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An Investigation into the Drivers and Barriers to Energy Efficiency within Medium and Large Manufacturing firms operating within the eThekwini Municipal Area

by

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Abstract

Preliminary investigations on energy efficiency of manufacturing firms operating in South Africa have shown that no previous study on the barriers and drivers to energy efficiency was conducted. It was also found that South Africa is the only member within the Brazilian, Russian, Indian, Chinese and South African (BRICS) community that has not conducted any formal study on the drivers and barriers to Energy efficiency despite the current energy challenges the country faces. Whilst the National Energy Efficiency Strategy (NEES) was developed and targets were set to improve the country's efficiency landscape, this strategy failed to account for the barriers and drivers to energy efficiency operating within the local context.

This research study sets out to investigate whether an energy efficiency gap exists within manufacturing firms operating in the eThekwini Municipal Area (EMA) and by inference, the national context. It goes on further to analyse the drivers and barriers to Energy Efficiency (EE) within such firms. Such drivers and barriers are then analysed by firm characteristics and across manufacturing sectors.

The results are interesting and contribute well to the general body of knowledge on EE in South Africa. It was found that whilst there is a degree of adoption and awareness of EE technologies amongst manufacturing firms, the quality of the adoption profile is poor. This poor quality profile suggests the possibility of an energy efficiency gap. The barriers and drivers that were found to be significant were also found to be mostly similar across manufacturing sectors. A main finding is that firms are very sensitive to cost and are mainly driven to adopt EE technologies only where there exists an opportunity for cost savings. It was also found that taken together, institutional barriers pose the greatest hurdle to EE adoption. Several interesting results were found in terms of how the barriers and drivers vary with the characteristics of the firm.

The findings of this research indicate that more can be achieved in terms of energy efficiency within the manufacturing subsectors in South Africa. Policy-makers should take into consideration the salient findings of this research when drafting new policy on energy efficiency.

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Acronyms and Abbreviations

BRICS – Brazil, Russia, India, China and South Africa
CFL – Compact Fluorescent Lamp
CIPRO – Companies and Intellectual Property Registration Office
CIPC – Companies and Intellectual Property Commission
DoE – Department of Energy
EE – Energy Efficiency
EEDSM – Energy Efficiency Demand Side Management
EFI – Energy Efficiency Intensity
EI – Energy Intensity
EMA – eThekwini Municipal Area
EMS – Energy Management System
FDI – Foreign Direct Investment
GDP – Gross Domestic Product
GHG – Green House Gas
GLM – Generalised Linear Model
GVA – Gross Value Added
HCI – Human Capital Index
IDA – Index Decomposition Analysis
IEA – International Energy Agency
IFC – International Finance Corporation
IRP2 – Industrial Resource Plan (revision 2)
ISO –International Standards Organisation
KZN – KwaZulu-Natal
LED – Light Emitting Diode
LMDI – Log Mean Divisia Index
MLMF – Medium to Large Manufacturing Firms
NEEAP – National Energy Efficiency Action Plan
NEES – National Energy Efficiency Strategy
NERSA – National Energy Regulator of South Africa
OECD – Organisation for Economic Co-operation and Development
SANEDI – South African National Energy Development Institute
SANS – South African National Standards
SCM – Supply Chain Management
SDA – Structural Decomposition Analysis
SIC – Standardised Industry Codes
SME – Small and Medium Enterprises
UNIDO – United Nations Industrial Development Co-operation

Chapter 1 Introduction

1.1 Introduction to the energy situation in South Africa

Energy sustainability has become a topical discussion amongst world leaders and political parties, and nations worldwide are beginning to realise the impact of this concept on social, environmental, and economic indicators (WEC 2012:3). Moving towards energy sustainability will require more than just changes in the way energy is generated and supplied but also in the way it is used. Energy efficiency is a key determinant of energy sustainability that offers significant potential upside benefits. Energy efficiency is seen as a cost effective approach towards sustainable economic development and the simultaneous reduction of energy consumption trajectories.

Historically, South African consumers enjoyed relatively cheap electricity which resulted in large and small scale industries operating inefficient plant and specifying inefficient processes from an energy point of view - giving the economy its high energy intensity character. In 2002, manufacturing a ton of steel used twice as much energy compared to more energy efficient countries (Aslund 2002). Eskom's electricity tariffs were amongst the four cheapest electricity producers in the world in 2007 (Fin24 2007). Figure 1 below presents South Africa as the cheapest electricity producer amongst a well-represented subset of countries in 2011. While this low tariff rate attracted and continues to attract Foreign Direct Investment (FDI), it creates significant sustainability concerns if manufacturing life cycle processes are well engineered and managed. Energy efficiency was not always a technical consideration in process design or within the agenda of the executive team of many businesses alike or was there any incentive to save energy. This is validated if one has to consider the South African energy intensity situation in economic terms. The country performs poorly amongst developing countries when comparing its value added in $GDP per kWh consumed (Kruger 2009). It uses more than four times the amount of energy to produce one economic unit of GDP compared to its more efficient counterparts i.e., Italy, Sweden, etc. (Kruger 2009). Figure 2 below shows the energy intensity comparative graph for BRICS countries. Over the last decade South Africa's energy intensity has been higher than the world average and has been the second worst performing country within BRICS. In 2007, China’s energy intensity trajectory improved beyond that of South Africa, leaving SA as one of the worst performing countries, second to Russia, within BRICS by energy intensity.

This inefficient use of energy results in South Africa's CO_2 emissions per person being more than double than that of the world average (Energy and Development Group 2015). Aslund (2002) shows that South Africa's addiction to coal has resulted in it being the highest CO_2 emitter on the African Continent. Approximately 90% of the electricity the country generates is produced from coal (DoE 2015a). In the short term, CO_2 emissions are set to grow with the commissioning of Kusile and Medupi. CO_2 pollution within communities impacts negatively on respiratory health.

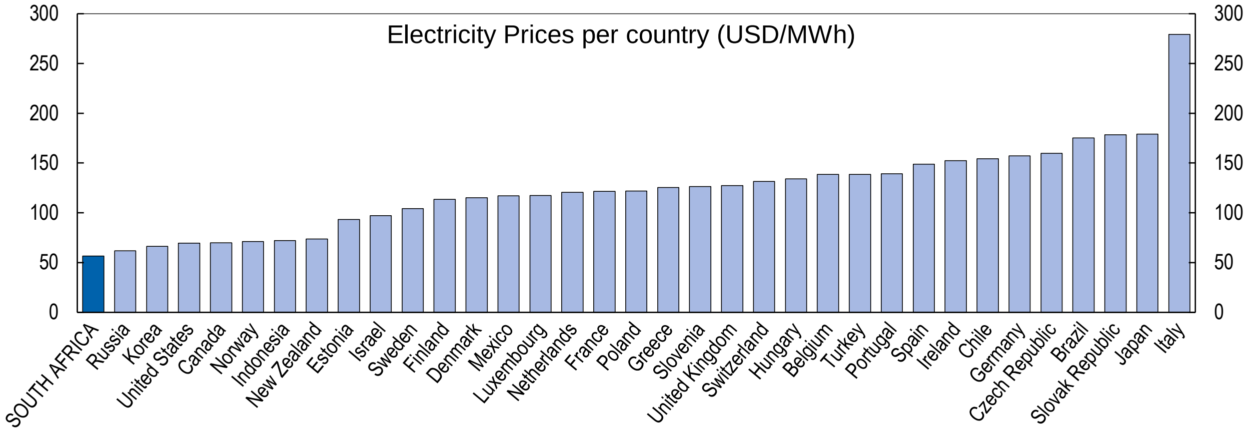

Figure 1 Electricity prices for industry

(2011 or latest year available, USD per MWh)

Note: Fiscal year (April 2011- March 2012) for South Africa, 2010 for Korea (industry only), Indonesia, Canada, Estonia and Brazil.

Source: IEA (2012), Energy prices and taxes, OECD estimates and Eskom.

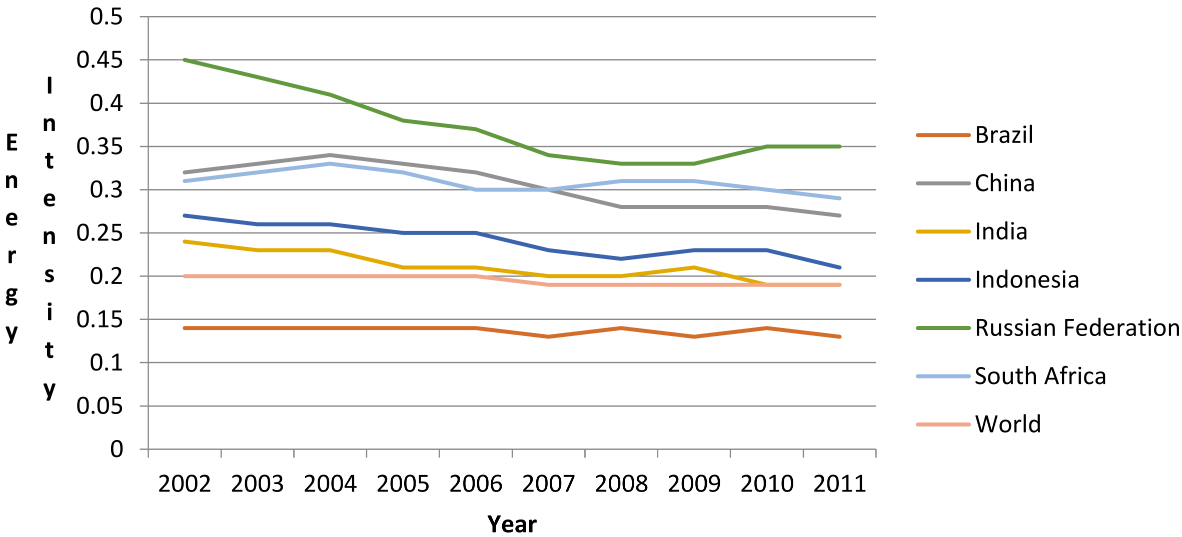

Figure 2 Energy intensity comparison for BRICS countries

(Tonnes of oil equivalent (toe) per thousand 2005 US dollars of GDP calculated using PPPs)

Source: OECDiLibrary, factbook 2014.

The social landscape in South Africa has been a significant contributing factor towards energy supply implications relating to peak consumption and energy demand. Pre-1994, two thirds of South Africa's population did not have access to basic electricity.

Post-apartheid saw the provisioning of electricity to previously disadvantaged areas as a key national objective. However, mass electrification schemes and provision of free basic electricity did not seize the opportunity to implement energy efficient mechanisms. Furthermore, the opening up of the markets together with the cheap price of electricity resulted in rapid economic growth. Unfortunately, such growth patterns were not catered for adequately within Eskom's Load Forecast Planning (Inglesi & Pouris 2010). This lack of capacity planning coupled with the growth trend in inefficient energy has resulted in the current electricity crises where demand outstrips supply.

The landscape however is beginning to change. With the recent annual average electricity increase of 12.69% for 2015/2016 (and higher for previous years) awarded to Eskom and sanctioned by NERSA (Eskom 2016), industrial consumers are now forced to reconsider their energy usage patterns in order to remain competitive. Furthermore, the recent promulgation of the Energy Efficiency Tax Credit Act viz., Section 12L, within the Income Tax Act of 1962 (KZN Energy 2014) serves as an incentive for businesses to move towards becoming more energy efficient. This is supported by the SABS:SANS 50010:2011 standard that is intended to ensure a standardised approach in the measurement and verification of energy savings through energy efficiency initiatives. Other efforts such as the development of national standards for energy sustainability e.g., SANS 10400-XA that governs building regulations and SANS 204:2011 that speaks to Energy efficiency within buildings, assist in ensuring governance in the movement towards energy efficiency (SABS 2011). South Africa recognises the need to transition towards a low carbon society from both a moral and legal standing (PMG 2015). The National Climate Change Response White Paper released by the Department of Environmental Affairs in 2011 highlights South Africa's mature and responsible stance towards global climate change objectives. Its commitment to the Kyoto Protocol already places legal binding obligations to monitor, report and sustainably manage Green House Gas (GHG) emissions.

In 2011, an International Standards Organisation (ISO) standard on Energy Management System (ISO 50001) was released. Such a system is integral for the systematic reporting and monitoring of energy performance within the confines set out by an organisation's energy policy (ISO 2011). Measuring energy efficiency progress encourages continuous improvement in energy efficiency through sustainable and efficient practices. Further, it allows consumers to understand the cost advantages and associated benefits in becoming energy efficient. Currently in South Africa, some large industrial consumers have already adopted this standard as part of a pilot Industrial Energy Efficiency Improvement Project. Bissoon (2012) shows that collectively, these participants achieved a total savings of 87 GWh per year through use of this standard, highlighting its effectiveness thereof.

Another Energy Efficiency drive pertinent to SA industry is a joint effort between UNIDO, the Swiss Secretariat for Economic Affairs, the UK Department of International Development, the SA Department of Trade and Industry and the SA Department of Energy. Together, these organisations embarked on a program to address Energy Efficiency, energy management and carbon emission abatement at several of South Africa's large industrial plants. It is also the objective of this joint venture to facilitate training to industry to ensure the long term sustainability of projects implemented from an energy point of view.

The Integrated Resource Plan Revision 2 (IRP2) of 2011 makes mention of Energy Efficiency Demand Side Management (EEDSM) as an important consideration for future generation options (DME 2011). The report highlights two scenarios with regard to EE viz., a high efficiency scenario and a conservative approach. The high efficiency scenario is however seen as a risky option for inclusion within capacity planning. The conservative approach takes existing EE programmes into consideration ensuring a higher level of energy security in future capacity. The final policy adjusted IRP2 had adopted the conservative approach EEDSM strategy.

In the short term there seems to be contradicting objectives within the Climate Change Policy White Paper of 2011 and the IRP2. Whilst the Climate Change Policy speaks to a reduction in carbon emissions, the Policy Adjusted IRP2 mentions an expansion in the coal fired fleet. The reasoning within the IRP2 is that the country should not abandon abundantly available fossil as coal based generation offers a less risky base load option compared to renewable options and EEDSM.

Focussed consideration for energy efficiency at the national level dates back to 2004 when the Department of Minerals and Energy (DoE) released the National Energy Efficiency Strategy (NEES) for the Republic of South Africa (DoE 2005). Whilst consideration was given for energy efficiency within earlier national white papers on energy policy it was only within the 1998 policy release wherein a formal strategy on

Energy Efficiency was proposed. This strategy aimed to enhance energy security, improve South Africa's global competitive stance by facilitating job creation, to de-couple energy consumption with economic growth, and to reduce Green House Gas (GHG) emissions (DoE 2005). This strategy was reviewed twice since 2005 and an output from the second review was a policy mapping study serving as an input into the National Energy Efficiency Action Plan (NEEAP). A proposed target out of the strategy is a final national energy demand reduction of 12% by 2015 (compared to business as usual) through energy efficiency mechanisms measured from a base year 2000.

1.2 Contextualising Energy Efficiency in industry

Energy intensive industries are more threatened by rising energy prices than less intensive industries. Thollander & Palm (2013) discuss that for non-energy intensive industries, the energy costs in relation to the value added is only 1% to 2% but for the more energy intensive industries, this could range anywhere between 20% (pulp and paper mills) and 515% (foundries).

In energy-intensive industries, production processes are capital intensive. Thus any changes to the process itself is cost prohibiting and therefore not easily accomplished. However for all industry types, supporting processes are generic and include ventilation, heating, cooling, lighting, etc. which all consistently offer huge energy reduction potential. While larger energy intensive firms offer the greatest step improvement in energy efficiency gains (process changes), it should be noted that SMEs should not be discounted as they offer a large relative potential in energy improvement. Within the global space, estimates reveal that 95% of enterprises across the world are SMEs (Edinburgh Group 2012).

1.3 Overview of eThekwini Municipality

eThekwini Municipality is one of six major metropolitans in the country. It is located on the east coast of Southern Africa within the province of KwaZulu-Natal (KZN). It covers an area of approximately 2 300 km^2, registers a population of approximately 3,5 million people and has a maximum energy demand of 1,9 GWh. It is the third largest metropolitan by economic activity (eThekwini Municipality[a] 2016).

eThekwini has a thriving economy that contributes to approximately 65,5% of KZN's GDP and 10.7% of SA's national GDP. These statistics are depicted graphically in

Figure 3 below. From this figure, it is clear that eThekwini plays an important part of KZN's and SA's national economy.

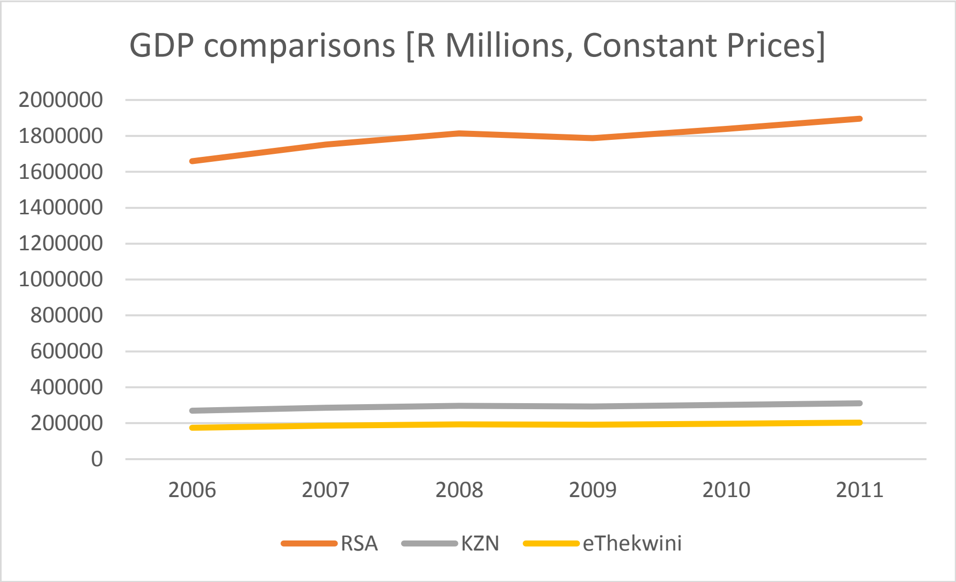

Figure 3 eThekwini, KZN and SA GDP comparison

Source: IHS Global Insight Regional eXplorer, Data version: July 2012

Its sector contribution to the local economy is shown in Figure 4 below.

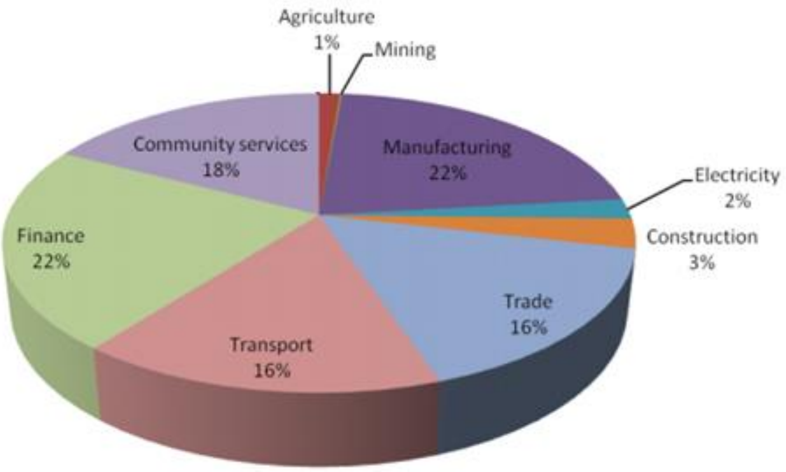

Figure 4 eThekwini's broad sector contribution to its GDP (2012)

Source: Global Insight

According to this figure, eThekwini's secondary and tertiary sectors dominate its economy. Manufacturing (secondary) and finance (tertiary) are both strong contributors. Within the manufacturing sector, it is notably the food and beverages, fuel, petroleum, chemical and rubber products that are the major contributors.

During the 2009 power crisis, eThekwini Municipality setup a standalone Energy Office with a mandate to create awareness about power conservation and to promote energy efficiency. The Office has implemented several energy efficiency projects to date focussing mainly on the residential sector and buildings in general. One of its flagship programmes is its involvement with the Private Sector Energy Efficiency Program (PSEEP). eThekwini views the private sector as a strategic partner in helping to reduce energy usage through energy efficiency means. Some sector specific projects have already been embarked upon which has shown huge savings with limited capital injection. PSEEP itself is a bi-lateral partnership between UK and SA that seeks to improve energy efficiency awareness amongst industrial companies with the objective of reducing their energy intensity. Through these various alliances and projects, the Energy Office has a vision to make eThekwini a sustainable energy manufacturing hub (eThekwini Municipality[b] 2016).

1.4 eThekwini's manufacturing sector

eThekwini's manufacturing sector is amongst the largest manufacturing zones in South Africa and is most representative in terms of sector type. An understanding of the energy efficiency investment behaviour of this region therefore offers a good perspective of the greater manufacturing context in South Africa.

The manufacturing sector within the municipality's boundary exists spatially as industrial hubs of excellence. A heat-map of the spatial distribution of the medium and large manufacturing firms within eThekwini is shown in Figure 5.

Figure 5 shows that there are at least 3 major concentrations of manufacturing industries within the municipality. These include the Pinetown, New Germany and the Durban South areas.

Manufacturing is listed as the most important employment sector within the region with 27% of the labour force employed within the key manufacturing subsectors (eThekwini Municipality[c] 2011). The main manufacturing subsectors within the region include Food and Beverages, Textiles and Clothing, Paper and Furniture, Chemicals, Iron and Steel, Metal, Electric and Electronic, Automotive, Leather and Footwear, and non-Metallic Minerals.

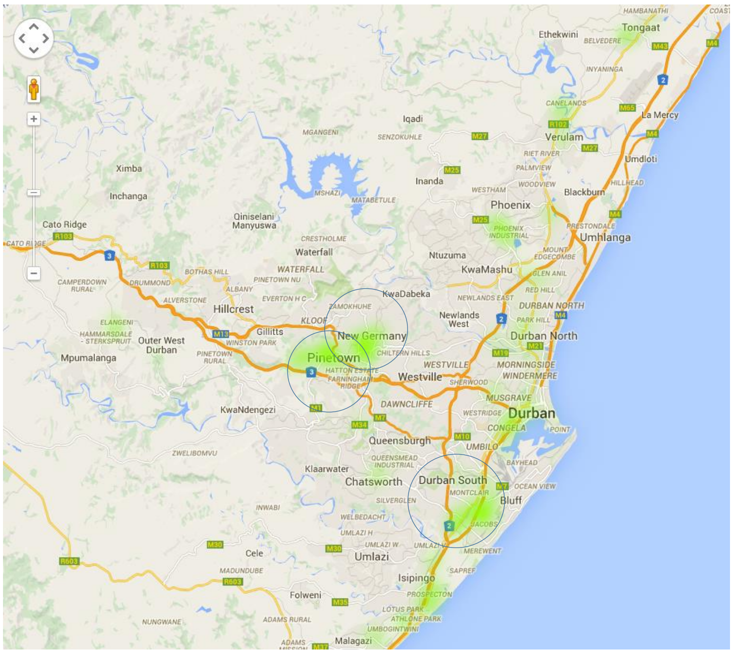

Figure 5 Heat map of MLMF distribution within eThekwini boundary

Source: manipulation of manufacturing data (2015) from the School of Economic studies, University of KwaZulu-Natal

Figure 6 below comparatively shows the relative strength of each manufacturing sub-sector.

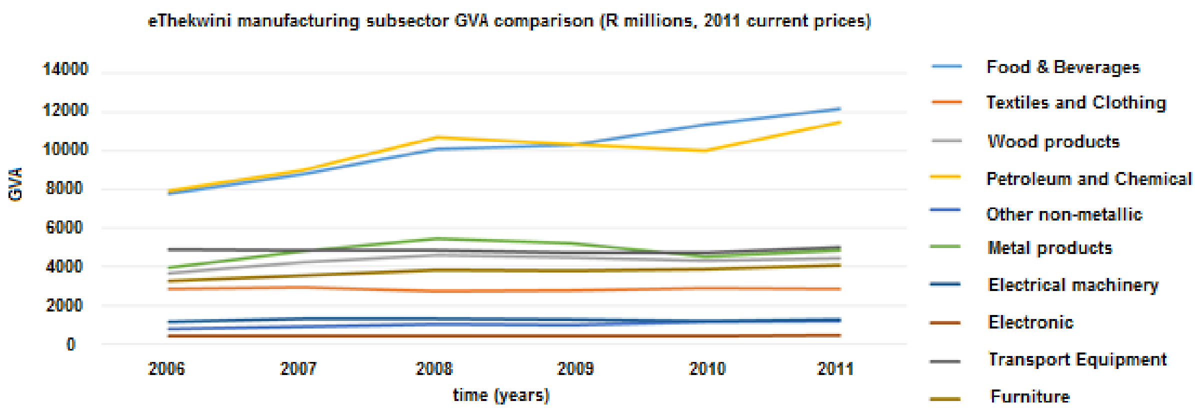

Figure 6 eThekwini subsector GVA

Source: IHS Global Insight Regional eXplorer, Data version: July 2012

Figure 6 shows that the Food and Beverages and Chemical and Petroleum subsectors dominate eThekwini's manufacturing landscape in terms of economic activity as measured by Gross Value Added (GVA).

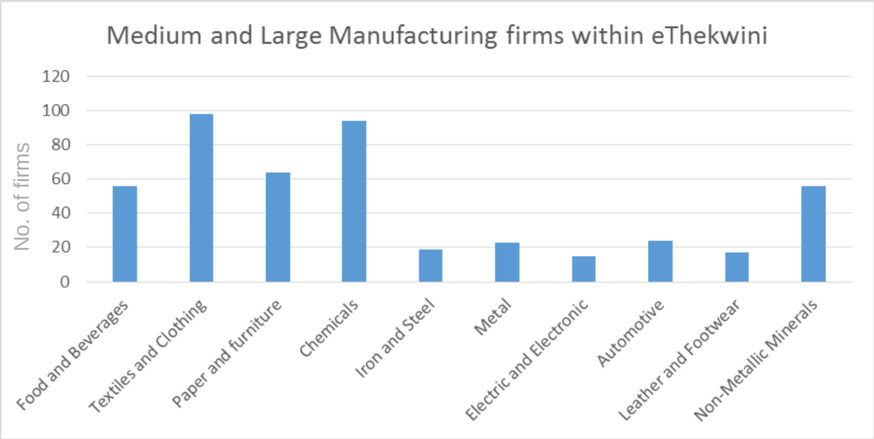

Figure 7 Distribution of MLMFs across eThekwini

Source: manipulation of manufacturing data (2015) from the School of Economic studies, University of KwaZulu-Natal

Figure 7 shows that eThekwini has a good representation of medium and large manufacturing firms across major sectors. Consistent with Figure 6, the Chemicals and Petroleum and Food and Beverages sectors are most prevalent. The high Textiles and Clothing sector count is in contrast to its GVA. This is possibly because of the competitive nature of the business and its inherently low value adding operation.

Figure 8 shows eThekwini's manufacturing GVA in comparison to the top 5 metropolitans across South Africa. The results show that eThekwini manufacturing GVA is second outside the province of Gauteng and amongst the top three. This validates the representativeness of eThekwini's manufacturing sector nationally.

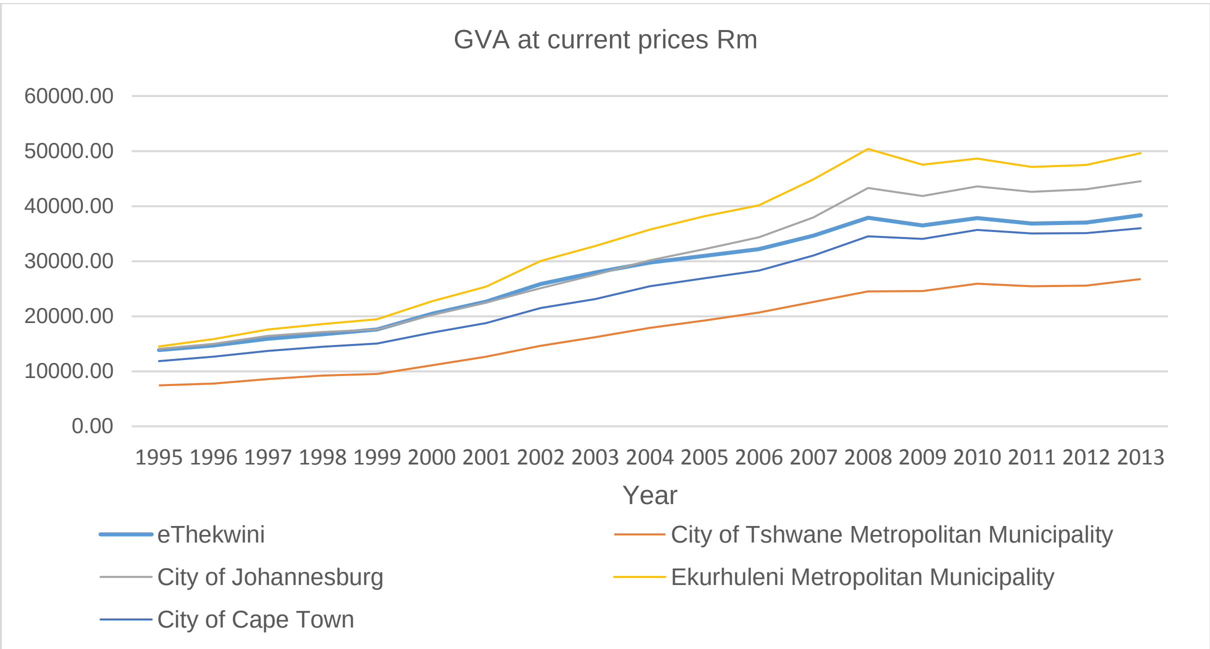

Figure 8 Metropolitan manufacturing GVA comparison

Source: Quantec databases

eThekwini's manufacturing sector relies mainly on electricity from eThekwini Municipality who in turn sources supply from Eskom. The manufacturing sector is therefore not protected from Eskom's power shortage crises and remains vulnerable to network constraints such as load shedding, etc. As the manufacturing sector contributes significantly towards eThekwini's GDP and employment, any disturbances to this sector will negatively impact the prosperity of the region.

While the population of study for this research are manufacturing firms operating within the eThekwini Municipal Area, in terms of firm count, sector density and GVA, the eThekwini region offers a representative population of manufacturing firms should the reader wish to generalise the results nationally. Section 6.6 of this research study does offer some cautionary notes that should be taken into consideration before any such inferences are made.

1.5 Motivation for the study

Due to historically cheap electricity prices, South African industry operates with a higher than normal energy intensity profile. This is a result of industry not taking energy efficiency design considerations into account during early stages of plant specification and the lack of effective legislation to regulate energy use by Industry. This coupled with the lack of foresight in generation capacity planning between 1993 and 2008, resulted in South Africa's energy reserve margin being reduced considerably to a point where any unplanned loss of generation capacity could now invariably lead to national blackouts. In 2008, this became a reality when the reserve margin dropped below 5% resulting in load shedding being initiated. According to NERSA (2008), this was underpinned by a higher than normal growth in electricity demand and limited investment in new generation infrastructure over the last 15 years. Creamer (2008:9) attributes this reduction in the reserve margin not only to poor planning but also to failure in policy. NERSA (2008) estimates the direct cost of the unserved energy to the economy during the 2007/08 supply shortages to be in the region of ZAR 50 billion. Part of the immediate response by SA government in 2008 to help alleviate the problem was to intensify Demand Side Management (DSM) efforts and implement a Power Conservation Programme (PCP). The intention of the PCP was to help reduce the need for load shedding in the short to near term while new power stations are being built. This provided a strong mechanism to accelerate investment in Energy Efficiency.

In a report by UNIDO (2011), it was shown that while South Africa's industrial energy intensity path reduced considerably since 1990 (it fell on average 0.4 toe for every 1000 USD of manufacturing value added), a significant gap still exists between its current energy intensity and that of the world average. In fact, currently South Africa operates with an energy intensity of more than double of the world average. A study on the technical potential of intensity improvement within the manufacturing sectors (WEC 2012:15) reveals that developing countries can improve the efficiency of their plants by as much as 30-35% through the co-ordinated use of best available technologies. The report goes on further to mention that in order to reap the full environmental, economic and social advantages associated to following a reduced energy intensity path, more policy and firm level efforts are required, particularly in overcoming institutional, economic and technical barriers to energy efficiency.

In order to reduce the inherently high energy intensity profile of the country (resulting in the simultaneous improvement in energy security and reduction in GHG emissions), energy efficiency mechanisms that reform the manner in which energy is sourced and applied needs to be considered. The National Energy Efficiency Strategy (NEES) of South Africa set out to address these concerns. However, a key component to the successful implementation of any national strategy on Energy Efficiency first hinges upon understanding the inherent barriers and drivers to the adoption of these technologies within the context in which they operate; and no such study was found within the South African industry. Fawkes (2005) raised this point in a paper on energy efficiency within the South African Industry in 2005. If the NEEAP addresses industry according to a generic subset of barriers that may not necessarily be pertinent to the South African industry, the implementation of any corrective measure will have a reduced effect.

It is the intention of this study to therefore address these concerns by first understanding the EE landscape in South Africa through an investigation of a mix of EE quality criteria and through an understanding of the drivers and barriers that affect the propensity of firms to adopt EE technologies. An investigation into how these barriers and drivers vary with firm and sector characteristics within the context of the South African environment shall also be conducted. Based on the results of this empirical study, future policy on Energy Efficiency could be more selective in associating policy mechanisms to counteract barriers according to the characteristics of the industry in which they are most prominent.

1.6 Problem statement

Preliminary investigations show that there is typically an underinvestment by South African industrial firms in energy efficient technologies amidst much research highlighting its potential upside advantages. Despite this energy efficiency paradox, no contextual study has been undertaken to investigate the key determinants for this underinvestment by South African manufacturing firms. International literature on the efficiency paradox has over time shown that the reasons for this deficiency lies in a body of knowledge referred to as efficiency barriers. Fawkes in his 2005 paper on Energy Efficiency in South Africa called for an empirical investigation into these barriers within the local context. However, since then, no such study has been found. The National Energy Efficiency Strategy Plan of 2005 recognises the need to identify pertinent barriers as fundamental for the successful implementation of the strategy itself. However, this document only provides a broad overview of the generic categories of barriers. The list itself is non-exhaustive and is not related to firm characteristics i.e., firm size, turn-over, intensity level, etc., or the sector in which firms operates. While some studies (UNIDO (2011:105-115) & Bennet (in Fawkes (2005:4))) have been performed within other national economies, it remains questionable whether the same factors apply within the South African context. Furthermore, when taken together these studies don't provide a consolidated and re-inforcing viewpoint. Effective policy to address the low adoption rates on Energy Efficiency can only be developed once a thorough investigation of the barriers that impede and drivers that support the adoption of such technologies is conducted and well understood.

1.7 Focus of this Study

The intention of this study was to understand the barriers and drivers to energy efficiency technology adoption by medium and large manufacturing firms operating within the eThekwini region. As the eThekwini Municipal Area is representative of manufacturing firms operating across South Africa, the results can be generalised to the national context taking into consideration special cautionary notes given in Section 6.6 of this report. The study also investigates how these barriers and drivers vary with firm characteristics and manufacturing sector. Based upon the results of this study, future policy implications that should be taken into consideration are prescribed.

1.7.1 Research objectives

The objectives of this research are achieved through three parts:

A. To determine whether there is an energy efficiency gap amongst manufacturing firms within the eThekwini region.

B. To understand the Energy Efficiency investment behaviour of manufacturing firms through an analysis of the barriers and drivers that impede or foster the adoption of energy efficient technologies

C. Upon understanding the firm specific investment behaviour to Energy Efficiency, it will be appropriate then to advise on policy implications based on the main findings.

1.7.2 Research questions

Based on the objectives of this study, this research attempted to find answers to the following basic questions:

1. Is there an EE gap among medium to large manufacturing firms operating in the eThekwini region?
2. What are the barriers and drivers to the adoption of energy efficiency technologies by medium to large manufacturing firms operating in the eThekwini region?
3. Do the barriers and drivers vary by manufacturing sector and with the characteristics of the firm? If yes, how do they vary?

1.8 Limitations of the study

The boundaries of this study were derived from the research objectives and are listed below:

1. This study was limited to medium and large manufacturing firms. Micro, very small and small enterprises require a separate research undertaking that takes into consideration the dynamics of these firms.
2. The empirical research was conducted on the South African Industrial landscape only. However, insights gained from this study may add to the general body of knowledge on barriers and drivers to energy efficiency internationally.

3. This study focusses on the manufacturing industries with the Standard Industrial Codes as defined in Table 9. The insights could however still be useful for sectors not covered in this study. Note that the residential sector is not within the scope of this research.
4. The empirical study was based on manufacturing entities operating only within the eThekwini Municipal region due to cost and time constraints. However, taking the special cautionary notes mentioned in Section 6.6 of this study into consideration, the results may be carefully extrapolated to the national context.

1.9 Structure of the chapters

Chapter 1 of this report provides the reader with insight into the energy landscape within South Africa. It also endeavours to provide a broad overview of the country's energy efficiency journey to date. It sets the boundaries to this study and reminds the reader on the focus of the research by clearly defining the research objectives.

Chapter 2 offers a review of the literature on Energy Efficiency. In the review of this literature, the funnel method was adopted where energy efficiency was first explored at the global level before perspectives on the local industry were examined.

Chapter 3 reviews the existing theoretical frameworks on barriers and drivers to energy efficiency. Using these frameworks, a taxonomy for empirical research is proposed. The industrial controls used for this research also discussed. Finally a conceptual model that that shows the interactions between the barriers, drivers and benefits to energy efficiency within a system is proposed.

Chapter 4 is a review of the research design and methodology used in this study. It attempts to provide the reader with an understanding of the process followed for data collection and analysis. It presents the research logic used, provides detail on the design of the research instrument, sampling frame and data gathering technique.

Chapter 5 presents a quantitative analysis of the data gathered. The analysis is conducted to answer the research questions raised earlier. A descriptive analysis of the results provides an indication of the EE landscape within the EMA. An analysis of the barriers and drivers to EE against manufacturing sector and firm characteristics is also conducted. The implications of the results are also presented.

Chapter 6 is a discussion of the salient points raised in the analysis of the data. These points are interpreted based on the research objectives and questions put forward in Chapter 1. It proposes future policy mechanisms to help improve the energy efficiency landscape within South African Industry. Shortcomings and limitations of the study are presented and recommendations for future research are also made.

1.10 Summary

The aim of this Chapter was to provide a background into the energy situation within the South African environment. It discussed the reasons as to why the energy market in South Africa is at a critical point and went on to discuss the various energy efficiency interventions by government to alleviate the already constrained supply network. A review of the National Energy Efficiency Strategy of SA and its relation to Industry led to a discussion on the motivation for this research study. As such, the chapter also set out the research objectives and questions upfront and identified and listed the limitations of this study.

The next chapter reviews the literature on energy efficiency by first understanding the international perspectives on the subject and then relating these to the local industry.

Chapter 2 Background

2.1 Introduction

This chapter aims to provide perspective of Energy Efficiency at an international and local context. It starts off by first exploring the concept of the energy efficiency gap paying particular attention to its origin. The funnel methodology is used in this chapter whereby we first investigate perspectives of energy efficiency at the global level and then drill down into energy efficiency within the South African context. In doing so, we consider the potential of industrial energy efficiency worldwide, the current industrial trends within emerging and developed markets and highlight specific convergences within these economies. In order to make comparisons and form baselines, we review the specific policies, targets, trends and barriers within Brazil, Russia, India and China. We then conduct an in-depth energy efficiency decomposition study in South Africa to track performance made since the release of the national Energy Efficiency Strategy of South Africa using year 2000 as a baseline. We also take a look at some past research on how barriers to industrial energy efficiency vary with firm characteristics and sector type. Finally, we consider past surveys conducted at international level on barriers facing Industry and summarise the salient findings. The chapter concludes with a summary of the literature review and highlights the key points raised within the chapter.

