1 GENERAL INTRODUCTION

1.1 Introduction

Electricity is defined as "... a form of energy from charged elementary particles, usually supplied as electric current through cables, wires, etc. for lighting, heating, driving machines, etc." (Oxford Advanced Learners' Dictionary, 2005).

Electricity is a low value yet necessary good within any economy and is one of the pillars of economic and social development (Blignaut, 2009). The generation, supply and distribution of electricity have the potential to unlock economic development.

Electricity consumption in South Africa has increased significantly over the past decade. The bulk of the country's greenhouse gas emissions (more than 60%) originate from the electricity generation sector which is heavily depended on coal-fired power stations (Blignaut, Mabugu, & Chitiga-Mabugu, 2005). Hence, the unprecedented rise in consumption has created serious concerns regarding the environmental effects, including higher CO_2-emissions as a result of the increased combustion of coal.

As a result, South Africa took the bold step at the beginning of 2010 to commit itself to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) in taking all the necessary actions to decrease the country's greenhouse gas emissions by 34% to below the "business-as-usual" scenario by 2020 (Republic of South Africa, 2010) .

In response to the international and local commitment for improvement of greenhouse gas emissions, global energy consumers have shown interest in switching from traditional forms of energy to renewable, cleaner ones and thereby improving the energy use and its detrimental effects on the environment.

This study will show that South Africa has the potential to follow the international trends and improve the current situation of electricity consumption taking into consideration the production capacity of the economy.

1.2 Problem statement

Over the past two decades, South Africa has undergone major political, social and economic changes. As a developing country on a path towards high and sustainable growth, it has experienced critical energy issues. The mismatch of the supply and the increasing demand resulted in the recent electricity crisis in 2008, affecting the whole economy considerably.

Since the country's democratisation, the local energy authorities have mainly focused their efforts on the increase of electricity supply by expanding the current electricity production rather than focusing on demand-side management. However, from an environmental point of view, the greater production of electricity will result in higher emissions of greenhouse gases, especially CO_2, due to the fact that electricity generation in South Africa depends mainly on coal-burning.

However, targeting the reduction of electricity consumption might prove detrimental to the economic output of the country. Major electricity consumers might prefer to decrease their output in order to comply with the rules and regulations focusing on the reduction of electricity usage.

International literature has shown that focusing on an indicator that takes into consideration both economic output and electricity usage is preferred. Hence, energy policy-makers should focus on the energy efficiency (intensity) of the economy not only on an aggregate level but also on a sectoral level.

This study proposes a solution that promotes demand-side management towards the improvement of electricity efficiency in South Africa. In order to do so, it is required to analyse the electricity consumption and efficiency of the South African economy in its entirety as well as in the various sectors. The mechanism that will finally be proposed is an electricity efficiency benchmark-and-trade system.

This system will encourage particularly the most electricity-intensive sectors to save electricity in order to avoid the cost-related and environmental consequences from the extensive use of electricity. The fundamental principles of such a benchmark-and-trade system would be based on the programmes related to air pollution, but applied to energy efficiency. According to the Environmental Protection Agency (EPA) (Environmental Protection Agency, 2008), a cap-and-trade system against the air pollution is "… a market-based policy tool for protecting human health and the environment". The idea of trading energy was first tried in the 1970s with trade of pollutants, such as sulphur dioxide and nitrous oxide, to combat acid rain. Moreover, the European Union used trading of carbon to reduce greenhouse gas emissions (BBC News, 2006).

The uniqueness of this study is two-fold. First, South African policy-makers have never proposed or discussed the implementation of a cap-and-trade system. Second, this system has never been proposed for the case of electricity efficiency.

1.3 Objectives of this study

The main objective of this study is to develop and design a market-based solution for the electricity efficiency in the South African economy. This may provide a long-term solution for the major electricity problems in the country. In order to do so, a thorough analysis of the behaviour of the economy in its entirety but also at a sectoral level is required.

The following specific objectives will guide this study:

- To conduct an extensive local and international literature review on electricity efficiency related matters
- To examine and analyse the South African electricity sector and its unique characteristics
- To estimate the sensitivity of the economy's and the different consumers' electricity demand to price changes over time
- To examine the role of electricity efficiency in the evolution of the country's electricity consumption and investigate how significant the role of the structure of the economy is

- To compare the country's total and sectoral electricity intensities with a group of developing and developed economies in order to conclude if South Africa is following international standards
- To design the proposed electricity efficiency benchmark-and-trade system, and make recommendations on how this market should be regulated and what the limits of the intervention should be in order for this market to be considered successful.

1.4 Structure of this study

The rest of this study is organised as follows:

Chapter 2 deals with the essential literature on energy efficiency matters, the specific case of South Africa and cap-and-trade systems. Section 2.1 focuses on the South African electricity sector. It presents the key players and the evolution of their roles and responsibilities during the last two decades, as well as the policies and regulations that are in place. Finally, the status quo is illustrated by presenting data and information on current electricity consumption and prices.

Section 2.2 provides information on the definition of energy (electricity) efficiency and intensity. It also evaluates the importance of the specific indicator and the different ways of measurement. Finally it concludes with discussing international and local efforts towards the improvement of efficiency.

Section 2.3 describes the fundamentals of a cap-and-trade system and discusses international applications. Subsequently, the system is assessed and its strong and weak points are presented.

Chapter 3 deals with the empirical evidence that led to the proposed model. Section 3.1 discusses the aggregate price elasticity of electricity demand in South Africa. The Kalman filter, an econometric technique, is employed in order to estimate the evolution of the sensitivity of electricity consumption to changes in price and output.

Section 3.2 analyses price elasticity in a disaggregated level. By using panel data techniques, the different behavioural responses of a number of economic sectors to changes in the sector-specific prices and output are shown.

Section 3.3 employs a decomposition analysis to examine the role of the changes in the structure of the economy, electricity efficiency and output with the increasing trend of electricity consumption of the country both at aggregate and sectoral level.

Section 3.4 provides a comparative analysis of the total and sectoral electricity intensities of South Africa to the OECD countries, taking into account dissimilar output structure of the various sectors.

Chapter 4 presents the proposed benchmark-and-trade system in order to improve the picture of electricity efficiency in South Africa. Section 4.1 explains in detail the theoretical mechanisms as well as the policy implications of the system for the country. It also discusses the economic and environmental benefits of the system and then compares it with the current basic alternative, the carbon tax.

Finally, Chapters 5 provides a general conclusion of this study. Section 5.1 synthesises the main points of the study and Section 5.2 restates the objectives, summarises the key findings and the proposed system, and provides policy implications. Section 5.3 proposes future research paths resulting this study.

2 LITERATURE REVIEW

Before proceeding to the analysis of the dissertation, it is imperative to provide information specifically on a) the South African electricity sector, its key players, policies and regulations, as well as the evolution of electricity consumption and price (Section 2.1); b) the definition of energy (electricity) efficiency and intensity, its importance and measurement, and international and local efforts towards its improvement (Section 2.2); and c) the implementation of cap-and-trade systems internationally as well as their advantages and disadvantages (Section 2.3).

2.1 Electricity profile: the South African case

The South African electricity sector has been characterised through the years by unique traits and it has passed through different phases where various key players had dissimilar responsibilities. In this section, the main phases as well as the key players and their roles in each phase are analysed. This is followed by a discussion on the evolution of policies and regulations regarding electricity through the years, as well as consumption and prices.

2.1.1 Electricity regulation and institutions

2.1.1.1 National Energy Regulator South Africa (NERSA)

Before the 1990s, regulators had limited power in the decision regarding electricity price-setting. However, the situation has changed since the establishment of the post-apartheid National Electricity Regulator (NER) and we turn to that next.

In order to establish a national regulatory framework for the electricity supply industry, the South African Government published the first Electricity Act in 1987 (RSA, 1987). With this Act the Electricity Control Board and the NER were established and the Act's main objectives were to:

a) "Achieve the efficient, effective, sustainable and orderly development and operation of electricity supply infrastructure in South Africa;

b) Ensure that the interests and needs of present and future electricity customers and end-users are safeguarded and met, having regard to the governance, efficiency, effectiveness and long-term sustainability of the electricity supply industry within the broader context of economic energy regulation in the Republic;

c) Facilitate investment in the electricity supply industry;

d) Facilitate universal access to electricity;

e) Promote the use of diverse energy sources and energy efficiency;

f) Promote competitiveness and customer and end-user choice; and

g) Facilitate a fair balance between the interests of customers and end-users, licensees, investors in the electricity supply industry and the public" (RSA, 1987)

According to the Act, the responsibilities and duties of the Regulator are now specified. The Regulator must:

a) "Consider applications for licences and may issue licences for the operation of generation, transmission and distribution facilities and for trading of electricity;

b) Regulate prices and tariffs;

c) Register persons who are required to register with the Regulator where they are not required to hold a licence;

d) Issue rules designed to implement the national government's electricity policy framework, the integrated resource plan and this Act;

e) Establish and manage monitoring and information systems and a national information system and co-ordinate the integration thereof with other relevant information systems;

f) Enforce performance and compliance, and take appropriate steps in the case of non-performance" (RSA, 1987).

In terms of the National Energy Regulator Act, 2004 (RSA, 2004), NERSA was established with the mandate to carry out the functions of the Gas Regulator, the Petroleum Pipelines Regulatory Authority as well as NERSA. NERSA's mission is "… to regulate the energy industry in accordance with government laws, policies, standards and international best practices in support of sustainable development" (RSA, 2004) and its main strategic objectives are as follows (National Energy Regulator, n.d.):

- "To implement relevant energy policy efficiently and effectively;
- To implement relevant energy law efficiently and effectively;

- To implement relevant energy regulations efficiently and effectively;

- To identify, develop and implement relevant energy rules efficiently and effectively;

- To establish the credibility, legitimacy and sustainability of NERSA as an independent and transparent energy regulator;

- To create an effective organisation that delivers on its mandate and purpose; and

- To evaluate the Energy Regulator's effectiveness" (National Energy Regulator, n.d.).

More specifically, "[u]tilities such as Eskom, Sasol, etc. cannot increase their regulated rates or alter their conditions of service until NERSA approves the new tariffs. To obtain approval, a utility must demonstrate that such a change is merited. The utility files an application with NERSA to 'prove' that an increase is justified. The advocacy role requires that there must be an independent body to represent the side of the consumers during the tariff determination, especially the voiceless consumers" (National Energy Regulator, n.d.).

Marquard (2006) also mentions that NER (now NERSA) played an important role in the distribution tariffs regulation and the launch of a Wholesale Electricity Tariff pricing system, as well as in the assistance and monitoring of the electrification programme.

