Due to the time constraints of new build programmes, primary focus is on energy efficiency and DSM. Therefore this section will investigate the electricity industry and will highlight the current state of the industry.

The remainder of this section is as follows. First an introduction followed by a brief history of the electricity sector and then the future of the electricity sector is investigated to explore possible sustainability issues that energy efficiency might address.

2.3.1 Electricity Generation Industry

South Africa consumes about 40% of the total electricity produced in Africa. About 96% of electricity is generated by Eskom power stations (DME, 2006). In 2009 about 93% of all electricity generated by Eskom came from conventional coal power stations (Eskom, 2009). The average thermal efficiency of Eskom power stations is roughly 33% and Eskom has an emission performance of about 1kg/kWh of electricity sold (Eskom, 2009). South Africa's reliance on electricity generation using coal is one of the reasons why the energy intensity is so high and also why South Africa is the 11th highest emitter of greenhouse gasses in the world (www.info.gov.za). The total net electricity supplied in 2009 by Eskom was 228942 GWh (Eskom, 2009).The following graph shows the shares of electricity production by fuel in 2009 by Eskom power stations.

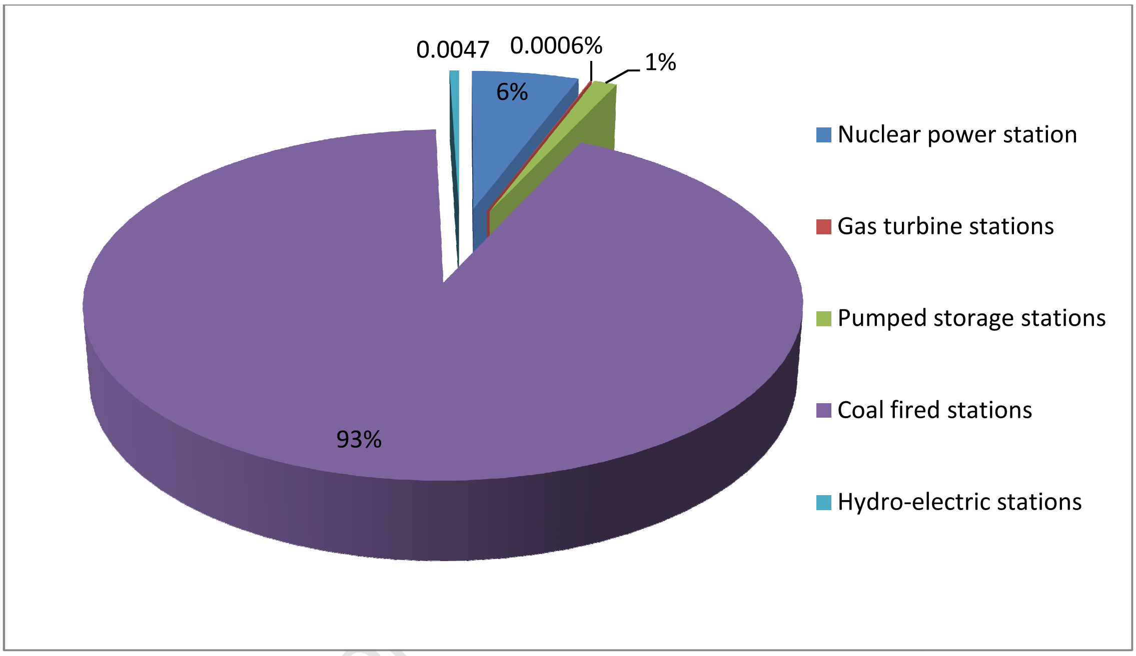


Figure 2.6: Output of Eskom plants as a percentage of electricity supplied in 2009 Source (Eskom, 2009)

Table 2.1: Analysis of South African licensed electricity capacity by fuel

Source: (NER, 2004)

Energy source	***Capacity (MW)***
Coal	38,209
Nuclear	1,800
Bagasse	105
Hydro	668
Gas turbines	660
Pumped storage	1,580
Total	43,022

South Africa's economy is largely based on minerals extraction and processing which is by its nature very energy intensive. Industry accounts for most of the electricity demand, approximately 40% whilst residential demand is about 17%. Although the residential energy demand is only 17%, its contribution to the winter peak demand is about 30%. Therefore measures aimed at reducing residential demand coincidental with the peak demand will increase the reserve margin and help avoid the use of expensive peaking stations.

2.3.2 Brief history

Energy policy in the apartheid era was more concerned with energy security than with social development. South Africa possessed an extremely energy-intensive economy, a world-class electricity supply industry in the form of the state utility Eskom, and a 55% reserve margin due to overbuilding in the 1980s (Louw K, 2008). After the 1994 democratic elections, energy policy shifted its focus from supply to demand. National electrification became a fundamental government goal.

The DME through its 1998 white paper on energy policy prohibited Eskom from building any more power stations, a decision lifted in 2004 by the DME sighting an impending electricity crisis in 2007. In 2006, Western Cape experienced the first major blackouts the country has ever faced and in 2008 the whole country followed. The crisis was largely due to the inadequacy of the reserve margin and the crisis was exacerbated by low coal reserves at Eskom's power stations, as well as coal quality-related issues. The heavy rains in January and February 2008 made the handling of coal a near impossibility at some stations (Eskom, 2009). Gas power stations (OCGTs) fuelled by diesel, and which are expensive to run were built and used and operated for long hours making the cost of generating electricity very high (Operating costs are around R1.60/kW compared with the Eskom average of 17c/kW).

2.3.3 The future of power generation in South Africa

South Africa needs to build 40 000MW of new generation capacity by 2025, of which 12 476MW are already under construction (mainly Medupi and Kusile power stations, return-to-service stations and Ingula power station) (Eskom, 2009). Medupi and Kusile are coal power stations with a combined generation capacity of about 9 600MW whilst Ingula is a pumped storage power station with a generation capacity of 1 400MW. The return-to-service-stations are also coal powered and have a combined generation capacity of 3 800MW. Most of the renewable energy projects were put on hold which seems to indicate that the future of South Africa's power production will be predominantly coming from coal power stations. Below is a table showing Eskom current and future generation projects

Generation projects	Megawatts planned	Project phase	Commercial operation first unit /last unit
Ankerlig and Gourikwa (OCGT Phase I)	1 043	Commercial operation	Mar 07/Jun 07
Camden RTS	1 520	Commercial operation	Jul 05/Jul 08
Ankerlig and Gourikwa (OCGT Phase II)	1 041	Commercial operation	Dec 08/May 09
Grootvlei RTS	1 200	Execution	Mar 08/Apr 10
Arnot capacity increase	300	Execution	Apr 06/Dec 10
Komati RTS	1 000	Execution	Jan 09/Jun 11
Ingula	1 352	Execution	Jan 13/Oct 13
Medupi	4 764	Execution	Apr 12/Aug 15
Kusile	4 800	Execution	Jun 13/Oct 16
Sere (wind farm)	100	Execution planning	Aug 10 (Project on hold)
Majuba rail	n/a	Execution planning	Nov 11 (Project on hold)
Tubatse (Lima)	1 500	Execution planning	Possible 2018 (Project on hold)
Total MW	**18 620**		

Figure 2.7: Generation projects.

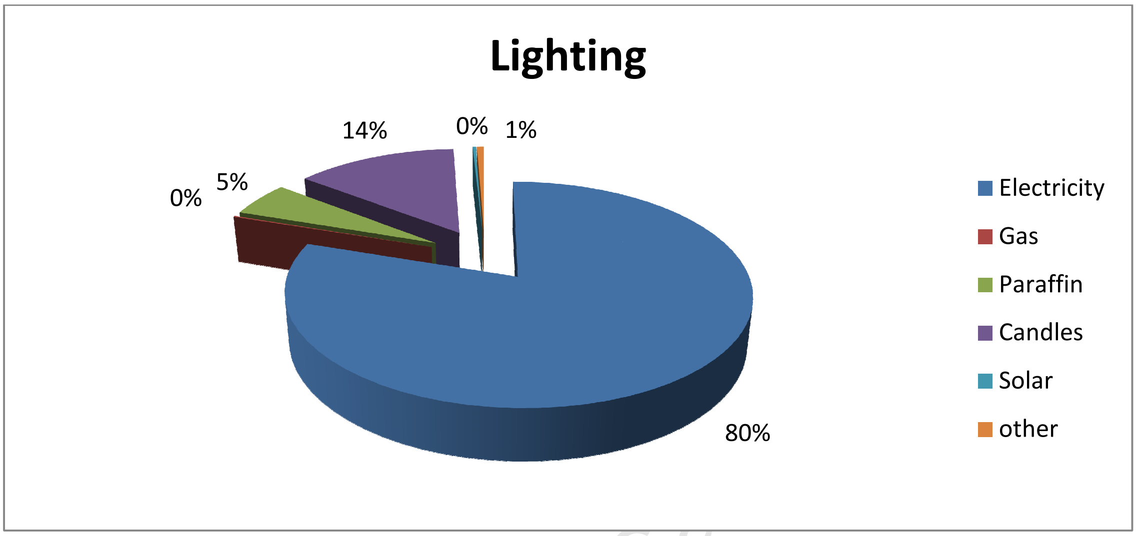
Source: (Eskom, 2009)

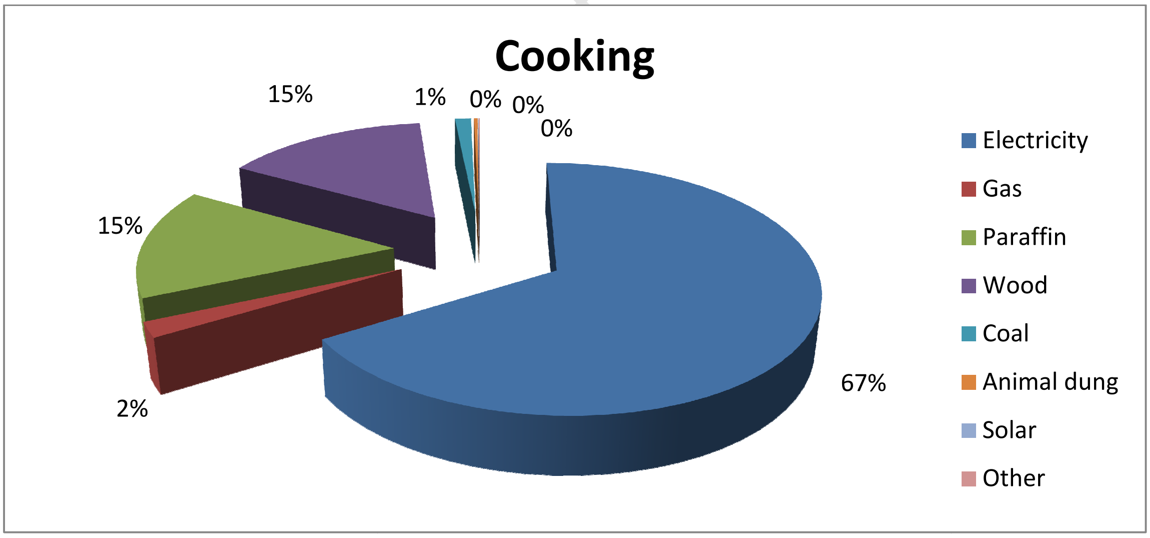
2.4 The residential energy sector

This section explores energy use in the residential sector. Aspects such as availability of other cheaper fuels, electrification and the cost of using electricity affect the consumption of electricity and will be used for modelling residential electricity demand in Chapter 5. The remainder of this section describes the multiple fuel use practised in the residential sector and also gives a summary of electrification in South Africa.

2.4.1 Multiple fuel use

In South African households, multiple fuel use is commonplace especially in poor households. Most electrified households use electricity for lighting. But for more energy intensive energy services, poor households supplement their energy needs by using a variety of fuels other than electricity because they cannot afford the electrical appliance or the electricity bills (Prasad, 2006). There is recent evidence of abundant electrical appliance ownership among low income households through a survey carried out in Zanemvula (Davis, 2010). Therefore there is a need for more current data on household appliance ownership and the 2011 countrywide censer provides an opportunity to update the database on household appliances. High income households mainly use electricity for all their energy needs. Below are graphs showing the diversity of fuels used for each energy end use.





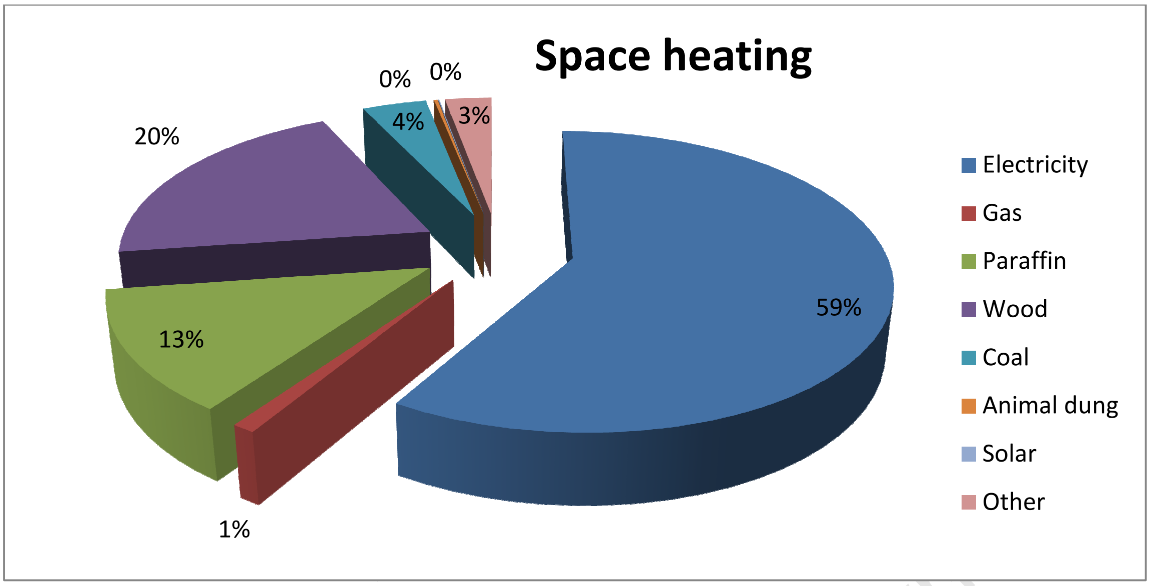


Figure 2.8: Residential fuel shares.
Source: (Stats SA)

The graphs show that electricity is fully utilised for energy services that demands relatively less power (like for lighting) but for energy services that demand much power, other fuels are also used (like for cooking and space heating).

