POLITECNICO DI MILANO
Facoltà di Ingegneria dei Sistemi

POLO REGIONALE DI COMO

Master of Science in
Management, Economics and Industrial Engineering

PROCESS DEFINITION FOR THE IMPLEMENTATION OF AN ENERGY EFFICIENCY PROGRAM IN MANUFACTURING FOCUSED ON KEY PERFORMANCE INDICATORS

Supervisor: Prof. Marco Taisch
Assistant Supervisor: Alessandro Cannata

Master Graduation Thesis by: Sara Maria Muñoz Lopez
Student Id. number 736514

Academic Year 2009-2010

CONTENT

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Scope of the thesis

The development of this thesis starts with the objective of understanding the general overview of the energy consumption and energy efficiency issues in the manufacturing sector and the use of key performance indicators for the analysis and evaluation of the organization´s performance in this field.

As energy is critical to economic and social development and is a valuable finite resource, the industrial energy demand varies across regions and countries and also depends on the level and mix of the economic activity and technological development among other factors; for those reasons the principal objective of this thesis is to define an energy efficiency program focused on key performance indicators and energy-related measurements, in order to help and to guide manufacturing organizations in measuring and setting indicators on its performance in this field with the aim of making the organization more efficient and aligned with sustainability objectives that nowadays is requiring worldwide. In this way, companies will be more competitive and the decision making process related to environmental, sustainability and economic concerns at different levels within the organization (strategic, tactical and operational) will be supported also with the information obtained from the energy consumption performance.

Regrettably, there is no an ideal or established energy efficiency measurements or indicators that can be applicable to every case or every industrial sector, the main reason is that according to the information available about “energy efficiency” it is difficult to define exactly its meaning (Kanako, 2008), because it can vary according to the context in which the concept is used; As well, in the industry and manufacturing organizations the measurement of energy efficiency performance takes various forms, purposes and applications according to objectives, availability of resources, production

mix, etc in each organization. Measurements and key performance indicators related to energy consumption in the industry, allows organizations in gaining an understanding of the major technological and economic influences on the total final energy consumption in its performance, indentifying where is located the energy consumption and which are the most energy consuming processes in order to make decisions about costs, improvements in procedures and technologies, etc related to this field.

For the reasons described above, as mentioned before, the purpose of this thesis is to give an understanding of the principal measurements and indicators use in the industry in this field, as well as its classification according to the decision levels in the organization, as a result an energy efficiency program definition is described in the chapter 3. Nevertheless, the current work will describe a process only related to the KPIs related to energy consumption, the limits and connections with other KPIs should be clarified from other sources.

Methodology

Mainly the methodology of this work was explorative. A literature review was carried out about concepts, frameworks, energy sources, general types of measurements and indicators used in the field of energy among different industries, as well as general information like relevance of energy consumption in the industry, worldwide energy supply, and so on.

Additionally to the information collected from the literature review during this work, some interviews were conducted in the home appliances industry in Colombia and Italy to determine the relevance of this subject in those companies and if the implementation of an energy program is considered important and useful for an organization. In order to do this research, an explorative empirical analysis of the literature review and the interviews was carried out consulting the energy

consumption and energy efficiency concern in the organizations and then compounding the results to conclude about this subject.

The main objectives of the methodology were:

- Establish theoretical foundations for establishing the key performance indicators to provide practical tools for the formulation of sustainability goals in the organization.
- Make the research about the indicators and measurements used in the industry associated to this issue, it means how companies measure its energy consumption and which indicators are useful and which ones are not.
- Sort the indicators obtained in the research according to the aggregation level that they can be performed, hence according to the decision levels into the organization (strategic, tactical and operational).
- Define the energy efficiency implementation process, focused on the definition and selection of energy consumption key performance indicators and measurement, as it was mentioned before, this work will be relevant only to the KPIs related with the energy consumption; other KPIs should be carried on outlined.
- Analyze and understand the impacts that KPIs related to energy consumption could have in the performance of the company or in other KPIs
- Validate the relevance of energy consumption and the use of measurements and key performance indicators through a survey in a group of manufacturing companies.

Results

After fulfilled the literature review and its analysis, a classification of the main indicators found was made with the purpose of giving an overview of the principal measurements and indicators used in the industry related to the energy consumption and energy efficiency and its classification according to its type, level of aggregation

and the decision level in the organization. The table 1 shows a summary of this classification, a better description and definition of the indicators will be found in the chapter 2 of the current work.

Indicator	Units	Type	Aggregation Level	Decision Level
Energy Efficiency and SEC (Specific Energy Consumption)	[GJ/ton of product]; [PJ/yr]; [MJ/ton]	Physical-thermodynamic	Aggregated/ Disaggregated	Strategic/Tactical/Operational
Energy intensity	[MJ/US$]]; [Btu/dollar of output]	Economic-thermodynamic	Aggregated/ Disaggregated	Strategic/Tactical
Total energy Consumption or Energy Use	[GJ]; [Kwh]	Thermodynamic/eco-efficiency	Aggregated	Strategic
Degree of efficiency	Factor	Physical-thermodynamic	Disaggregated	Operational
Thermal energy efficiency of equipment	[Mwh];[Kwh]	Thermodynamic	Disaggregated	Operational
energy–GDP ratio	[$/GDP US$]	Economic	Aggregated	Strategic
Percent energy from renewable	[%]	Eco-Efficiency	Aggregated	Strategic
Eco-efficiency	Product or service value/Environmental influence (The ratio depends on the aim of the company)	Eco-Efficiency	Aggregated	Tactical
CO2 Emissions	[Kg; ton]	Eco-Efficiency	Aggregated	Tactical

Table 1: Summary of the indicators classification from the literature review.

According to the information sorted and gathered from the literature review and from the interviews conducted, the definition of an implementation program for energy efficiency was defined in the chapter 3 of this thesis. This definition is based on some frameworks and processes steps found in the literature review related to the energy consumption carried out for the realization of this paper, as the BS EN 16001:2009

standard[1]. The difference with the frameworks and processes steps found in the literature and the one proposed in this thesis, is the focus on the definition and selection of the measurements and key performance indicators with the aim of giving a guideline for measuring the energy consumption and energy efficiency in a proper way in the manufacturing process, allowing the organizations to monitor, control and improve its performance in this field. In the figure 1, an overview of the process proposed is described.

This process definition for the implementation of an energy efficiency program has the purpose to guide the company in the implementation of an energy efficiency program that allows the integration of the most important aspects involved in this subject in order to achieve better results and potential improvements in the manufacturing process besides achieve objectives such as economic (cost reduction), environmental (reductions in emissions and consumption in general, not just energy), new technologies for increasing energy efficiency, etc.

[1] BS EN 16001:2009: BSI British Standards Energy management systems - Requirements with guidance for use.

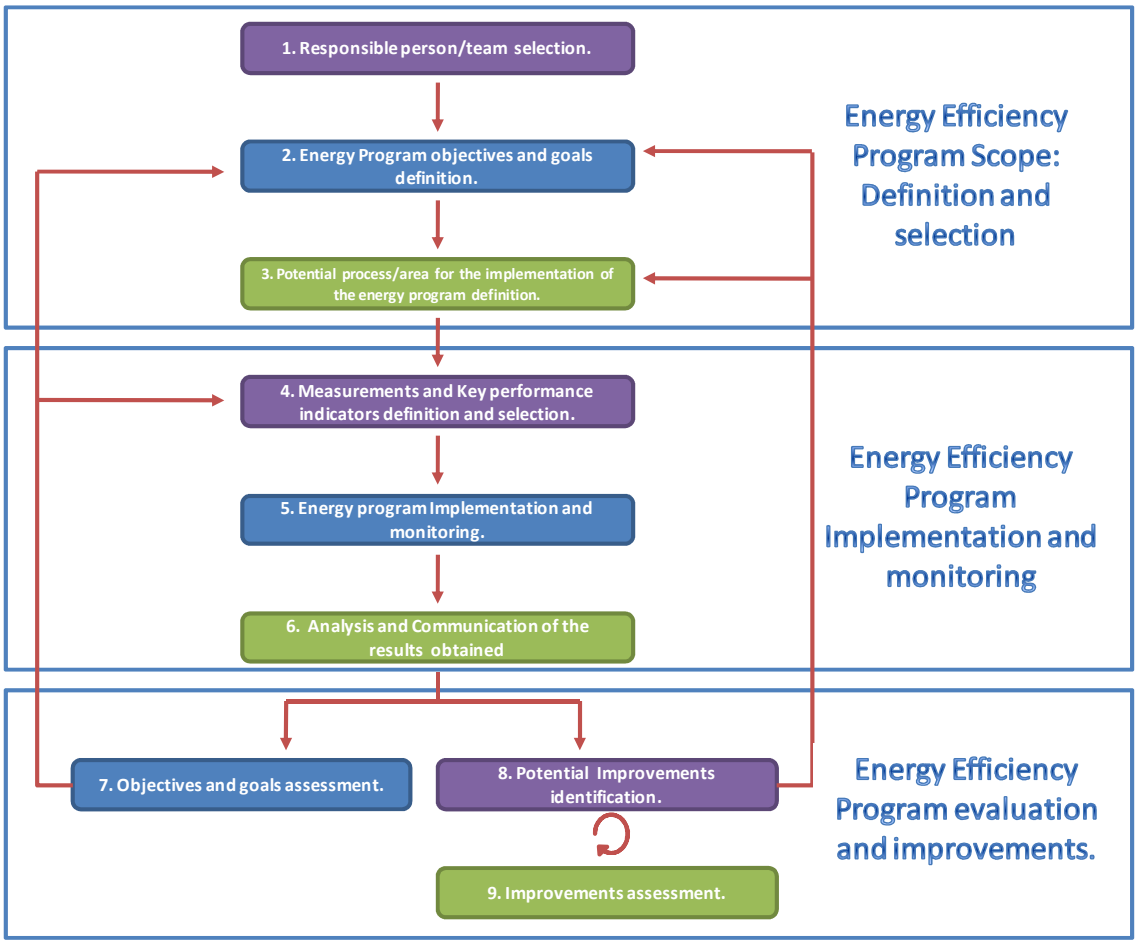

Figure 1: Phases for the energy efficiency implementation program based on key performance indicators.

The definitions of each step the nine phase's steps of the energy efficiency implementation program will be found in the chapter 3 of the current work.

INTRODUCTION

As energy is an integral component of the economy and society, nowadays, there is a growing concern about environmental problems associated with energy consumption and an increased desire to achieve sustainable development. As a result, the interest in the level of energy consumption and the potential for energy efficiency improvement to moderate future energy demand is increasing.

There is currently interest in many countries in analyzing energy use in the industrial sector, because generally is one of the most consuming sector into the nation´s economy. Energy is a key production factor in many industries and, with the growing pace of globalization, international competitiveness issues and so on, industries are placing greater emphasis on reducing production costs, including those related to energy. Moreover, the environmental impacts of energy use, notably CO_2 emissions from fossil fuel use, are an increasing cause of concern, nevertheless the industrial energy use and the opportunities for improving its energy efficiency depend on many technical, economic, institutional and political factors. (EIA, 2010)

Also the implementation of an energy efficiency program using established processes, measurements and key performance indicators allows organizations in improving its performance on this field and promote standardization in measurement and reporting as well as the development of core indicators which could be applied through companies and industrial sectors with comparison and improvement purposes. The implementation of this kind of program provides also flexibility to the organization in terms of developing their own production-specific indicators and focuses them on its organizational goals and objectives.

For these principal reasons the current work aim to show the importance of the energy consumption and energy efficiency improvements into the industrial sector, focused on manufacturing companies. The current work presents an exploration of the topics based on the literature review and information obtained through interviews conducted in some home appliances producer companies in Colombia and Italy. Based on that information, some general measures and key performance indicators are proposed with the purpose of helping the organizations in identifying its performance related to energy consumption Moreover the link between different decision making levels involved in company is addressed in the definition of appropriate indicators.

In order to integrate the selected and classified information, an energy program process is proposed and is focused mainly on the definition of the key performance indicators and measurements needed to obtain the necessary information for improvements into the organization related to the energy consumption in order to achieve benefits like cost reduction, emissions reduction, productivity, etc. Nevertheless, the current work will refer to key performance indicators and measurements related to energy consumption, the limits and connections with other indicators will need to be clarified from other sources.

CHAPTER 1: LITERATURE REVIEW: General concepts

Energy Efficiency Motivations

Energy is critical to economic and social development and is a valuable finite resource; energy has supported human development historically and has been particularly crucial in the rapid industrialization during the past few centuries. Technological innovation has been linked with the evolution of energy systems. Around 90% of the primary energy[2] used today, and indeed since the beginning of the 20th century, is harnessed from non-renewable fossil fuels that are being exhausted at a rate far faster than they were formed. This problem is compounded by the fact that these fuels are unequally distributed around the world, which has consequences in terms of energy access and security. Furthermore, the exothermic reaction of combusting these hydrocarbon fuels in air (or oxygen) releases carbon dioxide (CO_2) as well as other polluting oxides (nitrous, sulphides, etc.). Carbon dioxide (CO_2) is a so called greenhouse gas (GHG) because it contributes to the greenhouse effect, in which incident solar irradiation is trapped within the atmosphere, leading to a temperature increase (McKenna, 2009).

The figure 2 shows the total consumption of primary energy during the period 2003 – 2007. The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing by more than 2% a year. This may not sound like very much, but it represents almost a doubling of energy consumption over a period of 30 years. Out of the total amount of primary energy, around 80% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term. Over 3.5 billion tons of crude oil are

[2] Primary Energy: All types of energy extracted or captured directly from natural resources. E.g. fossil fuels: crude oil, coal, natural gas, oil shale, etc. and solar, wind, geothermal energy.

consumed every year. A major part of this is consumed by the transport sector, with the industrial sector as the second largest oil consumer. (Morvay & Gvozdenac, 2008)

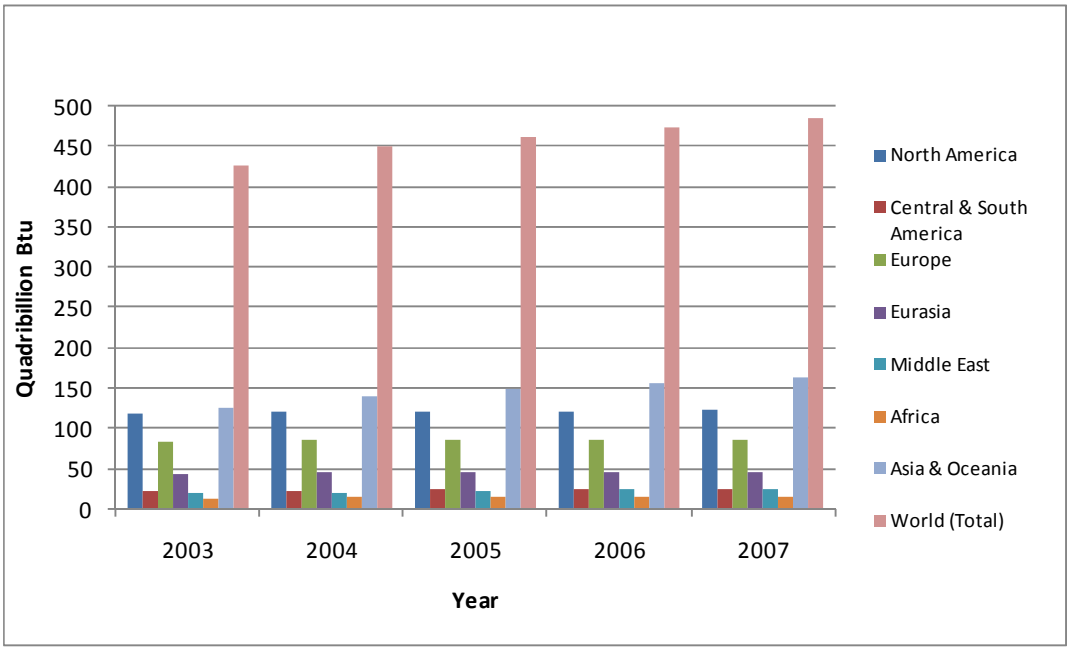

Figure 2: Total Primary Energy Consumption 2003 – 2007. Source: Energy Information Administration.

As the energy is a source which is need around the world with many purposes, another concern is about the security of energy supply which is related to its supply, its prices and distribution. Security of supply is multifaceted, but is often discussed in terms of physical availability of energy sources and their commodity price risk. (Jamas & Pollitt, 2008).