2.2 The Energy Efficiency gap

The energy efficiency gap is commonly described as the difference between the actual and optimal use of energy. Studies on the optimal use of energy dates back to the late 1970s during the period of the oil embargo crisis in the US. The result of this crisis led to several investigations into energy conservation techniques, primarily reports (as discussed below) that spoke to the potential energy savings through the use of energy efficiency technologies. The reasons as to why an efficiency gap existed was also investigated and the answer is known to lie in a concept known as the energy paradox.

This paradox is based on the premise that any economically superior technology should gradually diffuse through the market over time. In the case of EE technologies which has been proven to be cost effective, several studies have shown that this is typically not the case. Koomey, Sanstad & Shown (1996) show that energy efficient magnetic ballasts for fluorescent lighting were available since 1976. Even though these had far superior performance characteristics than standard ballasts, it was only until 1990 that federal standards prohibited the sale of the standard ballast. Studies have shown that customer confidence and reluctant retail distribution networks were the main causes for the slow diffusion of this technology. In another popular study conducted by DeCanio (1998) on energy efficient lighting, it was shown that even though significant cost savings could be incurred from utilising efficient lighting technology, its rapid deployment was not being realised because of deficiencies internal to private and public sectors. In a separate case study conducted by Meier & Whittier (1983), consumers were presented with a choice of two identical refrigerators that only differed in price and efficiency. The energy efficient fridge incurred savings of more than 25% of the total energy consumption but at a cost of $60 higher than the standard model. Despite the favourable long term cost benefits of the energy saving alternative, more than 50% of the population within the study chose the lower cost refrigerator alternative. In this case, the higher initial upfront cost posed a limitation to the adoption of the energy efficiency refrigerator.

The imploring question then is: if vast literature and case studies on specific technologies show favourable economics, why then do organisations not readily adopt them? Why is the observed rate of diffusion of these technologies shown to be much less than the optimal rate? The reasons for this were touched on above and resides in a body of knowledge known as barriers to energy efficiency.

2.3 The hypothetical potential of energy efficiency

In an article by Jaffe and Stavins (1994) that presents a view on the energy efficiency gap, the potential of energy efficiency is broken into three tiers viz., the economists potential, the technologists potential and the hypothetical potential i.e., if all limitations on its adoption are removed. This viewpoint was later criticised by Sorrel et al. (2000) who redefines the hypothetical potential even further by taking other softer issues into account viz., the human dimension and organisational dynamics.

Of a more practical account, in a study conducted by UNIDO (2011) in identifying the potential of industrial energy efficiency improvement projects, the following results were found for developing countries:

Table 1 Technical and energy savings potential of EE within developing countries

Sector	Technical potential (%)	Energy savings potential (EJ/y)
Petroleum refineries	70	4.6
Chemical and petrochemical	23	1.8
Non-ferrous minerals	31	1.1
Iron and steel	30	5.4
Non-metallic minerals	33	2
Pulp and paper	20	0.3
Textile	20	0.3
Food and beverages	40	1.4
Other sectors	30	8.7
Total	~33	~25

Table 1 shows that there is still significant potential for technical improvements within industrial process plants in developing countries. Based on the use of best of breed technologies (those used in the most energy efficient plants), the current technical potential stands at ~33 % when compared to business as usual and approximately 6% of the total worldwide energy use. The largest technical potential resides within process industries viz. petroleum refining, iron and steel, non-ferrous minerals (cement) and pulp and paper. With energy savings comes associated environmental benefits. UNIDO (2011) estimates the total CO_2 reduction potential from industry to be in the order of 12%. Further to this, energy savings improve the bottom line of firms resulting in profitability and ultimately the economic stability of nations.

While the potential for improvement exists and the technologies are available, too few opportunities are being taken. It is the intention of this study to investigate the reasons for this.

2.4 World-wide industrial Energy Efficiency

During the formative years of early industrialisation, energy seemed limitless. This view has recently changed as fossil fuels that generate this energy are now known to be less abundant than initially thought. Furthermore, we now have a deeper understanding what the impact of burning these fuels has on the environment. Historically economic growth (indicative of the competitiveness of nation) was directly proportional to energy consumption but this came at a cost to the environment.

UNIDO (2011) states that industry remains one of the most energy intensive sectors in the world i.e., more energy used to produce one economic unit of value. This is most prevalent in developing countries such as South Africa. Decoupling energy consumption from economic growth allows for achievement of economic and environmental goals.

A prevalent structural shift in developed economies show movement away from energy intensive manufacturing industries towards the services sector (refer to Figure 10). As such, the services sector in developed economies are larger than the manufacturing sector. The services sector uses less energy per economic output so a developed country's energy intensity is expected to be much less than that of developing countries. Developing countries are highly inefficient in terms of their energy use, especially those that are of a lower income. This is depicted graphically in Figure 9 below.

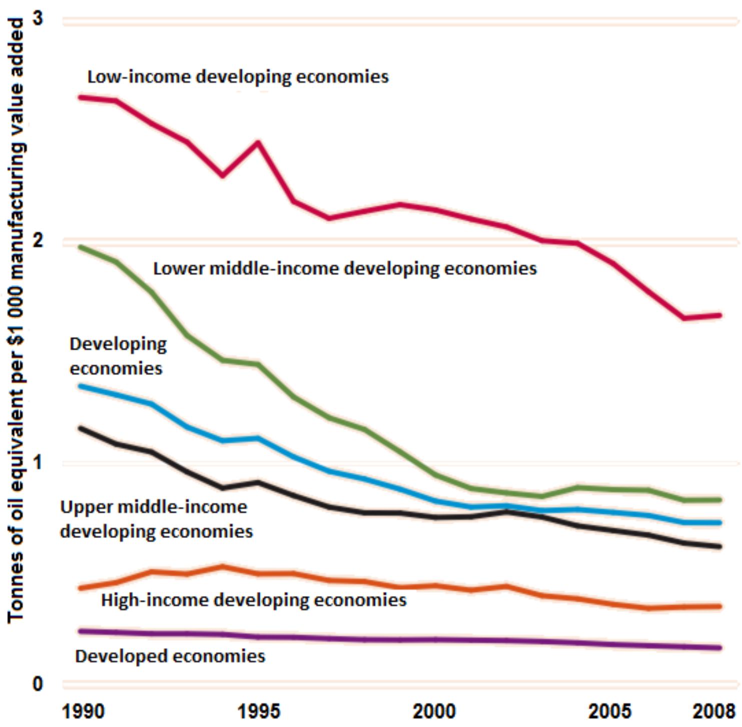

Figure 9 Industrial energy intensity by economy income group

Source: UNIDO Industrial Development Report 2011. UNIDO (2011)

In a report by ABB (2011) on global energy efficiency trends in 2011, global energy intensity decreased by 1.4 percent per year between 1990 and 2009. The reduction is driven mainly by carbon abatement policies, energy efficiency programs and structural changes in markets. According to this report the greatest reductions came from countries with the highest energy intensity in 1990. CO_2 emissions from energy use per GDP has also been decreasing (albeit at a higher rate than primary energy intensity) at a rate of 1.5 percent per year between 1990 and 2009. The figure is higher than the rate of decrease of primary energy intensity mainly due to the shift in energy sources viz., an increase in the use of renewables, nuclear, etc. Industry accounts for approximately 40% of the world's electricity consumption and has contributed approximately 30% of the overall decrease in energy intensity since 1990. Figure 10 below shows energy growth consumption trends. In particular, over recent years, the energy growth consumption of industry within developing economies have started to ramp upwards. This is mainly because such economies are transitioning from historically agricultural based economies to more industrialised markets. Figure 10 also shows the main differences between developed and developing countries in terms of their industrial energy consumption and the energy consumption of the services sector discussed earlier.

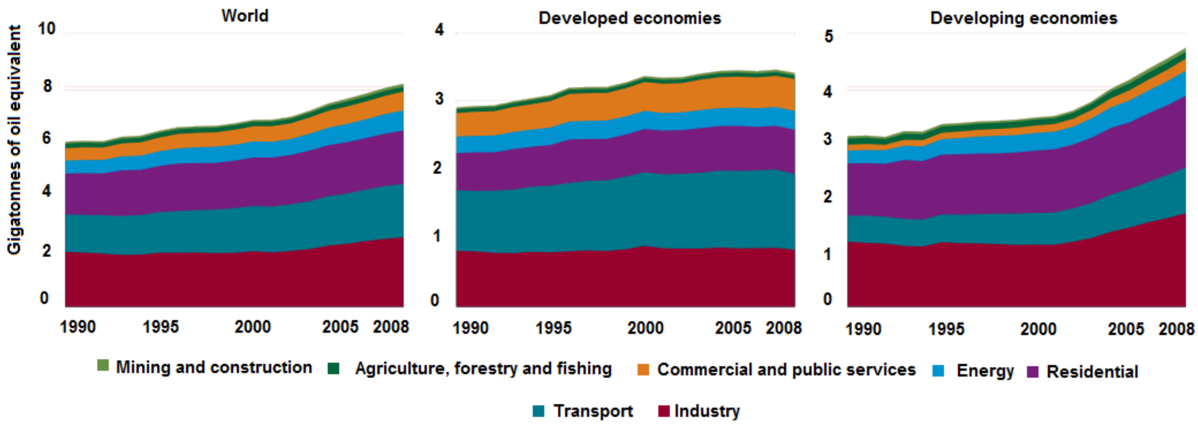

Figure 10 Growth in energy consumption by economic sector

Source: UNIDO Industrial Development Report 2011. UNIDO (2011)

Energy intensive industries account for approximately 55% of the total industrial energy consumption at the world level. Of the energy intensive industries, the steel industry which is the most intensive energy consumer, accounts for approximately 20% of industrial energy consumption. The non-metallic minerals sector accounts for approximately 15%, the chemical industry approximately 15% and the paper industry approximately 5 percent. China and Russia's industry contribute significantly to the global energy intensity profile.

The following sections look into the energy efficiency stance of BRICS countries. It highlights their specific policies, targets, and barriers to help gauge a global perspective on energy efficiency trends. Much of the statistics reported herein are summarised from a report on Global Energy Efficiency published by ABB (ABB 2011).

2.4.1 Energy Efficiency in Brasil

Brasil's primary energy intensity is lower than the world average. Industry is Brasil's largest energy consumer consuming just over 40% of the total final energy consumption of the country. The country's main source of energy within its fuel mix is hydroelectricity.

The national government of Brasil has taken a firm stance on energy efficiency and plans are in place to improve energy efficiency within all sectors of its economy. While no specific study on the barriers to energy efficiency has been conducted on industrial firms operating in Brasil, some studies pertaining to the barriers to energy efficiency adoption within buildings have been investigated by Johnson Controls (2013).

2.4.1.1 Policies and targets

Consideration of Energy Efficiency at the national level is regulated through the National Climate Change Plan. This is an overarching plan that focusses on addressing Climate change taking a systems perspective. The plan consists of three main legs viz. deforestation, energy efficiency and renewable energy. The target set is to save 109 TWh of electricity and 30 mt of CO_2 by 2030 through this Climate Change Plan.

2.4.1.2 Trends

The country's total primary energy intensity has been decreasing at a slower rate than the world average. Industry's share of final energy consumption has been moderately constant since 1990. CO_2 intensity has been decreasing more rapidly than primary energy intensity. This is mainly due to a shift in the fuel mix to renewable sources and the significant growth in hydroelectric power stations.

2.4.2 Energy Efficiency in Russia

Russia's primary energy consumption is twice that of the world's average. This is mainly because of its large share of energy intensive industry. Industry is its largest end user of energy (approximately 60% of total energy is consumed by Industry). Russia's main energy source is gas. Government sees energy efficiency as a high priority within its administration and intends revolutionising the energy market through a well-defined strategy. Energy intensive industries include, steel, chemicals and non-metallic minerals and these are becoming more prominent contrary to trends of most developed countries.

2.4.2.1 Policies and targets

An energy strategy is in place that sets a target to save approximately 56% of projected energy by 2030 using 2009 as a baseline. To achieve this, the strategy aims to implement new regulations and standards within the market e.g., tax incentives, penalties, building regulations, etc. Several policies and programmes are currently in place to achieve projected targets. These include:

a. Targeted energy efficiency programs that promote energy efficiency within specific sectors.
b. Federal law on energy conservation and energy efficiency—energy intensive industries are subjected to regular energy audits. Incorporation of tax benefits and incentives to promote energy efficient industry for the energy intensive industry.

2.4.2.2 Trends

Russia's average yearly primary energy intensity has been on the decrease since 1995. Moderate industrial energy intensity reduction has also been achieved. CO_2 intensity experienced similar decreases mainly due to reductions in energy intensity. While national energy intensity demonstrated constant reductions over the past years, the energy intensive industries showed a lessor reduction during the same period.

2.4.2.3 Barriers to industrial Energy Efficiency in Russia

In a study by the International Finance Co-operation (IFC) and World Bank on energy efficiency (IFC & World Bank n.d.), the following salient barriers were found to be significant within the Russian industry:

a. Lack of energy efficiency technology awareness by management
b. Split incentives by management to adopt energy efficient technologies
c. Skills and capacity to identify and analyse energy efficiency opportunities
d. Capital barriers and unattractive financing mechanisms to fund energy efficiency technology adoption
e. Very competitive energy tariffs allow businesses to remain competitive without need for the adoption of energy efficient technologies.

2.4.3 Energy Efficiency in India

India's primary energy consumption has seen significant yearly increases since 1990 mainly because of mass electrification schemes being implemented. India's main energy source is coal and its use is progressively increasing with consumption trends. India's Industry consumes approximately 40% of the final energy consumption of which the majority share comes from steel industry.

2.4.3.1 Policies and targets

India's energy efficiency drive is led through two main programs viz. Energy Conservation Act and National Mission for Enhanced Energy Efficiency (NMEEE) within A National Action Plan on Climate Change (NAPCC).

The Energy Conservation Act promulgated by government speaks to labelling and performance standards and has a main focus on heavy industry.

NAPCC was adopted in 2008 and a NMEEE was implemented with onerous targets set for 2015 viz., an averted generation volume addition of 19 GW and CO_2 mitigation of 98Mt. India's recent target was a 5% energy reduction by 2015 using 2002 as baseline. A Bureau of energy efficiency has been setup to implement, monitor and control these programs.

2.4.3.2 Trends

India's total energy intensity has been on the decrease since 1990. CO_2 intensity has also been on the decrease since 1990 but at a much slower rate than energy intensity; this is mainly attributed to coal being its main energy source and a decreasing share of carbon free sources in the energy mix.

Industrial energy consumption had increased considerably since 1990 backed by strong GDP growth. However, there has been a significant overall industry energy reduction trend since 1990.

Energy intensive industry's share in total energy consumption has been constant since 1990 and therefore there is focus by government on such industries.

Steel, non-metallic minerals and chemical sectors dominate as the main energy consumers in Industry.

2.4.3.3 Barriers to Industrial Energy efficiency in India

In a study conducted by UNEP (2006) into the barriers to Energy Efficiency within the Asian Industry in 2006, the following salient barriers in order of priority were identified in India:

a. There are no financial incentives from government to be energy efficient.
b. Energy efficiency is not seen as high priority; production time is more important to management.
c. Organisations are concerned that the investment costs are too high.
d. Authorities are not strict in implementing environmental legislations.
e. There is a lack of co-ordination between external organisations to facilitate energy efficiency.

2.4.4 Energy Efficiency in China

China's energy consumption per capita is close to the world average. Industry is the main consumer of energy and its share in overall energy consumption has been increasing since 1990. China's main energy source is coal and its share of coal within the primary energy mix has also been on the rise since 1990. The Chinese government has taken an aggressive stance towards energy efficiency and is determined to put China on a less energy intensive path.

2.4.4.1 Policies and targets

China has given energy efficiency highest priority within its energy strategy. Several policies and programs have been implemented to date and these include:

a. Policies to reduce capital barriers to energy efficiency adoption
b. Labelling standards that are in place and in use
c. Minimum efficiency standards for industry
d. Efficient SCM polices for procurement of energy efficient technologies

An energy programme is currently in place for China's top 100 Energy Consuming firms which together make up about 30% of the country's total energy consumption and 50% of its industrial demand. These firms are required to reach energy performance targets through a structured framework. China also has a program in place to decommission small and inefficient plants. Taken together all these policies and programs work together in achieving a 17% reduction in energy intensity by 2015.

2.4.4.2 Trends

Primary energy intensity is well above the world average. However, the rate of reduction of its total energy intensity is amongst the highest in the world mainly due to efficiency improvements within its cement industry.

CO_2 intensity is being reduced at a much slower pace than primary energy intensity mainly because the country is heavily reliant upon coal as its primary energy source and this share is increasing over time. Energy consumption in industry is growing rapidly (in stark contrast to world trends). The share of heavy industry on the overall industrial energy consumption has been on the increase since 1990. China's steel industry has been booming and its share of energy consumption has been growing over the years. The steel industry in the biggest single consumer of electricity in China, followed by non-metallic minerals (particularly cement) and the chemical industries.

2.4.4.3 Barriers to industrial Energy Efficiency in China

In a study by Wang, Wang & Zhao (2008) on the analysis of interactions among the barriers to energy savings in China, 13 barriers that were found relevant to their industry were raised. These include, the lack of awareness of the need for energy savings, lack of experience in management of energy savings projects, lack of available funding for energy efficient technology adoption, a limited policy framework to support energy efficiency initiatives, the lack of trained manpower to implement and support energy efficiency interventions within industrial organisations, the lack of consolidated public participation, the lack of data to support energy efficiency investments, energy efficiency technologies are seen as a high risk option, objections from firms that don't want change to their production processes, industrial frameworks that do not support energy efficiency, and the lack of strategic planning for industrial energy efficiency by government.

Within the commissioned UNEP (2006) study into the barriers to Energy Efficiency within the Asian Industry in 2006, the following salient barriers in order of priority were identified in China:

a. Authorities do not enforce environmental regulations strictly
b. Management within industrial firms are reluctant to invest in energy savings schemes because of the large upfront investment costs
c. Management finds production more important to energy efficiency investments

d. There is a lack of co-ordination between external organisations to support energy efficiency
e. Firms argue that it is difficult to access external skills and technical advice for energy efficiency projects.

2.5 Concluding remarks on energy efficiency trends of BRIC countries

Primary energy intensity and CO_2 emissions have been on the decrease for all BRIC countries. This is mainly due to ambitious efficiency targets and robust policy measures that have been put into place, especially within China to decouple economic and energy growth. China has strong industrial programs in place to support energy efficiency. They have specifically targeted their top 100 industrial energy consumers in reducing their energy intensity through a structured framework. What is also consistent amongst these countries (except for Brazil) is that they have each found the need to conduct contextual studies on barriers to energy efficiency within their local industries. Such studies have assisted in driving industrial policy on energy efficiency.

2.6 Energy Efficiency in South Africa – A decomposition analysis

2.6.1 Background

In 2012, Statistics South Africa released the energy accounts by sector for the period 2002-2009. The data contained within this report (summarised in Figure 11 below) shows that the manufacturing sector had consumed the highest amount of energy within this period despite showing significant year-on-year reductions since 2002 (StatsSA 2012). However, investigating the energy consumption alone doesn't paint a clear picture of the energy efficiency performance of these sectors. In order to understand this, it is necessary to relate the value added per sector with the energy consumed i.e., the energy intensity. Section 2.6.2 analyses the Energy Efficiency progress in South Africa from the base year 2000 until the date upon which the most recent data was available at the time of this study.

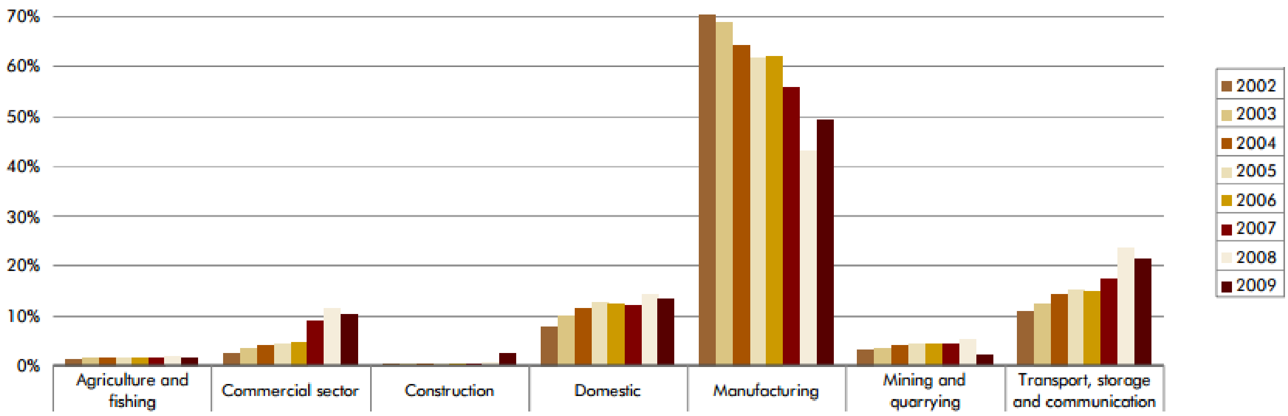

Figure 11 Energy consumption by sector in South Africa over an eight year period

Source: Statistics South Africa - Energy Accounts (2012:26)

In order to quantitatively understand the effectiveness of energy efficiency policy to date i.e., NEES-SA and whether it has reached its baseline targets over the period of interest (2000-2015), it is necessary to first decompose the energy profile of the country into its underlying contributors. These include structural, intensity and production components (Inglesi-Lotz & Pouris 2012). Energy intensity measures the relationship between final energy consumption and GDP (or Gross Value Added for a sectoral analysis) and is commonly used as an indicator for energy efficiency. The structural component indicates changes in the contribution of each economic sector to the energy profile. The production effect refers to the level of change of industrial output.

Further to this, a disaggregation of the energy trends into the contributing sectors of the economy shall help in finding focussed improvement areas where further research may be required. An output of this study shall also provide guidance in the development of future strategy on energy efficiency.

Inglesi-Lotz and Pouris (2012) have conducted one such study within the South African context during the period 1993 to 2006. However, the landscape of energy efficiency has been dynamic since 2005; with the promulgation of energy efficiency policy in 2005, and its review in 2008 and again in 2010. It is prudent then that a more contemporary study within the same context be conducted to examine the impact of such instruments.

Heinen (2013) considers that the primary goal of energy decomposition is to be able to quantify the contributions of pre-determined factors to the change in energy consumption. This shall allow us to understand and attribute the reasons for changes in energy consumption and importantly to gauge whether energy efficiency has been a major contributor. As an output, we shall be able to measure the effectiveness of energy policy.

2.6.2 Decomposition method

Vast literature exists surrounding the methods of energy decomposition. However, these may be categorised into two main methods viz., Structural Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) (Ma & Stern 2006). The IDA approach is generally more accepted in literature on energy decomposition as it can be applied to time-series data available at any level of aggregation as opposed to the SDA approach which relies on input-output data. Ma & Stern (2006) discuss that the main disadvantage of the IDA approach is that it cannot differentiate between direct and indirect energy demands. Within the IDA approach, several different indexing methodologies have been developed and are available for use. For this study, the Log Mean Divisia Index (LMDI) technique proposed by Ang & Liu (2001) shall be adopted. Ang and Liu (2001) argue that the LMDI methodology is superior to other methods for four reasons viz., allowance for perfect decomposition, path independency, ability to handle zero values, and consistency in aggregation. This is consistent with the Inglesi-Lotz & Pouris (2012) Energy efficiency decomposition exercise within the South African context.

If there are many sectors (n) defined as (Ei) and (Yi) that make up the total energy consumption and total production level respectively of the country, then the total industrial energy consumption can be specified as:

$$E_t = \sum_{i=1}^{n} \left(\frac{E_{i,t}}{Y_{i,t}}\right)\left(\frac{Y_{i,t}}{Yt}\right) Y_t = \sum_{i=1}^{n} I_{i,t} S_{i,t} Y_t \tag{1}$$

Where, in accordance with Xiaoli, Chunbo & Dongyue (2010) we define the following variables:

E_t: total industrial energy consumption in year t

$E_{i,t}$: energy consumption of sector i in year t

Y_t: total industrial production in year t (2005 constant prices)

$Y_{i,t}$: production of industrial sector i in year t (2005 constant prices)

$S_{i,t}$: production share of industrial sector i in year t; $S_{i,t} = \frac{Y_{i,t}}{Y_T}$

$I_{i,t}$: energy intensity of industrial sector i in year t

Equation 1 indicates that the total energy contribution is a composition of the sectoral energy intensities, sectoral production share and the total industrial production.

Changes in aggregate energy in the period (0,t) may be measured in terms of ratios or differences. Each has its own merits as discussed in Inglesi-Lotz & Pouris (2012). While the ratio method is more concise, the difference method is mathematically simpler and easier to comprehend. For this study the difference method shall be briefly discussed and implemented.

Using Equation 1, the change in energy consumption between a base year 0 and year t can be decomposed as follows:

$$\Delta E_{tot} = E_t - E_0 = \Delta E_{out} + \Delta E_{int} + \Delta E_{str} \quad (2)$$

Where:

ΔE_{out}= change in energy consumption due to production output changes

ΔE_{int}= changes in energy consumption due to energy intensity changes

ΔE_{str}= changes in consumption due to structural changes in the sectors

According to Ang (2004), these terms can be determined as:

$$\Delta E_{out} = \sum_i w_{i,t} \ln\left(\frac{Y_t}{Y_0}\right) \quad (3)$$

$$\Delta E_{int} = \sum_i w_{i,t} \ln\left(\frac{I_{i,t}}{I_{i,0}}\right) \quad (4)$$

$$\Delta E_{str} = \sum_i w_{i,t} \ln\left(\frac{S_{i,t}}{S_{i,0}}\right) \quad (5)$$

$$\Delta E_{tot} = \sum_i w_{i,t} \ln\left(\frac{Y_t S_{i,t} I_{i,t}}{Y_0 S_{i,0} I_{i,0}}\right) \quad (6)$$

where $w_{i,t}$ is known as the logarithmic weighting factor and is given by:

$$w_{i,t} = \frac{(E_{i,t} - E_{i,0})}{\ln\left(\frac{E_{i,t}}{E_{i,0}}\right)} \quad (7)$$

Now, utilising equations 3 to 7, we can determine the contribution that changes in energy intensity has made to the overall energy consumption profile during the period 2000-2012. Since we have energy and GVA information available on a per sector basis, we would also be able to identify which sectors have made the most effort in reducing their energy intensity profiles. Finally, we would be in a position to attempt to answer the question as to whether industry was able to reach its 15% reduction target as stipulated in the NEES of SA for the period 2000-2015.

2.6.3 Energy and Economic data

In decomposing energy into its production, efficiency and structural components, a measure of economic activity and energy consumption related to each sector is required. In this study we use GVA as a measure of economic activity rather than Gross Domestic Product (GDP). GVA and GDP are related by the following formula: GDP = GVA + taxes on products - subsidies on products. As taxes and subsidies on products are only available at the aggregate economy level, GVA was chosen as the appropriate measure. GVA data for the period 2000 - 2012 at constant 2005 prices was obtained from Quantec databases and cross validated against data from Statistics South Africa. The intention is to first consider macro-economic sectors viz., primary (agricultural), secondary (industrial and construction) and tertiary (services). As the manufacturing industry is the highest energy consumer and largest contributor to GDP, it will also be appropriate to further decompose this sector into its individual contributors. For this however, we are limited by the energy consumption data reported and made available by the Department of Energy (DoE). Table 2 below lists the sector decomposition that shall be used in this study together with the Standard Industry Codes (SICs). We do not consider the Residential sector as part of this study as it is not economically active and thus not directly linked to GVA. This requires a more specific study that is outside the scope of this work. Information on how this is handled in discussed in DME (2005). Energy consumption is measured in Terra-Joules (TJ) and takes into account Electricity, Petroleum, Oil, Coal, Gas, Nuclear, Renewables, Hydro and Heat. This data is reported at yearly intervals but delayed three years in being published. Thus the data used for this study is limited to 2012. Before the data received was used within this study, it was validated through simple aggregation tests. During this validation exercise, an error was picked up in the 2008 energy balances that was published by DoE. This error was corresponded back to the DoE and later rectified. The data used for this study is provided in Table 3 and Table 4 overleaf.

Note that we omit certain industries within this study because of discrepencies in the reporting of statistics between StatsSA, DoE and Quantec databases.

Table 2 Sectors in energy decomposition analysis

Sector	SIC Code
Iron and Steel	351
Chemical and Petrochemical	33
Non-ferrous Metals	352
Non-metallic Minerals	34
Transport Equipment	38
Machinery	36
Mining and Quarrying	2
Food and Tobacco	30
Pulp, Paper and Print	323
Wood and Wood Products	321 and 322
Textile and leather	311,312,316,317
Construction	5
Agriculture	11
Transport	7

Table 3 Gross Value Added (GVA) at constant 2005 prices in ZAR millions

GROSS VALUE ADDED (GVA) *(Y)*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total Industry	1189233.3	1243985.4	1317036.5	1356809.2	1410190.1	1464505.5	1522714.8	1599679.9	1655447.5	1605354.9	1654712.6	1662576.0	1671672.0
Chemical and Petrochemical	210159.4	222138.4	228647.0	231827.0	238740.0	246888.5	263451.4	268616.0	280411.0	270282.7	273992.0	270842.0	271183.0
Non Ferrous Metals	28498.6	26053.9	30605.0	28877.0	28219.0	27843.0	27736.0	32529.0	32349.3	26644.0	27475.4	28401.0	29073.0
Non Metallic Minerals	17624.9	18178.6	20800.0	21631.0	23082.0	24741.0	25628.0	28258.0	28466.4	25216.1	26191.6	26264.0	25978.0
Transport Equipment	108260.6	131288.3	128676.0	130938.0	139393.0	150693.5	156278.0	163072.0	153514.2	141164.5	145049.4	147383.0	150900.0
Machinery and Equipment	36101.9	38861.9	43582.0	40011.0	42365.0	44692.0	46923.0	48172.0	55316.4	55126.8	55807.3	57256.0	58256.0
Mining and Quarrying	171824.2	172167.8	173889.5	181171.2	185882.1	189494.6	188886.4	189949.9	179677.3	168806.2	178957.0	178998.0	173076.0
Transport and Storage	146880.0	152390.0	165900.0	175436.0	183252.0	187078.4	192556.0	198878.0	200369.5	203299.5	209552.0	207709.0	211177.0
Agriculture Forestry and Fishing	73682.2	74198.0	81321.0	83274.0	84124.0	84524.0	86302.0	92426.0	102930.0	102463.3	104063.9	104703.0	107285.0
Construction	108362.8	113886.6	116446.0	127295.0	132802.0	144967.3	163818.0	188708.0	203798.8	221516.9	228839.4	235941.0	238185.0
Iron and Steel	54007.1	54413.8	73188.0	74927.0	78581.0	77975.5	80840.0	86846.0	93347.7	86622.5	90694.1	94057.0	94633.0
Food and Beverages	140537.3	147689.7	152296.0	158997.0	169730.0	180111.8	182588.0	194332.0	202049.6	191204.5	198646.7	196744.0	196807.0
Paper and Paper Products	36292.7	36819.9	38809.0	38968.0	39834.0	43086.0	44656.0	44556.0	50939.7	45502.3	45771.3	44619.0	44569.0
Wood and Wood Products	17081.5	17707.4	19668.0	19720.0	20637.0	21151.5	21978.0	22064.0	24375.6	21940.8	22743.8	22948.0	23172.0
Textiles Clothing and Leather	39920.1	38191.1	43209.0	43737.0	43549.0	41258.4	41074.0	41273.0	47902.0	45564.8	46928.7	46711.0	47378.0

Table 4 Energy Output in TJ

ENERGY OUTPUT (TJ) *(E)*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total Industry	1465184.0	1519201.0	1493519.0	1534233.0	1599074.0	1610786.0	1585538.1	1716733.1	1840544.9	1698512.2	1528677.2	1526924.0	1441914.0
Chemical and Petrochemical	275002.0	235000.0	184584.0	178524.0	154006.0	141809.0	147625.0	150892.1	146467.0	124656.0	141022.8	143500.0	86343.0
Non-ferrous metals	56392.0	56974.0	58043.0	58530.0	64630.0	67104.0	67106.0	70143.5	64554.1	65444.2	66596.5	103388.0	96850.0
Non-metallic minerals	43524.0	43406.0	43944.0	59019.0	67349.0	74818.0	44867.0	63069.7	57209.8	106927.2	75190.7	64271.0	62850.0
Transport equipment	617.0	682.0	717.0	343.0	304.0	332.0	329.0	275.3	178.7	168.4	775.6	1831.0	1851.0
Machinery	981.0	1010.0	1019.0	2337.0	2071.0	2278.0	2479.0	2502.0	2497.8	8047.7	1685.2	423.0	398.0
Mining	130759.0	183744.0	183795.0	180699.0	190274.0	204592.0	201665.0	206349.9	211374.2	198054.8	157284.3	168545.0	169921.0
Transport	603985.0	620916.0	636332.0	656520.0	698552.0	710943.0	725321.0	803918.4	942396.8	914884.6	581440.7	756963.0	760567.0
Agriculture	64109.0	70003.0	72904.0	74998.0	77988.0	71534.0	70290.0	71441.4	70241.1	69242.4	251420.2	79943.0	60565.0
Construction	10671.0	15044.0	15816.0	16939.0	15982.0	16535.0	15917.0	17301.8	25344.1	34097.9	9605.9	8640.0	8660.0
Iron and steel	264322.0	277078.0	280727.0	292005.0	313771.0	305487.0	293426.0	314854.8	303805.7	157576.4	225783.1	172542.0	168786.0
Food and tobacco	3552.0	3724.0	3785.0	3688.0	3516.0	3783.0	4135.0	4152.2	4161.7	4544.8	5020.8	8437.0	7442.0
Paper pulp and print	8344.0	8835.0	8837.0	7777.0	7697.0	8635.0	9441.0	9148.5	9244.1	11144.9	10894.7	6195.0	5871.0
Wood and Wood products	1553.0	1011.0	1115.0	974.0	1044.0	1068.0	1069.0	1041.7	1542.1	987.9	955.7	993.0	1026.0
Textiles and leather	1373.0	1774.0	1901.0	1880.0	1890.0	1868.0	1868.1	1641.8	1527.8	2735.1	1001.0	11253.0	10784.0

2.6.4 Decomposition results and discussions

Figure 12 below shows the industrial energy consumption for the listed sectors during the period 2000-2012. The figure shows that the energy consumption had decreased since the base year 2000. This reduction could be as a result of structural shifts of the economy to less intensive activities, a possible decline in the economic activity or as a direct result of energy efficiency improvements. Conducting a decomposition analysis is therefore prudent to help identify the reasons/contribution to this energy decrease.

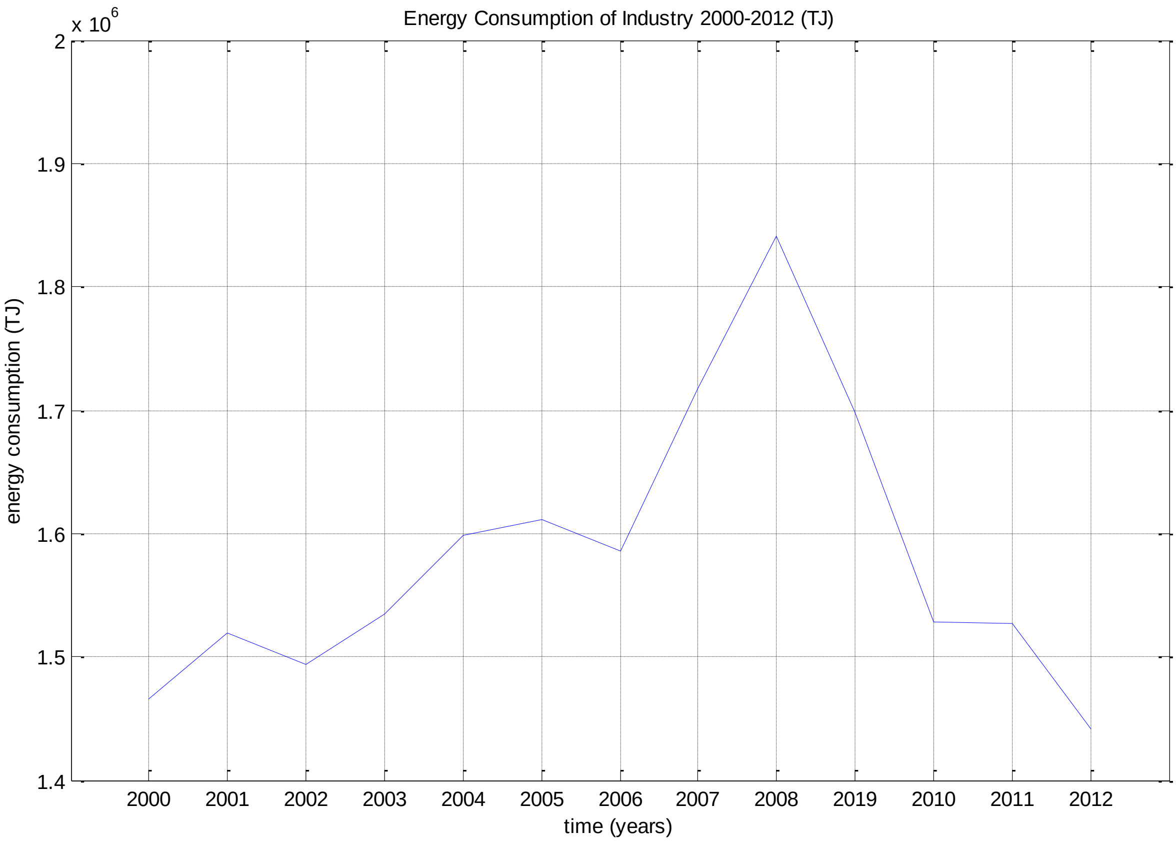

Figure 12 SA Industrial energy consumption (main sectors) for period 2000-2012

Using the data in Table 3 and Table 4 and the methodology described in Section 2.6.2, we can decompose the energy consumption into the components mentioned. The results are presented in Figure 13 overleaf. The results show that there has been significant growth in energy usage due to growing economic activity within the industrial sector. However, this growth in energy usage has been proportionally reduced by reductions in energy intensity efforts. It suffices to say that the energy consumption by industry would have been double the current usage if no energy efficiency efforts were made since year 2000. Only a small percentage of the total energy reduction can be attributed to structural shifts within the industrial sector constitution. At the aggregate level, the South African industry has been able to successfully decouple economic growth from energy use. The major contributor to this decoupling being the reduction in energy intensity improvements.

The decoupling of economic growth and energy consumption started long before the global financial crisis of 2008 and the subsequent electricity crisis the country had experienced. However, during the period of load shedding, there was a significant reduction in energy consumption due to ambitious efforts in energy efficiency to conserve energy.