2.4.2 Electrification in South Africa

This section explores residential electrification and also the cost of electricity. Socio-economic issues raised are used as motivation for the promotion of energy efficiency initiatives. Also this subsection provides a background study for the energy modelling that was carried out in this thesis.

Energy is a basic necessity. Easy access to clean, reliable, affordable energy facilitates development. For example providing electricity to communities that previously lacked any access to electricity might extend study and business hours because of electric lighting, facilitate for services like cooling of perishables and milling of grain using electrical appliances and also bring in new businesses opportunities in the retail industry around the community due to selling of electrical appliances. Access to electricity in itself is an energy efficiency initiative since electrical appliances are more efficient than most wood or paraffin appliances used in poor communities.

Therefore providing access to electricity for all citizens became a consistent government goal from the 1994 democratic elections up until now. The apartheid government policies were racially determined in terms of infrastructure and service provision. As a result approximately 36% of the total population; 50% of the urban population; and 12% of the rural population had access to electricity towards the end of 1993 (DME , 2010). Eskom launched the 'Electricity for All' programme in the early 1990's. After the democratic elections the new government supported the idea and the National Electrification Programme (NEP) Phase 1 was officially lunched in 1994. Policy for the electrification programme is specified in government economic programmes, namely the Reconstruction and Development Programme (RDP) and subsequently the Growth, Employment and Redistribution (GEAR) and the Accelerated and Shared Growth Initiative for South Africa (ASGISA) strategy (Louw K, 2008). 2.5 million electricity connections were made at a cost of about R7 billion (Prasad, 2006). The programme targeted disadvantaged areas and schools, clinics and households formerly without electricity were connected to the grid. During Phase 1, approximately 66% of all households were electrified; with 46% of all rural households being electrified whilst 80% of urban households had access to electricity (Prasad, 2006).

Phase 2 was started in 2000 with an annual target of 300 000 additional household connections every year. Over the next five years the target was fairly met but after 2005, the rates of electrification started to decrease as the cost for new connections started to increase.

Table 2.2: Table showing electrification data for the 1994 - 2000 periods.
Source: (The Presidency, 2009)

	1994	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***
Proportion of households with electricity	50.90%	54.10%	59.90%	62.50%	61.20%	61.10%	68.30%
New connections cumulative	478767	932762	1432073	1859499	2302789	2699808	3036726
New connections	478767	453995	499311	427426	443290	397019	336918

Table 2.3 Table showing electrification data for the 2001- 2008 period.

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Proportion of households with electricity	68.30%	70.00%	69.60%	72.00%	72.40%	71.80%	72.00%	73.00%
New connections cumulative	3036726	3375298	3654060	3902511	4144214	4330047	4452758	4748228
New connections	336918	338572	278762	248451	241703	185833	122711	295470

It was expected that the average demand of newly connected households would be approximately 350kWh/month. However it was discovered that low income households were using less than 50kWh/month, and households consume 132kWh/month on average throughout South Africa (Prasad, 2006). Also since some low income households could not afford to buy electrical appliances or pay for electricity, the use of non-electric fuels was still being practised by poor households. Therefore the benefits of having access to electricity is not fully realised by some households. A study by Gaunt (Gaunt, 2003) identified some constraints to the use of electricity. The initial connection cost, the cost of purchasing new electrical appliances, the sunk cost of old appliances and the electricity bill itself. Hence rolling out efficient electrical appliances to newly electrified RDP households would facilitate the use of electricity at relatively affordable prices. A 20A connection (weak grid approach) is provided free of charge and a 50kWh/month free basic allowance is given to low income households. The weak grid approach means that the number of electrical appliances turned on at any one time is limited and most thermal energy services would have to be provided for by other fuels. Energy efficiency and fuel switching initiatives would enable more energy services to become accessible and help improve the welfare of the poor households.

2.4.3 The price of electricity

Tariff increments can be used to encourage investment in energy efficient technologies and discourage energy consumption. In the short-run residential consumers have a higher response rate to changes in the electricity price (BUSA, 2008), with a -0.02 short term and a -0.04 long term residential demand elasticity to electricity (Ziramba, 2008). A price elasticity of -0.02 means that if the price of electricity increases by 100%, then the demand for electricity will drop by 2%. Given the above reasons the price of electricity is worth investigating. This subsection will explain why the price of electricity in South Africa has been historically low (and hence explain why investment in energy efficiency has been low) and also give reasons why there has been a need for steep tariff increments.

The capital cost of power generation plants and also of externalities (GHG emissions and local air pollution in areas around coal power plants) were not reflected in Eskom's tariffs in the past which resulted in South Africa's electricity supply being amongst the cheapest in the world. The cheap energy prices benefited the households and gave South African industry a competitive edge and since the price of energy was so cheap, energy efficiency had very little priority.

Recently NERSA has granted Eskom tariff increments to fund Eskom's new build projects and also Eskom's EEDSM projects. Included in the tariff hikes is a levy of 2c/KWh which translates to a tariff hike of about 10%. For 2009/2010 a tariff increment of 31% (was awarded by NERSA (Eskom, 2009). Eskom applied for new tariff increases for the period 2009 to 2013 through its MYPD 2 and recommended that for its business to be somewhat sustainable it needed a three year tariff increase of 45% (later revised to 35%). A yearly 35% increase was deemed to high as it would have affected both industry and society as many jobs would have been lost. NERSA awarded a 24.8%, 25.1% and a 25.9% tariff increase for 2010/2011, 2011/2012 and 2012/2013 respectively. The average electricity price will rise from a current R0.33/kWh to R0.415/kWh in 2010/2011, then go up to R0.52/kWh in 2011/2012 and finally to R0.65/kWh in 2012/2013 thus doubling the average rate in the next 3 years. NERSA also announced that a residential inclining block tariff structure will be used. This means that households that consume a lot of electricity will be penalized.

2.5 Energy Sustainability and Energy Efficiency in South Africa

This subsection is mainly a recap of the energy sustainability issues that have been mentioned in this chapter and also to emphasise the importance of energy efficiency initiatives in South Africa.

2.5.1 Energy Security and Economic Growth

Although averted for now due to the global economic crisis and consumer response to the 2006 Cape Town load shedding and the 2008 countrywide load shedding, South Africa still faces a potential power crisis until new baseload stations come online from 2012/2013. Therefore Eskom has placed great importance in its EEDSM programme as a short term solution to address the power and energy shortfall. It is very important therefore that such a programme be very successful in its implementation and confidence in its effectiveness be entrenched so that it can become a way of life.

The price of fossil fuels fluctuates and has historically brought about energy crises (1973 and 1979 oil crises) and also fuel costs are thought to increase as the fossil fuels run out (peak oil, peak coal). Open cycle gas turbines (OCGTs) are fuelled by diesel which is expensive to use compared to coal and is very sensitive to the international crude oil market. Excessive reliance on OCGTs will increase the price of electricity and compromise South Africa's energy security. Effective implementation of energy efficiency initiatives would reduce the peak demand and hence reduce the usage of OCGT power plants.

The cost of building new power stations will also increase the price of energy delivered to the customer. As seen by the recent Eskom tariff hikes due to new build programmes, any project which helps delay the need for new capacity will benefit industry and society as a whole. Therefore energy efficiency will help delay new build projects lowering the price of electricity.

Sustainable development is defined as "the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations" (DME, 2003). Coal resources although abundant, are also finite. Hence to prolong the availability of coal for future generations, the economy has to be less energy intensive and/or switch to renewable energy technologies. Energy efficiency has been seen as the cheaper alternative of the two choices.

2.5.2 Environmental Protection

About 90% of electricity in South Africa is produced from coal. South African electricity generation will continue to be heavily reliant on coal given the long life of coal power plants (30 to 50 years) and that most of the new generation capacity is coming from coal power plants. Climate change due to GHG emissions is now a growing concern. Electricity production from coal is the main contributor of GHG emissions in South Africa. This means that if the demand is lowered, the amount of GHG emissions will also lower. South Africa joined the Kyoto Protocol in 2002 and is funded for Clean Development Mechanism (CDM) or Verified Emission Reductions projects from international donors. Climate change science warns of the impending danger of relying on fossil fuel based power generation stations and restrictions might be placed on the use of fossil fuels in the future as countries worldwide commit to emission reduction targets. Quotations from a speech by President Kgalema Motlanthe at the Climate Change Summit are given below:

"It is in this context that the South African Government has agreed to a strategic policy framework for our emissions to peak between 2020 and 2025, and then stabilise for a decade, before declining in absolute terms towards mid-century. This will be possible if technology, investment and policy, identified as key planks in our strategic framework, are brought together into a coherent strategy...
In the short-term, we know that we need to dramatically increase our energy efficiency in order to reduce the pressure on our current electricity infrastructure and free up energy for new growth. We also know that, as most of our electricity comes from burning coal, energy efficiency is a win-win solution that increases our competitiveness whilst reducing our greenhouse gas emissions." (Motlanthe, 2009).

Since about 1kg of emissions is generated for every kWh sent out, reducing the demand of electricity will also reduce the amount of emissions; therefore energy efficiency and DSM also have an important role to play in maintaining South Africa's future international relations and its own environmental sustainability.

At local levels, energy efficiency will result in a reduction in sulphur and nitrogen oxides which are emitted from power generation and as well as a reduction in the amount of water consumed in the generation sector.

2.5.3 Social Development

The energy burden[4] for low income households is very high. Most grid connected low income households receive free basic electricity, 50kWh a month and some households

[4] Energy burden is a percentage of the annual income that is used to pay for energy services in a household throughout the year.

have ‘weak’ grid connections (they have 20A circuit breakers). The government is obligated to supply every citizen with cheap reliable energy and also to ensure that this energy is used effectively. Therefore if the government supplies low income households with efficient appliances and if new RDP households are built with improved thermal efficiency, these households will spend less of their income on energy and improve their quality of life and they would be able to use more appliances at the same time without tripping the circuit breakers.

Also the emergence of a new energy efficiency sector will increase employment and introduce new investment opportunities. For example the Minister of Energy announced during the 2010 budget speech that the government aims to localise the design and production of SWHs. The instalment and maintenance of solar water heaters will also create employment and build skills for the citizens.

Energy efficiency through use of more efficient energy carriers reduces risk of accidents and improves health. For example a thermally efficient home would reduce the need for space heating which would reduce accidents and respiratory health problems brought on by the use of paraffin.

The cost of additional connections is becoming increasingly more expensive. Energy Efficiency would help reduce the ADMD (after diversity maximum demand) thus reducing costs of connection and increasing the number of communities and households that can be reached within the available budgets.

If energy efficiency initiatives are combined with social development programs like the RDP housing programme and the ODA (Official Development Assistance), more funds would become available for both the energy efficiency initiatives and the developmental programmes. Opportunities for international funding from NGOs and from multilateral environmental agreements like the Clean Development Mechanism (CDM) and Verified Emission Reductions (VER) can be sorted out. For example South South North organisation was looking into funding of 2309 low cost houses in Kuyasa, Khayelitsha, Cape Town to have solar water heaters, ceilings and ceiling insulations installed through CDM funding (http://www.southsouthnorth.org).

It is important to note that because of suppressed demand in low income households, energy efficiency and fuel switching initiatives would also cater for latent demand and therefore consumption of energy might actually increase (rebound). Although evidence of rebound in this case indicates an improvement in welfare in poor communities and is therefore desirable, it needs to be acknowledged from a planning perspective. When applying for CDM funding, continual monitoring, measurement and verification also needs to take place through a Designated Operation Entity (DOE), to make sure that the CDM project is achieving its emission goals, therefore rebound might undermine the credibility of energy conservation initiatives.

2.6 Conclusions

This chapter reviewed the South African energy situation with an emphasis on the electricity industry. Electricity in South Africa is inefficiently generated using mostly coal power stations. Also electricity has been historically cheap and abundant and this has lead to intensive electrical energy use. Investment in energy efficiency by businesses and households has been low. Therefore the consumption of electricity has been intensive and has lead to the generation of much greenhouse gases and the depletion of natural resources.

Recently South African electricity supply has been heavily constrained and demand is still rising. Until new baseload stations come online, DSM and energy efficiency initiatives remain the best solutions for the electricity crisis. Energy efficiency can also potentially cater for other government goals such as improving the health and welfare of its citizens, reducing greenhouse gases and local pollutants, stimulating the economy and increasing employment. The government recognises that energy efficiency will lead to sustainable development and following chapter will review government policies and targets for energy efficiency.

3 ENERGY EFFICIENCY IN THE SOUTH AFRICAN RESIDENTIAL SECTOR

As stated in the previous chapter, energy efficiency plays a major role in the socio-economic development of South Africa. This chapter reviews the policies and targets for energy efficiency by the South African government and also reviews some of the potential savings from energy efficiency initiatives for the residential electricity sector. The review provides a background to the energy modelling which is described in chapter 5.

3.1 Energy efficiency policies and targets for the South African residential sector

Government advocacy for energy efficiency can be traced back through energy policy documents. The DME published the **1998 White Paper on Energy Policy**. The policy document suggested that appliance labelling and standards should provide the framework for energy efficiency strategies in the domestic sector. The DME realised that there is much potential for energy efficiency in South Africa and therefore through the1998 White Paper the DME proposed that energy efficiency targets should be established.

In 2003 the DME published the **White Paper on Renewable Energy**. The Government set a target of 10 000GWh (0.8Mtoe) of renewable energy contribution to final energy consumption by 2013. Solar water heaters are amongst the renewable energy technologies considered to meet this target. Solar water heaters in the domestic sector would delay the need for new generation capacity. The policy document assumes that 100% penetration of solar water heaters in urban residential households at the time would potentially reduce energy consumption by 5 900GWh and power consumption by 900MW which is equivalent to a large coal-fired power station.