2.1.1.2 Policies and regulations

Following the political restructuring in 1994 and the transition to democracy, the country started an initiative to eliminate inequalities and to provide electricity to the majority of the population. In 1994, the newly-elected government commenced discussions for a *White Paper on Energy Policy* which was finally released in 1998. Firstly, there was a need for a formal description of the South African energy sector both from a demand and a supply perspective.

From the demand perspective, the status quo is usually analysed in terms of energy needs and usage of households, industry, the commercial sector, mining, transport and agriculture. Regarding the supply, sub-sectors included for analysis are coal, electricity, nuclear, liquid fuels, gas and renewable forms of energy.

The *White Paper on Energy Policy* also specifies the cross-cutting issues for the future of the energy sector:

a) *Integrated energy planning:* the need for technical functions in order to achieve maximum success of energy policies.

b) *Statistics and information:* the need for a database covering numerous areas and provision of information by the government.

c) *Energy efficiency:* the need for energy efficiency consciousness in all aspects of economic activity by establishing energy efficiency standards for commercial buildings and industrial equipment. Government will promote improved appliances for wood and traditional fuels and it will set, monitor and evaluate targets for industrial and commercial energy efficiency improvements.

d) *Environment, health and safety:* the present and future energy policies need to take into account the environmental and health effects and provide solutions for the problems caused by energy use.

e) *Research and development:* appropriate research by government, the private sector and universities is essential.

f) *Human resources:* an attempt for further development of the human resources in the sector is needed.

g) *Capacity-building, education and information dissemination:* there is a need for government's support in the mentioned topics.

h) *International energy trade and co-operation:* possible reduction of trade barriers, facilitation of regional co-operation, and establishment of relationships with energy players internationally.

i) *Fiscal and pricing issues:* the need for alignment of fiscal and energy policies.

j) *Governance and institutional capacities.*

With the rapid electrification programme, the main electricity supplier (Eskom) and the new government made an effort to supply electricity to the majority of households, especially in the undeveloped rural areas. In 2001, the Free Basic Electricity policy (FBE) was introduced by Eskom following suggestions made by the Department of Minerals and Energy (DME).

The government argued that ''conventionally, the average poor household does not consume more than 50kWh of electricity per month" (Bureau of African Affairs, 2010) and therefore, this amount was to be offered free of charge. Additionally, it is difficult to determine a baseline as to who is poor and thus qualifies for this subsidy. That is why the subsidy became available to all consumers regardless of their income levels.

However, some questions were raised regarding the FBE. UCT (2003) argues that the FBE does not succeed in one of the main goals: the reduction of income disparities on household energy use. The main reasons is that the recipients of FBE do not fully comprehend the programme and the "... vendors are unwilling to supply the recipients with FBE credits without some form of compensation" (Bekker, Eberhard, & Marquard, 2008). Furthermore, Howells et al. (2006) worry whether low-income households have the necessary information and incentives to completely change their energy use from LPG or methane which is affordable, clean and easy to use, to electricity.

2.1.2 Electricity supply

According to Marquard (2006), the South African electricity system experienced three main phases. Phase one (late 19th century to 1900s), was characterised by the existence of small electricity systems set up by local authorities in cities and relatively bigger electricity systems that were set up by self-producers (mainly mines). Phase two (late 1900s till early 1920s) started with the development of an electricity generation monopoly in the Witwatersrand for the provision of electricity and compressed air to the gold-mining industry, namely the Victoria Falls and Transvaal Power Company (VFTPC). The third phase (from the early 1920s till today) started with the establishment of the state utility, Escom (now Eskom), which primarily aspired to produce bulk electricity and sell it to the local authorities, the railways and the mines. Eskom also had an agreement of co-existence with VFTPC that ended in the late 1940s (Marquard, 2006). The years following that can also be characterised as a new phase because the electricity system saw the transition towards an integrated national system, with Eskom being the generator, transmitter and main distributor of electricity.

Taking the above into account, there are two main role players in the development of the South African electricity system: a) Eskom and b) the local government. During the last couple of years, NERSA also found its place in the structure of the South African electricity system. Moreover, South Africa also trades electricity with mainly the Southern African Power Pool (SAPP) member countries.

Before analysing the key role players of the South African electricity market, selected electricity supply statistics are presented in Table 2.1 for 1992–2006. These figures show that the domestic supply increased slightly during the study period. However, the maximum generation capacity has a ceiling due to the existing electricity generation infrastructure. The need for new generation infrastructure in order to boost the current one and also to replace some of the older power stations is supported the last decade. However, the reasons for not building new capacity are mainly political and economic, and not reasons of questioning the necessity.

Table 2.1 Selected electricity supply statistics in South Africa: 1992–2006

	GWh				GW
	Indigenous production	**Imports**	**Exports**	**Domestic supply**	**Net maximum capacity**
1992	167,816	334	1,814	166,336	36.846
1993	174,581	100	2,589	172,092	37.636
1994	182,452	54	2,679	179,827	35.926
1995	187,825	149	3,000	184,974	35.951
1996	200,266	29	5,579	194,716	36.563
1997	210,052	5	6,617	203,440	37.175
1998	205,374	2,375	4,532	203,217	37.848
1999	203,012	6,673	4,266	205,419	38.517
2000	210,363	4,719	4,007	211,075	39.186
2001	197,908	9,200	6,996	200,112	39.810
2002	206,105	9,496	7,242	208,359	39.810
2003	221,642	8,194	10,263	219,573	39.810
2004	234,045	9,818	13,254	230,609	38.436
2005	230,024	11,079	13,422	227,681	38.644
2006	240,964	10,624	13,589	237,999	39.271

Source: (DME, 2010a)

2.1.2.1 Local government

From the start, the institutional development of the electricity system did not allow for an extended role by the local authorities although they were supposed to be the first suppliers of electricity.

Table 2.2 Gross energy sent out (GWh) in 2005

	Total	Eskom	Municipalities	Private
Gross energy	230,303	221,895	1,203	7,115
Ratio to total	100%	96.35%	0.52%	3.10%

Source: National Energy Regulator, n.d.

In 1940, only 25% of the local authorities bought electricity from Eskom or other private suppliers (DCGIS, 1940) and this percentage declined during the following years, until 2005 the local authorities produced only 0.6% of total electricity (National Energy Regulator, 2005), as shown in Table 2.2. This decrease was partially enforced by policies that allowed only Eskom to build new electricity generation plants.

2.1.2.2 Eskom

The state-owned company known as the Electricity Supply Commission (Escom) – later Eskom – was established in 1922 in terms of the 1922 Electricity Act and started its operations in 1923. Its initial responsibility was two-fold: a) to supply electricity anywhere in the country that it was needed, acting as the national electricity supplier; and b) to assist the local authorities in their electricity development plans, acting as a government unit to promote electrification.

Eskom's primary objective, as re-stated in the *1984 Annual Report* (Eskom, 1984, p. 8) was ".... to provide an adequate supply of electricity, at cost price, to be used for the economic advancement of South Africa". However, since the 1980s and towards the political transition of the country, Eskom acquired a second role. This role was to provide equal distribution of electricity for all. To do so, Eskom launched a new electrification programme which main objectives included providing electricity to poor black households and the development of a larger national grid.

During this initial period of existence (1923–1985), Eskom was governed by the Electricity Supply Commission. From 1985 until 2001, it was governed by a Management Board and an Electricity Council and their responsibilities were specified by the Electricity Amendment Act (50/1985). Since 2002, Eskom is being managed by a typical corporate governance structure.

As with any other state-owned enterprise, Eskom has been supervised by a number of government departments throughout the years:

- Department of Mines and Industry (until the 1930s)
- Department of Commerce and Industry (until the 1960s)
- Department of Industry (until 1980)
- Department of Mineral and Energy Affairs (until the end of 1980s)
- Office of Public Enterprise (OPE) (until 1994)
- Department of Mineral and Energy Affairs – now Department of Energy – for electricity policy matters, and the Department of Public Enterprises as its principle shareholder (to present)

The country’s economic growth, industrialisation and the electrification programme resulted in high levels of demand for electricity. This in combination with the limited supply, led to countrywide power outages in 2008 that had a significant negative impact on the entire economy. Eskom was responsible, as the national electricity supplier, for managing the situation and focused on demand-side management

(DSM) and an energy efficiency programme in the short-run, while planning to maintain and expand the current infrastructure in the long-run.

Table 2.3 Generation power plants (Eskom)

Power plant	Type	Location	Capacity (GW)
Acacia	Gas	Western Cape	0.171
Ankerlig	Gas	Western Cape	1.338
Arnot	Coal	Mpumalanga	2.352
Camden	Coal	Mpumalanga	1.520
Drakensberg	Pumped storage	KwaZulu-Natal	1.000
Duvha	Coal	Mpumalanga	3.600
Gariep	Hydro	Free State	0.360
Gourikwa	Gas	Western Cape	0.746
Grootvlei	Coal	Mpumalanga	1.200
Hendrina	Coal	Mpumalanga	1.965
Kendal	Coal	Mpumalanga	4.116
Klipheuwel	Wind	Western Cape	0.003
Koeberg	Nuclear	Western Cape	1.930
Komati	Coal	Mpumalanga	0.940
Kriel	Coal	Mpumalanga	3.000
Lethabo	Coal	Free State	3.708
Majuba	Coal	Mpumalanga	4.110
Matimba	Coal	Northern Cape	3.990
Matla	Coal	Mpumalanga	3.600
Palmiet	Pumped storage	Western Cape	0.400
Port Rex	Gas	Eastern Cape	0.171
Tutuka	Coal	Mpumalanga	3.654
Vanderkloof	Hydro	Northern Cape	0.240

Source: (Eskom, 2010)

The current installed capacity per existing power plant presented in Table 2.3, shows that the maximum electricity generated cannot be exceeded in the short-run.

Eskom plans to build new power plants in a five-year period (ending 2013) enabling them to cover the difference between the demand and the supply of electricity (DME, 2010a) focusing more on the long-run increase of the electricity supply.

The previous building programme includes four new power plants (Kusile, 4,800MW; Medupi, 4,800MW; Ingula, 1,332MW; Sere wind-farm, 100MW) that will boost the electricity supply to the country. A new project has also been launched in Botswana: a coal-fired power plant with a capacity of up to 4,800MW. Moreover, it is also necessary to upgrade the older plants, hence the electricity entity's intermediate plans, known as the Simunye projects. This rise in electricity supply, however, will only be in effect by 2013 or later. Therefore, the maximum supply remains constant in the short-run.

In May 2011, the new Integrated Resource Plan for electricity 2010-2030 (Republic of South Africa, 2011) was promulgated. According to this, the future projects have classified based on three timeframes: 1) to be decided before the next IRP; 2) to be confirmed in the next IRP; and 3) to be possibly replaced during the next and subsequent IRPs. The new build options that are to be decided before the next IRP include: Coal fluidised bed combustion units 2014/15; Nuclear power plants ; Import hydro (2022 to 2024); Gas Fired power stations (2019); Solar photovoltaic units (2012-2015) connected to the grid; Wind installations (2014/15); Concentrating Solar Power (CSP) units (2016).

2.1.3 Electricity consumption

Electricity consumption in South Africa has increased significantly over the past decade: from 11.96% (between 1995 and 2000) to 34.58% (between 2000 and 2006). This unprecedented rise has raised serious concerns regarding the environmental effects, including higher CO_2-emissions as a result of the increased combustion of coal. There is a direct link between electricity generation and consumption and CO_2-emissions. Therefore, one possible effective mechanism to reduce CO_2-emissions is to reduce the demand for electricity by strengthening the demand response or demand elasticity for electricity.

Each year, the National Department of Energy in South Africa releases an Aggregate Energy Balance of the country, which indicates the electricity consumption by sectors in MWh. Electricity consumption per sector, as well as the sectoral shares of total consumption, for the years 1995, 2000 and 2006 are presented in Table 2.4.

Table 2.4 Sectoral electricity consumption in South Africa: 1995, 2000 and 2006

	1995		2000		2006	
	GWh	%	GWh	%	GWh	%
Total consumption	143,173	100.0%	160,300	100.0%	215,739	100.0%
Industry sector	80,657	56.3%	99,703	62.2%	116,631	54.1%
Iron and steel	16,251	11.4%	20,913	13.0%	21,342	9.9%
Chemical and petrochemical	3,603	2.5%	2,640	1.6%	10,081	4.7%
Non-ferrous metals	6,956	4.9%	15,038	9.4%	18,640	8.6%
Non-metallic minerals	1,190	0.8%	1,154	0.7%	2,606	1.2%
Transport equipment	9	0.0%	69	0.0%	92	0.0%
Machinery	104	0.1%	53	0.0%	42	0.0%
Mining and quarrying	33,176	23.2%	29,038	18.1%	31,503	14.6%
Food and tobacco	454	0.3%	639	0.4%	761	0.4%
Paper pulp and print	975	0.7%	1,494	0.9%	1,756	0.8%
Wood and wood products	534	0.4%	412	0.3%	296,890	0.1%
Construction	14	0.0%	34	0.0%	54	0.0%
Textile and leather	475	0.3%	376	0.2%	519	0.2%
Non-specified (industry)	16,916	11.8%	27,842	17.4%	28,938	13.4%
Transport sector	4,297	3.0%	5,411	3.4%	3,480	1.6%
Other sectors	58,218	40.7%	55,186	34.4%	95,629	44.3%
Agriculture	5,301	3.7%	3,954	2.5%	5,841	2.7%
Commerce and public services	17,307	12.1%	17,164	10.7%	28,833	13.4%
Residential	24,369	17.0%	28,680	17.9%	39,671	18.4%
Non-specified (other)	11,241	7.9%	5,387	3.4%	21,283	9.9%

Source: (Department of Minerals and Energy (DME), Various issues)

As seen in Table 2.4, the 'industrial' sector has been the largest consumer of electricity for each of the years presented. The industrial sub-sectors that showed the strongest growth are 'chemical and petrochemical' and 'non-metallic minerals'. The 'construction' sector, although not a big consumer in its own right, has almost doubled its electricity consumption over the study period, which is an indication of the growth in the sector in the 2000s.

In addition, the 'non-ferrous metals' sector also doubled its electricity consumption within the study period. The 'residential' sector's electricity consumption has also increased, while keeping its share of the total consumption fairly constant at 17–18%. However, the 'residential' sector was the single largest consumer of electricity in 2005.

The electricity consumption of 'commerce and public services' increased in 2005. In comparison to other sectors, however, the 'commerce and public services' share remained at 12–13%.

The main reason why important changes are observed between the 1995 and 2000 sectors' electricity consumption shares is the economic and social structural conversion the country underwent post-1994.

Figure 2.1 presents the contribution of the various economic sectors to the electricity consumption of the country in 2006. The trends more or less remain the same as in 2005: the 'residential' sector was the single main electricity consumer (18.4%).

From the industry part (which contributed approximately 54% of the total), the 'mining' sector consumed 14.6%, 'iron and steel' consumed 9.89% and 'non-ferrous metals' consumed 8.64% of the total electricity used. From the rest of the economy, 'commerce and public services' was a significant contributor (13.36%) while 'agriculture' and 'transport', which are labour-intensive rather than capital- or energy-intensive, contributed only 2.71% and 1.61%, respectively.

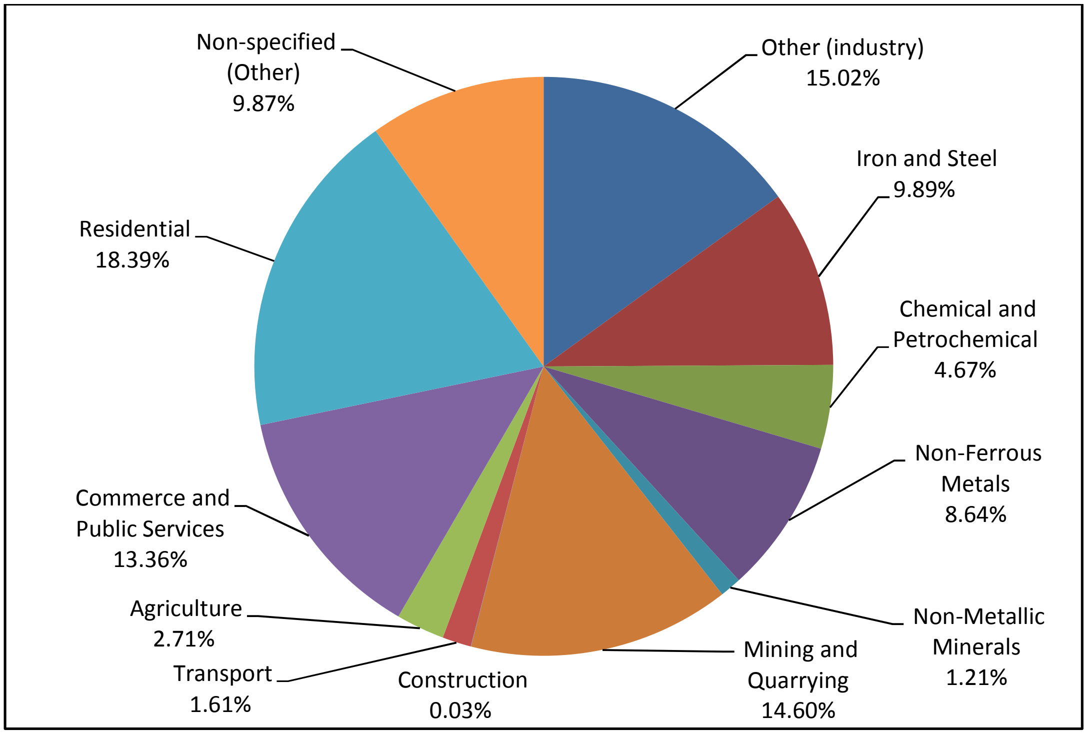

Figure 2.1 Electricity consumption by sector in 2006
Source: (Department of Minerals and Energy (DME), Various issues)

Note: From Figure 2.1 it can be seen that the 'industrial' sector in aggregate is the major electricity user. Of the industrial sectors, 'mining and quarrying' has the highest share of electricity consumption (14.6%). The 'residential' sector (with 18.39%) is the highest single electricity user while 'agriculture' and 'transport' do not use more than 5% of the total electricity use together.

The rising electricity demand in South Africa over the last few years and the need to restore its reserve margin led to the worst energy crisis this country has encountered at the beginning of 2008. Eskom made an effort to intervene in order to avoid this crisis through a national awareness strategy. As a last alternative, load-shedding was conducted in selected regions or sectors in order to prevent an economy-wide blackout. This however, had detrimental negative consequences for the South African economy. In 2009, the CEO of NERSA, while talking about the mining and metallurgical industry's response to the power crisis, stated that continuous load-shedding cost the economy R75 per kWh. NERSA estimated that approximately R50bn were lost during the 2008–2009 crisis (Mail & Guardian Online, 2008).

Although NERSA states that they were unaware of the significant problems in electricity supply, Eskom argues that it had experienced a lack of capacity in the generation and reticulation of electricity since 2007 (Inglesi, 2010). Eskom also says that substantial efforts were needed in order to convince both the private sector and the government that new capacity is necessary. However, the government was not convinced of the viability of this strategy and wanted to bring independent power producers into the market. In October 2004, the government had agreed to finance the construction of a new plant but due to insufficient time to finish the project, it could not be utilised to counter the deficit experienced in 2007−2008 (Eskom, 2010). An additional contributing factor was the increase of electricity demand (50%) in the country between 1994 and 2007. This increase might have been partially due to the implementation of the Free Basic Electricity Policy in 2001. Another contributing factor was the expansion of the economy after sanctions were lifted.

Pouris (2008) also argues that the lack of research on energy in general, and electricity in particular, before 2007 could be one of the factors responsible for Eskom’s predicament. In his paper, Pouris (2008) states that South Africa produces only 0.34% of the international research publications reporting on topics of energy and fuels while it contributes 0.5% of the academic research papers in all scientific disciplines internationally. Furthermore, he found that energy research literature constitutes 0.45% of the national effort. This share is much smaller than the top disciplines of the country, such as medicine (6.04%) and plant sciences (5.07%). He concludes that the lack of academic research in this field deprives the relevant stakeholders and government from insight and debate based on independent views (Inglesi & Pouris, 2010). However, this has changed drastically during, and especially after, the crisis of 2007–2008, for example Ziramba (2008); Odhiambo (2009); Amusa, Amusa, & Mabugu (2010); Inglesi (2010); Inglesi and Blignaut, (2010); and Inglesi & Pouris (2010).

The main reason provided by Eskom for the energy crisis was the imbalance between electricity supply and electricity demand. Inglesi (2010) examines the contributing factors of the South African electricity demand for 1980–2005 by applying the Engle–Granger co-integration technique and Error Correction model. More specifically, she analyses the relationship between the electricity demand and income, prices and population. Her results show that the long-term impacts of income and price are significant and are both estimated to be inelastic (0.42 and 0.55, respectively). In the short-run, the demand for electricity is explained by the Gross Domestic Product (GDP) and the size of the population of the country.

Two different scenarios were introduced by Inglesi(2010) to forecast the electricity demand until 2030. In both of these the population growth was 1% per annum (International Monetary Fund (IMF), 2009a). The following assumption holds for both scenarios: the electricity price will increase and double from 2008 to 2011 and then it will remain constant until 2025. The main difference between the two scenarios is that the economic growth will average 4% for the period 2009–2030 in the first; whereas, accelerated growth of 6% in average over the period 2009–2030 is proposed in the second.

According to these scenarios, the demand for electricity will decline after the price restructure that is being promoted by Eskom and NERSA. Furthermore, significant forces that drive the decline in electricity use are the lower population growth and the lower, more stable, economic growth of the country.

Based on Inglesi's (2010) assumptions, South Africa can experience up to 27% less electricity demand (comparison of 2007–2030 values) if the price of electricity doubles by 2011 and then remains constant with an average economic growth of 4% for the period until 2030. The picture does not change much if the economic growth is higher: an increase to 6% causes the electricity demand to drop by 24% by 2030.

2.1.4 Electricity prices

Recently, the electricity prices and their increases have become a topic for continuous debate in South Africa. This section presents the evolution of electricity prices in the country since the beginning of the 1990s at aggregate and sectoral levels as well as in comparison with international best practice.

Literature abounds with information describing South Africa’s historic electricity prices (Van Heerden, Blignaut, & Jordaan, 2008) (Odhiambo, 2009). It is noted therein that South Africa has had low and declining real prices of electricity for a prolonged period of time. The average real prices of electricity for the period 1993 to 2004 are shown in Table 2.5. Even after increases in the nominal prices for the various sectors, the growth rates in real terms during the study period were very low, even negative, in most instances.

Table 2.5 Average real electricity prices in South Africa (2005=100) and annual percentage growth

	c/kWh						
	Industry	**Mining**	**Transport**	**Agriculture**	**Commerce**	**Residential**	**Average**
1993	17.49	19.94	28.69	41.55	34.47	26.55	28.12
1994	17.09	19.40	27.45	40.54	33.44	32.15	28.35
1995	18.37	18.75	25.87	38.83	32.94	32.05	27.80
1996	16.63	18.14	25.20	38.50	32.08	32.02	27.09
1997	16.33	17.67	22.79	37.36	30.65	32.32	26.19
1998	15.63	17.33	21.13	37.48	26.74	32.26	25.09
1999	14.25	17.01	20.49	35.86	30.04	34.21	25.31
2000	15.28	16.52	19.65	36.97	28.98	35.46	25.48
2001	13.99	16.16	18.99	32.50	21.72	37.40	23.46
2002	14.29	15.69	19.03	29.37	21.65	37.09	22.85
2003	14.85	15.80	19.90	30.55	21.62	38.35	23.51
2004/05	14.44	15.88	20.02	31.87	22.61	40.00	24.14
2006/07	14.75	16.19	20.25	32.86	22.69	40.08	24.47
2007/08	16.52	17.19	22.28	34.32	23.75	42.59	26.11
Average	**15.71**	**17.26**	**22.27**	**35.61**	**27.38**	**35.18**	**25.57**

	Year-on-year change						
	Industry	**Mining**	**Transport**	**Agriculture**	**Commerce**	**Residential**	**Average**
1994	-2.25%	-2.72%	-4.31%	-2.44%	-2.99%	21.08%	1.06%
1995	7.45%	-3.30%	-5.76%	-4.20%	-1.50%	-0.31%	-1.27%
1996	-9.48%	-3.28%	-2.59%	-0.86%	-2.59%	-0.11%	-3.15%
1997	-1.76%	-2.61%	-9.58%	-2.96%	-4.46%	0.94%	-3.40%
1998	-4.30%	-1.89%	-7.25%	0.30%	-12.77%	-0.19%	-4.35%
1999	-8.86%	-1.85%	-3.04%	-4.31%	12.37%	6.07%	0.06%
2000	7.28%	-2.86%	-4.12%	3.09%	-3.54%	3.63%	0.58%
2001	-8.46%	-2.22%	-3.35%	-12.09%	-25.03%	5.48%	-7.61%
2002	2.15%	-2.90%	0.21%	-9.62%	-0.35%	-0.82%	-1.89%
2003	3.89%	0.71%	4.58%	4.03%	-0.13%	3.40%	2.75%
2004/05	-2.74%	0.48%	0.60%	4.30%	4.60%	4.29%	1.92%
2006/07	2.15%	1.98%	1.15%	3.12%	0.33%	0.20%	1.49%
2007/08	11.97%	6.21%	10.02%	4.45%	4.68%	6.26%	7.27%
Average	**-0.23%**	**-1.10%**	**-1.80%**	**-1.32%**	**-2.42%**	**3.84%**	**-0.50%**

Source DME (2005b)

The ‘industrial’ sector experienced decreases in its electricity prices for 1996–2001 with the increase of 7.28% in 2000 as the only exception. This, however, did not neutralise the effects of all the previous reductions. The price in 2004 was 11.28c/kWh; approximately 17% lower than the price in 1993.

The picture for the ‘mining’ sector is not dissimilar. The electricity prices decreased from 1993 to 2002 on a year-on-year basis, although at lower rates than the ‘industrial’ sector. However, the continuous reduction resulted in an overall reduction of 20% from 1993–2004 (15.56c/kWh to 12.41c/kWh).

In the ‘transport’ sector, large reductions of the electricity prices were characteristic during the study period, with a larger annual decrease in 1997 (-9.5%). The average decrease was -2.85% for the study period, but comparing the 1993-value to the 2004-value, a decrease of 30% is observed.

In the other low consumer of electricity, the ‘agriculture’ sector, the prices did not have a stable trend over the study period. The greatest increase was in 1993 (5.43%) and the greatest reduction was in 2001 (-12.05%) followed by a successive reduction of 9.45% in 2002. All-in-all, the prices decreased by 23% from 1993 to 2004.

The trend was similar in the ‘commercial’ sector. This sector experienced continuous decreases during the study period with the biggest reduction (25%) of the entire period and among all the sectors in 2001. However, in 2004 the prices started picking up again with an increase of 4.32%.

Finally, the only sector that differs from the rest was the ‘residential’ sector. Although the prices decreased substantially (-24.37%) for 1992–1993, it increased substantially (21.32%) in 1994. During the next decade, the real prices decreased (by less than 1% on an annual basis) in some years but for the majority of the years, it increased by approximately 3–6%. The overall effect was an increase of 51% from 1993 to 2004.

Eskom’s prices are adjusted on a year-to-year basis on 1 April every year (which is the beginning of Eskom’s financial year). Figure 2.2 shows the annual price adjustment changes for the overall economy and the Consumer Price Index (CPI) changes for 1993–2009/10.

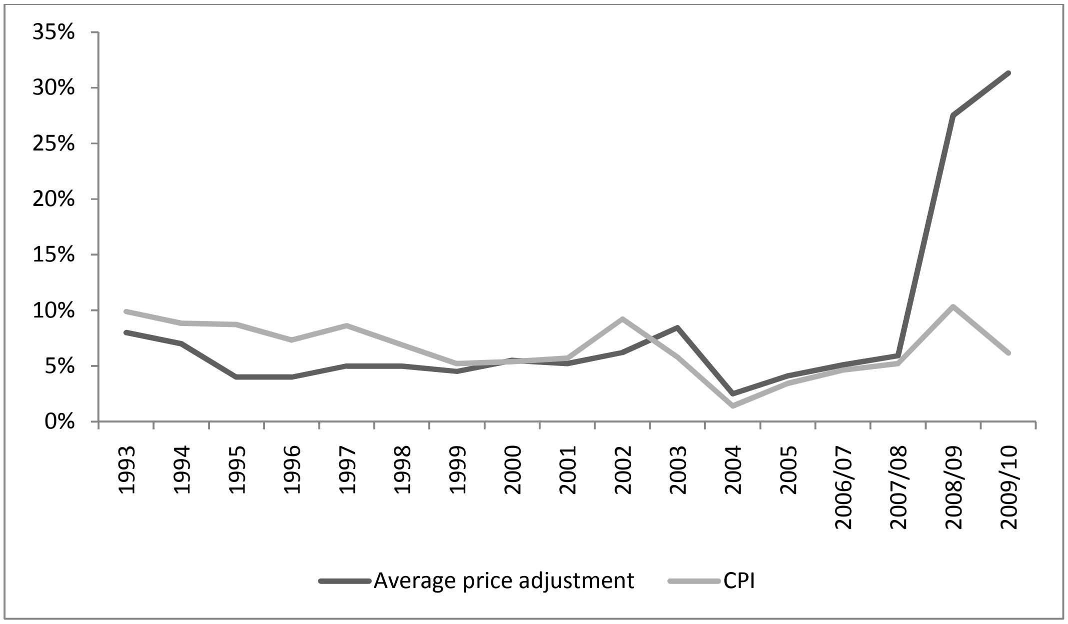

Figure 2.2 Average nominal price adjustments and CPI (%)
Source: Eskom website
Note: The average price adjustment was lower than the inflation rate in the country for the period 1993 to 2002. However, from 2004 the price restructuring changed the picture drastically. At the end of the period, the adjustments were even three times higher than the inflation rates.

As seen in Figure 2.2, the average price adjustment was lower than the inflation rate in the country for 1993–2002. In 2002–2003, Eskom's price reform started taking effect with significant increases from 2007/08 onwards. Figure 2.2 also shows that the average price adjustment for 2008/09 and 2009/10 was three times higher than the CPI change and has an increasing trend contrary to the inflation over that period.

To put the South African electricity prices in international perspective, Table 2.6 presents a comparison of the South African retail electricity prices and a number of upper-income and developing countries.

Table 2.6 Retail electricity prices (US$/kWh): International comparison 2004

Industrial electricity				**Residential electricity**			
Upper-income		**Developing**		**Upper-income**		**Developing**	
Australia	0.36	Czech Republic	0.06	Australia	0.06	Czech Republic	0.09
Belgium	-	Greece	0.06	Belgium	-	Greece	0.11
France	0.05	Hungary	0.09	France	0.14	Hungary	0.13
Germany	0.05	India	-	Germany	0.14	India	0.04
Italy	0.15	Korea	0.05	Italy	0.2	Korea	0.07
Japan	0.12	Mexico	0.06	Japan	0.17	Mexico	0.1
Netherlands	-	Poland	0.06	Netherlands	0.22	Poland	0.1
New Zealand	0.05	Slovak Republic	0.08	New Zealand	0.12	Slovak Republic	0.12
Spain	0.05	South Africa	0.01	Spain	0.11	South Africa	0.03
UK	0.06	Taipei	0.05	UK	0.13	Taipei	0.07
US	0.05	Turkey	0.09	US	0.08	Turkey	0.1
Average	0.1	Average	0.06	Average	0.14	Average	0.09

Source: International Energy Agency (2004b)

South Africa's industrial electricity is sold at 0.01US$/kWh which is lower than any other country and much lower than both the average for high-income countries (0.1US$/kWh) and the average for developing countries (0.06US$/kWh). With regards to residential electricity, South Africa's price (0.03US$/kWh) is the lowest of the sample; three times lower than the average of the developing countries (0.09US$/kWh).