Security of energy supply is a recurrent concept in national energy policies and also at the European and worldwide levels. In November 2000, the European Commission issued a green paper "Towards a European Strategy on Energy Supply Security". This report carried a strong warning about European dependence on imported energy that could increase from 50 percent in 2000 to 70 percent in 2020-2030. The European Parliament and the Council passed their agreements, stressing the importance to minimize the risks of dependency both by the EU and the member states. Since then,

terrorist attacks, storms, accidents, blackouts, wars, surges in fuel prices are threatening directly energy supply. (Chevalier, 2005)

The global economic recession that began in 2007 and continued into 2009 has had a profound impact on world energy demand. Total world marketed energy consumption contracted by 1.2 percent in 2008 and by 2.2 percent in 2009, as manufacturing and consumer demand for goods and services declined. Average oil prices increased strongly from 2003 to mid-July 2008, when prices collapsed as a result of concerns about the deepening recession. In 2009, oil prices trended upward throughout the year, from about $42 (dollars) per barrel in January to $74 (dollars) per barrel in December. Oil prices have been especially sensitive to demand expectations, with producers, consumers, and traders continually looking for an indication of possible recovery in world economic growth and a likely corresponding increase in oil demand. On the supply side, OPEC (Organization of the Petroleum Exporting Countries) above-average compliance to agreed-upon production targets increased the group's spare capacity to roughly 5 million barrels per day in 2009. (EIA, 2010)

For the reasons described, nowadays there has been a growing concern about environmental problems associated with energy consumption and an increased desire to achieve sustainable development. As a result, the interest in the level of energy consumption and the potential for energy efficiency improvement to moderate future energy demand is increasing. Improving energy efficiency offers a powerful tool for achieving sustainable development by reducing the need for investment in new infrastructure, by cutting fuel costs, and by increasing competitiveness for businesses and welfare for consumers. It creates environmental benefits through reduced emissions of greenhouse gases and local air pollutants. It can offer social benefits in the form of increased energy security (through reduced reliance on fossil fuels, particularly when imported) and better energy services.

Importance of Energy Efficiency in the industry

The world's industries make up a diverse sector that includes manufacturing, agriculture, mining and construction. Industrial energy demand varies across regions and countries, depending on the level and mix of economic activity and technological development, among other factors. Energy is consumed in the industrial sector for a wide range of activities, such as processing and assembly, space conditioning, and lighting. In total, the industrial sector uses more energy than any other end-use sector, consuming about one-half of the world's total delivered energy. Over the next 25 years, worldwide industrial energy consumption is projected to grow from 175.0 quadrillion Btu in 2006 to 245.6 quadrillion Btu in 2030. (EIA E. I., 2009).

Figure 3 shows how the industrial energy consumption is described by source in the year 2006, being the liquid fuels[3] the energy source most used in industry and the renewables[4] the less used by only 1%. Figure 4 shows also the projections made until the year 2030 in which we can see that the industrial energy consumption will increasing during the next years as has been increasing in the past.

[3] Liquid fuels and other petroleum (also referred to as "liquids") include all petroleum products, natural gas liquids, biofuels, and liquids derived from other hydrocarbon sources (coal to liquids and gas to liquids). Not included are compressed natural gas (CNG), liquefied natural gas (LNG), and hydrogen.

[4] Combustible renewable comprises solid biomass, liquid biomass, biogas, Biomass is defined as any plant matter used directly as fuel or converted into fuels (e.g. charcoal) or electricity and/or heat.

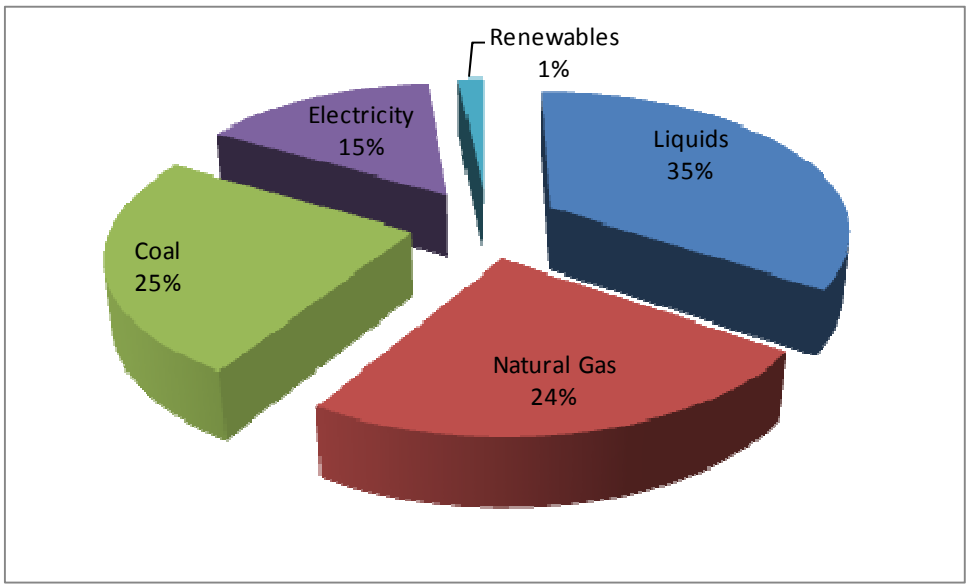

Figure 3: Industrial Energy Consumption by Source (2006). Source: Energy Information Administration (EIA), International Energy Annual 2006. Web site www.eia.doe.gov/iea

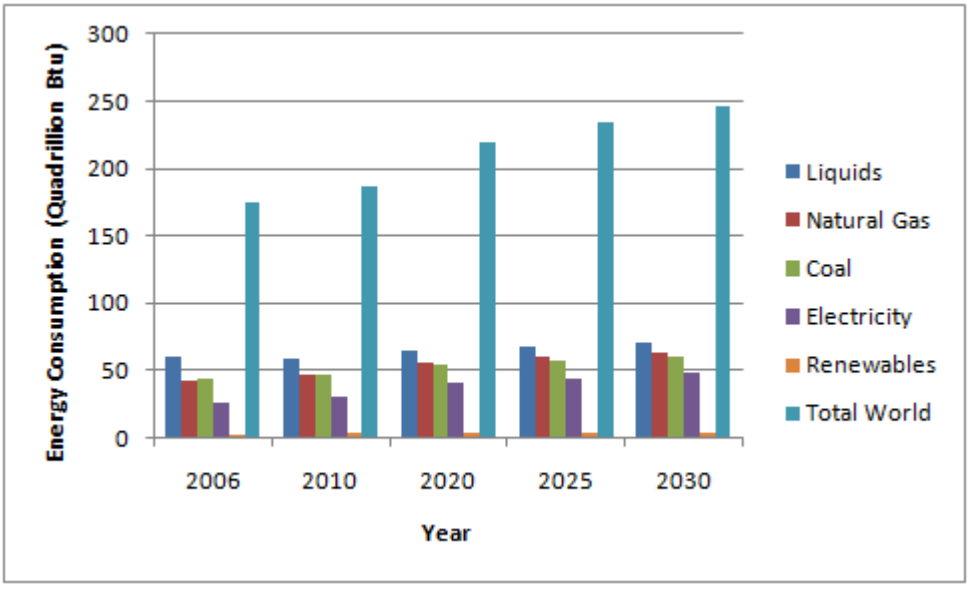

Figure 4: Industrial Energy Consumption by Source 2006 and projections until 2030. Source: Energy Information Administration (EIA), International Energy Annual 2006. Projections: EIA, World Energy Projections Plus (2009). Web site www.eia.doe.gov/iea

In the industry sector, energy is a key production factor, because of that, this sector is placing greater emphasis on reducing production costs, including those related to energy. Moreover, the environmental impacts of energy use, notably CO_2 emissions

from fossil fuel use, are an increasing cause of concern as we said before. The importance of energy efficiency as a policy objective is linked to commercial, industrial competitiveness and energy performance benefits, for this reason there are some international bodies that have defined a lot of guidelines and recommendations with the purpose of helping countries and policymakers in their aim to achieve sustainable development, some of those bodies found in most of the papers in the literature review are: International Energy Agency, World Business Council for Sustainable Development, Energy Valuation Organization, etc.

Respect to the measurement of the energy consumption in the industry, one of the main objectives of energy indicator´s use, is to obtain an understanding of the major technological and economic influences on the total final energy consumption in industry and in individual industrial subsectors. The analysis of energy efficiency indicators are focused on the improvement of the company´s performance related to this subject, and can reduce the need for investment in energy infrastructure, reduce costs and increase competitiveness. The large amount of recent work performed in the field of energy efficiency indicators and the growing interest of national and international administrations and institutions, such as the International Energy Agency (IEA) and other bodies as we mentioned before, show that this field is important, with increasing attention being paid to methodological and practical issues.

Another aim in the improvement of energy efficiency indicators and measurements, is the interest in knowing where is located the energy consumption which is one of the main costs into the companies, in order to make decisions about improvement in procedures and technologies related to this field. The effect of new technologies on energy consumption has important policy implications. Many environmental policy proposals can be expected to lead to the development of new technologies. For example, environmental policy proposals, such as carbon taxes, often take aim at

energy consumption. As these policies increase the cost of energy, they will lead to the development of more energy-efficient technologies. (Popp, 2001).

Increasing raw material prices, necessary investments for environmental technologies, potential penalties for lacking compliance with environmental regulations as well as certain regulative incentives, the introduction of CO_2 certificates or the rising public awareness on resource consumption and climate change, are just some examples that underline the increasingly important economic relevance of originally environmentally driven issues in the production companies. Energy consumption is certainly a major aspect in this context whereas it incorporates strong effects on both economic as well as ecological dimension. (Herrmann, 2009)

Many companies are starting to implement Energy Management Systems (EMS) or another programs related to energy consumption issues because of the advent of standards as ISO 50001 and EN 16001.

The International Organization for Standardization (ISO) recognizes the high need for an international energy management standard by introducing ISO 50001 which can be very helpful in commercial energy management. The need to promote energy efficiency, the adamant need to reduce carbon emissions, the higher prices of fossil fuels due to reduced supply, and the need to use renewable energy sources give enough reason for this new energy management standard to be developed which was based on advanced best practices and existing regional and national standards. (Stouffer).

Also the EN 16001 is a European Standard with the aim of help organizations to establish the systems and processes necessary to improve energy efficiency, in order to lead reductions in cost and greenhouse gas emissions through systematic management of energy. It is intended to apply to all types and sizes of organizations irrespective of any geographical, cultural and social conditions and it could be applied

to the activities under the control of an organization. This standard for energy management systems can be used independently or integrated with any other management system. To facilitate its use, the structure of this standard is similar to the structure of ISO 14001. (BSI British Standards, 2009)

Energy efficiency is a fundamental element in the progression towards a more sustainable energy future and has been on the business agenda of many companies and organizations, as global energy demand continues to grow, actions to increase energy efficiency will be essential. The current work tries to illustrate a tool for achieving this objective.

Energy efficiency: General Concepts

According to the information available about "energy efficiency", it is difficult to define exactly its meaning, because it can vary according to the context in which the concept is used; As well, the measurement of energy efficiency performance takes various forms, purposes and applications.

There is no an ideal or established energy efficiency indicator that can be applicable to every case or every industrial sector. It is not viable to select the best indicator for every analysis or case, but it is possible to choose an appropriate measure for the individual performance policy. (Kanako, 2008)

Energy efficiency is difficult to conceptualize and there is no single commonly accepted definition. An engineer, economist, environmentalist, etc, may each have a different concept of energy efficiency; the main idea of this section in the current work is to show the main definitions of "Energy efficiency" in the industry, in order to have a general idea and understanding about the concept.

Energy efficiency is a generic term, and there is no one unequivocal quantitative measure of "energy efficiency". In general, energy efficiency refers to using less energy to produce the same amount of services or useful output. For example, in the industrial sector, energy efficiency can be measured by the amount of energy required to produce a tonne of product. Therefore, there are some common definitions as follows (McKenna, 2009):

- ✓ The ratio between output of performance, service, goods and energy, and an input of energy.
- ✓ To obtain an unchanged output value at a reduced energy consumption level.
- ✓ To obtain an increased output value with unchanged energy consumption.
- ✓ The amount of energy consumption per unit of product/output.
- ✓ The amount of energy consumed per unit of feedstock.
- ✓ Energy consumption per unit of product (excluding feedstock).

In the industry sectors, the most common concept employed is the ratio "*amount of energy consumption per unit of product/output*", or energy consumption per unit of output. Energy efficiency indicators can be economic indicators or physical indicators. Two frequently used energy efficiency indicators are the *energy intensity* and the *Specific Energy Consumption* (SEC), with increasing energy efficiency resulting in a decreasing energy intensity or SEC. Usually the indicator is called energy intensity if the denominator (i.e. production) is measured in economic terms. The SEC is a physical energy efficiency indicator, which is sometimes also called the Unit Energy Consumption (UEC) or Physical Energy Intensity (PEI). (Phylipsen, 1997).

Energy intensity indicators measure the quantity of energy required to perform an activity. The measurement of indicators, either in physical or monetary units, and the type of indicator to use, as we said before, vary according to the nature of the analysis to be undertaken. Generally, indicators measured in monetary units are applied to the

analysis of energy efficiency at a macro-economic level, while physical units are applied to sub-sector level indicators. Indicators can be denominated in either physical units, where energy is directly related to the physical quantity of output, or alternatively in economic terms, where energy consumption is linked to the monetary value of production.

From the literature, the energy efficiency indicators are often measured in terms of thermodynamic indicators, physical-based indicators (energy requirements per unit physical output) and monetary-based indicators (energy requirements per dollar output); the following, are briefly definitions of these terms, in the next section (Charter 2: LITERATURE REVIEW: Indicators Classification) these definitions will be presented in detail:

Thermodynamic: these are energy efficiency indicators that rely entirely on measurements derived from the science of thermodynamics. Some of these indicators are simple ratios and some are more sophisticated measures that relate actual energy usage to an "ideal" process. (Patterson, 1996)

Physical-thermodynamic: these are hybrid indicators where the energy input is still measured in thermodynamic units, but the output is measured in physical units. These physical units attempt to measure the service delivery of the process, e.g. in terms of tonnes of product or passenger miles. (Patterson, 1996)

Economic-thermodynamic: these are also hybrid indicators where the service delivery (output) of the process is measured in terms of market prices. The energy input, as with the thermodynamic and physical-thermodynamic indicators, is measured in terms of conventional thermodynamic units. (Patterson, 1996)

Economic: these indicators measure changes in energy efficiency purely in terms of market values ($). That is, both the energy input and service delivery (output) are enumerated in monetary terms. (Patterson, 1996)

Eco - efficiency: these indicators have the purpose of measuring economic and environmental progress, which are necessary for economic prosperity, in order to have more efficient use of resources and lower emissions. Each group of these indicators tends to serve a certain purpose and the appropriate indicator to use depends on the objective, whether it is concerned with engineering/systems design, economic productivity, the environment, resource depletion, sustainability, national security, etc. (World Business Council for Sustainable Development, 2000)

Experience shows that none could be claimed to be the best in all situations. Relatively, thermodynamic indicators are not often used in national and international energy policy studies. The discussions often are focus on the physical and monetary based indicators. In this context, energy efficiency improvement generally means using less energy to produce the same amount of services or useful output (Ang, 2005).

Energy efficiency indicators, or more generally, energy performance indicators, give the links between energy use and some monetary or physical indicators, measuring the demand for energy services and also allowing the control on the achievement of the international, national or local policies.

The measurements of energy performance indicators can be applied to suit a range of purposes: an industrial facility operator seeking to use energy economically may focus on *thermal efficiency* as energy performance indicators, *i.e.*, the total output of useable energy divided by energy input; If a company wants to see the trend of energy use in different factories and compare their productivity per unit of energy used (so-called "*energy consumption intensity*" or "*unit energy consumption*"), it may adopt the energy input divided by output for each facility (Kanako, 2008), etc. This concepts and definition will be explained more clearly in the Chapter 2.

Boundaries of Energy Efficiency Indicators

As previously mentioned, the importance of energy efficiency performance has been growing for many reasons; however, countries and industries have very different political and cultural contexts, their goals differ and the resources at their disposal differ tremendously, for this reason, several barriers remain to energy efficiency improvements given the number and the complexity of industrial processes and also the different contexts in which energy efficiency could be used, designing a consistent, standard and comparable energy efficiency indicators is extremely difficult.

Businesses should develop new management approaches at management levels in order to take opportunities for increased energy efficiency, especially by increasing awareness of their energy consumption and savings in the long term. Energy efficiency has a crucial role to play in this regard and businesses all over the world have been leading the way.

