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Energy Efficiency and Management in Industries – a case study of Ghana's largest industrial area.

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~In Christ alone my hope is found~

Abstract

The judicious use of energy by industries is a key lever for ensuring a sustainable industrial development. The cost effective application of energy management and energy efficiency measures offers industries with an effective means of gaining both economic and social dividend, also reducing the negative environmental effects of energy use. Unfortunately, industries in developing countries are lagging behind in the adoption of energy efficiency and management measures; as such missing the benefits of implementation.

This study is aims at enhance the knowledge of industrial energy efficiency and management strategies in Ghana, by investigating the present level of energy (and efficiency) management practices in Ghana largest industrial park (i.e. Tema industrial area). The study also incorporates the investigation of also investigation of barriers to and driving forces for the implementation of energy efficiency measure; to shed light on the rationale for both the adoption and non-adoption of cost effective industrial energy efficient technologies in Ghana. This study was carried out using a semi-structure interview due to the explorative nature of the study. The interviews were conducted in sessions, in the first session respondents were asked describe the energy management strategies in used in the respective companies. In the second session, respondents were asked to fill a structured questionnaire covering the various aspects of the study.

The results reveal that energy is poorly managed in the industrial area and there is an energy efficiency gap resulting from the low implementation energy efficiency measures. In addition the reveals that the important barriers impeding the implementation of cost effective energy efficiency technologies or measures in the surveyed firms principally stems from rational behavior economic barriers, which are deeply linked to the lack of government frameworks for industrial energy efficiency. The study also finds that economic gains related to ‘cost reductions resulting from lowered energy use’ and ‘threats of rising energy prices’ are the most important drivers for implementing energy efficiency measures or technologies.

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Table of contents

CHAPTER 1 INTRODUCTION AND BACKGROUND..1
1.1 INTRODUCTION..1
1.2 BACKGROUND..2
1.2.1 Profile of Ghana...*2*
1.2.2 Case Study: Tema Industrial Area...*3*
1.3 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS..6
1.4 METHODOLOGY OF RESEARCH...7
1.5 DELIMITATION 8
CHAPTER 2 OVERVIEW OF ENERGY USE IN GHANA………..……………………………………10
2.1 ENERGY USE IN GHANA 10
2.2 ENERGY MARKET IN GHANA 13
2.3 INDUSTRIAL ENERGY USE IN GHANA..15
2.4 CHALLENGES FACING THE ENERGY SECTOR IN GHANA. 17
CHAPTER 3 THEORETICAL FRAMEWORK…………………………………………………….20
3.1 ENERGY SECURITY..20
3.2 INDUSTRIAL ENERGY USE: A KEY PROMOTER OF SUSTAINABLE INDUSTRIAL DEVELOPMENT. 22
3.3 INDUSTRIAL ENERGY MANAGEMENT...23
3.3.1 Effective Features of Energy Management Systems..*24*
3.3.1.1 Plan Phase..24
3.3.1.2 Do Phase..25
3.3.1.3 Check Phase..25
3.3.1.4 Act Phase 26
CHAPTER 4 LITERATURE REVIEW…...…………………………………………………...27
4.1 ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OF INDUSTRIAL ENERGY EFFICIENCY 27
4.1.1 Environmental *27*
4.1.2 Economic...*28*
4.1.3 Social benefits...*28*
4.2 SYSTEM OPTIMIZATION 29
4.3 ENERGY EFFICIENCY GAP 29
4.4 THEORETICAL BARRIERS...30
4.4.1 Economic barriers *31*
4.4.1.1 Economic barriers market failure related. 32
4.4.1.1.1 Imperfect information...32
4.4.1.1.2 Split incentives..33
4.4.1.1.3 Adverse selection 34

4.4.1.1.4 Principal-agent relationship 34
4.4.1.2 Economic barriers non-market failure related 34
4.4.1.2.1 Heterogeneity 34
4.4.1.2.2 Hidden costs: 35
4.4.1.2.3 Access to capital: 35
4.4.1.2.4 Risk 35
4.4.1.3 Organizational barriers 36
4.4.1.3.1 Power 36
4.4.1.3.2 Culture 36
4.4.1.4 Behavioural Barriers 37
4.4.1.4.1 Forms of information 37
4.4.1.4.2 Credibility and Trust 37
4.4.1.4.3 Values 38
4.4.1.4.4 Inertia 38
4.5 Empirical barriers to industrial energy efficiency 38
4.6 Theoretical barriers vs. Empirical barriers 40
Chapter 5 Results 41
5.1 Background of survey 41
5.2 Efficiency gap and energy management practices in Ghana 42
5.3 Industrial energy efficiency information source in Ghana. 44
5.4 Current energy efficient technology adoption in Ghana. 47
5.5 Barriers to energy efficiency improvement in Ghana 51
5.6 Driving force for improving energy efficiency in Ghana. 54
Chapter 6 Discussion 57
6.1 Challenges of current industrial energy efficiency and management practices in Ghana 57
6.1.1 Lack of policy framework *57*
6.1.2 Lack of access to funds *58*
6.1.3 Lack of management awareness *59*
6.2 Strengths of current industrial energy efficiency and management practices in Ghana 60
6.3 Bridging the industrial energy efficiency gap in Ghana 61
Chapter 7 Conclusion and recommendation 63
7.1 Conclusion 63
Chapter 8 Reference 65
Chapter 9Appendix 70
Questionnaire 70

List of Figures

Figure 1: Map of Ghana 3
Figure 2 : Tema Industrial Area....5
Figure 3: Energy Supply and Demand Sectors of Ghana.....10
Figure 4: Trends of Electricity Consumption by Sectors....11
Figure 5: Trends of Petroleum Consumption by Power Thermal Plants and Oil Refinery 12
Figure 6: Basic Structure of Electricity Sector in Ghana 14
Figure 7: Energy Sources and Industrial Sub-sectors 16
Figure 8: Trend of Industrial Energy use from 2000-2004. 16
Figure 9: Participating Industrial Sectors....41
Figure 10: Distribution of Position of Respondents 42
Figure 11: Energy Efficiency Opportunities 43
Figure 12: Energy Information System....44
Figure 13: Ranked results (from questionnaire) of energy efficiency opportunities information sources.....46
Figure 14: Average scoring of energy efficiency adoption assessment 48
Figure 15: Ranking results of barriers to improving energy efficiency 53
Figure 16: Ranking of driving forces for improving energy efficiency....56

List of Table

Table 1: Distribution of industries in the Tema Industrial Area.....4
Table 2: Names of Stakeholders and their Capacity ....**Error! Bookmark not defined.**
Table 3: Electricity Power Plants in Ghana....13
Table 4: Average scores of energy efficiency hotspots.....49
Table 5 : Classification of important barriers to energy efficiency 52

Chapter 1

Introduction and Background

1.1 Introduction

Energy is essential for the creation of wealth and improvement of social welfare; this means that adequate and reliable supply of energy is required to ensure sustainable development. However, the use and conversion of primary energy most of the time results in waste and emission; they are harnessed from limited resources which are considered environmentally unsustainable. The increasing rate of environmental problems related to energy use has led to a growing interest in issues of sustainable development thereby leading to a challenge of decoupling of economic growth and energy use (environmental threats related to energy use). To achieve this requires the judicious use of resources, technology, appropriate incentives and strategic policy planning (IAEA, 2005).

The judicious use of energy resources and technology to reduce the negative impacts of energy use are firmly embodied in two (2) concepts namely 'energy efficiency' and 'energy management'. Energy management refers to the "strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems" (Chakarvarti, 2011). Energy efficiency on the other hand is defined as a ratio between an output of performance, service, goods or energy, and an input of energy(EU, 2006).Thus,energy efficiency improvement basically refers to the reduction of energy input for a given service, goods or output. Notably, these two concepts advocate for the use of energy resources in a manner that will save energy (natural resources) and ensure minimal wastage, consequently promoting environmental sustainability.

In response to the wave of challenges related to energy use, some industries around the world have reduced energy intensities by adopting and developing energy efficient technologies and management strategies. This is a justification for their high energy end-use and high contribution to energy related environmental problems. By doing so, industries have not only gained improvement in environmental protection, but also gained economic and social dividends.

Numerous studies have highlighted the tremendous gains of implementing industrial energy efficiency and management measures. Notably, some of these studies reveal that greater savings can be realized in developing countries (UNIDO, 2005). Unfortunately, industries in developing countries like Ghana are lagging behind in the adoption of energy efficiency and management measures and as such missing the benefits of implementation. Most of these industries are limited by some critical factors, which mainly stem from a combination of market failures (related to energy-efficient goods and services), organizational failures and irrational human behavior.These factors (barriers) inhibit the adoption or encourage the slow adoption of cost effective energy efficient technologies. These barriers continue to persist in developing countries (despite having been known for years) because of the prevalence of lack of information, poor decision-making and choices, lack of financing and many hidden costs (UNIDO, 2011)

The existence of barriers offers justification for intervention from government authorities and policy makers to bridge the 'efficiency gap' by formulating innovative and comprehensive policies to boost and encourage the energy service market. Nevertheless, for any particular policy to succeed, a sound understanding of the barriers has to be addressed and a realistic assessment of the likely effectiveness of a policy is required (Golove & Eto, 1996).

1.2 Background

1.2.1 Profile of Ghana

The republic of Ghana is a country located in West Africa. It shares borders with Burkina Faso to the north, Togo to the east, Ivory Coast to the west and the Gulf of Guinea (550 km) to the south (Figure 1). The total land area of Ghana is about 238,539 square kilometers; it lies between latitudes 4º 30' S to 11º N and longitudes of 1º 10' E to 3º 15' W. The prevailing climatic condition is tropical with high mean annual precipitation in the southern part of the country and in the northern part, extreme savannah with dry conditions.

Figure 1: Map of Ghana. (Source : www.africa.com)

The national population of Ghana is estimate to be 25 million with a growth rate of 1.822 % (CIA World Fact book, 2011). The entire country is divided into ten administrative regions: Greater Accra, Western, Central, Volta, Brong Ahafo, Eastern, Ashanti, Northern, Upper East and Upper West Region. Each region is further subdivided into districts; these districts serve as the basic units for development. Greater Accra Region is the administrative capital city of Ghana and is important for both its business and industrial activities.

Ghana is well endowed with natural resources such as gold, bauxite and diamonds; its agriculture accounts for roughly one-third (⅓) of GDP and employs more than half of the workforce (CIA World Fact Book, 2011). The Ghanaian economy in 2010 showed a GDP of $2,500 per capita that represent a GDP growth rate of 5.7% with a percentage distribution of the various economic sectors as follows: 33.7% for the Agriculture sector, 41.7% for the Service sector and 24.7% for the Industrial sector.

1.2.2 Case Study: Tema Industrial Area

The city Tema lies 25km southeast of Greater Accra Region. As an Atlantic Coast City, it is locally nicknamed the “Harbor City” because of its status as Ghana's largest Seaport

(Ghanaweb, 2011). Tema has a total land size of approximately 100 km² with a population estimated to be 209,000 as at 2005. Tema is one of the few planned cities in Ghana with welled-ordered series of communities and well-developed infrastructures; the communities are linked with well-constructed roads, highways and railway lines.

The Tema Municipal Assembly is the cradle and hub of Ghana's industrialization, because the municipal houses the largest industrial area in the country. The Tema industrial Area is home to well over 600 industries; which includes aluminum and steel smelting industries, fish and food processing industries, textile industries, chemical industries, cement factories and an oil refinery.

Table 1: Distribution of industries in the Tema Industrial Area (Department of Factories Inspectorate Tema, 2012).

No.	Industrial Sector	Number of
1.	Plastic manufacturing companies	23
2.	Paper Cartons Manufacturing	7
3.	Water Producers	27
4.	Petroleum Refining, Storage & lubricants	67
5.	Cement Companies	2
6.	Flour Mills	7
7.	Lead Companies	5
8.	Scrap Yards	12
9.	Pharmaceutical Industries	6
10.	Cocoa Processing Industries	8
11.	Woodworking Industries	27
12.	Aluminum Companies	22
13.	Steel Companies	8
14.	Roofing Sheets Manufacture	14
15.	Paints Manufacture	6
16.	Miscellaneous Industries, Traders	69

(Note: the table only shows registered industries to the Department of Factories Inspectorates)

Most industries in the Tema Industrial Area are oriented towards fabrication of value added semi-finished and finished products for the Ghanaian, West Africa sub-region and the International market. The industrial area is strategically positioned close to the Harbor, to facilitate both importation and exportation of goods and raw materials; the activities of the industrial area make Tema one of the fastest growing cities in Ghana. The industrial area has no centralized managing body; however, there are some government regulatory bodies like Department of Factories Inspectorate and TMA (Tema Metropolitan Assembly), which are responsible to ensure that companies' operation comply with safety and regulations of the country. The Environmental Protection Agency of Ghana is also a body that ensures that factories in the area operate in an environmentally friendly way.

The total area of the Tema Industrial Area is approximately 23.019 km^2; this area is further sub-divided into two; the heavy and light industrial areas (see figure 2 below). The heavy industrial area contains high production capacity and high energy intensive companies like the Tema Oil Refinery, Volta Aluminum Company (VALCO) and many more. The light industrial area contains the low production capacity and low energy intensive companies like Pioneer Food Cannery Ltd, Cocoa Processing Company and many more.

Unfortunately, firms in the industrial area have been faced with huge economic risk due to hikes of energy prices (especially electricity); this has resulted in a decline of industrial productivity. An industrial intensity survey conducted in the year 2000 by Centre for Policy Analysis (CEPA) in collaboration with Energy Commission Ghana showed that manufacturing industries in the industrial area have very high energy intensive production processes as compared to similar processes in countries like India, USA and Germany. The difference was attributed to poor industrial energy management measure and technologies in Ghana. This spells the need for improving both energy management and efficiency in the area.

Figure 2 : Tema Industrial Area. (Google maps, 2012)

1.3 Research objectives and research questions

The primary aim of this project is to provide a comprehensive overview of the present energy management strategies in the Tema Industrial Area of Ghana. To better explore the nature of energy management strategies in the study area, the project will also investigates the barriers to and the driving forces for the implementation of energy efficiency measure.

Specifically, this thesis aims to:

- Study the on-going energy efficiency and management strategies/measures undertaken by industries in the Tema Industrial Area.
- Study major energy efficiency barriers and driving forces prevailing in Tema Industrial Area.
- Identify measures that can help improve energy management to bridge the present energy efficiency gap.

In order to achieve the aims of this thesis work, the under listed research questions will be addressed:

- What are the adopted industrial energy management strategies in Ghana? How effective are these strategies /measures?

- Is there an energy efficiency gap? What barriers hinder the implementation of energy efficiency measures in Ghanaian industries? What are the implications of such barriers to the industries? What are the driving forces for the implementation of energy efficiency in Ghanaian industries?

- What are the existing policy formulations and execution with regard to industrial energy management in Ghana? What are the implications of the policy with regards to improving industrial energy efficiency implementation in Ghana?

1.4 Methodology

This research analyses the level of implementation of industrial energy management and efficiency in Ghana. It provides comprehensive information about the industrial energy culture of Ghana derived from both primary and secondary data sources. Some of the secondary data sources used includes books, scientific articles, work papers, internet resources and so forth.

The methods used in this research are exploratory and qualitative, tailored to answer and satisfy both the aims and research question. The research employs an extensive review of relevant theories and literature related to energy security, energy management, energy efficiency, barriers to and driving forces for energy efficiency implementation. The study employed the use of semi-structured interviews to gather primary data related to energy efficiency and management practice in the industrial area. The interviews were carried out in two sessions; in the first sessions respondents were asked to describe the energy management strategies used in their respective firms, also they were asked to express their views on barriers and driving forces for energy efficiency implementation in their firms. In the second session, respondents were asked to fill a structured questionnaire covering the various aspects of the study. Every interview was recorded and on the average, each interview took about 40 minutes. The questions were organized under the following topics:

1. Information of the respondent
2. Company profile
3. Annual Energy use
4. Energy information system
5. Energy management profile
6. Energy efficiency opportunities
7. Energy efficiency information source
8. Implementation of specific energy efficient technologies
9. Barrier to energy efficiency improvement
10. Driving forces for energy efficiency improvement

The first four sections of interview guide were designed to derive information about the firm's profile and an overview of energy use and information systems. The fifth and sixth section surveyed the energy management profile and energy efficiency opportunities. In the seventh section respondents to were asked to assess the relevance of energy efficiency opportunities and information sources respectively. The eighth to tenth sections applied the use of a scale to quantify the implementation of energy efficiency measure, barriers to energy efficiency improvement and driving forces for energy efficiency improvements respectively. However, it should be noted that in the quantifications process large simplifications are made by the respondent, thus the results contains several perspective of issues other than the single score on ranking (Rohdin et al, 2007).