The low price level of electricity can be attributed primarily to the relatively low production costs of the key inputs of electricity generation, mainly coal (Van Heerden, Blignaut, & Jordaan, 2008). With this historically low electricity prices, it is expected that for a period of time, electricity consumption was relatively insensitive to changes in price.

Therefore, South Africa offers no means of predicting what the demand response would be to price increases such as those proposed by Eskom in September 2009. In the third quarter of 2009, Eskom applied to NERSA for an increase in the electricity prices in order to fund their current and future investment plans. At the end of September 2009, NERSA's decision was made public: an approximate 25% per year increase of the electricity prices for the subsequent three years.

NERSA's latest decision on electricity price increases was announced in February 2010 (South Africa web, n.d.):

- 24.8% for 2010/11
- 25.8% for 2011/12
- 25.9% for 2012/13

Long before NERSA's latest decision, there was a debate on whether South Africa needs a price increase and what the consequences of such an increase would be. On the one side, it was believed that price increases will affect the economy negatively in the long-run. On the other side, energy policy-makers were concerned about the funding needed for the further expansion and maintenance of the existing power plants in the country.

With specific focus on long-term, Van Heerden, Blignaut & Jordaan (2008) estimates the effect of a 10% increase in electricity prices on main economic indicators, keeping the elasticities constant. Under such a scenario, the long-term economic consequences are alarming, with an estimated reduction in investment of 0.37%, a decrease of 0.16% in GDP, and a rise of 0.5% in the CPI. In addition, Inglesi (2010) forecasts the behaviour of total electricity consumption until 2030, assuming that the electricity price would double over the period 2008–2011 and then remain constant until 2030. Her findings show that electricity demand decreases substantially after the implementation of higher prices (-24% assuming an average economic growth of 4% for 2009–2030; -27% assuming an average economic growth of 6% over the same period). She assumes, however, that the price elasticity remains constant at -0.56 on electricity consumption until 2030.

In summary, before implementing any policies or changes in price regimes, the price sensitivity of each sector should be taken into consideration because each of the sectors responded differently in the period when prices were kept low (mainly until 2004–2005).

2.2 Energy efficiency and intensity

This section discusses in detail the concept of *energy efficiency and intensity*: its definition and importance, ways of measurement, and international as well as local efforts towards its improvement.

2.2.1 Definition

The definition of energy (sic. electricity) efficiency seems to be complex and depends largely on the context within which the term is being used. An economist, a politician and a sociologist may have different opinions in defining the energy efficiency. When the Energy Information Administration (Energy Information Administration , 1999) asked participants in workshops to define "energy efficiency", the answers varied, ranging from a service to a mechanistic perspective. The World Energy Council (WEC) (2008:9), however, provides the following guiding definition:

“Energy efficiency improvements refer to a reduction in the energy used for a given service (heating, lighting, etc.) or level of activity. The reduction in the energy consumption is usually associated with technological changes, but not always since it can also result from better organisation and management or improved economic conditions in the sector (‘non-technical factors’).”

Oikonomou et al. (2009) define energy efficiency as the technical ratio between the energy consumed and the maximum quantity of energy services obtainable (heating, lighting, cooling, mobility and others). According to them, energy savings can only be achieved through efficiency or behavioural changes.

Bernard and Cote (2002) define the energy intensity as “… the real level of energy consumption per production unit or activity, whereas adjusted energy intensity is the level of energy consumption per production unit or activity, after taking into account the relative changes in production or activity among sectors or components of a sector”. *And they continue that* “… energy intensity is attributed not only to the changes in energy intensity at the level of entities composing a segment of an economic activity, but also the division of the production or activity among its entities”.

In the European Union’s Action Plan for Energy Efficiency (European Union, 2000), the concept of energy efficiency is defined as “... reducing energy consumption without reducing the use of energy-consuming plant and equipment. The aim is to make better use of energy. Energy efficiency means promoting behaviour, working methods and manufacturing techniques which are less energy-intensive”.

2.2.2 Importance of efficiency

The importance of electricity efficiency cannot be overstated. Globally, policies to this effect have been accepted as one of the most economical ways toward the reduction or slowing down of the increasing energy demand as well as its cost and environmental effects. Repetto and Austin (1997) further demonstrate the significance of electricity efficiency improvement for positive results not only in the energy sector and the environment, but also in the economy as a whole.

Knowledge of the evolution of energy intensity/efficiency is imperative because energy policy-makers should know how energy demand will increase or decrease if the economy faces critical changes in its structure and management (Markandya, Pedroso-Galinato & Streimikiene, 2006). For this reason, specific attention should be given to transition economies if the energy consumption increases a result of increased output.

In addition, Andrade-Silva and Guerra (2009) state that examining the energy intensity not only contributes to a more informed policy decision, but also reduces the risk related to energy firms. They mention that improvements in energy efficiency are an effective way of reducing greenhouse gas emissions. They also support the idea that striving for more energy efficient equipment might lead to increased competition with positive results for the consumers in the prices of products and services.

The European Union's Action Plan for Energy Efficiency (European Union, 2000) also states that "... [g]reater energy efficiency has a major role to play in meeting the targets set in the Kyoto Protocol. It encourages a more sustainable energy policy and is a key element in the security of energy supply in the European Community, a subject which has given cause for concern in recent years".

2.2.3 Measurement issues

In order to measure electricity efficiency, the Energy Information Administration (1999) proposes two methods: i) the market-basket approach and ii) the comprehensive approach. The market-basket approach refers to estimating the energy consumption for a set of electricity services based on their share in an index computed as the Index of Industrial Production. The comprehensive approach refers to estimating broader indicators and is an assessment of the changes that are not connected with electricity efficiency until only its effects remain.

In contrast to the above, Mukherjee (2008) proposes a measurement approach from a production theoretic perspective. His measurement models are based upon the objectives of energy management and cost minimisation as well as the capacity output of the economy. The conceptual difficulty in the analysis of energy efficiency, according to Bosseboeuf, Chateau & Lapillonne (1997), is that the evaluation and progress thereof is made after the implementation of energy efficiency policies. There is therefore a temporal, and even spatial, decoupling between the policy and its implementation, and that which is measured and observed later. This also complicates comparison among countries. For this reason, Bosseboeuf, Chateau &

Lapillonne (1997) make an effort to focus on the convergence of energy efficiency indicators globally by classifying the indicators used in the literature as follows:

- Macro-indicators versus micro-indicators: Macro-indicators are linked to the economy in its entirety or its main sectors. Micro-indicators are linked to the level of the main end-users such as companies or households.

- Ratios versus quantities: Ratios such as energy use per GDP or quantities such as variations in the demand for energy are both used in the literature.

- Descriptive versus explanatory indicators: The descriptive indicators explain the energy efficiency situation and progress; conversely the explanatory indicators describe the factors responsible for the evolution.

Following from the above, energy (read also electricity) efficiency is often measured in terms of the change in energy intensity in an effort to describe more accurately its quantitative nature. Energy intensity, in turn, is defined as the ratio of energy consumption to a unit of measurement (e.g. floor space, households, number of workers, GDP per capita) (Energy Information Administration, 1999). Freeman, Niefer and Roop (1997) critically assess the commonly used energy intensity indicators for analysis particularly of the ‘industrial’ sector, and in response Andrade-Silva and Guerra (2009) argue that there are six possible ways of calculating the energy intensity. These different measures are based on the definition of energy intensity as the energy consumption (numerator) divided by the production or economic activity (denominator) of the economy. Energy consumption can be measured according to its thermal equivalence (in joule), or in economic terms (price). Accordingly, the economic activity of a country can be measured as the value added, value of delivered goods (production value minus the value of inventories) or production value (Andrade-Silva & Guerra, 2009). Therefore, the proposed measures, in accordance with Bor (2008), are the following:

1. Thermal equivalence/added value
2. Thermal equivalence/value of delivered goods
3. Thermal equivalence/production value
4. Economic measure/added value
5. Economic measure/value of delivered goods
6. Economic measure/production value

Following a similar way of thinking, Markandya, Pedroso-Galinato and Streimikiene (2006) define energy intensity ε_{it} of a country i at time t as the country's total final energy consumption at time t (E_{it}) divided by total national income of country i at time t (Y_{it}): $\varepsilon_{it} = E_{it} / Y_{it}$

Andrade-Silva and Guerra (2009:2590) also state that:

"... even when the physical measures can be used at the desired levels (disaggregated and aggregated), the economic nature measures emerge more strongly within the upper aggregation levels. This feature leans on favouring the establishment of a standard consumption measure per national production unit such as the joule (J) per US$ of GDP".

Based on this, we have decided to standardise the definition of electricity intensity for our analysis as the ratio of electricity consumption divided by economic output. This is a common definition also used by Mukherjee (2008), Choi and Ang (2003) and Streimikiene, Ciegis and Grundey (2008). It is important to be noted here that in the literature, the intensity is considered the quantitative measure of the energy (electricity) efficiency. More specifically for the purposes of the decomposition exercise (section 3.3), the *intensity effect* is defined as changes in efficiency. In layman's terms, the more electricity intensive is a country/ household/ company/ individual, the more electricity it consumes per unit of output.

2.2.4 Global and South African efforts towards efficiency

The European Union countries focus on the environmental progress of energy conservation (Sebitosi, 2008:1592). The European Union presented its first Action Plan for Energy Efficiency (European Union, 2000) for the years 2000 to 2006. The main aim of the plan was to reduce energy consumption in order to protect the environment, improve security of energy supply and establish a unified energy policy.

According to this plan, numerous instruments, obligatory or voluntary, exist for its implementation in the European Union as a whole as well as each of the member countries individually. The proposed sub-actions are categorised in three main groups:

1. Channels to integrate energy efficiency into other policies

There are six main focus areas in this category: Transport; Modern Enterprise policy; Regional and Urban policy; Research and Development; Taxation and Tariff policy; International cooperation and pre-accession activities.

2. Motives to enhance the existing strategies

There is a need to enhance strategies of four priority areas that were identified: Transport; Household appliances, commercial and other equipment; Industry (including electricity and gas companies); Buildings. The proposed measures include both mandatory and voluntary mechanisms.

For the 'transport' sector, the European Union firstly focuses on the automobile industry and its high CO_2-emission rates. The Action Plan proposes a target of decreasing the average CO_2-emissions of new vehicles by a third by 2005/2010, with the aid of voluntary agreements with the industry's players.

Regarding the 'household, commercial and other equipment' sector, the proposed measures are based upon labelling systems and minimum standards for energy efficiency. In an attempt to have alternatives to legislation and mandatory measures, the Action Plan proposes voluntary agreements between the member countries and the industry concerning minimum efficiency standards. "The Commission itself has concluded two agreements of this type (one on energy consumption by televisions and video recorders in standby mode and one on washing machines)" (European Union, 2000). In the future, these agreements are to be extended to other appliances such as water heaters.