Some of the principle barriers which the definition of policies and indicators in the field of energy efficiency are described as follows:

Lack of information

Even in developed economies, people may lack information about energy efficient equipment and practices. Recent studies show that consumers tend to repeat prior decisions when faced with unfamiliar choices and to avoid cost minimizing choices that have higher upfront costs. Information gathering and analyzing consume time and human resources. The public often has insufficient information to measure energy efficiency profitability, particularly in developing economies. Two kinds of information problems generally exist. One is that energy efficiency information is not available, the other is that the information is not satisfactorily transferred to the public (Asia Pacific Energy Research Centre, 2000).

Management obstacles

Energy efficiency investments often tend to be classified as discretionary maintenance projects. They are usually given a lower priority to essential maintenance projects or strategic investments. Generally, top management has historically not considered energy-cost savings as a strategic priority in comparison to large strategic projects (ICC: International Chamber of Commerce. Commissions on Environment and Energy., 2009).

Financial obstacles

Investments in energy efficiency are often impeded due to the initial cost barrier and difficulties in raising capital, combined with relatively long payback periods. The inadequacy of traditional financial mechanisms for energy efficiency projects are also a challenge. Indeed, within a company, access to capital issues often stem from a neglect of energy efficiency within internal capital budgeting procedures, combined with other organizational rules such as strict requirements on payback periods (usually short periods with a required rate on return). Even if they have great access to capital, businesses may still be unwilling to accept payback periods stretched out over the life of the investment, given uncertainty about future energy prices and actual energy cost savings (ICC: International Chamber of Commerce. Commissions on Environment and Energy., 2009).

Limited technological capability

Energy efficiency programs and associated technologies require skills that can be in poor supply in developing economies. Even where new, energy efficient technologies have been installed, there may be a lack of skilled experts to keep the equipment operating at maximum efficiency, negating many of the potential benefits. More commonly, firms continue to utilize old equipment they are familiar with until maintenance costs make replacement an attractive alternative. In areas with low levels of industrialization in developing economies, old obsolete equipment will continue to

be used because replacement may not be a feasible option financially (Asia Pacific Energy Research Centre, 2000).

Trade barriers

Many trade-restrictive measures, including tariffs and border charges as well as non-tariff measures such as cumbersome trade-documentation systems, product standards, restrictions on after-sale services, complex certification requirements and restrictions on foreign investment deter businesses from exporting energy efficient products and technologies

In order to overcome these barriers, governments need to create a policy environment that rewards energy-efficient choices and encourages innovation. Economic and financial incentives and government support for professional training and consulting, research, development and deployment are a first step. (ICC: International Chamber of Commerce. Commissions on Environment and Energy., 2009). Also in the industry sector the use of measurements and key performance indicators in order to monitor, visualize and understand the energy consumption in the organzation is implementing with the purpose to confront this barriers.

CHARTER 2: LITERATURE REVIEW: Indicators classification

As it was mentioned above, the type of indicators that can be found in the literature are general ones, given the differences between industries and countries is very difficult to define standard indicators for all kind of industries and purposes related to energy consumption. However, in this current section, there will be described the definition and classification of some indicators, according to the principle types of energy efficiency indicators, their aggregation level and also to their relation with the decision making level into the organization.

Types of energy efficiency indicators

Indicators typically provide key information about physical, social or economic systems; they allow analysis of trends and cause-effect relationships. Energy consumption and energy efficiency indicators are related to the term "Sustainable Production" which is closely linked to "Sustainable Development[5]". Sustainable Production is defined as: "the creation of goods and services using processes and systems that are: non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for workers, communities, and consumers; and, socially and creatively rewarding for all working people[6]" and some examples of sustainable production indicators are: percent of raw materials from renewable resources; acidification potential, measured in SO_2 equivalent; kilograms of emissions to the air; amount of energy used per unit of product made or service provided (Veleva, 2001). The current work will be focused on those indicators of sustainable production related to energy consumption.

[5] Although the term sustainable development has been used for many years its meaning still defies simple explanation. The most commonly cited definition is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (Veleva, 2001)

[6] Lowell Center for Sustainable Production (LCSP) at the University of Massachusetts Lowell. The Center focused its work on sustainable systems of production.

Energy consumption indicators perform a variety of functions from the monitoring of energy efficiency, through to policy analysis and evaluation, and the appraisal of new technologies. However the usefulness and effectiveness with which energy efficiency indicator can be used is subject to a number of restrictions, particularly in relation to the availability and quality of data. Some of the mainly energy efficiency indicators could be sorted as follows:

Thermodynamic indicators:

In one sense, thermodynamic indicators of energy efficiency seem to be the most natural way to measure energy efficiency, as thermodynamics nowadays is often defined as, the science of energy and energy processes. Surprisingly, though, thermodynamic measures of energy efficiency are not as satisfactory measures of energy efficiency as they might at first appear (Patterson, 1996)**,** since for the production purposes these indicators should be combined with other ones, in order to create a relationship between the energy efficiency performance and the production aspects of the process which will be analyzed.

Physical-thermodynamic indicators

As we said in the description of the previous type of energy efficiency indicator, the traditional thermodynamic indicators for energy efficiency do not adequately describe the end use in the output measurement of production performance that is required by the users of the indicators.

Typically, the numerator in the thermodynamic efficiency ratios measures heat content, therefore, energy analysts have developed efficiency ratios that measure the output in physical units rather than in thermodynamic terms. These physical units are

specifically designed to reflect the end use service that consumers require (Patterson, 1996). For example, in a production process, the customer of the process, could be interested in knowing how the performance of the energy is related to the output of finished product, then, the units of the energy efficiency indicator in that production process could be “Energy Efficiency = Joules/tonne of finished product”.

Physical indicators calculate specific energy consumption relative to a physical measurement of production, such as tonnes of product (Phylipsen, 1997). The advantage of physical indicators is the direct relationship between the indicator and the energy efficiency technology. For example, improvements in technologies will be indicated as savings in the specific energy consumption, and result in an indicator that assesses a lower specific energy requirement per tonne of output.

Economic-thermodynamic indicators (Patterson, 1996)

These indicators are hybrid indicators, with the energy input being measured in thermodynamic units and the output being measured in terms of market prices ($). That is, instead of the output being measured in physical units as for physical-thermodynamic indicators, the output is measured in terms of the market value ($) of this output. These indicators can be applied to various levels of aggregation of economic activity - product, sector or national levels.

Energy -GDP and sector energy output ratios: These energy efficiency measurements of energy input divided by the output ($), can be applied at both the national and sector/sub-sector levels. The energy -GDP ratio is the most commonly used aggregate measure of a nation's energy efficiency, although there has been widespread criticism of the use of this indicator for this purpose, because this indicator does not measure the underlying technical energy efficiency.

Other factors such as changes in the sector mix in the economy, energy for labor substitution and changes in the energy input mix can influence movements in the energy-GDP ratio, and these factors have nothing to do with technical energy efficiency. Recently methods have been developed by Patterson (1993) and others, to specifically exclude these unrelated factors from the energy-GDP ratio, in order to isolate the underlying technical energy efficiency.

Energy productivity ratio: This is the reciprocal of the energy-GDP ratio, i.e. it is the GDP divided by a nation's energy consumption. The more goods and services (GDP) an economy produces per unit of energy, the more productive or efficient it is with respect to energy. The energy productivity indicator is similar to the well established labor and capital productivity ratios used in economics and it cans also be applied at the sector level.

The energy productivity ratio is seen as a mechanism for focusing attention on the productive use of energy as a complementary measure to the conventional capital and labor productivity ratios used in economic analysis. The use of the energy productivity ratio in conjunction with labor and capital productivity ratios can provide useful insights into whether energy inputs act as complements or substitutes to these other factor inputs.

Economic Indicators

Some economists argue that both, the input and output measurements of energy indicators should be computed in terms of economic value ($) it means using prices, rather than the economic-thermodynamic indicators. It is argued, for example, by the Joint Economic Committee of the Congress of the United States (1981), that the energy dollars-GDP ratio is a “more accurate reflection of the economic productivity of

energy, provided that energy prices reflect energy supply and demand forces" (Patterson, 1996).

The most widely advocated pure economic indicator of energy efficiency which has been proposed in the literature is: national energy input ($)/national output ($ GDP)

Apart from the theoretical and operational problems in using prices for measuring energy inputs in efficiency indicators, it could be argued that a pure economic indicator of energy efficiency is not truly an energy efficiency indicator. Instead, it is an economic efficiency indicator because it is fully enumerated in economic value ($) terms, and therefore it should be immediately dismissed as a candidate measure of energy efficiency because these types of indicators have not been developed for monitoring energy efficiency (Patterson, 1996). Due to this fact in the current work this type of indicator will not be used in the classifications that will be described or in the definition of the framework because is a measure which is mainly described in macroeconomic level.

Eco-efficiency indicators (Hendrik A. Verfaillie, 2000)

The concept of eco-efficiency was developed by the World Business Council for Sustainable Development (WBCSD) in 1992 and has become widely recognized by the business world. It refers to the economic and environmental progress, with the aim of increasing the efficient use of resources and lower emissions. Approaches to implementing the concept and measuring performance have varied widely, however.

There are two groups of indicators belong to the eco-efficiency concept: "general indicators" which are indicators that can be used by virtually all businesses, they are widely relevant and they relate to a global environmental concern or business value and methods, and their established measurements and definitions are accepted

globally. All other indicators which do not meet these criteria have been termed "business specific", meaning that they are more likely to be individually defined from one business or one sector to another. These indicators are not necessarily less important than the first group. That judgment will depend on the nature of an individual business. A company's eco-efficiency performance profile will include both types of indicators. Eco-efficiency is represented by the ratio: Product or service value/environmental influence.

The generally applicable indicators or measurements for the calculation of this ratio are: for product/service value: quantity of goods or services produced or provided to customers, net sales. Those relating to the environmental influence in product/service creation: energy consumption, materials consumption, water consumption, greenhouse gas emissions, ozone depleting substance emissions. In the Table 2, the most representative energy efficiency indicators are described according to their type as it was defined above. Then the definitions of these indicators will be provided in order to clarify the concepts:

Indicator	Units	Type
Energy Efficiency and SEC (Specific Energy Consumption)	[GJ/ton of product]; [PJ/yr]; [MJ/ton]	Physical-thermodynamic
Energy intensity	[MJ/US$]]; [Btu/dollar of output]	Economic-thermodynamic
Total energy Consumption or Energy Use	[GJ]; [Kwh]	Thermodynamic/eco-efficiency
Degree of efficiency	Factor	Physical-thermodynamic
Thermal energy efficiency of equipment	[Mwh];[Kwh]	Thermodynamic
energy–GDP ratio	[$/GDP US$]	Economic
Percent energy from renewable	[%]	Eco-Efficiency
Eco-efficiency	Product or service value/Environmental influence (The ratio depends on the aim of the company (see the definition below)	Eco-Efficiency
CO2 Emissions	[Kg; ton]	Eco-Efficiency

Table 2: Main Energy efficiency indicators according to its type

Thermal energy efficiency of equipment (Kanako, 2008)*:* Thermal efficiency is the term of thermodynamics and measures the ratio of *heat* and/or *work* to energy input. This is

expressed by: energy output/energy input, for end-use technology and energy conversion technology. For example, the energy efficiency of a steam boiler is energy amount as steam output divided by input heat to boil the water inside. In the case of motors, it should be power output divided by input electricity.

Energy Efficiency and SEC (Specific Energy Consumption): The SEC is a physical energy efficiency indicator, which is sometimes also called the Unit Energy Consumption (UEC) or Physical Energy Intensity (Phylipsen, 1997); as we described in the first part of the current work.

$$\text{Energy Efficiency} = \frac{\text{Energy consumption}}{\text{Physical value}}$$

$$\text{SEC} = \frac{\text{Net available energy consumption}}{\text{Total amount of product}}$$

$$\text{SEC} = \frac{\text{Final energy consumption}}{\text{Amount of specific product or intermediate}}$$

The numerator of the energy efficiency indicator measures the energy consumption. The numerator and the denominator depends on the aim of the analysis, it means that they depend on the information needed, for example, if the information is needed in an specific level (e.g. energy consumption of a specific activity to process a specific quantity of product) the energy efficiency indicator will be described as a SEC, but if the information needed is general the indicator is going to be referred as a energy efficiency (e.g. energy consumption of the gross production, industry sub-sector, etc.).

Energy intensity: as it was explained in the first chapter, when we are referring to the energy efficiency performance in economic terms we are talking about “energy

intensity", literally, the definition could be "The amount of energy needed to generate a unit of economic output" (Spalding-Fecher, 2003).

$$\text{Energy intensity} = \frac{\text{Energy consumption}}{\text{Economic value}}$$

Total energy Consumption or Energy Use: Energy consumption is a global issue and relevant to all businesses across sectors. This indicator is defined as the total energy consumed equals energy purchased or obtained (e.g. coal, natural gas) minus energy sold to others for their use (e.g. electricity, steam); (Hendrik A. Verfaillie, 2000).

In comparison to the application of thermal efficiency measurement, the indices which measures energy consumption, energy efficiency and energy intensity can be used to assess and compare energy performance for a broader set of objects: processes, factories, companies, and even countries (Kanako, 2008).

Degree of efficiency

$$\text{Degree of efficiency} = \frac{\text{Net energy}}{\text{Used primary energy}}$$

Net energy used in a system refer to the sum of energy an electric utility needs to satisfy their service areas, including full and partial requirements consumers (U.S. Energy Information Administration).

Primary Energy refers to all types of energy extracted or captured directly from natural resources. Primary energy can be further divided into two distinctive groups: Renewable (solar, wind, geothermal, tidal, biomass); Non-renewable (fossil fuels: crude oil, coal, natural gas, oil shale, etc.). The primary energy content is generally referred to as toe (ton of oil equivalent). (Bunse)

The primary energy content of all fuels can be converted to toe on the basis of the conversion factors: 1 toe = 11 630 kWh = 41 870MJ. (Morvay & Gvozdenac, 2008)

Energy–GDP ratio (Ang, 2005)*:* The ratio of total national primary energy consumption to GDP (or GNP), or the energy–GDP ratio, is one of the most enduring aggregate monetary-based energy efficiency indicators. This ratio is a measure of the energy intensity of the economy at the most aggregate level as we described in the "Economic type of indicator" in the current section. Computed on an annual basis, the energy–GDP ratio can be plotted annually to show the short and long term trends. A decrease in the ratio signifies, on the average, a reduction in energy requirements to generate a unit of national output. This is considered a desirable development. In energy demand projection, the ratio is often computed from the projected total energy requirements and GDP to show whether the economy will become increasingly more energy intensive or otherwise. Projections of national energy demand under different growth scenarios are often expressed in energy–GDP ratios, so that they can be compared.

Percent energy from renewable (Veleva, 2001)*:* The goal of this indicator is to increase the use of energy from renewable sources, such as: solar, wind and hydro-energy. The calculation of this percentage is as follows: calculate the total energy consumption of the process or service to be analyzed (the data could be found using utility bills, materials tracking system or published data); after that, calculate energy consumption from renewable sources (in the same energy units e.g. kWh). Divide the energy from renewable sources to the total energy used and multiply by 100 to convert to percent.

Eco-efficiency (Hendrik A. Verfaillie, 2000)*:* As it was described above this concept is represented by the ratio:

$$\frac{\text{Product or service value}}{\text{Environmental influence}}$$

There are numerous ways in which eco-efficiency can be calculated using this basic equation. Both product or service value and environmental influence include many different indicators (as in the example in the definition of this type of indicator) which cannot be merged into one single number. Companies will need to choose eco-efficiency ratios that best serve their process for communication and decision making. Specific calculations will depend upon the needs of individual decision makers. For example, a plant manager may wish to focus on the number of products shipped per "kilo joule" of energy consumed during manufacturing. A financial analyst may instead focus on the economic value of products sold per "kilo joule".

Value and environmental influence can also be measured for different entities, such as production lines, manufacturing sites, or entire corporations, as well as for single products, market segments or entire economies. In the same way, eco-efficiency ratios can be calculated and used for many of these entities. The same indicator may not be suitable for each one. For example, an eco-efficiency indicator for the manufacture of detergent could be kilogram produced per kilo joule of energy consumed during manufacturing. Alternatively, the product manager could calculate an indicator on the basis of economic value (e.g. USD detergent sales) per kilo joule of manufacturing energy consumed, or on a function delivered basis (e.g. average laundry cycles per kilo joule of manufacturing energy consumed). Indicators may also be useful in helping customers understand the environmental performance of products. (Hendrik A. Verfaillie, 2000).

CO2 Emissions (U. S. Environmental Protection agency) ***:*** Gases that trap heat in the atmosphere are often called greenhouse gases. Some of those gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), sulphur hexafluoride (SF_6).

Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. Normally, CO_2 emissions and another greenhouse gases are measured by special devices in laboratories for this purpose; and in the industry sector, the measures are given in units of mass (Kg, ton, etc.).