In 2005 the DME published the **Energy Efficiency Strategy**. The DME through the Strategy set a 10% residential energy savings target to be achieved by 2015. The target was expressed in relation to the forecast of national energy demand at that time, based on the 'business as usual' baseline scenario for South Africa modelled as part of the National Integrated Energy Plan (2003). Below is a table showing the measures proposed by the DME in order to meet the target.

Table 3.1: Measures proposed by the DME to meet the energy efficiency target for the residential sector
Source: (DME, 2005)

Output activity	***Measures***
Standard for Housing	• Standard 283 for energy efficient housing • Incorporate SANS 283 in National Building Regulations • Monitoring and dissemination of results
Appliance Labelling	• Establish standards for household appliances • Label household appliances • Make the Label mandatory • Market appliances with labels • Monitor progress
Awareness Raising Program	• Development of specific program • Implementation
Efficient Lighting Program	• Demonstration in all sectors • Implementation • Monitoring

Solar water heating was also mentioned in the 2003 Strategy but the high capital costs and also the lack of large scale manufacturing capabilities were seen as barriers that needed to be dealt with.

In 2008 the first **review of the National Energy Efficiency Strategy** was published by the DME. Apart from reiterating the 2003 Energy Efficiency Strategy, the review document also noted the urgency of the new DSM and energy efficiency drive since load shedding was experienced in 2008.

In 2008 the **National Electricity Emergency Programme** was launched in the wake of the 2008 blackouts. Power conservation and energy efficiency programmes were proposed as the short term solution to the crisis. Power conservation has negative impacts since it involves a decrease in activity so energy efficiency and behavioural changes were seen as better solutions. The following sections give brief descriptions of the proposed energy efficiency measures and potential energy/power savings for specific household energy services found in literature.

3.2 Main Energy Efficiency Initiatives for the Residential Sector

In this section, findings from a desktop study of methods of reducing residential electricity consumption for different energy services and raising awareness about energy matters in South Africa are reviewed. The review also highlights some achieved goals and future targets for different initiatives and gives assumed energy savings from these initiatives. There is a general lack of information available publically and therefore the review is not representative of all efficiency programmes carried out in South Africa.

3.2.1 Lighting

Lighting is estimated to use about 10 to 15% of the electrical energy used in the middle and high income households consuming about 750 kWh per month (DME, 2008). Lighting may be 100% of the electrical energy used in low and newly electrified households using about 40kWh per month (Henderson, 2007). CFLs use approximately 20% of the energy incandescent light bulbs use to produce the same amount of luminance. Although an efficient lighting programme might not have a profound impact on a micro level (household level) because the energy demand for lighting is relatively small for medium and high income households, the impact on a macro level (national level) might be significant because of the collective savings. Replacing incandescents with CFLs will reduce the peak demand.

In order to promote CFLs in 2004, the price of CFLs was dropped from between R60 - R80 per lamp in 2004 to R13 – R20 due to joint sales promotions with local suppliers and increased volume of sales of CFLs (Henderson, 2007). Since 2004 Eskom has embarked on a National programme to exchange incandescent lamps with CFLs in selected areas. According to the Eskom DSM website roughly 35 million CFLs have been rolled out since 2004.

Research into the potential for light emitting diode LED roll-outs is currently underway (Davis, 2010). Light emitting diodes are even more efficient than CFLs which means the demand due to lighting can potentially be reduced further. Developed countries can sponsor LED roll-outs for carbon credits. For example the UK is offering 10 million LED bulbs to South Africa in exchange for carbon credits (Elsa du Toit, 2010). The project aims to make a saving of about 18GWh annually.

Lighting technology is constantly improving with bulbs lasting longer and using less energy to produce the same amount of lumens. Just like the old arc lamps which were used in the late 19th century have been phased out of street lighting, incandescent lamps can also be phased out except when they are used for a dual purpose of heating and lighting. The government aims to eventually phase out incandescent light bulbs (Elsa du Toit, 2010).

3.2.2 Water Heating

Water heating in the South African urban high to medium income residential households accounts for 30% to 40% of the total electrical energy expenditure (Holm, 2005). Solar water heaters can save from 60% to 70% of this expenditure (Holm, 2005), (De Villiers, et al., 2000). South Africa has abundant sunshine and the average daily solar radiation is between 4.5 kWh and 6.5 kWh per square metre (Prasad, 2007). South Africa has a target of producing energy from renewable sources of 10 000GW by 2013 as stated in the 2003 White Paper on Renewable Energy (DME, 2003). It is believed that Solar Water Heaters (SWHs) can contribute about 23% of the target (Holm, 2005).

The solar water heating industry in South Africa flourished between 1978 and 1983. This was because the Centre for Scientific and Industrial Research (CSIR) developed effective communication strategies and projects, which motivated home-owners to install them (Prasad, 2007). The communication programme was discontinued in 1983 and the market collapsed. Insufficient information, high upfront cost and low electricity prices have been the major barriers to the dissemination of SWHs (Prasad, 2007) but recently because of the electricity crisis, the solar water heating market is being actively promoted by the government, Eskom and other municipalities.

Annual production of geysers was about 400 000 units in 2004 (Holm, 2005). Therefore there is great potential for the solar water heating market but South Africa's manufacturing capacity for solar water heaters is only 10 000 units per year (Holm, 2005).

Eskom offers rebates for SWHs that have passed the SABS approval. The City of Cape Town has taken the initiative to support renewable energies and is committed to ensuring that 10% of households have SWH systems by 2010 (Holm, 2005). Some lower income households which cannot afford solar water heaters are benefiting from local government development projects. For example the city of Cape Town has installed 2300 SWHs in low-income homes in Kuyasa in Khayelitsha Township (Prasad, 2007). Kuyasa is a pioneering roll-out funded off CDM credits. Other examples are the Nelson Mandela Bay project where 120 000 solar water heaters will be rolled out to low- and middle-income earning households over the next two years and the Cosmo city project where 700 solar water heaters and insulated ceilings were installed in 2010. After the 2008 electricity crisis, a target to install over 1 million solar water heaters over three years was proposed by the DME. The potential savings of this programme is 650 MW (DME, 2008).

The president of South Africa Jacob Zuma officially launched the National Water Heating Programme on the 28th of April 2010 in Winterveldt, where some 270 SWH units have already been installed. Eskom is subsidising the installation of 925 000 solar water heaters over five years, which is estimated to cut peak demand on the electricity grid by 578MW (GCIS, 2010). The programme is set to continue until all households have solar water heaters (Preident Jacob Zuma, 2010). Funding for the SWH programme comes from a number of sources, including Eskom's demand side management budget, a tariff from the proposed National Energy Regulator and from the World Bank's Clean Energy Technology fund (GCIS, 2010). Energy Minister Dipuo Peters explained that the first 200 000 units to be installed through the programme, would be imported whilst a local manufacturing industry is being created. The project will generate employment through the manufacturing and installation of solar water heaters and it will help South Africa gain a foothold in the solar water heating industry.

There are other methods which could reduce the amount of electricity used for water heating by reducing the standing heat loses of geysers or by reducing the amount of hot water used for showering without compromising comfort. Geyser blankets can reduce standing heat loses of electric geysers by about 12% (Winkler, 2006). An energy and water-saving showerhead typically has a flow rate of less than 10 litres per minute, compared with a conventional showerhead which has a flow rate of 15 litres per minute.

3.2.3 Cooking

Most high income households use electricity for cooking whilst poor households supplement their cooking needs with other fuels like wood, coal and paraffin. Studies for fuel switching have been conducted for cooking. A LPG exchange programme was conducted in Khayelisha Township in Cape Town in 2006 where households were encouraged to swap their two plate electric stoves for LPG stoves. Cape Town had recently experienced power failures and the LPG stoves were readily accepted. The use of LPG stoves by low-income households contributed to decreasing the peak by 20MW (rather than the targeted 40MW) (Mohlakoana, 2009).

3.2.4 Space heating

South Africa is generally a warm country with an average annual temperature of about 17^0C. Cold temperatures are experienced during winter nights and mornings. Demand for space cooling is generally in commercial buildings but there is a need for space heating in most households during winter nights which contributes significantly to the peak demand.

Houses designed to save energy, can reduce household space heating requirements. The Department of Housing in collaboration with the Department of Minerals and Energy has developed appropriate guidelines for the construction of thermally designed housing incorporating passive solar design (DME, 2005). Since most of the thermal energy in a house escapes through the roof, the single most effective intervention in the building shell is the installation of a ceiling (Winkler, 2006). It is technically possible to eliminate the need for space heating through proper insulation, orientation and ceilings (Holm, 2000). However most households will chose to use other appliances for additional space heating (Winkler, 2006) to further improve comfort levels (direct rebound). Also households can use the fuels saved from efficient housing for other energy services like cooking or lighting (indirect rebound).

3.2.5 Smart metering technologies

Smart metering involves the use of wireless technologies to remotely manage customer load. Energy intensive services would be switched off during the peak demand period which would effectively level out the load profile. Geysers and pool pumps are amongst the targeted technologies which would be managed by power meters. A saving of 3 265 MW during the peak period was estimated by the DME (DME, 2008).

Smart metering also allows for user feedback, that is, the user can self inspect how electricity is used in the household and program some appliances to switch on for limited periods of time. For example the geyser can be programmed to switch on only in the early morning and switch off around 10:00 in the morning so as to avoid standing loses.

3.2.6 Appliance Labelling and Mandatory Standards

Appliance labelling and mandatory standards are no cost initiatives which are driven by policy. Appliance labelling enables the consumer to make an informed choice regarding the lifetime running cost of domestic products. With the tariff increments that are expected in the near future, appliance labelling can have a significant effect. By imposing mandatory standards, the government can control the products on the shelves thereby promoting efficient appliances and entrenching energy efficiency in the households. At the moment, relying on anecdotal evidence, consumers are not aware of appliance labelling and the appliance labelling programme stated in the 1998 White Paper is not yet in effect although consumers can rely on the energy star ratings on appliances. The South African South African Bureau of Standards (SABS) tests and sets technical regulations to some household appliances. For example SABS laboratories tests solar water heaters and Eskom awards subsidies for those solar water heaters according to the amount of electricity which can be substituted by solar energy.

3.2.7 Raising Awareness

Energy savings can be achieved by behavioural changes alone and the government has been driving an energy awareness campaign by using local media. Hints and tips on saving electricity have been given through various forms of media such as the internet, news papers, radio and television. Web pages that offer advice on energy efficiency and energy saving behaviour have been set up by the DME, Eskom and other municipalities. Also educational handouts which advise residents on how to save energy have been distributed.

Energy consultants that can perform energy audits and offer energy saving advice have been advertising their services through the internet and the yellow pages in telephone directories. The government and Eskom have been implementing energy efficiency initiatives in public buildings as a demonstration to the public to show the impact of energy efficiency.

During the Cape electricity crisis in 2006, public service announcements on the status levels of the electricity grid were broadcast nationally on SABC television channels. This service was called the power alert. Savings of about 153 MW per day for Western Cape alone were estimated if residences complied with the broadcasts by switching off unnecessary appliances. Nationally savings of up to 393MW were reported by Eskom. The Power Alert programme was successful and it showed how much households are willing to save electricity to prevent load shedding.

Earth hour is a global event that takes place on the last Saturday of March annually. Households and businesses turn off non essential electrical appliances for 1 hour to raise awareness about climate change. South African citizens participated in this event and saved 420MW in 2010 according to Eskom (an improvement from the 400MW recorded in 2009). The amount of savings show that a significant number of South African's care about the environment and are willing to sacrifice some comfort to save it.

Below is a table which summarises some of the programmes mentioned above.

Table 3.2: Summary of some of the efficiency programmes being carried out in South Africa

Initiative	Programme	Notes
Efficient lighting	• CFL exchange • LED exchange	• 35 million CFLs exchanged from 2004. • Feasibility studies currently in progress for LED mass roll outs. • Incandescent bulbs to be completely phased out.
Water heating	• Solar Water Heater	• 1 million solar water heaters to be rolled out by 2014. • The programme will continue until all households have SWH's
Cooking	• LPG stoves exchange	• Not very effective. Only half of the expected savings were achieved.
Space heating	• Instalment of ceiling's in RDP homes	• Building standards to be set. • A ceiling instalment programme run in conjunction with SWH programme in Cosmo city
Appliance labelling and standards	• Energy star ratings • SABS testing and regulations	• There is a need to raise public awareness about appliance labelling.

Smart metering	• Controlled by municipality • Controlled by individual households	• Mainly for load shifting purposes • Useful for user feedback
Raising awareness	• By using media to educate the public about energy efficiency and energy matters	• Low cost intervention (to the government) with much potential for energy savings

3.3 Promotion and dispersion of Energy Efficient Technologies

A number of studies have concluded that policies and programmes, not ongoing technological trends or (at times) rising energy prices have stimulated most of the efficiency gains experienced in developed countries (Geller, et al., 2005).

Promotion and dispersion of Energy Efficient Technologies is mainly accomplished by:

1. Mass rollouts (inefficient technologies are traded often at no cost to the user for efficient technologies)
2. Subsidy schemes (whereby part of the investment cost is funded for according to the expected savings of the technology).
3. Soft loans whereby interests charged on investment for some products are below-market rate of interest.
4. Value added tax (VAT) can be removed or reduced for some efficient appliances making them cheaper and more accessible.
5. ESCOs can offer a service like providing hot water using solar energy and set a tariff for that service.
6. Marketing and encouraging voluntary take-up. The customers are educated on the break even period of products where the cost of investment is paid back by the avoided costs of the energy saved.
7. Awareness campaigns through public engagement helps involve and educate the public about energy efficiency and energy matters. An example of a public activity to promote energy efficient technology might be a competition where participants win energy efficient appliances by showing their knowledge of energy matters and the current electricity situation.

In low income households where the cost of investment of an appliance is usually the most determining factor when choosing household appliances, mass rollouts are used to promote energy efficiency whilst in high income households subsidy schemes are the most common methods for promoting energy efficient appliances. Also specific energy services can be targeted for different income groups according to which service consumes the most electricity. For example since low income households use electricity mostly for lighting, a CFL roll-out might be most effective in reducing demand in poor communities whilst promoting solar water heaters to medium and high income households might be most effective in reducing demand in affluent communities.

Roll-outs can have spill over effects by raising awareness about certain technologies and also mass production of energy efficient appliances might lead to a decrease in cost of those technologies.

3.4 Conclusions

Energy efficiency has been passively promoted by government until recently. The government, Eskom and other municipalities are engaged in an aggressive energy efficiency drive which is aimed at reducing electricity consumption as the supply of electricity is constrained. Much importance has been placed on the impact of mass roll-outs of efficient and fuel switching technologies, in particular, CFLs and solar water heaters.

Often when efficient appliances are rolled-out for free especially in developing communities, all the technical savings are not fully recognised because of the take-back or rebound effect. This is due to the fact that developing communities have latent demand. Latent demand is brought on by for example, the lack of modern fuels and also the cost of the energy service. The following chapter will cover the rebound effect in detail.

4 THE REBOUND EFFECT AND MITIGATIVE INTERVENTIONS

Intuitively it seems obvious that an increase in energy efficiency will reduce energy consumption but paradoxically, economic theory suggests that this decrease in demand and subsequent decrease in cost of using the resource could cause a rebound in demand (Gottron, 2001). The rebound effect was first described by Jevons in 1865, where he observed that the invention of a more efficient steam engine meant that the use of coal became economically viable for many new uses. This ultimately led to increased coal consumption, even as the amount of coal required for any particular use fell (Stanely, 1866).

In this section, a literature review of the rebound effect will be presented. Firstly the rebound effect is defined and the causes and consequences of the rebound effect are investigated. Empirical evidence of the rebound effect found in literature will be given. South Africa is a developing country therefore a section on the rebound effect in the context of developing nations is given and the main findings from a rebound effect study conducted in South Africa are given.

4.1 Definition of the Rebound Effect

The rebound effect is generally expressed as a ratio of the lost benefit compared to the expected energy saving benefit when holding consumption constant (Dimitropoulos, et al., 2006).

$$\textbf{Rebound effect} = \frac{\textbf{Expected savings} - \textbf{Actual savings}}{\textbf{Expected savings}}$$

Therefore if a saving of 10% was expected and a saving of 6% is observed, then a 40% rebound has been experienced. The following results can be expected when calculating for rebound.

1. When the actual savings are less than the expected savings, the rebound effect is between 0% to 100%. This is called the take back effect.
2. When the actual savings are greater than the expected savings, the rebound effect will be negative. This is very desirable and is usually witnessed when energy

efficiency initiatives are carried out in conjunction to tariff increases and/or energy awareness campaigns.

3. When an increase in consumption is experienced due to energy efficiency initiatives then the rebound effect will be greater than 100%. This is called the backfire effect and is experienced when the energy efficiency initiative also caters for unmet demand.
4. A fourth case is when the rebound is 0%, which means all technical savings have been achieved.

It is worth noting that rebound can be measured with reference to peak demand or energy consumed which would yield different results. Therefore direct rebound will increase the consumption of energy but the energy efficiency initiative might lead to the reduction in the peak power demand. For example if lights are left on for longer as a direct result of a CFL exchange programme, the peak demand might fall because CFLs use less power than incandescent but since the CFLs are being left on for longer, some of the energy savings will be degraded. Hence it is important to calculate rebound according to the priorities of the energy efficiency initiative; that is whether the initiative is meant to:

- reduce consumption of energy
- reduce peak demand
- reduce pollutants
- enhance the welfare of participants by reducing the usage of less effective fuels and appliances.

Therefore in the South African context, according to the findings in Section 2.3, the rebound effect should be calculated according to the expected energy savings.

4.2 Khazzoom-Brookes postulate

In 1992, economist Harry Saunders came up with the phrase Khazzoom-Brookes postulate to describe the idea that energy efficiency improvements, on the broadest considerations, are economically justified at the micro-level but lead to higher levels of energy consumption at the macro-level than in the absence of such improvements (Herring, 1998). In his modelling of efficiency gains he assumed that energy intensity for each unit of output will remain the same but energy demand will grow in lock step with economic growth given that prices remain fixed.

4.3 Types of rebound effects

There are three main types of rebound effects and to illustrate each type, efficient lighting is given as an example:

1. Direct rebound effects: Increased efficiency leads to increased consumption of that energy carrier for the same service because of the effective reduction in cost of that service (lights are left on for longer or more light fittings are added).
2. Indirect rebound effects: Savings made due to improved efficiency from one service are used to purchase or increase the usage of other services which may use the same energy carrier (money saved from efficient lighting is used to buy/use other electrical goods). Also due to the reduction in price of a service, other opportunities to utilise that service begin to emerge (Street lighting and night security lights).
3. Economy wide: Energy efficiency improvements may also reduce energy prices and increase economic growth, which could further increase energy consumption (Dimitropoulos, et al., 2006).

From a social development point of view, the rebound effect maybe an indicator of improved welfare as it shows increased activity, comfort and even provision of unmet demand. But when energy efficiency is initiated because of the need to curb demand or to reduce the Greenhouse Gas emissions from the generation of electricity from fossil fuels, then the rationale for the policy measures aimed at encouraging energy efficiency is undermined. Therefore in a developing country context, energy efficiency can be targeted for different income groups with different outcomes, that is energy efficiency initiatives can be targeted for high income groups to reduce overall energy consumption or to improve the living standards of poorer income groups.

Quantifying rebound effect is complex as it depends on human behaviour which is very dynamic as it is influenced by different factors which are not mutually exclusive. For instance, an increase in consumption can be attributed to other factors like increased income and economic growth and a decrease in consumption can be attributed to factors like tariff increments and raised awareness of consumers. Estimates of rebound also rely on the accuracy of the projections made in the business as usual baselines. Although there is a general concession that rebound does exist among academia and energy economists, who have investigated the rebound effect, the significance of rebound is under question especially in developed nations.

4.4 Other causes of rebound

There are other causes of rebound besides an increase in consumption due to an effective reduction in running/operating costs. These include dissatisfaction with the service provided by a new technology (linked to reversion; for example after failure of CFLs that were originally provided for free), cost barriers to entry, unwillingness to accept the new technology, changing trends and social factors leading to a shift in the demand for a particular service (Davis, 2010). Also if an energy efficient technology is given away for free, the purchase of that technology might be discouraged, consequently reducing stocking of the product in retail stores (Boardman, 2005).

4.5 Empirical Evidence of the Rebound effect from other studies

Most sources refer to L.A. Greening's summary of literature regarding rebound. The original table is given below which shows how many reports per category were reviewed.

Table 4.1: Empirical Evidence from Literature
Source: (Greening, et al., 2000)

EE	% rebound	Number of studies
Residential lighting	5-12	4
Space Heating	10-30	26
Space cooling	0-50	9
Water Heating	10-40	5
Home Appliances	0	2

Most articles reviewed support the idea that neglecting rebound effects in energy efficiency policies leads to inaccuracies in the calculation of potential savings although a few articles take offence at the notion of backfire due to energy efficiency initiatives (more consumption as a result of efficiency initiatives) (Herring, 1999). The significance of rebound does not go without its share of arguments. Therefore neglecting rebound for some countries can result in legal action as these countries have signed binding agreements on reducing green house gas emissions and also neglecting rebound might lead to constrained supply as consumption might not decrease as planned.

4.6 The case of suppressed demand in developing communities

The level of rebound cannot be expected to be the same for all households. Aspects such as method of procurement; whether it was an individual household initiative to purchase the efficient appliance or if the appliance was handed out for energy poverty alleviation purposes by an organisation, income levels, type of technology, level of education, environmental awareness, traditions and norms and demographic characteristics to mention a few should be considered when evaluating rebound. The diagram below by (Sorrel, 2009) summarises some of the conditions which influence the quantity of rebound that can be expected.

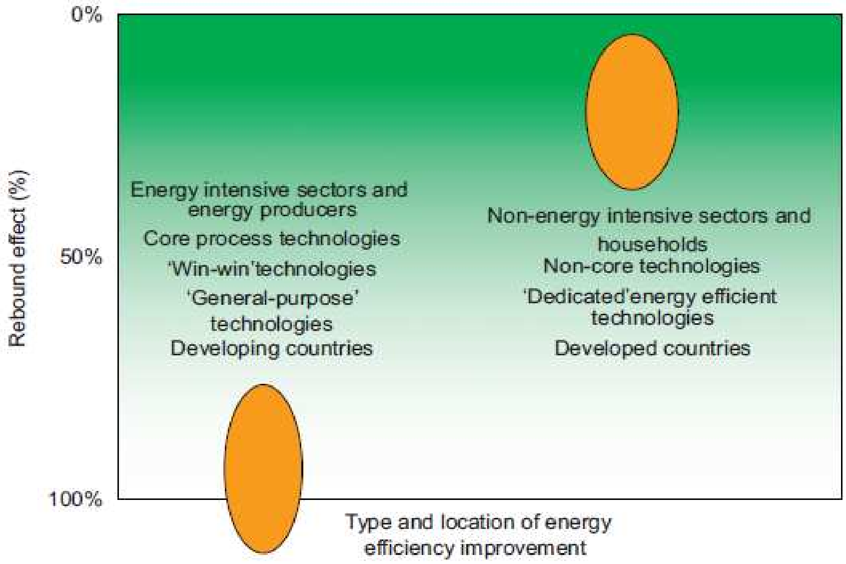


Figure 4.1: Conditions under which rebound effects maybe large or small. Source (Sorrel, 2009)

The most significant difference between households found in literature concerning rebound is the saturation of demand for a particular service (that is the level of provision of a certain energy service) [(Sorrell, et al., 2008), (Roy, 2000), (Murray, 2009), (Sorrel, 2009)]. Developing communities usually encompass a certain amount of latent demand whereby provision of a service is available but at very basic levels often met by appliances that pose health risks or appliances that use fuels which are very laborious to obtain like fuel-wood. Where the appliance uses a 'modern' fuel like electricity or LPG, the final-energy prices might be too high for the households to afford desirable levels of energy services. Hence when the service becomes cheaper and/or easier to acquire, demand for that service rises and this might lead to the backfire effect. The paragraph below summarises a study by (Roy, 2000) concerning an efficient lighting programme for rural households carried out in India.

The Roy (2000) study relates to a case of a non-electrified village where kerosene lamps fuelled by subsidised kerosene (efficiency 1%) were replaced by a relatively efficient renewable lighting technology, solar lanterns. One of the primary aims of the programme was to reduce the use of kerosene for lighting to zero except for the seasons when there is insufficient sunshine. The survey revealed that with the enhancement of the efficiency of the appliances capable of generating better quality of lighting (380 lumen compared to 10-20 lumen from kerosene lamps), the level of activity increased as a result of longer operating hours. Kerosene use could not be reduced to zero as anticipated due to increased demand for lighting and the inability of the solar lanterns to supply electricity for 24 hours. Rebound for this study is given below:

$$\text{Rebound effect [\%]} = \frac{100 \times (\text{Calculated savings (litres)} - \text{Actual savings (litres)})}{\text{Calculated savings (litres)}}$$

A direct rebound of 50% was experienced due to increased lighting activity. Indirect rebound where the paraffin was used for other energy end uses like cooking was not taken into account. When indirect rebound was taken into account a rebound of 200% was experienced for some households (the estimated 200% of rebound is valid for 76.89% of the households in India). The basic reasons for such a high rebound were given as:

- Large unsatisfied demand (quality and quantity)

- The new technology imposed no cost burden on the users and no upward adjustment to the kerosene subsidy was made. Therefore the financial gains of the initiative were reinvested in more energy use activities.

This study shows that rebound in developing countries can be very severe and should be considered if the energy efficiency initiative bares no cost burden to the users.

4.7 Mitigative measures

De Kock in his 2009 paper dissecting actions and responses to DSM measures around the world concluded:
"Whatever the sector, the key driver is self-interest. DSM promotion will not be truly successful until the community has passed the tipping point – where the value of changing outweighs that of no change." (Maphumulo, 2010)

Therefore it is suggested that, for energy efficiency to be very successful, there has to be a major driver for change which will benefit the households directly. Rather than marketing efficient technologies as alternative products, it is more effective to also factor in energy matters when promoting efficient appliances so as to offer up efficient appliances as solutions to the national problem of constrained supply. In South Africa, the 2006 Cape Town blackouts and the 2008 countrywide blackouts affected industry, commerce and the household sector as well. Jobs were lost because of the power shortage and also people in general were inconvenienced by the shutdowns. Therefore it was in everyone's interest that a solution be found. Energy efficiency was seen as the champion to the electricity crisis and media adverts were used to inform the public about the energy crisis and how the public can help avert the electricity crisis. The savings made by the power alert program show how people are willing to cooperate when the nation is in crisis.

Awareness includes:

- Information about energy matters
- Feedback on electricity consumption (individually by monitoring electricity bills or nationally using power alert)
- Blackouts
- Educating the public about the behavioural changes that can help save electricity and also the technologies available that can help reduce energy consumption

South Africa has in the past enjoyed amongst the cheapest electricity tariffs in the world. Recently the cost of using electricity has gone up and is set to continue to do so in the near future. The pay back period for some energy efficient and fuel switching technologies will be shorter creating an enabling environment for self funded efficiency projects. Self-funded projects are expected to have lower rebound than exchange projects. Also higher fuel costs will reduce the feedback of financial savings into more energy consumption therefore reducing or eliminating the rebound effect. The rebound effect is in fact a form of price elasticity since more energy consumption is experienced as a result of an effective reduction in the cost of the energy service. According to (Schettkat, 2009), (Danielsson, 2010), (Wackernagel, et al., 1997) price measures are relatively effective in counteracting the rebound effect.

4.8 Rebound in South Africa

The Energy Modelling group at the Energy Research Centre, University of Cape Town conducted case studies of some energy efficiency initiatives carried out in the South African residential sector. Energy efficiency programmes included a low-income solar water heating implementation in Zanemvula in the Eastern Cape, and an efficient lighting intervention in the Karoo town of Prince Albert in the Western Cape. The research also intended to study the impact of raised awareness and price increments on efficiency initiatives.