Another priority area concerns the 'industrial' sector and the aim is to achieve long-term agreements on minimum energy efficiency by implementing specific guidelines for efficient processes and production methods. The Action Plan also pays attention to future plans of increasing combined production of heat and power as well as increasing the role of energy efficiency in the energy services.

Finally, the last priority area is ‘buildings’ energy efficiency’. With specific focus on boilers and lighting, the European Union proposed a directive on the energy performance of a building in addition to the existing one (93/76/EEC) concerned with the energy certification of a building in order to limit their CO_2-emissions.

Furthermore, the Action Plan specifies a group of motives (‘horizontal’) that affects all the economic sectors in improving energy efficiency:

- Decentralisation of energy management at local and regional levels
- Strengthening third-party financing (for example, private undertakings)
- Better dissemination of information and training through a renewed community information campaign and specialised training
- Better monitoring and evaluation methods through greater harmonisation of national monitoring programmes and definition of indicators

3. New Policies and measures

The following new strategies concerning the improvement of energy efficiency should be implemented by all the members of the European Union:

- Promotion of energy efficiency in public procurement
- Cooperative technology procurement
- Energy audits in the industry and tertiary sectors
- Best practice

The European Union updated its first Action Plan and released a new one for 2007–2012. The main target now is a 20% reduction in energy consumption by 2020 (compared to the energy forecasts for 2020). This objective corresponds to approximately 1.5% savings per annum until 2020.

“The Action Plan includes measures to improve the energy performance of products, buildings and services, to improve the yield of energy production and distribution, to reduce the impact of transport on energy consumption, to facilitate financing and Investments in the sector, to encourage and consolidate rational energy consumption behaviour and to step up international action on energy efficiency” (European Union, 2000).

The updated key points of the 2007 Action Plan are the following:

1. Potential energy savings

The Action Plan shows that the biggest energy savings can be made in the following sectors: residential, commercial, manufacturing and transport, with potential reductions of 27%, 30%, 25% and 26%, respectively. These savings will also help decrease CO_2-emissions by 780 million tons per year.

2. Measures proposed

Although all the proposed measures are equally important, the Action Plan specifies that some should be adopted without delay while others can be implemented throughout the six-year period. The proposed measures are:

- Improving energy performance with specific focus on appliances and equipment by setting appropriate standards and evaluating performance

- Improving energy transformation: “The Commission will develop minimum binding energy efficiency requirements for electricity generation facilities, heating and cooling for facilities operating with less than 20 megawatts of power, and possibly for more powerful facilities too" (European Union, 2000).

- Limiting the costs linked to transport – the main targets are to achieve the threshold of 120g of CO_2/km by 2012 and to develop a European standard for rolling resistance and promoting tyre pressure monitoring.
- Financing, incentives and fares: the European Union plans to facilitate funding of investment with regards to the promotion of energy efficient methods. It also plans to relax the national legal barriers to shared savings, financing, energy performance contracting and recourses to firms providing energy services. Furthermore, it will revise the Energy Tax Directive and promote the potential for using tax credits as incentives for both firms and residential consumers.
- Changing behaviour
- Adapting and developing international partnerships

In 2007, US government set the basis for an energy efficient future by signing the Energy Independence and Security Act (US Congress, 2007). This Act includes mainly provisions designed to improve energy efficiency and promote the use of renewable energy. The highlights enacted into law with their standards are:

- Corporate Average Fuel Economy: target of 35 miles per gallon by 2020 for cars and light trucks
- Renewable Fuels Standard: starting at 9 billion gallons in 2008 and going up to 36 billion gallons by 2022

- Energy Efficiency Equipment Standards: new standards for lighting and residential and commercial appliances, such as residential refrigerators and commercial coolers and freezers

- Repeal of Oil and Gas Tax Incentives: repeal of two tax subsidies in order to counterbalance the cost of the Corporate Average Fuel Economy implementation

Two provisions were excluded from the Energy Independence and Security Act: the Renewable Energy Portfolio Standard and, as mentioned above, the repeal of tax incentives for oil and gas. Under the Renewable Energy Portfolio Standard, “retail electricity suppliers (electric utilities) must provide a minimum amount of electricity from renewable energy resources or purchase tradable credits that represent an equivalent amount of renewable energy production”.

Especially the Appliance Efficiency Mandate concentrates on new criteria for appliances; while the rest of the mandates also advance the lighting efficiency, the vehicle fuel efficiency as well as the contribution of the government facilities towards the goal of a less energy-intensive country.

Japan, although among the high energy consumers globally, identified energy conservation and environmental protection as key issues for growth and development in 1979. In this thirty-year period, Japan was able to reduce its energy intensity levels by 37% in terms of oil consumption per GDP growth. Furthermore, the Japanese energy policy-makers released the *New National Energy Strategy* (Japanese Government, 2006) in 2006 and its main goal was a further improvement of efficiency by 30% by 2030. The measures proposed by the strategy targets four main sectors: industrial, civil, transport and a sector for cross-cutting issues.

However, the higher impact is expected by the industrial sector, according to the strategy.

Following the political transition in 1994, the new democratically-elected South African government considered energy issues as of great importance for the economic development of the country. In the first *White Paper on Energy Policy* (Department of Minerals and Energy (DME), 1998), energy efficiency was mentioned among the cross-cutting issues. More specifically for the industrial and commercial sectors, the government committed itself to the following:

- Promotion of energy efficiency awareness
- Encouragement of the use of energy-efficiency practices
- Establishment of energy efficiency standards for commercial buildings
- Monitoring the progress

While progress regarding these was slow due to pressing socio-economic and development considerations, the South African Department of Minerals and Energy released its first *Energy Efficiency Strategy* in 2005 (DME, 2005a). The purpose of this strategy was to provide a policy framework toward affordable energy for all and diminish the negative consequences of the extensive energy use in the country. Its national target for electricity efficiency was to improve efficiency by 12% by 2015. It is stated in the document that this target can be questioned and challenged, but it was set in the wake of the fact that the country was the seventh biggest emitter of greenhouse gases on a per capita basis (Sebitosi, 2008). Furthermore, the national electricity intensity was almost twice the average of the OECD countries and efficiency improvements are a necessity. The strategy, however, has had limited impact to date and is currently being revised.

2.3 Cap-and-trade systems

In this section, the theory of the cap-and-trade system is described, as well as its international applications during the last two decades. Also, an evaluation of the system is presented by discussing advantages and disadvantages.

2.3.1 Description of the system

A cap-and-trade is a system that aims to steadily decrease emissions of the economy in its entirety in a cost-effective matter (Centre for American Progress. 2008). The proposed cap-and-trade systems have three main elements: a) the cap, b) the tradable allowances, and c) the formula for distributing the allowances (Shammin & Bullard, 2009).

In layman’s terms, the regulator (government or other institution) of a cap-and-trade system sets the participants and the total amount of emissions they are allowed to release, the “cap”, for a specific time period. Then, it allocates permits (“allowances”), to the participants usually equal to the size of the cap. One way of doing this is to estimate the allowances relative to contributions to total emissions in a selected base year and then freely distribute them. The allowable emissions can remain constant or be updated frequently (Edelston et al., 2009). This manner of allocation is widely discussed and criticised in the literature, and auctioning the permits is the proposed solution. Michel (2009) states a few reasons why auctioning is preferable to free distribution based upon previous performance:

- It provides a mechanism to allocate reduction of emissions' responsibility.
- The price is a motivation for consumers to reduce their energy usage.
- It prevents profits to generators that would accumulate free allowances.
- The revenue of the auctioning process can be used by the government to benefit the society.

In some applications, the participants receive allowances based on their historical emissions adjusted for the specific system's commitment (Braun, 2009). The cap usually reduces over time so that higher reductions will be achieved (APX Power Markets, 2008).

The regulated entities can then either use their allowances or trade it among themselves (Profeta & Daniels, 2005). The participants that emit less than their allowance can sell their credits (permits or allowances) to those that are not able to easily cut their emissions. The main reasons for that are either that the production technology that the companies/sectors/countries used before the trade may be difficult to change in the short-run or that the cost for reduction of emissions varies (Centre for American Progress, 2008). The system thus rewards the participants that were already doing better than their cap and the ones that managed to cut their emissions with the profits from trading.

From an economic viewpoint, the aim of a cap-and-trade system is to internalise the externality of the emissions by creating a market that puts a price on the emissions (Fell, Mackenzie & Prizer, 2008). Figure 2.3 graphically represents the decisions that a participating member (in this case a sector) makes.

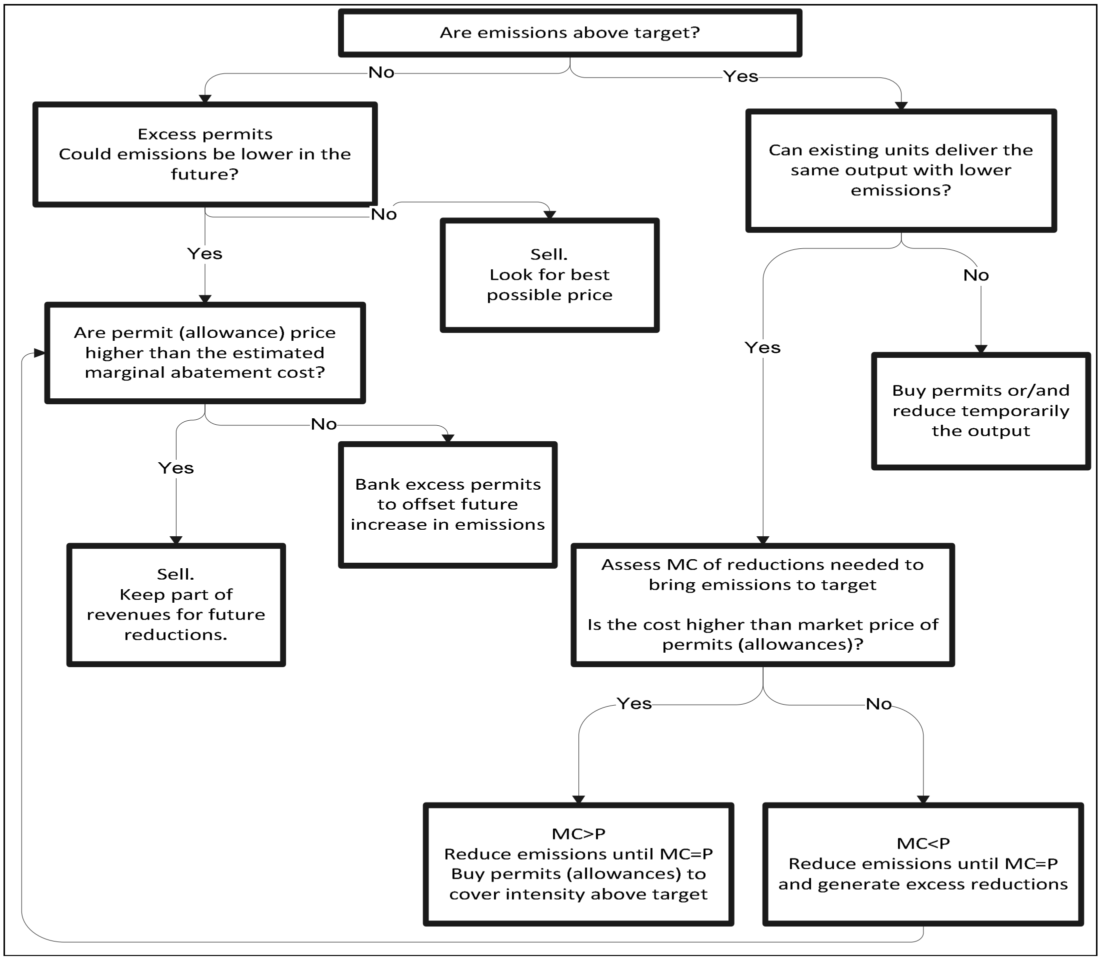

Figure 2.3 Participant's decision-tree in a benchmark-and-trade system
Source: International Energy Agency (International Energy Agency, 2001)
Note: Firstly the participants need to answer the question of whether their emissions are above the targeted level. That defines them as suppliers or consumers of permits in the market. If they are suppliers (emissions lower than target), they should evaluate if their emissions can be lower in the future. If no, they should sell the excess permits; if yes, they should compare the price of the permits with the marginal abatement cost: if the permit price is higher, then they should sell the surplus of permits – if not they should bank the permits for future use. On the other side, if the participant is a consumer of permits, first it needs to assess if it can lower its emissions. If no, it should buy permits; if

yes, the comparison of the permit price with the marginal cost of a reduction will assist it in deciding whether it should buy permits or reduce its emissions.

The first question in the decision-tree is the most significant for the position of the member. If the member's emissions are above the cap, then it can become a *buyer* in the system. However, if the member's emissions are below the cap, then it has the potential to be a *seller* and make revenue from the market.

2.3.2 International applications

The concept of cap-and-trade is neither recent nor new. This type of system has been used for different types of emission such as SO_2 and CO_2 as well as for greenhouse gas emissions (GHG) in general at a global level. Table 2.7 summarises the information on the most important applications of cap-and-trade systems since the 1980s around the world.

One of the first and most important cap-and-trade systems was that of the US in 1990s targeting SO_2-emissions which are linked to the phenomenon of acid rain, known as the *US SO_2 Trading Program* or as the *Acid Rain Program* (Ellerman, 2007). The overall goal of the programme was to reduce SO_2-emissions by 10 million tons taking into account the 1980s' levels.

Table 2.7 Main cap-and-trade systems since the 1980s

Programme	Year	Place	Focus	Goal
Leaded Gasoline Phasedown program	1980s	United States	Gasoline	Production of gasoline with a lower lead content
US Clean Air Act Amendments	1990	United States	SO_2 and NO_2	Reducing SO_2 to 50% of 1980 by 2000
Regional Clean Air Incentives Market (RECLAIM)	1994	Los Angeles air basin	NO_x and SO_x	Reducing emissions by 70% by 2003
Acid rain program – US SO_2 Trading Program	1995	United States	SO_2	Reducing SO_2-emissions by 50% of 1980 by 2000
North-eastern NO_x Budget Program	1999	USA: 12 north-eastern states and the District of Columbia	NO_X	Reducing emissions to 25% of 1990
NO_x Budget Program (SIP)	2003	USA: 22 states	NO_X	Reducing the transport of ozone pollution over broad geographic regions
European Emissions Trading System	1998	30 EU countries	GHG emissions	Reducing EU's GHG emissions (each EU member sets its own target, subject to review by the European Commission)
Carbon pollution Reduction scheme	to start in 2010	Australia	GHG emissions outside land and agriculture	Reducing GHG emissions by 5% at 2020 compared with 2000 levels

Sources: Schmalensee et al. (1998); Stavins (1998); Klepper and Peterson (2004); Profeta and Daniels (2005); Ellerman (2007); Stavins (2007); APX Power Markets(2008); Stavins (2008); Braun (2009); Ellerman (2009); Linn (2010); Monast (2010)

Its first phase commenced in 1995 and lasted for a period of five years. A total of 263 emissions-intensive units were allowed to emit SO_2 only if they had the appropriate allowances to cover their emissions (Stavins, 2007). Using the *grand-fathering method*, the Regulator allocated permits to each unit per year based on their share of heat input during a baseline period (1985–1987) in this programme. *Banking* and *borrowing* were allowed to promote cost-effectiveness and provide incentives.

In the second phase that started in 2000, the vast majority of power generating units participated in the programme. The main addition and greatest difference to the first phase was the introduction of *penalties* in case of non-compliance. The 'punishment fee' was $2,000 (in 1990 prices) for every ton of emissions above the assigned annual cap (Stavins, 2007).

Although as any newly-introduced policy, the programme had low levels of trading (Burtraw, 1996), its trading performance started to pick up in the later years (Schmalensee et al., 1998; Stavins, 1998; Burtraw & Mansur, 1999; Ellerman et al., 2000). On top of that, cost savings of approximately $1bn was the result of a well-designed market (Stavins, 2007). Regarding the environmental influence of the programme, Ellerman (2007) states that the reduction of SO_2-emissions was greater than expected: a 50% decrease in the first year. Furthermore, after the fifteen years, the SO_2-emissions decreased by 35% (US Environmental Protection Agency). Other benefits were the positive welfare effects (Burtraw et al., 1998) and the positive impact on human health affected by localised pollution. For Ellerman (2007), the creation of a market for SO_2 allowances was one of the important successes of the programme. The results of this market were even more impressive since the participation in the programme was voluntary, showing that economic incentives succeeded (Ellerman, 2004).

In 1994, the South Coast Air Quality Management District of US commenced a new two-fold cap-and-trade system with the goal of reducing NO_x and SO_x in the broader area of Los Angeles. All power plants, cement industries and any industrial source that emitted more than 4 tons per annum, were included. The programme's specific aim was to decrease emissions by 20% by 2003.

The NO_x sub-programme encountered difficulties in 2000–2001 that led to its partial suspension (Ellerman, 2007). The allowance prices hiked to $15,000 per ton – an increase of approximately 200% – within a few months resulting in the inability of the participants to comply with the rules. This price hike was caused by the absence of *banking* and *borrowing*, and the electricity crisis of California during the same period.

Two main aspects of the programme differentiated it from others. Firstly, it restricted trading from downwind to upwind resources, thus imposing a zonal restriction. Secondly, other forms of restriction did not provide the motivation to the participants for investing in equipment that can control pollution. For instance, Stavins (2007) indicates that in 2000–2001 the majority of the participants were unable to buy allowances for their emissions and therefore, the surplus of emissions spiked.

The environmental benefits of the programme were summarised in the *Annual RECLAIM Audit report for the 2004 compliance year* (South Coastal Air Quality Management district,2006): NO_x-emissions were reduced by 60% while SO_2 fell by 50% for 1994–2004. Furthermore, Anderson (1997) states that the system has the capability to offset the common cost-increasing setback of cap-and-trade systems by predicting 42% cost-savings or approximately $58 million per year.

In 1999, twelve US states and the District of Columbia launched an NO_x cap-and-trade system in the area. The main regulator distributed allowances to each state and their policy-makers decided how to allocate these allowances to individual units.

This programme also established the Northeast Ozone Transport Region, among others, including three geographic zones. In its first phase that lasted until 2003, a thousand units – mainly combustion sources – were included. In the second phase, when a new rule (NO_x SIP Call) was introduced and seven more states participated, more than 2,500 sources were incorporated in the programme (Market Advisory Committee, 2007).

From 1990 to 2006, under the NO_x budget programme, NO_x-emissions in the area decreased by 73% and the potential cost-savings were estimated to be between 40% and 47% for 1990–2003 in comparison with a command-and-control approach without trading (Farrell, Carter & Raufer, 1999). One of the main criticisms of the trade was the high price volatility in the first year. This was attributed to delays in the implementation of the programme as well as the allocation of the allowances. However, the prices stabilised in the following years (Stavins, 2007).

In Europe, the European Emissions Trading System (EU-ETS) was the first cap-and-trade system implemented among a number of countries. It was launched in 2005 (Ellerman & Buchner, 2007). The partial reason for its implementation was the need for the European Union to meets its commitments to the Kyoto Protocol (Stavins, 2007).

The EU-ETS covers approximately 50% of the EU CO_2-emissions (Ellerman & Buchner, 2007). Almost 12,000 greenhouse gas emitters in the energy and industry sectors were included: all combustion installations with at least 20MW thermal input capacity, coke ovens, steel plants, refineries and any installation producing bricks, glass and ceramics, pulp and paper (Stavins, 2007; Schleich, Rogge & Betz, 2009).

The EU-ETS is implemented in three phases. The first phase, referred to as the "learning phase" or the "pilot period", lasted from 2005 to 2007. During this phase, only trading in CO_2 was allowed and the penalties for violations were 40 Euros per ton of CO_2.

The second phase (from 2008 to 2012) is closely linked to the EU's commitment to the Kyoto Protocol. In addition to CO_2, the programme includes other greenhouse gas emissions and the fines increase to 100 Euros per ton of CO_2 (Stavins, 2007).

In both these phases, the caps and allowances are the individual members' responsibility. Every member state proposes its own cap based upon and linked to variables such as GDP, expected growth rate, energy type mixture and carbon intensity. These proposed caps are evaluated and approved or rejected by the European Commission. The Regulator also allowed the member states to distribute the allowances freely in these two phases.

The third phase is proposed to be from 2013 to 2020. The crucial difference of this phase will be that *National Allocation Plans* will not be required. An EU-wide cap of 21% reduction compared to 2005 emissions will be applied (Schleich, Rogge & Betz, 2009). Also, auctioning of the biggest proportion of the allowances may be approved.

Stavins (2007) argues that even though the EU-ETS has introduced a well-functioning CO_2 market, it is too soon to evaluate the system in its entirety as phase 2 has not ended. Schleich, Rogge and Betz (2009) specifically assess the incentives and motives provided by the EU-ETS for innovation and energy efficiency with regards to the allowance prices of the system. Their results show that due to the higher expected prices of phases 2 and 3, more incentives are given for carbon and energy efficiency and, to a certain extent, for a switch to demand-side energy efficiency. However, they express concern that this will not overcome market failures and other barriers such as information and transaction costs.

Among the market failures, high volatility in the prices of the allowances was proven to be a fragile point of the system. This was attributed to the lack of reliable data on emissions, oversupply of allocations and the absence of *banking of allowances* between the phases (Stavins, 2007). A characteristic example was observed during 2005–2006. In 2005, due to over-allocation of allowances, the prices of allowances dropped substantially. At the end of 2005, the prices rose again only to return to their 2005 levels in the next year.

Another mechanism that exists in the context of cap-and-trade or emissions trading schemes is the *Sector No-Lose Targets* (SNLTs) (Ward et al., 2008). This scheme is considered a form of sectoral agreement that can enhance sectors and sources where abatement potential exists in developing economies. SNLTs would be specified carbon emission targets that various developing countries take willingly for some economic sectors. The concept of “no-loss” indicates that in the case the targets are not met, the countries would not be penalised.

Developing economies are expected to be attracted in SNLTs for two reasons: a) through this mechanism, they will be able to seek investment from the private sector based on their development agendas; and b) in many emerging economies, carbon markets are not feasible and hence this type of policy tools are considered insufficient.

2.3.3 Advantages and general attractive characteristics

An emissions trading system has interesting features only if it is well designed and wholly accepted by the key role players. According to Shammin and Bullard (2009), a well-designed cap-and-trade system has all the desired characteristics of a policy instrument such as tax credits and regulations; however, it allows for efficiency and equity issues to be dealt with separately. On top of this, it ensures that the specific environmental goals will be achieved (Chameides & Oppenheimer, 2007).

According to Profeta and Daniels (2005) and APX Power Markets(2008), such a system has the following desired characteristics:

- Certainty of environmental performance: A well-established system will ensure that the emissions (or indicator targeted) will decrease to a certain level aimed for – the cap. Hence, the system 'works' towards a specifically established environmental goal.
- Business certainty: It provides certainty in its goals and assists the regulated entities with the monitoring and evaluation of their investments within the system.

- Flexibility: It allows the participating entities to look for the cost-minimising options within the entire system. The entities are free to either achieve their targets through technological improvements or buy allowances to cover any further emissions.

- Administrative ease: The main requirement for successful implementation is proper monitoring of the participants' reductions and ensuring the participants are in possession of the necessary allowances to cover their emissions.

APX Power Markets(2008) also stresses the importance of the technology investment and development that a cap-and-trade system can provide. Incentives are given to the participants to develop and use new technologies by "… providing a 'carbon price signal' that enables firms to capture the value of these technologies" (APX Power Markets, 2008:6). Some studies, furthermore, argue that cap-and-trade systems increase social welfare (Carlson et al., 2000; Ellerman et al., 2000).

Bosetti et al. (2008) measure the benefits based on the following four categories:

- Environmental effectiveness
- Economic efficiency
- Distributional implications
- Potential enforceability

The main incentive for countries, sectors or companies to participate in cap-and-trade systems is the possibility of increasing their profits by trading in the market. The literature presents contradicting results on whether the participants' profits increased or not. For example, for the *Nitrogen Oxides Budget Trading Program*

(NBP), Linn (2010) found that the firms' expected profits decreased by approximately $25bn. Palmer et al. (2001) also predicted that NBP would decrease profits. Conversely, studies on carbon dioxide regulation expect rises in profits, particularly in the electricity sector (Burtraw et al., 2001).

In conclusion, there are few key issues that are critical for the success of any cap-and-trade system, as identified by APX Power Markets (2008) and Profeta and Daniels (2005):

- Emissions measuring, reporting and evaluating: The success of the system is linked to the ability of the regulator to apply methods and procedures for measuring and evaluating the system's progress.
- Proper penalty system
- Transparency
- Companies/Sectors/Countries to be included
- Type of indicator (emissions) to be targeted
- Banking/Borrowing: Stavins (2008) explains that allowing for banking/borrowing can reduce some of the cost uncertainty for the companies by letting them shift the timing of their reductions depending on the high or low costs of the period.

However, the impact of any individual system specified for a single country is dependent on the actions of the rest of the countries (Stavins, 2008:318). Without an overall environmental climate agreement, the good results of one country's system would be cancelled by the inefficient policies of another. The opposite also holds: even if the countries reach a holistic environmental agreement, the good performance and commitment of each individual country is imperative. The fundamental purpose of cap-and-trade systems should be a solution that is scientifically reliable, economically efficient and politically realistic.

2.3.4 Points of criticism

As any other policy strategy, a cap-and-trade system is not perfect. There are design issues that should be addressed effectively by policy-makers before they are outweighed by the advantages of the system. Firstly, APX Power Markets (2008) argues that the system is as good as its cap. For example, the European Emissions Trading System (EU-ETS) was often criticised because it did not show any positive results in its first phase. The counter-argument to this is that the emissions cap was determined much higher than what was actually possible for such a short period of time.

Also, targeting the reduction of specific emissions requires advanced technological methods for the measurement and monitoring of the emissions. These data-capturing procedures could be time-consuming and prove detrimental to the overall cost of the method. Even worse, a lack of reliable data can over- or under-estimate the cap and the allocation of allowances (APX Power Markets, 2008).

Price volatility within the system also concerns the policy-makers. The auctioned prices may vary over time and hence, permit prices may fluctuate significantly. Participants will pay close attention for as long as the prices are high; however, low prices will not attract participants to the market and will not provide incentives to participants to invest in emissions reductions (Durning, 2008).

To ensure accountability in a cap-and-trade system, applying strict penalties for non-compliance is crucial. Lenient punishment is not an incentive for participants to obey the rules. For example, during the first years of the Regional Clean Air Incentives Market (RECLAIM), some entities found non-compliance less expensive than compliance (APX Power Markets, 2008) and hence, the desired goals were not achieved.

The disadvantages of a US cap-and-trade system with the ultimate purpose of addressing climate change are discussed in Stavins (2008), who summarises the main objections to the cap-and-trade system as follows:

- Cap-and-trade systems create hot spots of pollution.
- Upstream cap-and-trade will have minimal effects on the transportation sector.
- It would be better to begin with narrow coverage across a few sectors.
- A cap-and-trade system will create barriers to entry and reduce competition.
- The price strike in RECLAIM and the price drop in the EU-ETS demonstrate that extreme price volatility is an inherent part of cap-and-trade systems.
- A cap-and-trade system can put the US at a comparative disadvantage.

Other than the general criticism of cap-and-trade systems, numerous studies compared this market-based system with a tax on CO_2-emissions. Waggoner (2010) identifies the main disadvantages of a cap-and-trade system for the US economy in contrast to a tax measure.

A cap-and-trade system would not assist the US industry and its labour as their competition is foreign markets with factories and employees not subject to a cap-and-trade system. A tax on carbon emission would be better because it is imposed on the carbon content of imports and rebated on that of exports, similar to the function of Value Added Taxes.

Previous experience with SO_2 cap-and-trade systems should not be considered as a predictor for the success of a carbon cap-and-trade system as control of carbon is more demanding. Tax regimes are more trustworthy and are vastly implemented in numerous applications.

Reducing CO_2 will increase its price and it will effectively become a sales tax. In theory, to combat sales taxes, a rebate to low-income populations should be considered; something that a cap-and-trade system does not incorporate. According to Waggoner (2010), a carbon tax will create revenues from the onset of its implementation.

Waggoner (2010) is also concerned about the possible corruption an ill-designed cap-and-trade system might bring. In contrast, a carbon tax is simple and avoids administration problems and possible misconduct.

2.3.5 Comparison between cap-and-trade systems and taxation

The main alternative to a cap-and-trade system is taxation on the consumption of CO_2, mainly producing most of the harmful emissions. The South African National Treasury in its discussion document titled “Reducing Greenhouse Gas emissions: The carbon tax option” (National Treasury 2010) supports the idea that a carbon tax appears to be the most appropriate mechanism to reduce GHG emissions in South Africa.

Chameidis and Oppenheimer (2007) argue that a well-specified cap-and-trade system will have analogous results to an equivalent implementation of carbon tax. However, the advantage of the system is that the environmental goals would be achieved in a specific period of time. National treasury also agrees that in the short-term, a fixed quantitative reduction in emissions cannot be guaranteed with the implementation of a carbon tax even though in the long-run it has the potential of providing a strong price signal, acting as motivation to a behavioural change towards more environmental friendly energy usage.

But Parry (2007:3) stresses the main disadvantages of a cap-and-trade system, compared to the carbon tax implementation. Essentially, the main difference is that with a carbon tax the benefits are distributed over most households as compensation of higher electricity and fuel prices while the participating firms in a cap-and-trade system are the ones accumulating profits and are usually among the high-income groups.

Another constraint of a cap-and-trade system is the adjustment under new scientific or economic conditions and new information about the costs and advantages of SO_2-reductions. This type of system is usually regulated by ‘not-easily changeable’ documentation and agreements. Therefore, the new generation should be more flexible in response to new information, but such an approach must be joined with further improvement each time the conditions require it (Burtraw et al., 2001).

According to Parry (2007:3), the instability of prices is another possibly significant predicament of cap-and-trading systems. The CO_2 tax keeps the prices fixed allowing the emissions to fluctuate based on the economic situation. However, the demand of permits might change on a year-to-year basis due to changes in prices of fuels and energy.

There is also strong belief that the carbon tax approach leaves less chance for corruption compared to cap-and-trade systems where the permits are subject to change over time or according to future measurements (Nordhaus, 2007:39). Nonetheless, Burtraw et al. (2001) find that specifically the US SO_2 cap-and-trade system is “administratively transparent”. The fines are fixed and obedience by the participants has been exemplar.

From an environmental perspective, Bales and Duke (n.d.) argue that a cap-and-trade system provides “... more fundamental environmental certainty than a tax”. This is because such a system is designed to set a quantitative, legally enforceable limit on emissions, and continuously measure and monitor the performance towards the specific objective (Dikeman, 2010)

In conclusion, the main advantages of a cap-and-trade system are summarised by Dikeman (2010) and also discussed by Avi-Yonah and Uhlmann (2009) as disadvantages of a carbon tax. A cap-and trade system:

- assures the achievement of the targets, while desired reductions in emissions are not guaranteed with any tax level;
- grants the participants the power to decide how to meet their targets;
- defines the real price (or cost) of the targeted indicator;
- is better in equalising the price of credits so that the cost is the same for all participating members;

- is easier implemented in a multi-country environment;
- does not face the same political resistance as a tax regime probably would.

To conclude Chapter 2, it reviewed firstly, the characteristics of the South African electricity sector. Special focus was given to the past and current regulations and institutions, the main suppliers as well as the trends of electricity consumption and prices. Secondly, the concepts of energy efficiency and intensity were discussed in addition to a review of global and South African efforts towards efficiency. Finally, a review of the cap-and-trade systems was presented followed by a brief discussion of their advantages and disadvantages. From this chapter, it is evident that energy efficiency-related issues have attracted interest both locally and internationally and solutions are imperative towards future energy use reduction and environmental changes.