Aggregation levels and approaches in the definition of energy efficiency indicators

Energy efficiency aims to measure 'how well' the energy is used to produce an output. The calculation of indicators, either in physical or monetary units, varies according to the nature of the analysis to be undertaken. Generally, indicators calculated in monetary units are applied to the analysis of energy efficiency at a higher level of aggregation, while energy efficiency indicators denominated in physical units are more suited to detailed sub-sector analysis. (Asia Pacific Energy Research Centre, 2000)

Energy efficiency indicators can be developed according to many different formulations and each can be used to answer specific or general questions related to energy efficiency performance, as it was described in the previous section.

The following pyramid (Figure 5) illustrates the energy efficiency indicators system that the International Energy Agency defined. In the figure, indicators at the top level usually are energy productivity or energy intensity, and the ones at the bottom level are, in general, energy consumption per unit of the product or specific energy

consumption (SEC). The energy efficiency indicators system is widely accepted and has been used to evaluate national and industrial energy efficiency in many developed countries. From this perspective, since energy saving events occurs mainly at the process level, it is expected that energy savings that occur at the bottom level or process level will be reflected at the top level. If this reflection can be completed correctly, then it is possible to evaluate the role that energy saving has in all levels of the organization and even in national energy efficiency indicators system, in order to evaluate energy consumption by different sectors or subsectors. Unfortunately, there are extreme difficulties when this kind of work is attempted (Li-Ming Wua, 2007) due to the barriers in the implementation of the energy efficiency indicators system.

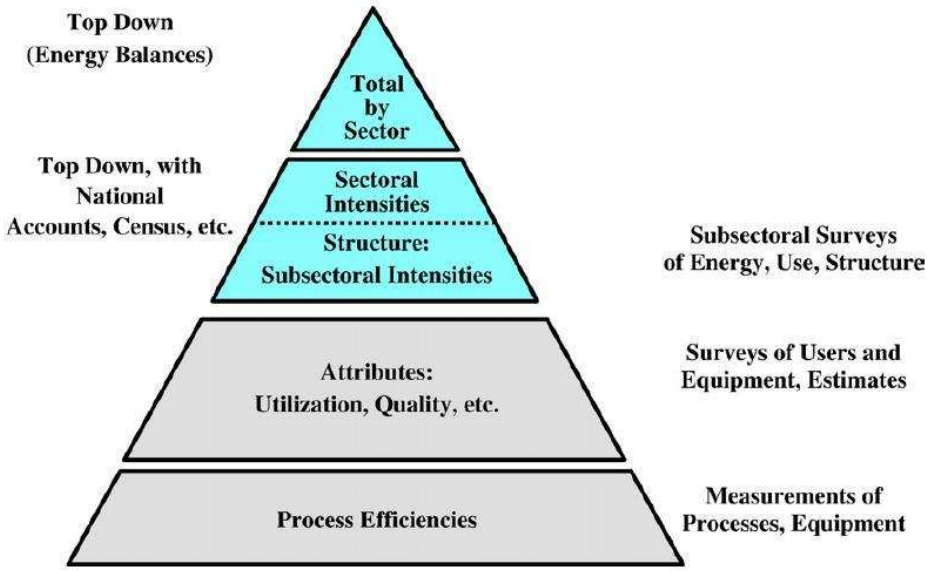

Figure 5: The concept of energy efficiency indicators. Source: International Energy Agency

Energy efficiency indicators can be established at different aggregation levels depending on the aim of the required analysis. The scope to which structural differences influence the energy consumption also depends on the aggregation level. The energy efficiency indicators are identified according to the aggregation level, when the level of aggregation is high, it is referred to “aggregate level”, e.g. the cement

industry; or when the aggregation level is low, it is referred to “disaggregate level”, e.g. separate indicators for clinker production and cement production; (Phylipsen, 1997).

Figure 6 shows and illustrates the variety of energy efficiency indicators that can be utilized according to the aggregation level; it means that indicators of energy efficiency can be constructed from international or national statistics or from output data coming from individual operating units within a plant. At the highest level, there are only a few indicators of energy efficiency that can be constructed.

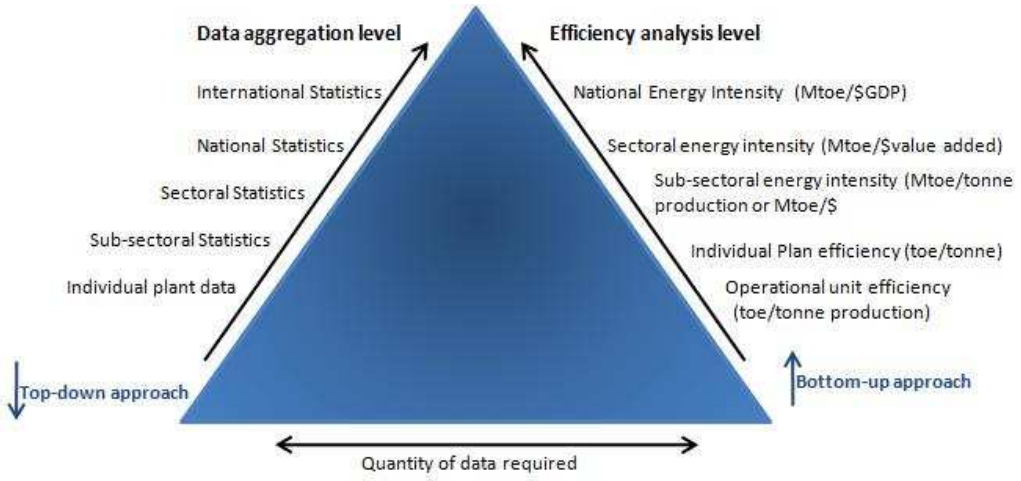

Figure 6: Energy efficiency indicators pyramid. Source: Adapted from Phylipsen *et al*, 1998.

As the level of aggregation decreases (moving down in the pyramid of the Figure 6), the influence of changing structural effects and other factors also decline. Clearly, moving further down the pyramid increases the understanding of the multitude of factors that affect more aggregated measurements of energy efficiency, and ultimately affect other variables such as national energy consumption. However, as the pyramid indicates, the quantity of data required (at the bottom of the pyramid) increases substantially, and the acquisition of data becomes increasingly laborious. Determining the appropriate level of detail for the construction of energy efficiency indicators

needs to reflect the goals of the specific analysis. (Asia Pacific Energy Research Centre, 2000)

The “bottom-up” approaches, refers to the data-intensive indicators, i.e. disaggregated level, within the manufacturing sector (e.g. individual products), due to the diversity of processes and heterogeneity of products, the establishment of an energy efficiency indicator, based on disaggregated physical data, involves complex methodological issues. For example, physical-based indicators (such as physical-thermodynamic indicators) are normally calculated at a disaggregated level, e.g. sub-sector or end-use, by relating energy consumption to an activity indicator measured in physical terms as it was described before, and they could associate energy use with a certain product, process or service. The activity indicator is given in a unit which is closely associated with the way energy is consumed, which varies from one end-use to another. This leads to different terms being used for physical-based indicators in the literature, such as energy intensities, unit energy consumption, specific energy consumption, etc., as we see in the table 1 in the previous chapter. Increasingly, the bottom-up approach has become more popular as it produces indicators which could better reflect changes in energy efficiency issues.

The “top-down” approaches reference to the aggregated level indicators. At an aggregate level (i.e. sector or sub-sector), useful output is usually measured on value or monetary-based terms. Monetary-based indicators are often used when energy efficiency is measured at a high level of aggregation, where it is not possible to characterize the sector with a single physical indicator across the whole spectrum of activities. Monetary-based indicators, given as ratios between energy consumption in an energy unit and economic activity in a monetary unit, are often referred to as energy intensities. As we mentioned before in the current paper, one of the monetary-based indicators is the energy–GDP ratio and industrial energy use per unit of industrial monetary output.

Energy efficiency indicators according to the decision levels

The aggregation level in the definition of the energy efficiency indicators is related to the decision level of the indicator´s analysis, because according to the objective of the analysis the data will be required in different aggregation level. Mainly in all companies the structure of decision-making process is defined by three hierarchical levels: Strategic, tactical and operational.

From the literature review, few papers and works can be found related to the decisional levels into the organizations and their link with the energy efficiency indicators, most of them described the relation of the energy consumption and energy efficiency indicators in a macroeconomic level; the hierarchical order is related to the complexity of company´s activities and the analysis of the energy efficiency indicators performance will be done in the current work basically in the three levels mentioned before (Strategic, tactical and operational).

The following are briefly definitions of these levels (Bunse):

Strategic level is long-term (generally, strategic goals are defined in a long time window like years) decision´s nature, and its consideration of business areas instead of single products. At this level, the decisions are made in relation to the market in which the company wants to operate and how the resources basically will be used. Related to energy management in this level the company could make decisions about energy policies, information systems, investment, etc.

Tactical level serves the efficient and effective realization of the goals, which were determined before at the strategic level, it means, how you are going to make it happen. At this level the capacities of the manufacturing process have to be planned. Task to be executed on this level comprise investment planning, equipment

acquisition, and their maintenance, as well as the design of products and the preparation of their production; e.g. Improvements in energy systems, energy-efficient technologies.

Operational level is the third stage of the hierarchic decision-making process and the objectives are defined for a short period of time like days or weeks, because in this level are preformed the diary process activities. The operational planning translates the targets defined in previous levels into precise activities. Decisions influence the kind and amount of the products, which have to be manufactured, and the production itself has to be organized and accomplished. For this level the use of disaggregated data is needed; e.g. energy consuming systems, energy measurement or data analysis, operating procedures, training.

As it was mentioned before, the aggregation level of the energy efficiency performance indicators is related to the decision level and the definition of the measurements and indicators will depend on the data detail needed in each decision making level for further analysis of results. The Table 3 describes the classification of the indicators defined in the previous section according to their aggregation level and decision level:

Indicator	Units	Aggregation Level	Decision Level
Energy Efficiency and SEC (Specific Energy Consumption)	[GJ/ton of product]; [PJ/yr]; [MJ/ton]	Aggregated/Disaggregated	Strategic/Tactical/Operational
Energy intensity	[MJ/US$]]; [Btu/dollar of output]	Aggregated/Disaggregated	Strategic/Tactical
Total Energy Consumption or Energy Use	[GJ]; [Kwh]	Aggregated	Strategic
Degree of efficiency	Factor	Disaggregated	Operational
Thermal energy efficiency of equipment	[Mwh];[Kwh]	Disaggregated	Operational
energy–GDP ratio	[$/GDP US$]	Aggregated	Strategic
Percent energy from renewable	[%]	Aggregated	Strategic
Eco-efficiency	Product or service value/Environmental influence (The ratio depends on the aim of the company (see the definition below)	Aggregated	Tactical
CO2 Emissions	[Kg; ton]	Aggregated	Tactical

Table 3: Main Energy efficiency indicators according to the aggregation level and the decision level

The classification of each indicator in the three decisional levels are made taking into account the relation between the aggregation level in each decision making level, in the higher level (Strategic) more aggregated data is need because the results will shown to stakeholders (e.g. indicators as total energy consumption, electricity consumption and so on; see some examples in appendix 1) and those indicators will be used to make decision will be affected the performance of the whole organization.

It is important to underline that generally the necessary data and measures for the definition and calculation of the energy consumption and energy efficiency indicators used in strategic and tactical levels are taking at the lower levels (Operational level), where the operations and core processes of the company are performed every day. That´s why in the lower level the aggregation level is lower, it means, in this level, data and information could be obtained more detail. Once if there is the need of making a strategic decision, if the company wants to make it happen, decisions have to be made at the other two levels. Making decisions at operational level without having decided

the strategic decisions, will lead the company to take actions which could be inconsistent in the long run with what the company decided. Making decision at a tactical level and going downwards to operational decisions without any strategy will lead to confusion, as different groups will see the long term future in different ways. Decisions at strategic and tactical level without any operational one, will keep the company where it is now since nobody is actually implementing the decisions with a real operational plan to make changes happen.

CHARTER 3: DEFINITION OF AN IMPLEMENTATION PROGRAM FOR ENERGY EFFICIENCY

Importance of key performance indicators for measuring the organization´s performance

One of the principle aims of key performance indicators (KPI) in general, is to help organizations to define and measure progress towards organizational objectives and priorities, resulting in a management tool to track performance. The purpose of their implementation is that the key performance indicators can provide a better mechanism for more effective performance monitoring, taking account of corporate strategies and policies, for continuous improvement and enhanced accountability on resources spent.

When an organization decides to use key performance indicators, those indicators can educate every person in the company with the aim to developing a strong team approach to business. Thus, measurement is part of any adaptive learning system. Organizational learning is critical for the survival of companies, especially in the globalized economy and market. Business needs carefully to follow its performance and customer needs, in order to make quick changes when needed. Monitoring, managing and analyzing key performance indicators takes time and energy, so it is necessary that appropriate ones are chosen to address the specific needs of the company.

A successful key performance indicator should contain the strategic, tactical and operational aspirations and goals of the organization. It should be easy to visualize and understand. It should never be ambiguous and should not conflict with other indicators or rules and regulations; it means that the indicators should not to be

incoherent or to have similarity with other indicators in order to avoid misunderstandings. A successful key performance indicator is also validated continuously, and over time it becomes one of the virtues of a company and assists in building up its values and guiding principles. A successful indicator is part of the company's DNA and assists the organization in performing its long and short-term prioritization, ensuring that the employees are guided in their work and spend as much time as possible on value-added activities. (Andersson, 2007)

The use of key performance indicators is a continuous and evolutionary process of business transformation through awareness raising and improved dialog with stakeholders. Indeed, by developing indicators to reflect its mission and goals, companies can identify potential areas for improvements. As part of a feedback system, measures help managers decide whether they are on course or if corrections are needed. In addition, key performance indicators can create a type of benchmarking within one's business. A person can see the present quality of their business and with the use of indicators, the company could carry out continuous improvements in different areas in order to ensure its future and its competition in the market where the company is; they help companies become what they deem the epitome of success through the process of managing, monitoring and analysis[7].

Energy management systems (EMS) and programs importance

Although technological changes in equipment conserve energy, changes in staff behavior and attitude can also have a great impact. Energy efficiency training programs can help a company's staff incorporate energy efficiency practices into their day-to-day work routines. Personnel at all levels should be aware of energy use and company objectives for energy efficiency improvement. Often such information is acquired by lower-level managers but neither passed up to higher-level management

[7] The Benefits of Key Performance Indicators To Businesses. Joanne Longo, Dundas. 2009

nor passed down to staff. Energy efficiency programs with regular feedback on staff behavior, such as reward systems, have had the best results. Though changes in staff behavior (such as switching off lights or closing windows and doors) often save only small amounts of energy at one time, taken continuously over longer periods they can have a much greater effect than more costly technological improvements (Christina Galitsky, 2008).

Changing how energy is managed by implementing an organization-wide energy management program is one of the most successful and cost-effective ways to bring about energy efficiency improvements. Energy efficiency does not happen on its own. A strong energy management program is required to create a foundation for positive change and to provide guidance for managing energy throughout an organization. (Christina Galitsky, 2008). Energy management programs also help to ensure that energy efficiency improvements do not just happen on a one-time basis, but rather are continuously identified and implemented in an ongoing process of continuous improvement. Furthermore, without the backing of a sound energy management program, energy efficiency improvements might not reach their full potential due to lack of a systems perspective and/or proper maintenance and follow-up. (Christina Galitsky, 2008)

In companies without a clear program in place, opportunities for improvement may be known but may not be promoted or implemented because of organizational barriers. These barriers may include a lack of communication among plants, a poor understanding of how to create support for an energy efficiency project, limited finances, poor accountability for measures, or organizational inertia to changes from the status quo. Even when energy is a significant cost, many companies still lack a strong commitment to improve energy management. (Christina Galitsky, 2008)

A successful program in energy management begins with a strong organizational commitment to continuous improvement of energy efficiency. This involves assigning oversight and management duties to an energy director, establishing an energy policy, and creating a cross-functional energy team. Steps and procedures are then put in place to assess performance through regular reviews of energy data, technical assessments, and benchmarking. From this assessment, an organization is able to develop a baseline of energy use and set goals for improvement. Performance goals help to shape the development and implementation of an action plan. An important aspect for ensuring the success of the action plan is involving personnel throughout the organization. Personnel at all levels should be aware of energy use and goals for efficiency. Staff should be trained in both skills and general approaches to energy efficiency in day-to-day practices. In addition, performance results should be regularly evaluated and communicated to all personnel, recognizing high achievement. (Christina Galitsky, 2008)

Progress evaluation involves the regular review of both energy use data and the activities carried out as part of the action plan. Information gathered during the formal review process helps in setting new performance goals and action plans and in revealing best practices. Once best practices are established, the goal of the cross-functional energy team should be to replicate these practices throughout the organization. Establishing a strong communications program and seeking recognition for accomplishments are also critical steps. Strong communication and receiving recognition help to build support and momentum for future activities. (Christina Galitsky, 2008).