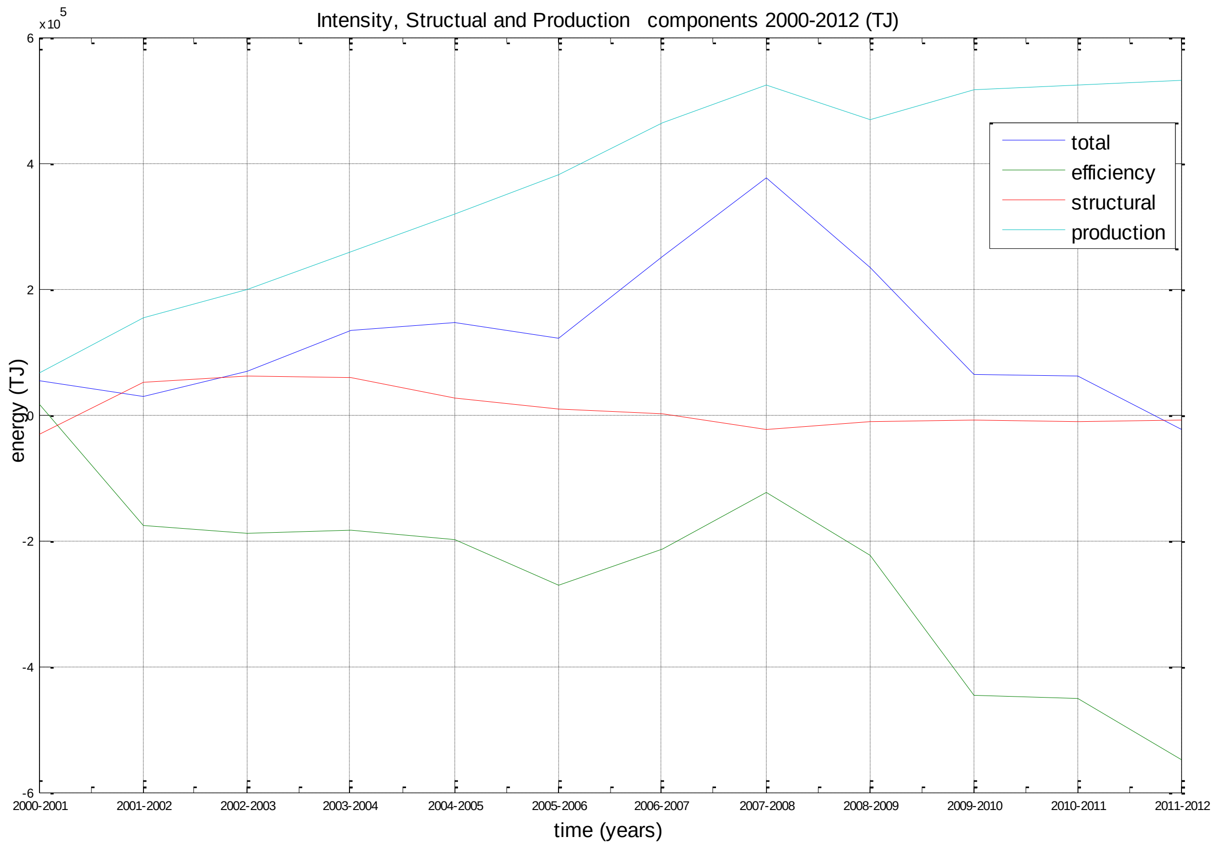

Figure 13 Energy decomposition results 2000-2012

In line with the objectives of this research, we now take the investigation further to better understand which industrial sectors contributed the most to the improvement in energy intensity. We first present the energy intensity profiles for the primary and secondary sectors and then later decompose the manufacturing sector into its contributing subsectors; which is relevant for the purposes of this research. Figure 14 shows the primary and secondary sector energy intensity profiles in relation to the overall intensity trend. With the exception of the mining sector, there has been a decrease in the overall intensity of the individual sectors. Within the agricultural sector, there was a significant increase in the energy usage in 2010 resulting from a sharp rise in the consumption of Diesel. In 2009, the reduction in intensity within the mining sector is a combined effect of the economic recession and the impact of load shedding that the country was experiencing at that time. It is clear that the mining, agricultural and manufacturing sectors are responsible for the above average energy intensity profile of the country. The overall intensity profile is lowered by the construction, commercial and financial sectors. The intensity of the commercial and financial sectors are not reported here as there is inconsistency in the reporting of gross value added and energy consumption by Statistics SA and the DoE respectively. One of the recommendations out of this research is to align the reporting of such sectors by SIC code across national departments.

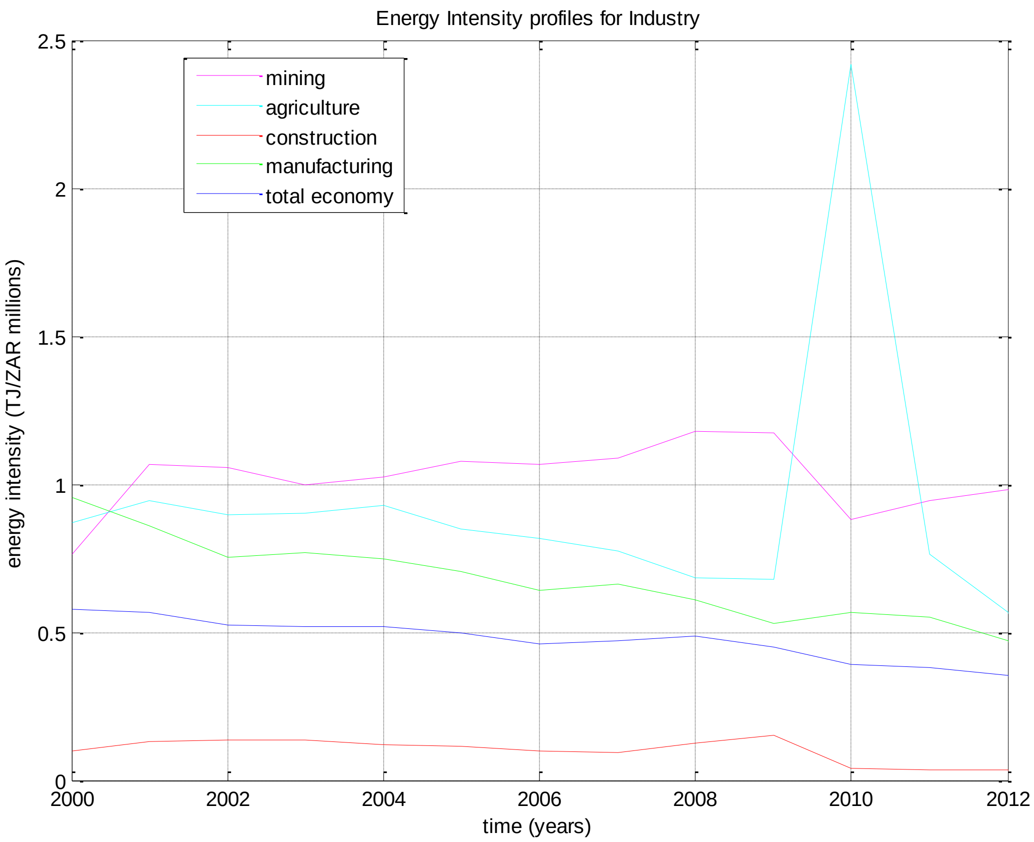

Figure 14 Energy intensity profiles for primary sectors

In line with the objectives of this research, we shall now try and determine the main manufacturing subsectors that contributed the most to the reduction in the overall manufacturing energy intensity trend. As part of this investigation we shall also identify the manufacturing subsectors that are underperforming. It is the intention of the field research of this study (see Chapter 4) to investigate the reasons for this underperformance. Figure 15 overleaf shows the intensity profiles for the disaggregated sectors. At a glance, whilst majority of the high intensity subsectors show a reduction in their energy efficiency trend, the non-metallic minerals and nonferrous metals subsectors show a growing upward trend. We take a deeper look into these trends by analysing the decomposition results for the individual sectors. Table 5 overleaf shows the contributing effects of the individual components.

Amidst positive production growth within the Iron and Steel manufacturing sector and significant structural increases in relative size, the Iron and Steel manufacturing sector still managed to generate the greatest energy intensity reductions when compared to all its manufacturing counterparts. This is purely as a result of energy efficiency projects.

The Chemicals and Petrochemicals sector achieved the second highest intensity reductions amongst its peers. Again, this is mainly due to energy efficiency projects initiated within the sector. There has also been some structural movements indicating a shrinkage in the relative size of the sector.

The non-ferrous metals subsector has been the worst performing manufacturing subsector in terms of energy conservation over the period of interest. Despite structural shrinkage in the sector, there has been an overall increase in its energy consumption profile mainly due to increases in its intensity levels.

The Food and Tobacco and Textiles and Leather subsectors have also performed poorly with regards to energy efficiency over the period of interest. The energy growth trend within these sectors have been mainly as a result of intensity increases.

Table 5 Sectoral energy decomposition results 2000-2012 (TJ)

	Total	Efficiency	Structural	Production
Chemical and Petrochemical	-188659.0	-235150.88	-11496.23	57988.11
Non-ferrous metals	40458.0	37137.58	-16517.31	19837.73
Non-metallic minerals	19326.0	64.70	2755.85	16505.46
Transport equipment	1234.0	998.46	69.02	166.53
Machinery	-583.0	-1469.99	451.11	435.88
Iron and steel	-95536.0	-254204.72	66012.55	92656.18
Food and tobacco	3890.0	2625.56	40.48	1223.95
Paper pulp and print	-2473.0	-4138.13	-1001.11	2666.24
Wood and Wood products	-527.0	-853.22	-10.28	336.51
Textiles and leather	9411.0	9020.50	-213.39	603.89

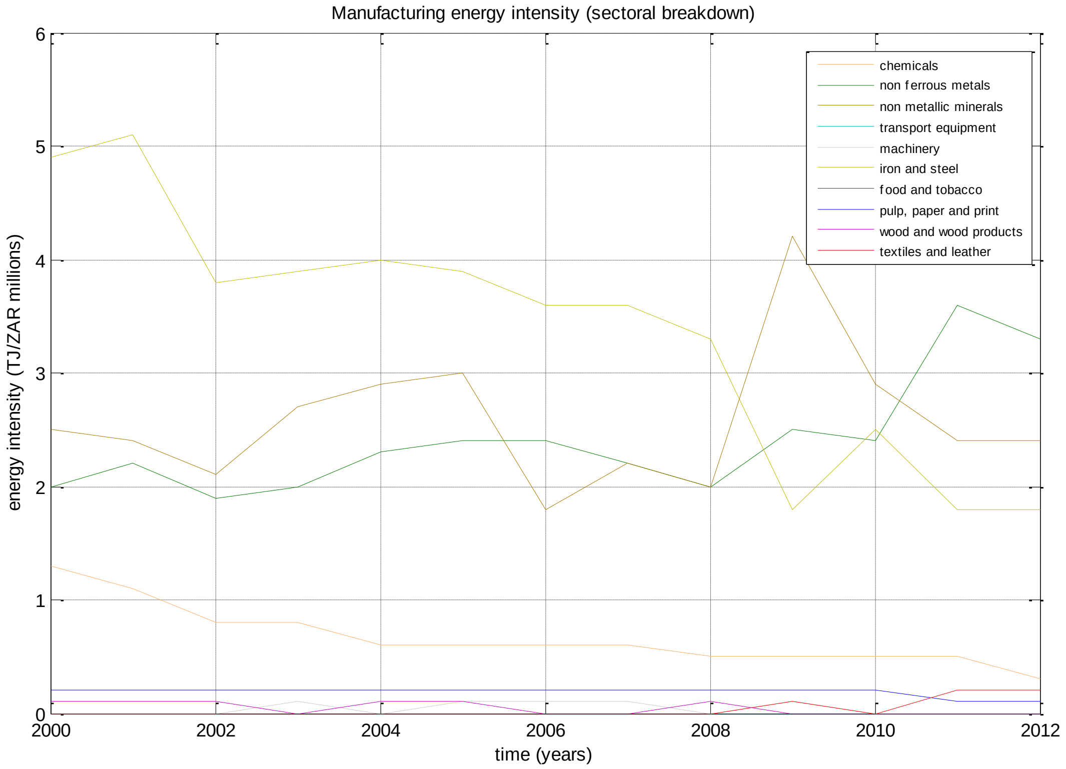

Figure 15 Manufacturing energy intensity (sectoral breakdown)

2.6.5 Key conclusions from decomposition results

The decomposition results reveal that the manufacturing sector plays an important role in determining the overall energy efficiency trend of the nation. It is therefore important that energy conservation within this sector is given special focus. This alone warrants this research on the topic.

The finer decomposition results show that whilst some manufacturing sectors have shown stellar performance in reducing their energy intensity trends through energy efficiency means, other sectors have become more inefficient. In some cases, there has been little or no trend in the intensity change of the sector. The Non-Ferrous Metals sector performed extremely poorly. The growth in Energy Intensity within this sector contributed to more than 80% of the overall growth in its energy consumption. The Iron and Steel manufacturing sector was the best performing in terms of intensity improvement. Energy intensity improvements in this sector was able to nullify all energy increases due to production and structural growth in the sector and still result in a net reduction in its overall energy consumption since base year 2000.

An investigation into the reasons of poor efficiency performance should be conducted within the following sectors: Non-ferrous metals, Non-metallic minerals, Transport equipment, Food and tobacco, and the Textiles and leather sector. An investigation into the Chemical and Petrochemical, Machinery, Iron and steel, and Paper, pulp and print sectors should be conducted in order to better understand how they were able to achieve net efficiency improvements since year 2000. The lessons learned and driving factors should be documented and disseminated to the poorly performing sectors mentioned above.

The final question that needs to be answered is whether the NEES target of a 15% reduction in energy intensity was achieved by Industry. From equation 1 above, if we divide both sides of the equation by Y_t, we determine the Energy Intensity (EI) as

$$EI = \sum_{i=1}^{n} \left(\frac{E_{i,t}}{Y_{i,t}}\right)\left(\frac{Y_{i,t}}{Yt}\right)\frac{Y_t}{Y_t} = \sum_{i=1}^{n} I_{i,t}S_{i,t} \qquad (8)$$

Following, a similar decomposition exercise described in section 2.6.2, we obtain the results given in Table 6 below.

Table 6 Industrial EE decomposition (TJ/ZAR (millions))

Year	Total	Efficiency	Structural
2000-2001	-0.0108	0.014033	-0.02484
2001-2002	-0.08724	-0.15058	0.06334
2002-2003	-0.00323	-0.01051	0.00728
2003-2004	0.003177	0.0047	-0.00152
2004-2005	-0.03406	-0.01112	-0.02294
2005-2006	-0.05863	-0.0478	-0.01083
2006-2007	0.031915	0.036495	-0.00458
2007-2008	0.038638	0.054519	-0.01588
2008-2009	-0.05378	-0.06073	0.006951
2009-2010	-0.1342	-0.13672	0.002528
2010-2011	-0.00542	-0.00332	-0.0021
2011-2012	-0.05585	-0.05802	0.002165
Total	-0.36948	-0.36906	-0.00043

There results show that there has been a reduction in energy intensity levels within Industry by ~ 0.3695 TJ/ ZAR (millions). The contribution to this reduction has been dominated mainly by energy efficiency improvement measures within Industry. There has been some structural movement away from Industry but this has been to a lesser extent.

Since year 2000, Industry has reduced its energy intensity levels through energy efficiency methods by approximately -0.3691 TJ/ZAR (millions). This amounts to a reduction of approximately 29.9% since year 2000. This confirms that by year 2012, industry (as defined herein) far surpassed the 15% reduction targets set out by the NEES in 2004. It should however be noted that not all sectors experienced reductions in intensity levels and the more intensive energy sectors contributed the most to the reductions experienced.

It is recommended that going forward, more ambitious targets are set out for industry taking into consideration the correct EI profile and the opportunities that exist. Furthermore, targets should be set at sector level and not only at the overall aggregate levels. This will allow for improved reporting and better sector accountability.

2.7 Previous findings on EE driver and barrier variation with sector and firm characteristics

In an international study conducted by UNIDO (2011) to identify how the barriers to Industrial Energy efficiency vary within different manufacturing industries, it was found that barriers do not affect all firms in similar ways. Barriers vary with the characteristics of the firm and the manufacturing sector in which they operate. For e.g. small firms tend to have limited capital for energy efficiency interventions when compared to larger firms. The study shows that larger firms are not sufficiently incentivised to invest in energy efficiency when energy tariff costs are too low or when such firms fear the risk of the disruption of their production processes.

Weber (1997) in a separate study on how barriers to industrial energy efficiency vary with sector type and firm characteristics in Greece, confirm that industries should be viewed as separate subgroups with different needs for energy conservation.

The results that were significant at 1% for the UNIDO (2011) study are summarised below:

The metals and textiles sectors stand out significantly from this survey. Within both sectors, limited access to capital and the high initial costs to energy efficiency were found significant. Transaction costs to energy efficiency are not considered a barrier to energy efficiency within the Metals industry. In the Food sector, it was found that management finds daily production processes more important to energy efficiency interventions. Due to the metals industry being energy intensive, the instability of future energy prices is a barrier to energy efficiency investments. Furthermore, in the metals industry, EE investments have to provide significant internal rates of returns as it has to compete for financial resources. There is also significant capital restrictive behaviour from management within the textiles industry.

The second part of the study investigated how the barriers vary with firm characteristics. The results that were significant at 1 and 5 % are summarised below:

It was found that firms with high energy costs typically have less capital readily available to invest in energy efficiency technologies. These firms also have a lack of skilled staff for energy efficiency support, have difficulty training such employees and experience significant bureaucratic procedures to obtain government financial support. Firms with high investment rates (i.e. those who re-invest significant proportions of their capital back into the business) typically have several competing investments. Only those with the best internal rates of returns are generally selected. Furthermore, those firms with high investment rates are not moved by future uncertainty in energy prices. Firms that have a high education rate typically have owners that understand the importance of energy efficiency. Such firms also have the requisite know-how towards energy efficiency and do not suffer from a lack of information regarding the profitability of energy saving mechanisms. A significant proportion of their financial resources are invested in energy conservation projects as such projects are seen as higher priority than other investments. Firms with large number of employees typically invest in other compelling projects.

2.8 Global barriers and drivers to energy efficiency within industry

Except for annual consolidated international surveys on barriers to energy efficiency within buildings, no other global studies have been under-taken to investigate the barriers to energy efficiency that industries face at the global level. However, a study by UNEP (2006) was able to consolidate responses from firms across Asian Industries and the results revealed are interesting.

77 respondents from industries within Bangladesh, China, India, Indonesia, Philippines, Sri Lanka, Thailand and Vietnam distributed across the Iron and Steel, Ceramics, Chemicals, Pulp and Paper and Cement industries rank the 5 critical barriers in order of importance as follows:

1. No government financial incentives for energy efficiency
2. Production time is more important than energy efficiency considerations
3. Investment costs to energy efficiency poses a hurdle to management
4. Lack of regulation and legislation on energy conservation
5. Lack of financing for energy efficiency projects

It is clear from these results that the financial aspect to energy efficiency investment poses a significant hurdle.

The same respondents rank the reasons for energy efficiency implementation in order of importance as follows:

1. Need for reduced energy costs
2. Need for reduced production costs
3. Need for reduced energy consumption
4. Compliance with regulations
5. Improvement in the quality of final product.

Whilst compliance to regulation is considered critical, the results show that costs are still a key driver to energy efficiency investment.

When these respondents were asked about what was needed for energy efficient adoption, they listed the following as important (apart from information and training)

1. Discounted expert advice
2. Loans and/or grants
3. Access to programmes
4. Directory with energy contacts
5. Software for energy monitoring

It is clear from these results that a wide array of services are necessary to support industry. This can be achieved through innovative frameworks that allows for effective policy enablement.

2.9 Summary

Many studies around the concept of the energy efficiency gap has been conducted since the early 1970s. Literature reveals that economic, institutional, behavioural and organisational barriers are the reasons for this gap. Significant technical potential remains in improving the energy efficiency of plants within developing countries. The most potential resides within process plants. At the global level, energy intensity decreased by 1.4 percent per year between 1990 and 2009. The reduction was mainly driven by carbon abatement policies, energy efficiency programs and structural changes in markets. Within BRICS, China has taken the most aggressive stance towards energy efficiency; their rate of reduction of total energy intensity is amongst the highest in the world. Developing countries should take heed of their approach and implement similar strategies/concepts where applicable in order to decouple economic growth from energy use. Past research has shown that industries should be viewed as separate subgroups with different needs for energy conservation. To this end, it was found that barriers vary with manufacturing sector type and with the specific characteristics of a firm. It was also found that the main barrier to energy efficiency within the Asian Industry is the lack of financial incentives from government. Their main driver to invest was found to be aimed at reducing their overall energy costs.

Chapter 3 Literature Review, Theoretical Framework and Conceptual Model

3.1 Introduction

This Chapter sets out to investigate and propose a theoretical framework and conceptual model on the barriers and drivers to energy efficiency based on the literature available on the topic.

The Chapter first opens up with a general discussion on the benefits associated with energy efficiency and classifies these at the local, sectoral, national and international level. After an examination of the literature on the topic, we propose a typology that incorporates the various dimensions of drivers and barriers. This typology shall be employed to investigate the types of barriers and drivers manufacturing firms operating within the EMA are subjected to. Literature also reveals that barriers and drivers to energy efficiency vary by manufacturing sector type and with the characteristics of the firm. We thus discuss various firm level characteristics that influence the propensity of firms to adopt energy efficient technology.

Lastly, we conclude the Chapter by seeking to integrate the barriers, drivers, and benefits to energy efficiency through a conceptual model of the enterprise and its interaction with the broader environment.

3.2 Benefits to Energy Efficiency

The benefits of energy efficiency reach beyond just energy bill savings. They are known to have far reaching effects ranging from the increase in productivity at the organisational level to the sustainability of society as a whole.

Ryan and Campbell (2012: 4) categorise the benefits of Energy Efficiency at the local (single user), sectoral (industry), national and international levels. It should be noted that an improvement made at any of these levels may overspill into any one or all of these categories. The benefits are discussed categorically below.

Local Level

At the individual or local level, several non-energy related benefits exist. Mills and Rosenfeld (1996:707-720) discuss these as improved indoor environment, better health, improved safety, increased comfort, lower noise and better amenity. As energy efficiency reduces energy costs, it makes it more accessible to the greater population. Cheaper electricity results in a higher disposable income to households. This available income indirectly stimulates the macro-economic environment.

Sectoral level

In a research study conducted by Worrel (2011) on the benefits to industrial energy efficiency projects, classifications into 5 broad categories were defined. These include benefits related to waste, emissions, operation and maintenance, production and the working environment. These are expanded upon below:

Waste: These include reduced energy usage, materials reduction and water savings

Emissions: The include reduced dust and GHG emissions

Operations and maintenance: These include a reduction in the labour requirements, reduced wear and tear, improved reliability, etc.

Production: Production improvements include improved product quality, greater production yields and improved equipment performance

Working environment: Within the working environment, improved air quality, better lighting, improved safety, etc. are expected.

Other unclassified benefits include improved public image, better worker morale and reduction in liability. Taken together all these benefits result in the improved competitiveness of the firm.

National level

The benefits at the national level are manifold, many of which talk to the objectives of the National Energy Efficiency Strategy of South Africa. Ryan & Campbell (2012) discuss these as an increase in job opportunities, energy security, and positive macro-economic effects.

Bell (2013) discusses a 2 factor link between job creation and energy efficiency. In the first instance, any direct investment in energy efficiency projects creates jobs in order to design, install and maintain these systems. Indirect jobs are created within the supply chain of the projects themselves e.g., plumbing jobs to support the implementation of energy efficiency projects. Finally induced jobs are created as newly employed workers spend their earnings – essentially a stimulus to the macro-economic environment. In the second instance, the savings generated by the firms through lower energy bills allow such firms to re-invest these funds in other capital projects generating a further cycle of job creation.

The NEES, the IEA and many other national policies on energy efficiency discuss energy security as a main benefit of energy efficiency investments. The impact of energy security can be described in four parts viz. a reduction in imported energy, reduction in domestic demand and maximisation of exports, increased reliability of the energy network and the ability to control the energy demand growth.

Reduction in imported energy: In 2010, SA imported approximately 21% of its total primary energy supply (DoE 2015b). As energy efficiency projects focus on the reduction of energy demand by users, this will allow the country to reduce its reliance on any imports. The more energy the country imports, the less the macro-economic environment flourishes.

Reduction in domestic demand and maximisation of exports: related to the point described above, as surplus energy becomes available, the country will be able to export this deficit resulting in the growth of national GDP.

Increased reliability: as energy efficiency projects aim to increase the energy reserve margin, the supply network will naturally become more resilient to disruptions due to maintenance issues, in climate weather conditions or operating accidents.

Ability to control the energy demand growth: with better regulations and policies in place on the use of energy, consumption demand by industry can be better controlled.

We have touched very briefly upon the macroeconomic benefits associated with energy efficiency in relation to job creation and exports of surplus energy resulting from savings. Further to this, as energy efficiency projects reduce the firm's energy costs and improves product quality, it results in a more competitive industry which contributes positively to GDP and the national competitive index of the country. As demand growth stabilises, less public funding is required for energy expenditures. This surplus funding can be used in innovative ways to stimulate the macroeconomic environment e.g., formation of new industry that provides a better ROI.

International level

At the international level, benefits of energy efficiency investment are common across all countries. These include reduced GHG emissions, natural resource management and global development goals (IEA, 2012).

GHG emissions: as energy efficiency projects reduce energy demand which is directly proportional to GHG emissions (especially in SA which is heavily reliant on fossil fuels), it is expected that there will be a reduction of these toxic gases into the atmosphere.

Natural resource management: related to the point above, as energy efficiency projects reduce the energy demand which is directly proportional to natural resource depletion (oil, gas, coal, etc.), the effect of this depletion is reduced and can be controlled.

Global development goals: related to the benefits discussed above, if energy efficiency can improve the livelihoods of the people then it is contributing positively to the upliftment of mankind. Furthermore, energy efficiency projects stimulate the macroeconomic environment in positive ways such that it contributes to economic development, social improvement and environmental sustainability.

3.3 Barriers to Energy Efficiency

Vast literature surrounding the phenomenon known as the efficiency paradox or efficiency gap has been published to date as discussed in DeCanio (1998:441-454), Weber (1997: 833-835), DeCanio (1993:907-914) and DeCanio and Watkins (1998: 275-294). This concept can be argued as follows: Whilst it is well known that from a technical point of view, energy efficiency improvement programs are economically profitable, it is not well understood why such technical solutions are not exhaustively exploited by firms. This singularity in economic theory on energy efficiency has been at the centre point of debate for many years. In order to understand the reasons behind this phenomenon, several studies have been conducted in investigating the barriers to the adoption of these technologies. A review on these studies will be the focus of this section.

Sorrell et al. (2000) defines a barrier as "a postulated mechanism that inhibits investments in technologies that are both energy efficient and (at least apparently) economically efficient". The resultant efficiency gap is in direct conflict to mainstream economic theories where firms always seek to maximise profits. The mechanisms that inhibit investment behaviour in energy efficiency technology are deeply entrenched in more recent studies on organisational and transaction cost economics. Sorrel et al. (2000) discusses that mainstream i.e. neoclassical economics alone is insufficient in providing a holistic view on the barriers to energy efficiency. A literature review on past and more recent studies show that there are a diverse range of barriers that contribute towards this efficiency gap. Sorrel et al. (2000) and Weber (1997:833-835) classify these barriers into three groups viz., economic, organisational and behavioural. More recent literature on the concept extend these classifications to include institutional barriers. Weber (1997:833-835) warns that whilst a taxonomy may be useful in general terms, the barriers themselves are not mutually exclusive i.e., each barrier will have economic, behavioural and organisational aspects. These notions and classifications shall be discussed hereunder.

3.3.1 Economic barriers

Blumstein et al. (1980) in Sorrel et al. (2000) identify economic barriers as one of the first form of barriers to inhibit investment in energy efficiency within the energy services market. Many of the barriers identified are violations of neo-classical economic assumptions that are based on the premise that consumers are rational, market transactions are costless and product information is perfectly diffused. In such cases, the non-adoption of any energy efficiency technology should be directly attributable to a pure market failure condition. Market failures occur as a result of a flaw in the way the market operates. Several market failures exist that are raised in Sorrel et al. (2000), Weber (1997:833-835), Jaffe & Stavins (1994:804-810), Brown (2001:1197-1207) and Ryan et al. (2011) are described categorically below. However, we also extend this discussion to look at cases where the assumption of neo-classical economic theory does not hold i.e. non-market failure conditions.

Economic Barriers: Market failure

Incomplete Markets: in such cases, the market will fail where property rights are not well defined. The actions of one economic agent infringes on the welfare of others unfairly and the spoils thereof are not captured by market transactions or prices (Sorrell et al. 2000). This can be attributed to unpriced costs associated with the negative impacts of production processes, etc. In South Africa today for example, more fossil fuel energy is consumed than is socially optimal and the negative externalities associated with the burning of this fuel is not quantitatively addressed in policy. As a result, environmental pollution is a reality. Until policy mandates the inclusion of more efficient mechanisms in industrial processes etc., the market shall remain incomplete and external costs unpriced.

Imperfect Competition: In a monopolistic market, organisations are able to charge prices that are severely in excess to the costs outlaid. This is considered an unhealthy market and is dangerous especially in those markets that are unregulated. In such cases it is only upon the firm to decide whether or not to include energy efficiency within its operations. As such firms do not need to compete with other firms, mechanisms like brand strengthening through environmental consciousness initiatives etc. are not within the horizon of such firms. The end result is that any efficiency drive will only be considered based on the firms' value system. Any cost incentives may not of any consideration as such a monopolistic company can divert such costs back to the customer by inflating final product prices.

Imperfect information: such situations occur when firms give out insufficient information to markets. To this end, consumers will be unable to make optimal choices. Supplying information may have public good characteristics i.e., it is difficult to exclude certain people from the benefits of the information. Obtaining information can be a costly exercise in itself and adds to the transaction costs faced by firms. This general lack of information impedes investments in energy efficiency. An example of imperfect information that South African consumers face on a daily basis is the lack of granularity in their household energy consumption bills. Most consumers do not receive a breakdown of their consumption (technical limitations or high transaction costs). This lack of information impedes consumers from understanding the dynamics of their consumption and as a result prevents them from taking any remedial action.

Asymmetric information: Is a derivative of imperfect information where two parties to a transaction have different levels of information. Asymmetric information results in three forms of market barriers. These are described below:

> **Adverse selection**: occurs when one party to a transaction has access to private information **before** entering into a contract which results in one of the parties acting opportunistically. This could be either the buyer or the seller. In one instance, the seller may not able to get important information across to the buyer e.g. information about quality, total costs of ownership, etc., and as a result the buyer makes a poor selection. In such cases, bad quality products drive out the

better, higher quality items. In the second instance, the buyer may not be able to able to articulate his or her requirements explicitly (possibly because of imperfect information) which results in the seller offering a product that may not meet the buyer's requirements adequately.

Moral Hazard: occurs when the agent's actions are unobservable to the principal and results in the agent acting opportunistically post signing of the contract. The main difference between adverse selection and moral hazard is the opportunistic behaviour taken pre/post signing of the contract. An example of moral hazard is a building contractor behaving opportunistically when choosing between standard and energy efficient products when building a house for a developer. This barrier is also tightly coupled to the rebound effect. If consumers are aware that they are conserving energy through efficiency mechanisms, they may tend to increase their energy usage.

Split incentives: occurs when the benefits of a potentially viable investment does not accrue to the party making the investment and as a result refrains the potential investor from investing. This is best explained through use of an example: a tenant may want to install a heat pump to save on electricity but may feel that she may move out before she starts to benefit from the cost savings. Similarly, the owner may not want to invest in the heat pump as he feels that it may be to the benefit of the tenant (through reduced energy bills). A possible solution is for the owner to invest in the pump and recoup the costs for the pump from the energy savings incurred. However, in such cases the transaction costs in correlating the billing information is too high and presents another barrier in itself.

Literature reveals that market failures alone do not exhaustively account for the energy efficiency gap but nonetheless still necessitate policy intervention. Non-market failure barriers is another body of theory that also accounts for the energy efficiency gap. These are discussed below.

Non-market related failures

Non-market failure barriers are those factors that explain the rational behaviour in decision making of individuals or firms when rejecting an energy efficient alternative. This could be a result of an energy efficiency alternative not delivering the stipulated outputs and therefore performs poorly when compared to a standard alternative. The company or individual's decision to reject the energy efficient alternative may thus be purely rational in such cases. A review on the literature of non-market related failures as discussed in Sorrell et al. (2000), Jaffee and Stavins (1994:804-810), Brown (2001:1197-1207) and Golove & Joseph (1996) show that there are at least four types of barriers that exist within this class viz., capital barriers, heterogeneity, hidden costs and risk. These are discussed below:

Capital Barriers: the ability to easily access capital can severely inhibit energy efficiency purchases by firms. This occurs because different firms have varying access to capital at varying rates of interest. There are thus two parts to this barrier:

Varying access to capital: the reasons for which capital is restricted vary across firms. Government limits the amount of lending to public firms because they see private industry as a more lucrative and as a less risky investment. Thus this capital rationing at the high level impedes energy efficiency investment as projects are not looked at on a case by case basis. In private firms, there may be (1) a restriction on the overall amount of borrowing by the company or (2) the access to capital may be based on a priority list of projects where low priority projects often do not get capital provisioned; energy efficiency is one such example of this type of low priority project. Private companies limit the overall amount of their borrowing as high exposure to debt increases their cost of capital, which leads to the second part of this barrier i.e. varying interest rates.

Varying rates of interest: different firms have access to capital at different interest rates. This stems from the knowledge base of the lenders, likely performance of the investment in question and financial risk of the potential borrower. Research has shown that interest rates that are available for energy efficiency projects are much higher than the utility cost of capital. This is because of the associated uncertainties and the irreversibility of energy efficiency projects that lead to a higher perceived risk. In such cases more stringent investment criteria and as a result higher hurdle rates apply (Hassett & Metcalf 1996). Irreversibility means that secondary markets are not well equipped to use energy efficiency products should the lender want to recoup costs due to non-payment. Thus once a consumer commits to such technologies, his commitment needs to be maintained regardless of his changing needs. Furthermore, smaller projects are often allocated capital at costs much higher than that for larger projects. As energy efficiency projects are generally smaller in size compared to other projects firms embark upon, the capital costs for such projects are generally higher (Brown 2001:1997-1207). This makes EE projects less desirable from a purely ROI point of view.

Heterogeneity: is associated with the fact that the cost effectiveness of a given technology is calculated for an average user within a particular class. Thus within a heterogeneous population, we would expect that even if a technology looks attractive to a subclass of users, there would still be a portion of the population that would view it in a less cost effective way. Thus the advantages of a particular technology may be overstated and may not apply to an entire population. An example that is often cited for this barrier is the replacement of incandescent lamps with Compact Fluorescent Lamp (CFL) alternatives. The cost benefit analysis of such a replacement is made on an assumption on the average amount of time the CFL is used. However, the lamp hour usage distribution may be normally distributed across a population implying that the value attained by certain users may be less than that expected (Golove and Joseph 1996). Thus, it is purely rational then for certain users not to adopt CFLs.

Hidden costs: Nichols (1994:840-847) mentions that technical-economic studies on EE technologies sometimes fail to take into consideration the reduction in benefits associated with energy efficiency investments or any additional costs that may arise as a result. In such cases, these technical models are known to overestimate the potential of energy efficiency technologies.

A study of the literature on hidden costs reveal four categories of such costs:

a. the general overhead costs of energy management e.g., costs of employing an energy manager, auditing costs, etc.;

b. specific technology decision costs e.g., costs of identifying and scoping opportunities, additional costs of maintenance, costs of replacement and the strategies thereof;

c. the loss of benefits associated with adopting energy efficiency equipment; which is normally unaccounted for e.g., increased noise levels, reduced quality, reduced safety, increased maintenance, reduced reliability, etc.;

d. information costs in obtaining the required information to make the necessary decision to invest or not (search costs). This also includes verifying the quality of the information, its reliability, etc.

Risk

The concept of risk was partly captured by other barriers. For e.g. high discount rates and the rejection of certain types of energy efficiency technologies that carry significant uncertainty represent a natural response to risk. To further classify this barrier, Sorrell et al. (2000) makes the following distinctions:

a. External risk: these refer to risk outside the control of the firm itself i.e., broader environmental risks for e.g., political changes, changes to government policy, market recession, changes to electricity tariffs, etc.;

b. Business risk: these refer to the risk that a business of a particular type is exposed to. Examples include: different trends of the economic sector that the business is operating within, and consumer patterns that an individual business is exposed to; and

c. Technical risk: these refer to the engineering risk associated with a particular technology. First mover adopters are typically exposed to such risk. Such risk involve: the technical performance of the technology or the uncertainty surrounding its reliability.

Based on a firms perceived risk, they can be very risk averse towards investing in energy efficiency investments. While it may be rational to inhibit investment based on perceived risk, it is an arguable case as to whether the perceptions themselves are rational. As such several economic investment models have been developed that attempt to account for the inherent risks in energy efficiency investments. These include discounted cash flow models, an application of the Capital Asset Pricing Model by Sutherland (1991:15-34) and a counter model by Hasset and Metcalf (1993:710-716). Each of these models however have been criticised for their lack of completeness. The bottom line is that risk in itself is a barrier; but not all energy efficiency investments should be subjected to high discounts rates. Based upon the risk dimensions discussed above, every business is unique and therefore should respond to risky investments differently.

Within the body of theory of non-market failure barriers discussed above, the organisation is still considered to be a unitary profit maximising entity as in the case of neo-classical economics. But, in more recent theories of the firm and in theories on organisational economics, the firm itself cannot be considered as an entity without internal dynamics. Such dynamics are known to hamper a firms profit maximising ability. In study by DeCanio (1993:907-914) on barriers to energy efficiency within organisations show that barriers to Energy Efficiency also exists within the firm itself. Thus a third subset of barriers exist which is referred to as organisational failures. Sorrel et al. (2000) define organisational failures as those barriers which result from organisational structure and policy. The following section considers this concept.

3.3.2 Organisational barriers

Organisational barriers is another grouping of barriers that is manifested in organisational theory. Sorrel et al (2000) notes that the body of literature surrounding organisational theory relevant to energy efficiency is not well developed. As a result, public policy that addresses organisational barriers is limited. A review of the literature suggests two barrier types viz. power and organisational culture. It is also worthy to mention that the organisational structure, while not barrier by itself, may however limit the potential of energy efficiency implementation within organisations. Sorrel et al. (2000) describes organisational structure as the framework for the analysis of the operation of barriers within organisations.

Power: this speaks to the amount of decision making ability given to energy personnel within an organisation. If energy management is seen to be a low priority function then energy efficiency initiatives may be stifled. Sorrel et al. (2000) discusses four ways in which Power manifests itself within organisations. These are described below.

a. Formal authority: the higher up the Energy Manager's post within an organisation's structure, the more authority he holds for decision making on energy efficiency investments.

b. Control over scarce resources: the more control the Energy Manager has over skills, materials and budgeting, the higher the probability of successful energy efficiency investments within firms.

c. Structure: the bigger the size and prominence of the Energy Branch within the organisational structure, the more pull it has over strategic investment and decisions.

d. Information and knowledge: having the requisite knowledge and the required information is a key enabler to successful decision making for EE investments.

It is important that the Energy management role has sufficient Power to influence the strategic direction of the organisation.

Culture: this is related to the values concept discussed later on. Individual worker values and behaviours taken together form the culture of the firm which includes the organisation's vision, norms, systems, beliefs and habits. An organisation may have one culture or several sub-cultures. Top management normally shape the culture of the firm. This takes us back to the point of the Energy manager securing a position within top management. This is necessary to ensure that energy efficiency and environmental concerns are part of the value systems of organisations. All energy efficiency initiatives should stem from the culture of the organisation.