Through research on household electricity consumption Davis 2010 was able to construct a systems dynamics model to investigate the impacts of different initiatives either implemented individually or concurrently and estimates of the various impacts of these initiatives were hypothesised. The model was tested against data collected from the Zanemvula and the Prince Albert case studies and the systems dynamics model was able to mimic real data. A more detailed description of the methodology used can be found in (Davis, 2010). The main findings from the systems dynamics model are:

- For efficiency interventions, rebound is experienced more in low income households
- High income households are more price-inelastic therefore price interventions have a limited impact on high income households but price interventions have a greater impact on low income households.

- High income households respond more to awareness campaigns about the impact of energy efficiency on the economy and/or the environment.
- Awareness campaigns about the cost effectiveness of efficient technologies have great impact on the low income households and very little impact on high income households.

4.9 Conclusions

The presence of the rebound effect in efficiency initiatives is largely undisputed in literature although its importance is always in question. Heed should be taken from the solar lantern study made in India as it shows the extent at which rebound can degrade energy savings especially in underdeveloped communities. Confidence should not be placed on the stated engineering efficiency savings for a particular technology.

The cumulative energy savings due to energy efficiency initiatives can be very significant. A culture of energy efficiency is therefore very important and it relies on the effectiveness of early programmes. Hence the rebound effect can have consequences for future generations and should be given careful consideration.

Various literature sources suggest that energy efficiency can be implemented most effectively when run concurrently with price interventions and/or awareness campaigns. Such hypothesis is difficult to test in the real world since residential energy consumption is very dynamic.

Based on the background literature review given in this report, the following chapter attempts to quantify possible savings when energy efficiency initiatives are carried out in the residential sector. Scenarios will be run which compare impacts of different interventions which can be run alongside efficiency initiatives.

5 MODELLING THE RESIDENTIAL ELECTRICITY SECTOR

The modelling methodology used in this thesis is explained in this chapter. A model is a simplified representation of a complex system which helps explain the relationship between different system components. Computer model simulations can be used to explore untested interventions which would help to anticipate the reactions of a real world system. The results can be used for better understanding of a system and can be used to develop scenarios of a system. Scenarios are useful for planning ahead and policy making.

5.1 Modelling requirements for this thesis

The energy modelling in this thesis serves to illustrate the impact of different scenarios based on different initiatives that would affect residential energy consumption. Although great care has been taken to model residential electricity consumption as accurately as possible, it would be misleading to declare the model as exact. There is a general lack of data for an accurate model of the residential sector to be compiled and also there are many variables that could change with time that are taken into account when projecting residential electricity consumption into the future. Therefore the model only serves to illustrate how different policies can potentially influence residential electricity consumption. The model was populated using data from South African statistical bodies and other South African energy related studies and when data was not available from a South African perspective, it was collected from related studies from other countries. Future work for further studies was recommended in chapter 6 to rectify the lack of data.

This study concerns the implementation of energy efficiency and fuel switching initiatives in the residential sector and therefore in order to illustrate the potential impacts of energy efficiency and DSM initiatives, the model aggregated the total amount of energy consumed from the end uses of energy. This gave the author the opportunity to explore the impact of mass rollouts of efficient appliances in the residential sector. The following section analyses some of the energy modelling tools used for energy planning.

5.2 Modelling tools for energy policy analysis

Modelling tools vary in complexity and ultimately in purpose. It is therefore important to investigate different modelling tools and then to select the best tool to use. The rest of this chapter follows by describing the modelling tool used in this study followed by an analysis of the parameters used to project demand.

There are basically three types of modelling tools namely optimisation, simulation and accounting tools.

1. **Optimisation tools**: Use a set of constraints to calculate the best cost effective solution. Therefore optimisation tells the user how to make the best of a given situation in relation to a predefined goal (Winkler, PhD, 2006).
2. **Simulation tools:** Simulate behaviour of energy consumers and producers under various signals (tariff increments, population growth, GDP growth for example).
3. **Accounting tools:** Rather than simulating decisions of energy consumers and producers, the modeler explicitly accounts for outcomes of decisions. Therefore instead of calculating market share based on prices and other variables, accounting tools simply examine the implications of a scenario that achieves a certain market share (Heaps, 2002).

The Energy Research Centre had previously modelled the South African energy sector using an optimisation tool called MARKAL and a simulation-accounting tool called LEAP. This study required an energy model to quantify energy savings from various energy efficiency initiatives from a projected baseline and to quantify the potential impact of the rebound effect and measures which would encourage energy efficiency and mitigate the rebound effect. Hence an accounting modelling tool was updated and used (LEAP). A number of scenarios are parameterised to explore the potential impacts on energy efficiency savings in the residential sector over the period from 2001 until the year 2030. Scenarios were also modelled with price and awareness interventions running concurrently with energy efficiency initiatives in order to determine the extent to which rebound effects may be mitigated using these options, and to suggest suitable policy options.

5.3 LEAP modelling tool

LEAP (Long Range Energy Alternatives Planning System) is a descriptive accounting and simulation tool for energy and environmental policy analysis. It is an integrated modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy.

LEAP allows the user to capture data to represent an energy system and analysis is conducted by constructing alternative futures, one of which is a baseline scenario which is used for comparison with all the other scenarios. The baseline scenario usually represents the business as usual or a growth without constraint scenario against which other scenarios can be tested. Ultimately all futures can be compared to one another and the "best" future can be used for policy suggestions.

LEAP can be used to simulate the behaviour of consumers and producers under various signals such as price increases, income levels growth, policies and GDP growth changes. It is a bottom-up tool which means that end use data can be aggregated to form a picture of the total demand. Supply options can also be investigated and LEAP has an integrated environmental and technology database which allows the user to investigate GHG emissions and also local pollutants for different technologies.

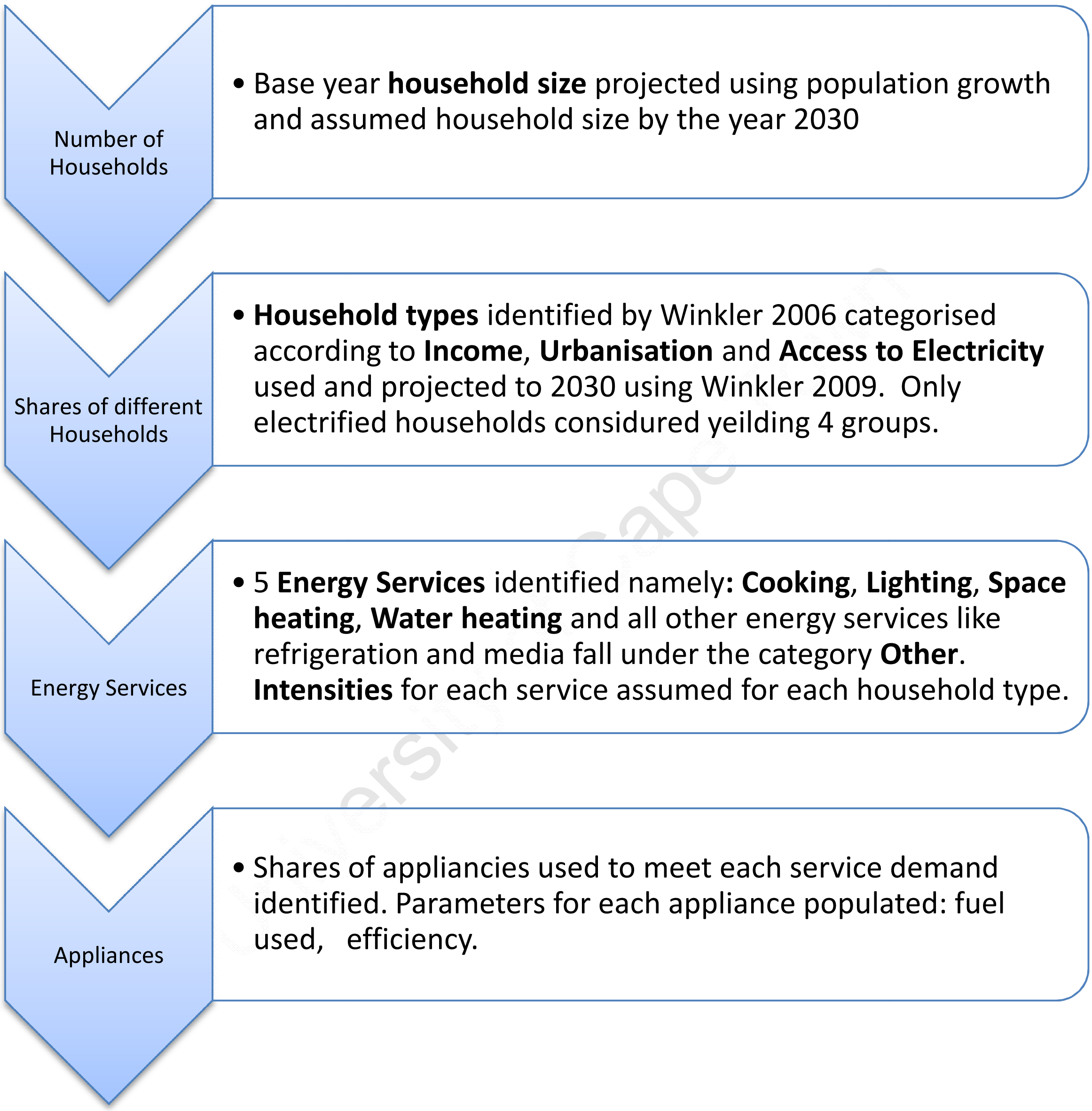
5.4 Drivers for residential energy consumption

In order to project residential electricity consumption, consideration of the common drivers of residential electricity consumption should be given. The drivers that will affect electricity consumption in this model are:

- Household growth (driven primarily by population growth)
- Incomes
- Urbanisation
- Rates of electrification
- Availability and affordability of different fuels and appliances used to utilise the fuels.

GDP is also an important driver for residential electricity consumption but it was not explicitly included in the model so as to reduce the complexity of the model. GDP would affect the composition of the different income groups and also the household sizes. The remaining section of this chapter will explore household growth projections, the different types of households used to define the residential energy sector and also the common energy end uses.

5.5 Structure of the LEAP model



5.6 Household growth Projections

It is common practice to model residential energy consumption per household instead of per person because it is easier to follow household patterns than a single individual's patterns (Winkler, 2006). Therefore it is important to project household growth. Although households are expected to grow as the population grows, the growth rates are different. Population growth is but one driver for household growth. Across South African cities, population growth between 1996 and 2001 was 2.8% per annum but the number of households grew at a rate of 4.9% per annum (Winkler, 2009). The average household growth rate for South Africa in 2009 was 0.5% (DWA, 2009). Average household size has declined from about 4.48 in 1996 to about 3.69 in 2005 (UNISA, 2007). Possible reasons for this might be people moving from informal to formal settlements, rural urban migration and lower levels of fertility. Some drivers for household growth are mentioned below.

- Population growth
- Population pyramid (Impact of HIV/AIDS especially on the young working class becomes apparent. If there are more dependants than working class, then there will be larger household sizes)
- Economic growth (greater preference for small family or single person households as average income increases and more houses become affordable). Government can also allocate more of the annual government budget to housing projects.

The growth rate of the South African population has been declining steadily between 2001 and 2007 from approximately 1.3% between 2001 and 2002 to about 1% for 2006 to 2007. The population of 51.5 million in 2025 was assumed in the original LEAP model and this was taken from (ASSA, 2002). For 2030 a population of 51.9 million people was calculated (Haw, et al., 2007).

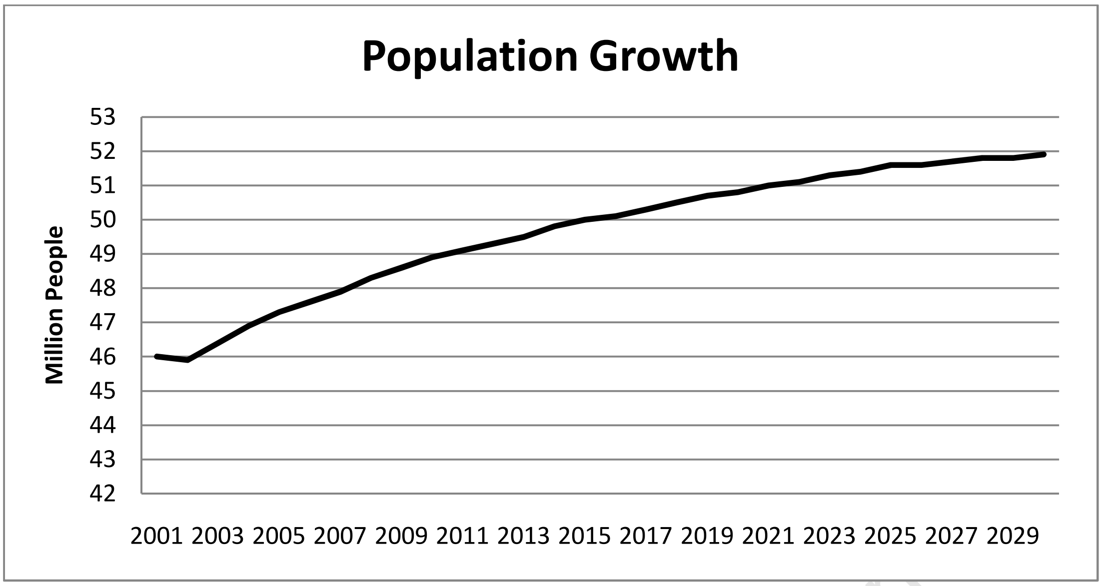


Figure 5.1: Population Growth Projections

Source: (ASSA, 2002)

A household growth of 1.3% between 2001 and 2007 has been recorded (The Presidency, 2009). Therefore the number of households was projected using the 1.3% growth rate. Using the population and household growth assumptions an average household size of 3 persons per household was calculated for the year 2030. An average household size of about 3 persons per household for the year 2030 was deemed reasonable since household size has been continually decreasing.

The graph below shows three household growth projections extrapolated from different sources of data.

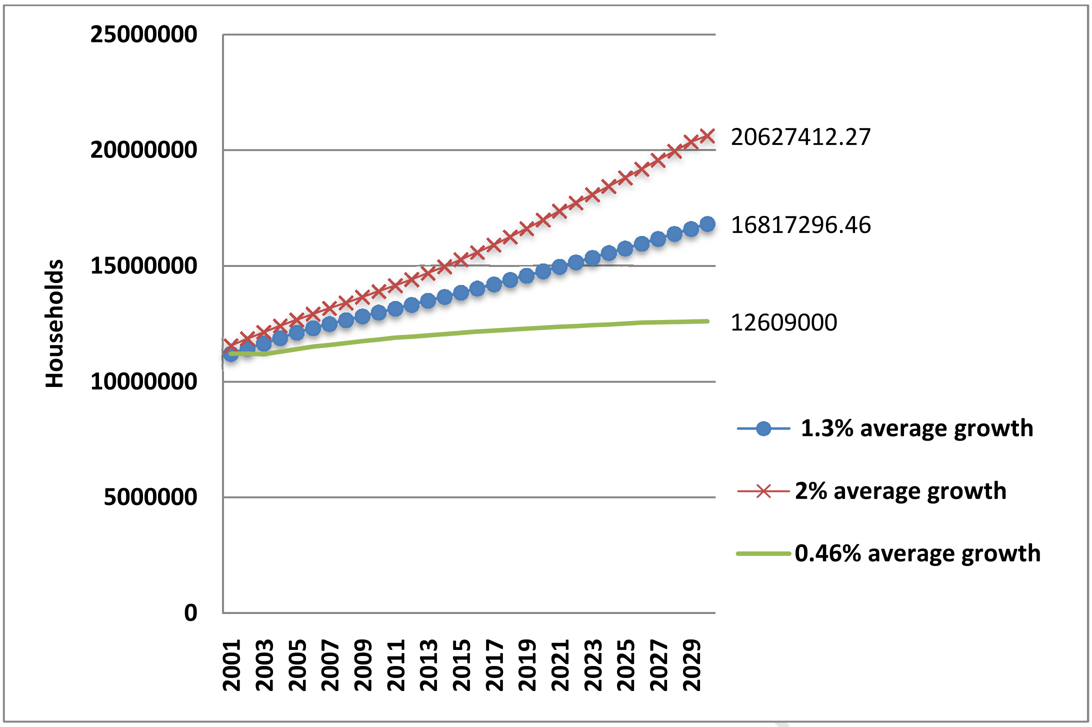


Figure 5.2: Household Growth Projections found in literature[5]

5.7 Household categories

(Winkler, 2006) identified 3 categories in the residential sector in terms of energy use patterns namely the rich/poor, urban/rural and the electrified/not electrified categories. This would yield 8 groups of households but almost all rich urban and rich rural households are electrified therefore only 6 groups were considered. This categorisation was adopted for the 2006 LEAP model. (Winkler, 2006) was used as the base reference for household

[5] Data from 2001 to 2021 for the 2% growth rate was taken from (UNISA, 2007) then extrapolated using a 2% growth rate.

Data for the 0.46% growth rate was taken from the original LEAP model (Haw, et al., 2007).

Data from 2001 to 2007 for the 1.3% growth rate was taken from (The Presidency, 2009) then extrapolated using a 1.3% growth rate.

categories. Since this report is limited to residential electricity usage, the households without access to electricity will be ignored leaving the:

- Rural Rich Electrified **(RHE)**
- Rural Poor Electrified **(RLE)**
- Urban Rich Electrified **(UHE)**
- Urban Poor Electrified **(ULE)**

5.7.1 Income groups

Stats SA divides different household income groups according to quintiles. For this study the bottom two quintiles are classified as lower income and the remaining 3 as higher income. Therefore the lower income group is composed of those households with an annual per capita income of less than R4 033 and an annual expenditure of less than R3 703 (Winkler, 2006).

In this study, in 2001 53% of the population was considered low income and by 2030 this share had dropped to 42% (Winkler, 2006).

5.7.2 Rural/Urban divide

It is important to note that due to the forced removals in the apartheid era, remote, under-serviced areas tended to have high population densities. By most definitions, rural areas are sparsely populated so the rural/urban category is ambiguous to South Africa. Nevertheless the category has been used for purposes of evaluating electrification by the National Electricity Regulator and for other statistical publications (NER, 2001), (UNDP, 2005). Major differences to note between the two categories (urban and rural), are the different rates of electrification, access to services and use of other fuels for different energy end uses (for example the use of biomass is significant in low income rural households whilst coal use is significant in low income urban households in Gauteng and paraffin use is significant in low income urban Cape Town and electricity is used predominantly in most high income households). The category has therefore been deemed suitable for analysis in this report.

A 60:40 split between urban and rural was assumed by (Winkler, 2006) for the year 2001. For the year 2008, the (CIA The World Fact Book) and (UNICEF, 2008) estimate that 61%

of the total population is urban. An average annual urban population growth rate of 2.1% for the period 2001 to 2008 was calculated by (UNICEF, 2008). In this study an average urban population growth rate of 1.6% was assumed for the period 2008 to 2030 with 65% of the total population being classified as urban by 2030.

5.7.3 Rates of electrification

Phase 2 of the governments NEP proposes that 300 000 new connections would be made each year from the year 2000 but as seen in Table 2.3 Table showing electrification data for the 2001- 2008 period.

	2001	2002	2003	2004	2005	2006	2007	2008
Proportion of households with electricity	68.30%	70.00%	69.60%	72.00%	72.40%	71.80%	72.00%	73.00%
New connections cumulative	3036726	3375298	3654060	3902511	4144214	4330047	4452758	4748228
New connections	336918	338572	278762	248451	241703	185833	122711	295470

, the rate of electrification has been decreasing. Government aims to achieve universal access to electricity by 2014. According to (Bekker, et al., 2008) who projected a 2.5% household growth the 2014 target will not be met. The average rate of electrification between 2001 and 2008 was 256 053 connections per annum. Therefore even with the modest 1.3% household growth rate used in this study, the 2014 target will not be met. In this report the average number of annual connections was 246 000 connections per year for the period 2001 to 2008 and 280 000 connections per year for the period 2009 to 2030.

For the year 2001 Stats SA reported that there were about 11.2 million households with 67% of the households having access to electricity (about 7.5 million households had electricity in 2001) and by 2030 given the household growth projections and the assumed rates of electrification, 92% of the households will have access to electricity. Below is a table showing shares of households used in this projection.

Table 5.1 shares of each household type used in this study

Source: (Winkler, 2009)

Household type	*2001*	*2030*
Rural rich electrified (RHE)	11	13
Rural poor electrified (RLE)	10	16

Rural poor not electrified (RLN)	20	6
Urban rich electrified (URE)	36	45
Urban poor electrified (ULE)	11	18
Urban poor not electrified (ULN)	12	2

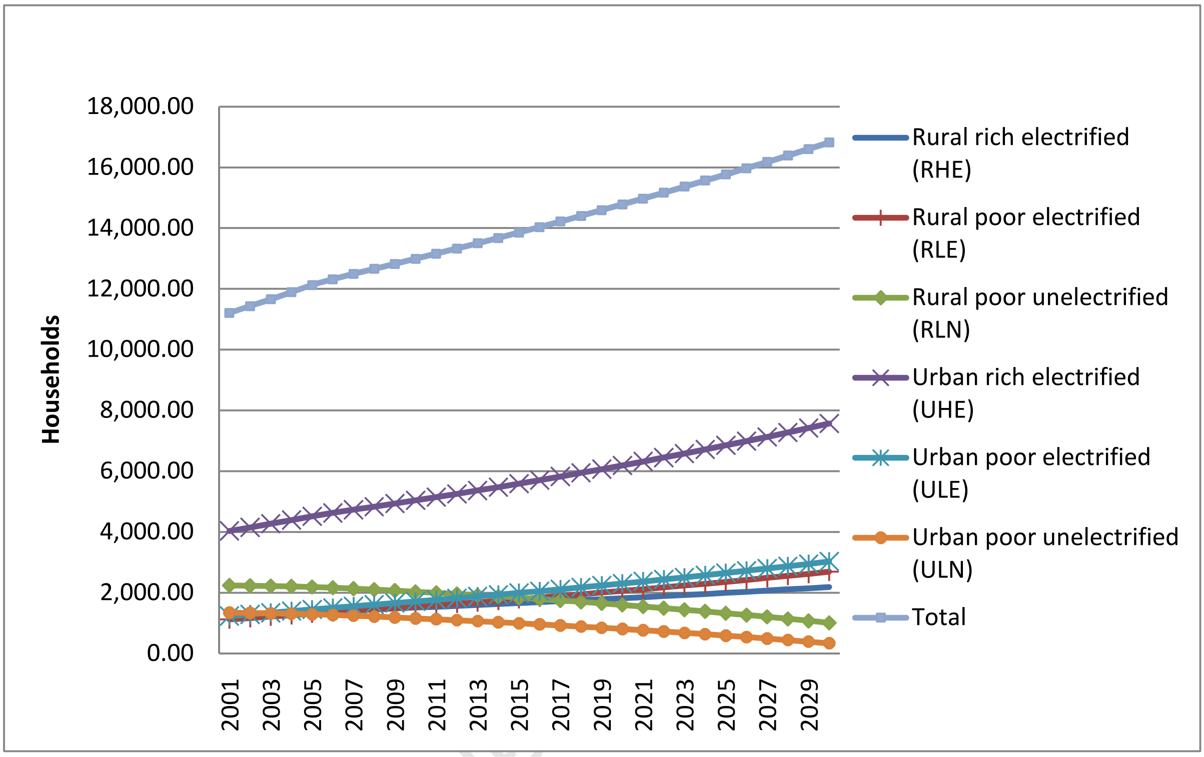


Figure 5.3: Number of Households in Each Subsector

5.8 Energy End Uses

The end use of energy was collected from 2001 census data. The 2001 census gave the total number of households at the time and also the types of fuels that were used for different energy services for different household types.

Five energy end uses commonly used to define South African residential energy consumption are given below:

- Cooking
- Water Heating
- Space Heating
- Lighting

- All other services such as refrigeration, electronic media fall under the category Other. Further classification was deemed unnecessary as national data is not available (Haw, et al., 2007).

The following table shows the final energy intensities for the different households. A more detailed description of the methodology used in calculating energy end use intensities is given in the documentation for the original LEAP model (Haw, et al., 2007).

Table 5.2: Final energy intensities for the different households [PJ/Million households] Source: (Haw, et al., 2007)

HH	***Cooking***	***Water Heating***	***Space Heating***	***Lighting***	***Other***
UHE	6.032	8.098	4.016	1.814	4.115
ULE	2.593	5.855	4.004	2.141	0.115
RHE	2.941	5.422	3.947	3.506	3.7
RLE	2.247	4.512	4.448	1.849	0.094

Table 5.3: Average monthly energy demands for the different households

Household	***Average monthly energy consumption (kWh/HH) (all fuels included)***	***Average monthly electricity consumption kWh/HH in 2030***
UHE	558	523
ULE	340	175
RHE	453	230
RLE	306	33

The difference between energy consumption and electricity consumption shows how much some household groups supplement their energy needs by using other fuels.

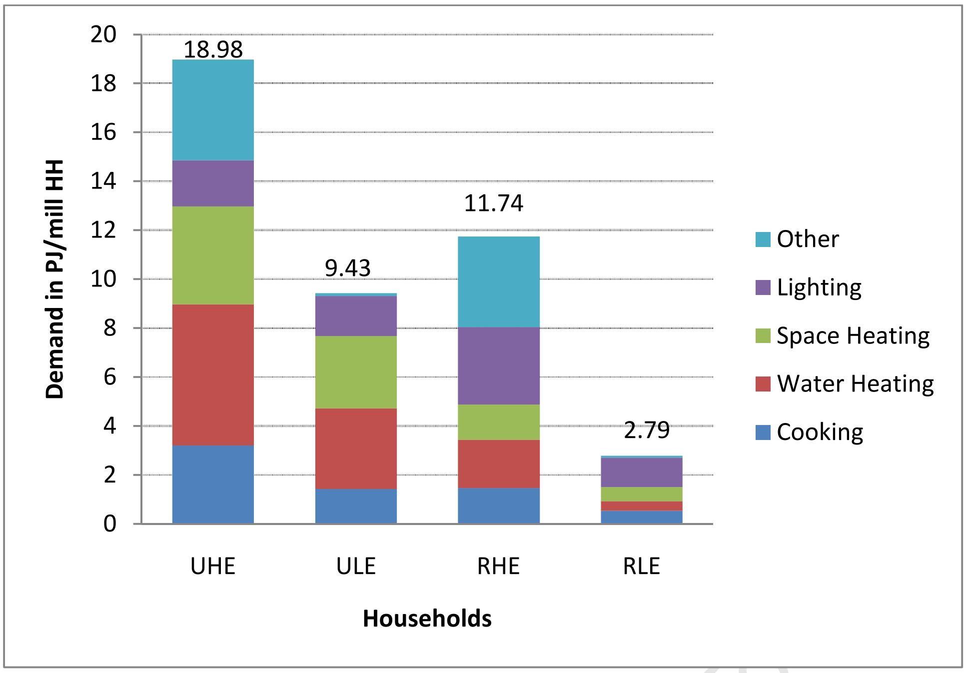


Figure 5.4: Graph showing end use demand for electricity per Million households

5.9 Scenarios

In this section projections of demand are explored for different scenarios using the LEAP modelling tool. The table below shows the scenarios under investigation, the main assumptions and the objective of running each scenario.

Table 5.4: Scenarios under investigation

Scenario	Definitive Assumptions	Illustration
1. Baseline growth without constraint scenario	No government or NGO sponsored Energy Efficiency drives	To show the worst case scenario from which all other scenarios will be compared to.
2. NERSA approved Tariff Hikes from 2010 to 2013	Inherits baseline scenario assumptions and also assumes price elasticity's of demand to tariff hikes	To show that tariff hikes alone will not be enough to reduce demand to the desired levels
3. Energy Efficiency	High penetration of efficient technologies according to (Winkler, 2009). No rebound.	To show the impact of a high penetration of energy efficiency technologies assuming all technical savings are achieved.