The division of energy systems, Linköping University, developed part of the questionnaire concerning driving forces for energy efficiency (through years of research and studies in Swedish industries e.g. Thollander & Ottosson, 2008). The rest of the questionnaires except the energy management profile section were developed by SPRU (2000).

The study also carried out additional interviews with four stakeholders with the intent of gathering information on the current energy efficiency policies and frameworks set by the government of Ghana and lastly gather information on administration of the Tema Industrial Area.

1.4 Delimitation

The study gathered data from 34 companies in the study area, thus the results of the study can be generalized using statistical generalization to provide a true reflection of industries in Ghana; however, the diverse nature of the manufacturing sectors surveyed also makes it difficult to generalize the result to specific sectors. However, these limitations do not defeat the purpose of the case study, because the study area is a high profile area with energy efficiency and management hotspots.

The selection of the companies was done at random based on the Tema Department of Factories Inspectorates list of registered companies. In total 76 companies (76 questionnaires administered) were visited, but due to bureaucracy and poor communication 42 firms declined to participate in the study. The participants of the survey were also reluctant to provide vital information like the annual turnover of the firm, ever when the confidentiality of the information was assured. Some aspects of the questionnaire were thus left blank due to the limited knowledge of the respondent or at times required the assistance of another department.

Assessment of some parts of the questionnaire required quantification; these assessments were subjective and based on the bias of the respondent. Despite this problem, the result of assessment provides a good basis for inferring the level of energy efficiency implementation, barriers to and driving forces for energy efficiency improvement. Review of Ghana's energy use was limited by lack of information or difficulty in accessing information, this problem also stems from bureaucracy within energy services bodies and energy regulatory bodies.

Chapter 2

Overview of Energy use in Ghana

2.1 Energy use in Ghana

The primary sources of energy in Ghana consist of electricity, fossil fuels and biomass; locally, energy production is mainly derived from biomass sources, hydroelectric dams, thermal electric plants and Sun (solar energy). In order to meet the country's energy demand, electricity, fossil fuels and crude oil are imported to supplement the primary indigenous energy production. This energy is supplied to the various economic and non-economic sectors of Ghana, which is made up of the Residential, Commercial & Services, Agricultural, and Fisheries, Transport and Industrial Sector (see figure 3). In 2004, it was estimated that biomass, fossil fuels, electricity and solar accounted for 66.9%, 27%, 6% and 0.1% respectively of total final energy supply in Ghana; corresponding to a net total of 7.1 million TOE (Energy Commission Ghana, 2006a).

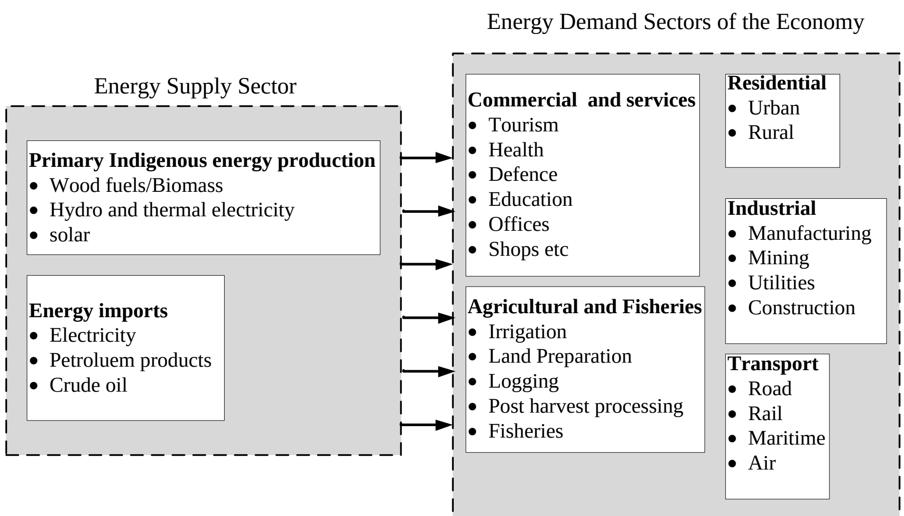

Figure 3: Energy Supply and Demand Sectors of Ghana.

Biomass is Ghana's dominant energy resource in terms of its endowment and consumption (Ministry of Energy Ghana, 2010). Approximately, about 20.8 million hectares of 23.8 million hectare land mass of Ghana is covered with biomass resources. Biomass fuels in Ghana mainly comprise of charcoal, plant residues and wood fuel. Wood fuel is the major form of biomass used as energy source for both domestic and commercial purposes in Ghana; about 90% of rural households depend on wood fuel and other biomass resources for domestic purposes (cooking, and heating, etc). However, the use of charcoal as a cooking fuel is common in urban areas. Some Ghanaian industries like, large sawmills and oil palm mills also use biomass residue to operate Combined Heat Power plants, to generate steam and supplementary electricity for their operation.

Electricity is one of the major modern energy forms boosting the economy of Ghana; it is mainly used in the industrial sector, followed by the residential and commercial (non-residential) sectors (see figure 4 below). In 2010, the industrial, residential and commercial sectors accounted for 46%, 40% and 14% respectively of the total electricity end-use in Ghana. The electricity distribution infrastructure is extensive and provides access to about 66% of Ghana's population (Ministry of Energy Ghana, 2010) with a large proportion in urban areas. For domestic use, urban areas accounts for 88% of residential electricity use whiles rural domestic use accounts for the remaining 12%; the use of electricity by urban residents usually includes lighting, ironing, refrigeration, air conditioning, television, radio, etc, however, the use of electricity for domestic cooking is very negligible.

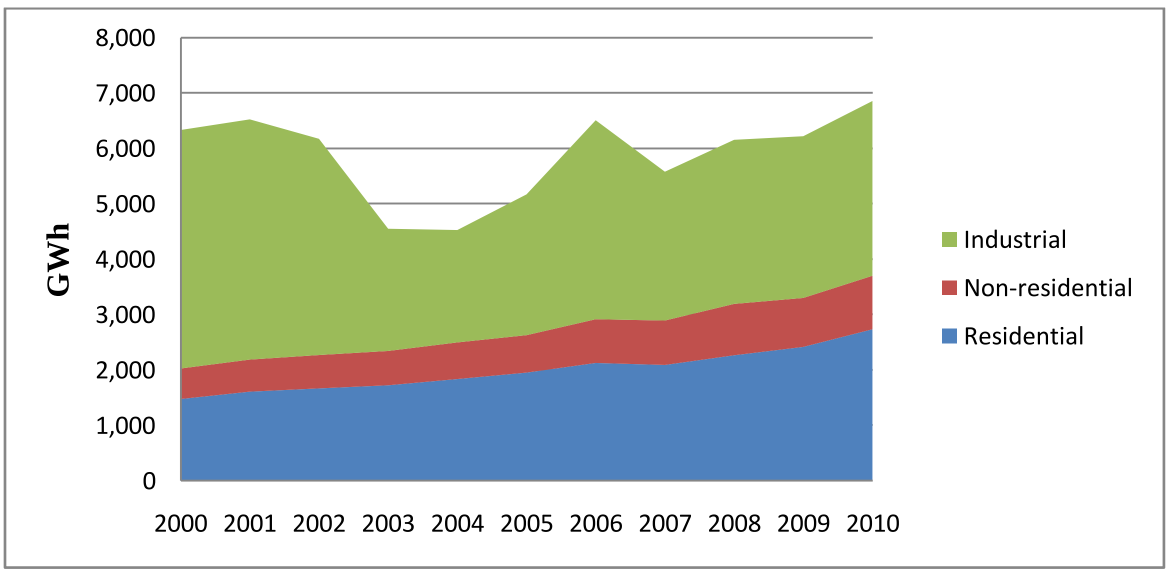

Figure 4: Trends of Electricity Consumption by Sectors (Source : Energy Commission)

The importation of crude oil and fossil fuels also forms an important aspect of the Ghanaian economy, especially in the transportation sector. Petroleum fuels like LPG, kerosene, gasoline, gasoline premix, residual fuel oil and diesel are the commonly used fuels on the Ghanaian market. A portion of the crude oil imported is used to fuel Power Thermal Plants for the generation of electricity ; whiles the rest is used to produce petroleum distillate by the Tema Oil Refinery (See figure 5 below).

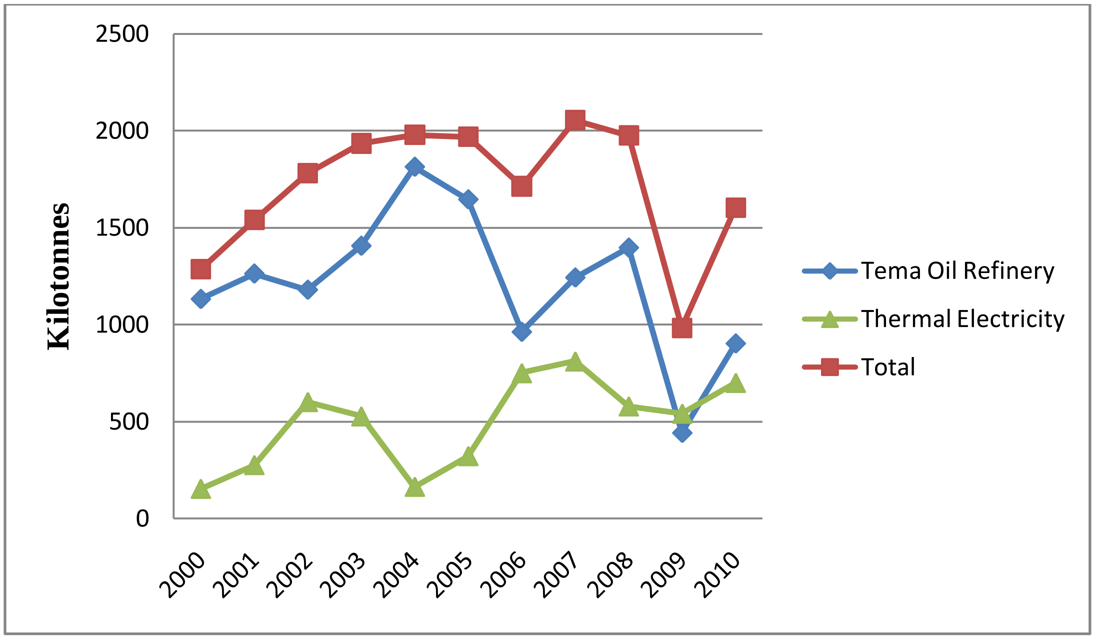

Figure 5: Trends of Petroleum Consumption by Power Thermal Plants and Oil Refinery (Energy Commission Ghana, 2010)

Commercial and residential sectors are the major consumers of LPG; the use of LPG represent about 4-6% of energy use in the residential sector (Energy Commission Ghana, 2006c); whiles a large proportion is used in the commercial and service sectors. Transportation sector accounts for about 99.7% of gasoline use in the economy, with the remaining 0.3% going into industries for general solvent use (ibid). Most (*approximately 85%*) of the diesel produced is taken up by the transport sector, whilst the remaining 9% and 5% go into the industrial and agriculture& fisheries sectors respectively.

The geographic location of Ghana makes the country well-endowed with solar energy, which can be exploited for electricity generation and low heat requirement for both industries and domestic purposes (Ministry of Energy Ghana, 2010). However, this resource is under exploited due to lack of adequate funds to acquire the solar conversion system (both electricity and heat). During the period of 2000-2004, solar energy accounted for over 12-15% of the agricultural and fisheries sector energy share, the use of solar energy in this sector is mainly for drying cereals, cocoa and other agricultural products.

2.2 Energy market in Ghana

Just like any other country, energy plays an important economic role in Ghana. The nexus between economic development and access to energy has from time to time raised debates on the inadequacies and inefficiencies existing in the Ghanaian energy market. These inadequacy and inefficiency have serious impacts on profit margins of businesses, employment and as well as government revenues goals. The formal Ghanaian energy market can be described as a centralized market which is mainly controlled by government institutes. These institutes are responsible for planning activities, regulatory activities and development of the energy market.

Approximately 57% of Ghanaian live in rural areas and most of these people lack access to modern form of energy like electricity and petroleum products as such most rural dwells rely heavily on biomass resources for energy. Wood fuel is the dominant and cheapest fuel available on the Ghanaian market; the production, transportation and sale of wood fuels are all undertaken by the private sector. There is no official government pricing regulatory body responsible for setting the prices of wood fuels in Ghana; rather the pricing is dependent on the supply and demand conditions.

Hydropower and imported fossil fuel are the main energy sources used to generate electricity in Ghana (fossil fuel is used to generate thermal electricity). In the year 2010, the amount of electricity generated amounted to 10166 GWh, hydro-electricity accounted for 6995GWh and the rest (3171GWh) from thermal electricity. Ghana has a combined capacity of both hydro and thermal electricity installation of 1960MW; electricity demand as at 2010 was 1400MW and this demand has a growing rate of 10% per annum (Ministry of Energy, 2010). The table below shows the electricity power plants in Ghana.

Table 2: Electricity Power Plants in Ghana

Hydro Power Plants	**Thermal Power Plants**
• Akosombo Hydro Power Plant • Kpong Hydro Power Plant	• Takoradi Power Company (TAPCO) • Takoradi International Company (TICO) • Mines ReservePlant (MRP) • Tema Thermal 1 Power Plant (TT1PP) • Tema Thermal 2 Power Plant (TT2PP) • SunonAsogli Power (SAP)

State owned companies solely undertake the generation and management of electricity in Ghana; Volta River Authority (VRA) is the company responsible for the generation of electricity and operates all power plants in Ghana. Electricity Company of Ghana (ECG) and the Northern Electricity Department (NED) (a subsidiary of VRA) are in charge of the distribution of electricity. Whereas, Ghana Grid Company (GRIDCO) is the body responsible for the transmission system of electricity (see diagram below).

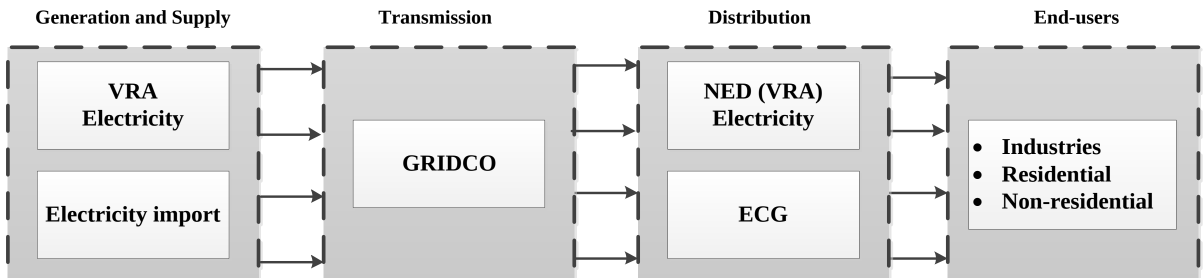

Figure 6: Basic Structure of Electricity Sector in Ghana

The Public Utility Regulatory Commission (PURC) and the Energy Commission are the bodies responsible for regulating the electricity supply industry (Ministry of Energy, 2010). PURC is the body mandated by government to set electricity tariff; the tariffs are normally set in consultation with key stakeholders made up of the generators, distributors and the representatives of major consumers (Energy Commission Ghana, 2006). The Energy Commission on the other hand is responsible for technical regulation and advising the Ministry of Energy on energy planning and policies. The electricity supply system in Ghana is divided into bulk electricity (transmission level) and final electricity (distribution level) (ibid). A block end user tariff system is used in Ghana and this is classified largely into industry, commercial (non-residential) and residential customers. The average tariff for final electricity use currently ranges between 5.2-8.2 US cents per unit; this tariff rate is relatively lower compared to other neighboring countries like Benin and Togo (ibid).