3.3.3 Behavioural barriers

Within the discussions above, it was assumed that the agents behaved in a rational manner. However, a more recent body of literature known as behavioural theory has empirically shown that this economic rationality assumed by users may not always be true. Even with guidance from economic optimisation models consumers deviate from cost minimisation opportunities. As such, the theory discussed thus far is therefore insufficient in explaining the energy efficiency gap. Perspectives on behavioural theory needs to be considered. A survey on the literature of behavioural barriers has been conducted and the various types of such barriers are discussed below.

Bounded rationality: Simon (1997) discusses bounded rationality as a behavioural failure and attributes this to 'limitations of knowledge and computational capacity' by energy purchasers and users. Generally, these surface as constraints in attention and time and the ability to process information. Gilliingham in Bhattacharaya & Cropper (2010) confirms that evidence to support bounded rationality by energy consumers are strong. Sorrel et al. (2000) discusses the use of routines to counteract this barrier. Examples include payback rules, capital budgeting procedures, etc. These assist in economising on bounded rationality. Energy Efficiency opportunities may be missed if they do not form part of standard routines in making decisions. Pollitt & Shaorshadze (2011) discuss some manifestations of bounded rationality. These are discussed below:

Choice overload: Although in traditional economics choice is normally favoured by consumers, empirical results show that consumers find it difficult to make a decision when faced with too many options.

Heuristics: Earlier we spoke to the use of routines to guide decision making. Heuristics are similar in that they are 'mental shortcuts' to decision making i.e. rules of thumb. Whilst these exist to economise on bounded rationality, it may lead to unfavourable outcomes as it discounts a systematic analyses of alternatives.

Failure to analyse statistical information: individuals do not process statistical information correctly and they are not moved by simple statistically correct information. They focus and overstate the small probabilities of adverse situations.

The Human dimension

Other forms of behavioural barriers are related to the human dimension which is manifested in the field of social psychology. The study of such barriers emanates from the psychological decision making process of energy efficiency investments. A review of the literature of these barrier types reveal four groupings viz., the form of information available, credibility and trust, inertia and values. These are discussed below.

Form of information: the manner in which information is presented to consumers is vital in order to ensure that it receives sufficient attention. Research conducted by Palm & Thollander (2013), Stern & Aronson (1984:237), and Thollander, Palm & Rohdin (2010) have shown that consumers are not necessarily information seekers but are rather selective in assimilating information. Sorel et al. (2000) discusses five criteria that should be considered concerning the form of information. These are listed below.

a. Information should be refined for its target audience i.e., it should be ***specific and personalised*** and it should be ***clear and simple***

b. Information must be ***vivid*** i.e., it must be delivered through practical sessions or graphical means

c. Information should be up to date and provided ***close in time*** to the relevant decision

d. **Feedback** should be provided on past energy efficiency investments

An additional viewpoint is that information is more likely to be assimilated by the recipient if it is presented by a source who has similar characteristics to the recipient itself.

Credibility and Trust: The perceived credibility of the source and the recipient's trust in her is also an important consideration in energy efficiency investments. Stern and Aronson's (1984:237) famous empirical study on this subject highlights this point clearly. In an effort to inform the residential sector on the ways to save energy when using air-conditioning systems, 1 000 pamphlets were distributed to 1 000 household in New York. 500 households received the information from a local electricity utility and the remaining from the state regulatory agency. Upon analysis, it was found that those households that received the information from the state regulating authority reacted in a more positive way than to those that received the information from their local electricity authority. As the state regulating authority is normally associated with a higher sense of trust and credibility than the local authority, it can therefore be concluded that recipients react more positively to sources that are trustworthy and of higher credibility. Trust and credibility is normally built through positive interactions, recommendations from other credible sources and other such interpersonal contacts and relationships.

Inertia: Inertia is another behavioural barrier to energy efficiency that contributes to the energy efficiency gap. Stern and Aronson (1984) describe this as consumers who typically want to avoid uncertainty or change in their environments. The introduction of new energy efficiency technology carries an element of uncertainty. As consumers prefer predictable outcomes, this element of uncertainty contributes towards inertia. Also, people act to minimise regret i.e. their regret is lessor if they do not invest in an opportunity which will not pan out well than if they do invest in the same opportunity. Finally, people often seek to justify decisions already made; even if proven otherwise.

Prospect Theory: Neoclassical theory of economics assume that an individual's preferences are independent from the composition of their current endowment. Kahnemann and Tversky (1979:263-291) have proposed an alternative viewpoint termed prospect theory which states that any changes to a consumer's welfare should be evaluated according to certain reference points. Three types are discussed below:

> *Loss aversion*: consumers treat gains differently from losses. They tend to value losses more than gains.
>
> *Endowment effect*: consumers place more value on assets they already own compared to those that they do not.
>
> *Status-quo bias*: people often feel comfortable with their current/default option. Alternatives present uncertainties that force a status quo bias.

Values: this category is yet another explanatory variable to the energy efficiency gap that speaks to the consumer's inner principles, beliefs and rules of conduct i.e. his moral obligations to utilise energy more efficiently generally brought out as a concern for the environment. Empirical studies have shown in some cases that if consumers are educated about energy efficiency in a way that appeals to their inner moral code, then there will be a positive improvement in their behaviour towards energy efficiency Thollander, Palm & Rohdin (2010:55). Furthermore, an organisation's value system/culture will have a direct impact on its public image.

3.3.4 Institutional barriers

Weber (1997:833-835) discusses institutional barriers as those that are created by government and local authorities. It may also be influenced by politics. Sound energy policies promote the adoption and diffusion of the energy efficiency technologies. A literature survey reveals at least four barriers worthy of discussion viz. regulation, distorted policies, market structure and technology and institutional change.

Regulation: inefficient regulation that imposes price inconsistencies, or limit the availability of technology or services, and those that align to inferior standards impact negatively on the adoption of energy efficiency technologies. Wiel and McMahon (2002) discuss the lack of sufficient regulation surrounding the energy labelling on products and the prescription of standards relating to energy performance. Energy labelling assists in providing the user with the necessary data to make informed energy purchasers. Labels could either take the form of endorsements, or could be used as a means for a quick comparison between products. Standards help prohibit the sale of products that are less energy efficient than the required minimum.

Distorted fiscal policies: in such cases, policies place burdens on organisations who wish to implement energy efficient technologies. Examples of policy burdens include over excessive or too stringent environmental requirements, tariffs that do not promote energy efficiency, etc. In particular, distorted fiscal policies may include long depreciation periods for capital goods. As the initial investment for energy efficient technologies are higher than for standard equipment, these long depreciation periods make investment in energy efficient technology unattractive compared to standard types.

Market structures: While this barrier is not cited often in the literature on energy efficiency barriers, Golove and Eto (1996) raise this as an important consideration that contributes significantly to the efficiency gap. In such cases malformed energy agencies are unable to prohibit powerful firms from monopolising the energy efficiency supply market and inhibiting vibrant competition. This eventually points to a market failure as it manifests as imperfect competition. Praetorious & Bleyl (2006:1520-1531) highlights the need for effective formal institutional structures in South Africa surrounding energy projects. Such structures will assist in the development of strategies, help supervise market operations, carry out public education and awareness on energy efficiency, help reduce informational search costs, etc.

Technological and institutional change: Golove and Eto (1996) raise the concern that policies emanating from energy institutes need to follow technological advances i.e. they need to be kept up to date. Since technology within the energy efficiency market changes rapidly, if public institutions are not constantly revising and updating their policies, they risk becoming outdated and irrelevant. This in turn may have a negative impact to the adoption of contemporary energy efficient technologies as such outdated policies may act as barriers.

3.3.5 Other barriers

Cagno et al. (2013:290-308) conducted an analysis of recent literature on barriers and proposed additions to the taxonomy proposed by Sorrel et al [27]. Of note are the barriers related to competencies, the low diffusion of technologies and the difficulty in gathering external skills. These are discussed below.

Competencies: The implementation and management of energy efficiency technologies requires a skills set commensurate to the level of the technology being implemented. This may be difficult for organisations to achieve especially for SMEs in South Africa. This hurdle may be overcome through large investments in training and the appointment of foreign consultants. Cagno et al. (2013:290-308) takes this point further to mention that specific competencies are also required in identifying the inefficiencies and opportunities for energy savings. In some cases, while the level of awareness for energy efficiency might exist, specific methods and tools in identifying inefficiencies and opportunities might not be available.

Low diffusion of energy efficient technologies: In much of the literature thus far, it is assumed that cost effective technologies are adopted without hesitation. However, Golove and Eto (1996) mention that adoption of new cost effective technology is typically gradual. Since energy efficient technologies are relatively new to the marketplace, it is expected then that only a small market share exists currently. Golove and Eto (1996) point out that stable levels of diffusion are not likely in the near future. This in itself poses a barrier for adoption.

Difficulty in gathering external skills: Further, from the competency barriers raised earlier, Cagno et al. (2010:916-926) discuss that the high costs and the availability of experts/foreign consultants to support local implementations may pose a barrier. Until such time when the local energy efficiency market is mature, stable levels of diffusion exist and local firms develop the requisite skill sets to manage energy efficiency interventions independently, the local market will be heavily dependent on such external/foreign skills.

3.3.6 Overlaps between barriers and implicit interactions

As mentioned earlier, Weber (1997:833-835) warns that while a typology of barriers provides a good guide for empirical research studies, it should be noted that they are not mutually exclusive. To this end, overlaps and implicit interactions are therefore expected. Cagno et al. (2013:290-308) distinguishes between overlaps and interactions in the following way: overlaps occur when two barriers address the same problem whilst implicit interactions implies that there may be causal relationships between them. Most of the theory discussed below is drawn from Cagno et al. (2013:290-308) and is not intended to provide an exhaustive account of barrier interactions and overlaps. It is the intention to merely indicate that relationships do exist and should be taken into consideration during empirical research.

Overlaps

Imperfect information: the hidden costs involved in searching for information may also be a contributing factor to the imperfection in the flow of information and not only because information may have public good characteristics.

Heterogeneity: the reason why a certain class of users may not find an energy efficiency technology cost-effective while others do could be a result of several barriers acting together e.g. firms may have varying risk profiles and may perceive the barriers differently or the firms may not generally have a culture to be environmentally conscious altogether.

Bounded rationality: again this may be a resultant of several barriers acting together. The inability to make an energy efficiency decision could be due to the lack of information available to the decision maker. This could be because of imperfect information, a general lack of competencies, hidden costs or information asymmetry.

Implicit interactions

Competencies and bounded rationality: the lack of requisite competencies may result in users making inefficient energy choices.

Risk and Capital barriers: the risks associated with energy efficiency projects may influence the availability of capital for such investments

Regulation and market failure barriers: for e.g. the lack of sufficient regulation may result in the inability to control opportunistic behaviour in a principle-agent relationship.

3.3.7 Taxonomy for empirical research

In order to understand the most pertinent barriers that face industrial firms within the population of interest, we propose the taxonomy listed in Table 7 that will be used in the empirical research. This taxonomy is a derivation from the literature survey.

Table 7 Taxonomy of barriers for empirical research

Perspective	Category	Barrier	Description
1. Economic	1.1 Market failure	1.1.1 Incomplete markets	In such cases, property rights are not well defined resulting in some organisations benefiting unfairly at the expense of society
		1.1.2 Imperfect Competition	A monopoly or stronghold exists in the market that prevents other companies from competing
		1.1.3 Imperfect Information	Firms give out insufficient information to the market which results in consumers making less optimal choices
		1.1.4 Asymmetric Information	One party to a transaction may have privileged information and may behave opportunistically
		1.1.4.1 Adverse Selection	One party to a transaction has access to private information before contract signing resulting in him acting opportunistically
		1.1.4.2 Moral Hazard	In a principle-agent relationship, the agent may behave opportunistically post signing of contract
		1.1.5 Split Incentives	The benefits of an investment may not accrue to the party making the investment
	1.2 Non-market failure	1.2.1 Capital Barriers	Funds may not be readily available for investment in energy efficiency projects
		1.2.2 Heterogeneity	A technology may only be cost effective for a proportion of users of a certain class
		1.2.3 Hidden costs	There may be costs that are not immediately explicit to the consumer or omitted in techno-economic studies
		1.2.4 Risk	There may be several technical, business or external risks associated with a product
2. Behavioural	2.1 Rationality	2.1.1 Bounded Rationality	Users may have limited time, ability or attention to process information and thus make efficient decisions
	2.2 Human Dimension	2.2.1 Form of Information	The manner in which information is presented to the agent is important for it to receive the required attention
		2.2.2 Credibility and trust	Agents react more positively to sources that are trustworthy and of higher credibility
		2.2.3 Inertia	Consumers typically want to avoid change in their environments and therefore maintain the status quo
		2.2.4 Values	This speaks to a person's moral obligations to utilise energy more efficiency out of a concern for the environment
3. Organisational	3.1 Power	3.1.1 Power	The higher the decision making ability of energy personnel in a firm, the higher the probability of EE investments
	3.2 Culture	3.2.1 Culture	If an organisation is environmentally conscious, it will invest more easily in EE initiatives
4. Institutional	4.1 Policies	4.1.1 Regulation	Ineffective regulation may impede the fostering of EE investments
	4.2 Structure	4.2.1 Market Structures	Inefficient market structures to support EE may lead to market failures/barriers
	4.3 Change	4.3.1 Technology and Institutional change	It is important that EE policies are kept up-to-date with contemporary technologies else they risk becoming irrelevant
5. Other barriers	5.1 Abilities	5.1.1 Competencies	Capabilities to support EE investments should exist. Employees should also be trained to identify EE opportunities
		5.1.2 External skills	The cost and availability of external skills to support a firm's EE investments pose a limiting factor
	5.2 Diffusion	5.2.1 Diffusion	Low diffusion rates of EE technologies limit its adoption potential by firms

3.4 Drivers to Energy Efficiency

Reddy (2007) discuss drivers for energy efficiency as those factors that promote private investment in energy efficiency. Cagno and Trianni (2013:276-285) take this definition further and discuss this as factors that facilitate the adoption of energy efficient technologies and practices including the promotion of an energy efficient culture and awareness.

A review of the literature on drivers to energy efficiency reveals that there is not much research on this topic when compared to the concept of barriers discussed earlier. One of the first efforts to classify energy efficiency drivers categorically has been by conducted Reddy (2007) who proposed groupings into 6 categories viz., awareness, lower technology prices, higher energy prices, technology appeal, non-energy benefits and environmental legislations. Thollander and Ottosson (2008:21-34) proposed a categorisation of drivers factors into 4 parts viz. market related driving forces, energy policies, organisational factors and behavioural factors. Other studies conducted by Rohdin, Thollander & Solding (2006:672-677) and the World Economic Forum & Accenture (2010) also add to the body of literature surrounding this topic.

It is the intention of this section to consolidate the literature on drivers to energy efficiency and propose a classification to the used within the empirical study. Furthermore, it is also the intention to provide a more practical account of these drivers within the current context of the South African environment. A set of drivers derived from the theory discussed above are listed below.

Energy Security: In South Africa, security of supply is one of the main drivers of energy efficiency from a policy perspective. In fact, this point is raised as one of the goals in the National Energy Efficiency Strategy of South Africa. Any form of energy conservation will ensure supply resiliency against disruption. Furthermore, it will reduce the country's dependency of any energy imports. In 2008, the rolling black-outs that South Africa experienced crippled large industry to a point where some manufacturers had to close down operations impacting negatively on the economy of the country. The importance of energy security and its impact on business operations became immediately apparent to industry. In such cases, these industries may now be motivated to play a part in preventing future recurrences of such events.

Rise of energy prices: As energy prices continue to increase, energy intensive firms may consider investing in energy efficiency technologies in order to remain competitive. Since 2008, typical MegaFlex tariffs have more than tripled (Britz 2013). As energy costs rise, local industry are exposed to the threat of international competition (Thollander & Ottosson 2008:21-34). It is noted that the costs savings that can be incurred through energy efficiency investments can be used to subsidise such interventions.

Clients wanting Energy Efficient production processes and/or products: As many South African industrial firms trade internationally, it is likely that they may be subjected to clients who impose stringent energy efficient production processes. Such clients may be regulated by strict laws within their local industry or they may do so purely from an environmentally conscious organisational culture. Further to this, with the advent of energy efficiency labelling regulations becoming more prevalent, organisations are required to produce comparatively more energy efficient products in order for them to stay competitive.

Great ambition and entrepreneurial mind: this driver was empirically tested and discussed by Rohdin and Thollander (2006:1836-1844) within an investigation of the non-intensive manufacturing industry in Sweden. In this study, it was concluded that organisations that have employees with real ambition have a higher energy efficiency implementation rate especially where an environmental sensitive culture is present. Typically these individuals should have the authority to influence energy efficiency investment decisions. If it is not the case, these individuals should be represented by management or an executive.

Grants, subsidies, allowances and public financing: this provides an avenue for firms to obtain the necessary resources to invest in energy efficiency technologies. The direct spin-off to this is that it promotes awareness and assists in the diffusion of such technologies into industry. Carbon financing through the use of the Kyoto Protocol is another practical example known to incentivise energy efficiency activities (Hamilton 2009). Investment subsidies are also sometimes bundled with expert support to ensure the effective delivery of energy efficiency projects as discussed in Thollander & Ottoson (2008:21-34)

Management Sensitivity: this is related to the culture of the organisations and the value systems of the investment decision makers. The sensitivity of the main decision makers within an organisation on energy conservation and environmental concerns play an important role in the propensity of an organisation to adopt energy efficient technologies (Cagno & Trianni 2013:276-285). This becomes more important when access to investment resources are constrained. The more sensitive management are about such concerns, the more likely the firm to invest in EE technology.

Information: as companies become aware of success stories of energy efficiency interventions by similar companies within the same operating sector, their propensity to implement similar interventions are higher given the reduced risk (Cagno & Trianni 2013:276-285). This driver is related to the awareness factor raised by Reddy (2007). As energy consumers become more aware of energy efficient technologies, either through marketing or advertising campaigns, they are motivated to adopt energy efficient technologies.

Technology appeal: Reddy (2007) discusses this driver as being related to the characteristics of the technology being deployed. If the characteristics of the technology improves the outlook of the organisation in ways that it makes them appear modern, techno-savvy or fashionable then there may be a higher probability of firms adopting such technologies. Typically such behaviour may be found in highly profitable consumers.

Lower technology prices: as energy efficiency technologies are fairly new to the market and constantly evolving at a rapid pace, the investment in such technologies by firms carry a considerable risk. These risks include technologies becoming obsolete, premature failures, lack of support, capital loss, etc. However, if the prices of such technologies decrease, it may improve the likelihood of investment in these technologies as the impact of the consequence in the risk factor is reduced. Note: the gradual adoption of these technologies will naturally resolve the technology risk factors as with demand, suppliers will be able to provide better support of their products, etc.

Non-energy benefits: Reddy (2007) list several non-energy related benefits as drivers to energy efficiency. The benefits can be realised at the national and at consumer level. However, for the purposes of this study, the benefits to an energy consumer considering the adoption of energy efficient technologies include: improved competitiveness through lower product prices (reduction in labour and energy prices) and better corporate image; improved working environment (noise reduction, improved health and safety) leading to better productivity; increased reliability, improved control of production process, etc. Refer to section 3.2 for a detailed explanation on the benefits to energy efficiency.

Environmental regulations: well-designed environmental regulations that internalise the cost of environmental pollution to organisations may motivate firms to consider investments in energy efficient technologies as a means to offset such regulatory impositions (Reddy 2007). As more external pressures (in the form of levies) are placed on industrial firms to reduce emissions (sulphur and nitrogen oxides and CO_2), organisations may want to reduce this burden by either investing in renewables or lowering their energy demand profile through the implementation of energy efficiency projects. Currently in South Africa, the introduction of the 12L tax incentive programme for industry offers motivation to reduce consumption through energy efficiency means. Other environmental regulations may be more direct and stipulate the technologies that firms should adhere to or risk facing penalties.

Long term energy strategy: In a study conducted by Rohdin & Thollander (2006:1836-1844) on non-energy intensive industries, it was found that top management’s concern for the long term survival of the firm was of a key consideration in EE investments. In cases where substantial increases in future energy prices pose a threat on the long-term strategy of the company, investment in energy efficient technologies offer an avenue to protect against future price fluctuations thereby ensuring the long term survival of the firm.

Table 8 Taxonomy of drivers for empirical research

Driver	Description
Energy Security	Industries understand the risks of operating in a vulnerable energy environment and will do their part in ensuring security of supply
Rise of energy prices	As energy prices continue to increase, organisations have to find innovative ways to remain competitive and thus invest in EE technologies
Clients wanting Energy Efficient production processes and/or products	As industries now compete within a global marketplace, international clients may have stringent energy efficiency product or process requirements.
Great ambition and entrepreneurial mind	It has been empirically shown that organisations with employees that have strong ambition operating within an environmentally conscious culture have a greater propensity to adopt energy efficiency projects
Grants, subsidies, allowances and public financing	Public financing mechanisms provide an avenue for firms to obtain capital at minimal/zero cost to invest in energy efficiency projects
Management Sensitivity	The more sensitive higher management is about environmental issues the higher the probability of energy efficiency technology adoption.
Information	As firms become more aware of success stories of energy efficiency interventions, they have a higher propensity to engage in such projects.
Technology appeal	Highly profitable firms may want to engage in energy efficiency projects because they are technologically appealing and may therefore improve their image as a techno-savvy, modern or fashionable organisation.
Lower technology prices	High energy efficiency technology prices increase the risk exposure of firms considering investing in such projects. If these prices are subsidised or reduced, then the risk impact will decrease accordingly. Lower risk impact may make energy efficiency projects/investments more appealing.
Non-energy benefits	There are several benefits to investing in energy efficiency projects; some include: improved competitiveness, better corporate image, improved working environment, etc.
Environmental regulations	Well-designed environmental regulations may internalise the cost of environmental pollution to organisations. As cost impositions affect the bottom line, industrial firms may want to act in ways to minimise this effect.
Long term energy strategy	Some executives may see investments in energy efficiency technologies as a necessary requirement for the long term survival of the firm.

3.5 Characteristics of industry

One of the research objectives in this study is to understand the extent to which energy efficiency adoption is influenced by firm-level and sector characteristics. This is necessary as a survey of the literature of energy efficiency indicate that patterns of energy efficiency adoption vary considerably across industrial firms each with differing operating characteristics. For e.g., Sardianou (2008:1416-1423) show that in Greek industries, the perceived knowledge of energy conservation practices is especially high in large industries i.e., those with larger number of employees or those with a larger square meterage. As a result, any policy mechanisms that is specified to reduce the effect of any barrier or enhance the influence of a driver, may need to be specific to the target sector/industry in consideration. For this study, firm characteristics are those which may influence the level of adoption of energy efficient technologies and may include for e.g., the size and sector of the organisation, its infrastructure, information around the employees of the organisation, etc. as discussed in Zilahy (2004:311-319).

Literature on the effect of firm-level characteristics in the participation of energy conservation programs or the adoption of energy efficient technologies are quite vast. These are discussed by Sardianou (2008:1416-1423), De Groot, Verhoef & Niekamp (2001:717-740), Cole, Elliot & Shimamoto (2006: 312-323), Decanio & Watkins (1998:275-294) and Aurora & Cason (1995:271-286). Decanio & Wakins (1998:275-294) show that the size of the organisation is a determinant to the investment in energy efficiency technologies. Aurora and Cason (1995:271-286) discuss that in a competitive industry, firms are motivated to differentiate products based on environmental qualifications and therefore may tend to make energy conscious decisions more readily. In the same paper they also discuss that larger firms are more incentivised to participate in environmental programs. Cole, Elliot & Shimamoto (2006: 312-323) consolidate various firm-level characteristics within the literature on Energy conservation in Japan and demonstrate that a firm's debt, size and marketing strength and its R&D investment ratios are significant factors in the characterisation of a firm's overall Energy management performance. De Groot, Verhoef & Niekamp (2001:717-740) show that a firm's energy intensity, size and competitive position are relevant factors in its behaviour and attitude towards policy. In a study on barriers to industry energy efficiency investments in Greece by Sardianou (2008:1416-1423), it is concluded that energy conservation policies in Greek industries should take due consideration of the specific characteristics of these industries. Evidently, from the studies described above, a discussion of the firm level characteristics that encourage or discourage the level of adoption of energy efficiency technologies relevant for this study is necessary for our empirical research. A classification of the pertinent characteristics are discussed below which are primarily derived from the literature review.

Human Capital Intensity (HCI): Firms with a higher human capital intensity tend to be more innovative and open to new technology. Yet still, a proportion of such firms experience impediments to EE technology adoption. We set out to investigate the reasons behind this.

Measurement: training plan and employ professional engineers and technicians.

Debt: Firms with higher debt ratios have less cash to invest in energy efficiency improvement projects. If such firms still do invest, what drives them to? And what impedes firms with lower debt ratios not to invest?

Measurement: Total debt relative to assets. The exact figure is not always readily available by respondents. Therefore, based on US figures surveyed over the internet (CSIMarket 2015), we categorise the ratios as: Low <40%; Medium 40%-70%; and High > 70%. This allows the respondent to provide a rough order estimate.

Marketing: Firms that have greater public exposure through marketing activities tend to be more conscious of the values upheld by the general public and therefore have a higher uptake of EE technology adoption. We investigate the drivers behind this and the complexities involved for those who do not invest.

Measurement: The cost of advertising as a proportion of sales. In a study conducted by the Chief Marketing Officer (CMO) council (Bransom 2015), it has been noted that a fair categorisation of marketing budgets are as follows: ≤ 4%, 4 - 20% and ≥ 20%.

Profitability: Profitable firms have a higher probability of investing in energy efficiency technologies as they have surplus funds available for such investments. They also may be more risk taking. However, some profitable firms still do not invest in EE technologies. We therefore wish to understand the reasons behind this. We also investigate whether there are any other specific drivers that encourage profitable firms to invest in EE technologies.

Measurement: Profit over the last 3 years

Firm size: larger firms may tend to adopt energy efficient technologies more readily for 2 reasons: (a) as they may be able to assign resources to energy conservation/environmental projects; and (b) they may be under the spotlight by environmentally monitoring agencies of the public in general. However such firms still experience difficulties in adopting EE technologies whilst others thrive. We investigate the reasons behind this.

Measurement: the number of employees

International Orientation: Firms that have an international orientation i.e. those firms that operate within the global marketplace, are more likely to be energy efficient due to market requirements and legislation. We measure International orientation using two measures viz. whether the firm exports products and or whether the firm has global facilities.

Export: it is to be expected that firms who export to international markets may be regulated by strong environmental or energy requirements. Furthermore, as such firms compete within the global marketplace, they face strong competition and are forced to streamline their products/processes to allow them to be more competitive. This may entail deploying energy efficient production processes or developing energy efficient products. The bottom-line is that firms who export a certain proportion of their output are more likely to implement energy saving technologies.

Measurement: export of goods

Global facilities: firms that have operating facilities overseas may be required to adhere to local operating legislations on EE.

Measurement: Global manufacturing facilities

We investigate the difficulties such firms experience to investing in EE technologies. We also probe such firms to try and understand the main drivers behind their EE investments.

Energy costs: Firms whose energy costs are a substantial proportion of their turnover may be more willing to invest in energy efficiency mechanisms so as to increase their profit ratios. This is further justified if one has to consider the Mega flex energy tariff increases over the last five years and the projected increases over the coming years.

In order to remain competitive, it may become obligatory that such firms invest in energy saving technologies. Many years back South Africa attracted much foreign investment, especially in energy intensive manufacturing because of its historically low tariff rate. With the recent energy dynamics in the marketplace, firms are forced to change their operating characteristics or face the risk of shutting down. Yet still, some firms do not invest in EE technologies. We investigate the reasons for this. We also investigate what drives firms with high energy costs to adopt EE technologies.

Measurement: cost of energy as a percentage of turnover

Competition: Firms operating in a competitive environment generally differentiate products based on energy efficiency qualifications. Such firms may also want to reduce costs in order to remain profitable and may therefore invest in energy efficient production facilities. We investigate what difficulties such firms experience in the investments in EE technologies and what drives them to invest.

Measurement: qualitative index of Low, Medium and High as per respondent's judgement. Results verified to be consistent.

Age of the firm: Older firms will tend to have less efficient building and process energy infrastructure than newer firms. In South Africa, awareness on energy efficiency started in the year 2004 when the energy efficiency strategy for the country was promulgated. However, typically, implementation only started after the energy crisis in 2008. Older firms tend to find it more difficult to make the transition to EE technology adoption. We investigate the reasons behind this. We also investigate what drives such firms to invest in EE technology.

Measurement: Age of the firm.

ISO14001 registered: Firms that are ISO14001 registered tend to be more driven to EE technology adoption as a result of their inherent culture. We investigate the specific drivers behind this. While some ISO14001 registered firms adopt EE technologies quite readily, a proportion still find difficulty in taking up such investments. We investigate the barriers such firms experience.

Measurement: ISO14001 registration

Invested in EE technology: We question firms on their previous/past investments in EE process and building technologies. We then investigate the main drivers and barriers such firms have experienced.

Measurement: Investment in building and process related technologies.

3.6 Conceptual model of the environment

In order to better understand how the actors, drivers, barriers and benefits to energy efficiency interact within a system, we propose the conceptual model shown in Figure 16 below.

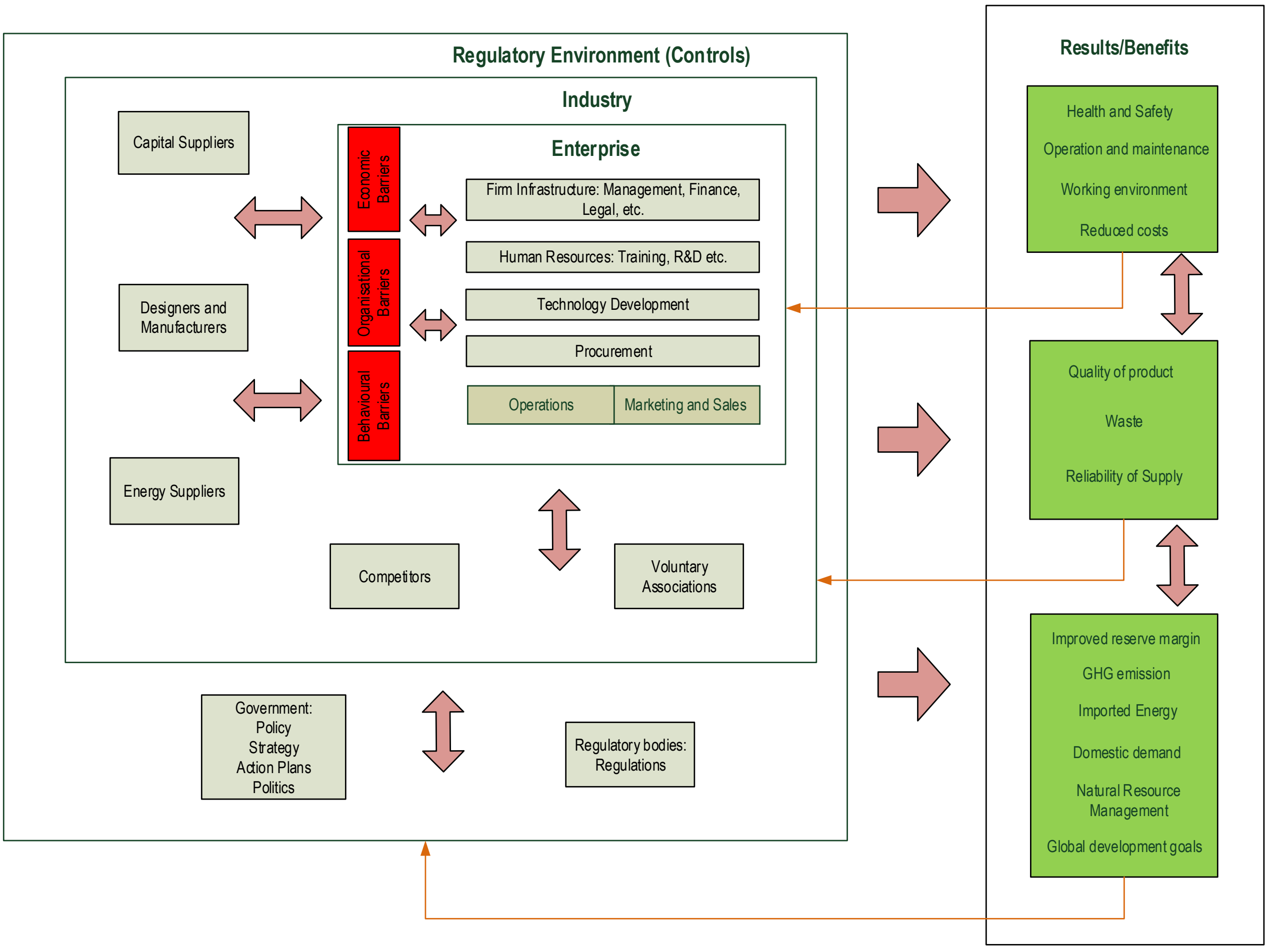

Figure 16 Conceptual model of EE relationships

The model demonstrates that the enterprise has its own internal dynamics that are influenced by the macro-environment. The enterprise works to achieve the benefits that EE has to offer either selflessly or as a way to comply with regulatory impositions. The magnitude of the results is constantly moderated by the barriers. Taken together, the barriers and drivers are a blend of the macro-economic environment and the internal dynamics of the organisation. As every enterprise operates in the same macro-economic environment, it is expected that, at the broader level, all organisations are exposed to similar barriers and drivers to EE. However, the characteristics of the enterprise determine the extent to which the enterprise itself is affected.

3.6.1 The Enterprise

In the modelling of the enterprise we have utilised Porter's approach (Porter 1985) in defining the functions of the organisation and revised it for relevance to this study. Essentially the organisation can be broken down into its primary value chain and secondary supporting functions. The elements of the value chain that is relevant to this study include Operations, Marketing and Sales. One of the main benefits to the deployment of energy efficiency lies in the improvement of the operations of the business e.g. improved health and safety, improved reliability, improved wear and tear, sophisticated control systems for energy reduction, etc. The point relating to Marketing and Sales was raised earlier; an organisation that has greater exposure to the market tends to have closer relationships with customers. Such organisations are more conscious of the environment and will uphold the values of their customers. The secondary supporting functions of the business include procurement, technology development, human resources and the firm infrastructure itself. Policies that support the efficient procurement of EE technologies should be advocated. In order to ensure that energy efficiency design considerations are taken into account during technology development, information in the correct form should be made available to the firm. The **Human Resources** function of the firm should ensure that employees have the requisite skills to effectively detect, deploy and manage energy efficiency technologies. The **Human Resource** function is also responsible for **Research and Development** and should ensure that sufficient funding is set aside for such activities. The **Firm Infrastructure** comprises of Management, Finance and Legal functions. There could also be sundry functions; however these may not be relevant to this study. In earlier discussions it was raised that management is responsible for setting the culture of the firm. If management do not develop and drive an energy conservation culture within the organisation, all energy efficiency initiatives shall be stifled. It is also important that the energy management team is represented on the finance board and can therefore motivate for energy efficiency investment. The **finance function** is responsible for sponsoring energy efficiency investments either through company profits or through the acquisition of public funding. The **legal function** is responsible for overseeing all lawful elements at the interface between the enterprise and the external environment. These may include for e.g. competitors and their impact on the organisation's trade, commitment to contractual obligations, etc.

We have discussed barriers to the adoption of energy efficiency technologies in detail. Refer to section 3.3. While a firm continuously strives to reap the benefits associated with energy efficiency investments, it is constantly subjected to behavioural, organisational and economic barriers amongst others. The Enterprise is also subjected to greater forces within the macro-economic environment viz. Industry and the broader Regulatory environment. These are elaborated upon below.

3.6.2 Industry

The market forces relevant for this study consist of capital suppliers, technology service providers, designers/manufacturers/suppliers, competitors, voluntary associations and energy suppliers.

Capital suppliers are the financing associations and may include banks, grant funding associations, etc. Capital suppliers operate within a well regulated environment and require enterprises to conform to certain criteria before being considered for funding approval. Designers/Manufacturers/Suppliers are the enablers to energy efficiency adoption for the enterprise. Within an efficient energy market, such firms make energy conservation technologies readily available to the market. This is necessary to initiate the adoption and diffusion of energy efficient technologies. Competing Enterprises adopt energy efficiency technology as a means to increase market share through differentiation. This could either be through changing process or product specifications. Enterprises may also elect to be part of non-profit/voluntary energy efficient organisations. This may be to increase their exposure as an environmentally conscious organisation or to keep abreast of progressive ways to reduce energy consumption. Examples of such organisations include the NBI discussed earlier; this is known to be the biggest industry energy efficiency non-profit organisation in South Africa. Industry is currently heavily affected by Eskom's (SA's monopolised Energy Supplier) tariff increases and the quality of the supply that it provides. It is also a major player in driving energy conservation due to its energy usage profile.

3.6.3 Regulatory environment

As a means to ensure the sustainability of the economy, to create an environment that attracts Foreign Direct Investment, and to ensure that industry operations are well regulated, Government and other Regulatory bodies monitor and control the macro-economic environment in which Industry functions. Currently in SA, in terms of energy, Industry is subjected to the National Energy Efficiency Strategy of SA which as discussed, aims to mainly improve energy security amongst other key objectives. Of note, this Strategy calls for a 15% reduction in total energy intensity by 2015 and for a 12% reduction in industrial energy intensity alone. The National Energy Efficiency Action Plan that talks to this strategy defines how the targets are to be achieved. The Energy environment is currently regulated by the National Energy Regulator of South Africa (NERSA). This body regulates industry in accordance to government laws and international best practices thereby ensuring sustainability of the energy market.

3.6.4 Results

The results are an amalgamation of the benefits associated with energy efficiency technology adoption and implementation. The effect of each benefit can be optimised through feedback upon quantitative measurement. It is thus important that results are measured at all levels and the impact of each be investigated across all actors. Currently, SANEDI is on a drive to develop an Energy Consumption Feed dashboard that collects energy data at a high level to help understand trends and patterns in consumption. ISO 50001 is also a relevant industry standard that ensures systematic reporting and measurement of energy performance against an organisation's energy policy. The adoption and alignment to such a standard is thus critical to ensure the standardisation of reporting. Such reporting will allow for the optimisation of energy-related benefits across all levels.

3.7 Summary

This Chapter provided a theoretical account of the barriers and drivers to energy efficiency. A taxonomy was developed and proposed surrounding each concept that is drawn from modern day literature on the topic. The Chapter also went on to look at the propensity of firms to adopt energy efficient technologies based on their firm-level characteristics. Finally, a conceptual model that integrates the drivers, barriers and benefits to energy efficiency was explored. This was model was created against the firm and its interaction with the macro-environment.

Chapter 4 Research Design and Methodology

4.1 Introduction

The aim of this research is to obtain a representative, municipal-wide view of the energy efficiency adoption behaviour of medium and large manufacturing firms within the region. As the EMA is representative in terms of the Medium and Large Manufacturing Firms (MLMF) profile in SA, we can carefully extrapolate the results as required. We sample such firms using a reputable sampling frame developed and maintained by the University of KwaZulu-Natal's Faculty of Population and Economic studies (UKZN 2016). The research is conducted through the use of surveys and structured interviews. The research objectives were set out in Section 1.7.1 and resulting questions were derived from this. We use this as an input into the research design. In this section we discuss the research population, sampling frames, research methodology and hurdles experienced as part of the field capture exercise.

4.2 Research type

The type of research for this study is a mix of descriptive and theory testing for the following reasons:

a. The research investigates the barriers and drivers to energy efficiency against a theoretical framework proposed from literature in Chapter 3 (descriptive); and,
b. it builds on the existing barrier and driver literature on energy efficiency by investigating the relationships between firm characteristics and adoption propensity (theory testing: inductive).