4. Rebound	Inherits Energy Efficiency scenario assumptions but with the presence of direct rebound.	To show the impact of a high penetration of energy efficiency technologies assuming rebound exists.
5. Energy Efficiency with Tariff hikes	Inherits the Rebound scenario assumptions but with tariff hikes to mitigate rebound	To illustrate the impact of Energy Efficiency run in conjunction with tariff increments
6. Energy Efficiency with Awareness	Inherits the Rebound scenario assumptions but with awareness campaigns to mitigate rebound	To illustrate the impact of Energy Efficiency run in conjunction with awareness campaigns

The impact of drivers like GDP and tariff prices will be ignored unless explicitly stated. The following segments of this section describe the rationale behind modelling each scenario and also the assumptions used for each scenario. The results will help derive some policy suggestions for effective implementation of energy efficiency initiatives.

5.9.1 Baseline scenario

The baseline scenario represents a growth without constraint scenario. In the baseline scenario, an energy efficiency enabling environment does not exist and minimal penetration rates of energy efficiency technologies are assumed. Technologies under consideration are CFLs, SWHs and geyser blankets. The purpose of the baseline scenario is to show how household electricity consumption would grow given the projections of households when there is no energy efficiency drive implemented by the government or by NGO's. The baseline scenario will be used for comparison to the other scenarios. The penetration rates used in the baseline scenario were taken mainly from (Winkler 2009).

Assumptions

The final energy intensities were assumed to remain constant for the baseline scenario. Also it is assumed that all technical savings for efficiency initiatives were realised and demand is impartial to external drivers like the cost of electricity and GDP. Rebound does not exist for the efficient technologies because it is assumed that the appliances are procured by individual households for the sole purpose of reducing electricity consumption.

Therefore electricity demand was affected by household growth, the shares of the different types of households, appliance efficiency and multiple fuel use.

Table 5.5: Assumed Penetration for CFLs

Source: (Winkler, 2009)

HH	***2001 (%)***	***2013 (%)***	***2030 (%)***
UHE	8	15	17
ULE	1	9	17
RHE	6	11	17
RLE	0	9	17

Water Heating

Although replacing electric geysers with solar water heaters is not really an energy efficiency initiative in the strictest sense but more of a fuel switching initiative, solar energy is for free and effectively reduces the electric demand for heating water. Therefore for modelling purposes, SWH initiatives can be treated the same way as energy efficiency initiatives. The efficiency measure is therefore the amount of electrical energy replaced by solar energy.

The total number of geysers installed in 2005 was between 2 million to 2.9 million with a solar water heater market penetration of about 1.3% in 2003 (Holm, 2005). The baseline assumes a 1.3% market penetration for SWH only for the urban rich and 0% for the other household categories. The above mentioned penetration rates are assumed to remain constant until 2030 for the baseline.

Geyser blankets save about 12% of the electricity used by a conventional geyser. 1% to 3% of households had geyser blankets in 2005 (Winkler, 2009). The table below shows the assumed share of households using geyser blankets and SWH.

Table 5.6: Assumed penetration of households using geyser blankets and SWH

Household	***2030 share of geyser blankets***	***2030 share of SWH***
UHE	10%	1.3%
ULE	4%	0

RHE	10%	0
RLE	8%	0

The following graph illustrates the total amount of electricity consumed between the different households.

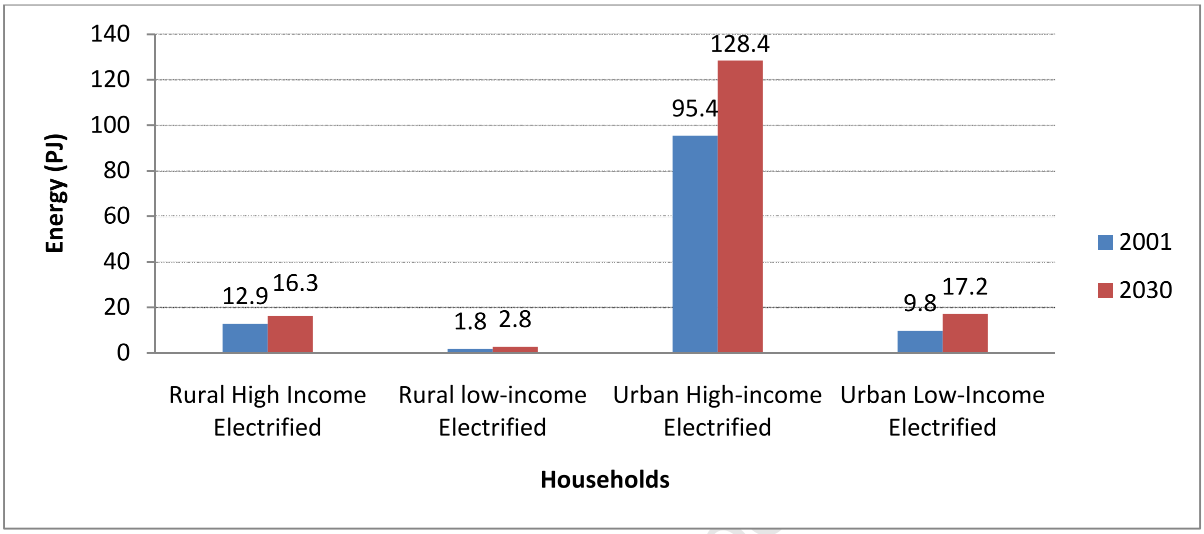


Figure 5.5: Graph showing total electricity consumption for the different household groups

The following graph illustrates the total electricity consumed for different energy services

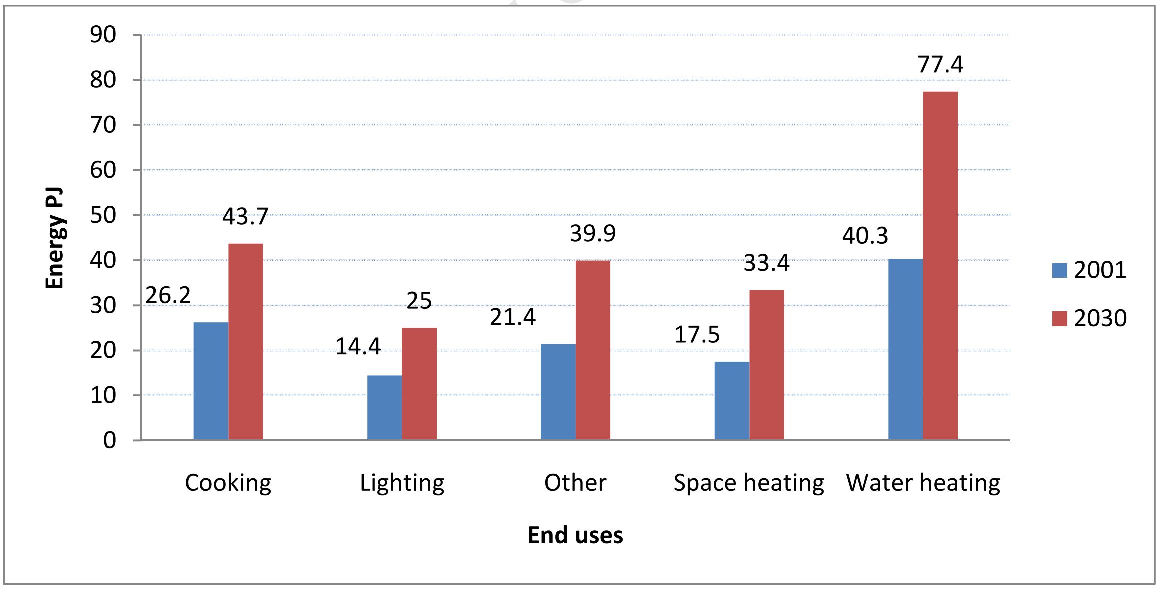


Figure 5.6: Graph showing total electricity consumption by end use

The total calculated demand in 2001 was 119.9PJ and for 2030 the total demand is 219.3PJ. From Figure 5.5 and Figure 5.6, energy efficiency initiatives should be focused on water heating in high income households to yield the most savings.

5.9.2 Tariff hikes scenario

Residential electricity demand is fairly inelastic in South Africa [(Ziramba, 2008), (Maphumulo, 2010)] but the NERSA approved Eskom tariff hikes from 2009 to 2013 are substantial. Below is a table showing the assumed tariff hikes for South Africa.

Table 5.7: Tariff hikes used in the tariff hikes scenario

	2010	***2011***	***2012***	***2013***	***References***
High Income	30.00%	24.80%	25.10%	25.90%	(South Africa Online)
Low income	15.00%	15.00%	15.00%	15.00%	Own assumptions

(Ziramba, 2008) found evidence of a -0.02 short term and a -0.04 long term residential demand elasticity to electricity prices in South Africa. For the Tariff increment scenario, a short term elasticity of -2% (4 years is considered short term) and a long term elasticity of -4% from the baseline scenario were assumed for the above tariff increments.

The tariff increments result in an energy saving of 5.78% from the baseline in 2030. The result illustrates that tariff increments alone might not be enough to reduce demand to the desired levels.

5.9.3 Energy Efficiency Scenario

The energy efficiency scenario tries to illustrate the impacts of achievable penetration rates of CFLs, SWHs and Geyser Blankets according to H Winkler. It is assumed that all technical savings are achieved in the Energy Efficiency scenario and that no additional savings due to awareness or tariff hikes are witnessed.

Table 5.8 Penetration rates of CFLs

Source: (Winkler 2009)

Household	***2013***	***2030***
Urban Rich (UH)	35%	50%
Urban Poor (UL)	20%	40%
Rural Rich (RH)	30%	50%
Rural Poor (RL)	20%	40%

Table 5.9: Table showing penetration rates of Geyser Blankets and SWHs for 2030.

Source: (Winkler, 2009)

Household	***SWH 2030***	***Geyser Blankets 2030***
Urban Rich (UH)	50%	20%
Urban Poor (UL)	30%	20%
Rural Rich (RH)	30%	20%
Rural Poor (RL)	20%	20%

To the authors knowledge, most government funded solar water heaters in low income households have no electrical backing whilst a high income household can chose to buy a solar water heater with electrical backing or a SWH would be used to preheat water before it enters an electrical geyser. Therefore I assume that all high income households with solar water heaters have an auxiliary electrical heating element and low income households with solar heaters have no electrical backing.

It is important to note that more rebound for SWH is expected in the low income households as the fuels saved from the use of SWH might be used for other energy services other than heating water. Literature on indirect rebound effects for water heating was not found. Also the multiple appliance and fuel use of low income households for a certain energy service would make the study of rebound for electricity difficult. Therefore rebound for the solar water heating initiatives was only considered for high income households which was deemed sufficient since electricity consumption for heating water is significantly much more in high income households than in low income households. The following table shows the calculated energy savings when all technical savings are achieved.

Table 5.10: Energy efficiency scenario energy savings from different technological interventions from projected baseline

Technology	*2030 Savings (PJ)*	*2030 savings (%)*	*Cumulative savings from 2010 to 2030 (PJ)*
Solar water heaters (SWH)	25.4	11.55	296.7
Geyser Blankets (GB)	1.1	0.5	12.5
CFLs	7	3.1	93
Energy Efficiency (EE) total	33.2	15.1	402.2

According to the Energy Efficiency scenario, the energy savings in 2030 constitute about 15% of the projected baseline. Since the energy efficiency initiatives mentioned above also cater for services which coincide with the peak, the peak power savings should be greater than the energy savings. A 15% energy saving for the year 2030 is impressive as it is a higher target for electrical energy savings than the 10% that was proposed for 2014 in the Energy Efficiency strategy (although the 15% is accomplished at a later stage).

From Figure 5.6 it is clear that an aggressive solar water heater campaign will yield the most energy savings, given that all technical savings are accomplished.

5.9.4 Rebound Scenario

The rebound effect scenario tries to illustrate the possible loses due to direct rebound on the energy efficiency initiatives under investigation. Empirical evidence of direct rebound from literature was used to explore the impact of the rebound effect.

The table shown below comes from (Greene and Greening 1998) review of over 75 estimates of rebound in literature. They restricted their study to examining the effects of fuel efficiency on a specific energy service rather than on fuel consumption (Greening, et al., 1998).

Table showing rebound estimates used in this study (based on estimates from Greening (1998)

Scenario	***Technology***	***Rebound***
Lighting rebound	CFL	12%
Water Heating	SWH	40%
Water Heating	Geyser Blanket	10%

A higher estimate for rebound for SWH than for geyser blankets was used because higher rebounds are expected when an appliance can save more energy (since rebound is a form of price elasticity it is assumed that a greater reduction in energy service cost will result in higher consumption of energy for that same energy service).

The following table shows the calculated energy savings from energy efficiency initiatives when rebound exists.

Table 5.11: Rebound effect scenario energy savings from different technological interventions from projected baseline

Technology	***2030 Savings (PJ)***	***2030 savings (%)***
Solar water heaters (SWH)	16.8	7.6
Geyser Blankets (GB)	0.9	0.41
CFLs	5.7	2.59
Rebound effect total	23.4	10.64

The following table shows how energy savings can be degraded when rebound exists.

Table 5.12: Loses due to the rebound effect

Rebound	***2030 loses (PJ)***	***2030 loses (%)***	***Cumulative loses from 2001 to 2030 (PJ)***
40% Solar water heater	8.6	26	102.9

10% Geyser Blanket	0.2	0.6	2.9
12% CFL rebound	1.3	3.9	17.6
Rebound total	10.1	30	123

Therefore 30% of the expected savings would be lost through rebound. In the rebound effect scenario, SWHs had high penetration rates and a very high rebound and so there was much leakage of savings (26% of the expected savings) for the SWH programme. The cumulative loses not only show how rebound affects energy security by increasing the consumption of South Africa's resources but also the possible environmental impacts through the continued use of fossil fuels to generate electricity. The results stress the need for interventions which reduce the impact of the rebound effect.

It should be noted that the results are dependant on rebound estimates taken from developing countries. Therefore it is possible that the estimates do not reflect rebound in the South African context. The study is meant to illustrate the possible effects of rebound based on empirical evidence found in literature.

5.9.5 Impact of price interventions on energy efficiency initiatives

This scenario illustrates the impact of a price intervention on an energy efficiency initiative. Tariff hikes or energy taxes reduce the amount of financial gains from energy efficiency interventions therefore limiting the amount of funds that might have been recycled back into more energy consumption. Therefore price interventions (tariff hikes or energy taxes) have the potential of negating the rebound effect.

Based on Davis (2010) study of the rebound effect, the level of rebound decreases considerably when a tariff increment of 10% is imposed concurrently with efficiency initiatives. The rebound effect might not be totally negated but almost all technical savings can be achieved. Based on Davis (2010), new rebound figures were calculated using the equation below.

$$\frac{\text{Unmitigated rebound (Davis 2010)}}{\text{Mitigated rebound (Davis 2010)}} = \frac{\text{Unmitigated rebound (Greening 1998)}}{\text{Mitigated rebound}}$$

$$\text{Mitigated rebound} = \frac{\text{Mitigated rebound (Davis 2010)} * \text{Unmitigated rebound (Greening 1998)}}{\text{Unmitigated rebound (Davis 2010)}}$$

The following table shows some of the results from Davis 2010 simulations of the effect of interventions on energy consumption.

Table 5.13: Savings after different interventions

Source: (Davis 2010)

	Low income (No environmental concern)	High income (No environmental concern)
10% Efficiency intervention	3.2%	7.2%
10% Efficiency intervention + 10% price intervention	9.4%	9.7%

The following table shows the rebound figures for the different efficiency initiatives.

Table 5.14: Table showing rebound estimates used in the Energy Efficiency + price intervention scenario

Scenario	***Technology***	***Rebound***
Lighting rebound low income	CFL	1.1%
Lighting rebound high income	CFL	1.3%
Water Heating	SWH	4.3%
Water Heating	Geyser Blanket	1.1%

The following table illustrates the resulting energy savings when an energy efficiency initiative is run concurrently with a price intervention.

Table 5.15: Energy Efficiency + price intervention energy savings

	2030 Energy savings	***2030 Energy savings***
Total energy savings when compared to the baseline	30.5PJ	13.87%

The following table shows the resulting energy loses due to rebound when an energy efficiency initiative is run concurrently with a price intervention

Table 5.16: Loses due to the rebound effect for the Energy Efficiency + price intervention scenario

	2030 Energy loses	***2030 Energy loses***
Total energy loses when compared to the energy efficiency scenario	2.7PJ	8.1325%

From the results, rebound was greatly reduced from 30% to 8.13% due to the 10% tariff hike. It should be noted that findings from this scenario are based on the strong assumptions used in Davis (2010) calculations on the impacts of different interventions on residential electricity consumption using a systems dynamics model.

5.9.6 Impact of raised awareness on energy efficiency initiatives

This scenario illustrates the impact of energy efficiency and raised awareness. If energy efficiency initiatives are carried out together with awareness campaigns, it is possible to anticipate even more energy savings than one would expect from efficiency initiatives alone. The Department of Minerals and Energy stated in the Energy Efficiency Strategy that major energy savings can only be achieved through changes in people's behaviour and that depends on informing them on what options exists (DME, 2005). Davis (2010) systems dynamics model illustrates the impact of raised awareness on energy efficiency initiatives. Awareness relates to user feedback on the cost of using electricity and the impact of using electricity on the environment and/or economy. The following table shows some results from Davis (2010) systems dynamics model simulation.

Table 5.17: Savings after different interventions

Source: (Davis 2010)

	Low income (No environ-mental concern)	*High income (No environ-mental concern)*
10% Efficiency intervention + information on cost	6.4%	9.7%
10% Efficiency intervention + information on impact	11.6%	14.1%

From the above results, it is possible to anticipate more than just the technical savings when awareness about the impact of consuming electricity on the environment/economy is raised because of positive behavioural changes.

Assumptions used in the Municipal Electricity Efficiency tool developed by (Sustainable Energy Africa) were used to estimate potential savings from behavioural changes due to raised awareness on not only energy efficiency but also the energy situation in South Africa.

Table 5.18: Assumed energy intensity drops for lighting and water heating due to raised awareness on energy maters.

Energy Service	*Behavioural Changes*	*Reduction in energy intensity*
Lighting	Efficient use of lights	10%
Water Heating	10^{o}C thermostat reduction	6%

The table below illustrates the impact when energy efficiency initiatives are run concurrently with awareness campaigns.

Table 5.19: Energy Efficiency + Awareness campaigns energy savings

	2030 Energy savings	*2030 Energy savings*
Total energy savings when compared to the baseline	38.1PJ	17%

5.10 Results

Table 5.20: Comparison of the different scenarios.

Scenario	*2015 savings (%)*	*Cumulative Savings [2010 to 2030] (PJ)*	*End Year Energy Savings (PJ)*	*End year Energy Savings (%)*
Tariff Hikes	4.09	189.1	12.7	5.78
Energy Efficiency without rebound	7.5	397.6	33.2	15.0978
Energy Efficiency with Rebound	5.13	274.6	23.1	10.5048
Energy Efficiency and price interventions	5.5	290.4	24.3	11
Energy Efficiency and raised Awareness	8.5	454	38.1	17

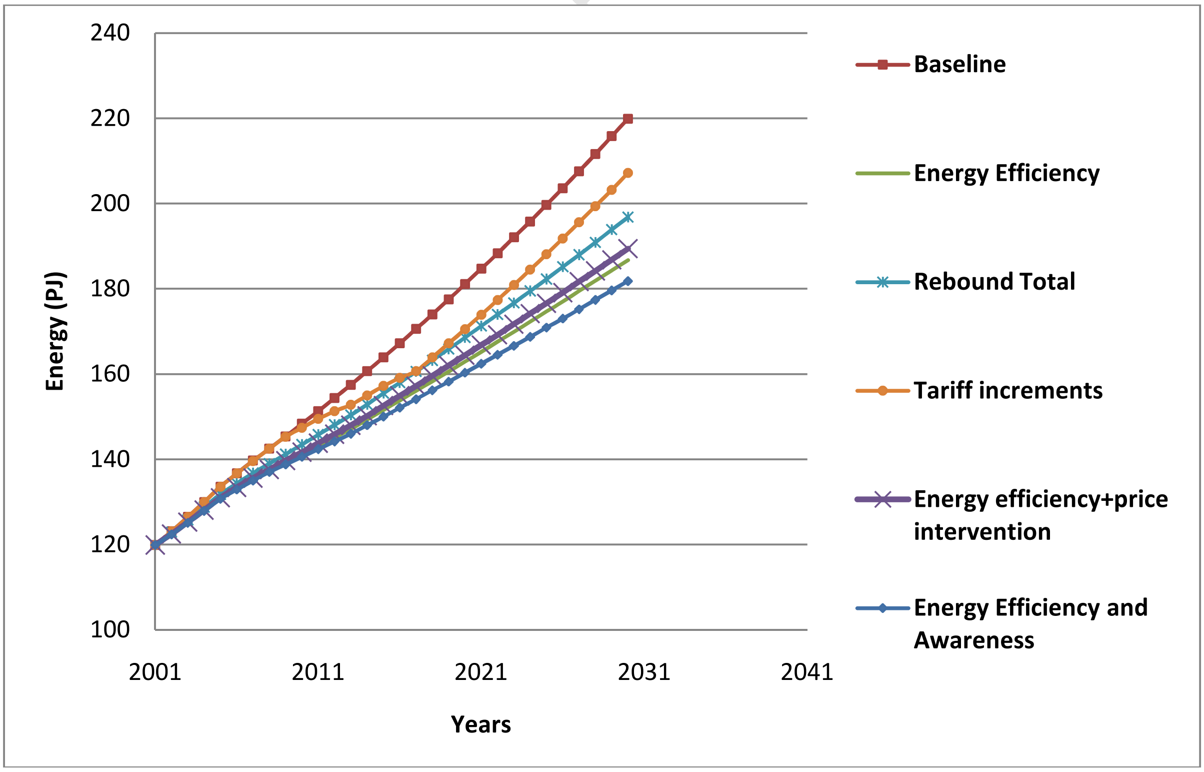


Figure 5.7: Shows a comparison between the scenarios

5.10.1 Discussion on results

Since all the scenarios run in this study do not reach the 10% target by 2015 which was proposed by the DME through the Energy Efficiency strategy, comparisons of the scenarios will be carried out for the year 2030. In this report the 10% target is extended for the year 2030.

- The tariffs approved by NERSA can potentially make an energy saving of 5.7% in 2030 which is below the 10% target and necessitates other interventions.
- If the suggested efficiency initiatives are implemented and all technological savings are achieved, a saving of approximately 15% from the projected baseline can be anticipated which is above the 10% target. However, if rebound is included the savings are just above 10% for the year 2030.
- The suggested energy efficiency targets are achievable but still quite optimistic as they are based on the highest penetration rates in the world (mainly in first world countries like Germany). This means that if the impacts of rebound are disregarded and such optimistic penetration rates are not achieved then the 10% electricity reduction in the residential sector might not be achieved.
- From the results, when efficiency interventions are run concurrently with tariff hikes, it is possible to mitigate the rebound effect but because demand is fairly inelastic to price signals, tariff hikes might not be enough to completely negate rebound.
- The positive behavioural changes caused by raised awareness can possibly negate the rebound effect as more savings can come out of the added behavioural changes. It should be noted that although increased savings due to raised awareness are a possible outcome, literature to support the finding was not found although simulations from Davis (2010) suggest it is possible.
- A scenario combining efficiency, price and awareness interventions was not carried out because such a scenario would depend on too many factors which would necessitate the need for strong untested assumptions. It is logical however to expect more savings when all three interventions are carried out simultaneously than when they are carried out individually.
- It is therefore recommended that awareness campaigns be carried out concurrently with efficiency initiatives and also any cost savings from efficiency gains be taxed away by the government in order to avoid rebound.

6 CONCLUSIONS

In this chapter recommendations based on the literature review given in this study and results from the LEAP modelling will be presented. Limitations of the study and recommendations for future work will be given followed by policy suggestions based on the findings of this study.

6.1 Limitations of the approach and future work

- The modelling done in this study aims to illustrate possible futures due to different interventions. Therefore it is not descriptive of the future but illustrates possible outcomes of different initiatives. The impact of for example raised awareness on a dynamic system such as residential electricity consumption is difficult to quantify as such a factor would be difficult to separate and study individually. Hence often strong assumptions based on untested hypothesis were used in order to illustrate an idea. Therefore there is a possibility that some of the findings in this report might turn out to be inaccurate in reality.
- Rebound figures were based on studies done in developed countries. Rebound is generally expected to be higher in developing countries therefore caution should be taken regarding the estimated rebound loses in these scenarios. Therefore empirical evidence of rebound should be gathered from South Africa.
- The results depend on the assumptions used for the baseline study. There is a general lack of household end-use data to accurately portray the sector. Therefore it is recommended that an updated baseline scenario which captures the current status of the residential energy sector be made out of the 2011 census data. Data on the current progress of energy efficiency initiatives is not readily accessible to the public. Therefore an accurate portrayal of the current situation of the energy efficiency situation in South Africa was challenging and could not be achieved.
- Although the DME has set its energy efficiency targets for the year 2015, it is not clear how they aim to achieve this exactly since specific targets for different technologies are not stated for the purpose of specifically meeting the target. The author failed to locate a document which tracks the progress of energy efficiency programmes in meeting the goals set in the Energy Efficiency strategy. The

penetration rates of energy technologies used in the forecasting carried out in this study appear to be optimistic compared to the current rates of procurement.

- Some methods of procurement will need continued support from the local governments and municipalities implementing energy efficiency initiatives and so some methods are more sustainable than others. Also different penetration rates and rebound effects can be expected for the different methods of procurement. It is recommended that cost optimisation be carried out to find the most cost effective methods of meeting the 10% reduction in residential consumption using various energy efficiency technologies.

6.2 Policy Suggestions

6.2.1 Creating an Enabling Environment

Approach:

- Tariff increments
- Environmental taxes on generation of electricity by fossil fuels

Motivations:

- So as to include externalities which are often neglected in the pricing of energy like pollution and the use of water for generation.
- So that technological savings and potential cost benefits from an energy efficiency investment can be realised.
- To discourage reinvestment of monetary savings due to efficiency initiatives into more consumption of energy.
- To provide funds for efficiency initiatives.

6.2.2 Financial Instruments

Approach:

- Subsidy schemes
- Excluding VAT on efficient products
- Offering soft loans
- Integrating energy efficiency with other developmental programmes like the RDP.

Motivations:

- To make efficient technologies more affordable and more competitive with traditional products on the market by reducing the lifetime costs of the products for the consumers.

6.2.3 Raising Awareness

Approach:

- Implementing mandatory standards, appliance labelling and advertisement.
- Community engagement programmes like promotional competitions.
- Including energy efficiency the primary, secondary and relevant tertiary curriculums.
- Leading by example by implementing efficiency programmes in government buildings like schools and hospitals and making the results publicly available.
- Setting mandatory building standards.

Motivations:

- To ensure a culture of energy efficiency and to create an energy efficiency consciousness.

6.2.4 Measurement and Verification

Approach:

- Independent institutions should conduct surveys and take meter readings before and after an energy efficiency programme.

Motivations:

- To ensure consumer satisfaction.
- To identify possible failures of an intervention and to implement mitigative measures for future programs.
- To implement measures which reduce the rebound effect and to entrench confidence in energy efficiency.
- To validate projects for CDM funding.

6.3 Conclusions

This section concludes the report and iterates the main findings of this study.

The use of modern energies in developing communities in South Africa has always been lower than what was intended. This is mainly due to the fact that developing communities find the cost of utilising electricity prohibitive (both the cost of the electrical appliances and the tariff prices). Therefore the electrification programme might be deemed incomplete as it does not adequately address the problems of energy poverty. The roll-out of efficient technologies provides developing communities with the technologies to gain access to some energy services in a more convenient manner at relatively lower costs. Since latent demand exists in developing communities, some level of rebound should be expected. Therefore rebound is not necessarily a bad phenomenon since it might be an indicator of improved welfare because of the increased comfort levels and economic growth because of increased activity. The purpose of this study was not to discredit the importance of energy efficiency initiatives if rebound exists, but to illustrate the impacts of the rebound effects and to suggest possible measures to mitigate rebound since the main goal of efficiency initiatives in South Africa is to reduce the consumption of electricity.

Therefore an understanding of how households respond to efficiency initiatives is essential but none the less, energy efficiency should be entrenched in households as it leads to sustainable development. For maximum energy savings energy efficiency initiatives should be run alongside price interventions and awareness campaigns.

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