A key step in improving corporate energy efficiency is to institutionalize strategic energy management; this aspect is suggested and covered also in the EN16001 standard, which was mentioned in the first part of the current work. Organizations that implement strategic energy management programs undertake a set of activities that, if

carried out properly, have the potential to deliver sustained energy savings. One key management opportunity is determining an appropriate level of energy performance for a plant through comparison with similar plants in its industry. Performance-based indicators are one way to enable companies to set energy efficiency targets for manufacturing facilities.

Energy Efficiency Implementation program description

Overview

The description of the energy efficiency program implementation proposed in the current work is based on some frameworks and processes steps found in the literature review related to the energy consumption carried out for the realization of this paper, as the BS EN 16001:2009 standard[8]. The main difference between the frameworks and processes step found in the literature and the one proposed here, is that the current one is also focused on the definition and selection of the measurements and key performance indicators with the aim of giving a guideline for measuring the energy consumption and energy efficiency in a proper way in the manufacturing process, allowing the organizations to monitor, control and improve its performance in this field.

Although the process described in this section is general and could be adapted to different approaches, the main focus is on manufacturing industries and the information and examples given are taken from this sector. The objective of the following process implementation description is to give guidance on the selection and implementation of the energy efficiency key performance indicators relevant at organization levels and to describe the factors and the steps that should be involved in the energy efficiency program with the aim of achieving the desired results.

[8] BS EN 16001:2009: BSI British Standards Energy management systems - Requirements with guidance for use.

According to the information gathered and sorted from the literature review described in the first and second part of the current work and also from the interviews made in some companies belong to the home appliances sector which is described in the part 4 of the work, companies are agree in the need of a energy efficiency program implementation in the production process of the organization. Few indicators have been identified as being valid for most of the businesses in the energy consumption and sustainable development, however, as it was mentioned before, the process description proposed in the current work is focused on the energy efficiency performance and energy consumption issues, other measurements and key performance indicators should be carried on from other sources.

The following diagram (Figure 7) describes the three main macro processes or areas which the energy efficiency program comprehended, and the nine phase's steps of the energy efficiency implementation program; in the section below each explanation and definitions will be found.

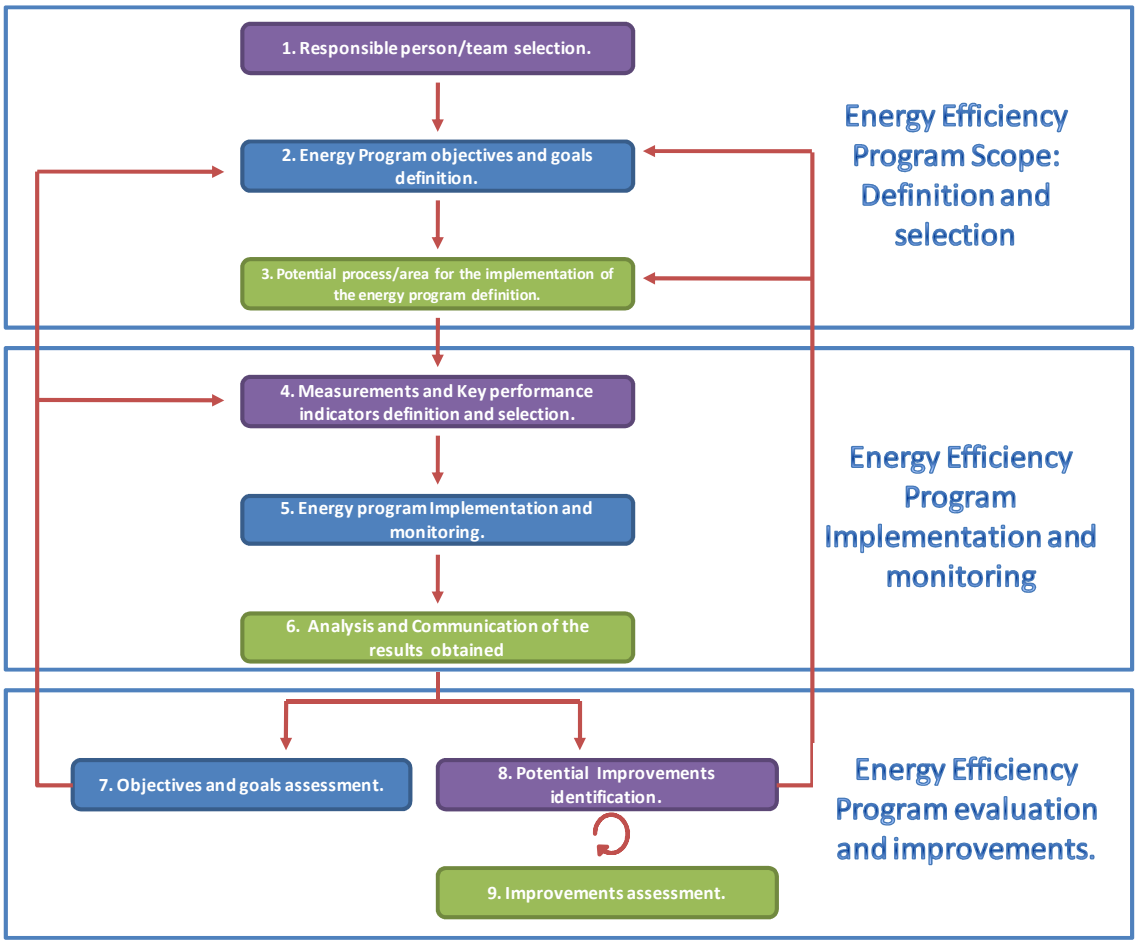

Figure 7: Phases for the energy efficiency implementation program based on key performance indicators.

Most of the frameworks related to energy consumption that have been defined and described in the literature review conducted in the first part of the current work, are focused on specific objectives such as economic (cost reduction), environmental (reductions in emissions and consumption in general, not just energy), new technologies for increasing energy efficiency, etc. The one proposed in the current work, has the purpose to guide the company in the implementation of an energy efficiency program that allows the integration of the most important aspects involved in this subject in order to achieve better results and potential improvements in the manufacturing process and to describe the relationship between the key performance

indicators selection and definition and the decision levels within the company, as well as its importance in the decision making process into the organization.

Energy efficiency implementation program steps

1. ***Responsible person/team selection***

The first step in the energy efficiency implementation program is to select the appropriate person/team who will be involved in the program; In many cases, improvement programs do not work or do not give the desired results because the organization and its employees do not recognize a program responsible/leader or the tasks and responsibilities are delegating to different areas even if they are or are not related to the objectives to be achieved.

Even the technology (machines, equipment, etc.) that the company uses or implements for improving the energy efficiency and energy consumption, is necessary the intervention of people for the data/results analysis and the decision making process through the organization; In many cases people are not aware of their importance in the execution of the improvement program, sometimes they think that technological improvements (i.e. machines and equipment) will give the desired results without their intervention and as consequence there will not performance improvements in the processes/areas. This is why, the personnel should be aware about the importance of energy consumption within the company in order to ensure the success of the energy efficiency program, and they will need to change their attitude about energy concept and its use in order to improve operational practices and routines.

In practice however, getting people to change is far more successful if they appreciate why change is necessary. Once they understand the “why”, they often will be able to contribute to the “how” and suggest better ways of achieving goals. Simple awareness

can achieve results surprisingly fast, especially nowadays that we are all more aware and concern about energy issues, climate change and environmental problems. Sometimes, the issue is that people just do not know how much energy is used by the processes they run or how easy it could be to use less (Energy Efficiency and Conservation Authority, 2008).

Also the energy program will need a strong element of motivation as well. Motivation is a matter of getting people to take responsibility as individuals, to understand that their actions are important and to realize that what they do can make a difference. Getting people on board means helping them feel that their actions can make a difference (Energy Efficiency and Conservation Authority, 2008).

Some of the aspects that the company should be considered for the person/team selection, are the following:

- *Number of members of the team*: it will depend on the work to be performed, the context of the organization and the available resources. The use of a team in the program will spread the knowledge and will get more people understanding the issues and committed to action.
- *Leaders and members:* if the team members are chosen wisely, it will involve natural leaders who are respected by their workmates. Their involvement and endorsement will make getting results much easier. The top management also has an important role in the program since their involvement into the program will make the members more committed.
- *Skills and knowledge of the potential members:* Should be considered the knowledge and the experience about energy consumption of the potential members, and if there is a lack of knowledge about this topic, the company should provide them with training programs or discussions in order to ensure the success of the program.

- *Tasks and responsibilities:* It is really important to define "what" and "how" each member will execute in the program (monitoring, controls, results analysis, report, improvements, etc.).

Once the person or team members are defined the next step in the energy efficiency implementation program is to identify the potential process, area or activity in which should be focused the energy program.

2. Energy Program objectives and goals definition

Once, the responsible person/team selection is done, the next step is the definition of the objectives and goals of the program, it is important that the person/team which will be involved during the execution of the energy program participate in the definition of the objectives and goals because they will be the responsible of the results achievement and evaluation and they should be agree with the objectives defined.

The definition of the objectives and goals are one of the most important steps, as the implementation and outcome of the energy efficiency program and the definition of the measurements and key performance indicators will be aligned to them. Also these objectives should be linked to the general objectives (strategic ones) and goals of the organization in order to ensure its good performance as well as its future.

From the definition of those objectives and goals the organization´s policies regarding energy efficiency and energy consumption performance could be derived. It is also very important to define the scope of the energy efficiency program and which decision levels will be involved in the analysis of results, with the aim of obtaining a better selection of indicators in step 4 of the current process description; for example, in the strategic level the decision could be related to new technologies, it the tactical

level to production planning and at the operational level related to the data collection and to the identification of most energy consuming processes, and for those objectives the selection of the indicators and measurements probably will be different.

As we discussed above, the key performance indicators that will be used in the energy efficiency program, should measure the performance of the organization and they are part of a feedback system, in this case, related to energy efficiency performance. For this reason it is important to take into account the following main objectives (Vesela Veleva, 2001) or aspects that the objectives and goals of the energy efficiency program should covered and comprehend:

- Educate business about sustainable production and the importance of energy consumption and energy efficiency improvement for achieving the results in this field.
- Inform decision-making levels by providing concise information about the current state and trends in a company/facility performance.
- Promote organizational learning about the importance of the energy program.
- Provide organizations with a tool to measure their achievements toward energy efficiency production process goals and targets.
- Allow for comparisons between organizations' performance in the environmental, social, occupational and economic aspects of their production (external benchmarking).
- Provide a tool for *"cross-checking" organization's mission* and reporting results to interested stakeholders.
- Provide a tool for encouraging stakeholder involvement in decision-making.

In this step of the energy efficiency program implementation, the management or the pioneer department of the company in charge of the program, should set specific or general targets that the program will achieve, for example, "reduce the percentage of

energy consumption used per unit of product by 25% in five years", and so on. This step is important, since it ensures management commitment and promotes responsiveness. As the objectives and goals are assessing, the energy efficiency program team can meet the need for setting new goals, objectives, or targets as part of a process for continuous improvement in all aspects of the energy program.

.

Two examples[9]of general objectives and goals that organizations define related to the energy efficiency and energy consumption in the manufacturing process are:

- ✓ Maintain energy cost indicators per unit of production or per machine into the established levels, i.e. into the financial goals given from the top management levels.
- ✓ Reduce the value of each measurement or key performance indicator used in the monitoring process[10] and to ensure that the indicator value will stay in the range set in the target and goals definition, i.e. technical range of the machine, or value range evaluation took from the process analysis.

Once the responsible team and the objectives and goals are defined, the next step is the definition of the potential process or area which will be the starting point for the monitoring and evaluation of the goals and objectives defined for the energy efficiency implementation program.

3. Potential process/area definition:

The main idea of this step is to select, prioritize and set a starting point for the implementation of the energy efficiency program and optimize it. There could be two scenarios: the first one, in which the company already has recorded data relating to

[9] These examples are taken from the interviews carried out in the home appliances companies described in the fourth part of the current work.

[10] Monitoring process is described in the step 5 of the current energy efficiency implementation program description.

energy consumption or the second case in which the company does not have any data about the energy consumption in the manufacturing process.

In the first case, if the information is available the recorded data should be analyzed in order to identify the critical process/processes, activity or area in terms of energy consumption in the manufacturing process of the company and defining the starting point for the monitoring and goals evaluation of the energy efficiency program, one tool that could be used for this purpose is the Pareto Principle[11]; further explanation of this principle should be effectuated from other sources.

If the information it is not available, the starting point could be set by the analysis of the energy consumption bills that the company had paid or through process management tools that the company applied for the identification of critical processes. The description and application of those tools will not be explained in the current work because is not the purpose of it, then, information and knowledge about those tools should be found from another sources.

The aim of the critical process/area identification related to the energy consumption, is to set a starting point; nonetheless, all the processes must be monitored in order to identify improvements or more critical issues which have not being identified until now, which will contribute to better results in the processes output. The proposal of the current work is to start the implementation of the energy efficiency program from the lower decision level into the organization, which is the operational level, it means, to start the monitoring of each machines, processes and activities that are directly involved in the manufacturing process.

[11] Pareto Principle: Observation that where a large number of factors or agents contribute to a result, the majority (about 80 percent) of the result is due to the contributions of a minority (about 20 percent) of factors or agents. Source: http://www.businessdictionary.com/definition/Pareto-principle.html

4. Measurements and key performance indicators selection and definition

Once the objectives, the responsible team and the starting point of the energy efficiency program are defined, the next step is the measurements and key performance indicators definition and selection. As has been shown in the current work, there are no standards measurements or key performance indicators for all the companies related to the energy consumption, because they will depend on each company, its performance, goals, priorities and requirements for energy quantity and quality in order to obtain the best results for further analysis and improvements.

There are a lot of factors that could influence the performance of the energy consumption in each process, activity or area; some of those factors are[12]:

- Product mix
- Product change
- Set-up time
- Cycle time
- Frequency and size of products order
- Frequency and size of products shipments
- Batch processing and intermediate storage
- Rejected products
- Reworks
- Production volume i.e. capacity utilization
- Raw material changes
- Equipment rated and actual efficiency
- Machine breakdown
- Planned maintenance
- Occupancy rate

[12] Applied Industrial Energy and Environmental Management. Zoran K. Morvay. 2008.

- Climate conditions (temperature, humidity, etc.)
- Working days, etc.

Due to the large number of factors that influence the energy performance, the following are some recommendations that could help the organization in the selection of the best possible indicators and measures:

- The indicators should be SMART (Specific, Measurable, Achievable, Realistic and Time-limited).
- Select the indicators that are easily understood for the people involved in the program. Aim for simple and easy indicators for the implementation phase, but emphasize the importance of developing more sophisticated indicators over time.
- Develop a clear and detailed guidance on how to use the methodology in practice and calculate the core indicators of the energy program.
- Include both quantitative and qualitative indicators.
- Emphasize the open and transparent process of indicator use and evaluation, where all the people involved in the energy program have access to information and are encouraged to participate in decision-making.

As it has been describing during the current work, the proposal for the implementation of the energy efficiency program is to start it from the operational level and select the key performance indicators in this level, then, with the information obtained at this level build the indicators for the higher decision levels (strategic and tactical) in order to help in the decision making process and in the evaluation of the objectives and goals related to energy consumption in the organization.

To select indicators, first we have to identify the drivers[13] and the units of measurement that can be used according to the process or machine output. In the figure 8 is giving a brief description of the steps involved in the selection and definition of the measurements and key performance indicators.

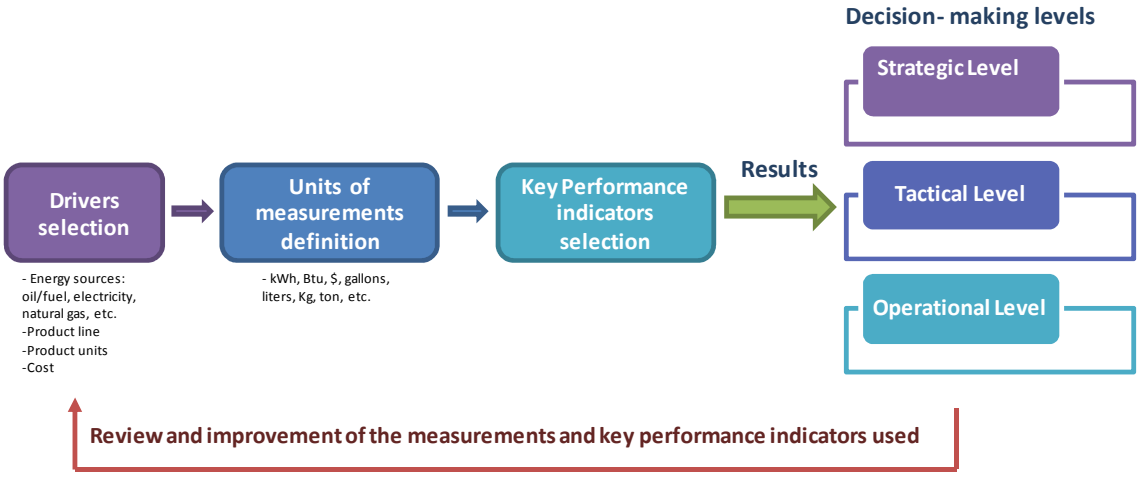

Figure 8: Selection and definition of the measurements and key performance indicators

.

The selection of the drivers and units of measurement, of course will depend on the manufacturing process of the company, the type of resources and energy sources used in the manufacturing process and also on the data availability. In the figure 9 there are some examples of units related to the energy source measurement and also related to the economic and physical values involved in the manufacturing process.

[13] *Definition of driver:* An aspect of a business that effects a change on another aspect of the business. A driver is most commonly a factor that contributes to the growth of a particular business. Source: http://www.investorwords.com/1586/driver.html

Energy source	Units
Electricity	kWh
Natural gas	m3 ; kWh
Diese or 35-second gas oil	Litre ; gallons
Heavy fuel oil	Litre ; gallons
Propane	Tonne ; Kg
Coal	Tonne ; Kg
Steam	Tonne

Physical/economic values
Tonnes of product
Kg of product
Units of product
Family of product (in units)
Thousand of $

Figure 9: Examples of energy measurements and units

Once the drivers and the units of measurement are selected, the next step is to define the key performance indicators that will be used in the monitoring step and will give the values/results for further analysis in each decision level when needed.

It is clear that not every organization that decides to implement an energy efficiency program will have goals and/or targets for each aspects of the manufacturing process. However, it is important to begin with some indicators, reflecting the main goals/targets, and as company gains experience, to establish new goals and introduce additional indicators when the program begins to be implemented.

As it was described in the second part of the current work, there are some key performance indicators related to energy consumption and energy efficiency that were suggested as general indicators, these indicators are summarized in the table 4 and they are suggested for the monitoring activity of the energy program with another indicators that the company considers that also should be monitored. If it is necessary more information related to the concept and calculations of these indicators, please refer to the second part of the present work.

Indicator	Calculation	Units	Decision Level
Energy Efficiency and SEC (Specific Energy Consumption)	Energy Efficiency = Energy value /Physical value SEC = Net available energy consumption/ Total amount of product SEC = Final energy consumption/Amount of specific product or intermediate	[GJ/ton of product]; [PJ/yr]; [MJ/ton] [MJ/US$]]; [Btu/dollar of output] [GJ]; [Kwh]	Strategic/Tactical/Operational Strategic/Tactical Strategic
Energy intensity	Energy intensity = Energy value/ Economic value	[MJ/US$]]; [Btu/dollar of output]	Operational
Total Energy Consumption or Energy Use		[GJ]; [Kwh]	Operational
Degree of efficiency	Degree of efficiency = Net energy/Used primary energy	Factor	Strategic
Thermal energy efficiency of equipment	energy output/energy input	[Mwh];[Kwh]	Strategic
Percent energy from renewable	(energy from renewable sources/total energy used) * 100	[%]	Tactical
Eco-efficiency	Product or service value/Environmental influence	Product or service value/Environmental influence (The ratio depends on the aim of the company (see the definition in the second part of the current work)	Tactical
CO2 Emissions		[Kg; ton]	Strategic/Tactical/Operational

Table 4: General Key performance indicators chart

According to the information gathered from the companies interviewed which belong to the home appliances industry, some examples of the indicators used for the monitoring of energy consumption and energy efficiency issues are shown in the figure 10, with the purpose to illustrate also the measurements and key performance indicators used in real situations and the relation with the theoretical ones found in the literature related to energy consumption. In these examples the term “unit of equipment” refers to unit of finished product, in this case could be a refrigerator, washing machine, oven, etc.

Measurements and indicators used in the home appliance industry related to energy consumption
Kwh/unit of equipment or tonne of finished product
Cost of electric energy/ unit of equipment
Gas consumption in cubic meters/ unit of equipment
m^3 of gas/ tonne of finished product
Energy Consumption Kwh/day
Cost of electric energy/ machine
Total cost of electric energy
energy consumption cost/unit of product
energy consumption cost/factory or plant

Figure 10: Measurements and indicators used in the home appliances industry

It could be noticed that the main indicators used in this industry sector are those ones related to the theoretical definitions of energy efficiency and SEC (Specific Energy Consumption), energy intensity and total energy consumption or total energy use.

Once the indicators are selected and defined should be "proved" during the implementation and monitoring step, and if needed, the drivers and measurements should be reviewed if some mistake in the calculation or units are noticed.

As it was discussed in the step number 2 ("Responsible person/team selection"), the top management commitment is really important in the implementation of the energy program, but cannot alone ensure successful implementation of the key performance indicators; for this reason the selection and definition of the measurements and key performances indicators need to include all the people involved in the process/processes or activities in which the energy program will be implemented because they have the knowledge about the whole manufacturing process and their participation will ensure data reliability, "wins" everyone for the program, and holds them also responsible at the implementation step.

5. Energy efficiency program Implementation and monitoring

To ensure a level of success for energy efficiency program completion, the organization needs to take a complete view of the starting point processes selected, in which will be focused the implementation and monitoring the measurements and key performance indicators selected. As it was discussed before, if it is possible also the whole processes involved in the manufacturing process should be considered in this step of the energy efficiency program for future analysis. The basic principles for optimizing energy performance are continuous monitoring of energy flows and connecting the measured amount of energy used by a process or activity and the measured output of this process or activity.

One of the considerations in the implementation of the energy efficiency program is to assign tasks to people involved; it is really important that people know their responsibilities and roles in order to obtain the desirable results in the execution of the program. Also the creation of detailed timelines could ensure that the project will be carried out according to a plan and in a period of time

In this phase is also involved the data collection and calculation of the measurements and key performance indicators. As it was mentioned in previous steps of the energy efficiency program description, the proposal is to start the data collection from the operational level (i.e. machines and core or critical processes). As well, it is important define the periodicity of data collection with the intention of preventing the generation of large amount of data that could be useless for the analysis and decision making, according to the information collected from the companies interviewed, generally the data collection are made monthly. The data collection is also very important in case that the company is planning to obtain a certification in the energy area, because usually in a certification process every aspect of the processes should be registered.

The technological and technical issues as what type of information system will be used to manage the data, what type of computer software will be used to report data, standard methods and tools required for the operation, etc. should be considered.

Only if each of these topics are planned and implemented to a certain degree and in a coordinated way, the effects necessary for overall success are achieved. Of course, the business situation, the cultural environment, and the available resources are additional boundary conditions which have to be considered in the setup of the contents and the timeline of the implementation phase.

This is the most time-consuming step and requires the participation of all the people involved in the program; also is important that energy efficiency program are not viewed only as a short-term project but rather become an integral part of the company decision-making program due to its importance in the results and performance of the organization.

6. Analysis and Communication of the results obtained

This step involves the analysis and communication of the results obtained from the measurements and key performance indicators selected in the step 4 and their monitored and calculated data in the step 5.

For the analysis of the data, comparisons should be carried out between the same indicators or measurements but in different activities or stages in the manufacturing process, or make the comparison with historical data or ideal data if it is available (i.e. standard measurements that should be obtained related to the specifications of the machines/technology or from the definition of general policies which involve emissions and consumption values and so on, in the whole industrial sector). The analysis also

should be focus according to the objectives and goals defined at the beginning of the energy efficiency program steps and with the tools that the company has available for the analysis process.

When deciding how to communicate the information obtained, the company needs to understand the users and their needs, it means, the decision levels or person/team that will realize the analysis of the data obtained and provide the results accordingly to their needs and in a correct way (i.e. kind of report or collected information formats).

The communication of the results should be in two directions: internally and externally. Internally means to report the analysis of results to the interested parties for the decision making process into the company and externally to the interested parties outside the company (shareholders, consumers, community, etc.). Also the frequency needed for the communication of the results should be defined. In this way the people involved in the energy efficiency program into the organization could see the results of their participation and to encourage their commitment, as well as the organization can significantly improve its public image and gain customers' trust through an open process of evaluation and communication of progress toward its mission and goals related to the environmental issues, most nowadays that there is a global concern about the environmental problems and people are aware that energy consumption and its use is part of this problem.

For continuous improvement to occur, the company needs periodically to communicate and evaluate results from the key performance indicators monitored. Therefore, it is recommended to establish a system for regular evaluation, interpretation and presentation of results to all the parties involved.

7. Objectives and goals assessment

The aim of this step is to look at the results obtained from the selections and monitors conducted during the steps 4 to 6 and make a comparison to the objectives, goals and targets defined at the beginning of the energy efficiency program. This is a key step, since it allows the responsible person/team to have an overview of the results obtained based on the objectives and goals that they agreed in the second step of the current proposed program.

As it is described in the diagram of the figure 7, from the analysis of those results new goals, objectives, targets, measurements or indicators could be evaluated and redefined if needed. It means that in this step should be verified if the defined goals were achievable, in the case that they were not, the objectives must be redrafted to ensure a better scope and results for the energy program (start again in the step 2);

Also the process of measurements and indicators elimination is important as the process of selecting new key performance indicators, i.e. also a review should carry out related to the measurements and indicators, and if some of them are useless or do not give the expected information, the step 4 should be reviewed and a new selection and definition of measurements and key performance indicators must to be done.

Only through a regular review and revision of goals, objectives and indicators can a continuous improvement be achieved.

8. Potential Improvements identification

As it was described in the step 3, the main idea of an identification and definition phase is to select, prioritize and set a starting point for potential improvements, but in the case of the third step of the current proposed energy efficiency program, the

identification of the potential areas is carry out focus on a high level of aggregation, it means looking out the main process because at this point, details and results related to the objectives and goals defined for the program have not obtained yet, while in the current step a more detail analysis could be performed, i.e. the data is analyzed in a lower level of aggregation.

Once the steps 4 to 6 are done, the analysis of the process/processes, areas or activities defined as starting point could be done, and then identifications of improvements could be carry out where needed. As it is shown on the diagram described in the figure 7, once the potential improvements are identified, it is possible that reviews or redefinitions in the steps 2 and 3 must be done. This step could be done in parallel with the previous one because in both of the obtained results for the analysis are the same ones.

Energy efficiency process performance must be evaluated and improved on two sides: first on the production side (how efficiently raw material is processed into a final product, how effectively energy is used to produce give amount of production) and second on the utilities side (how efficiently input energy is converted into utilities which are required by production). The process improvements will tend to address two aspects: more reliable calculation of the critical indicators/measurements and improvements in those critical indicators/measurements. Also is really important to encourage all the people involved within the operational, tactical or strategic levels in the energy efficiency program to contribute ideas for improvements and maintain effective communication with those affected by the improvements carried out into the energy program. From them the company can obtained improvements suggestions about quality, cost reduction, technological improvement, etc. and the feedback process will give better results.

There are many techniques and tools that can help to identify the processes improvements. The challenge is to choose the ones that best address the objectives set at the beginning of the program. As much as possible, this step should build upon existing methodology and procedures according to the manufacturing process nature or with tools that the company is already using for this purpose.

Some tools for process improvement analysis are the fish bone diagrams and value stream mapping. These tools will help identify where a process can break down and help to increase overall efficiency. In the current work the definition and methodology description of these tools will not be carrying out because is not the purpose of it; for further information about these methodologies you should refer to other sources.
As an example, in the case of the home appliances companies interviewed, with the data and results obtained from the measurements and key performance indicators the main improvements which they look for, are related to the following issues: cost reduction plans in general and related to energy consumption, energy consuming processes identification in order to plan the actions for reducing the consumption, improvement of production plans and proposals for improvements in single machines and also in processes/activities.

9. Improvements assessment

This step has the same aim of the step 7 “Objectives and goals assessment”, as this step intends to review the results of the improvement actions carried out in the energy program if it is the case. Also the relation between this step and the previous one (step 8) could be described as a cycle as it is described in the diagram of the figure 7, because the improvements defined and carried out in the step 8 must be assessed and then, with the obtained results again to identify potential improvements and refer to the steps 2 and 3 if needed, or if the improvements are giving the desired results continuing with the monitoring and analysis and communication of the results.

For doing this analysis, comparisons should be done in order to understand if the selected key performance indicators in the areas selected, were improved or not; also the comparisons could be done through a benchmarking activity with other similar processes in order to take corrective actions and demonstrates that key performance indicators and the energy efficiency program are a process of continuous improvement in the company which develop environmental, occupational and social performance are also involved.

Strengths and limitations of the energy efficiency program proposed

As it was mentioned during the overview description of the process proposed, the current energy efficiency program is focused on manufacturing industries, but it also could be adapted to other industries since the steps are mainly general for an improvement program.

The proposed steps of the energy efficiency program contain suggested measurements and key performance indicators which can be implemented at different levels within the organization. The type of organization, information needed and data availability will determine the choice in using the indicators in the decision making progress through the decisional levels. Also the steps provide guidance on how to focus and calculate each proposed measurement and indicators.

The implementation of an energy efficiency program using established processes/steps, measurements and key performance indicators promote standardization in measurement and reporting, and the development of core indicators which could be applied through companies and industrial sectors with comparison purposes. Also the implementation of the program provides flexibility, it means, the organization has the opportunity to develop their own production-specific indicators and focus them on its organizational goals and objectives.

In addition, the implementation of an improvement program like the proposed in the current work, allows the company in building experience in the field of energy consumption and therefore in the environmental/sustainability field. Also promotes continuous improvement through the process of indicators and measurement development and identification of potential improvements, for instance as results the company can reduce its energy consumption; at the same time the involvement of managers and workers are encouraged.

Unfortunately the current proposed energy efficiency program also has some weaknesses and limitations. The suggested key performance indicators and measurements involve some subjective aspects, it means that depends on the objectives and goals of the organization, its production mix, availability of resources and energy sources issues, the drivers for the measurements and indicators will be chosen and in the current proposed methodology no criteria are provided for distinguishing between effective and ineffective indicators for the measurement of the energy-related factors in the production process. One difficulty relates to the fact that the same indicator may be effective at one company and ineffective at another.

Although the goal is to suggest simple and easy to implement indicators and measurements, some organizations may still find these difficult to use. This is could be the case for organizations where lacks of resources and data availability are major barriers. Also concerns about the investment which the organization would have to do and the time required for the implementation of the program could be principle barriers as it was expressed in some of the interviewed companies described in the section below.

CHAPTER 4: ENERGY EFFICIENCY IN HOME APPLIANCES INDUSTRY

In the case of OECD[14] countries, residential appliances and equipment use 30% of all electricity generated in those countries, producing 12% of all energy-related carbon dioxide (CO_2) emissions. They are the second largest consumer of electricity and the third largest emitter of greenhouse gas emissions in OECD countries, for this reason there is a potential energy savings in this field. In Transition countries, comprehensive figures are not available, but some general statements are possible. The range of equipment and use is very wide among countries. In all cases, potential savings are expected to be high there too. (Thomas Guéret, International Energy Agency, 2005)

The contribution of residential appliances' uses to overall electricity consumption is usually less in developing than in OECD countries, as well as their absolute level per capita. Nevertheless, relative potential savings for domestic appliances in developing countries should be higher than in OECD countries at least in the short and medium term. This is because the average level of efficiency is lower there; both as a result of lower income and less developed markets, and few of these countries have implemented measures to improve appliance efficiency. The potential impact of new and more efficient appliances is higher because households still have to be equipped, whereas in OECD countries the markets are in a turnover phase. Furthermore, this impact would be felt even more in these countries, as they face problems installing generation capacity to keep up with growing demand. As home appliances are used all around the world, in most cases, the markets for electrical appliances are at least regional and more often global, for example CFLs (Compact Fluorescent Lamps), which are produced and trade for global companies as General Electric, Philips, etc. However,

[14] Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

this is not necessarily the case for other appliances. Some local or regional companies are stronger in the "cold appliances" market or for washing machines due to reasons as transport costs because is a barrier to accessing other markets. (Thomas Guéret, International Energy Agency, 2005)

With the purpose of improving and supporting the definition of the energy program implementation in the previous part, some interviews were carried out in order to get some information about the energy awareness and concern in the home appliances industry because of the relevance of this industry in the energy consumption sector as it was mentioned before. The interview objectives and definition of the surveys as well as the cases of study will be described in the following sections.

Companies interviewed

For the purpose of the current work, particular scope will be given to companies from two different regions: In Colombia the main three companies in the home appliances market were interviewed and in Italy, Whirlpool as one of the most representative companies in this sector. The following is a brief description of the companies, for privacy issues the real names of the companies will not mention in the current work. for more information please refers to appendix 1.

Home Appliances Companies interviewed in Colombia

Company 1: Colombian company.
Sales in**:** Colombia, Venezuela, Ecuador, Peru, United States
Products: Stoves, refrigerators, washing machines, heaters, air conditioners, toasters, ovens, microwaves.

Company 2: Mexican company with factory in Colombia.

Sales in: Mexico, Brazil, Argentina, Canada, Chile, Costa Rica, Ecuador, Guatemala, Panama, Peru, Russia, Venezuela.

Products: Stoves, refrigerators, washing machines, heaters, ovens, microwaves.

Company 3*:* Colombian factory, commercial refrigeration (for the preservation, exhibition and sale of food).

Sales in: Colombia, Ecuador, Venezuela, Panama, Peru, Mexico, Dominican Republic Salvador, South of United States and few Caribbean Islas.

Products: Freezers, Refrigerators, Refrigerated Cabinets, bottle coolers.

Home Appliances Company interviewed in Italy

Company 4: American company with plants and factories all over the world. In the case of Europe the company has around 20.000 employees.

Sales in: Basically all around the world. North America, Latin America, Europe, Asia.

Products: cook tops, ovens, microwaves, refrigerators, wine coolers, ice makers, freezer, dishwashers, disposers, compactors, washer, dryers, water heaters, water products (filtration, softeners, coolers), air conditioning, central heating, central indoor air quality.

Energy Consumption and Energy Efficiency Measurement – Interview guideline

The following is the description of the interview guideline with the questions and the information requested. The filled out questionnaires from the companies described above, can be consulted in the appendix 2.

Objective of the survey: The main objective of this survey/interview is to have an understanding about the awareness of the energy consumption in the production process of the company and the use of energy key performance indicators in this area; how it is measured, if there are some approaches or procedures related to energy efficiency in the company and which is the relevance of this subject for the organization.

Industry focus: Home appliances industry

General Information:

About the company:						
Company name:						
Address:						
Telephone/e-mail:						
Web site:						
Number of employees:						
Sales/year (Million €)	**0 - 10**		**10 - 50**		**> 50**	
About the person who is going to answer the survey:						
Position in the company:						
Contact address:						
Date:						

Questionnaire:

1. Is there some program about environmental sustainability in the company? If the answer is affirmative, please give a briefly description about the area in which that program is focused. (E.g. energy consumption, water consumption, gas emissions, etc.)

2. Is energy consumption an issue that is known and addressed through the organization? i.e. Is it monitoring? Is there any specific task or program related to energy consumption?
3. Does the company have any certification in energy consumption? Which one?
4. Which is the total energy consumption in relation to the production process (%)? Is this quantity of energy consumption relevant in the production process for the company? (I.e. in terms of costs, environmental terms, etc.)
5. In the production process, which activity is the most energy intensive?
6. In the company, is the use of key performance indicators in order to measure energy consumption implemented?
7. If the previous answer is negative, why is not measure the energy consumption in the company? Please give a briefly explanation.
8. If the answer to question number 6 was affirmative, please briefly describe the main indicators which are used:
9. Are there some measure, monitoring or implementation issues related to those indicators? (E.g. in a management point of view, technological issues, personnel knowledge, etc.) Which ones?
10. Is there a person in charge of this activity?
11. Mainly how are the indicators measured? By production line/ By energy source/ By product/ By activity/ Other, which one?
12. Is there any documentation of those indicators? Are they controlled? How often the control is made? Monthly/weekly, yearly, other?
13. The information obtained from the key performance indicators is used for decision making in some level of the company? (I.e. for strategic planning, for operational/production planning, etc.). If the answer is affirmative, for which purpose?
14. Are there some policies or goals related to the energy consumption in the company? Which ones?

15. Has the company implemented new technologies with the purpose of energy intensity improvement? If the answer is affirmative, in which level/activity/department?
16. In your opinion, could energy consumption´s measurement performance, help the company in saving costs and improving the production process performance?
17. Do you consider worthy the implementation of a program in this field?
18. Comments or suggestions

Information gathered analysis

From the information obtained with the guidance of the questionnaire described in the section above, some conclusion about the energy consumption issues and concerns were found in the home appliances industry which probably could be found in other manufacturing industries, as generally issues and concerns.

In all the companies interviewed, environmental programs are conducted, but in most of the cases, they are not implemented because of energy consumption matters the main considerations in these kind of programs are related to waste handling and disposal, water discharges control, noise controls and gas emissions, and the principal reason for carrying out these programs is because of regulations and laws in each place where they are located; Also the certifications obtained in some of the companies are related to production and environmental issues but not in the energy field. But it does not mean that energy consumption is not known or there are not concerns about it in those companies, in the recent years the issues related to energy consumption in the home appliances industry have been taking into consideration and the principal reason is the reduction of its total cost.

The energy consumption cost in all the companies interviewed are less than 10% in relation to the total production costs or total sales; it seems really low, and because of

this in most of the companies energy issues was not relevant compared to these costs, but when they consider and analyze the total cost of the different energy consumption involved in each production process, the amount is high and representative in financial terms hence, these companies began to consider the energy consumption importance in order to achieve costs reduction.

In all the cases of the interviewed companies the indicators and measurements are used in the monitoring of the energy consumption, mainly those indicators are measured based on the type of energy source involved in the process and on total energy consumption costs as it was shown in the figure 10 in the previous section. In the cases of the companies interviewed, the information gathered with the use of those measurements and indicators are used for purposes like: energy cost´s control, improvement plans, cost reduction plans (in general), in the identification of the most energy consuming processes in order to plan the actions and to reduce the energy consumption of each process, factory or plant, etc. However there are not established policies related to the energy consumption into the organization as a culture or core program, but there are some targets and objectives which justifying the use and monitoring and justifying the use of each indicator of each indicator.

All the companies interviewed agree on the importance of the implementation of a energy efficiency program in the decision making process as well as in the continuous improvement of production process and the environmental culture of the organization, for this reason the current work would like to give a guidance for companies interested in this field, in order to help in the implementation process of the program.

CONCLUSIONS

Energy is a critical resource in the economic and social development, for this reason, nowadays sustainable development is becoming an important worldwide concern, and improvements in energy efficiency may become an important goal within that context. Considering future trends in world energy use, increasing concerns about access to energy and energy security and supply, significant challenges need to be addressed in many sectors, in particular in the industry sector for which the analysis of the current work was carried out, where energy efficiency will be part of the solution. There are, however, a number of barriers to the implementation of energy efficiency programs, due to structural differences between companies, availability of resources and other cultural and behavioral factors into the organizations.

Measuring industrial energy efficiency performance takes various forms, purposes and applications. There are no ideal and established measures and key performance indicators that can be applicable to every case. It is not possible to select the best one for every set of circumstances, but it is possible to choose appropriate indicators and measurements for the individual purposes into the organizations.

From the literature review, few papers and works can be found related to the decisional levels into the organizations and their link with the energy efficiency concerns, most of them described the relation of the energy consumption and energy efficiency indicators in a macroeconomic level, for this reason, organizations should develop new management approaches at top management levels, but involving all the levels in the organization in order to fully exploit opportunities for increased energy efficiency, especially by increasing awareness of their energy consumption and savings in the long term.

The implementation of an energy efficiency program into an organization promotes standardization in measurement, reporting and processes' performance, and also the development of core indicators, measurements, targets and goals could be applied through companies and industrial sectors with comparison purposes, as well as it promotes continuous improvement and the identification of potential improvements helping the organization in the achievement of the desired results in this field, at the same time the involvement of managers and workers are encouraged.

BIBLIOGRAPHY

Andersson, K. (2007). The role of key performance indicators for corporate treasury. *Journal of Corporate Treasury Management* .

Ang, B. (2005). Monitoring changes in economy-wide energy efficiency. *Energy Policy, Vol. 34* , 574–582.

Asia Pacific Energy Research Centre. (2000). *Energy Efficiency Indicators.* Tokyo.

BSI British Standards. (2009). *Energy management systems: Requirements with guidance for use.*

Bunse, K. *Evaluating Energy Efficiency Improvements in Manufacturing Processes.*

Chevalier, J.-M. (2005). Security of energy supply for the European Union. *International Journal of European Sustainable Energy Market* .

Christina Galitsky, E. W. (2008). Energy Efficiency Improvement and Cost Saving Opportunities for the Vehicle Assembly Industry.

EIA, U. E. (2010). *International Energy Outlook.*

EIA: Energy Information Administration. (2009). *International Energy Outlook 2009.*

Energy Efficiency and Conservation Authority. (2008). *Staff awareness and motivation.*

Hendrik A. Verfaillie, R. B. (2000). *Measuring Eco-Efficiency.* World Business Council for Sustainable Development.

Herrmann, C. T. (2009). Process chain simulation to foster energy efficiency in manufacturing.

ICC: International Chamber of Commerce. Commissions on Environment and Energy. (2009). *Energy efficiency with case studies.*

Jamas, T., & Pollitt, M. (2008). Security of supply and regulation of energy networks. *Energy Policy 36 - Elsevier* , 4584 – 4589.

Joanne Longo, D. (2009). The Benefits of Key Performance Indicators To Businesses .

Kanako, T. (2008). Assessment of energy efficiency performance measures in industry and their application for policy. *Elsevier* , 2887– 2902.

Li-Ming Wua, B.-S. C. (2007). Structure model of energy efficiency indicators and applications. *Energy Policy Vol. 35* , 3768–3777.

McKenna, R. C. (2009). Industrial energy efficiency. University of Bath.

Morvay, Z. K., & Gvozdenac, D. D. (2008). *Applied Industrial Energy and Environmental Management.* Wiley.

Patterson, M. G. (1996). What is energy efficiency? *Energy Policy. Vol. 24* , 377-390.

Phylipsen, G. J. (1997). International comparisons of energy efficiency-Methodologies for the manufacturing industry. *Energy Policy, Vol. 25* , 715-725.

Popp, D. C. (2001). The effect of new technology on energy consumption. *Resource and Energy Economics 23* , 215-239.

Spalding-Fecher, R. (2003). Indicators of sustainability for the energy sector: a South African case of study. *Energy for Sustainable Development, Volume VII* , 35-49.

Stouffer, D. (n.d.). *Article Snatch: International Framework For New Energy Management Standard*. Retrieved Junio 2010, from http://www.articlesnatch.com/

Thomas Guéret, International Energy Agency. (2005). *International Energy Technology collaboration and climate change mitigation. Case Study 3: Appliance Energy Efficiency.*

U. S. Environmental Protection agency. (n.d.). *U. S. Environmental Protection agency*. Retrieved May 2010, from Greenhouse Gas Emissions - Climate change: http://www.epa.gov/climatechange/emissions/index.html

Veleva, V. (2001). Indicators of sustainable production. *Journal of Cleaner Production Vol. 9* , 447-452.

World Business Council for Sustainable Development. (2000). *Measuring Eco-Efficiency.*

APPENDIX 1: Energy Consumption Indicators used in the annual report of some companies

- From annual Report of Coca Cola Company 2009:

PERFORMANCE HIGHLIGHTS BY YEAR	2005	2006	2007	2008
BEVERAGE BENEFITS				
Company Global Product Quality Index rating (out of 100)	94.0	94.2	94.5	94.5
Number of low- and no-calorie beverage products in portfolio	475+	575+	700+	750+
ACTIVE HEALTHY LIVING				
Company investment in active healthy living programs	N/A	$3MM	$6MM	$9MM
Number of new beverage products introduced	450+	600	700+	700+
ENERGY MANAGEMENT AND CLIMATE PROTECTION				
Direct greenhouse gas emissions for the Coca-Cola system[1]	1.86MM t CO_2e	1.98MM t CO_2e	1.95MM t CO_2e	1.96MM t CO_2e
Indirect greenhouse gas emissions from electricity purchased and consumed (without energy trading) by the Coca-Cola system[1]	2.60MM t CO_2e	2.89MM t CO_2e	2.97MM t CO_2e	3.21MM t CO_2e
Total megajoules of energy used by the Coca-Cola system[2]	49.5B	55.0B	55.8B	58.6B

- From annual report of Danone 2009:

Environmental indicators	Total groupe 2009
Production ('000 metric tons)	22,587
Production sites[1]	
Total number	159[2]
Cover rate	85%[2]
Total number of sites certified compliant with ISO 14001	85
Thermal energy consumption ('000 MWh)	2,116
Electricity consumption ('000 MWh)	1,573
Total energy consumption ('000 MWh)	3,690
Total amount of waste generate ('000 metric tons)	238
Total amount of waste eliminated through specific waste management path ('000 metric tons)	214
Proportion of waste eliminated through specific waste management path ('000 metric tons)	86%
Total water consumption ('000 cubic meters)[4]	33,334
Waste-water COD (chemical oxygen demand) in '000 metric tons[3]	5,139
Significant emission incidents (chemical and hydrocarbons)	2
Emissions of greenhouse gases (CO_2, CH_4, N_2O, CFC, etc.) (in metric kilotons CO_2 equivalent)	499
SO_x (sulfur oxide emissions) in metric tons SO_2 equivalent	3,359
NO_x (nitrogen oxide emissions) in metric tons NO_2 equivalent	1,331
Gases depleting the ozone layer (in kilograms CFC equivalent)	801

APPENDIX 2: Interviewed companies information

COMPANY 1

This company is located in the city of Cartagena, Colombia. It was founded in the year 1956; it started in a small garage, along with a small group of workers and capital he began with the history of this commercial refrigeration industry. After several months of testing and hard work, finally the first model of a cooler with capacity for 200 bottles of soda and beer was produced.

Since 1960 the headquarters are located in the El Bosque, a neighborhood in the city of Cartagena de Indias, with an area of 16,000 square meters, representing approximately total assets for $25,000 million of Colombian pesos (approximately 13 million of US$), the plant has modern industrial equipment with capacity to produce 1800 units of product monthly. There are more than 35 models of products (bottle coolers, freezers, fridges and freezers exhibitors, etc.) sold through dealers (about 250) in the regional market and abroad.

COMPANY 2

This company has 65 years in the market. It produces heating and refrigeration products for domestic and commercial purposes which are sold through authorized distributors in Colombia and abroad. From a small electrical repair shop in 1940, this company nowadays has over 2,800 employees and presence in Colombia and international markets. This company obtained the international certification ISO 9001-2000 in 2004, for their cooling and heating processes. Then in 2005, it was certified in ISO 14001 for Environmental Management, it was the first Colombian company in obtaining it under the 2004 version; also in that year a factory was established in Ecuador with the purpose of increasing the positioning of the company abroad.

Nowadays is the most important company in the Colombian market and its brand is well known in the domestic market.

COMPANY 3

It is a global company which designs, produces, and distributes appliances to more than 70 countries around the world. The company was incorporated in 1946 in Mexico City. The company was initially dedicated to manufacture kitchen furniture. In the 1950s, began the manufacturing of various appliances such as gas ranges and refrigerators. Rapid growth allowed the company to become the leading exporter of appliances in Mexico in 1960. As the company continued to grow, exports and production remained concentrated in Latin America. By the mid '90s, it was one of the leading appliance manufacturers in the world with annual growth between 15 and 20 per cent. In Mexico, the company dominated the market, while in Latin America commanded a 70% market share in home appliances. In 1995, the company came to Colombia with practical new technologies, advanced designs and durability characteristics to facilitate life in Colombian homes.

COMPANY 4

The company was founded in United States and today is the world's leading manufacturer and marketer of major home appliances, realizing annual sales of approximately $19 billion in 2008, has 70,000 employees and maintains 67 manufacturing and technology research centers around the world. By the start of the 1970s, the company offered appliances to handle laundry, home heating and cooling, and the full cycle of food preservation, preparation, consumption and cleanup, in the kitchen. They continued introducing innovative products that performed more efficiently and helped make household tasks easier. To support our consumers, we introduced the Cool Line, the first toll-free consumer service support program in the

United States. In 1943 the company came to Italy, where the company gained an Italian home appliances company in 1989, and then started his business in whole Europe.

APPENDIX 3: Filled out interview guideline form

COMPANY 1

General Information:

About the company:						
Number of employees:	**229**					
Sales/year (Million €)	**0 - 10**		**10 - 50**	**X**	**> 50**	

Questionnaire:

1. Is there some program about environmental sustainability in the company? If the answer is affirmative, please give a briefly description about the area in which that program is focused. (E.g. energy consumption, water consumption, gas emissions, etc.)

Yes	X	No	

- Waste handling and disposal.
- Water discharges control.
- Noise control.

2. Is energy consumption an issue that is known and addressed through the organization? i.e. Is it monitoring? Is there any specific task or program related to energy consumption?

Yes	X	No	

3. Does the company have any certification in energy consumption?

Yes		No	X	Which one?	

4. Which is the total energy consumption in relation to the production process (%)? Is this quantity of energy consumption relevant in the production process for the company? (I.e. in terms of costs, environmental terms, etc.)

It represents about 3% of production costs; mainly electricity and gas are used. The percentage is relevant because the productions cost are high.

5. In the production process, which activity is the most energy intensive?

In order of relevance:

- Painting line, furnaces, burners and motors.
- Body shop section.
- Compressed air line (which feeds the pneumatic tools).

6. In the company, is the use of key performance indicators in order to measure energy consumption implemented?

Yes	X	No	

7. If the previous answer is negative, why is not measure the energy consumption in the company? Please give a briefly explanation.

8. If the answer to question number 6 was affirmative, please briefly describe the main indicators which are used:

The output of the manufacturing process is unit of refrigeration equipment. The KPI used are the following:

- Kwh/unit of equipment
- Cost of electric energy/ unit of equipment
- Gas consumption in cubic meters/ unit of equipment
- Total cost of electric energy (monthly)

- Total cost of gas (monthly)

9. Are there some measure, monitoring or implementation issues related to those indicators? (E.g. in a management point of view, technological issues, personnel knowledge, etc.) Which ones?

At the moment there are not difficulties in the monitoring of the indicators because they just do it at operational level. They do not have measurement devices in all the areas into the company.

10. Is there a person in charge of this activity?

Yes	X	No	

11. Mainly how are the indicators measured?

By production line		By energy source	X	By product	
By costs		By activity		Other, which one?	

12. Is there any documentation of those indicators? Are they controlled? How often the control is made?

Yes	X	No	

Weekly		Monthly	X	Yearly		Other?	

13. The information obtained from the key performance indicators is used for decision making in some level of the company? (I.e. for strategic planning, for operational/production planning, etc.)

Yes	X	No	

If the answer is affirmative, for which purpose?

- Energy cost´s control.
- Improvement plans
- Leak and waste detection
- Cost reduction plans (general)

14. Are there some policies or goals related to the energy consumption in the company? Which ones?

Yes. In general terms, one of the policies is to maintain the energy cost indicator/unit of equipment produced between the established levels and look for improvements in order to reduce this indicator.

15. Has the company implemented new technologies with the purpose of energy intensity improvement?

Yes	X	No	

If the answer is affirmative, in which level/activity/department?

In recent years they introduced a system in one of the production lines for the refrigeration equipment testing process, which reduced the energy consumption in the by 80% .

16. In your opinion, could energy consumption´s measurement performance, help the company in saving costs and improving the production process performance?

Yes. The projects that have been implemented as well as the energy consumption cost reduction have increased the productivity in the processes.

17. Do you consider worthy the implementation of a program in this field?

Yes. In fact, with some of local universities in Cartagena, Colombia, they have done some studies related to the improvements in energy consumption and that studies are in the preliminary phase.

18. Comments or suggestions

COMPANY 2

General Information:

About the company:						
Number of employees:	**2600**					
Sales/year (Million €)	**0 - 10**		**10 - 50**		**> 50**	**x**

Questionnaire:

1. Is there some program about environmental sustainability in the company? If the answer is affirmative, please give a briefly description about the area in which that program is focused. (E.g. energy consumption, water consumption, gas emissions, etc.)

Yes	X	No	

Integral energy management. (GEI: Gestión Energética Integral) Integrated water management (MIA: Manejo Integral del Agua) Integrated solid waste management (MIRS: Manejo Integral de Residuos Sólidos) Hazardous substances program (PSP: Programa de Sustancias Peligrosas)

2. Is energy consumption an issue that is known and addressed through the organization? i.e. Is it monitoring? Is there any specific task or program related to energy consumption?

Yes	X	No	

3. Does the company have any certification in energy consumption?

Yes	X	No		Which one?	ISO 14001

4. Which is the total energy consumption in relation to the production process (%)? Is this quantity of energy consumption relevant in the production process for the company? (I.e. in terms of costs, environmental terms, etc.)

In relation to sales the energy consumption is quantified by percentage and is 0,73%; but in relation to production processes is quantified as energy consumed/one tonne of finished product . In both cases the quantity is relevant.

5. In the production process, which activity is the most energy intensive?

Thermoforming process

6. In the company, is the use of key performance indicators in order to measure energy consumption implemented?

Yes	X	No	

7. If the previous answer is negative, why is not measure the energy consumption in the company? Please give a briefly explanation.

8. If the answer to question number 6 was affirmative, please briefly describe the main indicators which are used:

- m^3 of water/ tonne of finished product
- m^3 of gas/ tonne of finished product
- Kwh/ tonne of finished product

These measures are used in each operative business unit into the company.

9. Are there some measure, monitoring or implementation issues related to those indicators? (E.g. in a management point of view, technological issues, personnel knowledge, etc.) Which ones?

There are some issues related to the particular consumption measurement in each machines, because is needed a large amount of energy meters.

10. Is there a person in charge of this activity?

Yes	X	No	

11. Mainly how are the indicators measured?

By production line		By energy source	X	By product	
By costs		By activity		Other, which one?	

12. Is there any documentation of those indicators? Are they controlled? How often the control is made?

Yes	X	No	

Weekly		Monthly	X	Yearly		Other?	

13. The information obtained from the key performance indicators is used for decision making in some level of the company? (I.e. for strategic planning, for operational/production planning, etc.)

Yes	X	No	

If the answer is affirmative, for which purpose? The information is used in the proposals for improvement single machines and also in the processes.

14. Are there some policies or goals related to the energy consumption in the company? Which ones?

Reduce the value of each indicator described in question number 8, and to ensure that the indicator value is in the range set in the target and goals definition.

15. Has the company implemented new technologies with the purpose of energy intensity improvement?

Yes	X	No	

If the answer is affirmative, in which level/activity/department?

Once the analysis is carried out in each area of the process, if we identify a critical point of consumption, we propose the projects needed to reduce the energy consumption and if needed, the technology is acquired.

16. In your opinion, could energy consumption´s measurement performance, help the company in saving costs and improving the production process performance?

Yes, as we control the energy consumption and expenditures, we can provide corrective action and give the desired results through implemented improvements.

17. Do you consider worthy the implementation of a program in this field?

Yes, because if you measure, you can control and if you control you can make improvements.

18. Comments or suggestions

COMPANY 3

General Information:

About the company:						
Number of employees:	**1000**					
Sales/year (Million €)	**0 - 10**		**10 - 50**	**X**	**> 50**	

Questionnaire:

1. Is there some program about environmental sustainability in the company? If the answer is affirmative, please give a briefly description about the area in

which that program is focused. (E.g. energy consumption, water consumption, gas emissions, etc.)

Yes	X	No	

- Energy consumption
- Gas emissions
- Waste disposal and management
- Grease traps
- Noise
- Liquid spill

2. Is energy consumption an issue that is known and addressed through the organization? i.e. Is it monitoring? Is there any specific task or program related to energy consumption?

Yes	X	No	

3. Does the company have any certification in energy consumption?

Yes		No	X	Which one?	

4. Which is the total energy consumption in relation to the production process (%)? Is this quantity of energy consumption relevant in the production process for the company? (I.e. in terms of costs, environmental terms, etc.)

Is relevant, approximately 2% of production cost.

5. In the production process, which activity is the most energy intensive?

Extruding system and thermoforming process.

6. In the company, is the use of key performance indicators in order to measure energy consumption implemented?

Yes	X	No	

7. If the previous answer is negative, why is not measure the energy consumption in the company? Please give a briefly explanation.
8. If the answer to question number 6 was affirmative, please briefly describe the main indicators which are used:

- Energy Consumption Kwh/day
- Cost of electric energy/ equipment
- Total cost of electric energy

9. Are there some measure, monitoring or implementation issues related to those indicators? (E.g. in a management point of view, technological issues, personnel knowledge, etc.) Which ones?

For now there are no problems, as we have the technology and assistance for the consumption measurement.

10. Is there a person in charge of this activity?

Yes	X	No	

11. Mainly how are the indicators measured?

By production line		By energy source	X	By product	
By costs		By activity		Other, which one?	

12. Is there any documentation of those indicators? Are they controlled? How often the control is made?

Yes	X	No	

Weekly		Monthly	X	Yearly		Other?	

13. The information obtained from the key performance indicators is used for decision making in some level of the company? (I.e. for strategic planning, for operational/production planning, etc.)

Yes	X	No	

If the answer is affirmative, for which purpose?

With the obtained information, we look for improvement opportunities and for identifying which are the more energy consuming processes in order to plan the actions and to reduce the consumption.

14. Are there some policies or goals related to the energy consumption in the company? Which ones?

There are programs implemented related to: heating of equipment, automatic on/off programs for the equipment, measurement of critical equipment, training programs in order to create awareness about energy consumption.

15. Has the company implemented new technologies with the purpose of energy intensity improvement?

Yes	X	No	

If the answer is affirmative, in which level/activity/department?

Energy network analyzer (Computing system)

16. In your opinion, could energy consumption´s measurement performance, help the company in saving costs and improving the production process performance?

Yes, because it allows us to review the results each month, and to check if they are within the objectives of the costs of production.

17. Do you consider worthy the implementation of a program in this field?

It is very important because the results are reflected mainly n the income statement.

18. Comments or suggestions

COMPANY 4

General Information:

About the company:						
Number of employees:	**Approximately 20.000 (all Europe)**					
Sales/year (Million €)	**0 - 10**		**10 - 50**		**> 50**	**X**

Questionnaire:

1. Is there some program about environmental sustainability in the company? If the answer is affirmative, please give a briefly description about the area in which that program is focused. (E.g. energy consumption, water consumption, gas emissions, etc.)

Yes	X	No	

There are programs in the company related to products and production.

- About products: The programs or plans consist in making the products more "environmental friendly" in terms of energy consuming, emissions, efficiency, water consuming, etc. These characteristics are also identified by the customers and are important in terms of sales growth.

- About production (factories and plants): There are programs related to water discharged, emissions, etc in every plant in Europe but the goals and programs depend on the laws and regulations of each country. About energy issues, the company just started to create a program related to energy consumption about 18 months ago, because of the high costs of energy during the last years. It is not a structure program yet, but they are introducing programs in the plants and also in the offices they started the program "green teams" which have the task of checking the bills of energy every month, in order to control the energy consumption also in the offices.

Related to the sustainability for energy issues, the company has programs for developing technologies with the purpose of saving energy as solar panels; these kinds of programs have incentives from the government because they are expensive.

2. is energy consumption an issue that is known and addressed through the organization? i.e. Is it monitoring? Is there any specific task or program related to energy consumption?

Yes	X	No	

The monitoring process is doing from the bills of the energy consumption at the moment.

3. Does the company have any certification in energy consumption?

Yes		No	X	Which one?	They have ISO14001 in the Napoli plant, but not related to energy issues.

4. Which is the total energy consumption in relation to the production process (%)? Is this quantity of energy consumption relevant in the production process for the company? (I.e. in terms of costs, environmental terms, etc.)

In terms of production costs percentage is less than 10%, it seems to be not relevant, but in terms of total cost of energy consumption in the total plants and factories in Europe the amount is approximately $28 million of euro/year (this amount includes all the energy sources: gas, fuel, electricity, steam). One of the issues which influence this cost is, that some plants and factories have to import gas.

5. In the production process, which activity is the most energy intensive?

At the moment they are identifying the most consuming energy process in the production process, but from historical data and experience the two process which are more energy consuming are:

- The thermoforming process and in the oven production the enameling

The energy consuming processes also depend on the factory and plant.

6. In the company, is the use of key performance indicators in order to measure energy consumption implemented?

Yes	X	No	

7. If the previous answer is negative, why is not measure the energy consumption in the company? Please give a briefly explanation.

8. If the answer to question number 6 was affirmative, please briefly describe the main indicators which are used:

The key performance indicators and measurements depend on the plant and factory because the product mix and energy sources are different in each one.

The main indicators which are used are: energy consumption by product, it means:

- Kwh/unit of product
- m^3 of gas/unit product;
- energy cost/unit of product
- energy cost/factory

The analysis and control of these indicators are made by factory and plants because of the differences between them, the goals and target established for each indicator is based on statistical data (average of each year) and are different for each plant.

9. Are there some measure, monitoring or implementation issues related to those indicators? (E.g. in a management point of view, technological issues, personnel knowledge, etc.) Which ones?

Yes. From the management point of view, the main issue is financial and sometimes the principal management department of the company do not consider necessary to make changes or improvements related to the monitoring or implementation of energy consumption mainly because of the costs and the relation between costs and investment.

From the technological and technical point of view the main issues are related to the physical building of each factory or plant; the reason is that a lot of factories in Europe were built many years ago and during the expansion process of the company a lot of changes related to the layouts and technological issues in each production line have been making, and because of this fact, the control of some process and measurements is lost and sometimes the way to make tasks related to the production process also change and a new beginning and targets need to be set.

About people, is it difficult to make them aware of the energy consumption importance of they argue that they have no time to work, and sometimes lack of knowledge is also another issue.

10. Is there a person in charge of this activity?

Yes	X	No	

For all the headquarters in Europe there is a person in charge of the general program which is now being developed and for each factory and plant there are single person in charge of the detailed information registration needed for analysis and control.

11. Mainly how are the indicators measured?

By production line		By energy source	X	By product	X
By costs	X	By activity		Other, which one?	

12. Is there any documentation of those indicators? Are they controlled? How often the control is made?

Yes	X	No	

The documentation contents general data about the energy consumption, as quantity of energy consumed in each plant, energy costs, etc. and for the analysis the measurements and indicators are unified in the same unit of measurement (Mega joules).

Weekly		Monthly	X	Yearly		Other?	

13. The information obtained from the key performance indicators is used for decision making in some level of the company? (I.e. for strategic planning, for operational/production planning, etc.)

Yes	X	No	

If the answer is affirmative, for which purpose?

The decisions made from this information are mainly related to cost and to reduce the general energy consumption of each factory and plant.
In the strategic planning nothing is based just on energy but the decisions related to the cost and energy issues are made in this level. About the production planning and operational issues this information is not usually used because is not relevant at these

levels, it means, there are other important issues which influence much more the production process.

14. Are there some policies or goals related to the energy consumption in the company? Which ones?

Policies related to energy issues are not established yet into the company. But there are goals and target defined by statistic data as it was mentioned in the question number 8.

15. Has the company implemented new technologies with the purpose of energy intensity improvement?

Yes	X	No	

If the answer is affirmative, in which level/activity/department?
Mainly in the production process but not only related to energy consumption. For example the case of the solar panels where implemented for financial reasons (incentives from the government)

16. In your opinion, could energy consumption´s measurement performance, help the company in saving costs and improving the production process performance?

Yes. Related to the costs, energy performance helps the company to save money because is possible to use less energy, so, the costs are reduced, which is one and the most important reason for the beginning of the creation of a structure energy program in Whirlpool. In terms of production process improvements energy

performance also cans help, but it is expensive, it means, without money you cannot make improvements.

17. Do you consider worthy the implementation of a program in this field?

Yes. Is also important to include energy-related factor in the decision making process and to standardize the common process in each factory, it means, to standardize some aspects in the processes and activities that are common in all factories as painting, energy source used in the tools system (pneumatic, electric..) etc.; with the aim of having better control and of making decisions for continuous improvement in production process.

18. Comments or suggestions

About the energy efficiency program steps proposed in the thesis, the person interviewed considered that the steps are the logic ones and could be useful in the energy efficiency program implementation, but there are a several issues or factors which hinder the implementation of this kind of management program, mainly because it requires financial resources and is time-consuming, and many times top levels of the organization do not consider these investments important or they not consider worth its implementation mainly for the costs.

Regarding to the indicators proposed in step 4, in the case of this company, the indicators that have the driver “net available energy consumption” are not applicable because in order to register this specific data it would required a monitoring process in most parts of the production process in which the input of energy sources are done; and that activity involves many meters that implies more costs and it also needs a responsible person that also consume time, and as it was mentioned before, the energy consumption in terms of production cost is not relevant and do not justified to

make a large investment to get this data if other indicators could be used; but it does not mean that the indicators that have this driver cannot be used in other industries where the cost of energy in relation to production costs is the higher and more relevant such as the aluminum industry.

The other indicators the company are not using now and are proposed in the step 4 of the energy efficiency program in the thesis are considered useful but when the energy-related program is structured within the company.