4.3 Research logic

The research logic used within this study is provided in Figure 17 below. The objectives of this research shall be investigated through the application of barrier and driver theory on MLMF within the EMA. Firm characteristics and manufacturing sector are used as control measures. The output of this research will give an indication of the energy efficiency adoption propensity of MLMF within the South African context and advise on the pertinent barriers and drivers that such firm's experience.

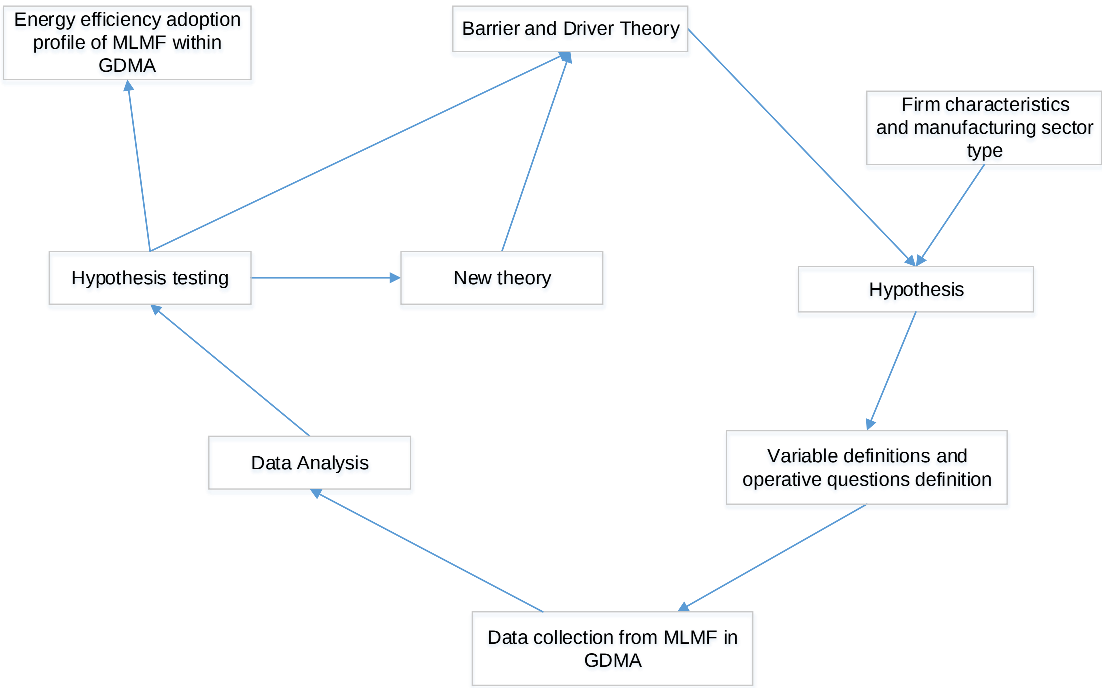

Figure 17 Research Logic

4.4 Research design

In order to conduct the field research, it is first necessary to convert the research questions into quantifiable variables and to have an understanding of the characteristics of the population of interest. From this, the research design can be established.

4.4.1 Translation of research questions into research variables

1. Is there an EE gap among medium to large manufacturing firms operating in the eThekwini region?

In order to answer this question, we first look at the awareness of and investment in EE technologies.

Awareness of energy efficiency technologies gives an indication of the level of diffusion of EE technology information.

Investment in energy efficiency technologies gives an indication of the adoption profile. These can be further qualified as to whether they are process or building related.

In order to determine whether an EE gap exists, we conduct a descriptive analysis of the results by looking at four key quality criteria:

1. The appointment of an *Energy Manager*
2. Setting of *Energy Efficiency targets*
3. Awareness of *Section 12L* energy efficiency tax incentive
4. *Energy Management System (EMS)* in place

Taken together, all of these measures help determine whether an Energy Efficiency gap exists amongst MLMFs operating within the EMA.

Type of variables: All 6 variables are nominal (yes/no)

Type of question: This question is descriptive in nature.

2. What are the drivers and barriers to the adoption of energy efficiency technologies by medium and large manufacturing firms within the eThekwini region?

We answer this question by ranking the attitudinal scores of barriers and drivers.

Based on the barrier taxonomy in Table 7 the following barrier variables have been generated:

Institutional policy barrier, distorted fiscal policies, Awareness, adverse selection, capital restraints, hidden costs, skills/abilities, policy constraints, organisational power, heterogeneity, risk, culture, bounded rationality, form of information, credibility and trust, inertia, power barrier, incomplete markets, Institutional structures, policy change, external skills.

Based on the driver taxonomy in Table 8, the following driver variables have been generated:

Energy security, rising energy prices, stringent product/process requirements, availability of public financing mechanisms, management sensitivity on environmental issues, credibility and trust, technological appeal, lower technology prices, non-energy related benefits, regulation compliance, the firm's long term strategy, customer relations improvement, morale improvement, improvement in product quality, cost reductions.

Type of variable: The driver and barrier variables are measured on a five point ordinal scale: strongly disagree to strongly agree.

Type of question: This question is explanatory (causal) in nature.

3. Do the barriers and drivers vary by manufacturing sector and with the characteristics of these firm? If yes, how do they vary?

This question is answered in two parts viz., how the barriers and drivers vary by:

a. Manufacturing sector
b. Firm characteristics.

PART A

Are the barriers and drivers different by manufacturing sector? If yes, how do they vary?

The *barrier taxonomy* in Table 7 shall be investigated against the *sector classifications in* Table 9*.*

Type of question: This question is exploratory and descriptive in nature.

To answer this research question, we test the following hypotheses

A.1	H_0= The barriers do not vary by manufacturing sector H_1= The barriers do vary by manufacturing sector

A.2	H_0= The drivers do not vary by manufacturing sector H_1= The drivers do vary by manufacturing sector

PART B

Do the barriers and drivers differ with the characteristics of the firm? If yes, how do they vary?

Various firm-level characteristics have been defined in section 3.5. Using this as a baseline, the following independent variables have been defined:

The number of *full-time employees* gives an indication of the **firm's size**. Numeric variable.

The production start date gives an indication of the **firm's age**. Numeric variable.

In determining the **international orientation** of the firm, we investigate two variables:

Product ***export***. Nominal variable.

Global Manufacturing facilities. Nominal variable.

The **Human Capital Intensity (HCI)** of the firm is determined by two variables:

Whether the firms ***employ certified engineers or technicians***. Nominal variable.

Whether the firm has a training plan ***in-place and in-use***.

The firm's debt ratio is determined by its ***debt relative to its assets***. Numeric variable. High debt ratio is considered to be ≥ 0.7. A low debt ratio is considered ≤ 0.4. A medium debt ratio is between these values.

The firms marketing strength is determined by its ***marketing cost relative to its sales***. Numeric variable. Market research has shown that firms who spend ≤ 4 % have a low marketing intensity. Those who spend between 4 and 20 % have a medium intensity and those who spend ≥ 20 % have a high marketing intensity.

The profitability of the firm is determined by whether the firm has seen ***year-on-year profits over the last three years***. Nominal variable.

The firm's energy intensity is determined as its ***energy costs as percentage of its sales.*** Numeric value.

The **competitive index** of the subsector is measured on an attitudinal Likert scale from 1 to 5 with 5 being most competitive; Ordinal value. This index is further qualified as to whether it is Local, Global or Both; Nominal variable.

The firm's environmental commitment is determined by whether it is ***registered with ISO 14001***. Nominal variable.

Property ownership is determined by whether the premises is ***rented or owned***. Nominal variable.

Whether a firm has invested in EE technologies is determined by their investment in either **process or building related EE technologies**.

Type of question: This question is exploratory and descriptive in nature.

To answer this research question, we test the following hypotheses

B.1	H_0= The barriers do not vary by firm characteristics H_1= The barriers do vary by firm characteristics

B.2	H_0= The drivers do not vary by firm characteristics H_1= The drivers do vary by firm characteristics

4.4.2 Research population

The population definition of a research study specifies 4 concepts viz. content, units, extent and time. In the case of this study, the population can be defined as:

All medium to large manufacturing firms within the eThekwini region that conducted economic activities in the year 2015.

Content: Manufacturing firms. The manufacturing subsectors covered by this survey are listed in Table 9 of this report.

Unit of analysis: Medium and Large firms

Extent: eThekwini region

Time: 2015

4.4.3 Sampling frame

A sampling frame is a listing of all elements in a population (Oerlemans et al. 2003). The actual sample is drawn from this listing. It is therefore imperative that the sampling frame is complete and adequate as it eventually determines the quality of the research output.

A preliminary investigation has led to the choice of the University of KwaZulu-Natal's (UKZN) Faculty of Population and Development Studies MLMF database. In 2002 the Faculty conducted research on the constraints to growth within the manufacturing sector in the eThekwini Metropolitan area. For this study, a database representative of the manufacturing industry was constructed using UNISA's BMR register, the SA Chamber of Commerce database, the Unemployment Insurance Fund database, the KwaZulu-Natal Tourism database and the Durban Yellow Pages. In 2014, a similar study of manufacturing firms within the eThekwini Metropolitan area was conducted and this database was subsequently updated. In this database, firms are stratified according to manufacturing sector. A profile of the database is given in Table 9 below.

Table 9 Manufacturing subsector classifications and firm count within EMA

Sector	Abbreviation	Firm count
Food and Beverages	FB	47
Chemicals	CM	93
Iron and Steel	IS	19
Metal	MT	23
Electrical and Electronic apparatus	EE	15
Automotive	AT	24
Non-metallic minerals	NM	25
Total		246

The database also confirms the company size (updated in 2014), the manufacturing subsector and the business address.

The manufacturing sector stratification is based on the World Bank's classification (UN 2008). The EMA has manufacturing entities operating within all strata of this grouping. An endeavour was undertaken to improve the stratification by using the Standard Industrial Code classification. Several emails and logs were made to the Department of Trade and Industry CIPC Division for this information but no headway was made.

The definition of medium and large firms are derived from the World Bank's Full-Time Employees (FTE) threshold. This is set to 50 employees.

4.4.4 Sampling design

A sampling design specifies the probability of every possible sample being drawn from within the sample frame. As part of the sampling design, the following subsections discusses the sampling method and sample size considerations for this research study.

4.4.4.1 Sampling method

Sampling methods can be classified into two types viz. probability and non-probability. Under each type, various classifications exist. For this research, probability sampling is employed as it ensures that every element in the population has a non-zero probability of being included. This then allows us to make statistical inferences about the population of interest from the sample being studied.

There are four main types of probability sampling (Buys 2012):

Simple random sampling: this is the most well received form of sampling. Each member of the population is chosen entirely by chance and every member has an equal opportunity of being selected.

Stratified sampling: In such cases, the population is divided into subgroups (strata) that share a similar characteristic. The independent samples are then selected from each stratum. Any sampling method can be applied to each stratum; when simple random sampling is used within the strata, then the design is referred to as stratified simple random sampling. This type of sampling ensures that an appropriate subgroup sample size is chosen for each stratum in the population of interest.

Systematic sampling: In these cases, members of the population are selected at regular intervals until an adequate sample size is achieved. It is similar to simple random sampling provided that the list from which samples are drawn do not have any hidden order.

Cluster sampling: in cases where the population may be spread across vast geographical areas, cluster sampling may be considered as an appropriate sampling method. The method involves first reducing the population of interest into groups or clusters. A number of clusters are then chosen at random to represent the entire population. All members of the cluster are included in the study. This method of sampling greatly reduces sampling costs.

For this research stratified simple random sampling is chosen as the preferred method of sampling for the following reasons:

a. It is a requirement that every manufacturing subsector is treated as an independent subgroup of the population in order to meet the objectives of this research
b. It is a requirement that the sample set drawn from the every manufacturing subgroup is representative of the subgroup itself.

4.4.4.2 Sample size

Table 9 above provides an indication of the ceiling value of firm count for each manufacturing subsector. It is clear from this table that the firm count varies significantly between subsectors ranging from 15 firms for EE to 93 for CM.

Choosing the correct sample size determines the extent to which the findings of the study can be accepted as valid for the population from which the sample is drawn i.e. the generalizability of the study. For hypothesis testing purposes, choosing the correct sample size reduces the effect of Type I and Type II errors.

There are many considerations to take into account when determining the sample size. The main contributing factors are listed below:

Cost considerations: Conducting a full census on the population of interest may be cost prohibitive especially for large populations. All research projects have to be completed within a pre-determined budget.

Confidence interval: is the degree of precision that we are willing to accept as measured by the margin of error. The lower the margin of error, the greater the sample size.

Confidence level: refers to the reliability of the study and is concerned with the extent to which consistent results are achieved i.e., the probability of getting the same results if the survey is repeated. The higher the required confidence level, the greater the required sample size. The confidence level is affected by the variability of the population/stratum. The greater the variability of the population/ stratum, the greater the required sample size for a specified confidence level.

Likely response rate: an understanding of the likely response rate upfront provides an indication of the allowance that needs to be factored into the required sample size to offset its impact.

For a large population, the sample size for simple random sampling is determined by:

$$ss = \frac{Z^2 p(1-p)}{c^2} \quad (9)$$

Where:

ss= sample size

Z= confidence level (CL)

p = response distribution as determined from previous studies.

c= confidence interval (CI)

For management research studies, CI = 10% and CL = 90% values are recommended. As no previous studies on Energy Efficiency have been conducted on the population of interest for this study, we assume a p=0.5. This is in line with common practice where the researcher is unsure about the response distribution.

For the purposes of this survey, Table 10 below describes the required sample sizes for each stratum.

Table 10 Strata sampling method and minimum sample size

Sector	Firm count	Sampling method	Sample size
FB	47	Simple random sampling	28
CM	93	Simple random sampling	40
IS	19	census	19
MT	23	census	23
EE	15	census	15
AT	24	census	24
NM	25	census	25
Total			174

Where simple random sampling is applied, firms are listed in sequence from 1 to the maximum number of firms within each strata. Random numbers are generated using excel between 1 and the max firm count for each stratum. The amount of random numbers generated is determined by the minimum sample size figure calculated in Table 10 above. Firms are then selected based on the random numbers generated.

While it is understood that it is advantageous for quality purposes to conduct a census on the entire population of interest, due to cost, administrative and time-line constraints, this research endeavours to meet the minimum sample size requirements at the very least as discussed in Table 10.

In order to cater for the non-responsiveness upfront, we oversampled each stratum by 10%.

4.4.5 Generalisability of the results to the national context

The eThekwini manufacturing industry is amongst the top three manufacturing zones in the country. All regional manufacturing firms operate within similar economic conditions viz., they are exposed to similar exporting rules, taxation requirements, policy mandates, energy supply constraints, etc. Therefore whilst this study is conducted within the EMA, it is reasonable to extend the results of this research to the greater South African context. Cautionary notes are mentioned in section 6.6 of this report. While the results could be extended with caution to the national context, one must be more careful when generalising to the global context as the results vary considerably with the macro-economic environment.

4.5 Data gathering

This research study utilises standardised methods and tools to collect data so as to ensure objectivity, validity and reliability in the research results. This also allows for the research results to be replicated should a similar study be conducted on the same population.

4.5.1 Data gathering technique

In this research study we utilise the survey approach to elicit data from MLMF within the EMA. A three part standardised questionnaire was developed and emailed to the manufacturing firms for completion. Telephone calls were first made to establish the correct respondent within the hierarchy of the firm and advise him/her on the purpose of the questionnaire and to determine if he/she was willing to participate (Annexure A contains the telephonic correspondence). An email with the questionnaire was then sent out to the identified and willing recipient (refer to Annexure B). After two weeks, a follow up email (refer to Annexure C) was made to all non-responding participants to assist them in answering the questionnaire. In order to improve the response rate, firms were initially told that the results of the survey will be made available to them. Further, their results were tailored so as to advise them on how they are performing amongst their peers within the same manufacturing stream and across streams. As part of this research, we had also engaged with the National Cleaner Production Centre of South Africa (NCPC-SA) who offered a free energy efficiency quick scan assessment to all participating firms.

4.5.2 Research instrument

A three-part questionnaire was developed in-line with the objectives of the research.

Part A: General characteristics of the firm
Part B: Barriers to energy efficiency
Part C: Drivers to energy efficiency

The intention was to have the energy manager/electrical engineer/production manager respond to the questionnaires as they would have a good understanding of the firm characteristics. Where it was found that such posts don't exist, it was necessary to reach out to the technical director or CEO.

The variables within the barrier and driver questionnaires were measured on a 5 point Likert scale. The variables within the general questionnaire were investigated through mainly nominal yes/no type questions.

The questionnaire was developed in MS Word 2013 using the developer toolbox. The questionnaire was designed in such a way that it was simple to pull in the completed questionnaire in to excel and then to export into SPSS. The questionnaire was designed to also limit the amount of free-text fields. The questionnaire used for this research is given in Annexure D.

A codebook was developed to manage the feedback received from the questionnaire. The SPSS statistical v2.20 tool was used for the development of the codebook and for the statistical analysis of the sampled data.

4.5.3 Research instrument pre-test

In order to ensure that the research instrument was valid, unambiguous and robust in the type of questions asked, the questionnaires were first sent out to one randomly selected firm within each stratum. It was found that the questionnaire was well received with only some respondents experiencing problems with the content controls within MS Word 2013. A pdf file-type of the questionnaire was therefore also sent out with the MS Word version of the questionnaire. No adjustments were made to the content of the questionnaire itself. Further as part of the pre-testing exercise and validity process, the results from the pre-test were checked as to whether they could be quantitatively analysed within the SPSS tool to meet the objectives of the research. No technical issues were found.

4.5.4 Administration and completion of the questionnaire

As the questionnaire was designed for self-completion, it was emailed to all participants. Approximately 20% of the respondents required assistance with the filling in of the questionnaire. Appointments were scheduled with these respondents and site visits were made.

As the respondents were typically Technical or Production managers, it was difficult for all such respondents to provide data relating to the financial side of the business.

Separate telephone calls were therefore made to the financial managers of the company who were in a better position to assist in the completion of these questions. While there was great interest to this survey, not all respondents had the time to participate immediately. It was generally only upon the second follow-up call that the respondents took the time to complete the questionnaire.

A subset of the non-respondents were contacted. Their reason for non-participation was the lack of time and resources available. This was an important discovery as their reasons for non-participation could have biased the results of the study.

4.5.5 Response statistics and data checking

Field research started on 18 May 2015 and was closed-off on 2 September 2015. A total of 179 companies were contacted by telephone and email across 7 manufacturing sectors. Approximately 400 telephone calls were made and 540 emails sent to these companies over this period. The response statistics per manufacturing stratum are provided in the table below:

Table 11 Stratum response rate

Manufacturing sector	Response rate
Food and Beverages	0.18
Chemicals	0.10
Iron and Steel	0.26
Electric and Electronic	0.27
Metals	0.17
Non-metallic minerals	0.12
Automotive	0.08
Total	0.16

The overall response rate of the survey was 16%. The survey resulted in an overall dataset of 27 firms. This response rate is higher than the average for surveys questioning barriers within industrial firms (cfi. Sardianou (2008), Shafron et al. (2000) & De Groot et al. (2001)) which had response rates of 6,5%, 12%, and 4,2% respectively.) In total, 1 845 questions were posed to the responding firms and only 20 remained unanswered across the various items and categories. The overall item response rate achieved was therefore better than 99%. This was initially lower but due to the follow up calls that were made, the final response rate had improved. The questions that remained unanswered were mainly pertaining to the financial side of the business which were difficult for some technical or production managers to answer. In such instances, follow-up calls were made to financial managers of the responding entities.

In order to hold the non-response bias to a minimum, extensive follow-ups were made to the non-responding companies. As mentioned, the reason for non-response was the lack of time and resources by firms.

4.5.6 Data analysis methods

Once the completed questionnaires were checked for completeness, they were numbered uniquely by case number. As a batch process, the data from all questionnaires were exported into a comma separated value file. The data was then formatted correctly in EXCEL. The format changes made were regarding decimal values and percentages only. The EXCEL file was then imported into SPSS v2.20. Missing value analysis was then conducted. Dummy variables were created where necessary in order to support the analysis required for this research.

4.5.7 Cronbach's alpha test

Cronbach's alpha is a coefficient of reliability and is used to measure how well a set of variables measure a single construct (Buys 2013). Tavakol & Dennick (2011) recommend an alpha coefficient within the range 0.7 – 0.95 a good level of reliability.

We utilise SPSS to determine the Cronbach alpha test coefficients for the barrier and driver constructs. The results are given in **Table 12** below.

Table 12 Cronbach alpha test

Construct	Cronbach's alpha
Barriers	0.841
Drivers	0.911

Since the alpha coefficients are within the recommended range we conclude that there is a satisfactory level of internal consistency between items within the barrier and driver constructs.

4.6 Summary

This Chapter presented the research methodology that has been used for this study. The study is descriptive and inductive in nature and adds to the body of knowledge on Energy Efficiency. The Chapter went into detail in translating the research questions into variables for empirical investigation. The sampling frame used for this study was an updated database of MLMFs from the UKZN's Faculty of Population and Development Studies. Field data has been collected through a mixture of telephonic interviews and on-site surveys using a structured questionnaire. This questionnaire was pre-tested on a subset of firms before being deployed in the main field study. The field study resulted in a 16% overall response rate while the questionnaire item response rate has been better than 99%. The survey response rate is considered to be higher than the average for similar studies conducted in other countries. SPSS has been chosen as the statistical analysis tool for this research study. The Chapter also discussed the external validity of the results when generalising to the national context.

Chapter 5 Data gathered and analysis

5.1 Introduction

This chapter presents and discusses the information collected as part of the research field study. The first part of this chapter provides a descriptive analysis on the profile of energy efficiency within manufacturing firms operating in the EMA. The Chapter then goes on to discuss the analytical models that have been deployed in order to test the Hypotheses presented in Chapter 4 of this report. Several assumptions had to first be tested for and justified before being employed. A short discussion ensues after every hypothesis test that relates back to the objectives of the research. The Chapter ends with an overall summary of the salient results derived as part of this study and are disucssed within the context of the research questions. Note the intention of this Chapter is to only analyse and present the results and not to draw any conclusions at this stage.

5.2 Descriptive analysis

The population of study was the Medium to Large Manufacturing Firms (MLMF) across manufacturing sectors within the EMA. The descriptive statistics discussed below are aggregated values at sector level. These descriptions provide insight into the energy behaviour and practices of such firms and are used to help gauge the overall energy efficiency profile and quality thereof.

5.2.1 Awareness of EE technologies

Firms were questioned whether they were aware of energy efficiency technologies available within their industry. The results are shown below.

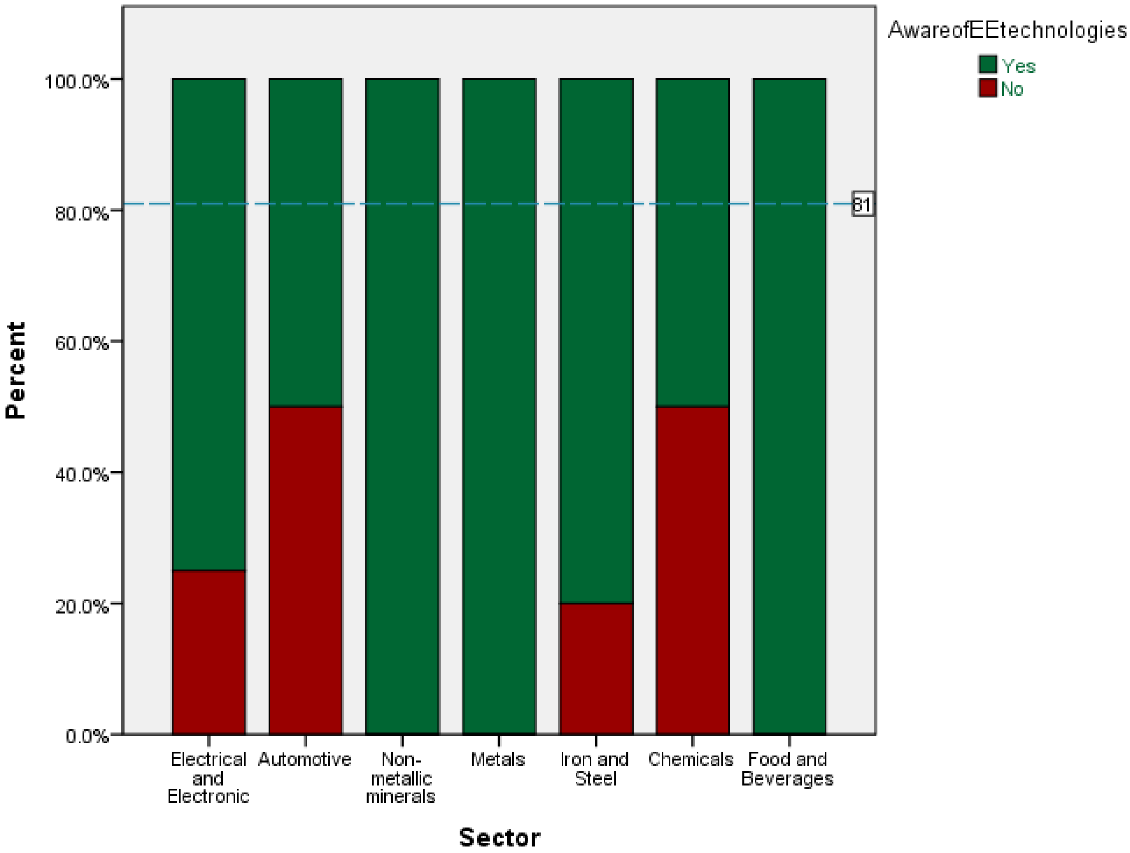

Figure 18 Awareness of EE technologies across sectors

Figure 18 above shows that there is generally a high level of Energy Efficiency awareness across the various manufacturing sectors. However, the figure shows that the more awareness on EE technologies needs to be created within the Automotive and Chemical manufacturing subsectors. There is generally a higher level of awareness within the Non-metallic minerals, Metals and Food and Beverages sectors. High awareness levels also suggests that there is a significant amount of information diffusion on EE technologies. Interestingly, there are some firms within the energy intensive categories that are still not aware of energy efficiency technologies that are available within their industry. Such cases should be urgently addressed.

5.2.2 Dedicated energy manager

Firms were questioned as to whether they had a dedicated energy manager within their structures. The results are shown below.

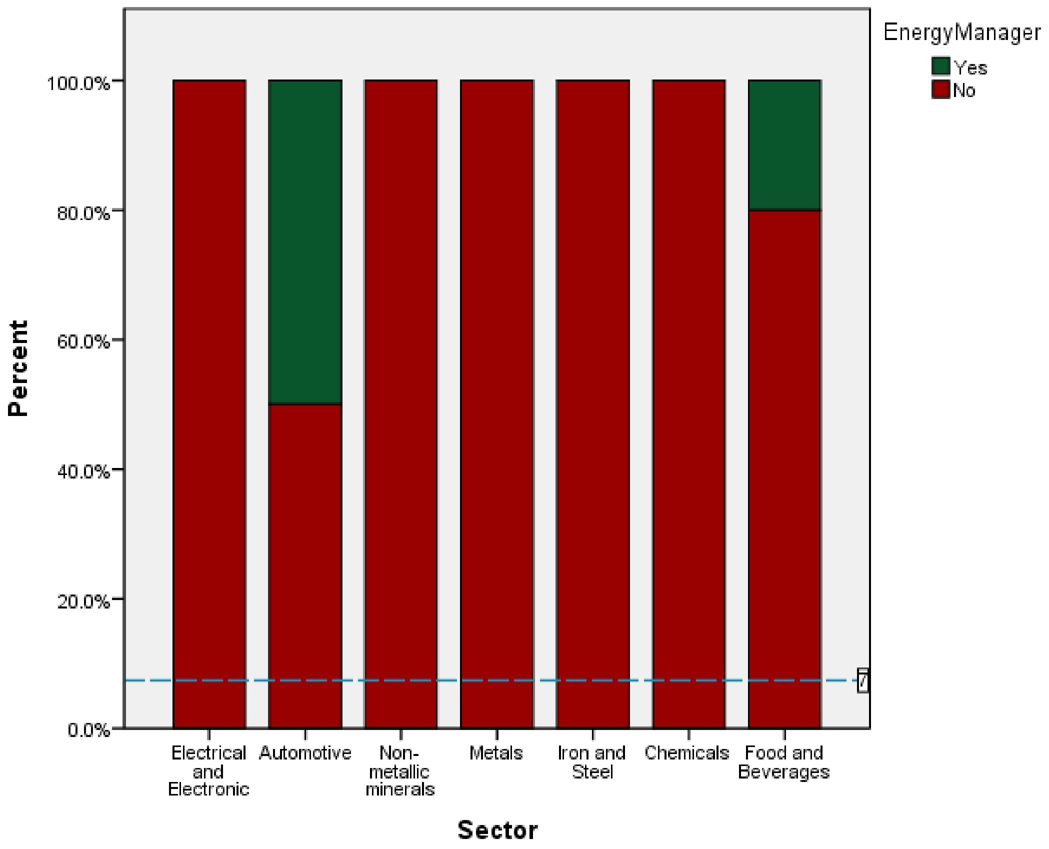

Figure 19 Appointment of an energy manager

Only approximately 7% of MLMF within the EMA have appointed a dedicated Energy Manager within their structures. The results show that these firms typically reside within the Automotive and Food & Beverages sectors. Of note, those firms that are energy intensive have no Energy Manager within their structures despite ISO 50001 and other best practices advising the appointment of an Energy Manager within such firms recommended. Of those who have reported that they do have an Energy Manager, only 50% communicated that this manager reports to the Board. The appointment of dedicated EE managers reveals management's perception on the role that EE plays within its operations. An appointment rate of 7% demonstrates that more awareness on the benefits that such an appointment can add to a company's operations should be created. It is also very important that such a manager is given a level of authority within the hierarchy of the firm commensurate with the decisions on energy that is required of him.

5.2.3 Energy Efficiency investments

Firms were questioned as to whether they have made any energy efficiency investments within their specific processes and as part of their general building infrastructure. They were also separately questioned whether each had resulted in any benefits. The results are shown below.

5.2.3.1 Investments in EE process improvements

Such investments include any specific EE process improvements within the plant. This could include heating, cooling, ventilation, fan optimisation, pump automation, etc. that are specific to the process.

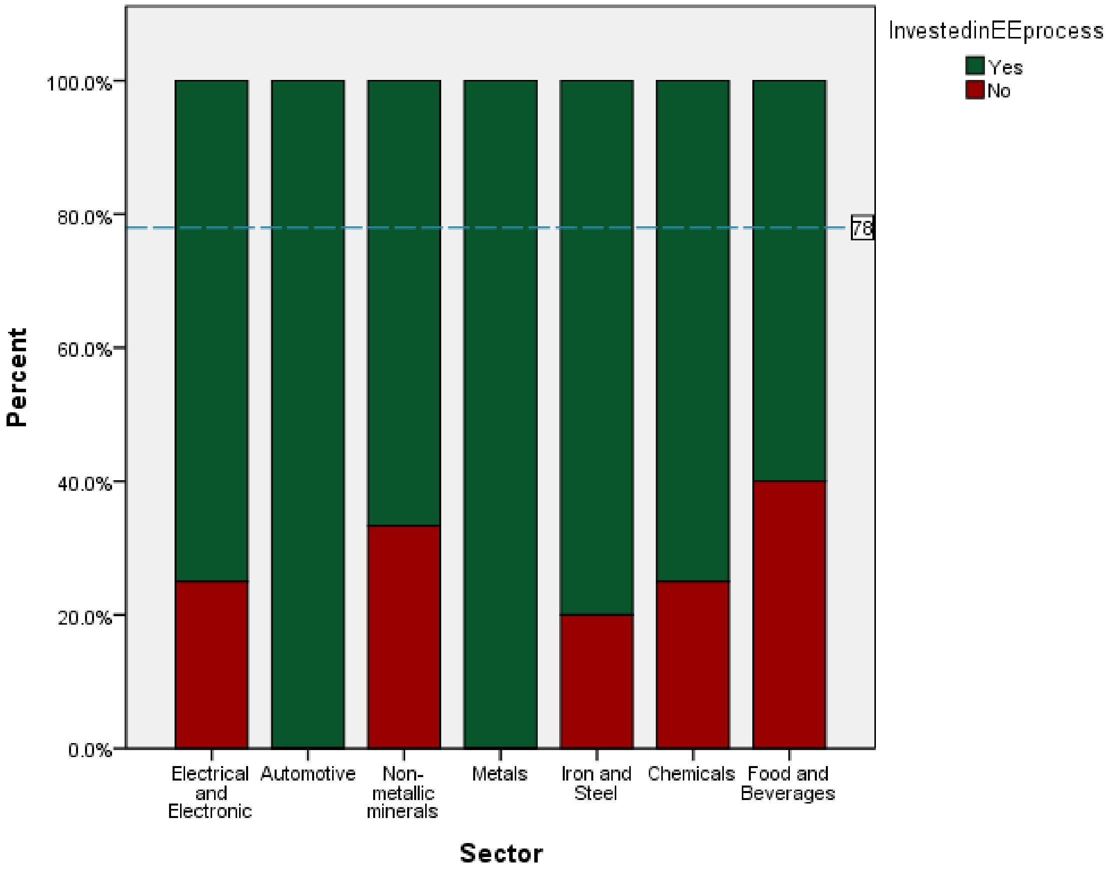

Figure 20 Investments in EE process improvements

The results show that there is generally a high level of investment in process related Energy Efficiency technologies (approximately 78% of firms reponding in the positive). There is especially a high level of investment within the Automotive and Metals sector. There is much room for improvement within the Non-metallic minerals, Chemicals and Iron and Steel Industries especially because they operate within an energy intensive environment.

Those who had invested were asked whether such investments resulted in any benefits. The results are shown below.

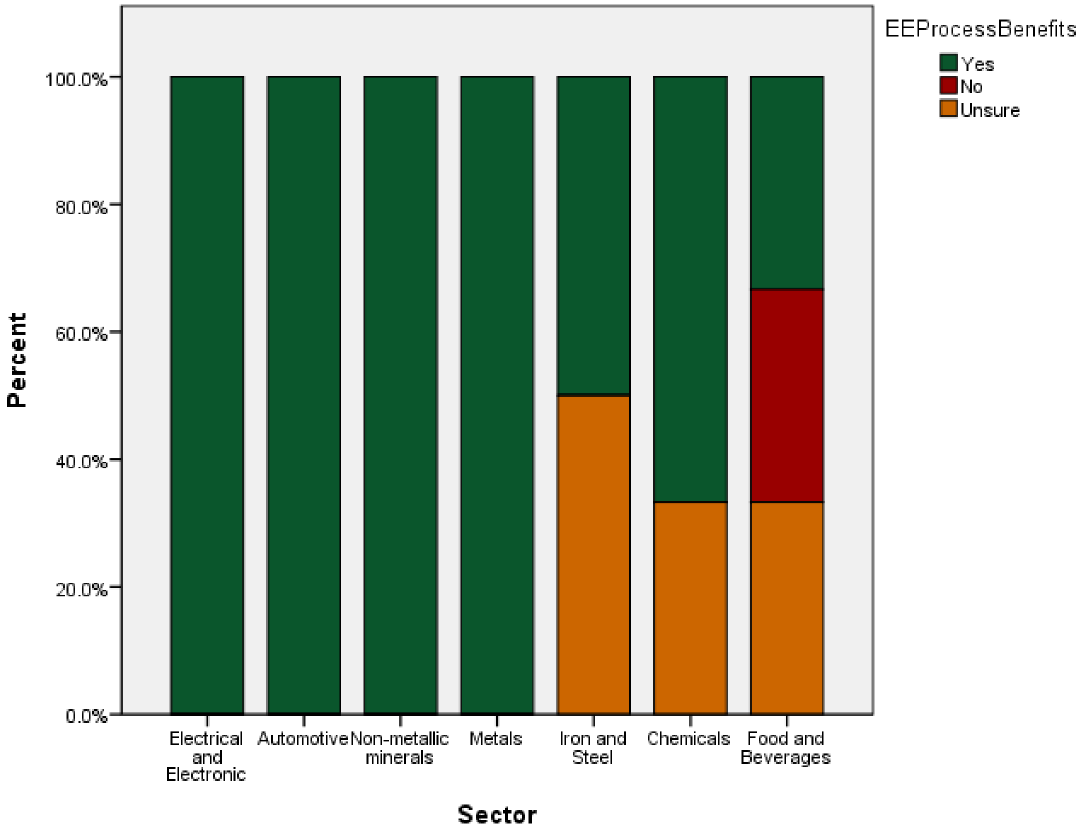

Figure 21 EE process benefits

Approximately 76% of those who have invested in EE technologies have seen a positive result. A further 19 % of those who have invested, were unsure if any benefits were achieved. This was either because they did not measure after investment or were not made aware of the associated benefits. A small percentage of those who have invested did not see any improvement. Investments in process related EE technologies within the Electrical and Electronic, Automotive, Non-metallic minerals and Metals sectors had generally an overall positive impact.

5.2.3.2 Investments in EE building improvements

Similarly to the above, firms were questioned as to whether they had invested in any EE building improvements. This could have been within their process facility or within administration, warehousing and other general related facilities. Typical EE building improvements include: lighting coordination, the change-over to LEDs lights, solar powered water heating, etc. The results are shown below.

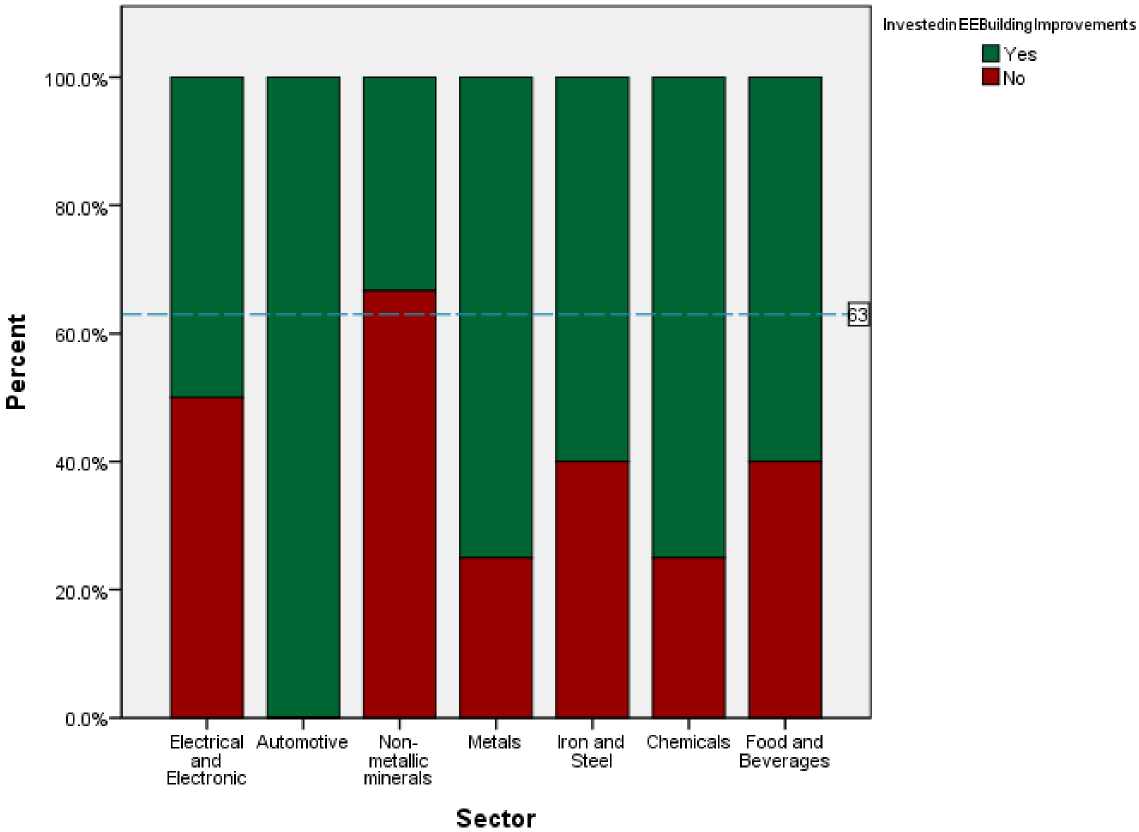

Figure 22 Investments in EE building improvements

The results show that there is generally a lower adoption rate of EE building technologies compared to process related options despite such options being considered lower hanging fruit. The average adoption rate of EE related building is around 63% across the MLMF within the EMA compared to 78% for EE process related technologies.

