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Abstract

In industry, energy efficiency reduces operating cost and emissions to the environment while enhancing energy security. In order to ensure the sustainability of micro and small scale businesses in a developing country such as Ghana, measures that can ensure energy efficiency are therefore essential for these businesses to have a productive and economical operation that will ensure their sustainability.

In this study, the potential of energy efficiency measures for micro and small scale businesses have been examined by performing industrial energy systems analysis on some selected micro and small scale businesses in Kumasi-Ghana through a practical study and administering of questionnaire about their energy consumption. Legislative instruments that are linked with energy use in Ghana were looked into. Some possible energy efficiency measures that could be adopted by these businesses have been analyzed.

In this study it is established that energy supply to these businesses is not reliable and it is continuously becoming expensive. In addition, other findings were that value could be added to the processes of these businesses if they incorporate energy efficiency measures in their operations. The main driving force that will encourage these businesses to incorporate energy efficiency measures in their operation is the energy prices increase; therefore, their interest is the measures that could reduce their energy cost rather than the positive impacts that will come to the environment. In doing this renewable energy has the greatest potential in ensuring energy efficiency to these businesses. Finally, it is established that there are no specific legislations on energy use that will bring negative effects to these businesses and this could create enabling environment for private investors of energy efficiency.
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1. INTRODUCTION

1.1 Background of study

The energy demand among small scale companies in Ghana are normally associated with regular price hikes of hydro electricity (which is the main energy source in Ghana). The frequent power outages have resulted in energy crisis and this poses challenges to the continued existence and survival of the small scale companies. This has further resulted in the decline of industry productivity due to high dependence on electricity which is at a consistently rising cost (Kumasi Metropolitan Assembly, 2006). Energy efficiency measures as well as possible energy economizing and alternative energy sources that will be feasible to the operation of such companies are therefore essential to look at for energy supplement. These energy efficiency measures have the potential of improving the productivity of industrial processes (Worrell et al., 2003). These improvements can come about in a number of ways including lower capital costs and operating costs, lower maintenance cost, increased yields and reduction of industrial energy use and safer working conditions. As a result, most current researchers are concentrating on measures to attain industrial energy efficiency for the productivity in industry. However, most of these researchers are particular about the developed countries and the large scale industries and very few have considered the small and micro businesses in the developing countries such as Ghana. In effect the micro and small scale businesses have been identified as the means through which the rapid industrialization and other developmental goals of these developing countries can be realized (Kayanula & Quartey, 2000). This therefore necessitated the initiation of this research.

This project therefore aims to study the energy consumption patterns of some selected micro and small scale businesses in Kumasi, Ghana and to identify feasible energy efficiency measures that will ensure productivity and sustainability of these companies in the micro and small scale perspective. The study performs energy system analysis of the unit processes of operation based on energy survey that consists of both support and production processes so as to identify energy use and energy demand in each unit process and to finally have an idea of the total energy consumption in that particular company. This helped to identify hot spots among the unit processes where possible energy savings could be made.

The Kumasi City

The city of Kumasi was founded in 1680’s by King Osei Tutu I to serve as the capital of Ashanti State. Given it strategic location and political dominance, Kumasi as a matter of course developed into a major commercial centre with all major trade routes converging on it. The city is the second capital of Ghana after Accra in terms of land area, population size, social life and economic activity. The city’s beautiful layout and greenery has accorded it with a name over the entire West African sub region as the Garden city of West Africa. The population is about 1,889,934 in 2009. The city is rapidly growing with annual growth rate of 5.47% with rapidly expanding economy and industrialization. The industrial sector is made up
of manufacturing and wood processing. The diagram below shows the map of Ghana and the location of Kumasi as Figure 1.

Figure 1: Map of Ghana
The city of Kumasi was chosen because it could be said of being the economic power house and a strong manufacturing location in Ghana especially in the small scale perspective and it will give a better indication in the context of this study.

1.2 Aim of the thesis

The aim of this thesis is to analyze energy consumption behaviours of micro and small scale businesses in Kumasi, Ghana and to propose ways for ensuring energy efficiency and energy savings for economic and environmental sustainability.

1.3 Research questions to be answered

In order to achieve the aim specified above, the project seeks to find solutions to the following research questions:

1. How is energy consumed and how can we add value to the operation processes of micro and small scale businesses in Kumasi-Ghana on their energy use?

2. Is the supply of energy to micro and small scale businesses in Kumasi-Ghana economically, technically and environmentally reliable and sustainable? If not, what are the challenges?

3. What are the legislations and regulations for energy use and how are they affecting micro and small scale businesses in Kumasi-Ghana?

1.4 Scope and delimitations

To be able to carry out the objective of this study the project considers micro and small scale businesses in Kumasi, Ghana which is defined as companies with headcount of employees less than fifty and their annual turnover not exceeding Ten million Euros (European Commission, 2005) in Kumasi, Ghana and analyzes their energy consumption patterns for possible efficiency measures with cost and environmental benefits.

Alternative energy sources for improvement in order to realize energy economizing and savings are also considered. Six companies of different industrial sectors in the micro and small scale perspective were selected for the study. The study uses Industrial Energy system analysis through energy survey/audit, Energy efficiency and economizing and system analysis.
1.5 Structure of the thesis

The study is made up of six sections. Each section takes on a new chapter. The first section is the introduction which presents the background of the study, aim, the importance and rational behind the study and scope of the project.

The second chapter is the review of literature relevant to this study. The findings from previous work relating to this topic are presented. In the third chapter the method used is explained. Industrial Energy system analysis was used and this included energy survey/audit, energy economizing and efficiency measures and system analysis. This was carried out through a practical industrial study and administering of questionnaire that also included information about policy instruments existing for energy use in the micro and small scale businesses.

The fourth chapter is the presentation of the results on the cost of energy use, reliability and policy instruments available and its effects.

In the fifth chapter, the results are analysed and interpretation given through a taxonomy table on feasible energy efficiency measures and its prospects for these companies. The policy instruments and power unreliability are also discussed further in this chapter.

The sixth chapter concludes the work by presenting the findings from the analysis and the interpretations of the results. The seventh Chapter points out some recommendations that will be useful to all stakeholders who will be interested in this research for future guidance or implementation in their businesses. Finally all the works cited for this study has been presented with their various authors included in the references in chapter 8. In addition, all calculations concerning the energy use and the questionnaire that was used for the study is found in the appendix as chapter nine.
2. REVIEW OF LITERATURE

This chapter reviews selected literatures concerning measures for energy economizing through efficiency in the industry concerning energy use. These literatures are selected to reflect relevant and current research studies and approaches to attain energy efficient industrial setting.

2.1 Resource efficiency

Global resources are quantifiable and measurable. This implies that global resources are exhaustible over a given period of time. It is therefore important to ensure the rational and effective use of resources so that wastage can be reduced to the bearer’s minimum to save the world from the negative consequences towards scarcity of resources. A potential response to this challenge is the concept of resource efficiency. The effective use of resources such as minerals, energy, water, raw materials etc will lead to sustainability.

Resource efficiency can be defined as using natural resources in the most effective way, as many times as possible, while minimising the impact of their use on the environment (Waste and Resources Action Programme WRAP-U.K., 2011). Resource efficiency is not only for environmental concern, it is also a good business initiative that has a potential of improving efficiency and saving cost in businesses such as raw material cost, energy cost and operation cost. In addition, for business perspective, it has potential of securing supply of resources and meeting customer demand for sustainable business practice. Therefore ensuring resource efficiency will be good for the economy by enhancing business profitability and growth while cutting cost for individuals. Again, the potential of using materials more efficiently and design processes can lead to enhanced productivity without compromising environmental burden and in the environmental perspective resource efficiency helps reduce CO$_2$ emissions and ensure best use of raw materials.

Resource efficiency are generally measured in terms of the percentage of purchased raw materials to finished product. Most at times smaller percentage of material input in processes end up as a finished product which presupposes that higher percentage of input materials come out as waste which are not effectively utilized. This is clarified by a research work conducted by sustainability Victoria on two adjacent companies (Clay, Gibson, & Ward, 2009) in an automotive supply chain, which showed only 50% of the material purchased by the first company ended up as product sold by the second. In addition (Clay, Gibson & Ward 2009) research further reveals that recycling opportunities for waste and eliminating process duplication will lead to the achievement of resource efficiency in the supply chain.

Global energy whether renewable or non renewable constitutes a resource and therefore ensuring energy efficiency which is partly singled out in this research for a comprehensive study forms part of the framework for resource efficiency. Energy efficiency is one of the areas that can ensure effective resource planning and it is highly commendable when energy efficiency is integrated in resource planning to attain sustainability.
2.2 Energy efficiency and value addition

Energy efficiency can be defined as the use of less energy to produce the same amount of services or useful output (Murray, 1996). This definition can be linked to the ratio of useful output of process to the energy input into a process. For economical production or service the smallest amount of energy input possible should be able to give a useful or maximum output of a process.

Considering the driving forces for the implementation of energy efficiency in the industry (Bunse et al., 2010) considers the three major driving forces of energy efficiency in the manufacturing companies point of view as

• Rising energy prices,

• New environmental regulations with their associated cost for CO₂ emissions such as the Kyoto protocol from 1997 and the Copenhagen Accord of 2009 and

• as a result of customers changing their purchasing behavior with regard to green and energy efficiency products and services because manufacturing companies think that good environmental performance can enhance their companies image and reputation and give them competitive advantage.

However, among the three driving forces put forward, in a related study (Streimikiene et al., 2006) dwells on and considers energy prices increase as the main and the most important driving force. He attributes this to the fact that the world wars were the factors that initiated a consistent energy prices increase and other factors today have ensured its continuous increases. This drawn the attention of many practitioners in the energy sector to start implementing measures that can ensure rational use of energy and its efficiency. This research that points out on the issue of energy prices increase as the main driving force is true is true for the small scale companies in Ghana. This is because the priority of the small scale companies in Ghana to implement measures for energy efficiency and rational use of energy is on how they can spend less on energy in order to maximize their profit. Despite the current issue on the environmental economics their attention is very low on environmental issues in implementing energy efficiency measures.

The merits associated with ensuring energy efficiency are undoubtedly high (Nagesha, 2008) discusses two of such common merits for energy efficiency implementation. The first is the better performance on economic front yielding higher returns and cost reduction and the second is the minimized energy related environmental pollution contributing positively to sustainable development. The first concerning better economic performance and cost reduction is of prime concern for many small scale businesses elsewhere and in Ghana as well. By concentrating on economic benefits and implementing energy efficiency, it will also be good because by ensuring this they indirectly contribute positively to sustainable development which may not be known to them directly.
(Cappers & Goldman, 2010) however, considers the climate change mitigation and fostering energy independence as other benefits that come along with energy efficiency. The energy independence can only be considered as a very important factor if businesses could ensure internal generation of energy and depend so much on renewable energy. In this case they will not rely on any external sources for energy supply within their business.

Despite all the merits associated with energy efficiency, certain barriers act as obstacles towards its implementation. (Rohdin & Thollander, 2005) explain these barriers as postulated mechanism that inhibits investment in technologies that are both energy efficient and (apparently) economically efficient. He further highlights some of these barriers of energy efficiency as economic non-market failure which means that not all technologies could be cost effective, economic market failure which makes it possible and as a result of lack of information lead to cost-effective energy efficiency measures opportunities being missed, behavioral which concerns itself with low ambitions of top management concerning energy efficiency and organizational as a result of low status of energy management which leads to lower priority of energy issues within organizations and finally, the issue of shortage of skilled energy management professionals in these regions targeted.

In order to address these energy efficiency barriers (Price et al., 2007) put forward a number of energy efficiency programmes and explains their characteristics and objectives that can assist both energy consumers (customers) and energy service providers to promote energy efficiency in businesses. The programmes highlighted are;

*Energy Audit*

An energy audit is a survey by visiting the site of a customer. The audit is associated with a review of customers equipment and their energy consumption, educating the customer on energy use on the practices adopted by the customer and marketing purposes of available energy efficiency programmes to the customer. This energy audit increases the awareness of how to improve energy use and encourages businesses to implement the recommendations of the auditors.

*Rebate Programme*

This programme is made up of two parts; first, the cash rebate programme and second, the upstream rebate programme. In the cash rebate programme, customers are provided with discount or cash rebate whenever they purchase known brand of highly efficient energy using appliance or equipment. In the upstream rebate programme, manufacturers of high-efficient appliances are provided with discount to the cost of their raw materials so that they can in turn reduce the prices of their products to customers. This brings a relief to customers by seeking the discount themselves whenever they purchase a known brand of highly efficient appliances for their business.

*Direct Install programme*

In this programme the energy utility providers have their layed down programmes to install energy efficient appliances for customers. One example of this programme is the commercial lighting retrofit programme that installs new energy efficient lighting for customers and this is
done by the energy utility providers themselves. These programmes normally improve the quality of installation of equipment and appliances and encourages customers to participate in the programme.

Education and Training programme

This programme provides education and training to all stakeholders in the supply chain of energy provision and consumption such as customers, retailers, architects, contractors and building inspectors concerning energy saving measures and ensuring that equipment are highly maintained to operate efficiently as possible to conserve energy.

Loans and On-Bill financing or Grants

Implementing energy efficiency in businesses goes with some initial cost that discourages or act as a disincentive to customers towards implementation of energy efficiency. This programme will provide credit and grants schemes to finance the initial cost concerning the implementation of energy efficiency measures for customers to eliminate the disincentive caused by the initial cost for energy efficiency implementation.

Bidding / Standard performance contracts

This programme encourages energy utility providers to outsource the implementation of energy efficiency measures to external contractors who are experts in the field of energy efficiency to manage and implement energy efficiency programmes for customers. This is because contractors in this direction can ensure and manage existing relationships with customers better than the energy utility providers themselves and this will increase the participation of customers for ensuring energy efficiency in businesses.

Upstream and midstream incentives

This is about the provision of incentives or assistant programmes to manufacturers, distributors or dealers to promote energy efficiency products. This assistant programmes will increase the participation of the use of highly energy efficient products.

Failure Replacement programme

This programme encourages customers to consider and install high energy efficient equipment or appliances during the time they are replacing old energy using appliances. An example is encouraging customers to purchase energy star certified equipment during the time for replacement of old energy using equipment. This practice can be best ensured by working with retailers or contractors who are into equipment replacement in businesses example HVAC – Heating, Ventilation and Air Conditioning contractors.

Early replacement programme

This programme aims at replacing equipment that are in operation which are not completely defective earlier enough with more energy efficient and morden components. This programme will require that customers could be convinced enough as to why they would have to replace equipment that are not defective and continue to be in operation. This will be a bit difficult
but if it works, it will maintain consistency in maintaining highly energy efficient equipment in businesses for reduction in the operation cost.

**New construction or installation programme**

When there is a new installation of an equipment or when there is a new construction of a facility this is the time for opportunity to use highly energy efficient equipment. This time is the best opportunity because most energy efficiency upgrades that must be designed are highly expensive or impossible to implement once the facility is already completed.

**Commissioning**

This is about having a form of ceremony to commission energy efficiency project that is completed and awarding the stakeholders who build or brought up the energy efficiency project and its implementation with either a certification or award. This further creates the awareness by encouraging and promoting energy efficiency in businesses.

Adopting these energy efficiency programmes and the technical energy efficiency measures in businesses is a way of ensuring value creation concerning the cost effectiveness of their manufacturing processes and their final products. Value creation is the enhancement added to a product or service by a company before the product is offered to customers. Example is the enhancement offered to industrial processes to reduce energy use and reduce environmental impacts to produce a product. This will encourage many manufacturing industries of today to be concerned with more other issues to the value creation of their products and manufacturing processes rather than mere functionality of their products. In view of this, producers therefore infer what would increase the value of their products to the likely users (Ueda et al., 2009). Many manufacturing industries are now rapidly shifting their attention to marketing and service businesses to increase their products value (Fry et al., 1994). This is because customers are currently demanding additional service value to the products they consume by putting demands on manufacturers. These manufacturers in a way are also forced to comply with these demands from customers because of new technology, global competition and convergence (Heikki, 2000). By complying with these demands, manufacturing companies raise their image and enhance the performance of their products in the market as well as enhancing their sustainability.

2.3 **Economic assessment of energy efficiency implementation**

Ensuring energy efficiency goes with some cost such as equipment purchase cost, cost of installation if any and ongoing operating and maintenance cost. Businesses will only be motivated enough to implement energy efficiency measures if the economic outcome can pay off the cost of its implementation. In evaluating this, the concept of the net present value (NPV) is used. The net present value can be defined as the difference between the present value of a project in terms of cash inflows and the value of the project outflows in terms of cash after a little modification or after the energy efficiency project is completed and in operation. This net present value is used to analyze the profitability of an investment or a
project. Therefore, for energy efficiency project to worth implementing the estimation of the net present value should be positive otherwise the project should probably be rejected as this value is directly proportional to the financial benefit or the profitability of implementing an energy efficient project.

Estimating the net present value mathematically (Lim et al., 2008) derives a method for this purpose. The net present value can be calculated using equation (1) while the annual revenue and expenditure can be calculated using equations (2) and (3) below respectively

\[
NPV = -C + \sum_{j=1}^{N} \frac{j_i - (E + F)(1 + g)^j}{(1+r)^j} \quad \text{----------------- (1)}
\]

\[
I = p \times (L \times P \times 365 \times 24) \quad \text{----------------- (2)}
\]

\[
E = Ef \times P + Ev \times Q \quad \text{----------------- (3)}
\]

C = Capital cost of the project

I = Annual income of the project

E = Annual operation and maintenance expenses

F = Annual fuel cost

\( g \) = Annual inflation rate

r = the Annual discount rate

N = lifespan of the project

p = the unit price of electricity in kWh

L = plant factor of the power plant

P = the rated power of the power plant in kW

Q = the total amount of energy sold per year in kWh

Ef = the fix operation and maintenance cost in kW/year

Ev = the variable operation and maintenance cost in kWh

\( j \) = the index for each year within the lifetime of the project

Another criterion for assessing the economic viability of energy efficiency project is the issue of pay-back time which is more straightforward. The pay-back period is the length of time that it takes for a project to recoup its initial cost out of the cash receipts that it generates. The general issue is that the more quickly an investment cost of a project could be recovered the more desirable the investment. The equation used in calculating the pay-back time for a new energy efficiency investment is stated below;

Pay-back period = Investment required / net annual cash inflow
The pay-back period is expressed in years and normally shorter pay-back periods for investment on energy related issues are preferred by most businesses. However, the short pay-back period cannot be the most adequate measure for evaluating in long term the benefits of an energy efficiency investment (Bee, 2008). This pay-back method could be deficient in its actual gains when it comes to investment that has long time to pay off in more abundant way. Most industries consider from 0 – 3 years as the adequate time frame for investment to pay off and investment are normally not worth considering if the pay-back time exceeds 3 years as can be compared with the general pay-off period of 4.1 years in a study of German industries from 1991 (Gruber & Brand, 1991).

2.4 Energy use in industry and negative environmental impacts

The global environmental problems are as a result of aggregation of several factors. The impacts associated with human activities come out to be the major factor of this menace. This is because of increase of world population, energy consumption, industrial activity etc (Dincer, 1999).

Conventionally, researchers have focused on the environmental impacts through the emissions of SO$_2$, NO$_X$, CO etc. Today energy use has come to be among one of the main factors that is not left out when it comes to the issue of sustainable development which has a variety of definitions with the common one as; ‘development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs’. The supply of sustainable energy is one of the factors that contributes to sustainable development and in this regard renewable energy is very promising (Dincer & Rosen, 1998). This is highly favoured by Small scale businesses because their operation equipment is not very robust and lesser capacities of renewable energy could still power the operation equipment of these businesses and this will make it possible for any known renewable energy of any kind to be utilized by small scale businesses. For instance, wind, solar and other renewable energy technologies are very promising to a clean energy future and as a result of easy implementation of renewable energy systems it has the potential of being the world leader in development and manufacturing with these technologies.

The increasing population and industrial growth will make the demand of energy to increase and this will result in energy related environmental impacts such as acid precipitation, stratospheric ozone depletion, smog formation and global climate change. Table 1 below shows various pollutants and their effects on the environment.

*Acid rain*

This is the deposition of a mixture of wet and dry materials from the atmosphere that has abundant amount of nitric NOx and sulphuric (SO$_2$) acids. SO$_2$ and NO$_X$ are also produced from the combustion of fossil fuels eg in smelters from non ferrous ores, transportation vehicles etc. Energy related activities are also a major cause of acid precipitation and therefore countries with excessive energy related activities are the major contributors of acid precipitation in the environment causing acid rain.
In the transportation sector, the use of more fuel efficient vehicles will contribute to part of the solution of acid rain.

**Stratospheric ozone depletion**

The ozone present in the stratosphere plays a major role by absorbing ultraviolet (UV) radiation and infrared radiation. The depletion of the ozone layer from the stratosphere which is known to be caused by the emissions of CFCs and NO\textsubscript{x} is a major environmental problem. When the damaging ultraviolet radiation reach the ground as a result of the depletion of the ozone layer possible effects will lead to skin cancer and eye damage.

Energy related activities are a small fraction concerning the contribution of stratospheric ozone depletion and example is the CFCs which are used as refrigerants in air condition and refrigerating equipment and in foam insulation as blowing agents.

**Climate Change**

The climate change is as a result of greenhouse effect which leads to the presence of water vapour and clouds warming the earth surface resulting in the increase of the earth temperature. Apart from CO\textsubscript{2} which is a major contributor of climate change (about 50\%) other greenhouse gases such as CH\textsubscript{4}, CFCs, Halogens, N\textsubscript{2}O, ozone (O\textsubscript{3}) and peroxyacetylnitrate also contributes to this problem and are called greenhouse gases (GHG). These greenhouse gases are normally produced as a result of industrial, domestic and general man made activities and some of these activities are energy related such as transportation and this could be solved by switching to the use of energy efficient vehicles and energy efficiency projects.
Table 1: Main gaseous pollutants and their impacts on environment

<table>
<thead>
<tr>
<th>Gaseous Pollutant</th>
<th>Greenhouse effect</th>
<th>Stratospheric ozone depletion</th>
<th>Acid precipitation</th>
<th>Smog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide CO₂</td>
<td>+</td>
<td>+/-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>+</td>
<td>+/-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitric Oxide (NO) and nitrogen dioxide (NO₂)</td>
<td></td>
<td>+/-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Nitrous Oxide (N₂O)</td>
<td>+</td>
<td>+/-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>-</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorofluorocarbons CFCs</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

Note: + stands for positive contribution and – stands for variation with conditions and chemistry, may not be a general contributor

Source: Speight, 1996

In a related study (Koh & Lim, 2010) put forward a number of feasible energy technologies that could be adopted by developing economies whiles protecting the environment at the same time. The research puts up a number of alternatives mostly in the renewable origin;

**Coal fired plant**

Coal fired plant which supplies about 41% of the world electricity generation in 2006 with high maturity and little technological risk in its investment. The negative effects of this technology with high green house (GHG) emissions could be overcome by integrated gasification combined cycle, pressurized fluidized bed combustion and carbon dioxide scrubber.

**Photovoltaic (PV) Panels**

Photovoltaic (PV) panels has very small technological risk and can be highly utilized in the tropic countries with abundant sun. The difficulty that is associated with high cost PV panels due to high area requirements of the PV panels could be reduced by encouraging consumers to install panels on their roofs through distributed generation configuration.
**Hydropower plants**

Hydropower plants are numerous and common but the power capacities are under utilized. This however, has less known environmental impacts.

**Biomass power plants (palm oil waste)**

This can use biomass from palm oil waste as a feedstock and it is proven to be utilized for electricity generation for commercial quantities eg in Malaysia. Other developing countries in the tropics that grow a lot of oil palm has the potential of adopting this technology for sustainable generation of electricity. This technology has minimum impacts to the environment and can further encourage agriculture.

**Wind Turbines**

Wind Turbines are potential renewable energy resource with high land requirements and its implementation will highly favour countries with high availability of land.

**Ocean energy (tidal current power plant)**

Ocean energy constitutes tidal and wave energy options which has not been explored so much and this poses technological risk to investors but at the same time have more potential that can be explored.

### 2.5 Industrial energy use and the energy sector in Ghana

Ghana’s energy debate has mostly centred on electricity use. However, Ghana’s energy sector is made up of other forms of energy. The major source of energy is neither electricity nor petroleum but traditional fuels made up of charcoal, crop residues, wood and other biomass resources. These traditional energy sources together accounts for approximately 67% whereas electricity accounts for only about 10% of total energy consumption in Ghana. Of the traditional wood fuels industrial consumption rose up over 46% from 1980 to 1996. Industry accounted for 47% of total electricity use in Ghana whereas residential and non-residential accounted for 39% and 14% respectively of the total electricity use in Ghana (U.S.A. Agency for International Development, 1999). The table below shows the energy consumption by type in Ghana in year 2000 as Table 2 and it is further illustrated in the pie chart below in Figure 2.
Table 2: Energy shares by type in Ghana

<table>
<thead>
<tr>
<th>Type of energy</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (unspecified)</td>
<td>0.6</td>
</tr>
<tr>
<td>Charcoal</td>
<td>15.1</td>
</tr>
<tr>
<td>Diesel</td>
<td>14.2</td>
</tr>
<tr>
<td>Electricity</td>
<td>9.8</td>
</tr>
<tr>
<td>Gasoline</td>
<td>10.4</td>
</tr>
<tr>
<td>Gasoline premix</td>
<td>0.6</td>
</tr>
<tr>
<td>Jet Kerosene</td>
<td>1.8</td>
</tr>
<tr>
<td>Kerosene</td>
<td>2.1</td>
</tr>
<tr>
<td>LPG</td>
<td>0.7</td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td>0.7</td>
</tr>
<tr>
<td>Wood</td>
<td>44</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Source: (Armah, 2000)*

Figure 2: Energy share by type in Ghana
Ghana’s 99% of electricity is supplied by hydro power plants at the Volta River in Ghana. Many manufacturing industries therefore rely solely on this for their daily operations which have made the electricity sector in Ghana suffer a lot of pressures and have resulted in inefficiencies and brought regular supply to a halt. Many industries and more especially small scale industries are affected the most.

As of October, 2006, Ghana has a total installed power capacity of 1730 MW which is made up of 1020 MW in Akosombo, 160 MW in Kpong, 330 MW in Takoradi T1 and 220 MW Takoradi T2 (Abeeku & Kemausuor, 2007). More attempts are also underway to expand this capacity and the Bui Power project in Ghana is an example. In January, 2007 the total capacity rose to 1772 MW which is made up of two hydroelectric plants on the Volta River, a 30 MW Diesel plant located at Tema and 330 MW combined cycle Thermal power plant at Aboadze in the Western Region near Takoradi (OSEC Business network Switzerland, 2007).

This available capacity serves both the residential and the industrial demand which brings a lot of pressure to the power supply. Despite this insufficient power supply and the shortage of hydro power, the country continues to expand power to Togo and Benin and interchanges power with Cote D’Ivoire and has also commenced supply to the southern border towns of Burkina Faso (OSEC Business network Switzerland, 2007).

Therefore new or improved programmes to better capture the enormous potential for energy savings in existing industries and buildings in the developing world have important roles to play for the environment and for economic development (Taylor et al., 2008). The inclusion of energy related issues and projections as in energy efficiency, diversity in energy supply, large increase in energy demand, increasing renewable energy systems, allowing private sector participation and new technologies including fuel cells in the vision 2020 document of Ghana (Abeeku, 2007) will lead to operation efficiencies and sustainability of micro and small scale companies in Ghana.

2.6 Contribution of renewable energy

The utilization of renewable energy in Ghana for energy supplement and energy economizing has gained strong consideration in Ghana. In a study on Hydrokinetic power for Energy access in rural Ghana (Miller et al., 2010) pointed out that in the mid 1980s Ghana set up funds to promote renewable energy and energy efficient projects by the levies on petroleum products.

The concern of the Ghana Government on the integration of renewable energy in the Ghana Energy sector made it possible to establish a strategic national energy plan which covers 2006 – 2020. In this plan Ghana Government hopes to achieve 15% penetration of rural electrification through decentralized renewable energy by 2015, expanding to 30% by 2020 (Miller et al., 2010).

In policy perspective (Kankam & Boon, 2009) suggests that achieving an energy future that has greater relevance to rural development in Ghana requires a mix of policy instruments that
enhance the delivery and use of modern energy systems in rural communities in the country, and in so doing renewable energy cannot be left out. In order to promote renewable energy in Ghana the Ghana renewable energy policy draft make provisions for incentives in order to overcome the barrier of high initial cost. The Government plans to grant capital subsidy to assist rural communities acquire renewable energy technologies. Again, the Government will nationalize the fiscal regime regarding import duty and VAT on Renewable Energy Technologies. Finally, the current tax and duty exemption for solar and wind power Equipment will be expanded on biomass utilization equipment, appliances and system components. This emerging policy frame work above validates the suggestion of (Kankam & Boon, 2009) on the need for a mix of policy instruments on renewable energy to support the course.

The benefits associated with the use of renewable energy cannot be downplayed. Among the lots are environmental improvement through reduction of power plants greenhouse emissions, thermal and noise pollution, increased fuel diversity, reduction of energy price volatility effects on the economy, national economic security (Menegaki, 2008). Again (Menegaki, 2008) estimates that 10% increase in the share of renewable energy avoids GDP losses in the range of $ 29 - $ 53 billion in the US and the EU ( $ 49 - $ 90 billion for OECD ) and these avoided losses offset half the renewable energy OECD investment needs projected by a G – 8 task force. Other benefits of renewable energy that (PIER55, 2009) consider includes job creation and ensuring that a country is less dependent on energy. This can be clearly understood because the money that is invested in renewable energy is typically spent on materials and staff that build and maintain equipment instead of importing energy.

2.7 Financing / micro financing of energy efficiency in small scale and micro businesses

Micro finance is the provision of broad range of financial services such as deposits, loan, payment services, money transfers and insurance to poor and low-income households and micro enterprises (4Shared, 2011). However, micro financing through collaboration with technical experts for service provision to micro and small scale businesses are not common and known and it is even more uncommon when the service is about energy efficiency.

(Rodriquez et al., 2002) concluded that there are three main constraints faced by small scale and micro businesses, namely constraint in policy and regulatory frame work, constraint in managerial capacity and lastly, constraint in access to financial markets. (Timberg & Thomas, 2000). (Beyene, 2004) also disclosed that rules and collateral were among the biggest problems faced by small scale and micro businesses as they are not able to fulfill minimum requirements as set by financial institutions.

These problems that researchers disclose above could be overcome if micro financial institutions could collaborate with experts to provide the service directly to these businesses and in this case micro financial institutions could lower the requirements for the small scale
businesses to access financing for their businesses when it concerns something on energy efficiency.

Energy efficiency in industries has become a global concern that has a potential of future cost reductions. According to (Turner & Doty, 2005) there is a direct economic return and most opportunities found in energy survey have less than two year payback. Some are immediate such as load shifting or going to new electric rate schedule.

Energy efficiency measures in industries may be implemented either as a retrofits whereby existing installations are improved through replacement with efficient components or energy efficiency investments can occur at the design and planning stage of new plants (United Nations, 1997).

Energy efficiency measures in small scale companies can be in a minimal cost whereby there is an efficient in house management through regular maintenance and housekeeping, through replacement of some selected equipment which may require medium size investment or through modification of entire manufacturing processes which is very high capital investments (United Nations environment and development division EDD, 1997). Again according to (United Nations environment and development division EDD, 1997) a considerable number of studies focused on the profit margin before making an investment decision. The efficiency measures that are likely to be supported are the once in which the investment can be recovered at short times. On the other hand investment that requires longer years as payback period normally gets approval from very few managers.

(International institute for energy conservation, 1998) estimated that at least US$ 500 million is available per year for the financing or energy efficiency projects in developing countries. The funds are in the form of loans or equity investment and it is expected to gain more grounds by the involvement of private commercial banks and other private sector investors.

According to (Kebir, 2009), Micro financial institutions are the best partners in the implementation process of energy efficiency financing in small scale companies provided they could be assured of quality. Small scale companies could therefore be made more energy efficient in their operation if the use of inefficient and low quality appliances could be avoided by simply replacing components with more efficient and high quality appliances. This investment could be best financed by collaboration between micro financial institutions and organizations with the technical knowhow on energy efficiency.

(FEEI, 2011) discusses the common barriers that are associated with the financing of energy efficiency. One was the fact that the private sector involvement in the financing of energy efficiency could be the solution but at present, private investors do not often finance energy efficiency projects due to the fact that the dedicated sources of financing are lacking and local banks are generally unfamiliar with such investments. There is therefore less doubt that in Ghana, it will take some time for the local Banks to be educated on such specific investments. The involvement of micro financial institutions in the form of micro credits could be a solution and this can work better for small scale businesses in the financing of energy efficiency. Another issue discussed by (FEEI, 2011) concerning the barriers for energy
efficiency financing is the absence of policy and institutional support for the implementation of the energy efficiency projects due to lack of knowledge.

(Painuly et al., 2003) Also highlights that in developing countries banks are unfamiliar with energy efficiency projects and are reluctant to fund them and even energy service companies that have the potential to address these problems is still a new concept in developing countries. (Painuly et al., 2003) again continues to provide solutions by highlighting on some feasible financing mechanisms for energy efficiency in developing countries. Among these suggested are The World Bank Group programmes like the International Finance Corporation (IFC), the energy sector management assistance programme, Asia Alternative Energy Programme, Renewable Energy and Energy Efficiency fund, Small and Medium Scale Enterprise (SME) programme of the IFC, and this is the largest source of financial and technical assistance to non OECD countries (Mullins et al., 1997).
3. METHOD

3.1 Selection of companies

Six Micro and small businesses in the Kumasi Metropolis were selected for the study. The selection was made by considering different industrial sectors in order to get a representative and true picture of the entire industrial setting of the small scale category in the Kumasi Metropolis. The companies that were selected for the different industrial sectors are presented in table 3 below;

<table>
<thead>
<tr>
<th>Industrial category</th>
<th>Selected companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel and Metal industry</td>
<td>Donyma steel complex</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>Locaf industry limited</td>
</tr>
<tr>
<td>Construction industry</td>
<td>Naachia Quarry and Granite Limited</td>
</tr>
<tr>
<td>Food Industry</td>
<td>Juaben Oil Mills limited</td>
</tr>
<tr>
<td>Gas industry</td>
<td>Air mate company limited</td>
</tr>
<tr>
<td>Drinking water industry</td>
<td>Everpure Ghana limited</td>
</tr>
</tbody>
</table>

3.2 Industrial energy system analysis

Industrial energy systems analysis is carried out in industries to maximize profits, reduce environmental impact and reduce use of resources. This is done in three parts; energy survey/auditing energy economizing and system analysis.

Industrial Energy system analysis was conducted on the companies listed above on two ways. First, questionnaires based on the energy use were administered to the companies in charge for responses as seen in appendix 9.2. The responses were made in a form of interview and were written down in the answering column on the questionnaire and recorded as well with the audacity software. Secondly, a practical energy survey was made in the companies concerned. This made it possible to appreciate the responses gathered on the questionnaire. The industrial energy system analysis consisted of energy survey, system analysis, Energy efficiency and conversion measures and documentation and these are explained below;
3.2.1 Energy survey / audit

Energy survey/audit are carried out in order to get information about the cost and quantity of each energy type used over a given time period. The unit processes are grouped into production and support processes and making use of data on energy use, energy bills, machines labels and specifications to quantify the energy use. Unit processes can be defined as the basic building blocks of energy use. The processes that make up production processes could be cooling, heating, mixing and cutting whiles support processes include lighting and ventilation. Unit processes provide a uniform means of making comparisons between plant processes, identifying potential energy savings, modeling energy systems and forecasting energy use (M Söderström, 1996). Examples of energy survey are shown in tables 2 and 3 for production and support processes respectively.

Measurements were carried out based on this with the help of watt meter to get the power consumption of various unit processes. Some of the parameters were also received through the energy bills of the companies concerned. The operation times of the machinery and the processes were asked for and this helped to get the energy consumption by multiplying the power and the operation time. Where the power consumption could not be measured or obtained directly, the current drawn and the voltage were measured with a meter and the three quantities (current, voltage and time) were multiplied together to get the energy consumption.

The various energy types such as electricity, oil, wood, steam or gas that go into the unit processes were classified for each unit process. The unit processes were grouped into production and support processes. Production processes were the actual processes such as cutting, crushing, milling etc. that are directly associated with production. Support processes are the processes such as ventilation which is not part of the actual production processes but that only helps for the operations to go on well.

Through the division the total energy consumption was obtained for production processes and support processes individually. The cost of electricity consumption was calculated by considering the current unit cost of electricity in Ghana.
### Table 4: Example of energy survey classification for production processes

<table>
<thead>
<tr>
<th>Branch</th>
<th>Unit processes</th>
<th>Production processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desintegration</td>
<td>Mixing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cutting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>joining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>coating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooling/freezing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Packing</td>
</tr>
<tr>
<td>Steel and Metal industry</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>chemical industry</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Construction industry</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>food industry</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Gas industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinking water industry</td>
<td>√</td>
<td></td>
</tr>
</tbody>
</table>

**V** = Unit process matching industry type

### Table 5: Example of energy survey classification for support processes

<table>
<thead>
<tr>
<th>Branch</th>
<th>Unit processes</th>
<th>Support Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compressed air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventilation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pumping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comfort</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal transport</td>
</tr>
<tr>
<td>Steel and Metal industry</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>chemical industry</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>construction industry</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>food industry</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Gas industry</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Drinking water industry</td>
<td>√</td>
<td></td>
</tr>
</tbody>
</table>

**V** = Unit process matching industry type
3.2.2 System analysis

System analysis links or interacts with the potential energy saving measures and other market parameters such as equipment cost, policy instruments, fuel and electricity prices increase. This makes it possible to evaluate the feasibility of any measure that will help bring energy savings.

A simple analysis on the energy cost to the various unit processes was made. The processes that have high energy consumption and low energy consumption were noted. Circumstances that bring about losses to the various unit processes were also considered. The operation times to the various machinery was also considered to determine the possibilities of reducing these operation times. The hot spots that have energy saving potential were considered. The processes that are not highly energy intensive was considered for a possibility of changing the energy carrier to a renewable energy and other strategies.

3.2.3 Energy economizing and efficiency measures

The three ways of enhancing industrial energy efficiency are to ensure more energy efficient behavior, conversion of energy carrier and switching to more energy efficient and modern technologies. These take into account less expensive and efficient energy saving measures in the process of energy efficiency and economizing.

Energy efficiency measures that are feasible to the processes with a potential of reducing energy consumption and energy cost were considered. The benefits that would come out as a result of this efficiency measures were looked into. Various efficiency measures were considered to find out which will suit a particular unit process.
4. RESULTS

4.1 Cost of energy use in small scale companies

Energy cost to the small scale companies is one of the key concerns to all the companies studied. This is because the profitability and sustainability of the entire company largely depends on the amount a particular company spent on energy in its operation.

The estimation of the energy consumption and cost in the companies has been calculated and it is shown in Tables 6 and 7 respectively.

4.2 Processes of the companies

4.2.1 Everpure Ghana Limited

Everpure Ghana Limited is a company that purifies raw water into good drinking water. Their production processes start with potassium ion exchange which removes hard mineral from water and replaces it with potassium. This is followed by activated carbon filtration that removes solvents and other organic compounds. Sediment filtration is done to remove dissolved particles in the water. Reverse osmosis Process ensures that only pure water passes through the system leaving minerals and other contaminants behind. Ultraviolet Sterilization process destroys all micro organisms and bacteria that may be found in the water. This process uses ultraviolet lighting machine. The final process which is the ozonisation process destroys any organic compound, biological contaminants or any virus that could be in the water and ensures long life span of the purified water.

Figure 3 shows the equipment in the production floor in the production processes.
4.2.2 Naachia Quarry and Granite Limited

Naachia Quarry and Granite Limited processes quarry aggregates for construction works. The main products are quarry dust; quarry aggregates or sometimes based on customer specifications. Their operation consists of two production processes which are primary crushing and secondary crushing. The primary crushing process uses primary crusher and crushes boulders into smaller aggregates and the machinery involve in this process uses electricity and diesel. The secondary crushing process also uses secondary crusher which further crushes the products from the primary crushing unit into sizes that are accepted by customers. This also uses diesel and electricity. The crushing process is done in a wet medium to reduce the dust that comes to the environment.

4.2.3 Air Mate Company Limited

Air mate co. Ltd is a manufacturer of industrial oxygen, nitrogen and acetylene. There are three main processes for the production. These are liquefaction of air, compression of air and expansion processes. The liquefaction process is used to obtain the oxygen in the air where the evolved gas mixture bubbles through liquid air which is rich in oxygen. The oxygen in the gas mixture then condenses and pure nitrogen gas leaves the column leaving pure liquid oxygen that is evaporated to get oxygen gas. The Compression process helps to increase the pressure of the air by reducing its volume. The expansion process cools the oxygen to a lower temperature.

4.2.4 Locaf Industry

This company processes raw bitumen into emulsion bitumen to be used by the construction companies for road construction and others.

The first production process is heating of the raw bitumen to a temperature of $140^\circ$C in order to ensure that the bitumen can flow in the rest of the plant processes and this is done by electrical burners that use electricity and diesel. The average daily consumption ranges from 6 to 9 units of electricity and it runs for 8 hours.

The Discharging process is the unit where the completed products are discharged and it also uses the same units of electricity and it also runs for 8 hours. The last production process is the plant section where the rest of the processes take place.

The support processes available are ventilation and lighting and the energy use for this is calculated in Appendix 9.1.
Figure 4 shows how the motor is integrated in the working processes.

![Motor working in one of the processes](image)

**Figure 4: Motor working in one of the processes**

### 4.2.5 Juaben Oil Mills

This company uses fresh fruit bunches to produce crude palm oil (C.P.O.) and palm kennel oil (P.K.O.) and then uses the C.P.O. to produce vegetable oil with by product of stearine and fatty acid. The company has three main production processes.

**Bleaching:** This changes the colour of the product after this process. The machinery used for the bleaching section is the bleacher or the acid reactor. Electricity and steam are the main energy types that are used in this section.

**Deodorizing:** This process gives a very good odour to the products. This second production process use deodorizer as the main machinery and this deodorizer use electricity and steam.

**Fractionation:** This process is for separation of the products. This section uses crystallizer, filter membrane. Electricity and steam are the energy used in this section.

The support processes are lighting and ventilation.

### 4.2.6 Donyma Steel Complex

This company deals with the manufacturing of nails, binding wires, roofing sheets, and toilet roll and shutter gates.

In terms of production, the first section is the nail processing section where the nails are manufactured. The equipment used in this section is the wire drawing machine which uses electricity and diesel when there is a power cut. Also furnace is the equipment used at the binding wire section and it as well uses electricity. IBR and the cutting machines are the equipment used at the roofing sheet section and they also use electricity and diesel. At the Toilet roll section toilet rolls are made and there is Jumbo and coiling machine that use...
electricity and sometimes diesel when there is no power. All the production sections named above run for 8 hours daily.

The support processes are as usual made up of ventilation that consists of fans and air conditioners and also bulbs for the lighting.

Tables 6 and 7 show the summary of the monthly energy consumption calculated for all the processes of all the businesses and monthly energy cost for all the businesses respectively. Donyma Steel complex registered the highest percentage of 30.20 in terms of its monthly energy use compared with its total monthly operation cost. This could be attributed to its melting process that consumes a lot of energy and comes out as a hot spot that will require more attention for energy saving techniques.

### Table 6: Monthly energy consumption in the various unit processes

<table>
<thead>
<tr>
<th>Business</th>
<th>Unit Processes</th>
<th>Ultraviolet machine</th>
<th>Reverse osmosis</th>
<th>Ozonation</th>
<th>Ventilation</th>
<th>Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everpure Ghana Ltd.</td>
<td>Plant section/ventilation/Lighting</td>
<td>288.00</td>
<td>8194.00</td>
<td>1424.00</td>
<td>79830.00</td>
<td>172.80</td>
</tr>
<tr>
<td>Naachia Quarry and Granite Ltd.</td>
<td>Primary crushing</td>
<td>15204.71</td>
<td>31134.00</td>
<td></td>
<td>2936.47</td>
<td></td>
</tr>
<tr>
<td>Air Mate Company Ltd.</td>
<td>Production processes (liquefaction, compression &amp; expansion)</td>
<td>32400.00</td>
<td>1296.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locaf Industry</td>
<td>Discharging / plant section</td>
<td>39921.84</td>
<td>15952.94</td>
<td>2316.55 litres</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juaben Oil Mills</td>
<td>Bleaching</td>
<td>20664.00</td>
<td>55706.40</td>
<td>110448.00</td>
<td>4309.20</td>
<td>725.40</td>
</tr>
<tr>
<td>Donyma Steel Complex</td>
<td>Plant section/ventilation/Lighting</td>
<td>94117.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7: Summary of the monthly energy cost of the various companies studied (1 GH¢ = € 0.47812) (Oanda, 2011).

<table>
<thead>
<tr>
<th>Company</th>
<th>Monthly energy cost in Ghana cedis (Gh¢)</th>
<th>Total overall monthly operation cost in Ghana cedis (Gh¢)</th>
<th>% of monthly energy cost over total monthly operation cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everpure Ghana Limited</td>
<td>15284.50</td>
<td>152,782.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Naachia Quarry and Granite Limited</td>
<td>16,352.88</td>
<td>96,193.41</td>
<td>17.00</td>
</tr>
<tr>
<td>Air Mate co. Ltd.</td>
<td>5,728.33</td>
<td>47,736.08</td>
<td>12.00</td>
</tr>
<tr>
<td>Locaf Industry</td>
<td>5,127.44</td>
<td>64,093.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Juaben Oil Mills</td>
<td>32,616.10</td>
<td>203,850.63</td>
<td>16.00</td>
</tr>
<tr>
<td>Donyma Steel Complex</td>
<td>16,000.00</td>
<td>53,009.56</td>
<td>30.20</td>
</tr>
</tbody>
</table>

4.3 Reliability of energy supply

Most of the companies studied revealed that the supply of energy and for that matter electricity is technically unreliable and inadequate. The main problem they pointed out was regular power fluctuation. Most times there are power cuts with no prior information or on very few occasions at short notices. They also get half current some times and are not able to power all their machinery as required.

For affordability, most pointed out that electricity tariffs are high and since electricity is the major source of energy available to them, they don’t have any alternative and they are forced to use it as it is. What they do is that they also try to adjust the prices of their products so that they can meet the amount of money they spend on energy. There are also regular increases of
electricity tariffs in Ghana and they are not able to have a long term plan on energy which affects them very well.

4.4 Existing practices for energy efficiency, energy economizing and value creation

Almost all the companies visited do not have laid down standard procedures they follow to ensure measures for energy economizing and efficiency. However, they are aware of the common practices that ensure energy economizing and efficiency but are not efficiently practiced. There are no clear checks and complete obligations on the practices that ensure energy efficiency. This is purely done on individual basis and willingness. Some of the existing common practices for energy efficiency and economizing to which the employees and for that matter the companies are aware but which are not efficiently practiced are simply shutting down of equipment and appliances when they are not use. Some also said that the machinery should be started sequentially in order to reduce maximum power demand and again continued to say that where possible the machines should run 24 hours a day for effective operation because any initial start of the machinery will demand a certain maximum power for start up. Some also said that if the frequent power fluctuations are stopped the energy use will be efficient for them.

Others were that machinery such as pumps and energy saving bulbs with less wattage or power consumption could be used instead of the usual ones with high power consumption and they stressed that this will require the complete change of the existing ones.

Everpure Ghana limited also mentioned that phase advance and capacity bank to improve the power factor is something they are thinking about installing for energy efficiency. Juaben Oil mills also mentioned that alternative voltage regulator is something they are thinking installing on their processes to be used for energy efficiency.

In order to enhance their processes and image in view of customers Everpure Ghana limited has adopted the practice of not using diesel or oil of any kind in their processes as a precautionary measure to avoid the spill of oil getting into their products since this is a water company. They have gone further to establish a communication with their customers and consumers so that they can get feedback on their products after consumption. In their reverse osmosis process, salt is added to give taste to the purified water and their customers accept this practice so much.

Juaben Oil mill has also instituted internal generation of electricity through a turbine that also supplies electricity to supplement its energy use. They also collaborate with local farmers in the area to cultivate the crops that could be used as raw materials for their work.

Naachia Quarry and Granite limited produces so much dust in the environment through their crushing process and the strategy they have adopted is that they have introduce wet crushing
through the addition of water in the crushers during crushing to suppress the dust into the atmosphere.

4.5 Legislations and regulations on energy use

The study revealed that there are no special legislations and regulations documented to be followed by micro and small businesses specifically on their energy use. Therefore these micro and small businesses are not affected by any regulation or policy instruments on their energy use and they could use any quantity of energy or could resort to any type of energy of their choice for their business.

However, these companies need to satisfy some regulatory bodies such as Environmental Protection Agency, Department of factories inspectorates, Ghana National Fire Service, Kumasi Metropolitan Assembly and Ghana Standard Board concerning cleanliness, quality production, fire safety, pollution control and others that are not specific on energy use.

The only policy available is that the Public Utilities Regulatory commission may terminate the service it provides to a consumer where the consumer fails to pay for the bills for the service used for more than 28 days from date of demand of payment (Ghana Public Utilities Regulatory Commission, 1999).

4.6 Energy efficiency financing and risks

Studies in the companies show that most of the companies concerned get part of their financing from the major Banks in Ghana and part from their own resources and capital. This is because most of the major banks are also into micro financing. Very few of these companies depend on micro financial institutions. Most of the micro financial institutions in the region deal with the buying and selling businesses more than the manufacturing ones. The concern of the companies is not only on energy efficiency financing but rather the financing of their entire business.

The major risks the companies concerned pointed out were the regular power fluctuation that ends up in damaging their equipment and slowing down their business operations and the consequence is that their profit margins are reduced over time and they spend extra money to repair their equipment and bring them to work.

The current high electricity tariffs paid by the companies are something that is also seen as a risk because they cannot also continuously increase the prices of their products to meet the cost of their operations.

The above risks mentioned were general to almost all the companies concerned. However, some companies specifically mentioned the risk that is peculiar to their business operations. Airmate Company mentioned that their businesses have health related implications over time and their processes are prone to explosion in case of excess pressure.
Naachia Quarry and Granite Limited also mentioned that their business is concerned with dust problem and falling objects which can cause accident some times.

Airmate Company is also concerned with calcium carbide formation which is associated with their business and it has toxicity implications to health. Explosion of oxygen is also something of concern to them.

4.7 Differences and similarities among the companies

One unique thing found in all the companies is the use of electricity through the available hydropower source. Therefore the unreliability of the electricity supply is a common problem faced by all the companies. The companies also lack a separate metering system for individual processes and this brings the general difficulty among the companies to quantify the electricity use for individual unit processes to know where the needed attention should be shifted for energy efficiency. It is also found that the use motors are common among all the companies and this will create the concern to be more particular in considering motor efficiency. Also because of the general expectation of regular uninformed power cuts most of the companies have a stand by generators which uses diesel and are used when there is a power cut. Those companies who don’t have the stand by generator are either planning to have one immediately or relaxing because of financial constraint to have one. Finally all the companies studied have a form of ventilation and lighting as their unit support processes.

Some differences were also observed among the companies. For instance Juaben oil mills have its own installed small turbine that generates its own internal electricity to be used as a supplement. Some of it’s by products are also used for a heating facility that powers the boilers. Apart from Juaben Oil mills none of the other companies have this facility. Also considering the hours of production, there is a substantial amount of differences. Some leave their machinery to operate for 6 or 8 hours and others like Juaben Oil Mills work for the whole 24 hours.
5. DISCUSSION

5.1 Selection of the unit processes

Unit processes are characterized as the building blocks of industrial energy use and are normally defined according to their aim and purpose. This has a great contribution and influence whenever energy audit is to be performed. This is because they split industrial energy use in smaller parts so that energy audits can be carried out without any difficulty. Again, unit processes are the components which together constitute the industrial energy use (Söderström, 1996).

There are eleven production and eight supporting processes that are common in all industries. The production processes are disintegration, mixing, cutting, joining, surface spreading, forming, heating, melting, drying and concentration, cooling and freezing and packaging. The supporting processes are lighting, compression (Air), ventilation, pumping, premises heating, premises cooling, tap hot water and internal transports.

Every industrial process could be described into one of these unit processes mentioned above and this is the basis and the selection criteria of the operation processes seen in the energy efficiency matrix in Figure 5.

5.2 Efficiency measures for energy consumption

From table where percentages of energy consumption are given in relation with the total operation cost, it could be seen that significant amount of operational expenditure goes into energy.

Donyma Steel Complex in the steel or metal industry consumes 30.2% of energy as compared with their total monthly operation cost which was the highest. This is partly because the melting process in their plant section is very energy consuming and this comes out as a hot spot that needs to be considered for energy saving measure. Any reduction of the energy cost through a possible energy efficiency measure or energy saving technique to reduce energy use or energy cost could add up a significant amount to the profit of the company. Even Locaf Industry which has only 8% of their operation cost as energy use still has a possibility to further reduce their energy use or energy cost through a possible efficiency measures. Any amount of savings through these efficiency measures would still be significant and could be used elsewhere in the business to strengthen other sectors of the business.

From the results on the existing practices for energy efficiency, it can be seen that measures that could promote energy efficiency for optimum operation are totally absent. Although very few techniques that could also promote energy efficiency are known to them, they are not actually practiced or not considered significant.
In order for these small businesses to add value to their operation processes they should incorporate energy efficiency measures to their processes. This value creation could lead to reduced energy use, reduced operation cost and environmentally friendly operation.

From the results of the study the following possible energy efficiency techniques could be analyzed to match the unit processes for effective operation. This is summarized in the Energy efficiency matrix based on the best available techniques as shown in Figure 5 and is discussed further according to the unit process.

*Lighting*

Lighting contributed significantly to the total energy cost of the small businesses studied when the results are considered. If an effective efficiency measure is considered in this area significant energy savings could be made. During the day most of the natural light could be utilized instead of electricity and this can help to significantly bring the cost of electricity down further. It would therefore do more good if the use of natural light in the businesses is optimized. This would require education to the building occupants. Greater reliance of natural light does not only reduce energy consumption but will positively impact on human health and performance.

The choice of lamps used in lighting could also contribute positively or negatively to energy savings. The replacement of incandescent bulbs with other more efficient types of bulbs such as fluorescent lights, high intensity discharge lamps, high emitting diodes etc could also contribute to significant amount of energy savings. The selection of fixtures and lamp types that reflect best available techniques for energy conservation and management is therefore important. Table 8 below shows the different types of lights and their efficiency level that will serve as a guide for the choice of lamp selection.
Table 8: Characteristics and efficiency of different light types (European Commission, 2009)

<table>
<thead>
<tr>
<th>Name</th>
<th>Optical spectrum</th>
<th>Nominal efficiency (lm / W)</th>
<th>Lifetime (mean time between failures, MTBF) (hours)</th>
<th>Colour temperature (Kelvin)</th>
<th>Colour rendering index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent light bulb</td>
<td>continuous</td>
<td>12 – 17</td>
<td>1000 – 2500</td>
<td>2700</td>
<td>Warm white (yellowish)</td>
</tr>
<tr>
<td>Halogen Lamp</td>
<td>continuous</td>
<td>16 – 23</td>
<td>3000 – 6000</td>
<td>3200</td>
<td>Warm white (yellowish)</td>
</tr>
<tr>
<td>Fluorescent lamp</td>
<td>Mercury line + phosphor</td>
<td>52 - 100</td>
<td>8000 – 20000</td>
<td>2700 – 5000</td>
<td>White (with a tinge of green)</td>
</tr>
<tr>
<td>Metal halide lamp</td>
<td>Quasi-continuous</td>
<td>50 - 115</td>
<td>6000-20000</td>
<td>3000 – 4500</td>
<td>Cold white</td>
</tr>
<tr>
<td>High pressure sodium</td>
<td>Broadband</td>
<td>55 – 140</td>
<td>10000 – 40000</td>
<td>1800 – 2200(3)</td>
<td>Pinkish orange</td>
</tr>
<tr>
<td>Low pressure sodium</td>
<td>Narrow line</td>
<td>100 - 200</td>
<td>18000 – 20000</td>
<td>1800(3)</td>
<td>Yellow, virtually no colour rendering</td>
</tr>
<tr>
<td>Sulphur lamp</td>
<td>continuous</td>
<td>80 - 110</td>
<td>15000 – 20000</td>
<td>6000</td>
<td>Pale green</td>
</tr>
<tr>
<td>Light emitting diodes</td>
<td>20 - 40</td>
<td>100000</td>
<td></td>
<td>(Amber and red light)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 - 20</td>
<td></td>
<td></td>
<td>(Blue and green light)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 - 12</td>
<td></td>
<td></td>
<td>(White)</td>
<td></td>
</tr>
</tbody>
</table>

(1) 1 lm = 1 cd.sr = 1 lx.m²
(2) colour temperature is defined as the temperature of a black body emitting similar spectrum. (3) These spectra are quite different from those of black bodies. (4) the colour rendering index (CRI) is a measure of the ability of a light source to reproduce the colours of various objects being lit by the source

Again light could be used in very efficient way when the use of natural light is optimized through proper planning of space and activities. In an environment where the weather is not very cold windows and doors could be left open for certain duration so that the environment could be exposed to natural light for a good vision. Electrical bulbs should not be necessarily left on in an environment where it is still possible to have a good sight with the available natural light. This will conserve a greater proportion of light energy.

In addition renewable energy sources such as solar energy especially in the tropic countries like Ghana and other known renewable energy potentials could be used for general lighting which could reduce significant environmental effects. In addition the use of lighting management control systems, sensors and timers will automatically determine when light is needed and to what intensity and act accordingly. This brings about the reduction in energy
consumption, increases bulb life and is cost effective and normally has a payback time of less than 2 years. Finally, occasional education for building occupants will go a long way to create the awareness for effective and efficient utilization of lighting.

Ventilation

Rooms with artificial ventilation should be left closed all the time so that fresh air that is supplied will not interact with the outside air temperature in order to maintain the room temperature stable for long. This can be ensured by using the automatic closure system of doors. The use of efficient fans that are designed to operate at the optimal rate will avoid excessive use of energy. Finally, the installation of variable speed drives (VSDs) with electrical motors will be able to accurately control the speed and power applied to the motor for efficient operation of the motor whenever motor is used to assist any ventilation set up or whenever electrical motor is used for any other purpose.

Electrical power supply

Importance should be attached whenever there is a Power supply by electricity because this area is very critical to look at when the issue of energy efficiency is considered. Whenever the electricity supply is by the help of motors, motors with high energy efficiency should be considered because inefficient motors have the capacity of consuming more energy. Again most electrical equipment and appliances have a specific rated voltage and care should be taken so that the rated voltage shall not be exceeded. In addition lightly loaded motors or motors that have been in idle for long should have a minimized operation. Finally, the installation of capacitors in the AC circuits will decrease the magnitude of reactive power by ensuring effective operation to reduce the waste of power.

Heating

Insulation is best known strategy to decrease heat lost in most systems. Therefore this strategy will contribute to the efficient ways of reducing heat losses in production systems. Most heat from systems that come out unused are normally considered as waste heat. Measures can be put in place to tap this waste heat to be reused in production systems to reduce the heating requirements for energy conservation. Finally automatic closure systems can also ensure the efficient use of heat to reduce losses.

Diesel generator

Most generators that are old tend to make a lot of noise when it is in operation. This noise level goes to increase the diesel consumption of the generator. It is therefore appropriate to use high energy efficient as well as a bit newer generators to reduce diesel consumption. Also instead of the use of diesel from the fossil origin it is worth considering using renewable energy sources such as biofuels for generator operation.
Air compressor

Air compression is a support process which is made up of a device that converts power into kinetic energy by pressure and compression of air. It is an energy intensive process and therefore there is the need to consider energy efficiency techniques for this process. The means by which the energy use in this process could be reduced for cost savings are the use of energy efficient motors to reduce current flow, the use of fixed speed compressors (FSC), reduction of any leakage in the compressed air system and the feeding compressor with cool outside air.
<table>
<thead>
<tr>
<th>Energy efficiency techniques</th>
<th>Operation Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>use recuperative and regenerative burners</td>
<td>Lighting</td>
</tr>
<tr>
<td>use fluidised bed combustion</td>
<td>Ventilation</td>
</tr>
<tr>
<td>use waste heat</td>
<td>Electrical power supply</td>
</tr>
<tr>
<td>efficient glazing</td>
<td>Electrical motor</td>
</tr>
<tr>
<td>insulation of pipes</td>
<td>Diesel Generator</td>
</tr>
<tr>
<td>add boiler refractory</td>
<td>Compression</td>
</tr>
<tr>
<td>adopt sequential boiler controls</td>
<td>Pumping system</td>
</tr>
<tr>
<td>install flue-gas isolation dampers</td>
<td>Steam system</td>
</tr>
<tr>
<td>use throttle control of pumps</td>
<td>Heating</td>
</tr>
<tr>
<td>use centrifugal pumps</td>
<td>Combustion</td>
</tr>
<tr>
<td>feed compressor with cool outside air</td>
<td></td>
</tr>
<tr>
<td>reduce compressed air system (CAS) leakage</td>
<td></td>
</tr>
<tr>
<td>use fixed speed compressors (FSC)</td>
<td></td>
</tr>
<tr>
<td>use high efficiency generator</td>
<td></td>
</tr>
<tr>
<td>installing high efficiency transmission / reducers</td>
<td></td>
</tr>
<tr>
<td>using energy efficient motors</td>
<td></td>
</tr>
<tr>
<td>avoiding the operation of equipment above its rated voltage</td>
<td></td>
</tr>
<tr>
<td>minimizing the operation of idling or lightly loaded motors</td>
<td></td>
</tr>
<tr>
<td>installing capacitors in the AC circuits to decrease the magnitude of reactive power</td>
<td></td>
</tr>
<tr>
<td>automatic closure of doors</td>
<td></td>
</tr>
<tr>
<td>optimize electric motors and consider installing a VSD</td>
<td></td>
</tr>
<tr>
<td>use fans of high efficiency and designed to operate at optimal rate</td>
<td></td>
</tr>
<tr>
<td>education of building occupants</td>
<td></td>
</tr>
<tr>
<td>use lighting management control systems including occupancy sensors, timers</td>
<td></td>
</tr>
<tr>
<td>select lamps according to specific requirements for intended use (refer table)</td>
<td></td>
</tr>
<tr>
<td>use renewable energy example solar, biofuel</td>
<td></td>
</tr>
<tr>
<td>optimize the use of natural light</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5: Energy efficiency matrix based on (European Commission, 2009)*

<table>
<thead>
<tr>
<th>Best available technique</th>
</tr>
</thead>
</table>
Proper selection of lights through identification of illumination needs for a given area, optimizing the use of natural light, selection of fixture and lamp types according to specific requirements for the intended use as is seen in table 2 and good management of lighting has a potential of reducing lighting energy use of between 30 – 50% (European Commission, 2009).

Other efficiency measures that could also be considered for significant energy savings in the operation of these small businesses could be in the form of renewable energy. Less energy intensive machinery used in these businesses could operate on solar. Although the initial installation cost of solar could be expensive, in the long term perspective when the pay-back time is due the operation on solar could be very cheap and will bring more profit to the business.

Another example is that most of these small businesses use stand by generator because of the unreliability of the power supply and regular power cuts. These stand by generators use diesel from the fossil origin. A possible replacement for energy savings could be the use of biofuels instead of fossil diesel if that would be cheaper compared to diesel. The biofuels in this instant if it could be cheaper than diesel will not only be cost effective but will also impact positively on the global environment although the businesses involved are more focused on the economic incentive that may result than the positives that will come to the environment.

Also another possible area of prime importance that is clearly mentioned in figure 5 is the replacement of equipment with highly energy efficient ones. This could contribute a significant savings in energy use. For instance when considering motors, the use of energy efficient motors provide energy efficiency in industrial settings. A significant energy savings of between 2 to 8% can be achieved for motors of 1 – 15kW (European Commission, 2009). Other benefits for resorting to energy efficient motors could be in increase of reliability, reduction of downtime and maintenance cost, increase in tolerance to thermal stresses, improvement of the ability to handle overload conditions, improvement of resistance to abnormal operating conditions – under and over voltage, improvement of power factor and reduction of noise.

Other potential efficiency measures that could match the unit processes and the operation of these businesses in consideration have been discussed further in the energy efficiency matrix found in figure 5.

5.3 Consequence of unreliability in the power supply

The unreliability in the power supply could lead to serious problems in the operation of these businesses. Sudden and uninformed power cuts could interrupt operation and further lead to a damage of appliances and machinery. This will need further capital and resources for maintenance thereby increasing the maintenance cost of these businesses. In addition there could be some delays in production and targets may not be met.
Therefore, a technique that could lead to efficient and reliable power supply should be considered. Alternative way of energy that will provide efficient and equal power supply that could meet the needs of these companies will be helpful. Again renewable energy such as solar could be a potential resource and may even be economically beneficial compared to the business-as-usual energy system (Mathiesen et al., 2010).

5.4 Energy use and legislations

The results above on legislations indicated that there are no specific and strong legislations concerning the use of energy by these micro and small businesses. This means that these companies concerned could rely on any energy types of their choice in their operations.

Again private organizations could be encouraged to come in to invest by financing energy efficiency for these companies since they would not be inhibited by hard and numerous legislations. This will promote profitability and sustainability of these companies. The best way could be collaboration between already existing financial institutions or more specifically micro financial institutions with technical institutions with the knowhow concerning energy efficiency techniques to realize this objective.

Because of non-existing of any strong legislation or regulation on energy use to these businesses and the little consideration on the environmental perspective which was found to be common to the businesses, any feasible energy efficiency measure would only be considered and embraced by these businesses if only it could meet their expectations in terms of economics by bringing down their energy cost rather than impacting positively on the environment. This is because there is the absent of any strong legislation that binds them for which they will be accountable on environmental issues.

In addition, the Government can also initiate a favorable renewable energy policy in Ghana such as subsidy programmes with cooperation with micro financial institutions in all small scale businesses who want to start renewable energy programmes for their businesses. This will encourage many small scale companies to start thinking about the use of renewable energy for their businesses.

5.5 Energy use and implications to the global environment

High energy use in the industries is a way of contributing to the \( \text{CO}_2 \) emissions to the environment which could lead to global warming. Inclusion of energy saving strategies in the processes of these small businesses will lead to reduced energy use and thereby impacting positively on the global environment.

More energy consumption leads to the creation of more by-products. Most of these by-products are pollutants to the environment. Therefore energy consumption have direct link with the environment and if energy use in these industries are reduced significantly through proper efficiency measures the pollution in the environment will also be reduced.
The source of energy is also an important factor. If these small scale businesses could rely on more renewable sources of energy, this sector of industry could contribute greatly and significantly to the solutions to the green house gases emission to the environment.

5.6 Service provision for energy efficiency

The implementation of the energy efficiency measures based on the energy efficiency matrix analyzed and summarized in Figure 5 could lead to higher quality of energy provision to these businesses and this can ensure a reduced energy use, reduced operation cost and more quality and sustainable oriented production processes. However, the businesses under consideration are not highly equipped enough in terms of finances and the technical knowhow to implement the measures analyzed.

Service provision for energy efficiency or leasing would therefore be logical to these businesses. In order for the service providers to get the needed returns on their service or investment in this field particularly to the small scale businesses, the concentration of their service would have to be on reduced energy use, quality and efficient energy provision such as the ones analyzed above in the energy efficiency matrix in Figure 5 that will eventually lead to a reduced energy cost to these businesses in comparison with their current expenditure on energy use. This is because the driving force that will ensure that these businesses patronize in this service provision is the reduction of energy cost to their businesses and not necessarily the positive impacts to the environment.

Because of the fact that these small scale businesses and most financial institutions are not familiar to this kind of investment opportunities they will require education to freely embrace this idea and involve participate. This additional task and responsibility on education would have to come from the service providers.

Furthermore, it is mentioned in the literature review that micro financial institutions could be the best option to collaborate with these service providers so that needed investment could be raised. Again because most of these financial institutions are new into this kind of investment and almost are unfamiliar with it they will also need education to patronize.

5.7 Answers to the research questions

Considering the first research question about how energy is consumed and how value could be added to the operation processes, it can be established that not all the energy supplied to these businesses are used efficiently due to lack of energy efficiency measures as a result of inefficient machinery, possible and preventable losses and lack of proper planning and available system for energy utilization. Value could therefore be added to the operation processes of these businesses by incorporating energy efficiency measures in the processes of these businesses. The literature review brings out the general importance and some of the techniques available for ensuring energy efficiency in companies in general. However, it should be noted that implementing these energy efficiency techniques in the businesses
targeted will need skilled energy management professionals and experts which is lacking and it is put forward by (Thollander et al., 2005) as one of the barriers to energy efficiency.

This thesis brings out a new idea to overcome this barrier by suggesting collaboration between financial institutions preferably, in the micro perspective and skilled energy management professionals and experts to help these businesses to implement the energy efficiency techniques.

In the research, concerning the reliability and the sustainability of energy supply as is in the second research question, the businesses under consideration suffer from consistent price increases of energy use which poses an economical threat for their continued existence and sustainability. Also technically there are regular uninformed power outages and low currents which make the supply of electricity and for that matter energy technically unreliable. Environmentally, the energy use which is from hydropower sources is from renewable origin and it is known for its environmentally friendliness which will enhance the environmental sustainability. What was observed in this research was that these businesses are concerned with the economic benefits of implementation of energy efficiency so by encouraging them to implement energy efficiency measures in their businesses with the concern of positive economic impacts, these businesses at the same time indirectly contribute positively to the environment by reducing the emissions of green house gases to the atmosphere as a result of the energy efficiency implementation.

Considering the social dimension in terms of sustainability, there is the possibility of further job creation in the energy efficiency implementation since a collaboration of energy experts, financial institutions and the businesses will bring expansion in terms of employment. In addition, the energy efficiency implementation will lead to a reduced cost concerning energy use and the extra income realized could be used to motivate employees to enhance their well being leading to increased production thereby enhancing social sustainability.

Finally, in the last research question about the legislations and regulations on energy use, the research finds that there is the existent of some legislations and regulations for the operation of these businesses; none of these regulations and legislations specifically concerns itself with energy use by these businesses. Another new issue put forward by this thesis is that enabling environment will be created for private investors to look at energy efficiency projects for these businesses and therefore this study has hinted financial institutions and private investors who are normally unfamiliar with energy efficiency projects as reviewed in the literatures of this study that there is more potential in investing in energy efficiency projects for the productivity of micro and small scale businesses in Kumasi-Ghana.
6. CONCLUSIONS

Energy efficiency is the use of the minimum or less amount of energy to produce the same service possible. Example is when you change equipment such as a washing machine or refrigerator or any office device such as a printer, photocopier or a computer with more energy efficient ones, the new equipment provides the same service but uses less energy because it is highly energy efficient. This brings money savings on energy bills and brings a reduction of greenhouse gases into the atmosphere. Micro and small scale businesses in Ghana are suffering from the rather use of large amount of energy to produce the same quantities and qualities of products which could have been possible in the same manner through a reduced energy use. In industry, energy efficiency reduces system cost and emissions to the environment and energy survey or audits are therefore carried out in industry to identify measures that would increase energy efficiency.

In this study industrial energy system analysis has been carried out to know the energy consumption pattern of micro and small scale businesses in Kumasi-Ghana and through this feasible energy efficiency measures have been analyzed and modeled in an energy efficiency matrix seen in Figure 5. The industrial energy system analysis was done through a practical study and the administering of questionnaire and this gave additional information on the policy instruments for energy use and their effects on these micro and small businesses. The findings of this study are relevant to the current issue over energy efficiency measures for micro and small businesses with regard to the minimization of energy use.

In considering the first research question about energy consumption and value addition on the processes of micro and small scale businesses in Kumasi-Ghana and the second question which is also on economics and environment, the research findings were that:

- Energy supply to micro and small scale businesses is not economically and technically reliable because of regular power cuts that disrupts production and it is becoming continuously expensive and this pose threats to the sustainability of such companies. The energy supply is only environmentally reliable and sustainable because the main energy use by the businesses studied is electricity from the hydropower source which is of renewable origin and poses less or no threats to the environment.

- Value addition to micro and small scale businesses could be achieved by incorporating energy efficiency measures in the processes of these businesses.

- The priority of micro and small businesses in Kumasi- Ghana for the implementation of energy efficiency measures is on economics of their businesses rather than the environmental sustainability perspective.

- Renewable energy could be the immediate long term solution in terms of energy efficiency for ensuring the sustainability of these businesses in Kumasi-Ghana.

Concerning legislations and regulations on energy use by these businesses that are addressed by the third research question, the study concludes that
• There are no specific legislations and regulations on energy use that affect the operation of these businesses and this could create enabling environment for private investors on energy efficiency for these businesses.

From the findings drawn above the study has hinted financial institutions and private investors who are normally unfamiliar with energy efficiency projects as reviewed in the literatures of this study that there is a potential in investing in energy efficiency projects for the productivity of micro and small scale businesses in Kumasi-Ghana. In addition stakeholders and experts in the renewable energy sector could rely on these findings and give a greater concentration to explore the potentials in the developing countries in their businesses settings. This could help achieve the economics these businesses seek on their energy use and indirectly ensure environmental sustainability which is of less concern to these businesses.

This project only concentrates in general terms the feasible energy efficiency measures that could allow these businesses save cost and attain sustainability. Future research prospects on the same issue could be the comparison of the different approaches analyzed in this study for energy efficiency to find out which of the energy efficiency measures will best suit a particular process for higher energy savings. The reference point could be the reliance of the current operation of these businesses with the hydroelectricity available without any changes to the existing processes which could play a vital role in having an effective comparison of the different approaches analyzed in this study for energy efficiency. Afterwards the best alternative among the ones put forward for individual processes from this study could be concluded on.

Since other developing countries have less explored the utilization of renewable energy techniques and the similarity of the energy consumption trend in their businesses as compared with the ones in Ghana from this thesis, there is the justification to generalize the findings from this research for all developing countries.

Shareholders for these businesses studied could also influence greatly by pressuring the businesses to implement energy efficiency measures in their operation to reduce operation cost so that profitability of shareholders could be enhanced.
7. RECOMMENDATIONS
In this study it is found that the incorporation of energy efficiency measures in the operation of the micro and small scale businesses will reduce their energy cost and make them more sustainable. It is therefore recommended that these small businesses incorporate the suggested energy efficiency measures as seen in the energy efficiency matrix in Figure 5, example the use of energy saving lamps for lighting in their operation to reduce their operation cost.

Also Technical experts, financiers and consulting financiers could come in and act as service provider with their technical expertise and finances in order to provide quality and efficient energy provision to these businesses to make them sustainable and help them reduce cost of operation. However these businesses will first need to be educated in this direction and their investment should concentrate on the reduction of energy use and thereby reducing energy cost to maximize the patronage of these businesses.

Again it is also recommended that technical experts and financiers of this field could still engage other companies of this category that were not studied in this project because they will also fall into the same category and they will have the same characteristics about their energy use but all of them will first need education. They could also explore other small businesses or homes that are not into manufacturing but still uses appliances that use electricity. In this sense the energy use may not be much and they could replace it with more efficient renewable energy technologies and this could attract patronage if the energy cost of the new technology would be less than the available electricity alternative.
8. REFERENCES


Rodriquez, & et al. (2002). *Report and recommendation of the president to the Board of Directors on a proposed loan and technical assistance grant to the Republic of Indonesia for small and medium enterprise export development: Asian development bank*. Jakarta: Asian development bank.


9. APPENDICES

9.1 Calculation of energy consumption

Everpure Ghana Limited

Energy use for production processes

Ultraviolet lighting machine

This machine uses electricity with 5AMPS of current running with a voltage of 240V. The machine runs 12 hours a day with the exception of Saturdays and Sundays. Therefore daily energy use can be calculated as

\[
\text{Energy} = 240 \times 5 \times 10^{-3} \times 12
\]

= 14.40 kWh

Reverse Osmosis Process;

The process uses electricity with multimedia machine that operates with 5AMPS and 415V. It also uses four electrical motors with horse powers 15, 15, 3 and 10 respectively. This system also runs for 12 hours a day and are shut down on Saturdays and Sundays since there is no production on these days.

Daily energy consumption in the multimedia machine = 5 \times 415 \times 12 \times 10^{-3}

= 24.90 kWh

Daily energy consumption for the four motors

= (15 + 15 + 3 + 10) \times 745.6999 \times 10^{-3} \times 12

(745.6999 is for conversion of horse power to power, 1 horse power = 745.6999) (Engineering toolbox, 2011).

= 384.80 kWh.

Total daily energy consumption for the reverse osmosis process = 384.80 + 24.90

= 409.70 kWh

Ozonization Process;

This uses electricity with one pump of horse power 3 and an ozonization machine that operates with 415 volts and a current of 8.9 AMPS. The system also runs for 12 hours excluding Saturdays and Sundays. Daily energy consumption is therefore calculated as

\[
[(3 \times 745.6999) + (8.9 \times 415)] \times 10^{-3} \times 12
\]
Therefore total daily energy consumption for production processes is given by
\[
14.40 + 409.70 + 71.20
= 495.30 \text{ kWh}
\]

*Energy use for Support processes*

The company has two main support processes which are lighting and ventilation. The lighting system uses electricity that consists of 19 pieces of 60 watt bulbs. Five of these 19 bulbs are in the production floors which are kept on for 12 hours. The other lights are only on for 6 hours a day from Monday to Friday.

The ventilation is also made up of two air conditioners with 1995 kW each and three fans with 0.5 kW each. The fans and the air conditioners work for 6 hours a day excluding weekends. Both supporting systems use electricity.

Daily energy consumption for the lighting system can be calculated as
\[
[14 \times 60 \times 10^{-3} \times 6] + [5 \times 60 \times 10^{-3} \times 12]
= 8.64 \text{ kWh}
\]

Similarly, the energy consumption for the ventilation system is given by
\[
(2 \times 1995) + (3 \times 0.5)
= 3991.50 \text{ kWh}
\]

The total daily consumption for support process = 8.64 + 3991.5
= 4000.14 kWh

Total daily energy consumption for both production and support processes is given by
\[
495.3 + 4000.14
= 4495.44 \text{ kWh}
\]

For 20 days operation in a month, the total monthly energy consumption for all processes is
\[
20 \times 4495.44
= 89908.80 \text{ kWh}
\]

Considering the current unit cost of electricity in Ghana to be GH¢ 0.17 / kWh (Ghana Public Utilities Regulatory Commission, 2010).

Total monthly cost of energy = 89908.80 \times 0.17
= GH¢ 15,284.50 (Ghana cedis).
Naachia Quarry and Granite Limited

Energy use for production processes

The primary crushing section always remains in operation 7 hours a day and the average daily power consumption of the primary crusher is 253 kWh. The daily total energy cost for the primary crushing section was giving as GH¢ 107.70 based on the responses to the questionnaire that was administered.

The secondary crusher at the secondary crushing plant consumes daily energy of 1297.25 kWh in the 7 hours of daily operation. The daily energy cost for this section was also given as GH¢ 552.87.

Therefore the total daily energy cost for the two production processes can be calculated as

\[ 107.70 + 552.87 = GH¢ 660.57. \]

The company works everyday with the exception of Saturdays. Therefore, for 24 days a month the monthly energy cost for the production is given by

\[ 24 \times 660.57 = GH¢ 15,853.68. \]

The support processes are made up of ventilation (fans and air conditioners) and lighting that use electricity with a total daily energy consumption of 48.8 kWh. The company also has a stand by generator that works with diesel and it is used when there is a power outage. On the average a total of 455 liters of diesel a day is used for this purpose. The total daily cost of energy for these support processes was given as GH¢ 20.80.

The monthly energy cost for the support process is therefore given by

\[ 24 \times 20.80 = GH¢ 499.20. \]

Therefore the overall monthly energy cost for the company can be calculated as

\[ 15,853.68 + 499.20 = GH¢ 16,352.88. \]
Air Mate Company Limited

Energy use for production processes

The three production processes are linked together and the total power consumption for one hour for all the three production processes was given as 150kW.

The company works from 8am to 5pm daily excluding Saturdays and that gives a total working hours for production to be 9 hours a day. Therefore the average daily energy consumption for the production processes can be calculated as

\[ 150 \times 9 = 1350 \text{ kWh a day.} \]

Therefore the monthly energy consumption for these production processes can be calculated as

\[ 24 \times 1350 = 32,400 \text{ kWh per month for production.} \]

The energy consumption for the support processes that are made up of lighting and ventilation as (air conditioning and fans) was given as two percent each for lighting and ventilation. Therefore 4% of the total energy consumption for production is spent as support processes made up of ventilation and lighting.

Therefore the total daily power consumption for support processes is given by

\[ \frac{4}{100} \times 150 = 6.00 \text{ kW} \]

For 9 hours of operation, the total daily energy use for support processes is given by

\[ 6 \times 9 = 54 \text{ kWh} \]

For 24 days a month the total monthly energy use for support processes can be calculated as

\[ 24 \times 54 = 1296.00 \text{ kWh} \]

The total monthly energy use for both support and production processes for the company is calculated below

\[ 32,400 + 1296 = 33,696 \text{ kWh} \]

For a unit cost of electricity of GH¢ 0.17 / kWh
The total monthly energy cost for the company is given by

\[ 33,696 \times 0.17 \]

GH¢ 5728.33

**Local Industry**

*Energy use for production processes*

The *Discharging process* uses electricity and it runs for 8 hours. The last production process is the *plant section* where the rest of the processes take place. It operates with pumps, motors and a mill and this section also uses electricity with an operating voltage of 415 volts and it runs for 7 hours a day.

The total daily energy cost for all the production processes was given as GH¢ 282.78.

*Energy use for Support processes*

Ventilation and lighting are the two main support processes and the daily total power consumption was given as 105 watts. Again the support processes are in operation from 7.30am to 6pm.

The daily total energy cost for the support processes (ventilation and lighting) was given as GH¢ 113. Also because of frequent power outages and in order not to disrupt the company’s operation a stand by generator that uses diesel is used whenever there is a power cut. The amount of money spent on fuel for the generator was given for a three month average from October to December 2010.

October 2010 - GH¢ 2,719.90
November 2010 - GH¢ 1,887.46
December 2010 - GH¢ 6,025.59

Therefore the average expenditure of fuel for the generator per month is estimated as GH¢ 3,544.32.

Also considering the total daily energy cost for production and support (ventilation and lighting) the two can be added as shown below

\[ 282.78 + 113 \]

\[ = GH¢ 395.78 \]

The company works only on week days and therefore has 24 days a month for operation. The monthly energy cost for production and support (i.e. ventilation and lighting) is therefore

\[ 4 \times 395.78 \]

\[ = GH¢ 1583.12 \]
When the monthly fuel cost for the stand by generator is considered, the overall monthly energy cost increases to
\[ 1583.12 + 3544.32 \]
\[ = \text{GH}£ 5,127.44 \]

**Juabin Oil Mills**

Energy use for production processes

**Bleaching**

The daily power consumption for the machinery in this section is 28.70 kW and it runs for 24 hours through the shift system. The daily energy for the 24 hours production in this process is therefore calculated as
\[ 24 \times 28.7 \]
\[ = 688.80 \text{ kWh} \]

The daily cost of energy for this process considering the unit cost is
\[ 688.8 \times 0.17 \]
\[ = \text{GH}£ 117.10 \]

**Deodorizing**

The daily power consumption for this process is 77.37 kW and for 24 hours of operation, the daily energy for this process is given by
\[ 77.37 \times 24 \]
\[ = 1856.88 \text{ kWh} \]

The daily energy for this is therefore given by
\[ 1856.88 \times 0.17 \]
\[ = \text{GH}£ 315.67 \]

**Fractionation**

The power consumption for this process is 153.40 kW. For 24 hours of operation, the daily energy for this section is
\[ 153.4 \times 24 \]
\[ = 3681.6 \text{ kWh} \]

Therefore the daily energy use in this section is
\[ 3681.6 \times 0.17 \]
From the above calculations, the daily energy consumption for all the production processes can be summed up as

\[117.1 + 315.67 + 625.87\]

= GH₵ 1058.64

For 30 days a month the monthly energy cost for production processes is calculated as

\[30 \times 1058.64\]

= GH₵ 31,759.20.

**Energy use for Support processes**

The support processes are lighting and ventilation. There are 31 fluorescent bulbs in the entire company of 60 watts each that are kept on from 6pm to 7am (13 hours). The daily energy consumption for the lighting is therefore

\[
\left(\frac{60 \times 31}{1000}\right) \times 13 \times 0.17
\]

= GH₵ 4.11

The ventilation is made up of 3 air conditioners with a power consumption of 1995 W each and 2 fans with a power of 0.5 kW each. The total daily energy is therefore

\[
\left(\frac{1995 \times 3}{1000}\right) + (2 \times 0.5)
\] \times 24

= 143.64 kWh.

The daily energy cost for this is therefore calculated as

\[143.64 \times 0.17\]

= GH₵ 24.42

Therefore for lighting and ventilation the daily energy cost is

\[4.11 + 24.42\]

= GH₵ 28.53.

Again for 30 days operation in a month, the overall monthly energy cost for support processes is calculated as

\[30 \times 28.53\]

= GH₵ 855.90.

For both support and production processes, the overall monthly energy cost for the company is therefore

= GH₵ 625.87.
31759.20 + 855.90

= GH¢ 32,615.10

**Donyma Steel Complex**

The figure that was given as the average monthly cost of energy for both support and production processes for the entire company is GH¢ 16000.
9.2 Questionnaire used for the study

Interviewer’s name: ....................................................................................................................

Respondent’s Name...................................................................................................................

Name of the company…………………………………………………………………………………

Respondent’s Position………………………………………………………………………………

A. Please provide a brief description of what the company does

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

B. Main product(s) of the company

1. .............................................................

2. .............................................................

C. Category of business (please tick the one that apply)

☐ Manufacturing / Engineering Company ☐ Fashion Company ☐ Trade

☐ Chemical company ☐ food company ☐ other (please specify)………………………………………………………………………………
D. What are the major risks for your business

E. What does your business need the most in order grow

F. Please provide the name of the financial institution that supports the company financially

G. What is the category of the financial institution named above (please tick the one that apply)

   [ ] Micro financial institution
   [ ] Major commercial Bank

H. Please name all and describe the various unit processes for production processes of the company operations indicated below

   Production process 1

   Name of machinery / equipment used for this process

   Type of energy use for this process

   Daily power consumption of this process

   Daily energy consumption for this process

   Daily cost of energy use for this process

   Any idea of how this type of energy use in this process could be improved

   Production process 2

   Name of machinery / equipment used for this process

   Type of energy use for this process

   Daily power consumption of this process

   Daily energy consumption for this process

   Daily cost of energy use for this process

   Any idea of how this type of energy use in this process could be improved

   Production process 3
Name of machinery / equipment used for this process…………………………………
Type of energy use for this process……………………………………………………
Daily power consumption of this process………………………………………………
Daily energy consumption for this process……………………………………………
Daily cost of energy use for this process………………………………………………
Any idea of how this type of energy use in this process could be improved…………
Production process 4……………………………………………………………………
Name of machinery / equipment used for this process…………………………………
Type of energy use for this process……………………………………………………
Daily power consumption of this process………………………………………………
Daily energy consumption for this process……………………………………………
Daily cost of energy use for this process………………………………………………
Any idea of how this type of energy use in this process could be improved…………
I. Please name all and describe the various unit processes for support processes of the company operations indicated below
Support process 1…………………………………………………………………………
Name of machinery / equipment used for this process…………………………………
Type of energy use for this process……………………………………………………
Daily power consumption of this process………………………………………………
Daily energy consumption for this process……………………………………………
Daily cost of energy use for this process………………………………………………
Any idea of how this type of energy use in this process could be improved…………
Support process 2…………………………………………………………………………
Name of machinery / equipment used for this process…………………………………
Type of energy use for this process……………………………………………………
Daily power consumption of this process

Daily energy consumption for this process

Daily cost of energy use for this process

Any idea of how this type of energy use in this process could be improved

Support process 3

Name of machinery / equipment used for this process

Type of energy use for this process

Daily power consumption of this process

Daily energy consumption for this process

Daily cost of energy use for this process

Any idea of how this type of energy use in this process could be improved

Support process 4

Name of machinery / equipment used for this process

Type of energy use for this process

Daily power consumption of this process

Daily energy consumption for this process

Daily cost of energy use for this process

Any idea of how this type of energy use in this process could be improved

What is the overall monthly energy cost of the company (use the below categories)

Energy type 1

Energy type 2

Energy type 3

Total monthly cost of energy use
K. Are there any demand(s) and requirements on your company’s energy use by Kumasi Metropolitan Assembly (KMA) or any other regulatory body?

Yes ☐ No ☐ (please tick the one that apply).

If yes to the question above, what is it? .................................................................

L. Please use the following to describe the energy supply to your company in terms of reliability and sustainability (tick as appropriate and provide justification)

Affordable economically ☐ yes ☐ No

If yes please justify.................................................................

If no, what are the challenges? .................................................................

Technically reliable ☐ yes ☐ No

If yes please justify.................................................................

If no, what are the challenges? .................................................................

Environmentally reliable ☐ yes ☐ No

If yes please justify.................................................................

If no, what are the challenges? .................................................................