Until 2011, Ghana was a non-oil producing country and depended largely on crude oil export to meet national demands. The discovery of oil is expected to stimulate economic growth and reduce poverty in Ghana. The petroleum sector in Ghana is divided into 3 segments namely; upstream, midstream and downstream. These segments cover activities from exploration and production of petroleum through to transportation to the marketing of the final products (Ministry of Energy Ghana, 2010). The Tema Oil Refinery is the only refinery in Ghana and it has a 45,000 Barrel-Per-Stream-Day capacity. Approximately 70% of petroleum product demand of Ghana is met by the Tema Oil Refinery's supply, whiles the remaining 30% of demand is supplemented by imports of petroleum products. The bulk supply of petroleum products across the country in achieved by an extensive infrastructure network comprising of storage depots located at strategic parts of the country, pipelines for the movement of petroleum products, Bulk Road Vehicles and also barges located on the Volta Lake (Ministry of Energy Ghana, 2010). The National Petroleum Authority is the sole body responsible for setting petroluem prices in Ghana. This authority is also responsible for licensing petroluem operator downstream and also incharge of setting technical standard and enforcements to regulate the petroluem industry of Ghana.

2.3 Industrial energy use in Ghana

The nation Ghana has a fairly large and vibrate industrial sector which contributes about 24% of the country's Gross Domestic Production (Wikipedia,2011); these industries are made up of mining, lumbering, manufacturing, aluminum smelting, food processing, cement and small commercial ship building(CIA World Factbook, 2011). This sector mainly produces and provides services not only to the local Ghanaian economy but also to the West Africa sub-region at large; and some semi-processed products are exported internationally to generate capital.

The major energy sources used for industrial purposes are wood fuels, electricity and petroleum products (diesel, gasoline and residual fuel oil) (see figure below). Industrial energy in this sector is used by subsectors like mining, utilities, manufacturing, construction and The Volta Aluminum Company (VALCO) (an aluminum smelting company). According to the Ghana Statistical Service, the manufacturing sector of Ghana is subdivided into formal and informal manufacturing companies; formal manufacturing companies consist of large industries like smelting companies, cement factories, textile factories and many more. The informal group comprises of small scale manufacturing businesses like carpentry and craft businesses. Since 2000, the manufacturing subsector has been the dominant energy consumer, accounting for about 74% of industrial energy share, followed by Mining and quarrying (9-10%) (Energy

Commission, Ghana, 2006c). Both the utilities and construction subsectors consume approximately about 2-3% of the annual industrial energy use (ibid).

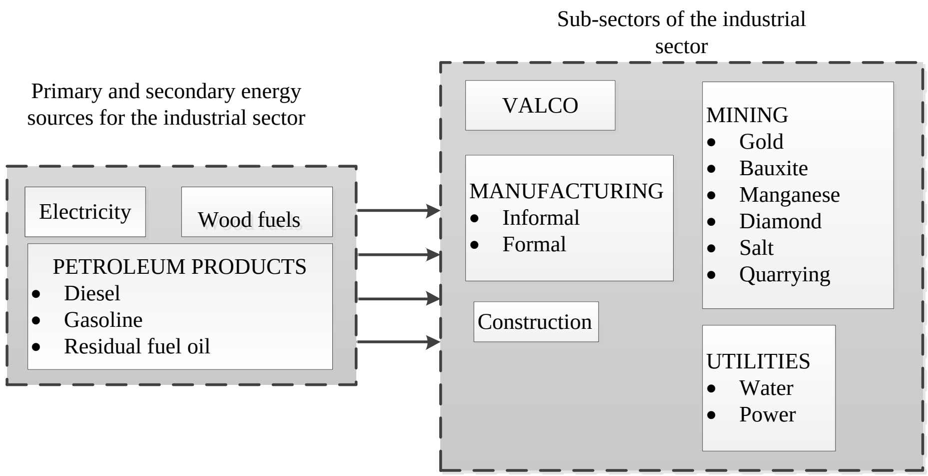

Figure 7: Energy Sources and Industrial Sub-sectors (Dis-aggregation adopted from the Ghana Statistical Services' classification)

The industrial sector is the largest consumer of electricity in Ghana, also electricity represent the largest form of energy used in the industrial sector (excluding informal manufacturing sector) it accounted for about 55-56% of the total industrial energy share during the period of 2000-2004 (see figure below). Most formal manufacturing companies (high-energy intensive) in Ghana are highly reliant on electricity; as such, hikes in electricity prices and unreliable supply of electricity affects the productivity of these industries.

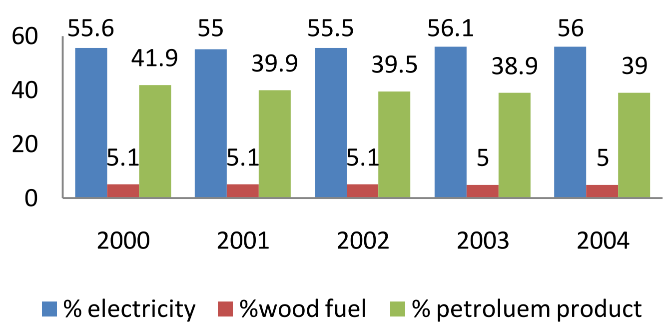

Figure 8: Trend of Industrial Energy use from 2000- 2004. (Energy Commission Ghana, 2006a)

Industrial electricity billing in Ghana consists of the following elements:

- Maximum demand in kVA
- Electrical Energy Consumption in kWh
- Power Factor surcharge
- National Electrification Scheme (NES) Levy per kWh
- Street Lighting Levy per kWh and a Service Charge

The maximum demand is charged according to highest kVA consumed over a period of thirty minutes during the month. Industries are also charged per unit kWh used in a month; industrial electricity bills also include the charging of power factor surges experienced. Industrial electricity bills are charged with the NES (National Electrification Scheme) and street light levies to subsidize domestic electricity use.

The predominant petroleum products used in the industrial sector are diesel and residual fuel oil. Petroleum products are the second largest energy form used in this sector; its share ranges between 38-42% during the year 2000-2004.Diesel is mainly used to power diesel engines in industrial outfits, whiles the residual oil is mainly used for heating purposes. Some industrial outfits in Ghana use gasoline to power their standby electricity generator when there is power outage.

The industrial sector is the second largest consumer of wood fuel in Ghana and it accounts for about 25% of total wood fuel (Energy Commission Ghana, 2004b). Wood fuel is the most used fuel in the informal manufacturing subsector. The use of wood fuel in this sector is mainly for firing boilers and other heating processes.

2.4 Challenges facing the energy sector in Ghana.

Issues of energy security constantly threaten Ghana's economy; these issues stem from challenges facing the energy sector of Ghana. The energy challenges in Ghana are mainly centralized on the supply side of the sector, thus undermining accessibility, affordability and reliability of energy supply. The development framework of Ghana is governed by two documents; The Ghana Poverty Reduction Strategy and the Coordinated Program of Economic and Social Development (Armah, 2003).The objectives of both frameworks are to provide strategies to boost economic growth and reduce poverty in Ghana. A critical factor for the successful realization of these growth objectives will be the ability to meet the energy needs of the country (Armah, 2003). Consequently, the expected economic growth coupled with population increase can further increase the challenges of energy access in Ghana.

In order to meet local demand of fuel, the economy of Ghana is now over dependent on the importation of crude oil to the extent that, crude oil imports represent a large portion of Ghana's international trade transactions. In 2001, crude oil importation accounted for approximately 80% of the trade deficit (Armah, 2003). Between the periods of 2000-2004 the volatile prices of crude oil also increased the cost of crude oil importation from US$280 million to over US$ 500 million respectively (Energy Commission Ghana , 2006a); thus the economy of Ghana is very sensitive to the price of crude oil. On a downside, an increase in the energy demand of Ghana (due to economic growth and population increase), can further increase the vulnerability of the country's economy to the volatile price of crude oil and subsequently lead to an economic instability. The over reliance on wood fuels for cooking is also another challenge facing the energy sector of Ghana; the excessive use of wood fuels by the rural communities due to their lack of access to other forms of energy and poverty, is a primary cause of deforestation in Ghana.

Energy losses as a result of inefficient conversion, distribution and use of energy resources are huge challenges in Ghana. Energy losses totaled about 26% of the total primary supply in 2000 and increased to about 30% in 2004 (Energy Commission Ghana, 2006a). The resultant high loss of energy on the supply side (utility side) is as a result of obsolete equipment and a lack of technical capacity to effectively manage the conversion and distribution of energy. The use of inefficient equipment for lighting, cooking/heating and cooling purposes is the major contributors of energy loss on the demand side of the economy. Growing concern regarding energy efficiency on both supply and demand side of the energy sector has necessitated action by the government of Ghana to reduce these inefficiencies. One of such action is the promotion of high-energy efficient lamps (CFL) in households. Additionally the Energy Commission of Ghana has introduced an appliance standards and labels to control the importation of inefficient second hand appliances into the country. With regard to commercial and industrial sectors, the government has made attempt to reduce government expenditure on electricity by installing Automatic Capacitor banks in some public facilities, also the Energy Commission of Ghana has embarked on numerous sensitization programs to promote and encourage the adoption of energy efficiency by private commercial and industrial outfits. The accumulated effects of these actions by government have resulted in significant energy saving; however, there still exists wide efficiency gap in the energy sector.

Lack of capital is a major challenge impeding the expansion and progress of Ghana's energy sector. Consequently, the energy sector lacks the capacity to adequately invest to meet the expanding demand of energy in the country; this problem mainly comes from the fact that energy pricing in the sector is not cost effective and as such Ghanaian energy service companies have a poor financial position in the energy market to make profits. Solar energy and other renewable source have a high potential of providing energy especially to rural locations in the country, but these resource are barely exploited due to lack of funds to afford the systems of conversion.

A large fraction of Ghana's electricity is generated from two hydro-electric dams (approximately 70% of actual electricity generated), as a result the Ghanaian economy faces severe electricity crisis when there is low water inflow into the hydro-electric dams. In recent time Ghana has experienced three drought-related electricity crisis; in 1998, 2002 and 2006 all resulting in an expensive load shedding program to cut down and manage the demand load of the country. This severe series of drought related electricity crisis has resulted in the shutting down of companies and industries in Ghana.

Chapter 3

Theoretical Framework

3.1 Energy security

In the last few decades, debates on sustainable development have been a high profile topic amongst policy makers and researchers worldwide; in the advent of rapid global economic and industrial growth, issues of energy use have also gained high attention in the same respect. Since, energy is an essential input for every nation; and it plays a vital role in the economic and security of any nation (Pode, 2010). Topical in the debate of developing a sustainable energy system is "Energy Security", this concept describes the ability to supply or utilize energy in a manner that is reliable, affordable, accessible and environmentally friendly. The World Bank Group defines Energy Security more broadly as the means of a country to produce and use energy in a sustainable manner and at a reasonable cost in order to; facilitate economic growth and, through this, poverty reduction; and directly improves the quality of peoples' lives by broadening access to modern energy services (World Bank Group, 2005). However, it is important to note that, notion of energy security frequently differ by personal and institutional perspectives, national styles, geology, geography, and time (Sovacool & Brown, 2010). This has resulted in diversity of definitions and perceptions, for instance the World Bank definition of energy security is based on three pillars that is energy efficiency, diversification of supply, and minimization of price volatility (World Bank Group, 2005). From an end users' perspective, energy security entails the supply of energy service without disruptions (Sovacool & Brown, 2010). For energy producers, it is the ability to secure long term and attractive markets for their natural resources that often underpin their economies (World Bank Group, 2005).In general, energy security consists of four interconnected criteria or dimensions: availability, affordability, efficiency, and environmental stewardship (Sovacool & Brown, 2009).

Availability dimension of energy security refers to procuring sufficient amount of energy to ensure uninterrupted supply and reduce foreign dependency on fuel (Sovacool & Brown, 2010). Availability in part also involves the diversification of energy service that can help in reducing energy security risk of individual. Diversification encompasses three dimensions namely (ibid):

- Source diversification requires utilizing a mix of different energy sources, fuel types, and fuel cycles.
- Supplier diversification refers to developing multiple points of energy production so that no single company or provider has control over the market.
- Spatial diversification means dispersing the locations of individual facilities so that they cannot be disrupted by a single attack, event, malfunction or failure.

Access to affordable and equitable energy supply is an important aspect of any country's energy security. Basically, the affordability dimension defines the provision of energy and energy services at a price that is affordable to all citizens in a country. Volatile energy prices can disrupt the energy security of a country; therefore, energy fuels and services must not only be affordable, but their prices should be stable (Sovacool & Brown, 2010).

Efficiency is a cost effective means of ensuring energy security by minimizing the unit resource input per unit output. Efficiency can be subdivided into parts namely economic and energy efficiency. In the economic sense, efficiency is the measure of improvement performance or increased deployment of more energy efficiency equipments and conservation (Sovacool & Brown, 2010).Whiles, energy efficiency refers to the improving the performance of energy equipment and altering consumer attitudes (Sovacool & Brown, 2009).

In recent years, the growing interest and consciousness of environmental protection is a major boost for issue of energy security; stakeholders worldwide are trying to find innovative means to protect the environment by minimize energy consumption from carbon intensive and non-renewable sources. The Environmental Stewardship emphasizes the importance of environmental sustainability, which consists of protecting the natural environment, communities and future generations (Sovacool & Brown, 2010; Sovacool & Brown, 2009).

3.2 Industrial energy use: a key promoter of sustainable industrial development

The quest to attain sustainable industrial development is one of the greatest challenges of the 21st century. Besides the fact that industrialization has brought unprecedented improvement of wealth and prosperity, industrialization has also produced many externalities. Externalities like the overexploitation of natural resources, air and water pollution, climate change and massive accumulation of waste on the earth surface. In recognition of the earth's limited capacity, researchers posit that industrial development must progress in a sustainable direction to insure that the needs of this generation are met without compromising the ability of future generations (UNIDO, 2011); this involves taking into consideration environmental protection, social advancement and economic development. The exploitation and harnessing of primary energy sources for industrial purposes is one the major threats of industrial development; thus, the progressive development of industrialization is vital dependent on industrial energy use.

The industrial sector uses more energy than any other end-use sectors and this sector represent about 37% of the world's primary energy consumption (Abdelaziz ,Saidur & Mekhilef, 2011); also industrial energy consumption is projected to grow at 2.4-3.2% per year through 2030 in developing countries and 1.2% in developed countries (UNEP, 2007).

For industries to operate in a sustainable manner it is then required that innovative mechanism are tailored to solve the negative impacts of industrial energy use particularly climate change. Industrial energy efficiency and management are effective means of mitigating the negative effects of industrial energy consumption and at the same time ensuring the improvement of both productivity and competitiveness of industries. In line with increasing industrial efficiency, industries need to switch energy sources (especially from carbon intensive sources) so that operations use the most suitable energy source, which can reduce environmental impacts of energy use (UNIDO, 2011). Energy efficiency standards for industrial motors have proven to be one of the most cost-effective methods of increasing energy efficiency in industries. The harnessing of low-grade heat from processes industries is another means of increasing the overall energy efficiency significantly (UNEP, 2007).

Improving energy efficiency goes beyond the efforts of individual industries; it also involves the active participation of governments and policy makers. Governments are responsible for enforcing market-based measures such as taxes and fees to encourage energy conservation; strict pollution policies; subsidies to stimulate cleaner technologies development and adoption.

3.3 Industrial energy management

Numerous studies conducted in the field of industrial energy efficiency shows that there are tremendous saving potential that can be achieved through the effective implementation of energy management in industries. A study by Caffal (1996) revealed that industrial energy management has the potential of saving about 40% of energy use in an industrial facility. Between the period of 1990-2009 Dow Chemical, reduced it's energy intensity by 38% by implementing an energy management system, which corresponding to an energy saving of 1,700 trillion Btu (Dow, 2012).Toyota North American Energy Management Organization also reduced energy use per unit by 23% since 2002 by applying an energy management system (Scheihing, 2009).However, the viability of such industrial energy saving potentials are dependent on a variety of factors like technical, economical, institutional and political (OTA,1993); consequently, these factors are either directly or indirectly related to the energy management of an industrial facility.

Energy use in industries is more dependent on operational practices (specifically energy culture of the industrial facility) than in the commercial and residential sectors (McKaneWilliams, Perry& Li, 2007). As such, most industrial energy efficiency improvements is achieved through changes in how energy is managed (or used) in the facility, rather than through installation of new technologies (McKane, 2009). Accordingly, it is then evident why upgrading the efficiency of technologies alone cannot achieve optimal savings, but when combined with operational and maintenance practices as well as management systems can lead to significant savings (Scheihing, 2009).

The implementation of energy management system in facility provides an enabling environment to identify opportunities for and to realize energy savings in a sustainable manner (Worrell, 2009); and also provides industries with the opportuntiy of integrating energy efficiency practises to suit existing management systems. Consequently, energy management is a key lever to realising a sustainable industrial energy efficiency worldwide. Several energy management system standards do currently exist at the national level (e.g. Denmark, Ireland, Sweden, United States, Spain, South Korea) or are under development (China, Europe via CEN and CENELEC, South Africa, Brazil) (UNIDO, 2008). Currently there exist new international energy management standards like the ISO 50001 and EN16001 which are designed suitable for energy management in all types and size of businesses across the worldwide. Both management systems are built on existing national standards and initiatives and successful ISO management standards (like ISO 9001 and ISO 14001).

3.3.1 Effective features of energy managementsystems

The purpose of an energy management standard is to provide guidance for industrial facilities to integrate energy efficiency into their management practices, including aligning production processes and improving the energy efficiency of industrial systems (McKane, Price and Rue du Can, 2008). Specifically, an energy management standard offers an expert and best practices framework for organizations and enterprises to develop energy efficiency goals, plan interventions, prioritize efficiency measures and investments, monitor and document results and ensure continuity and constant improvement of energy performance (UNIDO, 2008).

Most management standards (including energy management systems) are designed based on Plan-Do-Check-Act (PDCA) model, which fosters an organizational culture of continuous improvement in energy efficiency. The culture of continuous improvement ensures set goals are achieved in a gradual and continuous manner; in addition, it ensures that set goals are realistic, achievable and suits the resources (personnel, economic and technical) available to the firm.

3.3.1.1 Plan phase

One key requirement of an energy management standard is the establishment of an energy policy, which entails the energy plan, goals, commitments, targets and procedures of the top management; the energy management plan is implemented through an energy management program. McKane et al (2008) states that, “In companies without a plan in place, opportunities for improvement may be known but may not be promoted or implemented because of organizational barriers”. Therefore, the formulation of an energy plan and its implementation through an organizational-wide energy program is a cost effective means of overcoming energy efficiency barriers and improving energy efficiency. Energy audit is an important feature of an energy management systems; an audit is carried out to gather relevant historical data concerning energy consumption trends. An energy audit is conducted at the beginning of a program to establish both the present and past energy consumption of the facility; based on these data energy hotspots can be identified and benchmarks can be drawn for evaluating improvements. Energy audits are also conducted to assess the level of progress of ongoing programs.

3.3.1.2 Do phase

The Do Phase involves the implementation of the energy management program by aligning operation and activities of the firm to reduce energy use of equipment systems and processes.

A successful energy management program begins with a strong organizational commitment to continuous improvement of energy efficiency (Worrell, 2009); thus, an energy management program involves the assigning of management duties and the creation of a cross-functional energy committee in the Plan Phase. The responisibility of the committee is to steer and monitor the program and ensure the continuous improvement of goals; the motivation of worker (personnel) by top management is an effective means of involving company personnel with diverse expertise into the energy management program. The first step in an energy management program involves the training of the committee and workers of the firm at large, this is done to build the needed energy management competence and inform workers. The creation of documentation like an energy manual is an effective means of communicating and educating working personnel of the energy program.

3.3.1.3 Check phase

This phase aims at monitoring and measuring the performance (by conducting energy audits) in terms of energy saving and comparing objectives and set targets. If there are any shortfalls, it is then necessary that the causes are identified and analyzed to make corrections in order to realize set goals. It thus important that set goals should be quantifiable to facilitate the assessment of progress and improvements.

3.3.1.4 Act phase

The act Phase basically involve management reviews of audit, internal and external reports pertaining to the performance of the energy management program.Theses reports play an important role for the organisation to identify shortfalls and other missed hotspots to act upon them to ensure continual improvement.

Chapter 4

Literature Review

4.1 Environmental, economic and social benefits of industrial energy efficiency

4.1.1 Environmental

The extraction, treatment and end-use of most energy resource emits enormous amount of gases and aerosols, which includes greenhouse gases, nitrogen and sulphur oxides, metals (mercury, arsenic, nickel and cadmium) soot, dioxins, etc; these emission have detrimental effects on the environment. The increasing concentration of greenhouse gases has in recent time received the most attention due to its prevalent environmental effect. The Industrial sector contributes directly and indirectly about 37% of the global greenhouse gas emissions, of which over 80% is from energy use (Worrell , 2011). Consequently, industrial energy use has for a long time been identified as a key area of mitigating global warming. For this to be achieved, industries must change their energy culture by investing extensively in energy efficiency measures and practices.

Fossil fuel combustion in industrial equipment (boilers, furnaces, kilns) and in power generation produces large-volume air pollutants, such as sulphur dioxide, nitrous oxides and particulate matter, all with harmful consequences to human health and the environment (UNIDO, 2011). By applying the appropriate technology, industrial fossil fuel consumption and the related negative effects can be reduced.

Global industrial production involves massive extraction and processing of natural resources, which includes fossil fuels, ores, water and other raw materials. The exploitation of such resource is resulting in a rapid depletion of the earth’s natural resources; resource depletion is a particular concern for primary energy from non-renewable resources, both fossil and nuclear fuels (Ayres, 2010 cited in UNIDO 2011). Exploiting energy resources has accompanying negative effects like displacement of massive material, waste creation and pollution. The use of energy for industrial purposes also depletes other natural resources such as water, which is used for cooling power stations and energy intensive industrial processes (UNIDO, 2011). Thus, improving industrial energy efficiency is an effective means of reducing and improving both material and water use in industries; consequently, slowing down natural resources depletion.

4.1.2 Economic

The profit of a business is expressed as difference between sales revenues and input costs; the greater the difference the greater the profit margin. In competitive markets, firms tend to be price takers (UNIDO, 2011); as such firms have little control of the price of their goods on the market, which also implies that they have little control over their sales revenue (assuming production capacity is constant). In contrast, firms have a greater control of their input cost. The input cost of firm mainly includes utility costs (energy and water), labor cost and raw material cost. Consequently, input costs can be reduced in the short-term by optimizing production methods, using cheaper inputs and improving materials and energy use efficiency and in the long-term by introducing new equipment (UNIDO, 2011). Companies can realize significant profit margins by implementing energy efficiency by reducing both energy and material resources, when energy forms a large proportion of their input cost.

With the variability of global energy prices coupled with the rise of energy prices, companies that adopt energy-efficient technologies stand a greater chance of enhancing their long-term competitiveness and productivity; this is achieved by reducing the company's energy dependency and increasing security of energy supply. Investment in efficient technologies generally results in significant energy savings and an improvement in the quality of products. By implementing energy efficiency, firms can either reduce or avoid emissions and pollution taxes and levies.

4.1.3 Social benefits

Firms and industries that implement energy efficiency cost effectively improve productivity; increase in productivity is the main factor responsible for both industrial and economic growth. As such, an improvement in productivity translates into higher profit margins that can be redistributed as increased wages and also invested to expand output, benefiting both supplier and consumer (UNIDO, 2011).Improving productivity (as a consequence of increased industrial energy efficiency) can lead to the development of new innovations which can create new jobs and also expand employment. The implementation of energy efficiency can also improve the working environment of firms and the quality of life of the society.

4.2 System optimization

Evidence from industrial efficiency programs in China, United Kingdom and United States confirms that individual components have an improvement potential of 2-5% versus 20-50% for complete system improvement (REEEP,2007) ; thus, system optimization (in relation to energy efficiency) represents a more effective means of providing improved energy utilization for production process at the least cost possible. However, most adopters of industrial energy efficiency technologies tend to focus on individual components rather than a complete system optimization; and as such missing on the great saving opportunities that can be derived from system optimization. System optimization cannot be achieved through a standard energy efficiency approach (McKane et al, 2007); due to variation in equipment application, operational and management characteristics of industrial systems.

Individual energy efficiency improvement of technologies normally leads to misapplication of the technology (UNIDO, 2007) and consequently leads to problem shifting or sub-optimization. However, applying a Systems approach to improving energy efficiency will give a wide perspective and thus help in the proper application of technology to achieve a greater effect; also system optimization sheds light on root cause of inefficiency. Since the overall system performance depends on the individual component performance and more importantly the system design and operation (UNIDO, 2011), it is important that system optimization consider technical parameters of individual components and systemically upgrade and improve efficiencies of components.

4.3 Energy efficiency gap

Currently, countries worldwide are faced with challenges which are redefining global energy consumption. Higher energy prices, increased environmental consciousness and strict policy instruments and regulations affirm the importance of improving energy efficiency. Despite the great need to increase energy efficiency across boards, studies indicate that cost-efficient energy saving measures are not always implemented and this implies the existence of an "efficiency gap" (Rohdin, Thollander & Solding, 2007).

The efficiency gap is a phrase widely used in the energy-efficiency literature; it refers to the difference between levels of investment in energy efficiency that appear to be cost effective (based on engineering-economic analysis) and the lower levels actually occurring (Golove & Eto, 1997). Technologists and engineers are optimist that technological improvement is the pathway to improving energy efficiency. Consequently, this raises the question of why the existence of cost effective technologies have not bridged the ‘efficiency gap’; from an economist perspective the reason is attributed to market barriers that impede the diffusion of optimal technologies.

The definition of the efficiency gap seems quite easy at first glance, however, the definition becomes more complex when one attempts to identify or define the optimal level of investments, processes or technologies to be taken up by an industry or consumer (The Allen Consulting Group , 2004). Thus determining the size of the energy efficiency gap requires a clear definition of the optimality level of the investment. In a research on energy efficiency gap by Jaffe and Stavins (1994) five (5) separate levels of optimality were identified: the economists’ economic potential, the technologists' economic potential, hypothetical potential, the narrow social optimum and the true social optimum.

The energy efficiency gap asserts the existence of barriers to cost effective energy efficiency investments. Thus, understanding the nature and magnitude of the efficiency gap creates a baseline for understanding the nature of some prevailing barriers to energy efficiency. However, there are in existence some structural barriers or institutional barriers to energy efficiency that do not affect the ‘gap’ (SPRU, 2000), as such the study of these barriers do not complement the efficiency gap.

4.4 Theoretical barriers

The prospects of increasing energy efficiency are vast; however, they are usually overlooked since the potential of increasing energy efficiency are shrouded by critical limiting factors. These limiting factor are referred to as ‘barriers’ where in this context a barrier can be defined as: A postulated mechanism that inhibits investments in technologies that are both energy-efficient and (apparently) economically efficient(Sorrell et al., 2004; Rohdin & Thollander, 2006; SPRU, 2000). In order words a barrier comprises of all factors that hamper the adoption of cost-effective energy-efficient technologies or slow down their diffusion in the market (Fleiter ,Worrell & Eichhammer, 2011).

The study of barriers to energy efficiency is an interdisciplinary field with contributions from economics, engineering and social science. More specifically, the concept of barriers originates from theoretical backgrounds like, neo-classical economics, organizational economics, behavioral theory and organizational theory (SPRU, 2000). Based on these theories, barriers to energy efficiency are broadly classified under three main categories namely Economic, Organizational and Behavioral (Psychological) barriers (Palm & Thollander, 2010; Sorrell et al ,2004, SPRU, 2000). Nevertheless, these theoretical classifications of barriers are not exclusive (Weber, 1997); since, some barriers can have an overlapping perspective (SPRU, 2000), this means a barrier can have more than one meaning depending on the perspective of analysis. A taxonomy of barriers to energy efficiency developed by SPRU (2000) classified 15 theoretical barriers based on a comprehensive review of literature; the essence of developing the taxonomy was to unifying ideas of barriers to energy efficiency from existing theories (SPRU, 2000).

4.4.1 Economic barriers

The concept of barriers to energy efficiency originated from mainstream economic theory. However, the application of only mainstream economic theory is inadequate to fully grasp the understanding of barriers to energy efficiency; as such economist have widen the scope of study by incorporating new economic concepts like organizational and transaction economic (SPRU, 2000). Economic barriers can be subdivided into two categories namely, economic market failure and economic non-market failures. According to neo-classical economist, the basic theorems of welfare economic that governing an optimum market states that the allocation of resources will be optimal where (SPRU, 2000):

- A complete set of markets with well-defined property rights exist such that buyers and sellers can exchange assets freely;
- Consumers and producers behave competitively by maximizing benefits and minimizing costs;
- Market prices are known by all consumers and firms; and
- Transaction costs are zero.

In principle, a violation of these conditions can lead to the generation of four broad types of market failures namely, incomplete markets, imperfect competition, imperfect information and asymmetric information. In other words, a market failure can be defined as factors that inhibit the proper functioning of the market (diffusion of energy efficient technologies) and provide justification for government intervention (Jaffe & Stavins, 1994). Most empirical studies of energy efficiency are centered on two main market failures namely; imperfect information and asymmetric information (SPRU, 2000); the reason for this special3 interest is that both imperfect and asymmetric information adequately explain the existence of an efficiency gap in all studies. Whiles the other two market failures (incomplete market and imperfect competition) are less relevant to explaining the efficiency gap (ibid). Mainstream economic theory postulates that a true market failure may justify public policy intervention to improve energy efficiency (Jaffe & Stavins, 1994). However, according to Sanstad & Howarth (1994), market failures are pervasive and as such, the mere existence of market failures may not always be sufficient to justify government interventions.

Economic barriers related to market failure identified in literature are imperfect information, split incentives, adverse selection and principal-agent relationships. Heterogeneity, hidden costs, lack of access to capital and risks are barriers, which may be classified as non-market failure or market barriers. Market barriers exist although the market is functioning (Jaffe & Stavins 1994); and as such can be defined as any obstacles that are not based on market failures but which nonetheless contribute to the slow diffusion and adoption of energy-efficient measures (Brown, 2000).

4.4.1.1 Economic barriers market failure related.

4.4.1.1.1 Imperfect information

Information is a critical tool for making cost effective decision related to energy efficiency measure and as such imperfect information or insufficient information about the energy performance of technologies and measures can lead to sub-optimal decisions; consequently inhibiting investment or leading to underinvestment in efficient technologies (SPRU, 2000). There are several forms of imperfect information existing in energy services markets; Golove & Eto (1996) have identified three (3) forms of imperfect information which are as follows;

- Lack of information: Lack of information related to capital cost and operation cost can lead the consumer to make an irrational decision.
- Cost of information: The implicit cost of searching and acquiring information on energy performance of technologies can cause a consumer to make decision without acquiring full information thus, leading to a suboptimal investment.
- Accuracy of information: Acquiring accurate information on energy service market is difficult, since sellers of technologies may exaggerate or manipulate performance of technologies. As such, inaccurate information can lead to suboptimal investments.

According to Huntington et al (1994) (as cited in SPRU,2000), information problems (imperfect information) are the principal source of market failures. Consequently, problems of imperfect information provide a rationale for policy intervention (SPRU, 2000).

4.4.1.1.2 Split incentives

Split incentive is a form of market failure resulting from asymmetric information (Jaffe & Stavins, 1994).This form of barrier arises when there is disparity of benefits from investing in energy efficiency, such that, one party gains more than the other. In other words, split incentives may be explained as the inability to appropriate the benefits of an investment, or alternatively as a manifestation of asymmetric information and transaction costs (SPRU, 2000). Consequently, the existence of split incentives can lead to adopter of efficient technologies foregoing the opportunity. For example, if an individual or departments in an organization cannot benefit from improving energy efficiency it most likely that the interest of investing in energy efficiency will be low.

4.4.1.1.3 Adverse selection

Adverse selection is a form of asymmetric information resulting from a disparity in the level of information available to the two parties involved in a transaction. Adverse selection exists when one party is welled informed about the technology before entering into a buying or selling contract (SPRU, 2000), as a result the transaction cost may affect the efficiency benefits from being signaled. Adverse selection can be demonstrated when the producer of the energy efficiency technology has better or private information about the performance of an equipment than the potential buyer of the technology, this may lead to the buyer of the technology not buying the technology because the information available is inadequate to make a rational and cost effective decision.

4.4.1.1.4 Principal-agent relationship

Principal-agent relationships represent another form of asymmetric information; this type of barrier is more prevalent at the organizational level than in energy service market level (SPRU, 2000). Principal-agent relationships exist where the interests of one actor, the principal (owner), depends on the action of another actor, the agent (ibid). The principal-agent relationship is a consequence of imperfect information related to energy efficiency measure on the part of the principal; this may lead to the principal to impose strict investment criteria and thereby discouraging the agent to take up the cost effective investment (Jaffe & Stavins, 1994).

4.4.1.2 Economic barriers non-market failure related

4.4.1.2.1 Heterogeneity

The cost effectiveness of a technology is dependent on the characteristics of an average user with a particular class (SPRU, 2000), thus the cost effectiveness of a technology may vary depending on the characteristic of the adopter of the technology. The variation in cost effective experience by technology adopter is referred to as heterogeneity of the technology. Heterogeneity of a technology may discourage potential technology adopters not to take up energy efficiency technologies because the cost effectiveness of the technology is not 100% assured.

4.4.1.2.2 Hidden costs:

Both engineering-economic calculations tend to neglect the reduction in benefits associated energy efficiency technologies, due to incurred hidden costs (SPRU, 2000). These hidden costs consequently prevent firms from undertaking energy efficiency projects even though they are generally not quantified by firms and difficult to observe by outside observers

(Fleiter , Worrell and Eichhammer, 2011). However , it is argued that taking into account the hidden cost of energy efficiency technology, some technologies seize to be cost effective and as such not attractive for implementation. According to SPRU (2000), three broad categories of hidden costs can be identified:

- General overhead costs of energy management (e.g. cost of employing specialist and cost of information);
- Costs specific to a technology investment (e.g. cost of disruption or inconvenience and additional staff costs for maintenance); and
- Loss of benefits associated with an efficient technology (problems with safety, noise, working conditions, extra maintenance, reliability, service quality etc)

4.4.1.2.3 Access to capital:

Limited access to capital is commonly cited as a barrier to energy efficiency investment (SPRU, 2000). To invest in an energy efficiency technology, a firm requires funding either from an internal or external source. However, access to capital from external sources (commercial banks and financial institutions) may normally be limited by capital market failures (UNIDO, 2011).As a result of capital market failures, some banks and financial institutes (especially in developing countries) lack the technical capacity to correctly evaluate energy efficiency projects. As such, these investments are perceived as high risk and this prevents the banks from investing or issuing loans in that respect.

4.4.1.2.4 Risk

Risk also offers a valid explanation for the existence of an efficiency gap. Risk related to energy efficiency investments has many dimensions and they are broadly classified as external risk, business risk and technical risk (SPRU, 2000). External risk refers to socio-economic parameter, which directly or indirectly affect the energy service market. Factors such as economic trends, government policies and expected reductions in fuel and electricity prices are some of the external risk inhibiting energy efficiency investments. Business risk refers economic or financial factors directly related to business or sector, which makes investment in energy efficiency look like a threat thereby deterring investors. Many recommended energy efficiency technologies are well proven and apparently low risk; thus technical risk is unlikely to provide a reason for rejection of a technology, rather technical risk are more likely to be site specific ; such as the unreliability and low performance of the technology on a specific site (SPRU, 2000).

4.4.1.3 Organizational barriers

Organizational theory posits that organizational factors like power and culture of firm can constrain a range of viable energy efficiency investments (SPRU, 2000); these two factors are normally related to the structure, size and available infrastructure of the organization.

4.4.1.3.1 Power

Responsibilities of energy matters are typically assigned to engineering or maintenance departments that have a relatively low status within an organization (SPRU, 2000). Due to their low status, they lack sufficient power to initiate energy efficiency projects within the organization and as such are constrained by bureaucracy set by top management. However, the top management who has the power to initiate energy efficiency projects normally overlook such projects because, improving energy efficiency is not a core business activity and thus does not see the significance of energy efficiency projects.

4.4.1.3.2 Culture

According to SPRU (2000), the culture of an organization is not considered as a barrier to energy efficiency but rather an important explanatory variable for why cost effective energy efficiency solutions are not taken up by an organization (SPRU, 2000). In this context, culture can be seen in the light as any organizational values, norms and routines that may shroud important efficiency investments and consequently lead to the organization not adopting the investment. For example, companies with an environmental awareness culture are more aware of the environmental implications of energy use and as such are more likely of adopt energy efficiency than companies without the culture of environmental awareness. Therefore, the culture of an organization affects the actions of both top management and workers towards energy efficiency.

4.4.1.4 Behavioural Barriers

Decision-making process to invest in energy efficiency improvement, like other investments, is a function of the behavior of individuals or of various actors within the industrial firm (Sardianou, 2008). Some behavioural parameters like forms of information, credibility and trust, values, inertia, and bounded rationality can act as impediments to improving energy efficiency.

4.4.1.4.1 Forms of information

Information available to a firm is an important decision making parameter and at the same time aids in the cost effective implementation of energy efficiency programs. However, the effectiveness of information goes beyond the availability and content of the information (Stern, 1994 cited in SPRU 2000); thus, the form of information on energy efficiency is crucial (SPRU, 2000). The form in which information is disseminated and assimilated can impede the improvement of energy efficiency in a firm. SPRU (2000) outlined five elements of information that influence the effectiveness of information related to energy efficiency:

- Information should be specific and personalized;
- Information should be vivid;
- Information should be clear and simple;
- Information should be available close in time to the relevant decision and
- Feedback should be given on the beneficial consequences of previous energy decisions if subsequent efficiency measures are to be encouraged (Seligman et al, 1981).

4.4.1.4.2 Credibility and Trust

The credibility of the source of information is another important dimension of information that affects energy efficiency improvement; the credibility involves a combination of expertise and trustworthiness (SPRU, 2000). Thus, the effective dissemination and assimilation of information relies largely on the trustworthiness of sources. If the credibility of the source of information is questionable and not trustworthy, firms may be reluctant to invest in energy efficiency based on that information.

4.4.1.4.3 Values

Just like the culture of any firm, the values of firm is not termed as a barrier but instead an important explanatory variable to justify why firms adopt or do not adopt cost effective energy efficiency measures. When a firm is well entrenched in environmental awareness and energy efficiency values, they are more likely to invest in energy efficiency than a firm without values concerning environmental awareness and energy efficiency. As such, the values of a firm can explain why some firms do not take up energy efficiency whiles other do.

4.4.1.4.4 Inertia

Inertia in this context refers to the tendency of individuals or organizations to adopt to change contrary to their established habits and routines. Hence, agents justify their action (inertia) by downgrading contrary information (SPRU, 2000). The existence of inertia in firm can explain why cost effective energy efficiency investments are not taken because they are not in line with the routines of the firm.

4.5 Empirical barriers to industrial energy efficiency

Numerous empirical studies have confirmed the existence of barriers to improving energy efficiency in industries. As shown in literature, the nature of these barriers varies widely among technologies and technology adopters. Barriers also vary depending on sectors and regional condition (SPRU, 2000); these variations explain the diversity in empirical approaches to studying barriers to energy efficiency. Most of these empirical barrier surveys are aimed at explaining the existence of the energy efficiency gap, by investigating how barriers exist and operate, the contexts in which they arise and the manner in which different intervention can be used to bridge the efficiency gap (SPRU, 2000). Industries worldwide are faced with energy efficiency barriers ranging from financial, cultural, technical and external barriers (UNEP, 2006).

In an effort to capture the importance of the social and anthropological aspects of barriers to industrial energy efficiency, Palm (2009) probed lifestyle catergories to complement industrial energy efficiency barriers. The essence of this research was to deepen the understanding of why companies (industrial SMEs) do not improve energy efficiency, by looking into the energy culture of companies, perception of energy use and finally habits and routines that govern enegy use in industries (Palm, 2009). In a research by Palm and Thollander (2010) a unification of both engineering and social science was applied to explain barriers to industrial energy efficiency in Europe; this research is representative of the interdisciplinary nature of barriers to industrial energy effficiency.

A series of industrial energy efficiency barrier studies have been conducted in Sweden by Rohdin and Thollander (2006), Rohdin, Thollander and Solding (2007) and Thollander and Ottosson (2008)in different business sector; the prevailing barriers identified differ from sector to sector. In a study on Swedish pulp and paper industry by Thollander and Ottosson (2008) revealed that technical risks such as risk of production disruptions topped the barriers ranking; followed by cost of production disruption/hassle/inconvenience, which can be theoretically be attributed to hidden cost. In a similar study of barrier to energy efficiency in non-energy intensive manufacturing industry in Sweden by Rohdin and Thollander (2006) identified cost of production disruption/hassle/inconvenience as the largest barrier followed by lack of time/other priorities and difficulty/cost of obtaining information on the energy consumption of purchased equipment.

In an extensive survey of barriers to industrial energy efficiency in Asia under a project, dubbed "Greenhouse Gas Emission Reduction from Industry in Asia and the Pacific", four thematic categories in relation to barrier were studied namely; Management, Knowledge/Information, Financing and Policy. Commitment from the top management was identified as an energy efficiency factor, without which efforts to improve energy efficiency may be futile (UNEP, 2006). Secondly, Limited knowledge and information was also identified to impede the progress of energy efficiency. This is because a minimum technical knowledge and expertise of energy use and related processes are required to identify, investigate and adopt energy efficiency measures; as such the and lack of such knowledge will limit the extent to which an industry can adopt efficiency measures. Lack of financing and effective policies (legislation and enforcement) was identified as key barrier because most energy efficiency investments are capital intensive and as such limited capital can affect the extent to which a company can implement energy efficiency. Lastly, policy instruments and enforcement with regards to energy efficiency is an important tool of promoting energy efficiency in a country; as such lack of tool can negatively affect the adoption of energy efficiency measures in a country.

Based on the four (4) key areas two types of questionnaires were designed; targeting two separate groups of respondent that is, external stakeholders (Government agencies, financial institute, Consultants, research institutes and NGOs) and industrial companies. According to the companies, “lack of financial incentive from government” ranked as the largest barrier prevailing followed by “management finds production more important” because energy efficiency does not form part of the core activity of companies. Ranked in third position, “Management is concerned with the investment costs of energy efficiency measures”. From external stakeholders’ perspective “Management finds production more important” ranked as the largest barrier followed by “Authorities are not strict in enforcing environmental regulations” and “There is a lack of policies, procedures and systems within companies” in second and third positions respectively.

4.6 Theoretical barriers vs. empirical barriers

According to Sanstad & Howarth (1994), there is a debate between engineering and economic approaches to analyzing to energy efficiency (barriers). This conflict stems from two schools of thought; the first school of thought claims that engineering approaches to energy analysis are firmly based on economic principles whiles the other claims that markets are normally efficient and that engineering view lack economic justification. Sanstad & Howarth (1994) states that: To resolve this conflict, technology analysts must acknowledge that empirical findings are meaningful only when linked to a well-articulated theoretical framework. Similarly, economists must recognize that theoretical assertions are meaningful only if they stand up to empirical scrutiny’. This means that all empirical energy efficiency barriers have a theoretical connotation; as such theoretical barriers and their classification form a very important baseline or framework for defining empirical barriers. For example, theoretical barriers like ‘cost of production disruption’ and ‘lack of technical, knowhow or skills’ are termed in a theoretical sense as hidden cost and imperfect information respectively.

Chapter 5

Results

5.1 Background of survey

The aim of the survey was to determine the current practice of energy management in industries in the Tema Industrial Area; by investigating the extent of energy efficiency measures adoption, the barriers and driving force for the adoption of energy efficient investments.

A total of 76 questionnaires were administered; 2 via email and 74physically distributed. At the end of the exercise, 34 completed questionnaires were received. Exactly 29% of the industries surveyed fall within the steel and aluminum sector and this includes smelters (steel and aluminum), roofing sheet and angle rods manufacturers; 23% of the industries studied also fall within the food processing sector. Plastic product manufacturers took about 21% of the respondent; some of the plastic products produced by these companies include chairs, tables, buckets and canisters. The Petrochemical and chemical sector consist of Tema Oil Refinery (the only oil refinery in Ghana), paint manufacturers and petroleum products manufacturers; this sector represent 9% of the total respondents. The remaining 18% of the total respondents consist of a cement company, 2 textile companies, a compact fluorescent lamps manufacturer and 2 of paper products manufacturers.

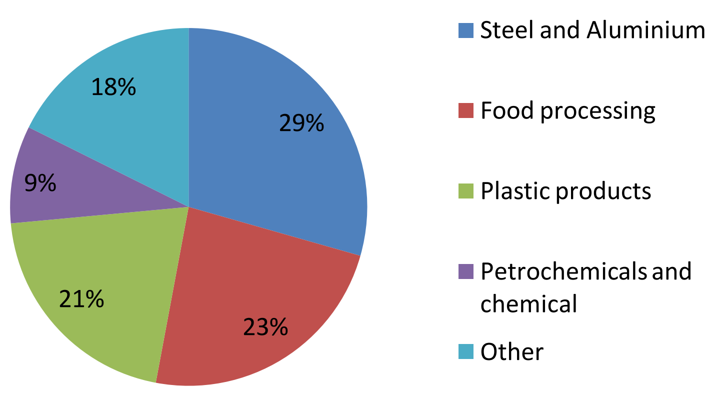

Figure 9: Participating Industrial Sectors

None of the surveyed firms had an energy manager and so the questionnaires were administered to Managers (or Technical Directors) and Engineering staffs who deal directly with energy issues. The table below shows the distribution of the positions of respondents. A total of 19 Technical Directors and Managers answered the questionnaires whilst the remaining 15 questionnaires were answered by engineering staffs (see figure 10).

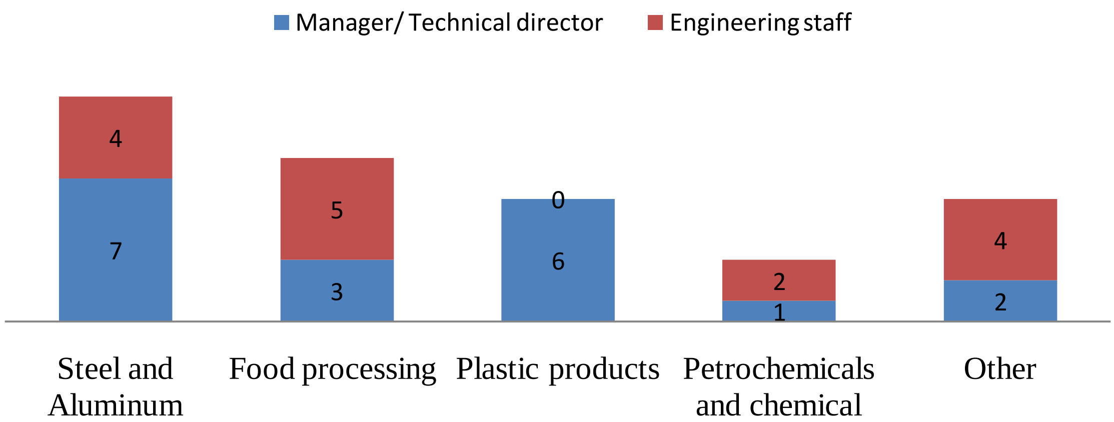

Figure 10: Distribution of Position of Respondents

5.2 Efficiency gap and energy management practices in Ghana

Energy efficiency offers developing countries a vast resource of gain, only if they apply innovative and comprehensive solution to bridge the efficiency gap. Most of the theoretical and empirical literature on the "energy efficiency gap" are relates to industrialized countries (Schleich, 2011). Nevertheless, there are anecdotal evidences that suggest there is the existence of a wide energy efficiency gap in developing countries. Low technology, lack of financial capacity and most importantly, investment inefficiencies prevailing in developing countries are evidence enough of this energy efficiency gap. Bridging the industrial energy efficiency gap is especially crucial for developing countries to ensure a sustainable development.

In order to confirm the existence of an energy efficiency gap in the various industries, respondents were asked to assess the existence of cost effective energy efficiency opportunities in their firms. All respondents affirmed the existence of energy saving opportunities; 2

respondents strongly agreed whiles 32 merely agreed that there are energy efficiency opportunities in their firms (see figure 11 below).

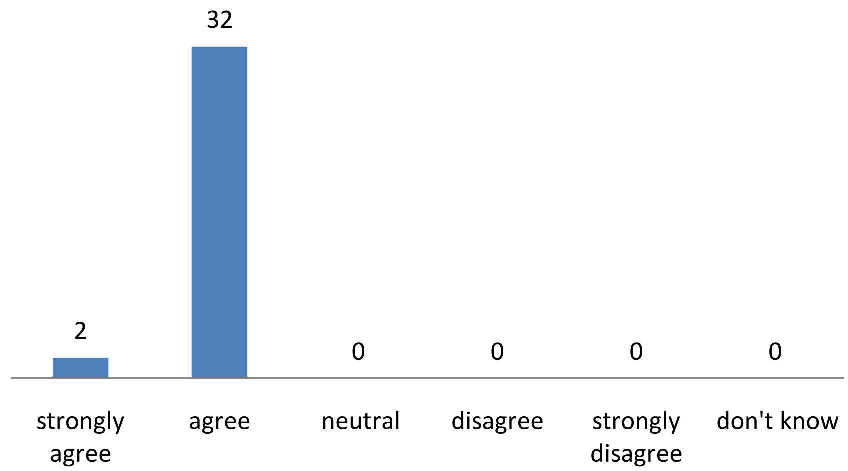

Figure 11: Energy Efficiency Opportunities

This result reveals a strong knowledge of the existence of an efficiency gap in the surveyed firms.

To draw a baseline for assessing energy management, respondents were asked to answer questions on their energy information system; about 70% of respondents said that they had meter electricity at both site and building level whiles remain 30% had meter electricity on equipment lines. About 90% of respondents record electricity use on monthly basis. Approximately, 80% of respondents monitor the trends of energy consumption whiles about 18% of them use monitoring and targeting schemes to manage their electricity use. About 12% of respondents had benchmarks to compare their energy use against.

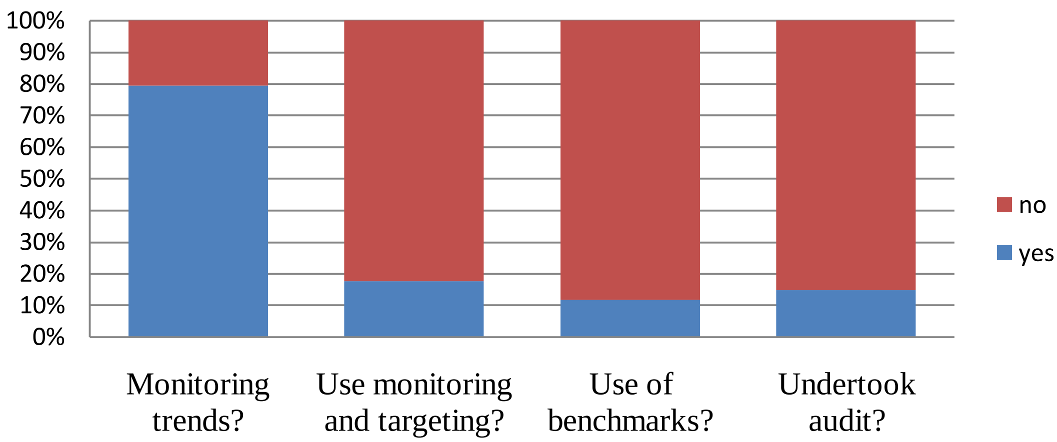

Figure 12: Energy Information System

To determine an energy efficiency gap, it requires the use of empirical energy use data to estimate the average returns of the investment (Allcott & Greenstone, 2012). Even though majority of respondents monitor their energy use, only 15% of them had undertaken energy audits. Thus, a large number of the assessments of the efficiency gap by respondents were based on intuition rather than empirical data (audit data) to ascertain the magnitude of saving opportunities.

With the baseline set, participants of the survey were asked answer question related to their energy management system. The survey revealed that majority of the surveyed industries had no standardized energy policy and management system. Five (5) firms had subscribed to ISO Standards (ISO 22000, ISO 9001 and ISO 14001); out of these five firms only 2 firms (OT5 and SA4) had energy policies which formed part of their ISO 14001 subscription. Both respondents stated that the implementation of the energy policy was not extensively executed because the use of energy was not an environmental hotspot. None of the industry had a standardized energy management scheme nor did they have a personnel specially assigned to management energy, most of the energy issue were handled by the Technical Directors and Managers.

5.3 Industrial energy efficiency information source in Ghana.

Access to information is a vital tool for investments decision making and implementation of industrial energy efficiency practices. The credibility and source of the information is equally as important as the worth of the information. In Ghana, the Energy Commission, Energy Foundation and Electricity Corporation of Ghana (ECG) are the bodies officially responsible for providing and disseminating energy efficiency information. The Energy Commission is a regulatory body in charge of ensuring both energy providers and clients manage energy in an effective and efficient manner; the Energy Foundation Ghana is a non-profit, private sector institution devoted to promoting energy efficiency in Ghana; whiles, ECG is an electricity utility company. There are other unofficial sources in existence like trade union, energy consultants, colleagues within firms and written sources like journals and manuals.

Participants of the study were asked to rank the effectiveness of some official and unofficial information sources with regard to energy efficiency in Ghana. An average scoring of the response indicated that information from the electricity utility company, ECG, is ranked as the best source(see figure 13).

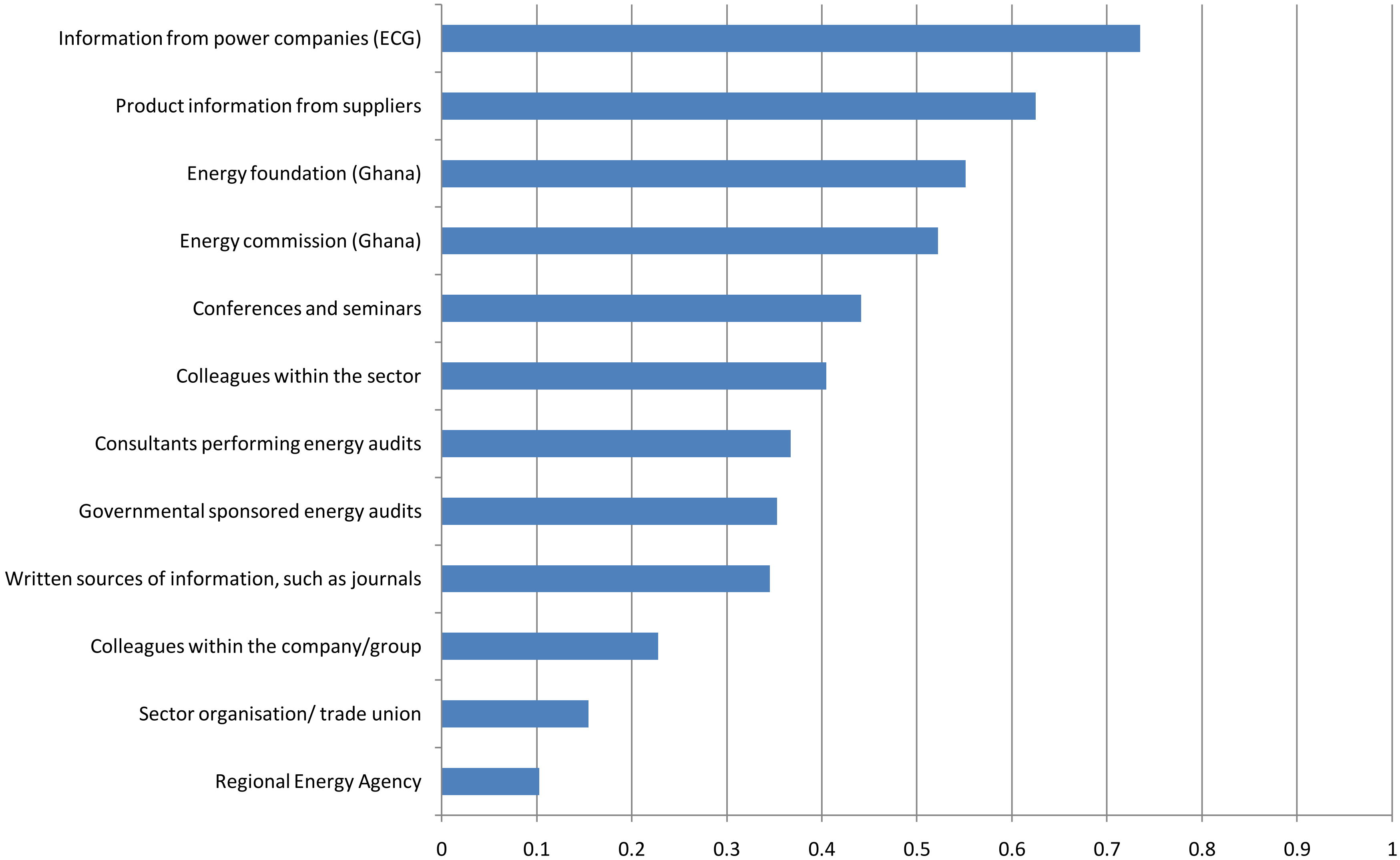

Figure 13: Ranked results (from questionnaire) of energy efficiency opportunities information sources.

Public utility companies like ECG are well positioned in the energy market to promote industrial energy efficiency in Ghana because of their strong energy ties with customer and the technical familiarity with customer equipment. One respondent confirmed that during the 2002 hydro-electricity crisis in the country, ECG organized a nationwide sensitization exercise on industrial energy conservation, this exercise included seminars and workshops. Another respondent confirmed the participation of ECG in a program to promote monitoring and targeting electricity use in industries; the respondent said that ECG was responsible for preparing a manual for electricity conservation.

Information from suppliers of equipment was ranked as the second most effective source of information. It is important to note that information from these sources is subject to be imperfect or asymmetric, because energy efficient equipment produced in developed countries may not suit the conditions in developing countries and as such information regarding equipment may not be so reliable/perfect.

Information from Energy Foundation and Energy Commission were ranked in third and fourth positions respectively. Energy efficiency information from Energy Commission was popular among government-owned industries; this is a consequence of government's effort to reduce electricity expenditure.

Information from trade unions (or sector organization) and regional energy agency were ranked in eleventh and twelfth position respectively, thus signifying poor sources of information.

5.4 Current energy efficient technology adoption in Ghana.

A pilot survey of the study area revealed that large energy saving potentials exist for the following heat treatment and boiler systems; compressor and pump systems, lighting systems and electrical systems. The pilot survey also revealed that the energy saving potential for space conditioning was very low and thus, required no attention. Based on the findings of the pilot survey, the questionnaire was redesigned to query these energy saving hotspots (i.e. heat treatment and boiler, compressor and pump systems, lighting and electrical equipment).

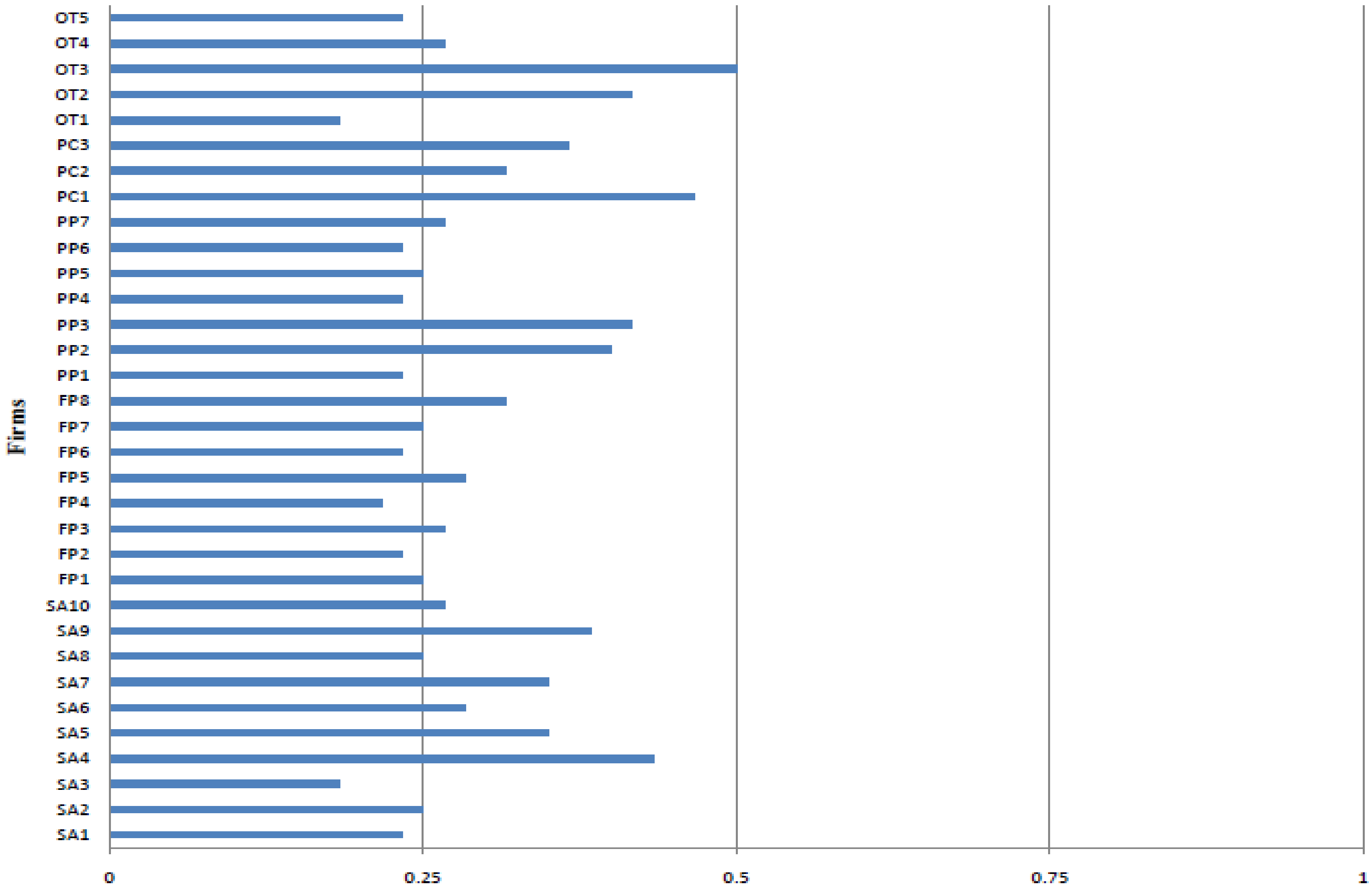

Figure 14: Average scoring of energy efficiency adoption assessment

Respondents of the survey were asked to assess the extent to which they had adopted various energy efficient technologies and measure, categorized under the various hotspots, using a scale of 0 (not adopted) to 1 (extensively adopted). The graph above shows the mean score of rating of energy efficiency technology and measures assessed by the various respondents. The firms were coded according to the sector they fall within (where Steel and Aluminum industries=SA, Food Processing industries= FP, Plastic Product industries =PP, Petrochemical and Chemical industries= PC and Other= OT).

The graph (see figure 14) gives an insight into the level of energy efficiency implementation in the firms; even though the rating of implementation is very subjective, it can also be used to complement the existence of an efficiency gap. It is evident from the graph that majority of the firms have fairly implemented energy efficiency measure. Firm OT3 and OT1 had the highest and lowest score of energy efficiency implementation respectively. Thus, it can be deduced from the graph that firms OT3 is likely to have introduced the most energy efficiency investments whiles OT1 is likely to have introduced the least energy efficiency investments. Relative to the maximum score (of 1 point) the level of energy efficiency implementation is very low in all the firms; the reason for this huge gap will be made clear by the barrier analysis.

Table 3: Average scores of energy efficiency hotspots

Energy Efficiency Hotspots	Average score
Heat Processing and Boiler Measure	0.17
Compressor and Pump Measure	0.33
Lighting measure	0.36
Electrical equipment	0.39

Note: 0(not implemented) to 1(extensively implemented)

Electrical systems are major energy efficiency hotspot, because most of the industries in Ghana are highly reliant on electricity. However, electrical appliance ranged as the area with the highest technology implementation. Power factor correction is one of the most cost effective measures dominantly used in Ghana. The Technical Director of a steel smelting firm (SA4) claimed that the implementation of power factor correction reduced the firm's annual electricity bill by 5%-10% since 2001. The study reveals that 50% of the surveyed industries had not implemented power factor correction; the low patronage can be attributed to lack of funds or ignorance of the benefits. The avoidance of idle operation of pumps, fans conveyers and other electrical equipment is another effective means of reducing electricity consumption. None of the industries surveyed had automatic switching off systems to put off idle equipment. The respondent of SA5 (Technical Director) and FP4 (Manager) claimed they have labels and posters that always prompt workers to switch off equipment which are not in use; however, both respondents (i.e. SA5 and FP4) could not confirm the effectiveness of this measure since it had not reflected any significant electricity savings since its inception.

Some of the measures adopted by the industries to reduce heat losses and ensure fuel efficiency are proper insulation of distribution pipes and valves and the use of boiler refractory. The study revealed that approximately 80% of these industries claimed they have insulated pipes and valves, whiles only two firms (OT2 and PC1) claimed they use boiler refractory. Firm OT2 claimed the boiler refractory were pre-installed in the boiler before purchase, whiles PC1 claimed that a post installation of the refractory were done to reduce fuel consumption of boilers after purchase. Additionally, to ensure optimal operation of boiler, all the industries except OT1 and SA6 ensure an accurate control of boiler temperature, pressure and air /fuel ratio. Firm OT2 also claimed they had installed a boiler sequence control to improve the efficiency of boiler. The study also revealed that PC1 was the only firm that had a heat recovery system, which is used to electricity.

Measures used to reduce energy consumption by lighting systems includes; replacement of tungsten filament lamps with Compact Fluorescents Lamps (CFL), optimization of daylight and replacement of 38mm fluorescents with 26mm, etc. It was revealed through the study that none of the firms had light control systems (occupancy sensors) to automatically switch lights on and off when needed. Most of the firms have extensively replaced tungsten lamps with CFLs; the reason for this high rate of implementation is attributed to efforts by the Ghanaian government in the promotion of CFLs in the country. Most of the firms optimized daylight by properly positioning their windows and also by using skylight to reduce the use of artificial lights during the day.

The use of appropriate and efficient motors to drive compressor and pumps is a major measure implemented by all the industries with the exception of SA3. Most of the firms surveyed used centrifuge pumps and throttle control as another form of measure to reduce excessive energy consumption. The inspection and elimination of leaks for compressors seemed not to be extensively applied in these industries due to poor maintenance culture (mostly found among

Ghanaian industries). This poor practice or lack of it was confirmed by three respondents (SA1, FP7 and PP5) who said that maintenance of most machinery were carried out on rare occasions and if and when they were done too, it was only after the machines become faulty.

Other efficiency measures adopted by these industries include load management; firms FP2,FP3,SA1,PC2 and OT3 usually move/shift some of their high electricity demand operations to low peaks hours to reduce cost of electricity. Firm OT3 also improves boiler performance by installing scale blaster to eliminate lime scale formation.

5.5 Barriers to energy efficiency improvement in Ghana

The identification of an energy efficiency gap or energy efficiency opportunities always brings up the questions of 'what are the factors resulting in this gap?' Theoretically, economists try to answer this question by exploring market and non-market deficiencies (barriers) that explain either the slow adoption or the non-adoption of cost effective energy efficiency solutions. Empirically, the researcher tends to answer this question by exploring specific impeding factors (barriers) that can add reason to why individuals or firms do not implement cost effective energy efficiency solutions.

To complement the existence of an energy efficiency gap, respondent of the survey were asked to rate the importance of 21 barriers to energy efficiency; using a scale of 0 (not important), 0.5 (often important) and 1(very important). The average score of all the surveyed firms ranged from 0.19 to 0.82 (See figure 15 below). An empirical result of a barrier survey can best be interpreted by using a theoretical framework (table 4 below shows the ranking and theoretical origins of barriers with great importance i.e. barriers with average scoring greater than or equal to 0.5).

Lack of budget funding was considered as the most important barrier followed by access to capital; theoretically, these two barriers originate from the barrier "access to capital". Several factors related to capital market failures make access to funds for industrial energy efficiency difficult in developing countries (UNIDO, 2011). The main reason for this can be attributed to the lack of technical capacity of both firms (surveyed)and banks to accurately evaluate the benefits of energy efficiency investments thereby leading to the non-allocation of funds (investments) by firms into energy efficiency measures, and consequently making it difficult for banks to access loan. 'Other priorities for capital investment' follows the ranking of empirical barriers in third position as it is theoretically related to hidden costs. Generally, if energy consumption forms a small portion of the total production cost, managers tend not see the benefits of investing in energy efficiency.

Table 4 : Classification of important barriers to energy efficiency

Ranking	Empirical barrier	Related Theoretical Barrier
1	Lack of budget funding	Access to capital
2	Access to capital	Access to capital
3	Other priorities for capital investments	Hidden costs
5	Technology is inappropriate at this site	Heterogeneity
5	Technical risks such as risk of production disruptions	Risk
6	Lack of technical skills	Imperfect information
7	Conflicts of interest within the company	Split incentives
10	Cost of production disruption/hassle/inconvenience	Risk
10	Cost of identifying opportunities, analyzing cost effectiveness and tendering	Hidden costs
10	Lack of time or other priorities	Hidden costs

In fifth position are the barriers 'technology is inappropriate at this site' and 'technical risks such as risk of production disruptions'. Production risks and externalities associated with changing of technology (due to improving energy efficiency) was cited by approximately 15% of respondents as often being an important factor as to why they do not take up energy efficiency improvement. Additionally about 17% of respondents also claimed that the heterogeneity of technology is often an important factor impeding energy efficiency improvement. In fact, one respondent (PP6) complained about the underperformance of a technology below the expected performance as assured by the supplier. In sixth and seventh positions are 'lack of technical skills' and 'conflicts of interest within the company' respectively; to evaluate and operate the performance of an energy efficiency technology, it requires specialized skills and as such, lack of this technical skill limits the ability of a company to take up the technology.

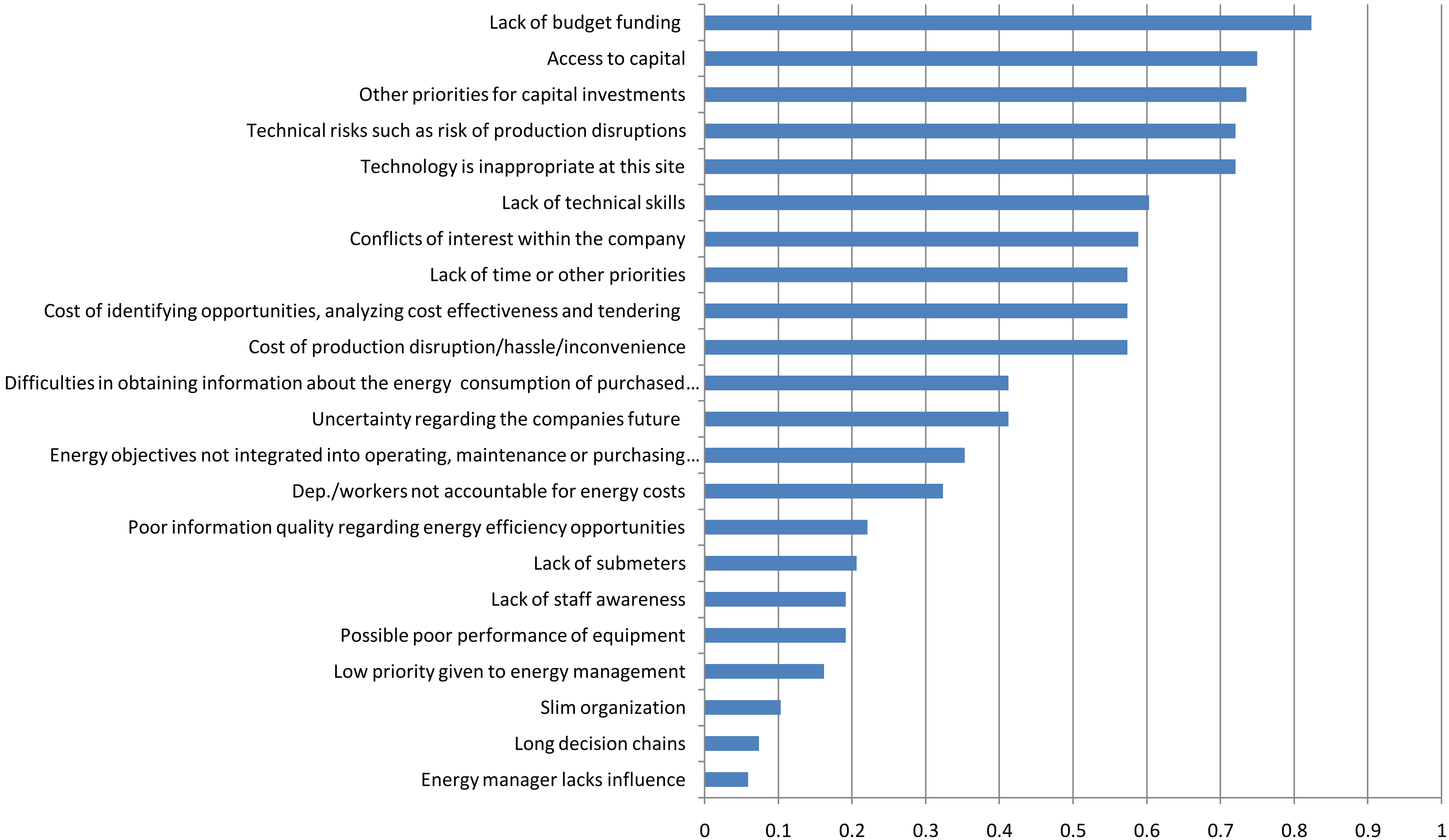

Figure 15: Ranking results of barriers to improving energy efficiency

When departments or companies cannot appropriate all the benefits of an investment, they are less likely to invest (UNIDO, 2011); this many develop a conflict between parties who stand to gain more from the implementation of energy efficiency measure and the parties that gain less.

Other barriers (ranked in decreasing order of mean score) include ‘lack of submeters’, ‘lack of staff awareness’, ‘possible poor performance of equipment’, ‘low priority given to energy management’, ‘slim organization’, ‘long decision chains’ and ‘energy manager lacks influence’.

5.6 Driving force for improving energy efficiency in Ghana.

The rationale for adopting or improving energy efficiency in firms can be motivated by either internal or external forces or a combination of both. The study of driving force for implementing energy efficiency gives good insight to policy makers on how to boost implementation of energy efficient measures and technologies. To establish the reasons why industries implement energy efficiency, respondents were asked to rate the importance of 17 driving forces, using a scale of 0 (not important), 0.5 (often important) and 1 (very important).

The average score of all the surveyed firms ranged from 0.12 to 0.75 (See figure 16 below); ‘cost reductions resulting from lowered energy use’ ranked as the most important driver, closely followed by ‘threats of rising energy prices’. Both drivers are market related with the sole purpose of increasing the firm’s dividends or securing it future dividends. Respondents also ranked ‘Energy efficiency requirements by Ghanaian government’ as the third most important driver, even though there are no specific stringent laws or standards with regard to energy use in industrial outfit by the Ghanaian government. Energy tax is also another effective driver used world-wide by governments to promote energy efficiency in firms, but in this survey, it was ranked in ninth position. The result of this low priority/ranking by Ghanaian industries can be attributed to the fact that energy prices in Ghana are heavily subsidized and as such lack competitive pricing or taxes to influence efficiency improvement. ‘Environmental company profile’ and ‘Environmental Management Systems (EMS)’ were ranked in seventh and eighth position respectively. These external drivers are very important for improving energy efficiency, especially with companies that compete on an international market with high levels of environmental concerns and high restrictive environmental regulations.

Some lowly ranked drivers include ‘publicly financed energy audit by sector organization expert’, ‘general energy advices through journal or booklet’, ‘publicly financed energy audits by energy consultant’, ‘international competition’ and ‘voluntary agreements with tax exemption’.

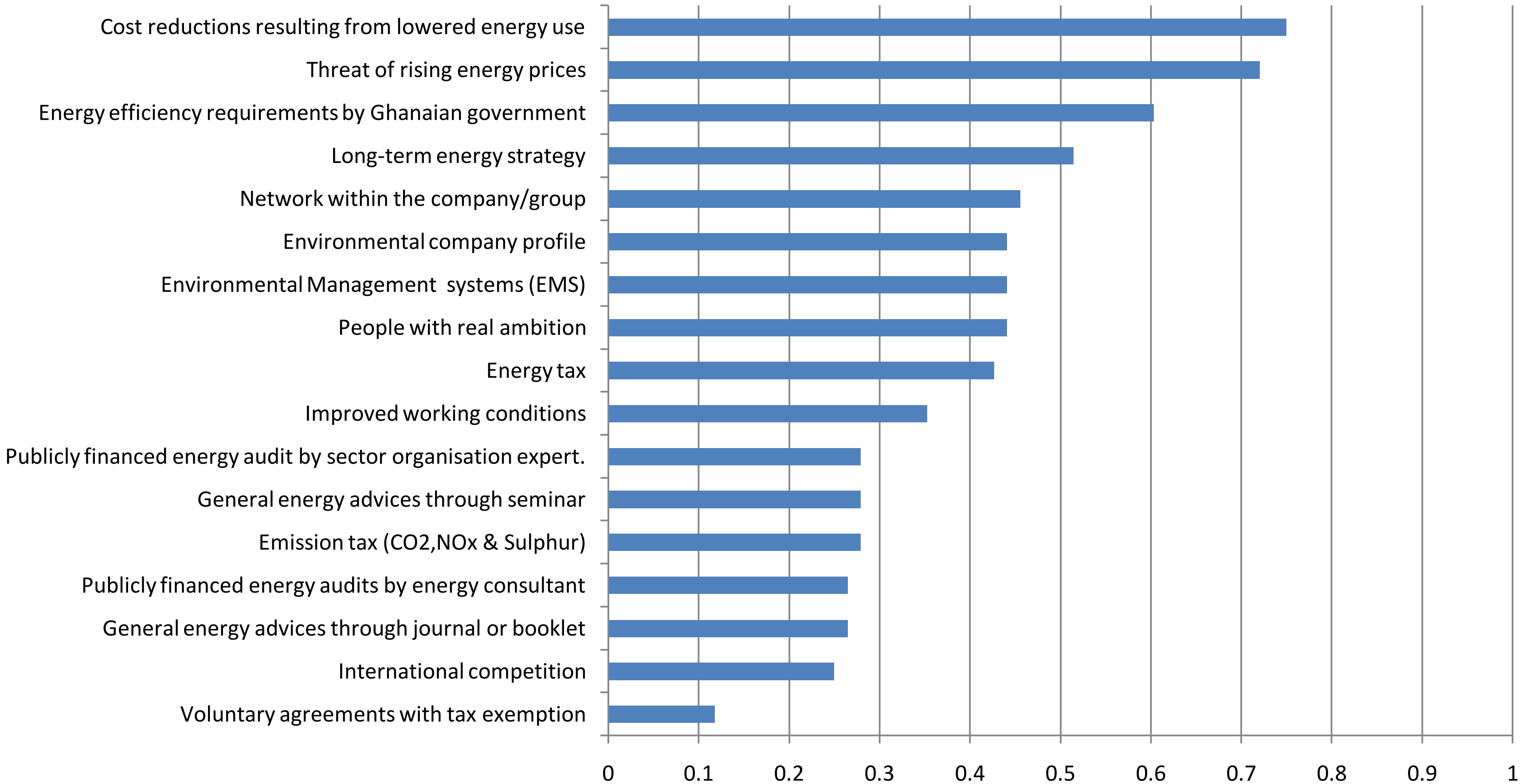

Figure 16: Ranking of driving forces for improving energy efficiency

Chapter 6

Discussion

6.1 Challenges of current industrial energy efficiency and management practices in Ghana

6.1.1 Lack of policy framework

Part of chapter 5 identified barriers hindering firms from investing in cost effective energy efficient technologies (measure), the results (see table 3) revealed that all the barriers considered to be of high importance are of economic origin (theoretically related to economics). Furthermore, all the barriers with the exception of 'lack of information' are rational behavior (economic) barriers. Behavioral changes (with regard to energy efficiency improvement) require policies with strong implementation mechanisms and regular evaluation (UNIDO, 2011). Therefore, the prevalence of rational behavior barriers supports the lack of a clear-cut policy or structured framework for industrial energy efficiency and management in Ghana. As part of efforts by the Ghanaian government to promote energy efficiency, there are policy instruments which indirectly promote energy conservation in industrial firms. One of such policy is the implementation of efficiency standards and labeling for air conditioners and lamps. The aim of this instrument is to ensure that both imported and locally manufactured appliance meets a minimum energy efficiency requirement. This policy instrument has been effective in improving energy efficiency on the support side (processes) of industrial outfits rather than in production process.

Currently in Ghana, there are policy instruments counteracting the improvement of industrial energy efficiency rather than promoting them. Ghana's energy market is characterized as a regulated market, thus government in an attempt to make energy affordable, heavily subsidizes energy prices (particularly with electricity and petroleum products). These subsidies end up distorting the real cost of energy supplied to industries and in effect sends the wrong energy price signals to the industries. As it well proven, higher energy prices are associated with significantly higher rates of adoption of industrial energy efficient equipment (UNIDO, 2011); on the other hand, lower energy prices in Ghana tends to motivate little improvement in industrial energy efficiency and management. Another policy instrument drawback is the lack of taxes or levies to cover environmental externalities in energy pricing. This drawback also contributes in sending the wrong price signals to industrial consumers. The study of driving forces for improving energy efficiency in Chapter 5 reveals that 'energy tax' and 'emission tax' are lowly ranked (in 9^{th} and 13^{th} position respectively); notably, the results also reveals that the 2^{nd} highest ranked driving force is related to energy price signals (threats of rising energy prices). These two points highlights the need of the Ghanaian government to price energy in a very competitive manner to promote industrial energy efficiency management.

Voluntary agreement have proven to be an effective substitute to mandatory policy instrument, especially in developing countries where there are low compliance to laws and the non-existence of strict energy and environmental laws. The lack of such a policy instrument explains its ranking as the lowest driving force.

6.1.2 Lack of access to funds

As highlighted in the barrier results, the 2 highest ranked barrier is related to financial limitations. This revelation spells out the importance of access to funds to the improvement of energy efficiency in Ghana. The most mentioned barrier is 'lack of budgeting'; most respondents attribute this barrier to lack of interest by the top management to improve energy efficiency as such they do not place priority on energy efficiency investments. One respondent (Technical Director) explained that in the payback period (i.e. > 3yrs) of energy efficiency, investment opportunities were a major deterrent for his firm's top management. He also stated that those in top management were much more interested in investments that could improve productivity and produce immediate dividend in less than a year.

Access to external funding in the form of loans, was another major barrier mentioned by most of the respondent as hindering the improvement of energy efficiency. One shortfall in Ghana is the lack of technical capacity and experience in banks or financial institutes, thus there is no proper evaluation of credit worthiness of firms and risks associated with energy efficiency projects; this results in lack of loans for viable energy efficiency projects. Another shortfall is the high interest rate associated with loans in Ghana this inhibits most industries from going in for loans for projects. According to two respondents, their company's top management are uncomfortable in going in for loans to fund projects because of the high interest rate and the uncertainties associated with those projects.

6.1.3 Lack of management awareness

Regardless of the high awareness of energy efficiency improvement among respondents (Technical Directors and Middle Managers), most respondents confirmed that the level of awareness in relation to energy management and efficiency among top managers in Ghana is generally low. This low awareness level (among top managers) is reflected in the poor energy culture seen among the industries surveyed. From the results of the barrier survey 'other priorities for capital investment' is considered as an important barrier (ranked in 3rd place); the ranking of this barrier partly stems from the low awareness level among top management. The low level of awareness results in top management perceiving energy efficiency improvement issues as secondary to other 'important' investments. The rationale for this position is connected to the perceived risk associated with energy efficient equipment (i.e. risk of production disruptions and heterogeneity of technology) and the ignorance of the benefits associated with energy efficiency investments by top management. One respondent (manager) stated that his firm's top management would rather allocate funds for energy equipment like electricity generators (to ensure reliable supply of electricity) than invest in energy efficient equipment.

Most respondents confirmed that lack of awareness of energy efficiency by top management is a critical factor inhibiting their efforts to increase energy efficiency. This resulted in the high ranking of 'conflict of within companies' which emanates from a split in incentives, where top managers are more focused on increasing production and profits rather than reducing emission or energy cost. The lack of awareness among top management can also be linked to other low ranked barriers like 'lack of staff awareness', 'low priority given to energy management'.

6.2 Strengths of current industrial energy efficiency and management practices in Ghana

Regardless of the current existing challenge of industrial energy efficiency and management practices in Ghana, there are some enabling features that have the potential to boost the current state of energy management in Ghanaian industries; that is if they are well developed by the Ghanaian government.

Currently, there are some government frameworks that can enhance the enactment of an industrial energy efficiency policy; these frameworks may include the labeling and standard scheme, the setting of national targets and the assigning of an energy efficiency regulatory body. The passing of the energy efficiency standards and labeling regulation in 2005 is good platform to develop more specific energy efficiency policies; the impressive results of the standards and labeling scheme is boosting efforts by the Energy Commission to implement more specific energy efficiency policies/schemes in Ghana. In a Strategic National Energy Plan (2006-2020) prepared by the Energy Commission of Ghana in 2004, 3 key national targets were outlined with regards to improving industrial energy efficiency. The overall objective of these recommendations is to ensure sufficient, cost effective and affordable energy supply to meet the expanding industrial sector (Energy Commission Ghana, 2004a). The industrial energy efficiency targets made included (ibid):

- Achieving an average of 95% power factor per annum in the industrial sector by 2015, increasing to 98% by 2020;
- Introducing pollution charges in high-energy intensity industries to encourage efficiency by 2015.
- Developing a local market for the industrial use of natural gas when the West Africa Gas Pipeline project is complete, including displacing all fuel oil use by 2015.

In summary these targets were fashioned to improve the overall power factor of industries, improve price signals of industrial energy use (to encourage the judicious use of energy) by charging industries for environmental externalities and lastly replacing fossil oils with natural gas (which is considered as environmentally friendlier and more efficient for heating purpose). However, due to lack of funds little action has been done with regards to the passing of an industrial energy efficiency policy to ensure the targets are achieved.

Notably, 'energy efficiency requirement by Ghanaian government' is ranked as the third most important driver for improving industrial energy efficiency (note: the motivation for this ranking stems from the 'Energy Efficiency Standards and Labels' established by government); this fact spells out the potential importance and strong influence of government authorities in the implementation of energy efficiency in Ghanaian industries. The Energy Commission of Ghana in collaboration with other government agencies (like ECG, and VRA) has over the years championed the cause of industrial energy efficiency improvement in Ghana. Some of the mechanisms used include public campaigns and the provision of technical support. Sensitization programs like seminars, training of personnel and workshops are some of the public campaign measures adopted by the government bodies to increase the awareness and promote industrial energy efficiency in Ghana. The provision of technical support by these bodies is in the form of energy audits, installation of efficient technologies; and correction, repair and maintenance of technologies. Notably, in relation to technical support, 'lack of technical skills' was ranked as an important barrier in 6^{th} position. However, due to lack of funding, most of these technical support activities are mainly provided to government owned industries.

Ghana has an impressive strong cooperation with international bodies (like Danish International Development Agency (DANIDA), World Bank, International Institute for Sustainable Development, (IISD) and many more) in an effort targeted at promoting energy efficiency in Ghana. Some of relevant actions of this cooperation include provision of funding and technical support for industrial energy efficiency projects. Most of these aids are encouraged by the commitments of the Ghanaian government to promote energy efficiency.

6.3 Bridging the industrial energy efficiency gap in Ghana

As demonstrated in many studies across the world, political intervention is essential to energy efficiency improvement in any country; consequently, political influence will play a central role in bridging the industrial energy efficiency gap in Ghana. Based on the results highlighted, the government of Ghana needs to develop a broad-based framework in order to promote industrial energy efficiency improvement. These frameworks initiative should be focused on changing irrational energy use among Ghanaian industries and also develop market-based policy instruments that will send the right energy price signal to industrial consumers. The implementation of a voluntary industrial energy efficiency scheme with attractive financial gains can also be an effective tool in increasing industrial energy efficiency and management in Ghana. The government of Ghana also needs to develop market mechanism that can boost the development of new private ESCO and support existing ESCO (like Energy Foundation Ghana). The promotion of private ESCO can supplement technical support provided by the Energy Commission of Ghana. Some of the services that could be supplemented by private ESCO include energy audits, energy management trainings, optimization of heat treatment processes and many more. Government needs to extend the labeling and standards scheme to cover production machineries.

Despite the access to financial aid from foreign donors to promote industrial energy efficiency, there is the need for government to develop innovative funding schemes with competitive interest rates and flexible payback terms. This will encourage industries to access local funds with ease and less apprehension. The government of Ghana also needs to secure or allocate adequate funds to the Energy Commission so as to enable them extend their technical support services and education campaigns to private firms as well. Government needs to initiate an industrial energy efficiency program with the focus of raising awareness and building capacity through training. Training programs should be fashioned to develop the knowledge of conducting audits or assessments to identify energy efficiency improvement opportunities and also identify how to access funds for energy efficiency projects. In disseminating information, there is the need to focus on creating awareness among top management, because most of the highly ranked barriers are deep rooted in the lack of awareness by top management. The information campaign should highlight benefits of industrial energy efficiency and link those benefits to increase in reliability and productivity.

Chapter 7

Conclusion and Recommendation

7.1 Conclusion

The findings of this thesis present a general overview of the energy efficiency and management practices in the Tema Industrial Area. In addition, the report explores factors that inhibit or promote energy efficiency improvement in the industrial area.

Ghana's energy system can be characterized as centralized system with government as the major steering body. The study has revealed that, the government of Ghana over the years has made significant efforts to improve energy efficiency and management in Ghana; by formulating policy instruments and initiating energy efficiency schemes and programs. However, there still remains a huge 'efficiency gap' in the industrial sector for the reason being that, government's efforts to improve energy efficiency has been directed towards residential and commercial sectors of the economy.

Information dissemination geared towards increasing industrial energy efficiency is generally very low in Ghana; the study has revealed that public campaigns to increase the awareness of industrial energy efficiency and management are mostly intensified when there is an energy crisis in the country. The provision of technical and financial support by some government bodies (like the Energy Commission, Ghana) to increase or improve energy efficiency in industries are limited to only government owned firms because the government lacks adequate funds to extend it to private own firms.

Deducing from the results, it could that energy is poorly managed in the Tema Industrial Area; with a low implementation of cost effective energy efficiency technology in the respective industries studied. A majority of the industries (except 2 firms) surveyed had neither a standardized energy policy or energy management system (because of the low priority given to energy efficiency investment by Ghanaian firms). The low implementation of cost effective energy efficiency technologies or measures in the surveyed firms principally stems from rational behavior economic barriers, which are deeply rooted in the lack of government frameworks for industrial energy efficiency. Respondents identified internal and external limited access to funds as the most important obstacle preventing energy efficiency from being improved. Internal access to funds is limited by the low awareness of top management to energy efficiency improvement measures which in effect results in low priority of energy efficiency investments. On the other hand, external access to funds is limited by high interest rates associated with loans from banks and financial institutes. Most of the surveyed industries had no energy management policy.

Economic gains related to 'cost reductions resulting from lowered energy use' and 'threats of rising energy prices' are the most important drivers for implementing energy efficiency measures or technologies; also government efficiency requirements is another important promoting factor for implementation.

An essential extension of this research work will be to incorporate the views of external stakeholders like researchers, equipment dealers, financial organizations, local government, trade associations/unions and many more on the barriers and drivers for improving industrial energy efficiency. By so doing, claims made by respondents could be supported or refuted and an additional broad base knowledge suitable for policy implementation will be developed.

Lastly, studies could be narrowed down to high-energy intensive and low energy intensive firms.

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Appendix

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Department of Management and Engineering
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Questionnaire for thesis work on energy efficiency and management in industries – a case study of Ghana's largest industrial area.

1. Identification

Name of company………………………………………………………………………………......

Name of person……………………………………………………………………………….......

Position / title……………………………………………………………………………………..

2. The company

Number of employee (approximate)……………………………………………….............................

Annual turnover (approximation)………………………………………………………………........

3. Annual energy use

Please indicate your company's approximate annual consumption of:

Fuel ……………………………………………
Electricity…………………………………………

(Please indicate units)

Please indicate your company's approximate annual expenditure on:

Fuel…………………………………………
Electricity…………………………………………

4. Energy information systems

At what level is energy use generally metered?

	Whole site	Building	Individual equipment
Electricity			
Steam/hot water			

How frequent is energy use generally recorded?

	Annually	Monthly	Weekly	Daily
Electricity				
Steam/hot water				

	Yes	No
Do you monitor trends in energy consumption?		
Are consumption records adjusted to energy price change?		
Is a monitoring and targeting scheme employed?		
Is energy performance advised to staff?		
Is consumption compared with benchmarks?		
Have you conducted energy audits?		

5. Energy management profile

i. Does your company have an explicit energy policy?
Yes [ ] No [ ]
ii. If yes, is the top management of your firm full committed to the energy policy?
Yes [ ] No [ ]
iii. If yes, is the energy policy fully integrated into your firms operations?
Yes [ ] No [ ]
iv. If yes, what is the level of the policy awareness among staff in the firm?
v. High [ ] Low [ ]
vi. Does your company have an implicit energy policy
vii. Yes [ ] No [ ]
viii. If yes, please state the related system or policy
…………………………………………………………………………………………
……….
ix. If yes, is the top management of your firm full committed to the energy policy?
Yes [ ] No [ ]

x. If yes, is the energy policy fully integrated into your firms operation?
Yes [ ]   No [ ]

xi. If yes, what is the level of awareness among staff in the firm?
Yes [ ]   No [ ]

xii. Does your firm have an energy management system(EnMS)?

xiii. If yes, name and comment on the features of the EnMS
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6. Energy efficiency opportunities

i. There exist cost-effective energy efficiency measures at my company, which can be implemented and considered profitable according to the company's investment criteria?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know

ii. What is the estimated payback time for investing in the energy efficiency measures at the current energy prices?

No idea	< 1yr	< 2yrs	< 3yrs	>3yrs

7. Information sources

How useful do you consider the following sources to be as regards information on energy efficiency measures?

	Excellent (1)	**Good (0.75)**	**Average (0.5)**	**Poor (0.25)**	**Don't use (0)**
Colleagues within the company/group					
Colleagues within the sector					
Sector organisation					
Written sources of information, such as journals					
Conferences and seminars					
Information from power companies (ECG)					
Product information from suppliers					

Consultants performing energy audits					
Governmental sponsored energy audits					
Regional Energy Agency					
Energy commission (Ghana)					
Energy foundation (Ghana)					

8. The following tables list some common measures for reducing energy consumption. **Please indicate the extent to which your company has implemented each measure by assigning it a number on a scale from 0 (not implemented) to 1 (extensively implemented).**

	0	0.25	0.5	0.75	1
BOILER PLANT:					
Proper Insulation of distribution pipes, valves and boiler ?					
Accurate control of furnace temperature, pressure and air/fuel					
Use of boiler refractory ?					
Heat recovery from boiler & process plant?					
Installation of thermostatic radiator valves?					
LIGHTING:					
Replacement of 38mm fluorescents with 26mm?					
Replacement of tungsten filament lamps with compact					
Use of high frequency fluorescents in new & replacement fittings?					
Use of photocell, acoustic or movement sensors?					
Optimize the use of natural light					
COMPRESSOR and PUMP MEASURE:					
Use of centrifuge pumps and throttle controls?					
Use of appropriate and efficient motors (or variable speed					
Regular inspection & elimination of leaks?					
ELECTRICAL EQUIPMENT:					
Power factor correction?					
Automatic switch off of pumps, fans, conveyors & other equipment when not required?					
Purchase of energy efficient computers, photocopiers & other office equipment?					

Others

Please highlight any other major energy efficiency measures that you have implemented but which are not indicated above:

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9. Barrier to energy efficiency improvement

Studies by researchers identify energy efficiency measures which are cost-efficient but which are not implemented. According to the aggregated experience in your company, how do you value the following factors impact on the implementation of cost-effective energy efficiency measures at your company?

	Often important **(1)**	Sometimes important **(0.5)**	Rarely important **(0)**
Technology is inappropriate at this site			
Cost of production disruption/hassle/inconvenience			
Cost of identifying opportunities,analyzing cost effectiveness and tendering			
Possible poor performance of equipment			
Access to capital			
Slim organization			
Lack of budget funding			
Other priorities for capital investments			
Technical risks such as risk of production disruptions			
Uncertainty regarding the companies future			
Poor information quality regarding energy efficiency opportunities			
Difficulties in obtaining information about the energy consumption of purchased equipment			
Lack of time or other priorities			
Lack of technical skills			
Lack of staff awareness			
Dep./workers not accountable for energy costs			
Energy objectives not integrated into operating, maintenance or purchasing procedures			
Low priority given to energy management			
Energy manager lacks influence			

Conflicts of interest within the company			
Lack of submeters			
Long decision chains			

Do you have any further comments on barriers to energy efficiency improvement?

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10. Driving forces for energy efficiency improvement

Successful industrial energy management is characterized by a number of factors, external as well as internal. According to the aggregated experience in your company, how do you value the following factors impact on the implementation of cost-effective energy efficiency measures at your company?

	Often important **(1)**	Sometimes important **(0.5)**	Rarely important **(0)**
People with real ambition			
Long-term energy strategy			
Environmental Management systems (EMS)			
Environmental company profile			
Improved working conditions			
Cost reductions resulting from lowered energy use			
Network within the company/group			
Threat of rising energy prices			
International competition			
Energy tax			
Emission tax (CO2,NOx &Sulphur)			
General energy advices through seminar			
General energy advices through journal or booklet			
Voluntary agreements with tax exemption			
Energy efficiency requirements by Ghanaian government			
Publicly financed energy audits by energy consultant			

Publicly financed energy audit by sector organisation expert.			

Do you have any further comments on driving forces for energy efficiency improvement?

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Thank you very much for completing this questionnaire.