Those who had invested were then asked whether such investments resulted in any benefits. The results are shown below.

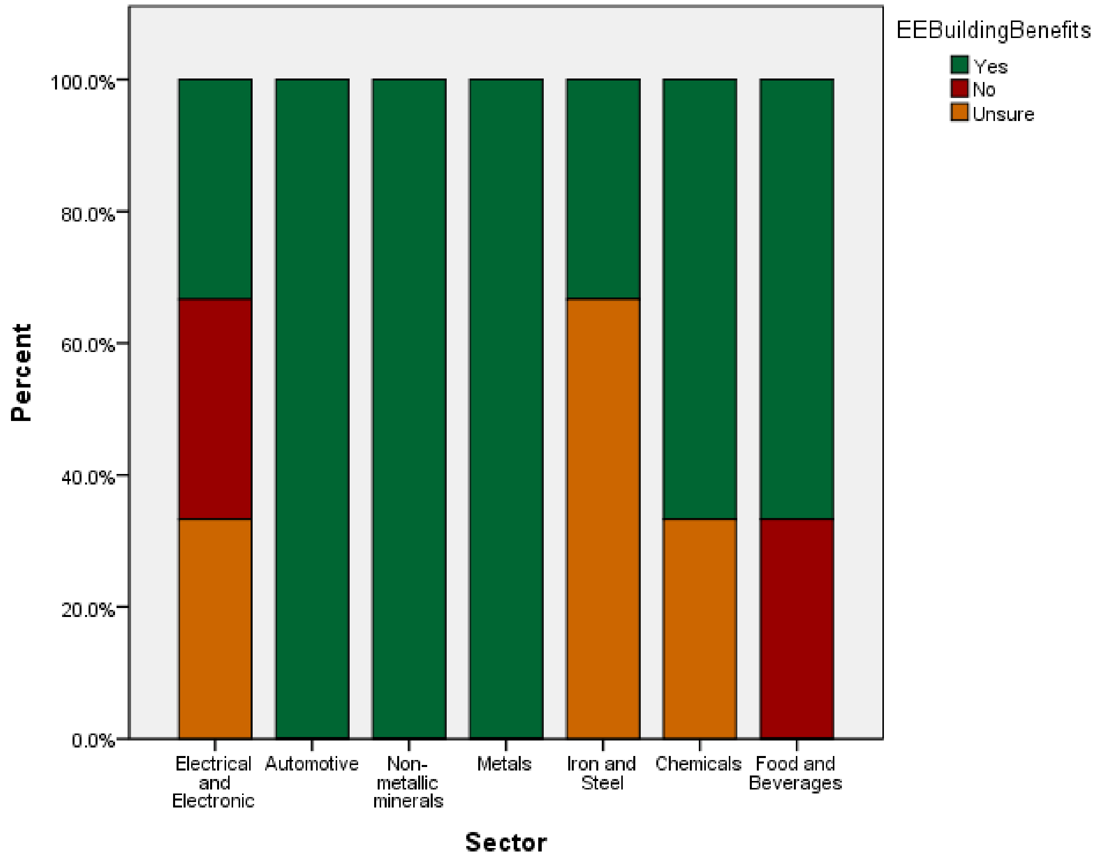

Figure 23 EE building benefits

Approximately 67% of those companies who have invested in EE building technologies have seen positive results through reduction in costs, etc. Further to this, approximately 22 % have either not measured the results or have or have not been made aware of the associated benefits. A lower percentage of respondents (approximately 7%) advised that they have seen no positive reduction in costs. These results are similar to the results presented for the derived EE benefits from process related investments.

5.2.4 Energy improvement targets

Firms were questioned whether they had set any energy improvement targets as part of a strategy to reduce their overall energy consumption. The results are shown below.

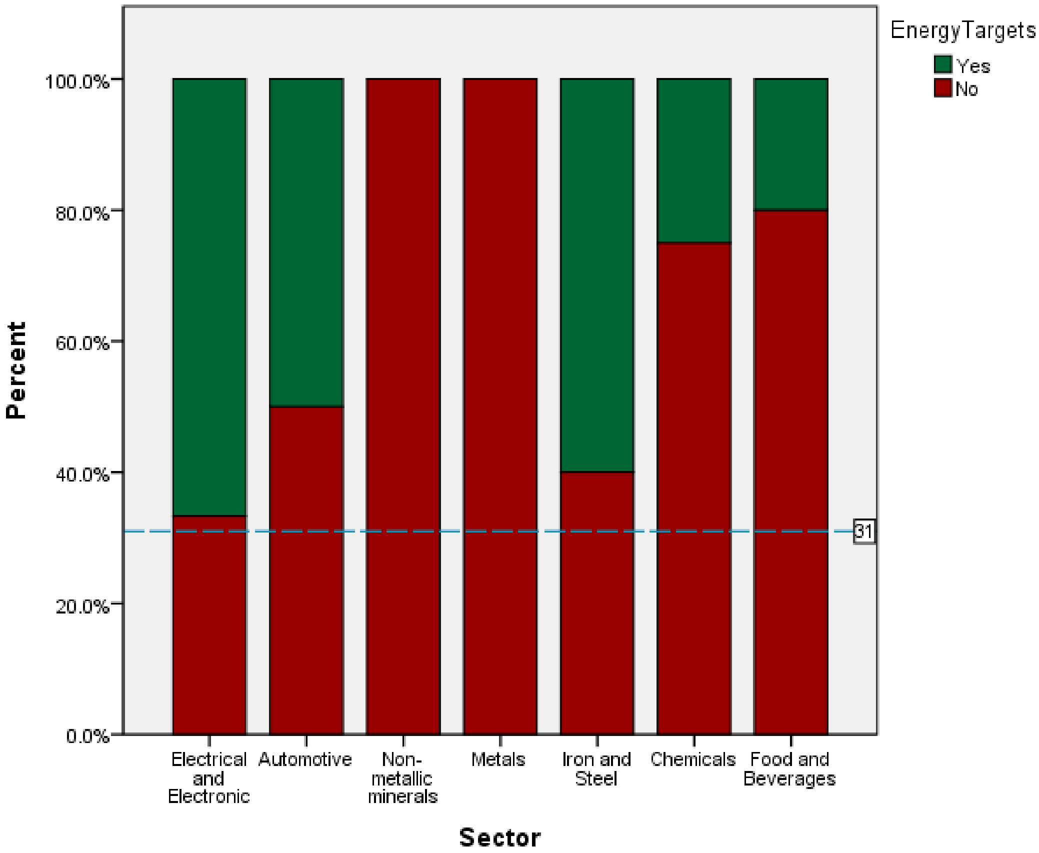

Figure 24 Setting of energy improvement targets

The results show that approximately 31% of firms have energy improvement targets in place. It is highlighted that all firms sampled within the Non-Metallic Minerals and Metals sector have no Energy Improvement targets in place despite their classification as energy intensive. Overall, there is generally a low uptake by manufacturing entities across all manufacturing entities in the setting up of energy improvement targets.

5.2.5 The implementation of an Energy Management System (EMS)

Firms were questioned whether that have implemented an EMS system within their business. An EMS assists an organisation to follow an orderly and methodical approach in achieving continual improvement in energy performance. The results are shown below.

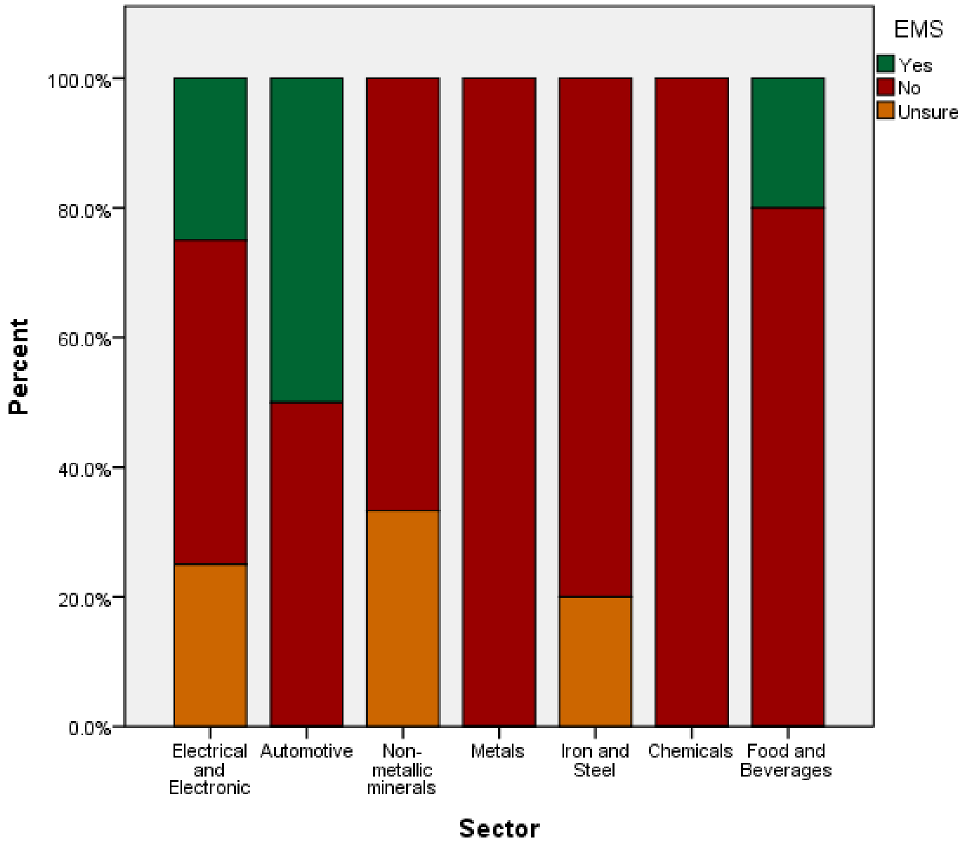

Figure 25 EMS in place

The results indicate that only 11% of the firms sampled have an EMS in place. Of note are the Non-Metallic Minerals, Metals, Iron and Steel and Chemicals subsectors who either do not have an EMS in place or are unsure despite their classification as energy intensive. There is much room for the uptake of EMS systems within such sectors. While a high adoption rate of EE technologies exist, the sustainability of such solutions are questionable without formal management practices in place.

5.2.6 Awareness and implementation of Section 12L

The recent promulgation of the Energy Efficiency tax credit Act, Section 12L within the Income Tax Act, 1962 (KZNEnergy 2014) serves as an incentive for businesses to adopt energy efficiency technologies. Firms were asked whether they were aware of this Act and if so, whether they had made use of this option.

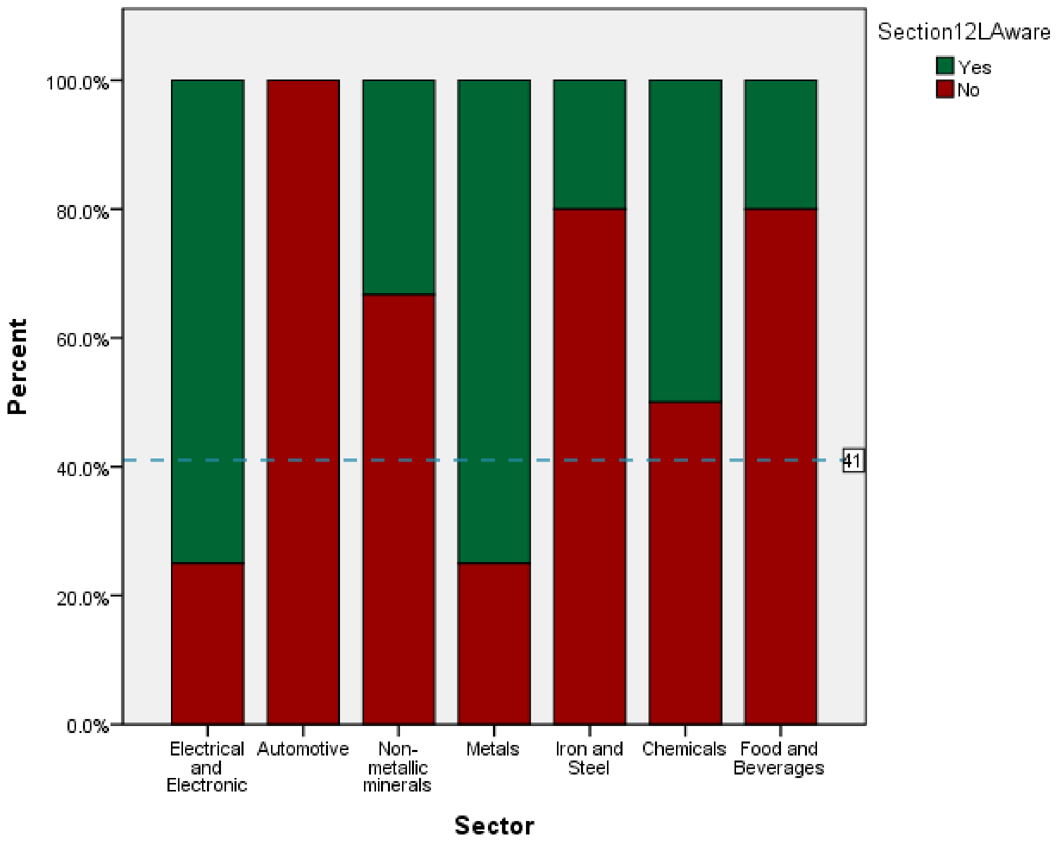

Figure 26 Section 12L aware

Approximately 41% of the sampled population are aware of the Section 12L EE tax credit Act promulgated by government. The level of awareness varies widely across the manufacturing subsectors. The Electrical and Electronic and Metals subsectors have a generally higher level of awareness of the Act when compared to the other sectors.

Of those who are aware of the Act, approximately only 7 % have implemented it. Such firms reside within the Electrical and Electronic and Food and Beverages manufacturing subsectors.

As this Act provides an incentive for companies to engage in EE activities, its low awareness and implementation rate reveals that higher adoption rates of EE technologies are indeed possible.

5.2.7 Energy costs

Firms were asked to provide an estimate of their total energy costs as a proportion of their overall sales (turnover). As most firms could not provide an accurate value, the data received was recoded into an ordinal scale. By analysing the cumulative percentages, the data was categorised into either Low, Medium or High. The results per sector is shown below.

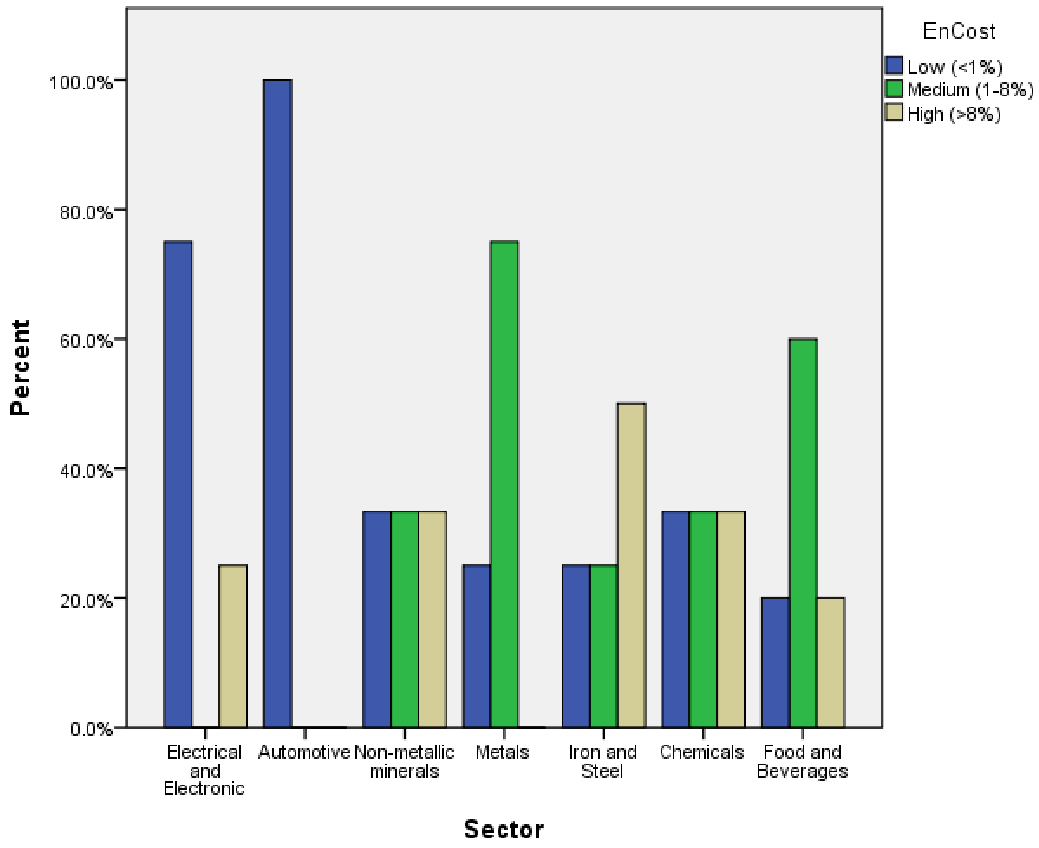

Figure 27 Energy cost

Consistent with manufacturing sectors globally, the Iron and Steel manufacturing subsector has the highest proportion of energy intensive entities. The Non-metallic metals, Chemicals, and Food and Beverages sectors within the EMA are also energy intensive in their operations. Becoming more energy efficient within these subsectors will certainly assist in improving bottom line results.

5.2.8 Investments in alternative energy resources

Firms were questioned whether they have an intention to invest in alternative energy resources. Becoming energy efficient may obviate this need. The results are shown in the figure below.

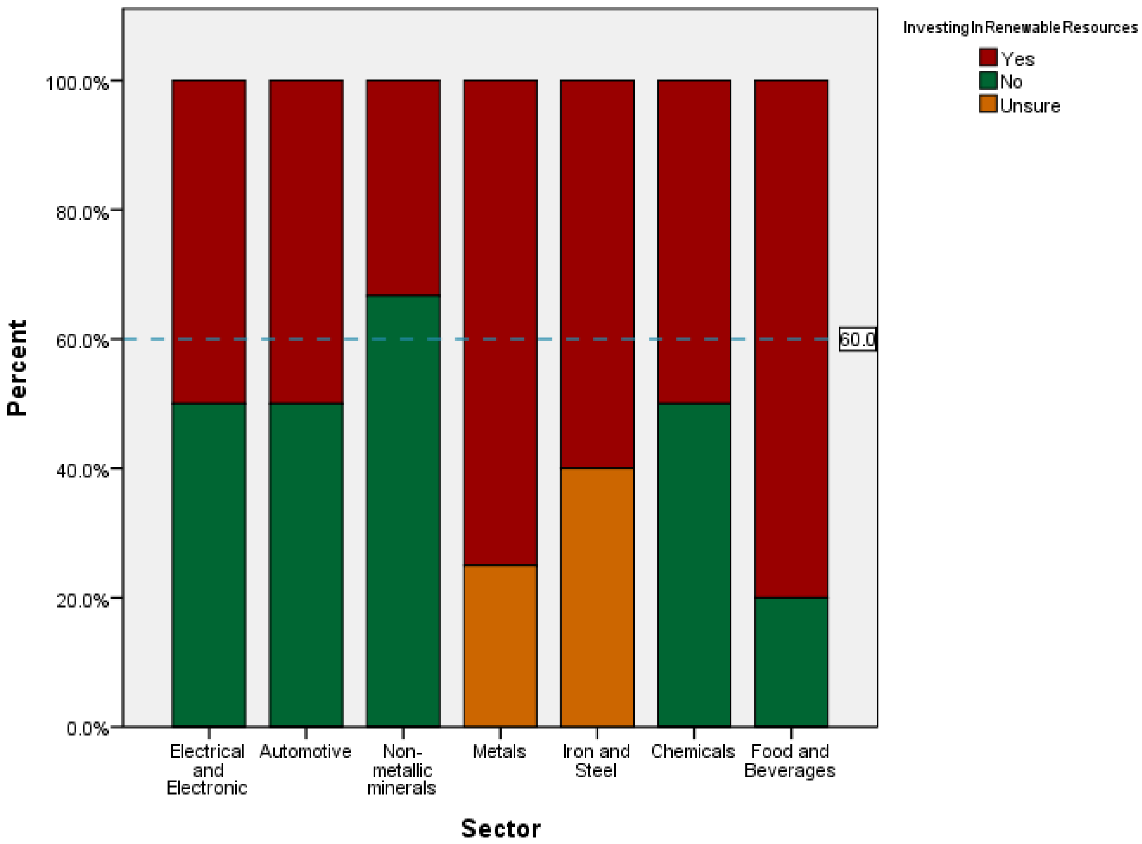

Figure 28 Intention to invest in alternative renewable energy resources

Approximately 60% of those sampled have an intention to invest in alternative renewable energy resources. There is greater interest within the Metals, Iron and Steel and Food and Beverages subsectors. In general, there are firms across all manufacturing subsectors that have an interest to invest in alternative energy resources despite opportunities that exist for EE investment. The results serve as a leading indicator to base national load capacity planning forecasts.

5.2.9 Results discussion

The descriptive statistics present a profile of the EE performance amongst MLMF within the EMA. A quantitative inspection of the results using 4 key quality criteria will help ascertain whether an energy efficiency gap exists.

The results show that more can be done to improve the efficiency landscape in the area especially within the energy intensive manufacturing sectors. While there exists a generally high level of awareness and adoption of EE technologies within the EMA, the quality of the implementation profile is poor. There is an extremely low appointment rate of Energy Managers (7%), a poor adoption rate of Energy targets amongst firms (31%), a generally low level of awareness of EE tax incentives offered by government, and amongst the high energy users, there is a low adoption rate of Energy Management Systems.

While many firms are indeed aware of EE technologies that are available on the market, there still remains a proportion (19%) that have had no exposure yet. Despite government's initiatives in the provisioning of subsidies for EE building improvements, a third of the firms sampled have not implemented any EE technologies within their buildings to date. Finally, it was found that a proportion of those who have invested in EE technologies were also not able to determine whether there has been any return on their investment especially for EE building technologies.

These factors taken together indicate that an energy efficiency gap still exists within the market.

The low awareness of Section 12L offers hope that higher adoption rates of EE technologies are still indeed possible once consumers become more aware of this option. There is also much room for the setting up of Efficiency targets within the Metals and Non-metallic minerals sectors especially since they are considered energy intensive. While sufficient opportunity exists to invest in EE technologies, firms are starting to consider investing in renewable resources. A co-ordinated investment in EE technologies across industry may remove the need for any private investment in renewables. Where firms have already invested in EE technologies, it is important that they put in mechanisms in place to monitor and report on such improvements so that the benefits do not go unnoticed.

5.3 Analysis of barriers

One of the main objectives of this research is to better understand the factors that prevent firms from adopting energy efficiency technologies. This section aims to first go about ranking the mean score of barriers received as part of this survey. It then goes on to investigate how these barriers vary by manufacturing sector and firm characteristics.

5.3.1 Ranking of barriers

Firms were asked to rank barriers on a Likert scale (strongly disagree=1 to strongly agree=5). The mean scores are shown in Figure 29 below.

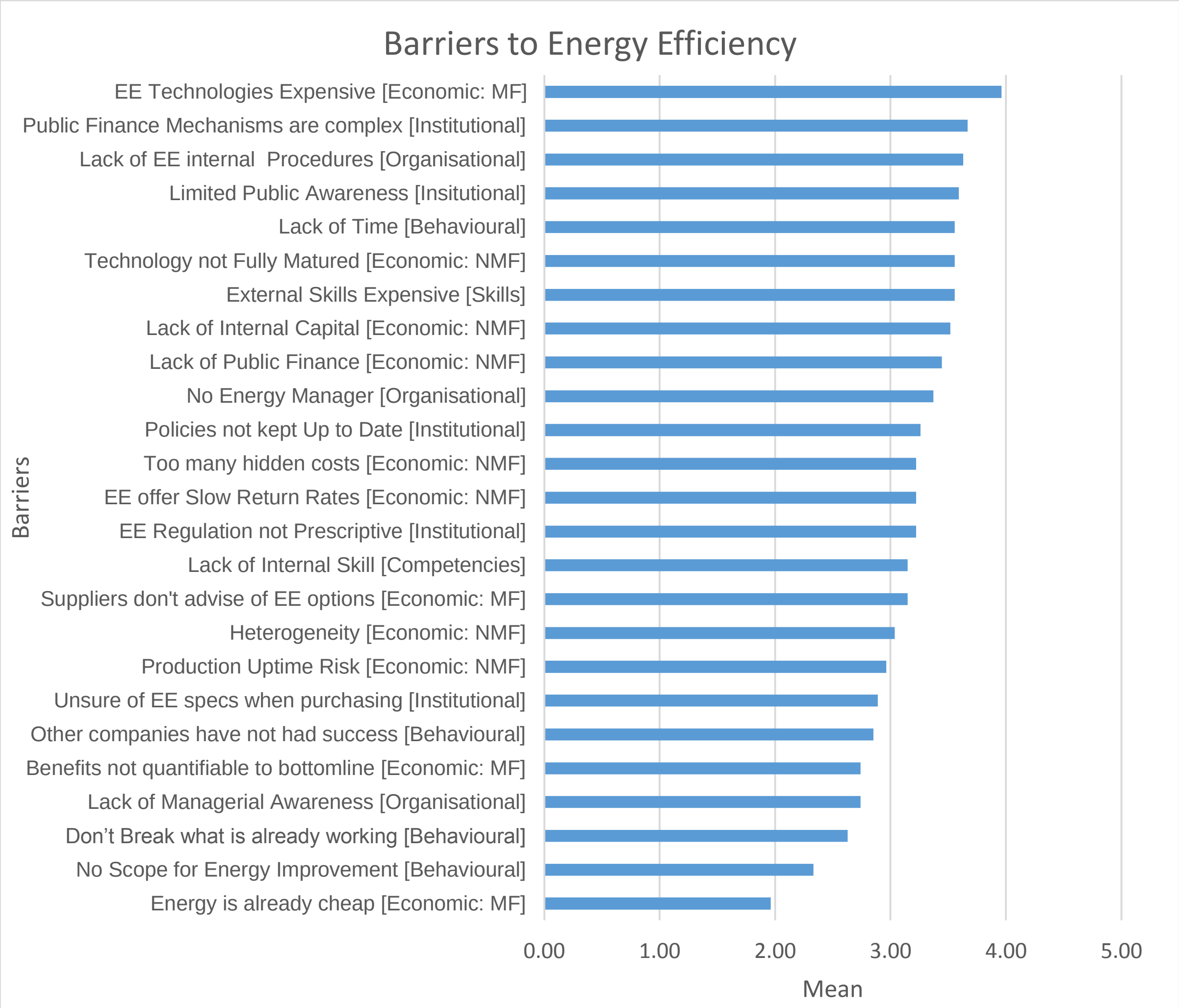

Figure 29 Ranking of barriers to EE by mean score

Figure 29 indicates that the mean score for barriers range from 2 to 4. The top five barriers are discussed below.

The main barrier that prevents firms from investing in Energy Efficiency is the cost of EE technologies. This is a market related issue that points to the possibility of imperfect competition that may exist in the market or the lack of sufficient economic stimulus to help make such technologies more viable in terms of price.

Where public finance mechanisms exist, they are still quite complicated to access. Institutions need to better facilitate the provisioning of grants, subsidies and loans for EE investments.

Firms also feel that there is a lack of internal policies and procedures within the business that can promote the adoption of Energy Efficiency. While this is an Organisational related barrier, it does not remove the need for institutional support in specifying such policy and mandating compliance.

Firms also feel that there is a lack of awareness in terms of Energy Efficiency. More public programs and workshops are therefore required to close this gap.

Finally firms feel that there is a lack of time available to investigate the associated benefits that EE has to offer. This barrier in part talks to the form of information in which EE business cases are presented. Such cases need to talk directly to the bottom line. The benefits that EE provide should be stated upfront so that firms could make decisions more easily. EE labels should be mandatory on products and must relate benefits in Rand terms.

Several other barriers exist. Figure 30 summarises the barrier score by category and indicates that institutional barriers play the greatest role in the inhibition of EE adoption amongst MLMF within the EMA.

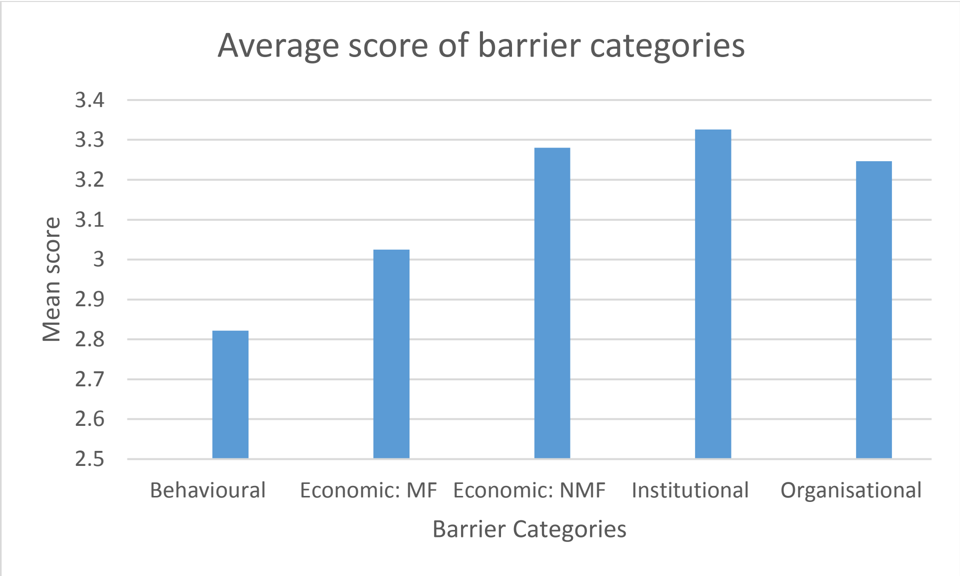

Figure 30 Barrier category scores

5.3.2 Barrier variation across manufacturing sectors

As part of the research agenda, the investigation of how barriers vary by manufacturing sector was also raised. This section therefore aims to investigate this requirement formally through the testing of hypothesis A.1.

Sub-Hypothesis for Test A.1

H_0: The mean scores for the barriers is the same for all manufacturing subsector population groups.

H_1: The mean scores for the barriers is NOT the same for all manufacturing population groups.

5.3.2.1 Analysis plan

Significance level: We choose to report significance levels at the1%, 5% and 10% levels.

Test method: A non-parametric test shall be performed as the sample sizes per sector are small and tests for normality couldn't be determined with confidence. As we are testing for statistical significance between two or more groups, the Kruskal-Wallis H test shall be employed.

Assumptions: Before the Kruskal-Wallis H test can be employed, 4 assumptions need to be met.

Assumption 1: The dependent variable should be measured on an ordinal or continuous scale. As the barriers were measured on an ordinal, 5 point Likert scale, this assumption is therefore met.

Assumption 2: The independent variable shall consist of two or more categorical independent variables. Since seven independent manufacturing subsectors shall be analysed, this assumption is therefore met.

Assumption 3: Independence of observations shall exist. As there are different participants in each group and no participant being in more than one group, this assumption of sample independence is therefore met.

Assumption 4: If the distributions in each group have the same shape then the comparison of medians shall be employed. If the distributions have a different shape, then a comparison of mean ranks is required. Exploring the data by looking at the ranges and variances indicates that the variability for each group is not the same. This implies that the comparison of mean ranks shall be employed.

5.3.2.2 Analysis results

The Kruskal-Wallis H test was utilised in SPSS v20. The results are shown in Table 13 below.

Table 13 Kruskal-Wallis H test for significance of barriers to EE

Barriers	Chi-Square	df	Asymp. Sig.
EE Technologies are Expensive	5.331	6	0.502
Public Finance Mechanisms are complex	9.243	6	0.160
EE Regulation not Prescriptive	6.635	6	0.356
Energy is already Cheap	3.373	6	0.761
Limited Public Awareness	4.271	6	0.640

Policies not kept up to date	5.635	6	0.465
Suppliers advise of EE alternatives	4.174	6	0.653
Unsure of EE specs when purchasing	4.232	6	0.645
Lack of internal capital	3.671	6	0.721
Lack of public finance	1.809	6	0.936
EE offer slow return rates	5.302	6	0.506
Too many hidden costs	7.496	6	0.277
Lack of internal skill	2.951	6	0.815
External skills expensive	.784	6	0.992
Heterogeneity	6.816	6	0.338
Production uptime risk	6.246	6	0.396
Technology not fully matured	4.567	6	0.600
Lack of time	4.636	6	0.591
No scope for energy improvement	5.817	6	0.444
Lack of managerial awareness	5.180	6	0.521
Benefits not quantifiable to bottom-line	5.131	6	0.527
Other companies had no success	5.302	6	0.506
Don't break what is already working	**13.322****	**6**	**0.038**
No energy manager	4.990	6	0.545
Lack of EE policies & procedures	3.692	6	0.718

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

The Kruskal-Wallis H test shows that mean scores barriers are similar across manufacturing sub-sectors except for the inertia barrier where there was a statistically significant difference in the mean scores, $\chi^2(6) = 13.22$, $p < 0.038$, with means given in Table 14 below. The null hypothesis A.1 is therefore rejected on the inertia barrier.

Table 14 Sector mean scores for the inertia barrier

Barrier	Manufacturing sector	Mean score
Don't break what is already working	Electrical and Electronic	15.25
	Automotive	22.75
	Non-metallic minerals	21.83
	Metals	9.50
	Iron and Steel	11.30
	Chemicals	18.00
	Food and Beverages	7.90

In order to test for which sectors differ significantly on the inertia barrier, we deploy a post hoc Kruskal-Wallis test. The post hoc test involves pairwise comparisons of the mean –ranked inertia variable score with the various sectors (Dunn's Test). The results of the post-hoc tests are shown in Table 15 below.

Table 15 Pairwise comparisons of groups

Comparison	Test Statistic	Sig.
Food and Beverages - Metals	1.6	0.744
Food and Beverages - Iron and Steel	3.4	0.462
Food and Beverages - Electrical and Electronic	7.45	0.134
Food and Beverages - Chemicals	**10.1**	**0.039****
Food and Beverages - Non-metallic minerals	**13.933**	**0.009*****
Food and Beverages - Automotive	**14.85**	**0.015****
Metals - Iron and Steel	-1.8	0.713
Metals - Electrical and Electronic	5.75	0.266
Metals - Chemicals	-8.5	0.1
Metals - Non-metallic minerals	**12.33**	**0.027****
Metals - Automotive	**13.25**	**0.036****
Iron and Steel - Electrical and Electronic	3.95	0.42
Iron and Steel - Chemicals	-6.7	0.172
Iron and Steel - Non-metallic minerals	**10.533**	**0.048****
Iron and Steel - Automotive	**11.45**	**0.061***
Electrical and Electronic - Chemicals	-2.75	0.594
Electrical and Electronic - Non-metallic minerals	-6.583	0.238
Electrical and Electronic - Automotive	-7.5	0.236
Chemicals - Non-metallic minerals	-3.833	0.492
Chemicals - Automotive	-4.75	0.453
Non-metallic minerals - Automotive	0.917	0.891

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

The results in Table 15 above indicate that the inertia barrier is less prominent in the Food and Beverages sector when compared to the Chemicals, Non-metallic and Automotive sectors. Similarly, the Inertia barrier is less prominent in the Metals sector when compared to the Non-metallic minerals and Automotive sectors. Finally, the inertia barrier is also less prominent within the Iron and Steel industry when compared to the Non-metallic minerals and automotive sectors.

5.3.3 Concluding remarks on barrier variation by manufacturing firm type

The results indicate that all barriers act similarly across all manufacturing sectors with exception of the Inertia barrier. We therefore reject the null hypothesis of Test A.1 and conclude that the barriers do indeed vary across manufacturing sectors. When developing policy in this regard, the findings in Section 5.3.2.2 should be taken into account in order to ensure that corrective measures are well targeted.

5.3.4 Barrier variation with firm characteristics

Further to the research agenda, the variation of EE barriers with firm characteristics was also raised for investigation. This section therefore aims to analyse how the EE barriers vary with characteristics of the firm. For the purposes of this research, the following firm level characteristics were collected as part of the field study:

Table 16 Summary of firm characteristics

Property ownership type [N]	Number of full-time employees [I]	Age of business [I]
Export goods [N]	Manufacturing facilities overseas [N]	Employ professional engineering practitioners [N]
Training plan for staff [N]	Debt ratio [C]	Marketing costs [C]
R&D budget [N]	Profitable over last three years [N]	Energy cost [I]
Competitive nature of business [C]	Energy manager [N]	Invested in EE process improvements [N]
Invested in EE building improvements [N]	EMS in place [N]	ISO 14001 registered [N]
Aware of the 12L EE tax credit option [N]	Aware of EE technologies in the market [N]	

Notes: N, C and I refer to Nominal, Categorical and Interval scales respectively.

5.3.4.1 Analysis plan

Since the barriers were measured on a five point Likert scale, we choose to utilise the ordinal regression method to evaluate the hypothesis B.1. Other options include treating the ordinal response variable as continuous and performing Multiple Linear Regression (MLR) or collapsing the response variable into a dichotomous nominal variable and employing binomial logistic regression. Whilst both options offer easier analysis and in the case of MLR, easier interpretation of the resulting coefficients, both are considered less superior in the modelling of ordinal data.

Ordinal regression falls within the family of models commonly known as Generalised Linear Models (GLM). Similar to binomial regression, ordinal regression uses a link function to transform the probabilities of the outcomes. However, in ordinal regression, the link function is used to transform the cumulative probabilities of the ordered dependent variable into estimates. Five types of link functions are most common in literature with the most common being either the Logit or Probit functions. The main difference between these functions is that while the Logit link function assumes log distributions between categories of the dependent variable, the Probit function assumes a normal distribution. The Logit link function is most commonly cited in literature Hox (2010:114) and is therefore chosen for this study. It is also known to have several advantages over the Probit model as described in Hox (2010:226).

When the Logit Link function is utilised in an ordinal regression model, the model is then referred to as Ordinal Logistic regression.

The Ordinal Logistic Regression model with a set of predictors can be written as follows:

$$Y_i = logit(\pi(x_i)) = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_p X_{ip} \qquad (10)$$

Where $\pi(x_i)$ represents the success probability of the i[th] case given a set of X covariates.

In order to address the main questions of this study, we regress each barrier on firm characteristics as follows:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_5 X_{i5} + \beta_6 X_{i6} + \beta_7 X_{i7} + \beta_8 X_{i8} + \beta_9 X_{i9} + \beta_{10} X_{i10} + \beta_{11} X_{i11} + \beta_{12} X_{12} \qquad (11)$$

Where

β_1 = Size of company (as indicated by no. of employees)

β_2 = Competitiveness of environment

β_3 = Age

β_4 = Energy costs

β_5 = Property ownership type

β_6 = Training plan

β_7 = Debt ratio

β_8 = Profitability

β_9 = Marketing costs

β_{10} = Invested in EE technologies

β_{11} = International Orientation

β_{12} = ISO 14001

Before any conclusions are to be drawn from the proposed model, the ordinal regression method has several assumptions that first needs to be tested. These are discussed categorically below.

5.3.4.1.1 Ordinal regression assumptions

The assumptions for ordinal regressions are listed below and were derived from Laerd Statistics (2015).

Assumption 1: Dependent variable should be measured at the ordinal level.
As the barriers were measured using a 5 point Likert scale, this assumption is valid.

Assumption 2: One or more independent variables that are either continuous, ordinal or categorical. Within the ordinal regression method, ordinal independent variables must be treated as either interval or categorical.

Table 16 above shows the type of variables used in the study which all comply with the requirements of assumption 2. Since debt ratio, marketing costs and competitive index are ordinal independent variables, a decision had to be made on how to treat them in our analysis. We treat debt ratio and marketing costs as categorical as they only have 3 levels low, medium and high. We treat the competitive index, which is measured on a 6 point Likert scale as an interval variable and add cautionary notes when interpreting the results.

Assumption 3: There is no multicollinearity within the independent variables.

This assumption requires that the explanatory variables are not highly correlated with each other. We test for this using the collinearity statistics in SPSS. Multicollinearity can be assessed by investigating the tolerance or Variance Inflation Factor (VIF).

Cohen et al. (2003:423) advise that if the VIF or tolerance statistics are above 10 or below 0.1 respectively, then there is evidence of significant multicollinearity amongst explanatory variables. We iteratively tweak the model of explanatory variables until we meet this requirement whilst maintaining all relevant variables necessary to meet the objectives of this research. Table 17 shows one example of the VIF values obtained against an optimised set of explanatory variables. All VIF values achieved were below 5. The results therefore indicate that there is no violation of the third assumption for Ordinal Regression. Table 18 summarises the final set of explanatory variables used in the model.

Table 17 Multicollinearity statistics of firm characteristics

Model	Collinearity Statistics	
	Tolerance	VIF
Competitive	.651	1.537
No. of Full Time Employees	.451	2.220
In-operation	.332	3.009
Energy Costs	.515	1.942
Training Plan	.489	2.044
Medium Debt	.382	2.616
High Marketing Costs	.531	1.882
Medium Marketing Costs	.564	1.772
Profitable	.512	1.954
EE Invested	.598	1.672
International Orientation	.241	4.156
ISO14001Registered	.405	2.470

Coefficients: Dependent Variable: Property Ownership

Table 18 Summary of firm characteristics used for statistical analysis

1. Property ownership type	2. Debt ratio
3. International Orientation	4. Profitable over last three years
5. Training plan for staff	6. Age of business
7. Competitive index	8. Marketing costs
9. Number of full-time employees	10.Energy quotient
11.Invested in EE technologies	12.ISO14001

We omit the EMS, R&D budget, Competition type, Professional employment and Energy manager as explanatory variables as they are highly correlated with the core subset of variables of interest for this research. While the individual pairwise correlations are small, there appears to be significant dependence with three or more variables resulting in VIF values greater than 10.

Assumption 4: Proportional odds exist i.e., each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. We check this assumption for each barrier using the test for parallel lines as part of the ordinal regression procedure. The hypothesis for this test is as follows:

H_0: the slope coefficients are the same across all response categories

H_1: the slope coefficients are not all the same across all response categories.

For each regression, we test this hypothesis. There were no rejections of the null hypothesis at the 10% level for 24 of the 25 barrier regressions. The test for parallel lines could not be performed for at least one of the barriers viz., “EE regulation is not prescriptive”. This is because convergence in estimating the general model could not be attained. We therefore remove this barrier in the reporting of the results.

Brant (1990) describes the test of the proportional odds assumption as anti-conservative in that it nearly always results in the rejection of the proportional odds assumption, especially when the there is a large number of explanatory variables present or when there is a continuous variable in the model (Allison 1999).

Taking these views into account, the OLR model was nonetheless applied to the barrier that failed the proportional odds assumption viz., “EE regulation is not prescriptive”. No significant results were found at the 1%, 5% and 10% levels.

5.3.5 Results discussion

Since the ordinal regression method produces coefficients at log odds, we limit the interpretation of the results only to the direction of the effects and not the magnitude of the results. The regression results are shown in Table 19. We list significant results at the 1%, 5% and 10% levels. In total, nineteen significant results were found of which six were at the 5% level and thirteen were found at the 10% level. We therefore reject the NULL hypothesis B.1 and confirm that the barriers to EE adoption by MLMF operating within the EMA do indeed vary with the characteristics of the firm. The extent of the variations are discussed in the findings overleaf.

Table 19 Barriers to EE adoption against firm characteristics

Barriers	Size	Competitiveness	Age	Energy costs	Property [Renting]	Training plan	Debt ratio [med]	Profitability	Marketing costs [high]	Marketing costs [med]	EE investments	International orientation	ISO14001 registered
EE technologies expensive	-0.01	0.18	-0.12	0.94	-11.20	22.59	-5.33	-10.39	-16.33	-4.74	5.62	8.40	-8.29
Public finance mechanisms is difficult	-0.01	-0.06	0.20	**-1.52****	**-12.99***	**16.34****	4.29	1.94	**-35.24****	**-9.37***	8.34	8.30	**-10.10****
Energy is already cheap	0.00	1.22	**-0.21****	**-0.69****	-3.05	3.47	**6.64****	0.54	-33.31	-1.07	-0.76	1.89	-1.75
Limited public awareness	-0.01	1.34	-0.03	0.46	-1.19	**4.05***	2.96	3.78	-7.11	-3.61	4.04	-1.10	-2.92
Policies not kept up-to-date	-0.01	4.39	-0.10	-0.65	**-15.43***	0.47	**21.28***	28.61	**-24.07***	-11.35	6.85	3.78	-3.85
Suppliers advise of EE alternatives	-0.11	63.75	6.10	36.41	166.75	-363.86	248.56	964.89	-142.88	-450.60	-233.24	-111.98	-91.70
Inclusion of EE in specifications	-0.02	0.23	0.28	0.79	-1.30	-0.53	20.27	1.47	-35.57	6.93	6.12	-31.38	6.95
Lack of internal capital	-0.08	-21.21	0.23	6.20	-53.12	145.36	20.71	-185.28	-19.15	45.05	-13.45	18.84	-86.38
Lack of public finance	0.01	15.46	-0.41	1.91	-34.67	-24.50	7.21	16.99	**-52.09***	**-28.94***	-0.54	15.94	3.01
EE offer slow return rates	-0.01	-0.57	0.07	0.72	-3.40	-6.73	18.01	10.45	-33.71	-17.63	4.70	-11.82	-0.66
Too many hidden costs	-0.01	-2.12	0.20	0.62	5.06	0.35	11.50	30.84	6.24	-12.14	2.18	-22.57	18.75
Lack of internal skill	0.00	4.55	-0.90	-2.61	-45.91	51.74	47.02	-3.31	-101.72	-5.83	3.29	43.19	-43.81
External skills expensive	-0.01	1.96	-0.15	0.03	-6.27	12.11	7.45	18.28	-24.46	-11.03	6.45	18.32	-8.76
Heterogeneity	0.00	**-2.55****	-0.05	-0.07	-0.96	3.27	0.03	-0.41	-5.66	-3.01	1.75	7.67	1.53
Production uptime risk	-0.01	-7.47	0.67	1.15	20.07	-14.91	-8.00	-6.17	34.50	-7.97	-33.17	5.28	-27.79
Technology not fully matured	0.00	-6.75	0.06	0.45	-13.90	15.06	-14.71	**-25.28***	-1.36	3.34	-12.26	**19.94***	4.73
Lack of time	-0.03	-21.66	1.00	-3.92	-20.91	43.04	-53.41	0.46	44.64	28.59	-74.59	105.46	5.26
No scope for energy improvement	-0.02	-4.81	0.24	-0.13	8.84	-3.73	-3.98	8.88	12.91	-9.15	-9.98	-2.65	4.34
Lack of managerial awareness	-0.01	-3.85	0.16	-0.25	15.04	-9.14	9.99	-1.77	13.27	-5.82	-14.90	-13.50	0.97
Benefits not quantifiable to bottom-line	-0.02	1.73	0.12	1.51	-11.27	-9.90	0.99	-35.95	0.77	-11.22	-1.07	7.94	-20.43
Purchase based on recommendations	-0.01	-3.49	-0.04	0.75	-2.82	8.95	12.24	-10.67	-14.00	-3.23	-12.67	0.17	-6.50
Don’t break what is already working	-0.01	-8.45	-0.18	0.11	8.81	1.65	14.46	12.54	-33.65	-13.70	-0.33	-8.91	-0.80
No energy manager	-0.02	-0.69	0.36	0.73	9.78	-19.13	-3.35	7.55	35.06	7.97	-15.92	-26.53	3.26
Lack of EE policies procedures	-0.04	11.28	0.83	2.05	8.57	-57.53	30.21	-8.99	-25.06	-56.56	-38.96	-8.92	**-24.56***

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

1) Competitive organisations are associated with a reduction in the odds of considering heterogeneity of EE technologies a barrier, with a log odds ratio of -2.55 (95% CI, -5.116 to 0.022), Wald $\chi 2$ (1) =3.775, $p < .052$. Interpretation: Competitive organisations are more likely to feel EE technologies can be used across engineering domains. This is likely as competitive firms are cost driven. Implication: More awareness on EE technology homogeneity within less competitive sectors is required from a policy point of view.

2) An increase in age (expressed in years) is associated with a decrease in the odds of considering energy to already be cheap as a barrier to EE investments, with a log odds ratio of -0.21 (95% CI, -.379 to -0.035), Wald $\chi 2$ (1) =5.580, $p < .018$. **Interpretation**: Older organisations are less likely to consider the cheap price of energy as a barrier to EE technology investment. **Implication**: younger organisations should be advised of the secondary benefits to EE investments and be less cost driven about EE investments.

3) An increase in energy costs (expressed as a ratio of sales) is associated with a decrease in the odds of considering energy to already be cheap as a barrier to EE investments, with a log odds ratio of -0.69 (95% CI, -1.300 to -0.077), Wald $\chi 2$ (1) =4.876, $p < .027$. **Interpretation**: Higher energy users do not consider the already cheap price of energy as a barrier to EE technology investment. **Implication**: This finding is good news to policy makers as high energy users are still driven to invest in EE technologies despite the cost of energy. With regards to low energy users, more business cases that take the secondary benefits of EE into account should be put forward.

4) The log odds of firms with a medium debt ratio (between 40% and 70%) considering energy to already be cheap as a barrier to EE investment is 6.639 (95% CI, -0.007 to 13.285) times higher than that of firms with a low debt ratio, a statistically significant effect, Wald $\chi 2$ (1) =3.834, $p < .05$. **Interpretation**: Firms with a higher debt ratio find that the low cost of energy prevents them from investing in EE technologies. **Implications**: Firms with high debt ratios probably find the cost of energy cheap when compared to the interest that such firms will pay on new EE capital projects. New EE capital projects will incur more debt at high interest rates and further increase their already high liability.

Such firms should be made aware of the EE tax credit option available by government and include this within their costing models for EE projects. They should also be made aware of the several secondary benefits to EE.

5) An increase in energy costs (expressed as a ratio of sales) is associated with a decrease in the odds of considering public finance mechanisms to be difficult as a barrier to EE investments, with a log odds ratio of -1.517 (95% CI, -2.957 to -0.078), Wald $\chi 2$ (1) =4.269, $p < .039$. **Interpretation**: Those organisations that have high energy costs do not find public finance mechanisms difficult to access. **Implication**: While this proves that EE institutions are targeting the right audience i.e. energy intensive firms, they should ensure that less intensive users are not kept on the back burner for too long. It should be noted that there is great economies of scale for EE reduction that can still be leveraged out of the high volume of low intensity firms.

6) The log odds of firms who rent that consider public finance mechanisms to be difficult as a barrier to EE investments is -12.988 (95% CI, -27.755 to 1.779) times lower than firms who own the property on which they operate, a statistically significant effect, Wald $\chi 2$ (1) =2.972, $p < .085$. **Interpretation**: Firms that own the property on which they operate generally find public finance mechanisms difficult to access as compared to those that rent the property. **Implications**: Firms that own the property on which they operate are probably more active in accessing EE public financing mechanisms, and whilst doing so, find these mechanisms difficult to access. EE institutions should therefore investigate possible bottlenecks in their administration – or initiate a secondary project to investigate the apparent problems.

7) The log odds of firms who have a training plan in place and in use that consider public finance mechanisms to be difficult as a barrier to EE investments is 16.335 (95% CI, .911 to 31.760) times higher than firms who do not have a training plan, a statistically significant effect, Wald $\chi 2$ (1) =2.972, $p < .085$. **Interpretation**: Firms with a skilled workforce find public finance mechanisms difficult to access. **Implications**: Consistent with point 6 above, such firms are probably more active in accessing public mechanisms. Again, EE institutions should investigate possible bottlenecks in their administration.

8) The log odds of firms with a medium marketing cost ratio (between 4% and 20%) considering public finance mechanisms to be difficult as a barrier to EE investments is -9.370 (95% CI, -20.408 to 1.669) times lower than that of firms with a low marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =2.768, $p < .096$. **Interpretation**: Those firms with higher marketing costs do not find public finance mechanisms difficult to access for EE technology investment. **Implications**: As marketing costs are used as an indication of a firm's image in the marketplace, well known firms seem to experience less difficulties than others in accessing public finance mechanisms. This talks to point 5 above. Institutions should make sure that smaller and less popular firms are not kept isolated from such mechanisms.

9) The log odds of firms with a high marketing cost ratio (> 20%) considering public finance mechanisms to be difficult as a barrier to EE investments -35.224 (95% CI, -69.738 to -.751) times lower than that of firms with a low marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =4.010, $p < .045$. **Interpretation**: Those firms with higher marketing costs do not find public finance mechanisms difficult to access for EE technology investment. **Implication**: This point further validates point 8 above. Therefore, the same conclusions can be drawn.

10) The log odds of firms who are ISO14001 registered that consider public finance mechanisms to be difficult as a barrier to EE investments is -10.098 (95% CI, -20.039 to -0.157) times lower than firms who are not ISO14001 registered, a statistically significant effect, Wald $\chi 2$ (1) =3.964, $p < .046$. **Interpretation**: Those firms that are ISO14001 registered generally do not find public finance mechanisms difficult to access for EE technology investment. **Implication**: Firms that are ISO14001 registered find it easier to access public finance mechanisms. Consistent with point 8 above, the administration of public finance mechanisms should adopt a homogenous approach ensuring that proportions of firms are not isolated from such benefits. It also suggests that ISO14001 may serve as an enabler to accessing public finance mechanisms for EE investments.

11) The log odds of firms that rent considering Policies not kept up to date as a barrier to EE investments is -15.429 (95% CI, -32.251 to 1.393) times lower than firms who own the property on which they operate, a statistically significant effect, Wald $\chi 2$ (1) =3.231, $p < .072$. **Interpretation**: Those firms that own the property on which they operate find that policies on EE are not kept up to date which serves as a barrier to EE investment as opposed to those that rent the property. **Implication**: As firms that own the property on which they operate are more likely to be more active on the EE forefront, such firms find that the policies on EE do not track technology well resulting in policies becoming outdated, posing as a barrier to EE adoption in itself. Policy should therefore be revised more frequently to take into account newer technologies that enter the market.

12) The log odds of firms with a medium debt ratio (between 40% and 70%) considering Policies not kept up to date as a barrier to EE investment is 21.283 (95% CI, -1.882 to 44.448) times higher than that of firms with a low debt ratio, a statistically significant effect, Wald $\chi 2$ (1) =3.243, $p < .072$. **Interpretation**: Firms with medium debt ratios (between 40-70%) are more likely to find policies not being kept up to date as a barrier to EE investment. **Implication**: policies not being kept up to date make it more difficult for heavily indebted firms to adopt EE technologies. Such policies pose a risk to firms especially those who are highly indebted; such firms are generally already risk averse. Similar to point 11 raised above, policy should be revised more frequently to take into account newer opportunities that enter the market.

13) The log odds of firms with a high marketing cost ratio (> 20%) considering Policies not being kept up to date as a barrier to EE investments -24.067 (95% CI, -52.265 to 4.130) times lower than that of firms with a low marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =2.798, $p < .094$. **Interpretation**: Firms with higher marketing costs are less likely to find policies not being kept up to date as a barrier to EE investment. **Implication**: Points 11, 12 and 13 indicate that there is a difference in opinion on whether policies are indeed kept up to date depending on the characteristics of the firm. This point should be addressed by investigating the reasons behind the differences of opinions on the subject. Where policies are indeed found to be lacking in

update, they should be revised more often to take into newer technologies that enter the market.

14) The log odds of firms who have a Training Plan in place and in use that consider limited public awareness as a barrier to EE investments is 4.054 (95% CI, -.712 to 8.820) times higher than firms who do not have a training plan, a statistically significant effect, Wald $\chi 2$ (1) =2.779, $p < .096$. **Interpretation**: Firms that have a training plan in place and in use are more likely to find limited Public Awareness on EE as a barrier to EE investment. **Implication**: Firms with a training plan in place and in use generally have a skilled workforce. Such employees are aware of the potential that EE has to offer but feel that there is limited Public Awareness on such opportunities. More Public Awareness campaigns should therefore be put in place to reduce the effect of this barrier.

15) The log odds of firms with a medium marketing cost ratio (between 4% and 20%) considering the Lack of Public finance as a barrier to EE investments is -28.925 (95% CI, -63.194 to 5.324) times lower than that of firms with a low marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =2.740, $p < .098$. **Interpretation**: Firms with higher marketing cost ratios are less likely to find the lack of public finance as a barrier to EE investment. **Implication**: Again, as marketing costs are highly correlated with a firms image in the marketplace, well known firms seem to have easier access to public finance. This talks to point 5 raised above. Institutions should make sure that smaller and less popular firms are not kept isolated from such facilities.

16) The log odds of firms with a high marketing cost ratio (> 20%) considering the lack of Public Finance as a barrier to EE investments is -52.087 (95% CI, -109.734 to 5.559) times lower than that of firms with a low marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =3.136, $p < .077$. **Interpretation**: Firms with an even higher marketing cost ratios are less likely to find the lack of public finance as a barrier to EE investment. **Implication**: This point validates point 15 above. The same conclusions can therefore be drawn.

17) The log odds of firms who are Profitable that consider Technologies not being fully matured as a barrier to EE investments is -25.285 (95% CI, -54.799 to 4.229) times lower than firms who are not profitable, a statistically significant effect, Wald $\chi 2$ (1) =2.819, $p < .093$. **Interpretation**: Firms who are profitable are less likely to find technologies not being fully matured as a barrier to EE investment. **Implication**: Firms that are profitable generally have a greater risk appetite to take on new innovative technology. Less profitable firms may not share this risk appetite. EE institutions should ensure that there is diffusion of such EE adoption cases. Further, to help control the impact of the risk, EE institutions should mandate suitable guarantees be offered on all EE products entering the market.

18) The log odds of firms that have an International Orientation (measured by export and global facilities) that consider Technologies not being fully matured as a barrier to EE investments is 19.937 (95% CI, -3.163 to 43.037) times higher than firms who do not have an international orientation, a statistically significant effect, Wald $\chi 2$ (1) =2.862, $p < .091$. **Interpretation**: Firms that have an international orientation are more likely to find technologies not being fully matured as a barrier to EE investment. **Implication**: Technologies that are not fully matured create significant risk in EE investment options. EE institutions should investigate the reasons for the difference in perspectives on the maturity of EE technologies within the local and international context. More research on what drives this opinion may be required. The difference in perspective may be driven out by exposure. Firms that operate within an international context may have greater exposure to EE technologies which drives their perspective. EE manufacturers should consider offering higher guarantees on products to allay fears on product maturity.

19) The log odds of firms who are ISO14001 registered that consider the Lack of internal EE policies and Procedures as a barrier to EE investments is -24.564 (95% CI, -53.668 to 4.539) times lower than firms who are not ISO14001 registered, a statistically significant effect, Wald $\chi 2$ (1) =2.737, $p < .098$. **Interpretation**: Firms that are ISO14001 registered are less likely to find the lack of internal policies and procedures as a barrier to EE investment. **Implication**: Policy should place a greater amount of focus on a firms

ISO14001 registration/compliance as this acts as an enabler to EE adoption. Firms that are ISO 14001 registered already have internal policies and procedures in place. Naturally, ISO14001 would drive EE adoption i.e., ISO14001 has a spill-over effect.

This draws to conclusion the investigation on how the barriers vary with the characteristics of the firm.

5.4 Analysis of drivers

A second-tier objective of this research is to better understand the drivers that stimulate firms to adopt energy efficiency technologies. Similar to the study conducted for barriers, this section aims to first go about ranking the mean score of the drivers to Energy Efficiency received as part of this survey. Thereafter, an investigation into how these drivers vary by manufacturing sector and firm characteristics. The section will conclude with a discussion and summary of the findings.

5.4.1 Ranking of drivers

Firms were asked to rank drivers on a Likert scale (strongly disagree=1 to strongly agree=5). The mean scores are shown in Figure 31 below.

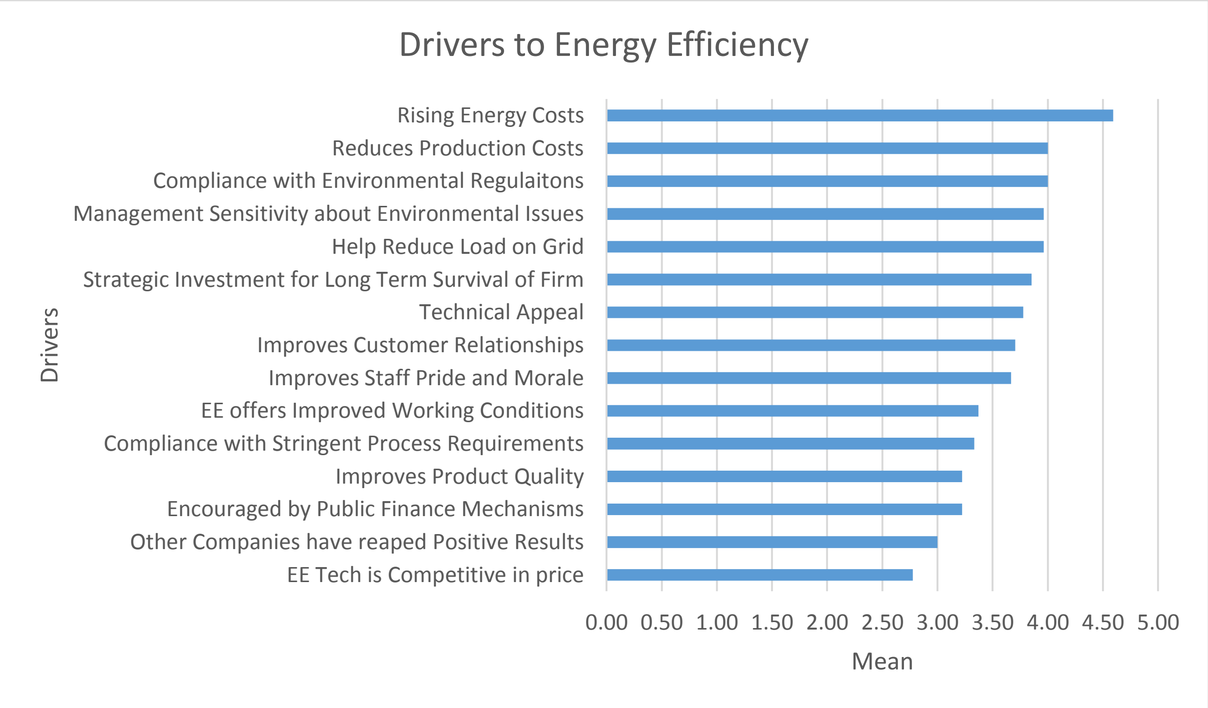

Figure 31 Ranking of drivers to EE by mean score

Figure 31 shows that the mean score for drivers to EE range from 2.75 to 4.6. The top four and bottom two drivers shall be discussed.

The main driver to EE investment is the rise in energy costs. Firms feel strongly that an investment in EE technologies will help them alleviate the sharp rise in energy costs.

Firms also strongly believe that an investment in EE will help reduce production costs. This inevitably will impact the bottom line.
It is clear that the 2 main drivers to EE are both cost related. Firms are therefore very cost centric in their approach to EE adoption. Marketing efforts on energy efficiency should therefore ensure that cost improvements are made explicit. However, more awareness on the secondary benefits to EE adoption is also necessary.

Compliance with Environmental regulations is also felt strongly amongst firms as a driver to them adopting EE technologies. In terms of building regulations, compliance is now mandatory for new establishments. A high level of management sensitivity towards the environment also serves as a strong driver to EE technology adoption. This is positive feedback as management's sensitivity in such issues sets the culture of the organisation.

It is also interesting to investigate those drivers that firms disagreed to have incentivised them to adopt EE technologies. In such cases, these drivers actually serve as barriers. Firms are of the consensus that EE technologies are currently not competitive in price. This again speaks to the price sensitivity of firms raised earlier regarding EE technologies. The non-competitiveness in price serves more as barrier to EE adoption. There also appears to be poor diffusion of EE success stories within the market as firms are not persuaded enough to invest in EE technologies based upon peer references. EE institutions should ensure that success stories are well communicated.

5.4.2 Driver variation across manufacturing sectors

Further to the research agenda on driver analysis, we now investigate how the drivers vary across manufacturing sectors (Hypothesis Test A.2). We follow the same analysis plan to that conducted for barriers in Section 5.3.2.

Test A.2 sub-hypothesis

H_0: The mean scores for the drivers is the same for all manufacturing subsector population groups.

H_1: The mean scores for the drivers is NOT the same for all manufacturing population groups.

The results for the Kruskall Wallis H test is given in Table 20 below.

Table 20 Kruskall Wallis H test for significance of drivers to EE

Driver	Chi-Square	df	Asymp. Sig.
Help Reduce Load on Grid	2.946	6	0.816
Rising Energy Costs	7.141	6	0.308
Compliance with Stringent Process Requirements	9.381	6	0.153
Encouraged by Public Finance Mechanisms	4.748	6	0.577
Management Sensitivity about Environmental Issues	7.194	6	0.303
Other Companies have reaped Positive Results	**11.314**	**6**	**0.079***
Technical Appeal	5.095	6	0.532
EE Tech is Competitive in price	2.640	6	0.852
EE offers Improved Working Conditions	6.394	6	0.381
Compliance with Environmental Regulations	7.220	6	0.301
Strategic Investment for Long Term Survival of Firm	8.843	6	0.183
Improves Customer Relationships	6.326	6	0.388
Improves Staff Pride and Morale	9.141	6	0.166
Improves Product Quality	8.057	6	0.234
Reduces Production Costs	13.631	6	0.034

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

The results in Table 20 show that there is at least one driver (other companies have reaped positive results i.e., diffusion driver) that differs significantly χ^2 (1) =11.314, $p < 0.079$ across sectors. We therefore reject the null hypothesis B.1 and confirm that the drivers to Energy Efficiency by MLMF operating within the EMA do vary across sectors.

The mean scores across sectors for the diffusion driver is shown in Table 21 below.

Table 21 Means scores on the diffusion driver across sectors

Driver	Sector	Mean score
Other companies have reaped positive results	Electrical and Electronic	14.50
	Automotive	20.00
	Non-metallic minerals	6.5 0
	Metals	11.50
	Iron and Steel	12.10
	Chemicals	14.50
	Food and Beverages	19.20

In order to test for which sectors differ significantly on the diffusion driver, we deploy a post hoc Kruskal-Wallis test similar to that in Section 5.3.2. The post hoc test involves pairwise comparisons of the inertia variable with the various sectors. The results are shown in Table 22 below.

Table 22 Kruskall Wallis post-hoc driver tests for significance

Pairwise comparison	Test statistic	Significance
Non-metallic minerals - Metals	-5	1
Non-metallic minerals - Iron and Steel	-5.6	1
Non-metallic minerals - Electrical and Electronic	8	1
Non-metallic minerals - Chemicals	-8	1
Non-metallic minerals - Food and Beverages	**-12.7**	**0.092***
Non-metallic minerals - Automotive	13.5	0.322
Metals - Iron and Steel	-0.6	1
Metals - Electrical and Electronic	3	1
Metals - Chemicals	-3	1
Metals - Food and Beverages	-7.7	1
Metals - Automotive	8.5	1
Iron and Steel - Electrical and Electronic	2.4	1
Iron and Steel - Chemicals	-2.4	1
Iron and Steel - Food and Beverages	-7.1	1
Iron and Steel - Automotive	7.9	1
Electrical and Electronic - Chemicals	0	1
Electrical and Electronic - Food and Beverages	-4.7	1
Electrical and Electronic - Automotive	-5.5	1
Chemicals - Food and Beverages	-4.7	1
Chemicals - Automotive	5.5	1
Food and Beverages - Automotive	0.8	1

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

The results show that the Diffusion driver differs significantly between the Non–metallic Minerals manufacturing sector and the Food and Beverages sector, $p < 0.092$. While on the average the Food and Beverages manufacturing sector feels that the diffusion driver does in fact contribute to them adopting energy efficient technologies, the Non-metallic minerals sector feels otherwise. More awareness about EE success stories within the Non-metallic sector needs to be created. This sector should adopt the diffusion strategy existent within the Food and Beverages sector.

5.4.3 Concluding remarks on driver variation by manufacturing firm type

The results indicate that the drivers act similarly across all manufacturing sectors with exception of the diffusion driver. We therefore reject the null hypothesis of Test A.2

and conclude that the drivers do indeed vary across manufacturing sectors. When developing policy in this regard, the findings in Section 5.4.2 should be taken into account in order to ensure that any corrective measures are well targeted.

5.4.4 Driver variation with firm characteristics

Similar to the case presented for barrier analysis, we now investigate how the drivers vary with the characteristics of the firm. We attempt to conduct this analysis using the same methodology utilised in Section 5.3.4. The first three assumptions regarding the use of the ordinal regression method remains valid. The dependent variable (drivers to EE) is measured on the same Likert scale as the barriers to EE. The set of explanatory variables remains the same (i.e., the firm characteristics) so assumptions 2 and 3 are remain valid (refer to Table 17 for multi-collinearity results). The test for proportional odds (assumption number 4) was tested as part of the regression analysis. For each regression, we test the hypothesis of the slope coefficients (refer to assumption 4 in Section 5.3.4.1.1). There were no rejections of the null hypothesis at the 10% level. This meant that each independent variable had an identical effect at each cumulative split of the ordinal dependent variable.

Table 23 Drivers to EE adoption against firm characteristics

Driver	Size	Comp.	Age	Energy costs	Property [RENT]	Training plan	Debt ratio [MED]	Profit.	Marketing costs [HIGH]	Marketing costs [MED]	EE inv.	Int. orientation	ISO14001 registered
Help Reduce Load on Grid	-0.04	-12.38	**1.48***	2.73	12.85	12.34	-41.91	-24.72	95.38	9.65	-6.73	9.51	-9.05
Rising Energy Costs	-0.03	-0.08	1.10	1.77	-3.38	16.32	-44.04	-6.07	49.69	1.80	0.75	38.42	-19.65
Compliance with Stringent Process Requirements	-0.00	1.15	**0.28***	**0.79***	5.99	-0.52	2.37	**25.01***	15.96	-5.68	-4.30	-4.57	**-6.32***
Encouraged by Public Finance Mechanisms	-0.00	-0.11	**0.19***	0.41	2.27	-4.31	-0.30	-3.24	34.36	-4.41	-4.38	1.33	-2.56
Management Sensitivity about Environmental Issues	-0.02	-2.17	0.42	2.69	3.27	9.22	-31.75	-16.54	57.64	18.12	28.21	-2.25	-5.71
Other Companies have reaped Positive Results	0.00	2.01	0.14	0.49	27.65	-6.64	0.37	6.24	52.64	-2.33	-13.04	-13.63	9.54
Technical Appeal	0.00	-0.87	0.21	0.36	3.08	5.25	-7.37	-2.87	36.80	0.75	5.22	3.31	1.63
EE Tech is Competitive in price	-0.01	-1.88	0.35	-0.24	**13.29***	-5.42	-2.37	10.28	**23.29***	-8.65	**-10.33***	0.91	-2.33
EE offers Improved Working Conditions	0.00	0.35	0.08	0.15	2.97	-0.79	0.15	0.04	41.59	0.49	1.04	-2.76	-0.27
Compliance with Environmental Regs	-0.01	-6.90	0.49	0.75	9.58	13.16	4.74	-2.40	30.51	0.59	-27.89	14.76	-3.23
Strategic Investment for Long Term Survival of Firm	-0.02	3.80	0.31	1.29	7.71	1.58	-2.81	-2.81	31.49	-7.47	-22.53	2.58	-13.81
Improves Customer Relationships	-0.02	3.74	0.07	0.79	-2.73	12.53	-6.92	12.94	21.54	-2.25	-16.02	5.85	-5.69
Improves Staff Pride and Morale	-0.02	4.93	0.22	2.65	4.53	4.71	-11.18	10.58	46.53	-2.50	-17.08	-4.42	-9.78
Improves Product Quality	-0.02	-0.783	**0.501***	1.133	13.222	-8.257	-4.803	9.335	**40.375***	-9.529	-6.197	-19.041	10.275
Reduces Production Costs	0.009	11.210	-0.091	0.153	2.105	-17.879	16.669	11.638	15.288	-22.026	-10.059	-14.707	11.637

Notes: ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

5.4.5 Results discussion

Similar to the discussion on barrier variation with firm characteristics, we limit the interpretation of the results only to the direction of the effects and not the magnitude of the results. The regression results are shown in Table 23. We list significant results at the 1%, 5% and 10% levels. There were 11 significant results at the 10% levels. We therefore reject the NULL hypothesis for Test B.2 and confirm that the drivers to EE adoption by MLMF operating within the EMA do indeed vary with the characteristics of the firms. The extent of the variations are discussed in the findings below:

1) An increase in age (expressed in years) is associated with an increase in the odds of considering reducing load on the grid as a driver to EE investments, with a log odds ratio of 1.48 (95% CI, -.167 to 3.143), Wald $\chi 2$ (1) =3.106, $p < .078$. **Interpretation**: Older firms are more likely to consider reducing load on the grid as a driver to EE technology investment. **Implication**: More awareness on load reduction for grid stability is necessary within newer firms.

2) An increase in age (expressed in years) is associated with an increase in the odds of considering Compliance with Stringent Process requirements as a driver to EE investments, with a log odds ratio of 0.28 (95% CI, -.008 to 0.572), Wald $\chi 2$ (1) =3.633, $p < .057$. **Interpretation**: Older firms are more driven to adopt EE technologies due to compliance with stringent process requirements. **Implication**: There may exist less stringent process requirements for new startups. Policy should address this issue. Where new plants are setup, the design should pass through a regulatory board that ensures compliance. New firms should be made aware on the benefits of compliance.

3) An increase in energy costs (expressed as a percentage of sales) is associated with an increase in the odds of considering Compliance with Stringent Process requirements as a driver to EE investments, with a log odds ratio of 0.79 (95% CI, -.023 to 1.612), Wald $\chi 2$ (1) =3.628, $p < .057$. **Interpretation**: Firms with high energy usage are more driven to adopt EE technologies due to compliance with stringent process requirements. However, it is positive to note that high energy users comply with stringent process requirements. **Implication**: There appears to be a gap in terms of process regulatory compliance between high

and low energy firms. Firms should be made to comply with stringent process requirements irrespective of energy usage.

4) The log odds of firms who are Profitable that consider Compliance with Stringent Process requirements as a driver to EE investments is 25.01 (95% CI, -0.504 to 50.542) times higher than firms who are not profitable, a statistically significant effect, Wald $\chi2$ (1) =3.691, $p < .055$. **Interpretation**: Profitable firms are more driven to adopt EE technologies due to compliance with stringent process requirements. **Implication**: there is a positive relationship between compliance with EE process requirements and the profitability of a firm. More awareness around such individual success stories should be created.

5) The log odds of firms who are ISO14001 registered that consider Compliance with Stringent Process requirements as a driver to EE investments is -6.322 (95% CI, -13.547 to 0.903) times lower than firms who are not ISO14001 registered, a statistically significant effect, Wald $\chi2$ (1) =2.941, $p < .086$. **Interpretation**: Firms that are ISO 14001 registered are less likely to consider compliance with stringent process requirements as a driver to EE investments. **Implication**: Firms that are ISO 14001 registered are generally environmentally conscious. Any engagement in EE activities will therefore be based on a consciousness to the environment and not necessarily only a compliance to process requirements. When developing policy on compliance, process compliance is therefore not necessarily the only factor to be considered. ISO 14001 compliance is also important. Naturally there may be positive spill-overs out of ISO 14001 compliance that may automatically drive compliance with stringent process requirements.

6) An increase in age (expressed in years) is associated with an increase in the odds of public finance mechanisms being a driver to EE investments, with a log odds ratio of 0.193 (95% CI, -.027 to 0.413), Wald $\chi2$ (1) =2.945, $p < .086$. **Interpretation**: Older companies are driven to adopt EE technologies because public finance mechanisms are available. **Implication**: More awareness on public finance mechanisms should be created especially amongst younger manufacturing firms. The administration of Public Finance Mechanisms should adopt a homogenous approach.

7) The log odds of firms that rent who feel that EE technology being competitive in price is a driver to EE investments is 13.299 (95% CI, -0.714 to 27.313) times higher than firms who own the property on which they operate, a statistically significant effect, Wald χ^2 (1) =3.460, $p < .063$. **Interpretation**: Firms that rent the property on which they operate find EE technologies competitive in price and are therefore driven to adopt. **Implication**: There is a difference in perspective of price competitiveness. Those that own the property on which they operate possibly take a longer term view that incorporates system lifecycle costs which impacts on the price competitiveness of the technology. It is important that such costs are made available upfront the consumer.

8) The log odds of firms with a high marketing cost ratio (> 20%) that find EE technology being competitive in price as a driver to EE investments is 23.299 (95% CI, -1.831 to 48.429) times higher than that of firms with a lower marketing cost ratio (<4%), a statistically significant effect, Wald χ^2 (1) =3.302, $p < .069$. **Interpretation**: Firms with high marketing cost ratios (more well-known) are more likely to adopt EE technologies as the technology prices are competitive. **Implication**: In relative terms, the cost of EE technologies is considered to be competitive in price when compared to the impact it has on the image of a firm. More research on the impact EE has on the image of the firm is warranted.

9) The log odds of firms who have invested in EE technologies that consider EE technology being competitive in price as a driver to EE investments is -10.332 (95% CI, -13.547 to 0.903) times lower than firms who have not invested in EE technologies, a statistically significant effect, Wald χ^2 (1) =3.788, $p < .052$. **Interpretation**: Firms that have already invested in EE technologies are less likely to be driven to adopt because of price competeveness. **Implication**: This is an interesting result that rings an alarm bell. Firms who have already invested in EE technologies may have done so because of the secondary benefits that it may have or because of regulatory compliance impositions. Their perspective on EE may have also changed post investment likely because of lifecycle costs. Further research is warranted on the matter.

10) An increase in age (expressed in years) is associated with an increase in the odds of considering EE technology improving product quality driver to EE investments, with a log odds ratio of 0.501 (95% CI, -.31 to 1.033), Wald $\chi 2$ (1) =3.411, $p < .065$. **Interpretation**: Older companies are more driven to adopt EE technologies due to it improving product quality. **Implication**: Awareness on the secondary benefits associated with EE technologies should be created amongst younger firms. Comparative labelling on products showcasing the quality improvements due to EE should be considered.

11) The log odds of firms with a high marketing cost ratio (> 20%) that are driven to adopt EE technologies due to its improvement in product quality is 40.375 (95% CI, -4.601 to 85.351) times higher than that of firms with a lower marketing cost ratio (<4%), a statistically significant effect, Wald $\chi 2$ (1) =3.096, $p < .078$. **Interpretation**: Firms with high marketing cost ratios (more well-known) are more likely to adopt EE technologies as it improves product quality. **Implication**: Success stories on EE quality improvement should be communicated in the market. Comparative labelling showcasing quality improvements due to EE technologies should be better campaigned especially within less popular firms in the marketplace.

5.5 Summary

This Chapter set out to discuss and analyse the data collected as part of the field study. It first went on to provide a descriptive analysis of the results on a per sector basis across eight key criteria pertinent to Energy Efficiency. The results of the descriptive analysis provide a profile of the Energy efficiency landscape within the manufacturing sector in the EMA. The results help determine whether an energy efficiency gap exists.

The descriptive analysis reveal that whilst there is a generally high level of awareness on Energy Efficiency, firms generally scored poorly across the 8 key measures. This suggests evidence of the existence of an EE gap.

In order to investigate the determinants to this status quo, the Chapter went on to investigate the drivers and barriers to Energy Efficiency. These barriers and drivers were analysed across manufacturing sectors and firm characteristics.

The analysis reveals that the top barrier and driver to EE are both cost related. Should the cost of EE technologies improve, there may then be a greater uptake to EE technologies. Firms are also mostly driven to adopt EE technologies due to the rising price of energy. A comparison of barriers by category reveals that taken together institutional barriers pose the greatest hurdle to investing in energy efficiency.

It was found that the different manufacturing subsectors experience similar drivers and barriers to the adoption of EE technologies with exception of the inertia barrier and diffusion driver. At least 30 significant results were found for barrier and driver variation across firm characteristics at the 10%, 5% and 1% levels. The most interesting results as summarised below:

- EE price competitiveness is still a concern. There is evidence to suggest that firms are interested in overall lifecycle costs and not just the upfront costs.
- Public finance mechanisms should be made equally available to all firms irrespective of age or energy intensity.
- There is evidence to confirm that ISO14001 is an enabler to EE technology adoption. ISO14001 has a positive spill-over effect to EE adoption.
- In cases where energy is already considered cheap, more innovative pricing models need to be developed in order to encourage firms to adopt EE technologies.
- Firms in general should be made aware of the other secondary benefits associated with EE technologies. Comparative labelling on products showcasing the quality improvements and overall lifecycle cost savings against standard alternatives should be considered.
- There is concern on the maturity of EE technologies especially amongst firms that are less profitable. EE technologies should offer better guarantees to allay fears. Initial capital costs should be subsidised or be allowed to be paid back from savings over the lifecycle of the technology.

Chapter 6 Conclusions and recommendations

6.1 Introduction

The objective of this research was threefold: a) to determine the energy efficiency profile within the EMA and advise whether an energy efficiency gap exists, b) to understand the drivers and barriers to EE that determine the status quo, and c) to understand how these drivers and barriers vary by manufacturing sector and firm characteristics.

This Chapter aims to consolidate the significant results found as part of this investigation and is used to answer the main research objectives. It then goes on to discuss the implications of such results on EE policy in South Africa. Specific recommendations are also made arising out of these implications. Finally the limitations and shortcomings of this study shall be put forward and discussed.

6.2 Summary of findings

An investigation into the South African Industrial Energy landscape was conducted as part of the introduction of this research. At the aggregate level, the South African industry has been able to **successfully decouple economic growth from energy use**. The results of this investigation revealed that there has been an overall reduction in the energy usage by manufacturing entities in SA for the period 2000-2012. The reduction has been from a contribution of energy efficiency improvements and to a lesser extent, structural changes within the manufacturing sectors themselves.

Whilst the manufacturing sector as a whole was able to **achieve the efficiency targets set out in the NEES**, it was found that **all manufacturing sectors did not contribute equally** to the aggregate results; some sectors showed an almost zero improvement while others showed either an increase or decrease in their energy efficiency performance. The Non-ferrous metals, Non-metallic minerals, Transport equipment, Food and tobacco, and the Textiles and leather sector showed an overall poor energy efficiency performance whilst the Chemical and Petrochemical, Machinery, Iron and steel, and Paper, pulp and print sectors demonstrated positive EE improvements.

The investigation revealed that by 2012, the aggregate effect of all the sectors investigated showed a 29,9% reduction in energy intensity through energy efficiency mechanisms despite some sectors performing poorly. This far surpassed the 12% target set out in the NEEAP. **More realistic targets** that take into account the barriers and drivers to energy efficiency and the country's status quo energy efficiency profile needs to be considered within future EE action plans.

An investigation into the energy efficiency landscape of SA revealed that **no previous study into the barriers and drivers to energy efficiency within the local context of South Africa was conducted**. The NEES was therefore based on barriers and drivers of a generic context. This may have contributed to its underestimation of efficiency targets. All member countries within the BRICS association with the exception of SA have conducted a barrier analysis to EE within their local operating context. This research study aimed to close these gaps.

The descriptive analysis of the EE landscape helped determine whether an energy efficiency gap is prevalent within the EMA. The results show that while there is a high level of awareness and adoption of EE technologies across manufacturing sectors, the quality of the EE adoption profile is poor. When manufacturing entities were measured across four key EE criteria, it was found that **more can be done to improve the efficiency landscape in the area**. There is an extremely low appointment rate of Energy Managers (7%), a poor adoption rate of Energy targets amongst firms (31%), a generally low level of awareness of EE tax incentives offered by government, and amongst the high energy users, there is a low adoption rate of Energy Management Systems. We therefore **conclude that an energy efficiency gap exists within the EMA**. In order to address this gap, **policy should make EMS implementation mandatory** for energy intensive industry. This will naturally encourage industry to set energy targets and appoint an Energy manager to manage such interventions. More awareness needs to also be created around the section 12L tax rebate option. Technical teams should present business cases to EXCO showing EE investment returns from tax rebates. Such interventions will improve the implementation and diffusion rate of EE technologies within the EMA.

A second objective of this research was to investigate the barriers and drivers to Energy Efficiency. The results of the research reveal that there currently exists a significant amount of barriers within the Economic, Institutional and Organisational barrier categories. Taken together however, Institutional barriers pose the greatest hurdle to EE adoption. In summarising the main findings, we engage Pareto's principle, and discuss the top 20% of barriers in Table 24 below.

Table 24 Remarks on barriers

Barrier	Category	Score	Comment
EE Technologies Expensive	Economic	3.96	While policy has already partly addressed this concern through the promulgation of the Section 12L tax credit Act, more awareness of this Act needs to be created, as noted earlier, to reduce impact of this barrier. Furthermore, when presenting business cases on EE, companies should put into perspective total lifecycle costs of EE technologies during the comparison to standard alternatives.
Public Finance Mechanisms are complex	Institutional	3.67	This points to an institutional complexity that needs to be addressed to better facilitate the provisioning of EE financing mechanisms. More research on this complexity is required.
Lack of EE internal Procedures	Organisational	3.63	The adoption of an EMS will ensure the formalisation of internal EE procedures for the long term sustainability of EE projects.
Limited Public Awareness	Institutional	3.59	This again points to an institutional related concern. EE institutions should do more to promote the importance of EE technologies through public campaigns, advertisements, etc.
Lack of Time	Behavioural	3.56	While behavioural in nature, this barriers stems from the fact that firms are unable to see the importance of EE within their operations. EE solutions should be better marketed taking the whole system whole lifecycle costs into consideration.
Technology not Fully Matured	Economic	3.56	This points to an economic risk barrier and may be a result of false perceptions. More global success stories of EE implementations should be made available to reduce the impact of this barrier.

With regard to the drivers to EE we similarly engage Pareto's principle and highlight the top 20% measured in Table 25 below.

Table 25 Remarks on drivers to EE (Top 20%)

Top 20% of Drivers	Score	Comment
Rising Energy Costs	4.59	The constant rise in energy cost is the main driver to EE investment. However, in order to decouple adoption rate of EE technology to price, more awareness on the secondary benefits associated to EE is required.
Reduces Production Costs	4.00	The top two drivers to EE technology is centred on cost. While it is noted that EE technologies reduce production costs, more awareness around other secondary benefits are required. Firms should not only be cost centric in their approach to EE adoption.
Compliance with Environmental Regulations	4.00	It is encouraging to learn that compliance to environmental regulations lies within the top three drivers to EE technology adoption. This implies that regulation efforts on environmental matters are working. To induce further compliance, EE institutions should investigate and market the cost of non-compliance to such regulations.

Management Sensitivity about Environmental Issues	3.96	It is again encouraging to learn that there exists a level of management sensitivity on environmental issues. This finding validates the previous finding on environmental regulation compliance. Management's sensitivity on such issues sets the culture within the firm.

It is also interesting to highlight those drivers that do not seem to improve the EE landscape within the EMA. We list and comment on the lower 20% of drivers in Table 26. Such Drivers act as Barriers to EE investment.

Table 26 Remarks on drivers to EE (Bottom 20%)

Lower 20% of Drivers	Score	Comment
EE Tech is Competitive in price	2.78	There is a general feeling across the board that EE technologies are not competitive in price. EE institutions need to consider better capital financing proposals/subsidies so as to improve the adoption rate of such technologies.
Other Companies have reaped Positive Results	3.00	There is a lack of diffusion in the market on successful EE implementation case studies. More awareness is required.
Encouraged by Public Finance Mechanisms	3.22	Public finance mechanisms are either not available or difficult to access. EE institutions need to unravel the complexities surrounding this topic. Further research may be required on this challenge.

Table 24, Table 25 and Table 26 overwhelmingly indicate that the main barriers and drivers to EE adoption are cost related. Whilst government has made an effort to address this concern in terms of the Section 12L Energy Efficiency Tax Credit Act, more innovative financing mechanisms or subsidies are still required. Firms should also be made more aware of the secondary benefits to EE.

The third objective of this research was to investigate how the barriers and drivers varied by manufacturing sector and firm characteristics.

Section 5.3.2 of this research employed the Kruskall Wallis H test to investigate how the barriers discussed earlier varied by manufacturing sector. With all test assumptions being met, the results revealed that all entities felt similarly across all manufacturing subsectors on the type of barriers they experience with the exception of only the inertia barrier (do not change what is already working). To investigate how this barrier varied by manufacturing sector, we engaged the Kruskall Wallis post-hoc test. The results revealed that the **Food and Beverages, Metals, Iron & Steel manufacturing sectors are affected to a lesser degree by the inertia barrier** when compared to the other sectors.

Similarly, in Section 5.4.2, we employed the Kruskall Wallis H test to investigate how the drivers varied by manufacturing sector. Again, with all test assumptions being met, the results showed that all entities felt similarly on the drivers to EE with exception of the diffusion driver (other companies have reaped positive results). To investigate how this driver varied by firm characteristics, we employed the same post-hoc Kruskall Wallis test to the above analysis. The results revealed that the Non-metallic minerals sector differed significantly from the food and beverages sector on this driver. While this driver is most prominent within the Food and Beverages sector and to a lesser degree, the other sectors, it is most uncommon within the non-metallic minerals subsector. This **means that more information diffusion of EE success stories is required within the non-metallic minerals subsector**.

Barrier variation across firm characteristics

Section 5.3.4 investigated how the barriers to EE varied with firm characteristics. For this investigation, ordinal regression was employed whereby each of the 25 barriers were regressed across 12 firm characteristic variables. Nineteen significant results were found across 8 barriers at the 1%, 5% and 10% levels. The results are summarised below.

Public finance mechanisms are difficult to access

This barrier was found to be significant across six firm characteristics. Firms with following characteristics are more likely to experience this barrier:

a. Firms with lower energy costs
b. Those that own the premises on which they operate
c. Those that have a skilled workforce
d. Those firms that are less popular in the marketplace
e. Those firms that are not ISO14001 registered.

Implications: EE institutions should investigate the reasons behind the complexities surrounding the access to public finance mechanisms. It is important that the administration of public finance is equitable and that minority groups do not go unheard.

Energy is already cheap

This barrier was found to be significant across three firm characteristics. Firms with the following characteristics are more likely to experience this barrier.

a. Younger firms
b. Firms with lower energy costs
c. Firms with higher debt ratios

Implications: It is imperative that awareness around the secondary benefits associated with EE investment is created. As a subset of firms appear to be cost centric, more innovative energy pricing models that take the whole system and whole life-cycle costs into consideration should be investigated. Funding institutions should consider offering better interest rates to subsidise the capital that is outlaid when purchasing EE technologies.

Limited public awareness

This barrier was found to be significant with firms that have a skilled workforce. Such firms are of the opinion that more awareness on EE technologies is required across the industry.

Implications: Poor awareness on EE technology ultimately results in low EE adoption rates. EE institutions should address this concern by showcasing success stories of EE implementations through campaigns, conferences, etc. Further investigation into the reasons for poor diffusion of EE information should also be considered. Policy makers should identify key actors in the EE space (those who are persuasive or trend setters in industry), and encourage them to transition into becoming more energy efficient. Case studies on such implementations should then be showcased and made public knowledge.

Policies not kept up-to-date

Policies not being kept-up-to-date was found to be significant across at least three firm characteristics. Firms with the following characteristics are more likely to experience this barrier:

a. Those that own the property on which they operate
b. Those that have a high debt ratio
c. Those that have low marketing costs (less popular in market)

Implications: this points to an institutional barrier. Policies that are out of date create risk for firms adopting EE technologies. It limits the potential that EE investment can achieve as prescribing policy becomes irrelevant. Policy makers should align to best practice in terms of policy revision and ensure that newer technologies are given due consideration within revised policies. SCM policies for the procurement of EE technologies should be adaptable to newer EE innovations in the marketplace.

Lack of public finance

This barrier was found to be significant within firms that are less popular within the market.

Implications: There appears to a bias in the provisioning of public finance options within the market where less popular firms seem to be kept isolated. The administration of public finance should adopt a homogenous approach. Policy makers should address this issue by way of mainstream public communication and awareness campaigns/workshops etc.

Heterogeneity of EE technologies

This barrier was found to be significant by firms that are less competitive in nature. Such firms believe that EE technologies cannot be used across engineering domains.

Implications: More awareness on the homogeneity of EE technologies should be created especially within firms that are less competitive in nature. As firms start to adopt EE technologies across engineering disciplines, we would expect better cross pollination of success stories.

Technology not fully matured

This barrier was found to be significant across two firm characteristics. Firms with the following characteristics are more likely to experience this barrier:

a. Those that are not profitable
b. Those that have an international orientation

Implications: Technology that is not fully matured exposes the business to significant production and investment risk. Policy makers should ensure that there is sufficient diffusion of success stories of EE technologies. To boost consumer confidence, technologies introduced within the local context should be subjected to quality regulation e.g., SABS before they are allowed to enter the market. An investigation into the EE technologies available within the global market should also be conducted and compared to the local context. This will help ascertain whether there is a good supply of quality EE products in SA.

Lack of internal policies and procedures

This barrier was found to be significant by firms that are not ISO14001 and registered.

Implications: Firms that are ISO 14001 registered generally already have a well-defined subset of internal policies and procedures regarding environmental management. As firms that are not ISO 14001 registered experience the lack of such documentation a barrier to EE adoption, it fair to propose then that ISO 14001 registration is an enabler to EE investment. This opens the door for a symbiotic relationship between EE and environmental policy makers. Policy makers on EE should work with environmental policy makers in specifying unified policies that support both objectives.

Driver variation across firm characteristics

Section 5.4.4 of this research investigated how the drivers to EE varied with firm characteristics. Similar to the investigation on barriers, ordinal regression was employed whereby each of the 15 drivers were regressed across 12 firm characteristic variables. Eleven significant results were found across five drivers at 10% level. The results are summarised below.

Help reduce load on the grid

This driver was found to be significant within older firms.

Implications: More awareness on the importance of grid stability needs to be created in general especially within firms with high energy consumption. Newer firms should be made to realise the impact on the total loss of supply of the grid.

Compliance with stringent process requirements

This driver was found to be significant across at least four firm characteristics. Firms with the following characteristics are more likely to experience this Driver:

a. Older firms
b. Firms with a higher energy costs
c. Profitable firms
d. Firms that are not ISO 14001 registered

Implications: Policy makers should consider the option that mandates all new process designs to pass through a regulatory board on EE before being implemented. Compliance to EE requirements should be mandatory irrespective of firm characteristics. Interestingly, it should be noted that profitable firms adopt EE technologies in order to comply with stringent process requirements.

Encouraged by public finance mechanisms

This driver was found to be significant within older firms.

Implications: Consistent with earlier findings, cost remains a significant hurdle to the adoption of EE technologies especially within older firms. EE institutions should become more innovative with costing / financing models on EE and research into how other international markets address this issue should be conducted. Policy makers should create an environment whereby firms are encouraged to adopt EE technologies and cost is not a significant hurdle.

EE technologies are competitive in price

This driver was found to be significant across three firm characteristics. Firms with the following characteristics are more likely to experience this Driver:

a. Those that rent the property on which they operate
b. Those that are reasonably popular in the market
c. Those that have not invested in EE technologies

Implications: An interesting finding is that firms who have already made the investment in EE technologies do not consider the price of EE technologies as a driver to future investment. More awareness on the reasons why such firms feel this way should be created in the market. Policy makers should consider the option of labels for energy products that give an estimation of whole system and whole life cycle costs associated with EE products vs standard alternatives. Until the off-the-shelf price becomes competitive, policy makers should investigate the avenue of price subsidies.

Improves product quality

This driver was found to be significant across two firm characteristics. Firms with the following characteristics are more likely to experience this driver:

a. Older firms
b. Those firms that are reasonably popular in the market-place.

Implications: More awareness around the secondary benefits associated with EE should be created especially on product quality. Policy makers should again consider comparative labelling on EE products to showcase the benefits EE technologies offer compared to standard alternatives.

6.3 Salient findings and contribution to general theory on Energy Efficiency

The salient findings of this report are summarised below and should be taken into consideration in the development of future policy on EE.

1. Firms are primarily cost centric in their approach to EE. Regulatory compliance and a consciousness to the environment are mostly considered as secondary drivers.
2. Institutional barriers pose the greatest hurdle to EE adoption amongst MLMF within EMA.
3. More effort to improve the quality of the EE profile especially amongst high energy intensity users is recommended. Adoption of ISO50001 will help improve the quality of the EE adoption profile.
4. Consideration on the setup of a regulatory board that ensures EE process compliance for new start-ups is necessary. This regulatory board should also regulate the quality of EE products entering the local market.
5. The drivers and barriers to EE have been found to be mostly similar across manufacturing sectors within EMA.
6. EE price competitiveness is still a concern. There is evidence to suggest that firms are interested in overall lifecycle costs and not just the upfront costs.
7. Public finance mechanisms should be made equally available to all firms irrespective of age or energy intensity.
8. There is evidence to confirm that ISO14001 is an enabler to EE technology adoption. ISO14001 has a positive spill-over effect to EE adoption.
9. In cases where energy is already considered cheap, more innovative pricing models need to be developed in order to encourage firms to adopt EE technologies.
10. Firms in general should be made aware of the other secondary benefits associated with EE technologies. Comparative labelling on products showcasing the quality improvements and overall lifecycle cost savings against standard alternatives should be considered.

11. There is concern on the maturity of EE technologies especially amongst firms that are less profitable. EE technologies should offer better guarantees to allay such fears. Initial capital costs should be subsidised or be allowed to be paid back from savings over the lifecycle of the technology.

6.4 Specific recommendations from this study

The following recommendations have been derived from this study most of which have been based upon hurdles experienced during the research.

1. DoE and StatsSA should standardise on industry classifications and report statistics accordingly. This standardisation will allow for the improved analysis of Energy and GDP related information.

2. Energy data should be broken down and reported per province and where possible by municipality according to standardised industry codes. This will allow for better reporting granularity of the decomposition results.

3. There are occasional errors within the DoE published data. Validation of data through cross checks etc. should be carried out before data is utilised for studies. DoE should employ better data validation and error checking methods before publishing results.

4. The revised NEES and NEEAP should take into due consideration the barriers and drivers and their variation across sectors and firm characteristics listed in this report when designing new policy.

5. Future strategies on EE should set more realistic EE industry targets taking into consideration the trends found within this research report.

6. There were complexities in trying to determine the exact number of active manufacturing firms per province and local municipality. Furthermore, this complexity is heightened when trying to qualify such firms by industrial code. There is a disconnect between CIPRO, StatsSA and DoE. Such government institutions should work of one database. This will improve reporting statistics.

7. There should be consideration given for the setup of an EE regulatory board that governs process plant designs. This board will ensure that industrial plants are designed in an energy efficient manner. A regulatory board that inspects all

energy related products entering the SA supply market for minimum EE compliance is also required.

6.5 Recommendations for future research

The following gaps were identified for further research as part of this study:

1. An investigation into the bottlenecks that exist within the administration of EE institutions should be conducted especially regarding financing mechanisms.

2. In countries where energy is cheap, more innovative pricing models should be investigated that fosters EE investment. Such models should internalise the cost of pollution as a result of serving inefficient energy.

3. While this study focussed on medium to large manufacturing firms, a significant scope for energy improvement lies within small to medium manufacturing firms. While the per-firm reductions may be smaller than for energy intensive industry, the higher volumes creates scope for economies of scale benefits. Research on the EE performance of such firms should be conducted.

4. The existence of an energy efficiency gap prompts further investigation into the maturity levels of EE technologies and diffusion rates of success stories.

5. Background studies within the EE landscape in SA revealed that no research on EE performance has been conducted within the residential, mining, transport and energy sectors. Research on the operating efficiency of such sectors are therefore required.

6. There is evidence to suggest that there is a positive link between firm profitability, compliance with strict process requirements and EE adoption rates. More research into detail of these relationships is required.

7. It was found that firms who have already invested in EE technologies find the price of such technologies non-competitive in price. An investigation into the reasons behind this finding is warranted.

6.6 Limitations of this research and shortcomings

During the period of this research, SA's economy was noted to be in a technical recession. This was validated by the manufacturing output as reported by StatsSA

(StatsSA 2015). Load shedding was also very prevalent at the time of field capture which further contributed to the downturn in the economy. Taken together, these circumstances may have affected the response rates and attitudinal scores collected as part of the survey.

While it was successfully argued that the eThekwini region is representative of the manufacturing landscape of South Africa, the generalisability of the results should be approached with caution. Municipalities offer varying levels of service quality and energy tariffs which may affect their attitudes towards energy efficiency. Some manufacturers may also be fed directly from Eskom and may have SLAs in place. These cautionary notes should be taken into account when generalising the results or when making inferences.

The lack of awareness of the quality criteria for EE viz., Section 12L implementation, Energy targets and ISO 50001 implementation resulted in the inability to test for relationships between firm profitability with such criteria.

Due to the lack of reporting of energy data per SIC code at municipal level, this study was not able to conduct a decomposition analysis for manufacturing within the eThekwini region but rather only at national level. This shortcoming was highlighted earlier and a recommendation to rationalise such reporting was raised.

6.7 Conclusion

This study set out to investigate the energy efficiency landscape within MLMF operating within the EMA. As the EMA manufacturing circle is diverse and well represented in all sectors in terms of the national profile of manufacturing firms, the results may be extended to the national context but with the cautionary notes listed in Section 6.6.

Preliminary studies into the energy landscape of South Africa has shown that Industry at the aggregate level has done well to meet energy efficiency targets as set out in national policy. However, a decomposition analysis of this energy efficiency performance has revealed that not all industrial sectors performed equally well. While the energy intensive sectors have done a good job in reducing their intensity levels, other sectors have not responded well. These findings call for improved reporting through the allocation of sector specific targets within new policy amongst other factors.

Through the use of 4 key criteria on energy efficiency, the results of this study have shown that there currently exists an energy efficiency gap within manufacturing firms in South Africa. More focussed efforts can be made to improve the quality of the EE adoption profile by ensuring alignment to the ISO 50001 Energy Management Standard.

It was found that the most significant barrier and main driver to energy efficiency are both cost related. While in some cases EE technologies offer significant benefits to overall cost reduction, in some other cases, EE technologies seems to be priced outside the market. In order for the EE technology adoption profile to improve, consumers need to have the right information at hand in order to make the right decisions. Policy-makers should consider introducing mandatory EE labelling on components that can provide the consumer with immediate lifecycle cost comparisons against standard alternatives. Innovative public financing mechanisms that assist with financing the high initial capital outlay required for EE technologies should be considered. The interest paid on such financing arrangements can be derived from the lifecycle cost savings.

The barriers and drivers were found to be similar across manufacturing sectors but were found to have differed considerably with the characteristics of the firm. Twenty five significant findings were made of which 6 require urgent policy attention. More awareness on the secondary benefits associated with EE technologies should also be considered.

Policy-makers should take into consideration the salient findings of this research when drafting new policy on energy efficiency. Several recommendations for future research have also been proposed as part of this study. It has been noted that while this research study focussed on medium to large manufacturing firms, a huge potential for energy efficiency research exists within SMEs who represent a significant portion of SA’s energy profile.

6.8 Chapter Summary

This Chapter set out to derive the conclusions and recommendations of the field study based on the objectives set out in Chapter one of this study. A discussion of the results were documented and the salient findings summarised. Specific recommendations from this study and recommendations for future research were raised.

This Chapter also presented the limitations of this research and the cautionary notes that should be given consideration when interpreting the results. Several future policy implications were also highlighted and discussed.

Finally, the conclusion of this Chapter drew together and presented the main points of this research study in a summarised form that speaks to the research questions that were raised in the conceptual phase.

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Annexure A – Telephonic correspondence

Secretary

Good day, you are speaking with Resham from eThekwini Electricity. I am conducting a survey on energy efficiency and would like to speak to either the production manager, the plant engineer, or owner of the company if possible.

Relevant staff

Good day, you are speaking with Resham from eThekwini Electricity. I am conducting a survey jointly with the University of Pretoria on energy efficiency within manufacturing subsectors and I have identified your company as one that is vital to understanding the efficiency landscape in SA.

Participation in this study will help you improve the energy efficiency within your operations. A copy of the research results will help you determine how energy efficient you are amongst your peers within the manufacturing sector that you operate within.

Your feedback will also be used to improve local and national policy on energy efficiency. As I work for the municipality, I will personally ensure that your comments are heard.

All information provided during the interview will be treated as confidential. Your company name will not be linked to any results. Results will be published only by manufacturing sector. A confidentiality disclaimer is provided on the cover page of the questionnaire which I can email to you for your records.

Your participation is voluntary and you may opt to pull out at any time.

Will you be interested in participating? The interview will take about 15 minutes. I can conduct this telephonically or I may send you the questionnaire and you can fill it in at your own leisure.

I will really appreciate your feedback.

Annexure B – Email correspondence

Dear Vivian

Many thanks for taking my call today regarding your participation in our Energy Efficiency survey. This survey is a joint research project of the University of Pretoria and eThekwini Electricity.

We have identified at least 93 companies within the Chemicals manufacturing sub-sector in Durban and we have noted Hi-Tech Chemicals as relevant and vital to help understanding the energy efficiency landscape in the area.

Your input will assist to develop local and national policy on energy efficiency and to further raise awareness on the topic.

As a reward to your valued participation, we will provide you with a copy of the research results. You may use this as a yardstick to measure your existing energy efficiency performance amongst your sector peers.

As a next step of engagement, should your performance need to be improved, we will put you in touch with the National Cleaner Production Centre of SA (NCPC-SA) who will assist you with specific process efficiency improvements in your plant and help you develop a business case for Donar funding on your behalf.

All information received during this study will be treated as strictly confidential. Company specific information will not be revealed in any of the results. Please see our confidentiality disclaimer on the cover page of the questionnaire booklet attached. Note that this is the first stage of engagement that looks at only the awareness aspects of energy efficiency in your company. Once we provide feedback on the results you may choose to engage with us further on the more practical steps. This is when NCPC-SA may then engage with you personally through site visits etc.

Please feel free to contact me should you have difficulty answering any of the questions. I look forward to your valued input.

Regards,

Resham Singh - Pr. Eng

Chief Engineer

eThekwini Electricity

HV Network Control

Network Management

Annexure C – Follow up email

Hi Shaun

Many thanks for taking my call a while ago regarding the energy efficiency survey that we are conducting. This is just a small reminder to complete the questionnaire booklet. If you prefer that I come through to your premises and assist you to complete the questionnaire, please let me know.

Remember, participation in this study may help you reduce your energy consumption profile by way of donar funding for energy efficiency improvements.

The survey takes at most 20 minutes to complete. Please fill in what you can and kindly send through the information. The questionnaire booklet is re-attached for your convenience.

Should you have difficulty completing any of the questions, please let us know. If there are any confidential questions that you do not want to answer, please feel free to omit them in your response.

Remember, the better the quality of your input, the better the results of our research.

Should you not wish to participate in our survey, please let me know.

Looking forward to your reply.

Regards,

Resham Singh - Pr. Eng

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Annexure D – Survey Questionnaire

ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
ETHEKWINI MUNICIPAL REGION 2015

ENERGY EFFICIENCY MANUFACTURING SURVEY

QUESTIONNAIRE

A joint research project of:

University of Pretoria	UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA
eThekwini Electricity	ETHEKWINI MUNICIPALITY

Primary Investigator: Mr Resham Singh (Pr. Eng.)

Supervisor: Dr. J Lalk (PhD, Pr. Eng)

CONFIDENTIALITY CLAUSE

The information received during this field study shall be treated as strictly confidential and will be used solely for research purposes. Any information that can be identified with you or your company shall remain confidential. Under no circumstances shall this information be distributed, re-printed or re-produced without the written consent from yourself.

Page 1 of 9 Id. | | | |

ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
ETHEKWINI MUNICIPAL REGION 2015

In order to understand and improve the energy efficiency landscape of the manufacturing industry in South Africa, we will like to investigate the reasons as to why some companies in South Africa tend to improve their energy efficiency whilst others do not. The outcome of the main contributing factors consolidated from various manufacturing firms contacted within this survey shall be used to help improve local and national policy on energy efficiency.

This questionnaire takes about 20 minutes to complete, of which most of the questions are multiple choice.

The questionnaire consists of three parts:

Module 1: General questions about the company [10 minutes]

Module 2: Barriers to Energy Efficiency [6 minutes]

Module 3: Drivers to Energy Efficiency [4 minutes]

This questionnaire is to be filled in by either the production manager, technical director, or plant engineer.

Within the questionnaire, you will be requested to share information regarding your business. Again, this information shall be treated with strict confidentiality.

A copy of the results will be shared with you which can be used as a yardstick to measure your existing energy efficiency performance amongst your sector peers. The results of this survey will also benefit the scientific community at large.

Your participation in this study is voluntary and you retain the right to withdraw at any stage without any penalty or future disadvantage whatsoever. Note that you are not waiving any legal claims, rights or remedies because of your participation in this research study.

The Higher Degrees Committee and the Research Ethics Committee of the University of Pretoria have approved this field study.

The primary investigator, Mr R Singh, can be contacted during office hours on (031) 311 9449, or on his cellular phone on 073 219 7401. The study leader, Dr J Lalk, can be contacted during office hours on (012) 420 4925.

Your participation in this study will be sincerely appreciated.

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ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
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MODULE 1 GENERAL

1. We would like to know a little about your company and yourself.

1.1 Establishment name: Click here to enter text.

1.2a Physical (street) address: Click here to enter text.

1.2b Postal code: Click here to enter text.

1.3a Respondent Name: Click here to enter text.

1.3b Respondent Position: Click here to enter text.

1.4 Telephone no.: Click here to enter text.

1.5 E-mail address: Click here to enter text.

PART 1 GENERAL

1.6 Does the firm rent or own the premises from which it operates? | 1 RENT ☐ | 2 OWN ☐ | 3 UNSURE ☐ |

1.7 What type of products does this establishment produce? (List the **main product** – e.g. spices, garden chair) Click here to enter text.

1.8 Approximately how many full time employees does the firm have? Click here to enter text.

1.9 In what year did production start at this location? Click here to enter text.

1.10 Do you export manufactured goods? | 1 YES ☐ | 2 NO ☐ | 3 UNSURE ☐ |

1.11 Do you have manufacturing facilities overseas? | 1 YES ☐ | 2 NO ☐ | 3 UNSURE ☐ |

1.12 Does the organisation employ professional engineers or technicians? | 1 YES ☐ | 2 NO ☐ | 3 UNSURE ☐ |

1.13 Does the organisation have a training plan for technical employees that is in-place and in-use? | 1 YES ☐ | 2 NO ☐ | 3 UNSURE ☐ |

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MODULE 1 GENERAL

1.14 What is the company's total liabilities relative to its total assets (i.e. debt ratio)? Click here to enter text.

If unsure of the numeric value, tick the most appropriate box

< 40% ☐	40 – 70% ☐	> 70% ☐

1.15 What is the organisations cost of marketing relative to sales?

< 4% ☐	4% – 20% ☐	> 20 % ☐

1.16 Does the company have a Research and Development budget?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.17 Has the organisation been profitable year-on-year over the last three years?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.18 What is the firm's energy cost as a proportion of turnover (approximate)? ______ %

1.19a How competitive is the Industry that you operate within?

1 VERY UNCOMPETITIVE ☐	2 UNCOMPETITIVE ☐	3 SOMEWHAT COMPETITIVE ☐	4 COMPETITIVE ☐	5 VERY COMPETITIVE ☐	6 UNSURE ☐

1.19b If you have answered 3 and above to 1.19a, then what best describes this type of competition?

1 LOCAL ☐	2 GLOBAL ☐	3 BOTH ☐	4 UNSURE ☐

1.20a Does the firm have an Energy Manager?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.20b If YES to 1.20a above, then does he report directly to the board?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.21a Has the firm ever invested in any energy efficient process improvements?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.21b If YES to 1.21a above, then has there been any reduction in energy costs since implementation?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.22a Has the firm ever invested in any energy efficient building improvements?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.22b If YES to 1.22a above, then has there been any reduction in energy costs since implementation?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.23 Does the business have an Energy Management System (EMS) in place?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.24 Has the business set any energy improvement targets?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.25 Is the company registered with ISO 14001?

1 YES ☐	2 NO ☐	3 UNSURE ☐

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1.26a Is the company aware of the energy efficiency tax credit option available with SARS i.e., Section 12L?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.26b If YES to 1.26a above, then has the company implemented it?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.27 Is the company aware of existing energy saving technologies that are available on the market?

1 YES ☐	2 NO ☐	3 UNSURE ☐

1.28 What is the impact of load shedding on company turnover?

1 NO IMPACT ☐	2 MODERATE IMPACT (<30% of turnover) ☐	3 SIGNIFICANT IMPACT (≥ 30% of turnover) ☐	4 UNSURE ☐

1.29 Is the company considering investing in alternative energy sources as a result of load shedding?

1 YES ☐	2 NO ☐	3 UNSURE ☐

END OF PART 1

Id.

ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
ETHEKWINI MUNICIPAL REGION 2015
MODULE 2 BARRIERS

PART 2 BARRIERS

Our company finds it difficult to invest in energy efficiency technologies because:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2.1.Energy efficiency technologies are expensive	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.2.Public finance mechanisms e.g., grants, subsidies, etc., are difficult to obtain for energy efficiency projects	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.3.Energy efficiency regulation is not prescriptive enough on what to do	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.4.Energy is already cheap and therefore there is no need to invest in energy efficiency technologies	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.5.We feel that there is not much public education, information and awareness campaigns on energy efficiency	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.6.We feel that policy on energy efficiency does not keep up to date with newer technologies	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.7.Suppliers of manufacturing equipment do not advise us on energy efficient alternatives	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.8.We do not know what energy efficiency specifications to include when purchasing manufacturing equipment	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.9.There is a lack of internal capital for energy efficiency investment	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.10.There is a lack of public finance (grants) available for energy efficiency investment	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.11.Energy efficiency offers lower return rates when compared to other capital investments	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.12.There are too many unknown hidden costs associated with energy efficiency technologies	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.13.There is a lack of internal technical skills available for energy efficiency investment	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.14.There a lack of external technical skills in the local market to support energy efficiency projects	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.15.Where external technical skills exist, they are too expensive	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.16.We feel that energy efficiency products offered in the market suit other industries but not our own	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.17.Implementing energy efficiency projects risk production uptime	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.18.Energy efficiency technologies have not yet fully matured	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.19.There a lack of time to investigate new energy efficiency opportunities	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.20.There is no scope for energy improvement within our business	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.21. There is a lack of managerial awareness to energy efficiency	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.22.Energy efficiency benefits are not quantifiable to the bottom line	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.23.Other peer companies have not had any success with the implementation of the energy efficiency technologies	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.24.We don't want to break what is already working fine	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.25.There is no specific person dealing with energy efficiency within our company	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.26.There is a lack of energy policies, procedures and systems within our company	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

 Id. ☐☐☐

Is there anything outside the table above that hinders your company from investing in energy efficiency?	1 YES ☐	2 NO ☐	3 UNSURE ☐

If YES, please explain: Click here to enter text.

Click here to enter text.

Click here to enter text.

Click here to enter text.

Click here to enter text.

END OF PART 2

Id. | | |

ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
ETHEKWINI MUNICIPAL REGION 2015
MODULE 3: DRIVERS

PART 3 DRIVERS

Our company is motivated to invest in energy efficiency because:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3.1.We wish to help alleviate load on the national grid	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.2.There is concern of the rising energy costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.3.We have to comply with stringent energy efficiency product and/or process requirements	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.4.Public financing mechanisms e.g., grants, subsidies and allowances that exist encourage us to adopt energy efficiency technologies.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.5.Management is sensitive about environmental issues and want to reduce the company's carbon footprint	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.6.Other companies within our manufacturing sector have reaped positive results with energy efficiency	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.7.Energy efficiency technologies are appealing and it will improve the company's image as a techno-savvy, modern and fashionable organisation	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.8.Energy efficiency technology products are now competitive in price and therefore offer appealing long term investments compared to standard alternatives	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.9.Energy efficiency offers improved working conditions	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.10.We have to comply with environmental regulations and targets	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.11.It is a strategic investment necessary for the long term survival of the firm	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.12.It improves relations with customers	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.13.It improves staff pride and morale	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.14.It improves product quality	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.15.It reduces production costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Is there anything outside the table above that drives your company to invest in energy efficiency?	1 YES ☐	2 NO ☐	3 UNSURE ☐

If YES, please explain: Click here to enter text.
Click here to enter text.
Click here to enter text.
Click here to enter text.
Click here to enter text.

THE END

THANK YOU FOR PARTICIPATING

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ENERGY EFFICIENCY SURVEY OF MEDIUM AND LARGE MANUFACTURING FIRMS
ETHEKWINI MUNICIPAL REGION 2015
MODULE 3: DRIVERS

FOR OFFICE USE ONLY

Date Completed: ____________________

Comments: ____________________

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Annexure E – Ethics approval

Reference number: EBIT/39/2015 22 June 2015

Mr R Singh
P O Box 167
Desainagar
Tongaat beach
4405

Dear Mr Singh,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Ethics Committee refers.

1 I hereby wish to inform you that the research project titled "Barriers, drivers and opportunities for energy efficiency within medium and large manufacturing firms of the Greater Durban Municipal Area (GDMA)" has been approved by the Committee.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Codes of Research Ethics of the University of Pretoria, if action is taken beyond the approved proposal.

2 According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of any member of the Faculty Committee who will deal with the matter.

3 The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY