POLITECNICO DI MILANO

Department of Management, Economics and Industrial Engineering

Implementing an Energy Management System:

Status Evaluation and Concept for Implementing Energy Consumption Data Monitoring Instruments using the example of Knorr-Bremse

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ABSTRACT

In the context of the ever increasing concern about reducing energy costs and environmental impacts, there is an intensification of the importance on Energy Management. The similarity of Quality, Environmental and Energy Management Systems makes possible not starting the implementation of the Energy Management System from the very beginning, allowing the reduction of related costs and efforts. Even having the basis of the previous management systems, the Energy Management System requires particular actions, such as a more detailed energy measuring and monitoring system. This research is aimed to present instruments for helping the implementation of Energy Management System in a company. The analysis is divided in two parts; the first one makes a comparison between the international environmental and energy management standards and presents a tool for assisting the status evaluation of the company regarding an Energy Management System, the second part is a concept, focused on implementing or improving instruments for energy consumption data monitoring.

EXECUTIVE SUMMARY

The concern about the impact of the energy consumption in the environment and the possibility of scarcity of energy resources, together with the potential cost reductions in this area, turns the organizations' attention to the importance of energy efficiency issues.

Energy efficient activities generate the same results using fewer energy resources and to help companies organizing themselves in a way to achieve energy efficiency, several instruments are available nowadays, such as international standards, procedures, guidelines and so on.

This paper is focused in the international standard for energy management, ISO 50001:2009 (draft version) and the European standard EN 16001:2009. The aim is to start introducing an energy management system in an organization.

To fulfil the objectives two steps were developed, first the analysis of the as is situation of the company in respect to an energy management system. Taking into account that companies that already have other management systems ongoing may not have to start the implementation of the energy management system from the zero.

A comparison between environmental and energy management standards was done and from the analysis of the standards and their comparison a checklist was developed. This checklist aims to evaluate the status of the energy management system in a company, and for testing its applicability it was applied in 17 sites from Knorr-Bremse Group, the results obtained with the tool led to the second objective.

In the second part a concept was developed with the intent to assist companies in deciding when to invest in energy consumption monitoring instruments. Since it is hard to manage what cannot be measured and the more accurate the data the better the final results, investment in equipments for metering energy consumption may be required.

Having in mind that the return on investment in metering equipments is hard to estimate and at a first sight they represent only costs, the suggestion is a plan for implementing or improving energy consumption data monitoring schemes that can be gradually and continuously upgraded.

Both instruments the checklist and the plan, help giving a direction for starting the implementation of a management system that may become increasingly demanded in the course of time.

Management System Status Evaluation

The status evaluation of a management system is made to verify if some of the requirements of the new management system, which shall be implemented, were already accomplished. This avoids replicated work and consequently reduces related efforts and costs.

For starting the analysis a research about management systems was done, the literature review embraces the following main topics:

1. Quality Management System and ISO 9001:2008;
2. Environmental Management System and ISO 14001:2006;
3. Energy Management System, EN 16001:2009 and ISO 50001:2009 (draft version);
4. Integrated Management System;
5. Sustainability and international climate policies.

Method and Instrument for Status Verification of an Energy Management System

Analysing the international management standards it was verified that they have more or less the same structure and similar requirements. The most alike were ISO 14001:2008 and ISO 50001:2009 (draft version).

The first step was to make a comparison between the requirements of the environmental and the energy international standards, assuming that with this comparison it is possible to have an overview of the similarities.

The main differences identified are shown blue and orange in Table 1. The requirements in blue represent the slight differences, where it was only done a more detailed description of the requirement, such as in '4.3.1-Environmental aspects' in the environmental standard that was divided into '4.4.2-Energy profile, 4.4.3-Energy baseline and 4.4.4-Energy performance indicators' in the energy standard.

The lines in orange show the new points added into the standard, for example, it is relevant for the ISO 50001:2009 (draft version) to direct a specific attention to the process of buying energy, so it was included as a particular requirement in the standard.

Table 1: Comparison between the international environment and energy standards

Comparison between standards			
	ISO 50001:2011 Energy Management		**ISO 14001:2009 Environmental Management**
4.1	General requirements	4.1	General requirements
4.2	Management Responsibility		
4.2.1	Commitment of top management		
4.2.2	Roles, responsibility and authority	4.4.1	Structure and resposibility
4.3	Energy policy	4.2	Environmental Policy
4.4	Planning	4.3	Planning
4.4.1	General		
4.4.2	Energy profile	4.3.1	Environmental aspects
4.4.3	Energy Baseline		
4.4.4	Energy performance indicators		
4.4.5	Legal and other requirements	4.3.2	Legal and other requirements
4.4.6	Objectives, targets and action plans	4.3.3	Objectives and targets
		4.3.4	Environmental management programme (s)
4.5	Implementation and operation	4.4	Implementation and operation
4.5.1	Competence, training and awareness	4.4.2	Competence, training and awarness
4.5.2	Documentation	4.4.4	Documentation
4.5.2.1	Documentation requirements		
4.5.2.2	Control of documents	4.4.5	Control of documents
4.5.3	Operational control	4.4.6	Operational control
4.5.4	Communication	4.4.3	Communication
4.5.5	Design		
4.5.6	Purchasing energy services, goods and energy		
4.5.6.1	Purchasing of energy services and goods		
4.5.6.2	Purchasing of energy		
		4.4.7	Emergency preparedness and response
4.6	Checking performance	4.5	Checking and corrective action
4.6.1	Monitoring, measurement and analysis	4.5.1	Monitoring and measurement
4.6.2	Evaluation of legal/other compliances		
4.6.3	Internal audit	4.5.4	Environmental management system audit
4.6.4	Nonconformities, corrective, preventive and improvement actions	4.5.2	Nonconformities, corrective and preventive actions
4.6.4.1	Nonconformities		
4.6.4.2	Corrective and preventive actions		
4.6.5	Control of records	4.5.3	Control of records
4.7	Review of the energy mgmt system by top management	4.6	Management review
4.7.1	Inputs to management review		
4.7.2	Outputs from management review		

(blue: slight differences; orange: new inclusions)

The analysis of both international standards and their comparison confirmed that there are some activities carried out in the environmental standard that do not have to be repeated while implementing the energy standard. For instance, the communication's, documentation's and control of records' plan.

From this analysis the checklist represented in Figure 1 was formulated and applied in the sites of Knorr-Bremse, division for Commercial Vehicle Systems.

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Please use 'x' in evaluation box

Status evaluation for the implementation of an Energy Management System according to ISO 50001 draft

LOCATION: *please enter here location name*
DATE: *DD.MM.YYYY*
NAME: *please enter here contact person*

Req. No	Element Requirement / Questions	Evaluation: Not Fulfilled	Evaluation: Partly	Evaluation: Fulfilled	Evaluation: not applicable	Comments to explain the evaluation i.e. evidences	rating score and inter-mediate results (%)
4.1	**General requirements**						0%
1	Has the organization defined an Energy Management System accordingly to ISO 50001?						0
4.2	**Management responsibility (4.2.1/ 4.2.2)**						0%
1	Has the organization defined an energy management representative (energy manager) and defined their roles, responsibilities and authorities?						0
2	Are the specialized skills, human, financial and technological resources necessary for energy management identified and provided by the board?						0
4.3	**Energy policy**						0%
1	Has the board defined in writing a policy, which includes also a commitment to continuous improvement of energy efficiency?						0
2	Does the policy show a commitment to achieve the energy management objectives and to reduce energy related emissions?						0
3	Is the policy available to internal and external public?						0

Figure 1: Part of Checklist created according to ISO 50001:2009 (draft version)

The checklist was sent to all the 17 division’s locations, only one did not answer the checklist (Japan), and the final analysis was done based on the region named ‘Europe + São Paulo’ considered the most likely to start the implementation of an energy management system.

The tool generates a graph as the Figure 2, where it is possible to identify how much from each requirement analysed was fulfilled. Green means fulfilled, orange means partially fulfilled and red stands for not fulfilled. The last column, in blue, indicates the final general score.

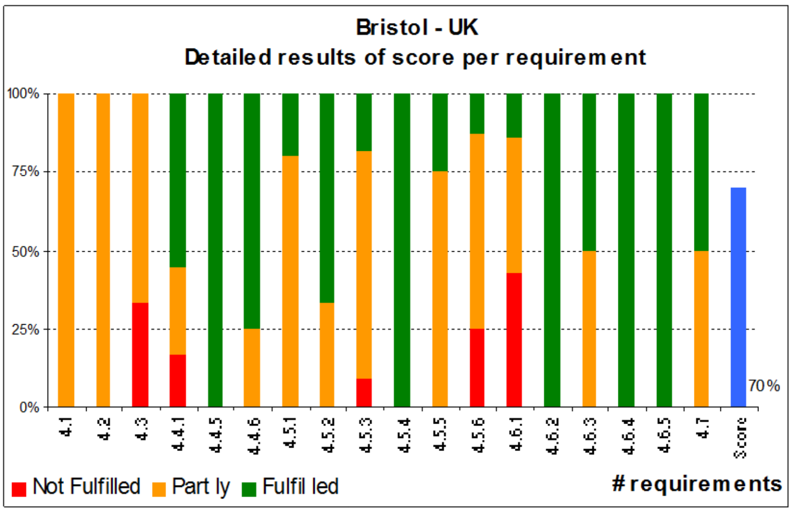

Figure 2: Results per requirement - Bristol

Figure 2 shows the results from the location Bristol (UK), which is already certificated with ISO 14001:2006, and the figure bellow (Figure 3) displays the results from Dalian (China) that does not have ISO 14001:2006 certification.

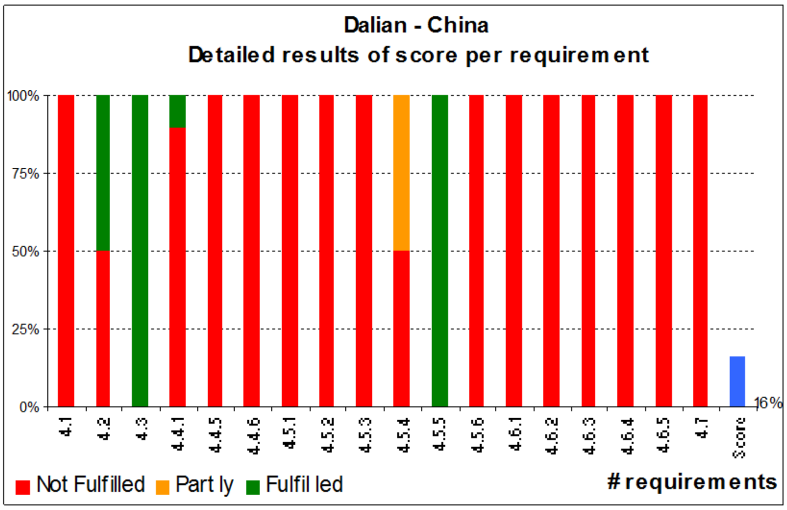

Figure 3: Results per requirement - Dalian

The problem identified in the checklist was related to the interpretation of the questions, different locations had a different view of the purpose of the tool, such as São Paulo, who understood that it should analyse requirements fulfilled by only an energy management system, i.e. they did not assumed the possibility of an integrated management system, where some requirements of other management systems could be used in the energy management system as well, as mentioned before.

Results

Results obtained with the answers from Knorr-Bremse locations (Region Europe + São Paulo) were analysed and three main gaps were identified, in requirements:

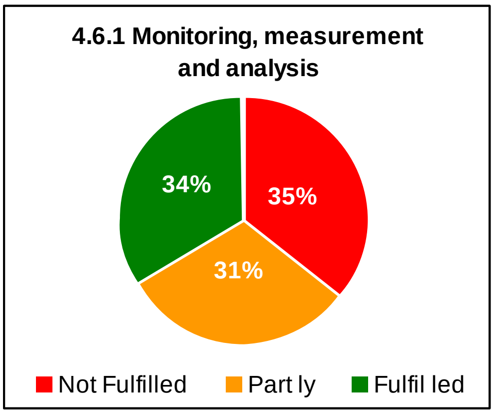

Figure 4: Requirement 4.6.1

- 4.5.6-Purchasing , 43% not fulfilled;
- 4.5.1-Competence, training and awareness, 50% not fulfilled; and
- 4.6.1-Monitoring, measurement and analysis, 35% not fulfilled (Figure 4).

Considering that for improving the results of requirement '4.5.6-Purchasing' the main actions to be taken are related basically to changes in processes and improvements in '4.5.1-Competence, training and awareness' involve mainly the inclusion of energy related issues in the already existing competence and training plans, the decision of developing the next concept was based in requirement '4.6.1-Monitoring, measurement and analysis'.

Even showing the lower percentage, the requirement 4.6.1 represents an important step in implementing a management system, since other decisions also depend on monitoring, measurement and analysis, such as the definition of energy profile, baseline and performance indicators, which also will be the basis for setting objectives, targets and formulating action plans.

Conclusion

The checklist turned out to be an applicable instrument, direct and simple, that does not require much time for answering. Even though some attention should be drawn to the fact that may be different interpretations of the use of the checklist, it still helps to have a general overview about the status of an energy management system inside the organization.

Different interpretations may occur not only in the case mentioned previously (São Paulo), other reasons to misinterpretation can be related to the fact that the checklist will be received by the employees as a control tool, used to investigate if they are doing their work well, this leads to wrong answers, normally driven by fear.

In any case, the checklist is still useful, once having the answers in hands, they can be the basis for further investigations.

Monitoring Measuring and Analysis

Deciding that the further step would be taken regarding the requirement '4.6.1-Monitoring, measurement and analysis', it was identified the lack of energy consumption metering instruments, which can provide more accurate monitoring and analysis.

At this point, the objective became to develop a concept to start the introduction of instruments for energy consumption data monitoring where better suited, or implementing where they already exist but do not provide the desired information.

The literature review of this chapter approached some basic information about energy metering and the identification of energy consumption systems that can be found inside industry. Being aware of how these energy consumption systems work, helps to understand where energy is used inside the industry.

Methodology: Concept for introducing instruments for energy consumption data collection

Aiming a gradually and continuously improvement of the energy consumption monitoring, measuring and analysis, a concept with six steps was proposed to guide the activity, as represented in Figure 4.

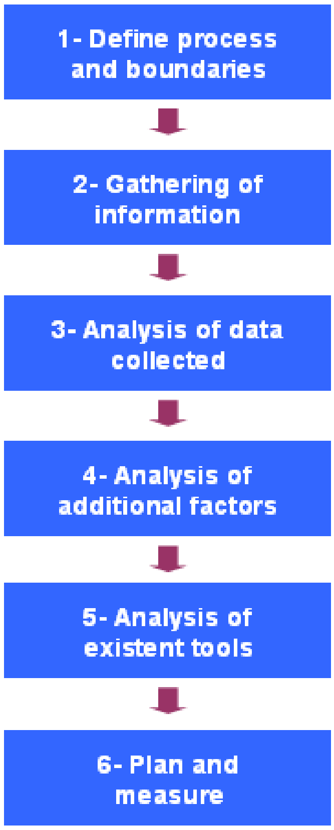

Figure 5: Steps for Implementing an Energy Consumption Monitoring System

In the first step the types of energy input and energy output are defined, as well as the scope (or level of detail). Energy output, in this case, means all sort of energy that is lost in the process, for different reasons, due to leakages or lack of an appropriate reuse system.

Level of detail represents how deep the information will be investigated, for instance if data will relate to the whole production, to the single process line, to the process or to the specific machine, and so on.

Table 2 shows the tool created for assisting in the identification of energy inputs, outputs and level of detail that exist inside a company. Pointing out that energy inputs and outputs may vary from company to company as well as the number of level of detail.

Table 2: Identification of Energy Sources and Consumers

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS														
Location: Date:				Identification of energy inputs/ outputs										
				Energy Input						Energy Output				
				Gas	Electricity	Fuel (oil / coal)	Compressed air	Steam	Water	Electricity	Compressed air	Thermal energy	Steam	Water
Level 1	Level 2	Level 3	(...)											

Step 2 is the gathering of information, that depends on the information available and step 3 is the analysis of data collected, for work in both steps it was formulated the Table 3, where data can be gathered and facilitates its observation.

The 3 first columns of ‘electricity-input’ are dedicated to data analysis that is done with the help of a Pareto Chart. The column of level, frequency, mobility, data collection, focus, history and type indicate characteristics of the instrument used for the data collection. In the output part there are two types of information, if any kind of energy output (loss) is measured (yes/no) and which.

Table 3: Electricity Consumption Analysis

ELECTRICITY CONSUMPTION ANALYSIS															
Location: Date:				Identification of energy inputs/ outputs											
				Electricity - Input										Output	
				Consumption	Percentage	Cumulative percentage	Level	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name of metering equipment	Type of energy output/ loss	Measured (y /n)
Level 1	Level 2	Level 3	(...)												
Production	Assembly	A1													
	Assembly	A2													
	Assembly	A3													
	Assembly	A4													
	Machining	M1													
	Machining	M2													
	Machining	M3													
	Machining	M4													
	Machining	M5													
	Machining	M6													
			TOTAL												

Using the Pareto principle (80-20) the focus of the analysis is established. This focus can still change, after step 4 that verifies the possibility of any anomaly in the energy consumption that even do not representing a large energy consumer, may deserve priority.

The step 5 investigates if there are any instruments for energy consumption data collection, the Table 3 is also useful in this case.

Last part, step 6, is the deployment of a plan for introducing instruments for energy consumption data monitoring, represented in the example of Figure 6.

Plan: Introduction of Instruments for Energy Consumption Data Monitoring					
Reference	Production – Truck				
Action	Study of saving potentials				
Budget (€)	€ 9.533,30				
Resources					
Current situation	No meter, just estimations				
Indicators	(will be defined in phase 6)				
Saving potentials	Main part of this plan				
Approval & completion	Industrial Engineering Manager				
Task	**Priority**	**Responsible**	**Start date**	**End date**	**Comments**
1. Outsourcing or internal	2	Internal	Jan.2010	Jan.2010	
2. Research of suitable equipment	2	To be defined	(...)	(...)	
3. Verification with budget	1	To be defined	(...)	(...)	
4. Identification of saving potentials	1	To be defined	(...)	(...)	
5. Definition of new baselines	1	To be defined	(...)	(...)	
6. Definition of targets	1	To be defined	(...)	(...)	
7. Definition of responsible for achievement of targets	2	To be defined	(...)	(...)	
8. Definition of next phase	1	Industrial Engineering Mgr	Dec.2010	Dec.2010	

Figure 6: São Paulo, Plan to Introduce Instruments for Energy Consumption Data Monitoring

The introduction of instruments for energy consumption data monitoring is not supposed to be a 'one time' activity. The intention is to introduce an activity of continuous improvement.

Test and results

For testing the applicability of the concept, three examples were used. The tool was applied in the site productions of Knorr-Bremse Group, division of Commercial Vehicles Systems, in the locations of Aldersbach (Germany), Bristol (UK) and São Paulo (Brazil).

Different results were achieved. In the case of Aldersbach it was possible to define a plan for each large energy consumer, in the other hand the information handed for Bristol did not allow an accurate verification of the situation, being not possible the Pareto analysis. Considering this, the plan for Bristol was settled in a way to gather better information for further analysis.

São Paulo turned out to be an atypical situation, a new plant is being built and in this case, the plan was established in order to avoid in the new plant the typical anomalies that can occur and cause waste of energy.

Conclusion

The concept developed happens to be applicable and flexible. It can be used not only to plan the installation of instruments for energy consumption data monitoring, but also to continuously improve the monitoring, measurement and analysis of energy consumption data.

General Conclusion

Apart from the conclusions reached applying the tools developed during this work, important benefits for companies while implementing an energy management system, were identified.

The benefits were categorized in three scopes described in Figure 7.

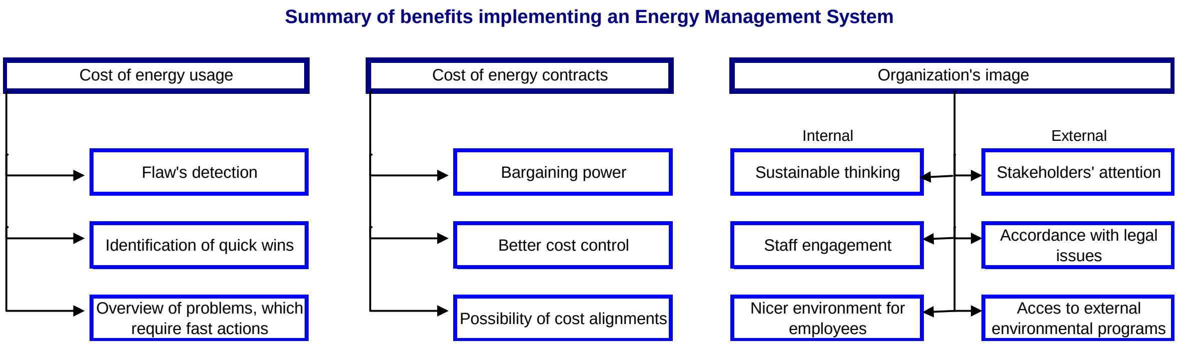

Figure 7: Summary of benefits

The reduction of costs applied to flaw’s detection does not resume only in costs of energy consumption, but also embraces general production costs, for example, the number of scraps generated due failures in the processes.

Despite the necessity of investments and the not easily visible return these investments can bring to an organization, an energy management system still demonstrates to bring significant benefits to a company. Not mention the increasingly significance, which has assumed in industrial scenarios, both to reduce costs and to sustain a positive image before the stakeholders.

Further investigations are suggested, for instance the creation of a concept for analysing purchasing processes and adapt them to the new reality about energy consumption, and also the development of a model to assess cost-benefit of energy metering practices, in order to continuously improve the energy management system.

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FIGURES

TABLES

1 INTRODUCTION

As an economy grows, demand for energy increases. According to the Reference case projection from the International Energy Outlook of 2009 (IEO 2009) it was predicted a rise of 44% in energy consumption between 2006 and 2030, driven by economic growth in developing countries.

The results changed in the forecast of the Reference case projection presented in 2010, showing a rise of 49% in the marketed energy consumption by 2035, increasing mainly in non-OECD[1] countries.

Along with the increase of energy consumption it was also projected a growth of 43% energy-related carbon dioxide emissions. These considerable figures turn everyone's attention to the urgent need to reduce energy consumption, and what was an issue for large energy consumers, has become of interest to all industries, bringing more weight to the subject 'energy efficiency'.

Importance of energy efficiency lies in the fact that it ensures provision of same level of energy using fewer amounts of resources. Due to the rising demand and limited availability of resources, the whole world has become aware of the relevance of energy efficiency, which also helps in reducing energy consumption and costs.

Organizations' concern, related to energy and climate change issues, has growing significantly in the last years, not only because of their impacts in costs and governmental legislations, but also because they are calling the attention of several stakeholders and affecting the company's image.

Companies are resorting to various instruments to guide them to direct their efforts regarding energy issues, among them are national standards and guides.

In the last years, several countries launched their own guidelines with the intent to start changing the critical situation of energy, in Europe the requirements of the European standard EN 16001:2009 have already been applied in several companies.

International Organization for Standardization (ISO) also realized the need for effective energy management and started working in a new international standard, which should come out the beginning of 2011. The standard shall be known as ISO 50001:2011 and can already be found in its draft version, ISO 50001:2009.

This thesis regards the importance of an Energy Management System as a value adding activity, not only as a significant potential to save energy and reduce costs, but also

[1] Organization for Economic Co-operation and Development

because of its role in reducing greenhouse gas (GHG) emissions and other environmental impacts.

1.1 Problem Statement

The current need for companies to improve their processes in terms of energy efficiency, first to be competitive and further to be social responsible and environmentally friendly, conduce to the necessity of implementing actions that lead to proper management of resources, by monitoring, control and verification of the aspects that characterize energy consumption.

Considering the rising costs of energy in industrial processes, the growing concern with the shortage of energy resources and the significant increase of GHG emissions, it was verified the importance of developing an Energy Management System inside a company.

The use of management system as a tool to fulfil these needs, specify the requirements necessary for a company to develop and implement policies and objectives taking into account legal issues and relevant information that have to be considered.

From the urgency to reduce consumption of fossil fuel, GHG emissions and at the same time to promote energy efficiency and the use of renewable energy sources, the International Organization for Standardization started developing the ISO 50001, which will provide management system requirements combined with guidance for use, implementation, measurement and metrics.

For starting guiding the implementation of an Energy Management System it was chosen the international standard ISO 50001:2009 (draft version).

1.2 Objectives

The main objective of this thesis is to give an orientation for starting the implementation of an Energy Management System and it was divided into three specific objectives, first of all the comparison between environmental and energy management standards, taking into account that their similarities can shorten the path and diminish costs in implementing a second standard in organizations that already have applied one of them.

From the ISO 50001:2009 (draft version), develop a status analysis tool, a checklist to verify the fulfilment of ISO 50001:2009 (draft version) requirements by an organization, with the intent to know how far a company is to complete the implementation of an Energy Management System.

Based in the results of the status evaluation (checklist), indentify the gaps or weaknesses in the process and develop a concept or tool to facilitate starting the implementation of the Energy Management System.

The developed tools were tested inside the Knorr-Bremse Group, division for Commercial Vehicles System, in this way the decision about the tool developed to accomplish the third specific objective, is based on the results of the status evaluation of this company.

1. Comparison between international energy and environmental management standards;
2. Status evaluation tool, checklist;
3. Analysis of status evaluation and development of a concept to further implement energy consumption data monitoring instruments.

Even identifying more than one gap in the analysis of the status evaluation, only one is chosen, according to its relevance, to be further exploited in this paper

1.3 Methodologies

The paper was divided in two main parts, Management System Status Evaluation and Monitoring, Measuring and Analysis.

1.3.1 Management System Status Evaluation

In the first part it was developed the comparison between ISO 14001:2004 and ISO 50001:2009 (draft version) using an excel table (see Tables 4 and 5). The table has four columns, being:

1. Item: describing the point compared in that line;
2. ISO 14001:2004 EMS, explaining how the standard works for the Environmental Management System;
3. ISO 50001:2009 (draft version) EnMS, explaining how the standard works for the Energy Management System;
4. Remarks: observations about the comparison made in a specific line.

The column ‘Item’ presents 29 points, most of them based in the requirements of the standards and the others related to its characteristics such as concept, scope, control degree and so on.

After that, a checklist was developed, based on the requirements of ISO 50001:2009 (draft version) and the analysis of the comparison, as observed in the Figure bellow.

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Please use 'x' in evaluation box

Status evaluation for the implementation of an Energy Management System according to ISO 50001 draft

LOCATION: *please enter here location name*
DATE: *DD.MM.YYYY*
NAME: *please enter here contact person*

Req. No	Element Requirement Questions	Evaluation: Not Fulfilled	Evaluation: Partly	Evaluation: Fulfilled	Evaluation: not applicable	Comments to explain the evaluation i.e. evidences	rating score and inter-mediate results (%)
4.1	**General requirements**						0%
1	Has the organization defined an Energy Management System accordingly to ISO 50001?						0
4.2	**Management responsibility (4.2.1/ 4.2.2)**						0%
1	Has the organization defined an energy management representative (energy manager) and defined their roles, responsibilities and authorities?						0
2	Are the specialized skills, human, financial and technological resources necessary for energy management identified and provided by the board?						0
4.3	**Energy policy**						0%
1	Has the board defined in writing a policy, which includes also a commitment to continuous improvement of energy efficiency?						0
2	Does the policy show a commitment to achieve the energy management objectives and to reduce energy related emissions?						0
3	Is the policy available to internal and external public?						0

Figure 8: Part of Checklist created according to ISO 50001:2009 (draft version)

The checklist was tested in 17 different sites of Knorr-Bremse Group, division for Commercial Vehicles Systems, two of them without ISO 14001:2009 certification.

1.3.2 Monitoring, Measuring and Analysis

As a result from the status analysis, the ‘Monitoring, Measuring and Analysis’ was chosen as a critical point deserving further development in this paper, composing the second part.

For this point it was decided to develop a concept, or model, to introduce instruments for energy consumption data monitoring . The model was divided in six parts:

1. Definition of processes and their boundaries;
2. Gathering of information;
3. Analysis of data collected;
4. Analysis of additional factors;
5. Analysis of existing tools; and
6. Plan and measure.

The concept was tested in three different locations: Aldersbach (Germany), São Paulo (Brazil) and Bristol (UK), with the intention to observe its applicability.

1.4 Outline

This academic paper is divided into two main parts, each one with three other subparts, which are literature review, methods and instruments and analysis of results.

The first part is Management System Status Evaluation that makes a comparison between two international management standards and its implementation in the organization. In its literature review subjects related to management systems and international environmental policies are covered.

The second section is Monitoring, Measuring and Analysis and describes a concept for installing or improving energy consumption data monitoring instruments inside the organization. Its literature review describes some energy consumption systems inside an industry and presents some basics for understanding energy monitoring.

The instruments developed in each part of the paper were tested in the real case of Knorr-Bremse Group, division for Commercial Vehicle Systems. Further chapters are introduction, presentation of the company and conclusions.

2 THE COMPANY KNORR-BREMSE GROUP

The Knorr-Bremse Group is the world's leading manufacturer of braking systems for rail and commercial vehicles that has operated in the field for over 100 years.

Other lines of business include automatic door systems for rail vehicles air conditioning systems and torsional vibration dampers for internal combustion engines.

In the fiscal year of 2009, the Knorr-Bremse Group achieved sales of EUR 2.76 billion, in contrast with the EUR 3,38 billion of the previous year. The group employed around 15.000 people in over 60 locations in 25 countries.

The Table below gives an overview about the history of the company.

Table 4: Knorr-Bremse History (Source: Knorr-Bremse website)

Knorr-Bremse History	
1905	Knorr-Bremse GmbH founded in Berlin by Georg Knorr.
1910 **1924**	Development of air brakes for freight trains turns Knorr-Bremse into the largest European brake manufacturer for rail vehicles.
1922	Development of air brakes for commercial vehicles commences
1931 **1939**	The Hildebrand-Knorr (HiK) braking system is used for express trains in 17 countries. 90% of all German trucks in the 7-16 t range are fitted with Knorr breaking systems
1945 **1953**	Development and manufacture of braking systems begins again in the western part of Germany, with the main emphasis on the HiK system. Berlin plant is confiscated after WWII, company headquarters are relocated to Munich.
1985 **1993**	During a difficult phase in the company's development, Heinz Hermann Thiele acquires a majority share in Knorr-Bremse and launches a radical restructuring program and becomes a global player. The AAR DB60 control valve gains Knorr-Bremse access to the North American market.
1996	Series production of pneumatic disc brakes for commercial vehicles begins.
1999	Robert Bosch GmbH merges its activities in the electronic brake control sector with Knorr-Bremse Commercial Vehicle Systems. Knorr-Bremse takes a 60% share, giving it overall managerial control of the joint venture; Bosch retains a 20% share.
2002	Knorr-Bremse takes over from Honeywell International Inc., USA its share of joint ventures in Europe, Brazil and the USA. Bendix Commercial Vehicle Systems becomes a subsidiary of Knorr-Bremse AG. The Knorr-Bremse Group achieves sales of EUR 2.1 billion for the first time.
2005	Centenary of operation.
2008	Joint ventures in the Chinese and Russian markets.

Knorr-Bremse is structure based in two corporate divisions: Commercial Vehicles Systems and Rail Vehicle Systems. Within each division resides a set of Business Units (BU) and these Business Units are divided into Centres of Competence (CoC) and central support functions.

Centres of Competence are departments that cluster a group of product and have their own head of department, purchase and development areas.

The structure leads to a flexible product- and system-oriented approach, the figure below shows the presence of Knorr-Bremse in four different regions.

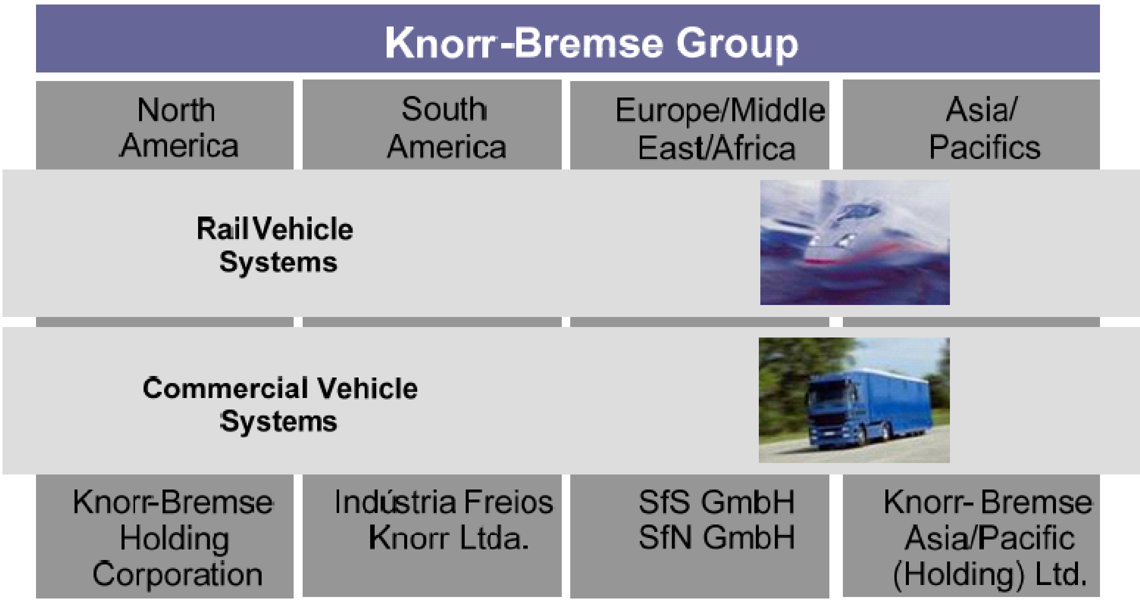

Figure 9: Knorr-Bremse Structure (Source: Knorr-Bremse website)

2.1 Knorr-Bremse Rail Vehicle Systems Division

The division ‘Rail Vehicle Systems’ is formed by the following Competence Centres:

- Hydraulics;
- Brake Control;
- Air Supply;
- Bogie Equipment;
- Platform Screen Doors;
- Toilets; and
- Zelisco, subdivided into three areas:
  - Medium-voltage instrument transformers;
  - Signalling systems for roads and railways; and
  - Traffic management systems for the public traffic.

Apart from the seven CoCs the division has six associated companies:

- Westinghouse: manufacture, installation and maintenance of platform screen systems.
- Merak: specialized in design and production of heating, ventilation and air conditioning equipment for railway vehicles.
- IFE (Innovation for Entrance Systems): manufacturer of Automatic Door Systems for Railway Vehicles.
- Microelettrica Scientifica: electromechanical and electronic components for rail vehicles, traction power and industrial applications.
- Rail Services: maintenance, overhaul and repair of brake systems and on-board systems of rail vehicles. Rail Services provides the ideal tailor made service package for every requirement, whether for freight wagons, tramways, metros or for locomotives and high-speed trains.
- New York Air Brake: is a supplier of innovative train control systems for the American railroad industry.

In the Figure 10 and Figure 11 it is possible to identify the presence of Knorr-Bremse in the rail industry.

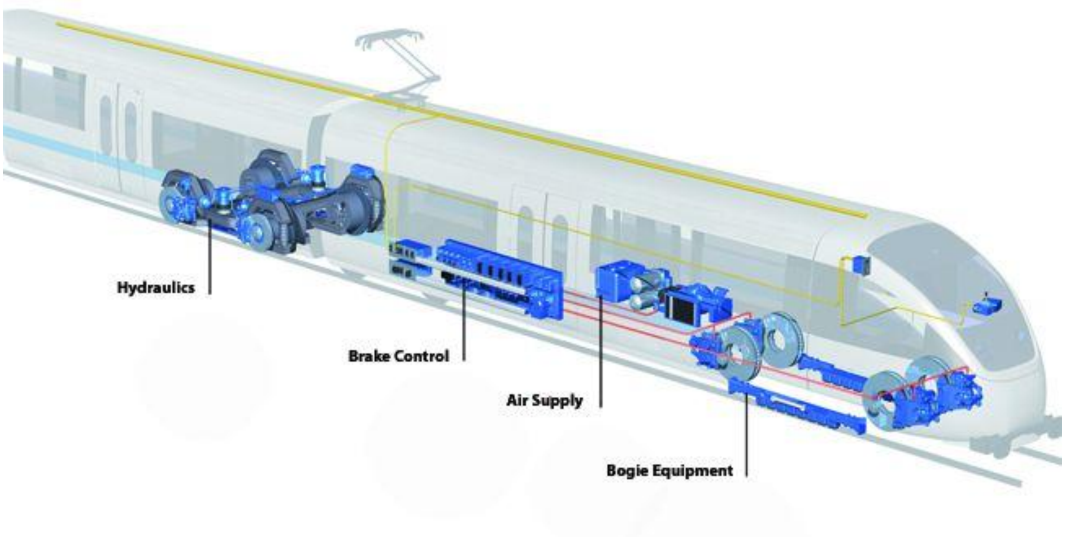

Figure 10: Internal components for train (Source: Knorr-Bremse website)

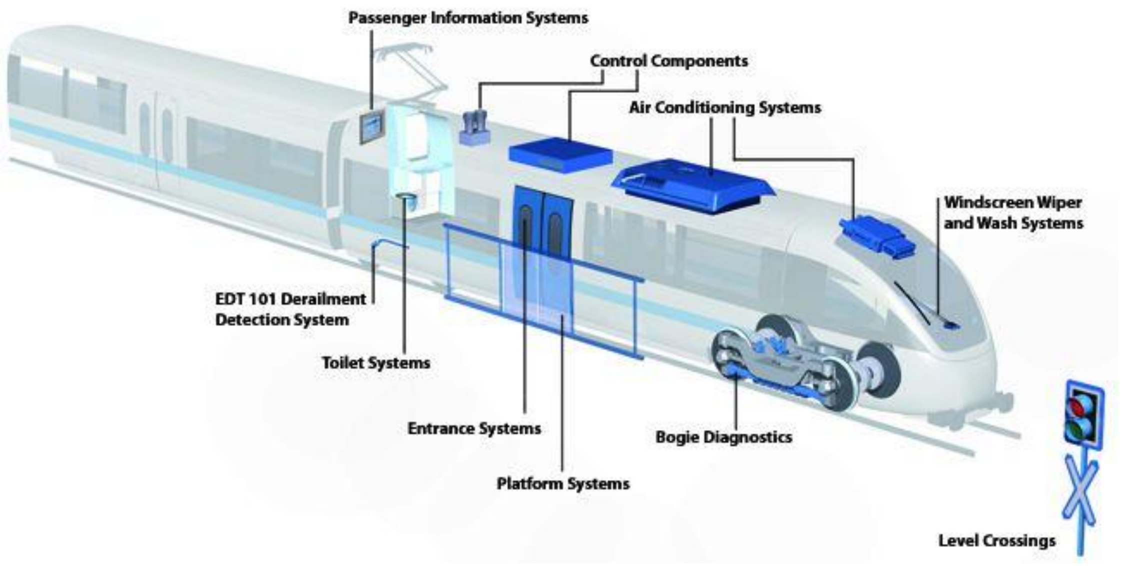

Figure 11: External components for train (Source: Knorr-Bremse website)

2.2 Knorr-Bremse Systems for Commercial Vehicles Division

Knorr-Bremse Commercial Vehicle Systems (CVS) is a leading worldwide supplier of medium and heavy-duty vehicle braking systems, active vehicle safety systems, and other related components. The division is organized as follow:

- BU 1 - Air Supply; comprising the following CoCs:
  - Compressors: compressed air provides the basic ‘energy’ for all commercial vehicle air braking and suspension systems.
  - Dampers: reduce torsional vibrations in crankshafts, camshafts, and injection pumps, prevent noise and thereby guarantee a long and reliable engine performance.
  - Air Treatment: for optimum performance and protection of the pneumatic systems, the compressed air must be dried, regulated and distributed efficiently.
- BU 2 - Brake Control; having the CoCs:
  - Electronic Systems: in braking and suspension systems, electronics can provide not only Antilock functions but full Electronic Braking Systems and Systems to control coupling forces, vehicle stability and suspension levelling.
  - Valves: control the supply of compressed air to the braking actuators and suspension below.
- BU 3 - Wheel Brake; encompasses the CoCs:
  - Drum Brakes.

- Actuators: by utilizing the energy of compressed air or a mechanical spring, Brake Actuators provide the input force to operate the braking mechanisms at each level.
- Disc Brakes: provide a highly efficient means of converting the output force of the Brake Actuator to a braking torque at the wheel.

- Bendix: compressors, valves, ABS, stability systems, driver assistance systems, and industry standard air dryers, total foundation brake coverage through Bendix Spicer Foundation Brake (joint venture with Dana Corporation).
- Hasse & Wrede: develops, manufactures and markets Visco-Dampers for combustion engines for automotive, naval and stationary applications. Visco-Dampers balance out torsional vibrations, preventing crankshaft cracks, and thus ensure safe reliable motor operation.

An example of the products of Knorr-Bremse for the truck industry can be observed in the Figure 12.

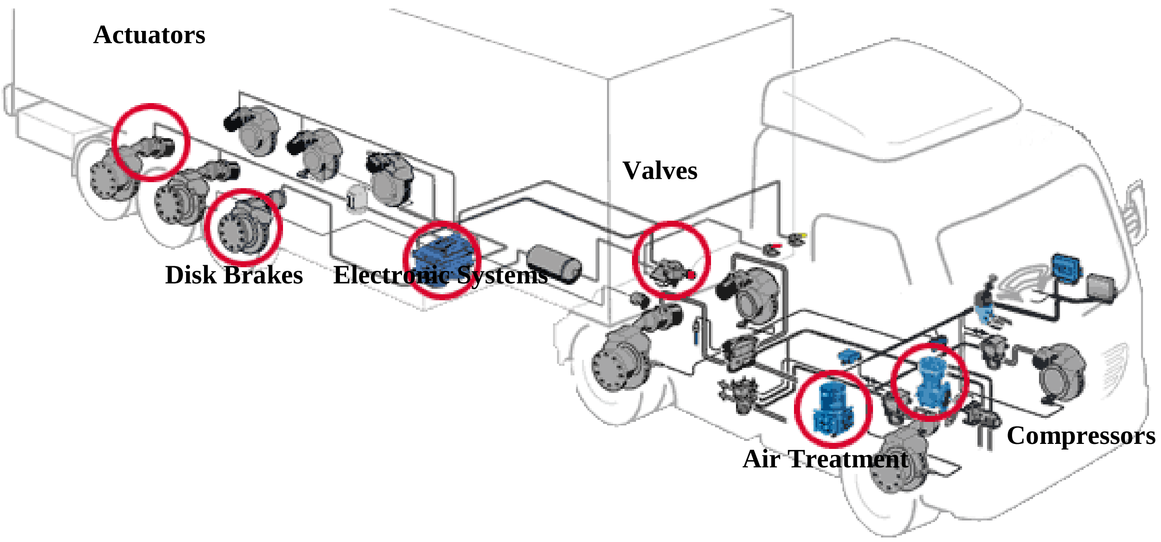

Figure 12: Components for trucks (Source: Knorr-Bremse website)

2.3 Knorr-Bremse Environmental Commitment

Energy is becoming increasingly costly and raw materials ever scarcer, the Knorr-Bremse group started doing its bit by launching in 2009 the ECCO_2 initiative.

The new ECCO_2 project initiative for saving energy and resources is designed to cut costs long-term and to make an important contribution to the environment. Constant improvements in the company's ecological balance sheet and innovative, energy-efficient products will help to secure and strengthen Knorr-Bremse's competitive position.

$ECCO_2$ is an energy- and resource-saving project and stands for Efficient Cut of CO_2; the logo of the initiative is shown in the figure below.

Figure 13: Project logo (Source: Knorr-Bremse intranet)

In the long term, increasing worldwide shortages will make the use of energy and natural resources more critical in environmental terms and more expensive in financial terms. The stakeholders are therefore calling for continuous improvements in the ecological balance sheets of companies. Stricter legislation is expected in several countries in the fields of climate protection, energy management and use of resources.

The easy-to-remember 20/20/20[2] formula, based on the climate targets agreed by the EU at the beginning of 2008, is the basis for the $ECCO_2$ initiative. It is translated inside the company as improving energy efficiency across the group by 20 per cent in order to achieve a 20 per cent reduction in carbon dioxide emissions by 2020. (20 per cent related to data from 2009)

The $ECCO_2$ initiative should be supplemented in the long term by an energy management system, which can be identified as a priority focus because of the significant potential to save energy and reduce greenhouse gas (GHG) emissions.

Summarizing, it is possible to say that the $ECCO_2$ initiative aims:

- To increase the energy efficiency by 20% until 2014 related to 2009;
- To reduce the emissions of CO2 by 20% until 2014 related to 2009;
- To reduce costs;
- To introduce a systematic energy management;
- To raise environmental awareness of all Knorr-Bremse employees.

For achieving this targets, all Knorr-Bremse locations should make a contribution to climate protection, help to contribute to the necessary reduction of costs and strengthen its future competitiveness.

The involvement of all the group's sites and operations around the world and the awareness of the importance of improving energy and resource efficiency, not only benefit the environment, but also contribute to the group's long-term competitive ability.

[2] The EU Clima and Energy Package, European Commission, Jan. 2008

3 MANAGEMENT SYSTEM STATUS EVALUATION

3.1 Literature Review

This literature review starts with a broader view, describing sustainability and climate policies in some countries, since nowadays these subjects are related to energy consumption an greenhouse gas emissions.

In addition, this secion provides an insight of management systems, its roots and some of the standards and tools recognized in Europe and internationally. Management systems are frameworks for managing and continually improving an organization's policies, processes and procedures.

An energy management system has the same intention of the other management systems, however regarding energy consumption issues.

3.1.1 Sustainability

One of the most widely accepted definition for sustainability is that found in the Brundtland Report (UN, 1987): "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

A significant event that marks the first step toward sustainability was the 1972 United Nations Conference on the Human Environment in Stockholm, Sweden. "This global forum began the attempt to find positive links between environmental concerns and economic issues such as development, growth and employment". (Edwards, 2006)

However the emergence of sustainability in its contemporary forms have roots in 1983 in the UN's creation of The World Commission on Environment and Development, headed by Gro Harlem Brundtland, former prime minister of Norway.

Giving sequence to the main events related to sustainability, held in 1992 in Rio de Janeiro, Brazil, the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit.

"Those attending the Earth Summit agreed to the 27 principles on environment and development of the Rio Declaration - which "made it plain that we can no longer think of environment and economic and social development as isolated fields"- and adopted a global program for action on sustainable development through Agenda 21 (…)" (Edwards, 2006)

With the signing of Agenda 21, the international community has committed itself to promote the transition to sustainable development in industrialized and developing countries.

In 1997 the ‘Kyoto Protocol’, named after the Kyoto conference, was signed by several countries. It entered into force in 2005 and expires in 2012. The Kyoto Protocol is a supplement to the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is a part of the negotiation results of the UNCED of 1992. The protocol provides for reducing the GHG emissions of industrialized countries in 5,2% a year, between 2008 and 2012.

At the UN Climate Conference in Copenhagen in 2009 should be found a replacement for the Kyoto Protocol that expires in 2012. Since no regulation could be adopted, the aim is to do this at the UN Climate Change Conference 2010 in Mexico.

The basis of contemporary sustainability, as stated by Edwards (2006), is also known as the Three Es, which are: ecology/environment, economy/employment and equity/equality. The author also suggests a ‘plus one’ adding education in the list. In his opinion, “Through education we gain knowledge with which to overcome the cognitive and normative – and hence emotional – obstacles to understanding our global dilemma.”

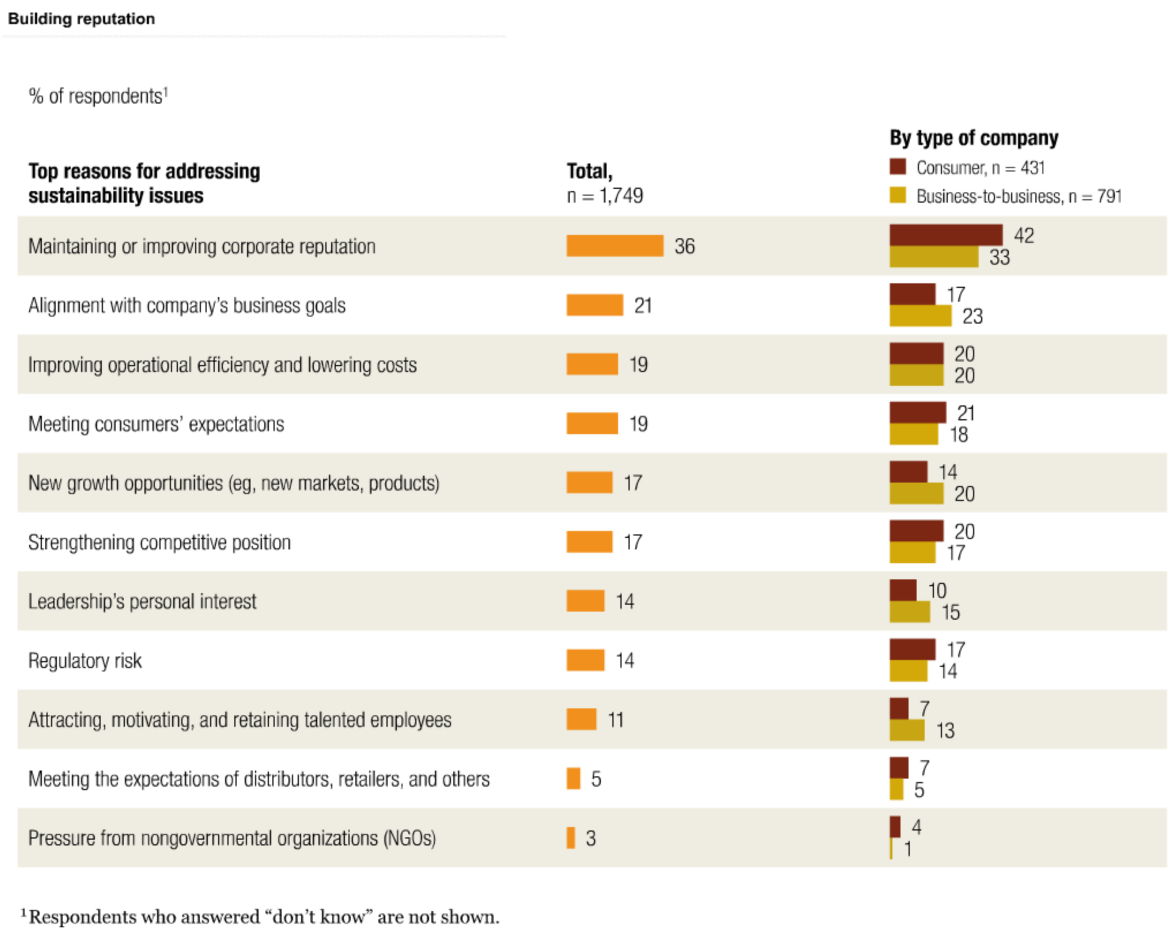

Figure 14: Sustainability (Source: McKinsey)

Sustainability is considered an important issue for an organization. In the research made by McKinsey in 2010 (Figure 14), it is possible to identify the different reasons why companies are investing in sustainability, such as building or managing a corporate reputation or seeking new growth opportunities through sustainable activities.

Inside organizations, in some cases, the concern with sustainability is closely related to the issues of social responsibility.

3.1.1.1 Corporate Social Responsibility

Corporate Social Responsibility is defined by Kotler & Lee (2005) as "… a commitment to improve community well-being through discretionary business practices and contributions of corporate resources".

In other words it is possible to state that Corporate Social Responsibility represents a responsible and sustainable corporate conduct, a voluntary business contribution to sustainable development that goes beyond the legal requirements.

The International Organization for Standardization plans to publish in 2010 a standard providing guideline for social responsibility. It will be identified as ISO 26000:2009 and it will not include requirements, therefore will not be a certification standard.

3.1.1.2 Climate Policies

The chapter about sustainability shows at the beginning the international concern with the environment in general, the following topics give an overview of what has been done by some big players regarding GHG emissions and energy consumption.

3.1.1.2.1 European Climate Policy

In 1995 was written the White Paper "An Energy Policy for the European Union", in which three fundamental goals were defined: competitiveness, security of energy supply and environmental protection, this goals have been replicated in the subsequent years.

For the achievement of the goals, the first step was the submission of the White Paper "Energy for the Future: Renewable Sources of Energy", adopted in November 1997. In that document the European Commission decided for a "… objective of 12% for the contribution by renewable sources of energy to the European Union's gross inland energy consumption by 2010." against a value of 6% from 1995.

This objective was further formalized in the Directive 2001/77/EC, "Promotion of electricity produced form renewable energy sources in the internal electricity market", where reaffirms the non-binding nature of the objective.

After those directives two other important steps were taken, the Directive 2003/30/EC “Promotion of the use of bio fuels or other renewable fuels for transport” and Directive 2003/87/EC “Establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC”.

In 17th December 2008, the European Parliament launched an Energy and Climate Package that proffered ample occasion for discussion.

Overall, the package includes six areas of regulation, including the revision of the Directive 2003/87/EC, this directive defines the European emissions trading for the third trading period (2013 to 2020). As part of the climate package, the Parliament confirmed the EU commitment to reduce GHG emissions by 2020 compared to 1990 at least 20 percent and 30 percent, if another developed countries commit themselves to comparable emission reductions.

The package, adopted in 2009, focuses on three areas: emissions cuts, renewables and energy efficiency, where the overall targets can be summarized in 20% cut in emissions of GHG by 2020, compared with 1990 levels; a 20% increase in the share of renewables in the energy mix; and a 20% cut in energy consumption.

3.1.1.2.2 Chinese Climate Policy

In May 2009, China defined its basic position for climate negotiations in Copenhagen in December 2009. Thereafter industrialized countries, among other things, have to reduce emissions of greenhouse gases by 40% by 2020, with reference to 1990, while developing countries and emerging economies should reduce within their national capacities and needs, as well as sustainable development. The People's Republic of China, which sees itself as a developing country, confirmed this position in August 2009 and declared to reduce its carbon intensity until 2020 in 40 to 45 percent over 2005. This is not an absolute reduction target, as the Chinese government does not want to jeopardize the country's economic growth.

The Chinese market for environmental technologies can reach until 2013 a volume of 500 billion USD to 1,000 billion USD or respectively 15 percent of Chinese gross domestic product. This as a result from “China Greentech Report 2009”, presented for the public by the China Greentech Initiative in 10th September 2009. The report focuses on the areas of energy, energy supply, buildings, transport, industry and water. The China Green Initiative is a consortium of 80 companies, which are leaders in their technological sector.

3.1.1.2.3 Climate Policy in USA

The US House of Representatives approved the energy and climate legislation in 26th June 2009, but a draft for the US Climate Protection Legislation is still being discussed in the US Senate. The presentation of the House of Representatives consists of around 1300 pages and is divided into four chapters (clean energy, energy efficiency, reduction of greenhouse gases and the transition into a clean energy economy).

At the beginning of the UN World Climate Change Conference in Copenhagen, the U.S. Environmental Protection Agency (EPA) declared six greenhouse gases as harmful, including CO2, and announced that a regulation for their emissions is necessary.

EPA can assess the GHG emission through the Clear Air Act of 1990, according the decision of the U.S. Supreme Court in 2007.

This official assessment of EPA is a formal condition that the U.S. government may adopt if necessary, without the consent of the Climate Protection Laws from the U.S. Congress. EPA regulations maybe different than laws, they can be changed, for example, after a change in the government.

The focus of the U.S. government is more on the ongoing legislative procedure with binding reduction targets and a national Emission Trade System.

In the UN Climate Conference in Copenhagen, the USA announced a reduction of 17% of their GHG Emissions until 2020 over 2005, what corresponds to a reduction of 3 to 4 percent over 1990.

3.1.2 Quality Management System

The Quality Management can be considered as a collection of activities that organizations use to direct, control and coordinate quality.

“A Quality Management System is the organizational structure of responsibilities, activities, resources and events that together provide procedures and methods of implementation to ensure the capability of an organization to meet quality requirements.” (Tricker & Lucas, 2005)

The Quality Management System can also be described as a set of tolls, process and procedures that a company applies to ensure that customer satisfaction and quality requirements are met or exceeded. It provides a platform for continual improvement of company performance.

3.1.2.1 Historical Background

The advent of industrialization is considered by different authors as the starting point for quality assurance as a critical step in the production process.

According to Sallis (2002) before the industrialization craftsmen set and maintained their own standards, on which their reputation and livelihoods depended. The start of the mass-production changed the emphasis completely. The individuals were no longer responsible for the manufacturing of the whole product and this, took away from the worker the possibility of self-checking quality.

At this moment, the specialized function of inspection conduced by individuals not directly involved in the production process took the place of the inspection by a skilled craftsman.

Vasconcelos (2004) mentioned that specialization of labour and quality assurance took a giant step forward in the late 1800s, when Frederick Taylor developed his system of scientific management, which emphasized productivity at the expense of quality. Taylor separated the planning from the execution and put the quality assurance in the hands of inspectors.

Graves et al. (1993) identifies the beginning of the modern scientific quality management with the creation of a method for quality control for production, using statistical methods, proposed by Walter A. Shewhart in 1924.

According to Arcaro (1995) Shewhart's work was later developed by Deming, who recognized that a statistically controlled management process gave the manager a newfound capability to systematically determine when to intervene and, equally important, when to leave a process alone.

Arcaro (1995) stated that Deming applied statistical process control methods in the United States during the World War II, achieved successful quality improvements in the manufacture of munitions and other strategically important products.

The Department of Trade and Industry (UK, 2000) points out that the early work of Shewhart, Deming, Dodge and Romig constitutes much of what today comprises the theory of statistical process control (SPC).

After the World War II, Japan decided to make quality improvements to rebuild their economy and required the help of Shewhart, Deming and Juran amongst others. The Japanese developed the ideas of Juran and Deming into what they call Total Quality Control (TQC).

In 1951, the Union of Japanese Scientists and Engineers (JUSE) instituted the Deming Prize to reward individuals and companies who meet stringent criteria for quality management practice.

Vasconcellos (2004) brings up that in the early 1960 the Japanese contribution to quality came from Genichi Taguchi, who developed the Quality Loss Function, and Kaoru Ishikawa, who developed, for example, the cause-and-effect diagram as a device to assist groups or quality circles in quality improvement.

Improvements in Japanese quality were slow and steady, around 20 years passed until the quality of Japanese products exceeded that of Western manufacturers and by the 1970s Japanese companies' penetration into Western markets was significant, mostly as a result of the higher quality levels of their products.

"With the 80s came a radical change. It should not just product quality but also the entire process chain from the supplier are tested up to the customer. This was no longer a purely technical problem, but also a management task, in which many managers and employees were involved.” (Evans, 2008)

Evans (2008) states that as organizations began to integrate quality principles into their management systems, the concept of total quality management (TQM) became popular.

In 1987 the Malcom Baldrige National Quality Award was established in the USA.

Vasconcellos (2004) mentions the award as “…one of the most important factors for the transformation of American business; the award criteria have evolved to become a national standard, providing a framework any organization can use to achieve superior competitiveness.”

In 1988 the presidents of 14 major European companies founded the European Foundation for Quality Management (EFQM). According to Thorpe & Sumner (2004), the idea was to develop an European framework along the lines of the Malcom Baldridge Model in the USA and the Deming Prize in Japan, since these awards have demonstrably improved service and manufacturing quality in the organizations that used them.

Nowadays the Deming Prize, the Malcom Baldridge Model and the EFQM are the most known business excellence models, they provide a stimulus to companies to develop quality improvement initiatives and demonstrate sustainable superior performance in all aspects of the business.

The quality concern in the companies grew from simple control activities, predominant in the 1940s, 1950s, and 1960s, to quality engineering in the 1970s and finally to quality systems in the 1990s, which are taking into account the whole business activity.

3.1.2.2 International Organization for Standardization (ISO)

ISO was established in 1946 from two organizations: the ISA (International Federation of the National Standardizing Associations) and the UNSCC (United Nations Standards Coordinating Committee).

The intention was to create a new international organization, of which the object would be to facilitate the international coordination and unification of industrial standards.

The name ISO, derived from the Greek *isos* (equal), was chosen with the intention to unify the short form of the organization’s name worldwide, since the use of different acronyms would be possible (“IOS” International Organization for Standardization; “OIN” *Organisation Internationale de Normalisation*).

The ISO (2010) states that so far about 8800 standards were created and published. Among them the standards of ISO 9000 family, which are applied in about over 129 countries.

3.1.2.3 ISO 9000 for Quality Management

In May 1987, after seven years of preparatory work, the ISO 9000:1987 was introduced.

In accordance with Hutchins (1997), the ISO 9000 evolved from different existing standards, among them the military quality standard from 1963, MIL-Q 9858A, the NATO quality standard, AQAP 1 and the British quality standard, BS 5750.

ISO 9000 primarily exists to give the customer confidence that the product or service being provided will meet certain specified standards of performance and that the product or service will always be consistent with those standards. (ISO, 2010)

The ISO 9000 family is comprised of the following elements:

ISO 9000:2005 Quality Management Systems – Fundamentals and Vocabulary

ISO 9001:2008 Quality Management Systems – Requirements

ISO 9004:2009 Quality Management System – Guidelines for Performance Improvements

The new model described in ISO 9001:2008 requires a process-oriented approach, as shown in Figure 15.

According to ISO 9000 (clause 2.4), a process approach considers the interaction between process, inputs and outputs that tie the processes together, where the output of one process is often an input to another.

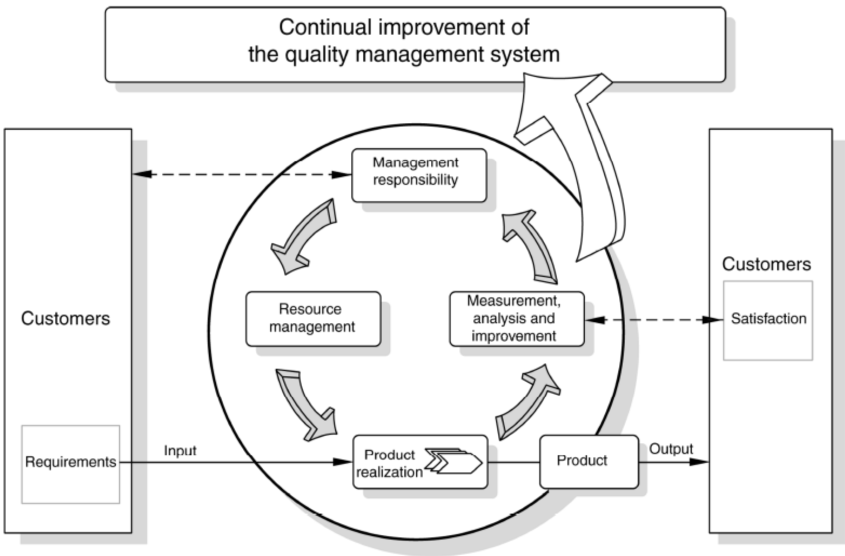

Figure 15: Model of a Process Oriented Quality Management System (Source: ISO9001:2008)

The intention of the ISO 9000 is to promote process approach in the management of a company, however any company can decide to make changes (or exclusions) if, at the end, the operational requirements are met.

Borror (2009) states that the requirements of the Quality Management System are divided into: Management Responsibility, Resource Management, Product Realization and Measurement, Analysis and Improvement.

Ernst (2008) says that the above represented model can be identified as a representation of PCDA Cycle, also known as Deming Cycle.

3.1.2.3.1 Deming Cycle

According to Campbell & Craig (2005) the PDCA cycle, represented in Figure 16, was at first developed by Walter Shewhart, but it was popularized by Edward Deming, who promoted the cycle as an effective continuous improvement tool.

Figure 16: PDCA Cycle (Source: www.jwssolutions.com, 2010)

They refer to the PDCA cycle as a checklist of the fours stages to be addressed in facilitating processes from 'problem facing' to 'problem solving' situations:

- Plan: planning of components of a process, in order to improve the results.
- Do: execution of necessary actions, conform concepts established in the planning phase.
- Check: monitor results, according to pre-defined criteria, to know if the changes are working.
- Act: analysing the gains, if successful or deciding about important changes to improve the process.

When the Act stage is achieved the attention moves again to the Plan stage, giving the PDCA cycle the characteristics of continuous improvement.

3.1.3 Environmental Management System

After the Quality Management System another important and widely used instrument is the management system for an organization's environmental program.

Environment is defined by the International Standards Organization (2010) as the "…surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation".

"Environmental Management should consider the relevant legislation, regulation and standards and should aim at achieving environmental compliance, controlling and reducing pollution and environmental impacts from resource use in industrial operations." (Morvay & Gvozdenac, 2008)

Coglianese & Nash (2001) wrote that the Environmental Management System should consist of a regulatory structure that arises from within an organization and not like public regulations, which impose requirements from the outside.

According to the Institute of Environmental Management and Assessment (IEMA, 2010) an Environmental Management System (EMS) is a structured framework for managing an organization's significant environmental impacts.

The following statements are mentioned as parts of this framework:

- Environmental policy;
- Environmental impact identification;
- Objectives and targets;
- Consultation;
- Operational and emergency procedures;
- Environmental Management Plan;
- Documentation;
- Responsibilities and reporting structure;
- Training;
- Review audits and monitoring compliance;
- Continual improvement.

Pinero (cit. in Harrisson, 2007) stated that environmental management is a broader term that also encompasses the organization's overall culture, commitment, and approach to achieve performance goal.

3.1.3.1 Environmental Management System Standard – ISO 14000

The International Organization for Standardization (ISO, 2004) explains an Environmental Management System as that "... part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy".

For an Environmental Management System to work successfully, several conditions have to be satisfied, Morris (2004) suggests basically the following requirements: the orientation towards prevention of the occurrence instead of merely fault detection, the awareness and engagement of all employees in all levels, the designation of an EMS manager, the evolution and development of environmental management procedures over the time (in technological and regulatory terms) and the necessity of measurement.

These general principles orientating the establishment of an efficient EMS have been developed over a number of years, and national standards, such as the British Standard BS 7750 existed before the publication of ISO 14001 and contained many of the clauses and recommended procedures that are now included in ISO 14001.

"Thus, ISO 14001 has resulted from the international community getting together under a technical committee set up by the International Standards Organization and agreeing a common international standard that now supersedes the earlier national ones." (Morris, 2004)

According to the International Standards Organization (2010):

> "ISO 14001:2004 specifies requirements for an environmental management system to enable an organization to develop and implement policy and objectives which take into account legal requirements and other requirements to which the organization subscribes, and information about significant environmental aspects. It applies to those environmental aspects that the organization identifies as those which it can control and those which it can influence. It does not itself state specific environmental performance criteria."

The ISO 14001 is based, such as the ISO 9001, on the Deming Cycle, i.e. Plan, Do, Check and Act (optimize). This process, represented in the Figure 17, is intended to ensure the continuous improvement of the environmental management system.

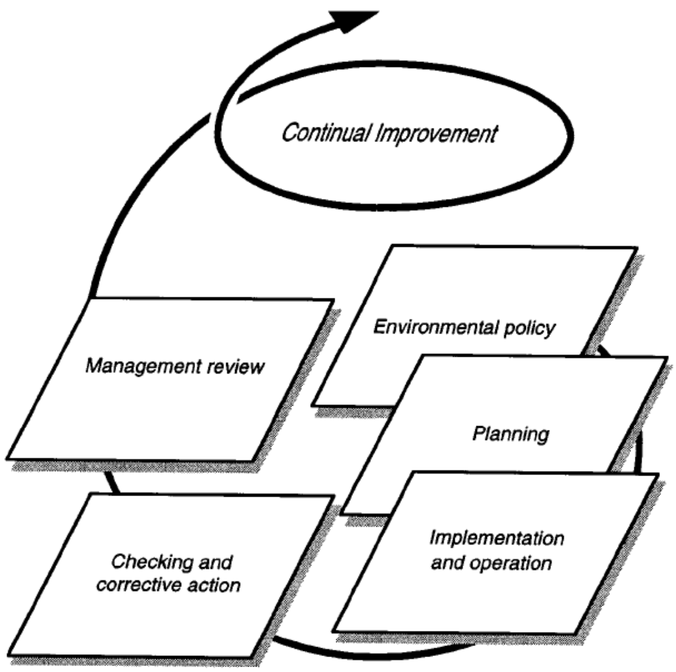

Figure 17: Environmental Management System Model for ISO 14001 (Source: ISO14001:2004)

3.1.3.2 Eco-Management and Audit Schemes (EMAS)

The Eco-Management and Audit Scheme also known as EMAS is a voluntary environmental management tool active since 1995, which allows a better management of environmental issues and credible information on these issues.

This tool aims to help companies and other organizations in evaluating, reporting and improving their environmental performance, focusing the continual improvement.

The core elements of EMAS are:

- Performance: carrying out annual updates of environmental policy targets and actions to implement and evaluate these targets;
- Credibility: third party verification from independent auditors guarantees the value of both actions taken and disclosed information;
- Transparency: environmental statement provides information to the public on environmental impact and performance of the organization.

Organizations operating in all economic sectors and the ones located inside or outside the European Union (EU), the European Economic Association (EEA) and Accession countries can register for EMAS.

To register for EMAS an organization needs:

- Environmental policy;
- Environmental review;
- Environmental management system;
- Environmental audit;
- Environmental statement;
- Registration by competent body and use of EMAS logo (Figure 18).

Figure 18: EMAS logo (Source: European Commission website, 2010)

The benefits identified are cost reductions through better management of resources, risk minimisation, great awareness of regulatory requirements, regulatory relief, improved relations with internal stakeholders due to employee involvement and training, improved relations with external stakeholders leading to an increase of credibility and transparency, and competitive advantage.

The first form of EMAS, known as EMAS I, was based on the idea that the companies are independently responsible for implementing environmental protections and acting sustainably.

In April 2001 the scheme was reviewed, extended and called as EMAS II, the main improvement was the addition of an environmental advisory committee.

In 2009 the EMAS Regulation has been revised and modified for the second time. The new provisions of EMAS III include the improvement of applicability of scheme and the strengthening visibility and outreach of scheme.

EMAS expects more than ISO 14001, it requires more employee participation, more public reporting, more performance improvement, more legal compliance and the final registration by public authority.

When an organization is already ISO 14001:2004 certified, it still needs additional steps for EMAS registration, such as an initial environmental review; an environmental statement based on the data generated by the environmental management system and the validation of the environmental statement and performance.

3.1.4 Energy Management System

Closely related to the Environmental Management System is the Energy Management System, which has become more attention due to the current concern in reducing energy consumption and GHG emissions.

Depending on the use or function, there are different designations for energy, as illustrated in the Figure 19:

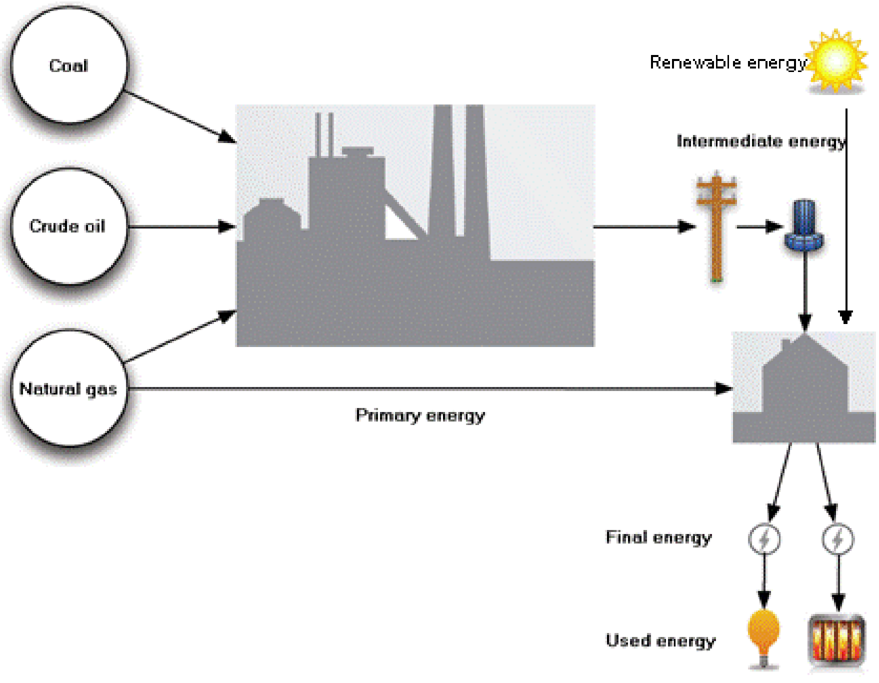

Figure 19: Energy sources

Morvay & Gvozdenac (2008) explain primary energy as all types of energy extracted or captured directly from natural resources, they can be further divided into renewable and non-renewable, as shown in Figure 20. Intermediate energy is primary energy converted into other forms and final energy is the one that consumers buy or receive in order to carry out desired activities.

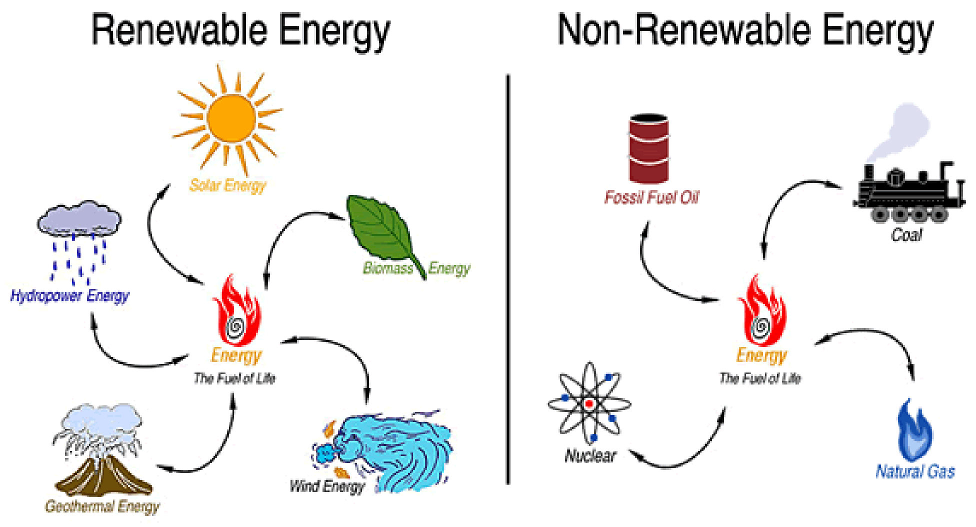

Figure 20: Renewable and Non-renewable energy (Source: www.windy-future.info, 2010)

For some authors, as for Capehart et all. (2008), Energy Management is related to the efficient and effective use of energy to maximize profits and augment competitive position.

Patterson (1996) explains energy efficiency as a generic term, that in general "... refers to using less energy to produce the same amount of services or useful output".

Morvay & Gvozdenac (2008) broadened the definition of Energy Management saying that it is "… concerned with the efficient use of energy, water and other material resources, waste minimization in manufacturing operations and continuous improvement of performance of resources use in a company." The authors said also that "… energy management specifically links and relates energy use to production output, aimed at achieving the required level of output with the minimum use of energy and other resources."

Hence we can define Energy Management System (EnMS) as a framework for the systematic management of energy, in order to enhance energy efficiency, reduce related costs and reduce greenhouse gas emissions.

Nowadays the EN 16001 is recognized in Europe as an Energy Management Standard and the ISO 50001 is being developed as an international Energy Management Standard.

3.1.4.1 European Standard for Energy Management System: EN 16000

The EN 16001 Energy Management Systems was published by the European Committee for Standardization in the summer of 2009.

"The standard aims to help organizations systematically evaluate their energy consumption in order to continuously improve energy efficiency, reduce costs and comply with relevant legislation." (EMAS website, 2010)

The Workpress Law Group (2010) defined the EN 16001 as a framework for the systematic management of energy, a management system standard that demonstrates how to establish the systems and processes necessary to improve energy efficiency across all operations. Published by BSi in the UK the standard potentially enable organizations to make energy cost savings and reduce their greenhouse gas emissions.

The standard has a similar structure as the ISO 14001, as it is possible to identify in the Table 5.

Table 5: Comparison between the requirements of EN 16001:2009 and ISO 14001:2004

Comparison between standards			
	ISO 14001:2004 Environmental		**EN 16001:2009 Energy**
4.1	General requirements	3.1	General requirements
4.2	Environmental Policy	3.2	Energy Policy
4.3	Planning	3.3	Planning
4.3.1	Environmental aspects	3.1.1	Identification and review of energy aspects
4.3.2	Legal and other requirements	3.3.2	Legal obligations and other requirements
4.3.3	Objectives and targets	3.3.3	Energy objectives, targets and programs
4.3.4	Program with responsible, means and time frame		
4.4	Implementation and operation	3.4	Implementation and operation
4.4.1	Structure and responsibility	3.4.1	Resources, roles, responsibilities and authority
4.4.2	Training, awareness and competence	3.4.2	Awareness, training and competence
4.4.3	Communication	3.4.3	Communication
4.4.4	Environmental management system documentation	3.4.4	Energy management system documentation
4.4.5	Document control	3.4.5	Control of documents
4.4.6	Operational Control	3.4.6	Operational Control
4.4.7	Emergency preparedness and response		
4.5	Checking and corrective action	3.5	Checking
4.5.1	Monitoring and measurement	3.5.1	Monitoring and measurement
4.5.2	Nonconformance and corrective and preventive action	3.5.3	Nonconformity, corrective action and preventive action
4.5.3	Records	3.5.4	Control of records
4.5.4	Environmental management system audit	3.5.5	Internal audit of the energy management system
4.6	Management review	3.6	Review of the energy management system by top management
		3.6.1	General
		3.6.2	Inputs to management review
		3.6.3	Outputs from management review

EN stands for *Europäische Norm* or European Standards, which are rules that have been ratified by one of the three institutions: European Committee for Standardization, or *Comité Européen de Normalisation* (CEN), European Committee for Electro-technical Standardization, or *Comité Européen de Normalisation Electrotechnique* (CENELEC) and European Telecommunications Standards Institute (ETSI). All EN Standards are created by a public standardization process.

3.1.4.2 International Standard for Energy Management System: ISO 50001

In February 2008, based on the idea that effective energy management is a priority focus because of the significant potential to save energy and reduce greenhouse gas (GHG) emissions worldwide, the Technical Management Board of ISO approved the establishment of a new project committee to develop the new ISO Management System Standard for Energy. (ISO, 2008)

According to draft version of the ISO 50001 created in 2009:

> "This International Standard (ISO 50001) specifies requirements for an organization to establish, implement, maintain, and improve an energy management system, which enables an organization to take a systematic approach in order to achieve continual improvement of energy performance, energy efficiency, and energy conservation."

As seen in the standards before (ISO 14001:2004 and ISO 9001:2008) the standard for energy management is also based on the Plan-Do-Check-Act continual improvement framework and it is represented as in the following figure:

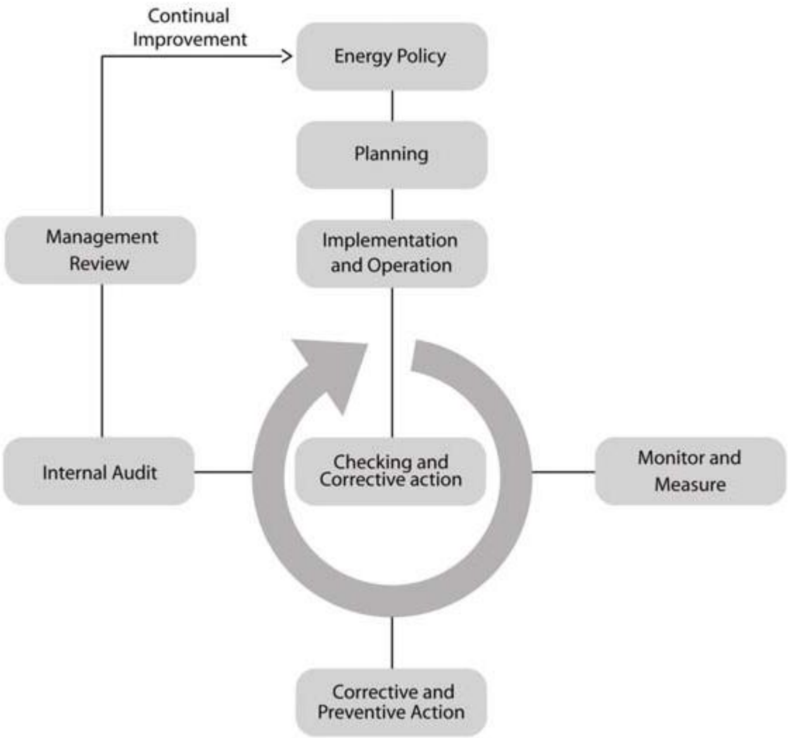

Figure 21: Energy Management System Model (Source: ISO 50001 draft version)

The International Organization for Standardization assures that the document is based on the common elements found in all of ISO's management system standards, this guarantee the high level of compatibility with ISO 9001 and ISO 14001.

According to the International Organization of Standardization, following benefits can be achieved with the implementation of an Energy Management Standard:

- A framework for integrating energy efficiency into management practices;
- Making better use of existing energy-consuming assets;
- Benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reduction in GHG emissions;
- Transparency and communication on the management of energy resources;
- Energy management best practices and good energy management behaviours;
- Evaluating and prioritizing the implementation of new energy-efficiency technologies;
- A framework for promoting energy efficiency throughout the supply chain;
- Energy management improvements in the context of GHG emission reduction projects.

Table 6 shows the comparison between the European and the International Standards for Energy Management.

Table 6: Comparison between the requirements of ISO 50001 and EN 16001

Comparison between standards			
	ISO 50001:2009 Energy Management (draft version)		**EN 16001:2009 Energy Management**
4.1	General requirements	3.1	General requirements
4.2	Management Responsibility	3.4.1	Structure and responsibility
4.2.1	Commitment of top management		
4.2.2	Roles, responsibility and authority		
4.3	Energy policy	3.2	Energy policy
4.4	Planning		
4.4.1	General		
4.4.2	Energy profile	3.3.1	Energy aspects
4.4.3	Energy Baseline	3.3.1	Energy aspects
4.4.4	Energy performance indicators	3.3.1	Energy aspects
4.4.5	Legal and other requirements	3.3.2	Legal and other requirements
4.4.6	Objectives, targets and action plans	3.3.3	Objectives, targets and programme(s)
4.5	Implementation and operation		
4.5.1	Competence, training and awareness	3.4.2	Training, awareness and competence
4.5.2	Documentation	3.4.4	Energy mgmt sys. documentation
4.5.2.1	Documentation requirements	3.4.4	Energy mgmt sys. documentation
4.5.2.2	Control of documents	3.4.5	Document control
4.5.3	Operational control	3.4.6	Operational control
4.5.4	Communication	3.4.3	Communication
4.5.5	Design	3.4.6	Operational control
4.5.6	Purchasing energy services, goods and energy	3.4.6	Operational control
4.5.6.1	Purchasing of energy services and goods	3.4.6	Operational control
4.5.6.2	Purchasing of energy	3.4.6	Operational control
4.6	Checking performance		
4.6.1	Monitoring, measurement and analysis	3.5.1	Monitoring and measurement
4.6.2	Evaluation of legal/other compliances	3.5.2	Evaluation of compliance
4.6.3	Internal audit	3.5.5	Energy management system audit
4.6.4	Nonconformities, corrective, preventive and improvement actions	3.5.3	Non-conf., corrective/preventive action
4.6.4.1	Nonconformities		
4.6.4.2	Corrective and preventive actions		
4.6.5	Control of records	3.5.4	Control of records
4.7	Review of the energy management system by top management	3.6	Energy Management Review
4.7.1	Inputs to management review		
4.7.2	Outputs from management review		

ISO 50001 is expected to be published as an International Standard by early 2011.

3.1.5 Integrated Management Systems

Nowadays organizations have to fulfil different requirements to satisfy the demand of various stakeholders. The business drivers are regulatory, statutory, customer, quality, environmental, IT, health and safety to name but a few, and the list seems to be growing all the time.

Several management systems are developed to comply with the different requirements for those drivers. These management systems, when developed isolated from each other, can end up conflicting, due to the use of different performance indicators, the rework of similar activities, etc.

The optimal solution would be to have only one management system that fits to all the requirements and converges the organization's objectives.

According to the British Standards Institution (2010) an integrated management system incorporates all of an organization's systems and processes into one complete framework, permitting the organization to work as a single unit with unified objectives.

Whitelaw (2004) stated that the integration is concerned with elements of 'compliance of procedures' and "…considers a narrow set of criteria of running a business such as: management responsibilities and accountabilities; business processes; deployment of resources, skills, knowledge and technology".

Figure 22 illustrates the integration of management systems concerning quality management and responsible care.

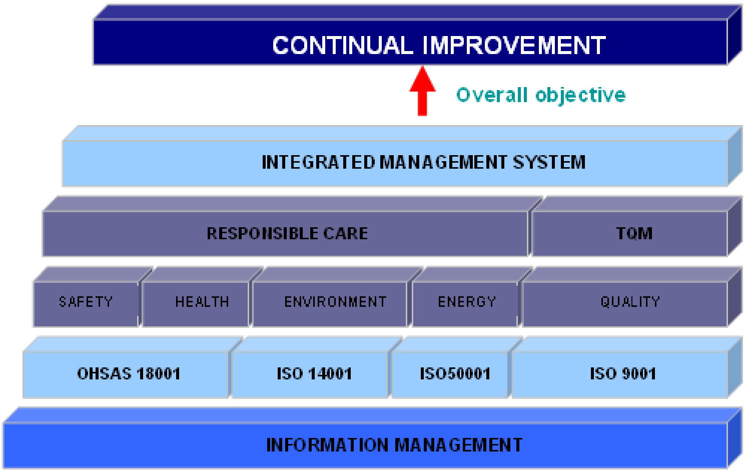

Figure 22: Integrated Management System

Combined management systems should run concurrently with each other and both should be capable of being audited by an external body to a recognized standard. Thus should create less workloads, reduced certification time, costs and documentation.

3.2 Methods and Instruments for Status verification of an Energy Management System

This academic paper started with the study of standards EN 16001:2009 and ISO 50001:2009, given that they are important tools to assist the implementation of an Energy Management System.

After comparing both standards, a checklist was developed, the intention of the checklist is to visualize the status “as is” of the company and have an overview to define the priorities in the implementation of an energy management system.

Taking into account that the objective in implementing an Energy Management System does not only embraces one branch of the organizations and also the fact that the tool has to be useful in all locations from a company, not only Europe, the main basis for the creation of the checklist was the International Standard for Energy Management ISO 50001:2009.

3.2.1 Purpose of developing a checklist

The aim of the checklist is to have a tool to facilitate the evaluation of the current situation of the company with respect to the introduction of an Energy Management System.

It is an instrument that can be easily used by other branches of the organization or even by other companies.

3.2.2 Comparison between International Energy Management and Environmental Management Standards

As seen in the literature review chapter, an Integrated Management system brings several benefits for a company, such as avoiding duplicity of information, costs and data conflict.

The Management Systems that follow the ISO logic have certain requirements in common. Having this idea in mind, this work began with an analysis of the requirements of ISO 14001, EN 16001 and ISO 50001, mainly identifying their similarities, according to Table 7 and Table 8.

Table 7: Comparison between ISO 50001 and ISO 14001 (a)

Item	ISO 14001:2004 - EMS	ISO50001:2008 draft - EnMS	Remarks
Core concept	Environment – it determines relevant requirements based on the "identification of significant external environmental aspects of the production process" which may or may not include issues as delivery and after sales service	Energy - it determines relevant requirements based on "energy consumption of the whole organization/ production process"	
Control scope	Focus mainly on production process. Activities of the suppliers and customers may also be within the control of EMS, but not explicitly required, therefore less applied	"It applies to all factors affecting energy use that can be monitored and influenced by the organization". Energy supply, procurement and design practices for energy-using equipment, system and processes are within the control scope.	
Control objects	Environmental targets which are mainly related to the EMS objectives, which requires the consideration of environmental aspects, relevant laws and regulations and other mandatory requirements	Energy performance and consumption targets which should be determined by the organization's policy and objectives, and by the requirements of laws and regulations, where relevant	
Control degree	"Absolute" control but without the "concession" option	"Relative" control. It pays more attention on continual improvement of energy performance, energy conservation practices and energy efficiency	
Application scope	is widely used in raw material and production sectors. In general the software and service industry have less environmental impact	Expected to be widely used in production, raw materials and services sectors. According with ISO, ISO 50001 could potential impact 60% of global energy consumption	
Management performance	The performance is mainly seen from the "conformity", namely whether the emission targets conform to the specified requirements	The performance is related to conformity with requirements, continual identification and implementation of energy performance improvement interventions, measured by means of quantitative comparison against an organization's baseline	
Management responsibility (4.2)		Definition of an Energy Manager	Mainly about commitment and support of Top Management. The HSE Manager can include in its responsibilities the energy issues, for that he/she has to have the appropriate skills, time and their responsibility has to be defined and communicated
Policy (4.3)	The organization's significant environmental impacts together with applicable legal and regulatory requirements are the main concern	The organization striving for profits, reduced production costs, enhanced competitiveness combined with relevant law and regulation requirements, where relevant, will be the main concern	There is no need of a policy only for energy, the energy policy may be combined into another already existent
Planning (4.4.1 to 4.4.6)	To identify environmental aspects, requirements of relevant laws and regulations. Then to establish the environmental objectives, targets and programmes	To develop an energy profile, identify significant energy uses, define an energy baseline and energy performance indicators. Identify applicable laws and regulations, and then establish objectives, targets and action plans	It requires efforts identifying detailed information about energy consumption, since in the environmental management system the information about energy consumption is roughly analyzed
Baseline (4.4.3)	No specific requirement beyond continual improvement	The establishment of an organization's energy baseline is a fundamental element of the EnMS, since "Changes in energy performance shall be measured against the energy baseline"	Specific for EnMS
Objectives and targets (4.4.6)	Environmental objectives and targets are either related to an organization's significant environmental impacts or to "external mandatory requirements" set mainly by relevant laws and regulations	Energy objectives and targets are primarily "internal management objectives", mixed with "external requirements" where laws and regulations may apply (i.e. greenhouse gas reduction targets for large emitters)	More detailed information for Energy
Competence, training and awareness (4.5.1)	General training plan	General training plan	Information about energy use has to be included in training plans
Documentation (4.5.2)	Define how to keep the documents	Define how to keep the documents	It can follow the same logic
Operational Control (4.5.3)	Identification and planning of activities that have any environmental impact	Identification and planning of activities that impact in the energy consumption	It is necessary to review activities and processes to ensure that energy consumption is taken in consideration
Communication (4.5.4)	Communication procedure	Communication procedure	It can follow the same logic
Design (4.5.5)	Design control is not included as a separate clause. The production process, which sets the design specifications, is indeed related to the environmental aspects. The focus is therefore mainly on "production processes"	Design is part of ISO 50001 Implementation & Operation, "..consider energy performance improvement opportunities in the design, modification and renovation of significant energy consuming facilities, equipment, systems and processes"	New in energy management

Table 8: Comparison between ISO 50001 and ISO 14001 (b)

Item	ISO 14001:2004 - EMS	ISO50001:2008 draft - EnMS	Remarks
Purchasing (4.5.6)	Purchase control is not included as separate sub-clause, but is mentioned under operational control	It includes separate sub-clauses for the purchasing of energy services and goods and purchasing of energy (the applicability of the latter is subject to the specificities of the market in which an organization operates)	New in energy management
Monitoring and Measurement (4.6.1)	It should monitor & measure key "process characteristics" that are related to identified significant environmental impacts, and consequently objectives and targets	It requires to monitor, measure and analyze the key characteristics of an organization's operations that determine energy performance. Key characteristics include also effectiveness of actions plans in achieving objectives and targets	It may be necessary to improve monitoring and measuring methods
Evaluation of legal and other compliances (4.6.2)	Plan to evaluate legal and other compliances at determined intervals	Plan to evaluate legal and other compliances at determined intervals	It can follow the same logic
Internal Audit (4.6.3)	Internal audit procedure	Internal audit procedure	A new audit procedure has to be designed, since different aspects are going to be audited
Nonconformities, corrective, preventive and improvement actions (4.6.4)	Procedures for dealing with nonconformities	Procedures for dealing with nonconformities	It can follow the same logic
Control of records (4.6.5)	Maintenance of records	Maintenance of records	It can follow the same logic
Management Review (4.7)	Review from top management at planned intervals	Review from top management at planned intervals	It can follow the same logic
Implementation		ISO 50001 is based on the same Plan-Do-Check-Act approach of ISO 9001 and ISO 14001 and it draws extensively on the structure and content of the QMS and EMS.	
I: Laws and regulations	The 'legal-drive' for implementation is comparatively strong. However, ISO 14000 family standards are voluntary standards and they do not substitute the control to be exerted from authorities related to legal compliance	The company's bottom line will be the primary driver for implementation. However, regulatory or agreed requirements may become relevant as part of a country's policies and/or obligations towards the achievement of energy security and/or Climate Change mitigation	
I: Benefit and management performance	Implementation of EMS can bring direct economic benefits through resource savings and cleaner production, latter saving the costs of regulated "clean-up". The "instant" achievement of EMS can be made evident by monitoring of environmental indexes	Implementation of EnMS brings direct economic benefits in the form of reduced energy costs originating entirely within an organization's fence. EnMS' achievements can be measured by the energy performance indicators.	
I: Market drive	The market drive (i.e. customers demand and supply chain) is playing an increasingly important role in motivating companies to implement EMS	Currently the market drive has primarily the form of rising and volatile energy cost. Other market drivers may result from the establishment of policy-driven mechanisms (i.e. govt. procurement rules, white certificates, GHG emission reduction targets, etc.) or customers demand	
I: Certification program support	Certification is also an important way to promote EMS	Whether certification will play an important role in promoting implementation of ISO 50001 is likely to depend on the strength of the energy-cost-reduction thrust, the market drivers that may arise, the policy requirements and support that could be established	
I: Technical support	It also employs typical management technologies & methods as backup. In addition, specific control technologies and methods targeting special industrial sectors are very important to EMS	It will employ specific technologies and management methods as backup, such as energy audits. But Best Practice Guides on the application of energy conservation technologies & methods in specific industrial sectors will prominently boost wide-spread implementation of EnMS.	

From this comparison, a checklist was developed to verify which of the requirements were already accomplished by the organization, i. e., a gap analysis to show how far the company is from an Energy Management System implementation.

3.2.3 Checklist for gap analysis of an Energy Management System

The development of the checklist was mainly based on the draft version of the ISO 50001:2009, questions were formulated from the requirements of the standards and they were grouped into the following points:

	Requirements ISO 50001:2009 (draft version)
4.1	General requirements
4.2	Management responsibility (incl. 4.2.1/ 4.2.2)
4.3	Energy policy
4.4.1	Energy profile/ Baseline/ Energy Performance Indicators (incl. 4.4.2/ 4.4.3/ 4.4.4)
4.4.5	Legal obligations and other requirements
4.4.6	Objectives, targets and action plans
4.5.1	Competence, training and awareness
4.5.2	Documentation (incl. 4.5.2.1/4.5.2.2)
4.5.3	Operational control
4.5.4	Communication
4.5.5	Design
4.5.6	Purchasing (incl. 4.5.6.1/ 4.5.6.2)
4.6.1	Monitoring, measurement and analysis
4.6.2	Evaluation of legal/ other compliances
4.6.3	Internal audit
4.6.4	Nonconformities, corrective, preventive and improvement actions (incl. 4.6.4.1/ 4.6.4.2)
4.6.5	Control of records
4.7	Energy Management Review (incl. 4.7.1/ 4.7.2)

For each question it was possible to choose one of the options: not fulfilled, partially fulfilled, fulfilled and not applicable, simply filling the space with an X.

The Figure 23 shows a part of the checklist for “Status evaluation for the implementation of an Energy Management System according to ISO 50001:2009 (draft version)”, the complete list can be found in Appendix I.

KNORR-BREMSE
Systeme für Nutzfahrzeuge

Please use 'x' in evaluation box

Status evaluation for the implementation of an Energy Management System according to ISO 50001 draft

LOCATION: *please enter here location name*
DATE: *DD.MM.YYYY*
NAME: *please enter here contact person*

Req. No	Element Requirement	Questions	Evaluation: Not Fulfilled	Evaluation: Part ly	Evaluation: Fulfil led	Evaluation: not applicable	Comments to explain the evaluation i.e. evidences	rating score and inter-mediate results (%)
4.1	**General requirements**							0%
1	Has the organization defined an Energy Management System accordingly to ISO 50001?							0
4.2	**Management responsibility (4.2.1/ 4.2.2)**							0%
1	Has the organization defined an energy management representative (energy manager) and defined their roles, responsibilities and authorities?							0
2	Are the specialized skills, human, financial and technological resources necessary for energy management identified and provided by the board?							0
4.3	**Energy policy**							0%
1	Has the board defined in writing a policy, which includes also a commitment to continuous improvement of energy efficiency?							0
2	Does the policy show a commitment to achieve the energy management objectives and to reduce energy related emissions?							0
3	Is the policy available to internal and external public?							0

Figure 23: Part of Checklist created according to ISO 50001:2009 (draft version)

For a further analysis, it was included a field for comments and evidences, to know the reasons for the status of each requirement.

In the superior corner on the right side of the checklist, it was included a notice displaying its status.

If the checklist is totally blank appears the sentence “Please use ‘x’ in evaluation box”. After starting answering the completion the information changes to “Not all questions answered! Please complete!”. Once completed it shows “Completed! Thank you!” and in case of more than one answer for each question, the document is considered not correct “Completion not correct. Please check!”

By answering the questions a graph is obtained, this graph can be used for gathering two kinds of information. The columns in green, red and yellow show which percentage of each requirement is fulfilled, partially fulfilled or not fulfilled and the blue column allows the comparison of the results between different location, providing a general percentage, as in the example in the Figure 24.

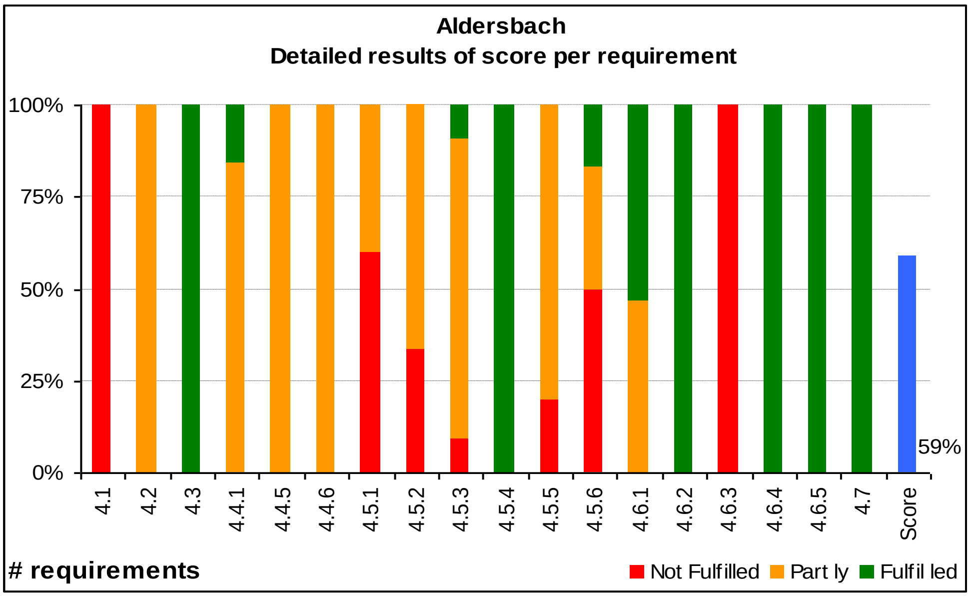

Figure 24: Example – Results of requirements per location (ALD)

In other words, the red, yellow and green columns show how far the specific location is from completing each requirement and the blue column shows the score for the implementation of an Energy Management System.

In the blue column, in order to differentiate the importance of fulfilled, partially fulfilled and not fulfilled requirements, the following score were given for each of the possible answers:

- Fulfilled – 1 point;
- Partially – 0,50 points;
- Not fulfilled – 0 points;
- Not applicable – when crossed, eliminate that question from the calculation of the final percentage.

This checklist was sent to the 17 locations of Knorr-Bremse CVS, with the results it was defined that this paper would focus on the point 4.6.1 of the standard - Monitoring, Measuring and Analysis - more specifically Metering Equipments.

The focus on requirement 4.6.1-Monitoring, Measuring and Analysis was chosen according to the final results obtained applying the checklist in the Knorr-Bremse (Region Europe + São Paulo), it turned out to be one of the more relevant gaps identified, the outcome can be seen in the next section, the analysis of results.

Graphs showing the results received from the locations can be found in the Appendix II.

3.3 Analysis of results from Checklist

The checklist was sent to the locations of Knorr-Bremse CVS represented in the list below, from those, only India and China have not implemented ISO 14001:2009 yet.

Table 9: Locations of Knorr-Bremse CVS

	Region Europe + SAO		
1	Brazil	São Paulo	SAO
1	Czech Republic	Liberec	LIB
1	France	Lisieux	LIS
1	Germany	Aldersbach	ALD
1	Germany	Berlin	BER
1	Germany	Schwieberdingen	STR
1	Hungary	Budapest	BUD
1	Hungary	Kecskemét	KEC
1	Italy	Arcore	ARC
1	United Kingdon	Bristol	BRI
	Region Asia		
2	China	Dalian	DAL
2	India	Pune	PUN
2	Japan	Tokyo	TKY
	Region North America - Bendix		
3	Mexico	Acuña	Bendix
3	USA	Bowling Green (Kentucky)	Bendix
3	USA	Elyria (Ohio)	Bendix
3	USA	Huntington (Indiana)	Bendix

The intention of the checklist was to compare the "as is" situation of each location with the requirements of ISO 50001:2009 (draft version) and identify the possible gaps that would need more attention in the implementation of an Energy Management System.

To exemplify how the checklist works and its analysis can be done, some results were chosen, such as in the Figure 25 that shows the results for the location Bristol (UK):

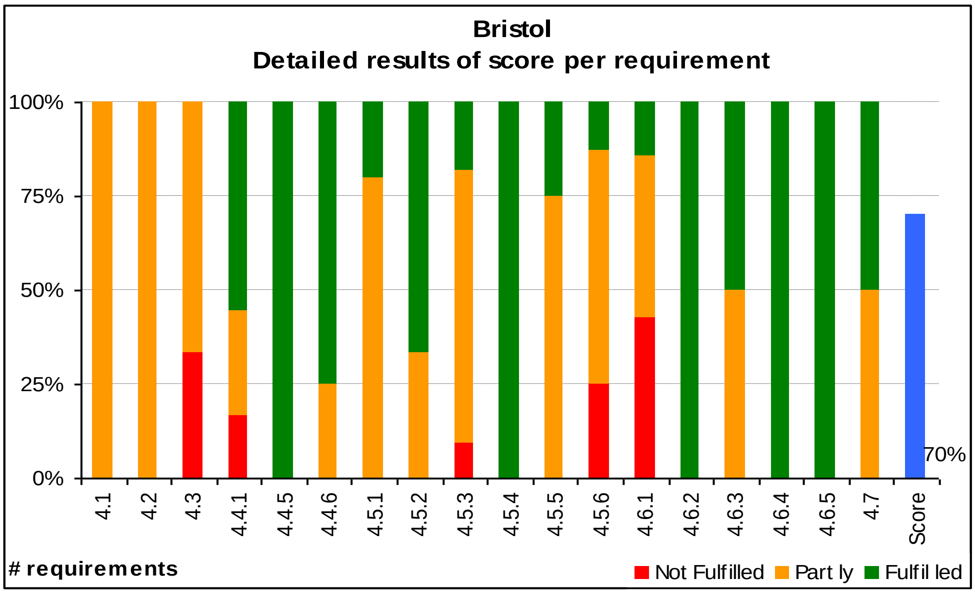

Figure 25: Results per requirement - Bristol

This graph shows that the location Bristol is doing very well in preparing for an Energy Management System, having a final score of 70%.

The requirements represented by the bars in 100 percent green (4.4.5-legal obligation and other requirements, 4.5.4-communication, 4.6.2-evaluation of legal and other compliances and 4.6.5-control of records), can be directly related to the requirements of ISO 14001:2009, as can be observed in Table 7 and Table 8.

In the other bars is possible to identify characteristics closely related to energy, in which the organization is still working.

The requirement that shows the greatest percentage in red refers to monitoring, measurement and analysis. Observing more carefully the questions elaborated for this point, it is possible to identify the absence of appropriate equipments for measuring energy consumption, since 5 from 6 questions not fulfilled in this area, are about metering equipments.

In a further analysis, the figures below shows how the field dedicated to comments and evidences helped to understand the answers:

4.3	Energy policy	Not	Partly	Yes	N/A	Comments	33%
1	Has the board defined in writing a policy, which includes also a commitment to continuous improvement of energy efficiency?		X			No energy policy known. However, some related elements in the HSE policy	0,5

Figure 26: Field for comments and evidences (a)

In this case, there is no policy set specifically for an Energy Management System, but the Environmental Policy recognizes the significance of sustainable use of energy.

It is a matter of interpretation, it shows that this location knows about the policy and the standard, because the standard says that it is not necessary to have an specific policy for the Energy Management System: “If there are other policies in place within the organization, the energy policy may be combined into one of them or it could be maintained as a separate policy." (ISO 50001:2009 – draft version, A.3 Energy Policy)

The box below shows the identification of similarities with ISO 14001:2009, as appointed before, which also justifies the implementation of an integrated management system.

4.4.5	Legal obligations and other requirements	Not	Partly	Yes	N/A	Comments	100%
1	Does a procedure exist in order to identify current applicable legal obligations and other requirements related to energy usage/consumption on site?			X		Same process as for Environmental Legislation	1

Figure 27: Field for comments and evidences (b)

The following figure is an example of not applicable, where the location does not develop the related activity.

4.5.5	Design	Not	Partly	Yes	N/A	Comments	63%
1	Is there any guideline/procedure that takes into account the energy efficiency when designing/ modifying a new plant/ building?				X	Do not have design responsibility for new products in Bristol	0

Figure 28: Field for comments and evidences (c)

It was also possible to identify the locations that could not understand the purpose or meaning of the questions, in these situations the locations were contacted again, this time by telephone. It was explained once more the importance of the checklist and the possible similarities from ISO 50001:2009 (draft version) and ISO 14001:2009.

In this way, after contacting the location and better explaining the intention and importance of the checklist, they had the chance to complete the checklist one more time, correcting the answers.

The locations were divided into 3 regions: Europe + São Paulo, Asia and America (Bendix) and the information were further analysed, first each requirement was compared per location (e.g.: Figure 29), then an overview of the results was presented.

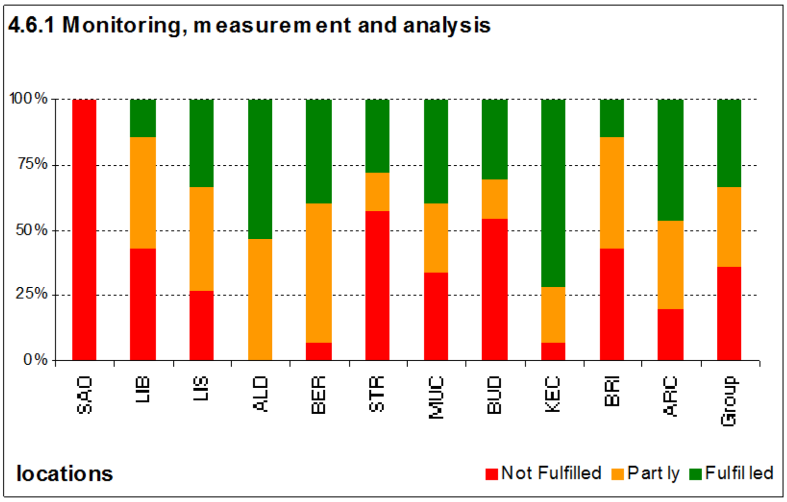

Figure 29: Results per location – Requirement 4.6.1

The Appendix IX presents a graph with the results of the three groups per requirement analysed.

In the group overview per requirement is easier to identify the weaknesses and strengths in the Energy Management, the following graphs represent the results from 'Europe + São Paulo' region. For this analysis there were considered the requirements that deserve a closely attention in terms of energy management, that means, they can not be fulfilled only with the requirements of ISO 14001:2009.

For example, the requirement '4.5.4-Communication' demand the development of a communication procedure, if there is already a communication procedure created for another management system previously installed in the company, this procedure can also be used for the new energy managment system, sometimes just with slight modifications.

This decision was taken based in the assumption that less general requirements demand more efforts and generate more costs, thus deserving more attention.

Energy profile, energy baseline and energy performance indicators are important parts from the planning part in the PDCA cycle (plan, do, check, act).

According to the standard, the aim of an energy profile is to understand the areas of significant energy consumption and considerable potential energy savings, so that the efforts can be prioritized. The energy baseline is the initial profile that will be used in comparisons, it is the starting point for measuring and the energy performance indicators are used to compare and analyse the performance in different points of time.

There are considerable information for monitoring and assessing results and analysing how the company is doing, whether the activities are being effective.

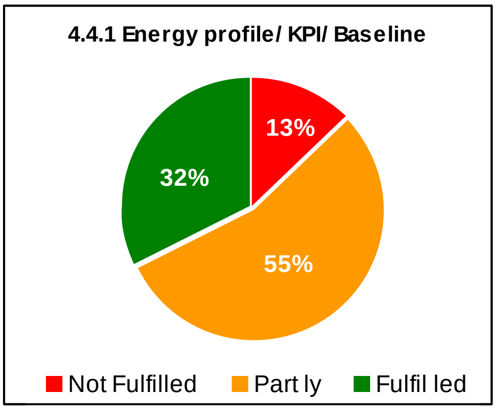

Figure 30: Requirement 4.4.1

The locations considered the general key performance indicators and baselines established for energy consumption, there is still the need of working in more detailed performance indicators, such as consumption per equipment, per line, and so on.

Objectives, targets and action plan show the direction the organization have to take to improve energy performance, in other words, there are the means to transform the policy into action.

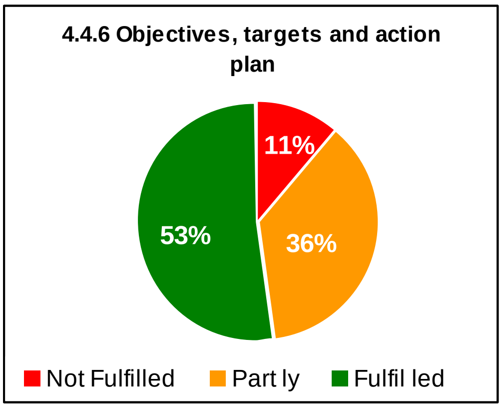

Figure 31: Requirement 4.4.6

The Figure 31 shows that even without a complete Energy Management System the organization has good results in 'objectives, targets and action plan'.

The 53 percent of fulfilled points results from the ECCO$_2$ initiative, as it is confirmed in the answers given by the example below.

4.4.6	Objectives, targets and action plans	Not	Partly	Yes	N/A	Comments	88%
1	Has the organization defined an objective related to consumption of energy; eg. increasing of energy efficiency?			X		Energy Consumption Ratio is monitored against predefined targets on monthly basis	1
2	Are specific and measurable targets, and related specific indicators, defined for significant energy usages?		X			Average PF, compressors duty cycle etc. are monitored on monthly basis	0,5
3	Has the organisation defined an action plan for achieving objectives and targets?			X		ECCO2 project action plan is prepared	1
4	Has the organization put in documented action plans, the responsabilities, times and means for their achievement?			X		ECCO2 project action plan is prepared	1

Figure 32: Field for comments and evidences (d)

In general a local training plan already exists, nevertheless it was considered as a requirement closely related to energy management, because a general training plan usually does not cover energy related information, it was the case of Knorr-Bremse, as stated in the graph below.

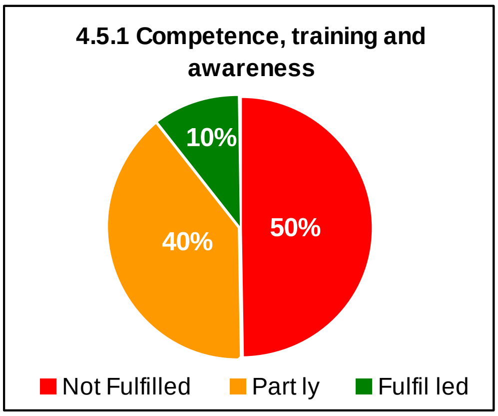

Figure 33: Requirement 4.5.1

It is possible to identify the necessity of including more specific energy related information in the already existent training plans.

The group of requirements 4.5 – Implementation and operation, represents also the ‘D’, or do, part of the PDCA cycle and includes the following points:

4.5.1 Competence, training and awareness

4.5.2 Documentation and 4.5.2.2 control of documents

4.5.3 Operational control

4.5.4 Communication

4.5.5 Design

4.5.6 Purchasing energy services, goods and energy (4.5.6.1 and 4.5.6.2)

In this part the requirements about operational control, design and purchasing need a closer attention, as detailed in Table 7 and Table 8.

Operational control includes identifying activities with significant impact in energy consumption and ensuring that they are conducted in a way to improve company’s energy performance.

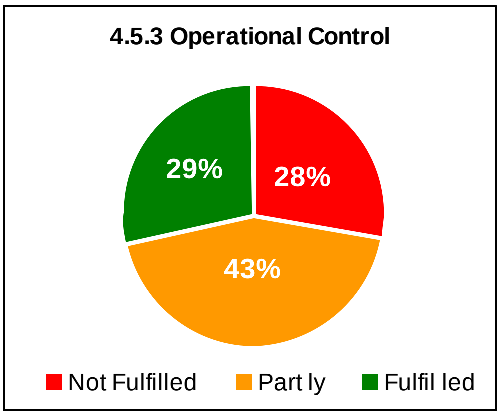

Figure 34: Requirement 4.5.3

This information can be superficially found in the processes’ descriptions of the organization, though some effort has already been done to fulfil this requirement.

Design and Purchasing were not specifically mentioned in standards before ISO 50001.

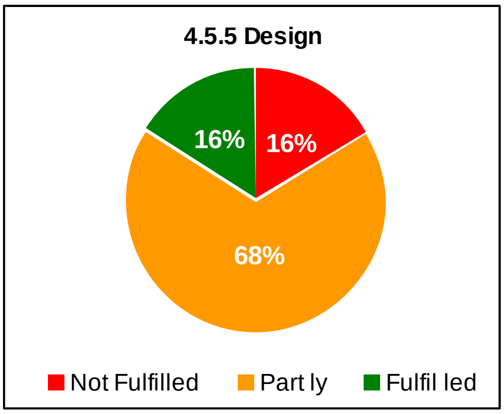

Figure 35: Requirement 4.5.5

Energy performance improvements have to be considered in the design of new and modified production lines, products, buildings, equipments, processes and activities. This requires a closely review of the processes.

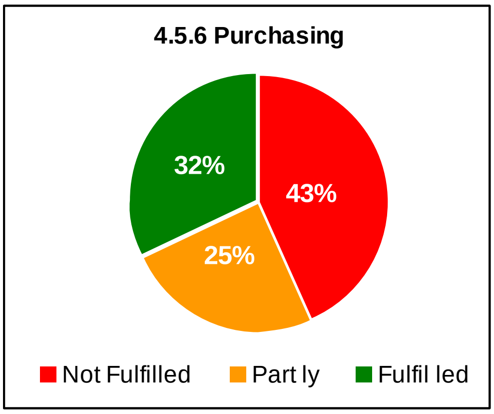

Figure 36: Requirement 4.5.6

The same is valid in the purchasing of energy services, products and equipments with considerable energy consumption.

Monitoring, measurement and analysis are already been done based in general energy bills and estimations. In this field it is still necessary to work with the singularities, so it is possible to evaluate specific issues in energy consumption and focus efforts in the largest consumers and potential energy savings points.

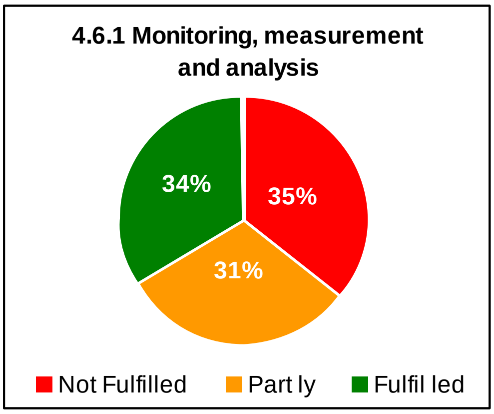

Figure 37: Requirement 4.6.1

From the responses received it was identified that the 34% of fulfilled actions include monitoring and measuring through estimations, i.e. without using appropriate instruments.

Considering the whole picture, the highest percentages of not fulfilled requirements found were in competence, training and awareness (50%), purchasing (39%) and monitoring, measurement and analysis (36%).

Competence, training and awareness is an specific field, it has to be improved, but its improvement will be more effective after the other requirements are better specified and normally organizations already have a competence, training and awareness plan that can be adapted adding energy consumption issues.

Purchasing is a matter of analyzing processes and identify were they have to be changed, it is also a punctual improvement.

Monitoring, measurement and analysis impact directly in other important requirements. Without measuring it is hard to identify the correct energy baselines that are the basis for the energy performance indicators' comparisons, which in turn are used for controlling the achievement of the targets.

In this way, inaccurate monitoring and measurement of energy data affects further requirements of the international standard, such as energy baselines, profile, performance indicators, targets and objectives.

It can be considered the starting point for a solid Energy Management System. Without information on energy consumption it is not possible to establish any of the just mentioned requirements.

This reasoning led to the choice of focus the starting point of the implementation of the Energy Management System in the requirement ‘4.6.1-Monitoring, measurement and analysis’ of ISO 50001:2009 (draft version), considering it as a cruscial point in energy management.

For this reason in the next chapter the foucus will be on a concept to introduce instruments for energy data consumption monitoring.

4 MONITORING, MEASURING AND ANALYSIS

After analysing the results obtained collecting information with the checklist, it was evident the lack of data for managing energy consumption and without this kind of data, baselines, targets and objectives are unlikely to be established, as well as a energy savings plan.

In this way it was decided that monitoring and measurement were important issues, since what cannot be measured, can also not be managed.

Talking to the HSE (health, safety and environment) managers from the locations, it was possible to find out that the energy consumption is almost everywhere controlled through reading energy bills sent by the energy supply companies.

The chapter of Monitoring, Measuring and Analysis is dedicated to describe a concept to facilitate starting the implementation of metering instruments to improve the energy monitoring conditions of a company.

It is divided into review of the literature that describes some aspects related to energy consumption monitoring, such as energy consumption systems, to understand where energy can be monitored inside the industry, and basics about energy metering.

The methods and instruments part describes the concept developed to introduce instruments for energy consumption data monitoring inside an organyzation and the analysis section gives three examples where the concept was used to test its applicability.

4.1 Literature Review

In this chapter are reviewed the concepts that are important to know in order to better understand the research problem and analysis of this paper, it is divided in two parts: energy consumption systems and basics for energy measuring and monitoring.

“Having the meters is not enough. A system must be designed to gather and record the data in a useful form. Meters can be read manually, they can record information on charts for permanent records, and/or they can be interfaced with microcomputers for real-time reporting and control.” (Capehart, 2008, p. 33)

4.1.1 Energy Consumption Systems

This part of the literature review describes some of the scopes that can be analysed in an industrial company, regarding energy consumption.

4.1.1.1 Industrial Steam System

Steam systems generate and distribute thermal energy in the form of steam, which is then used for several process applications, such as heating raw materials and treat semi-finished products, it is also a source of power for equipments plus for heat and electricity generation.

"Steam is one of the most abundant, least expensive and most effective heat-transfer media obtainable." (Schmidt cit. in Doty 2009)

The Figure 38 represents a typical steam system:

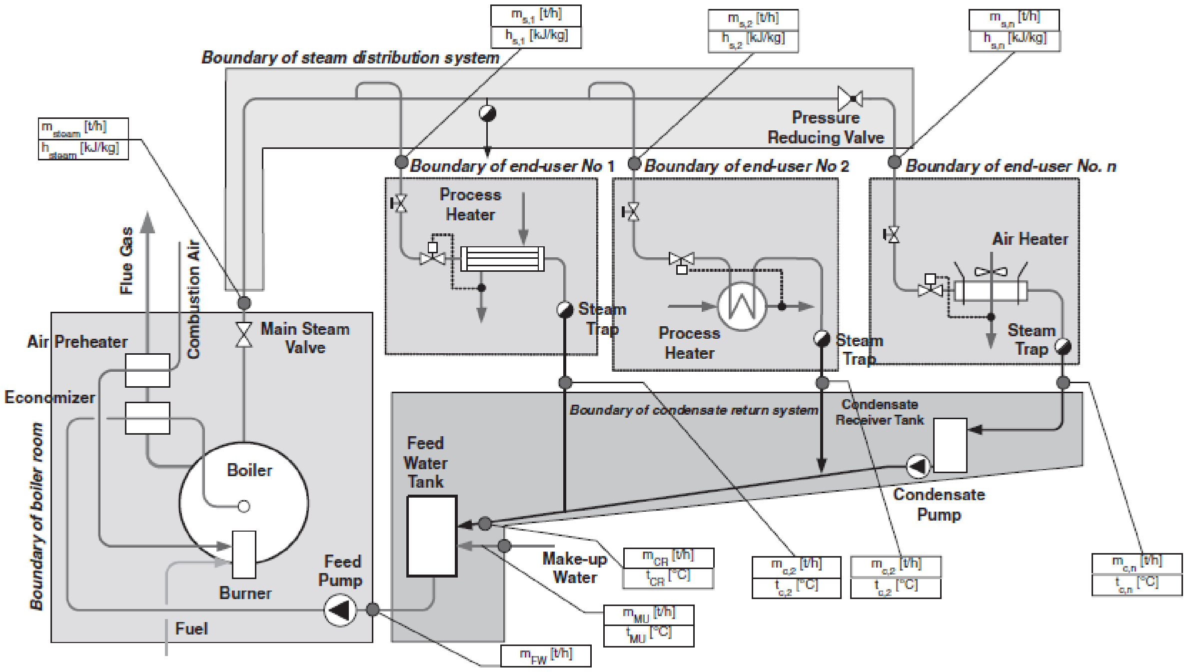

Figure 38: Overall Steam System Definition (Source: Morvay & Gvozdenac, 2008)

Schmidt (cit. in Doty 2009) also says that steam processes are relevant energy consumers among the industries.

Morvay & Gvozdenac (2008) corroborate the statement saying that normally 40% of all fuel burned in industry is consumed to raise steam.

The efficiency of steam systems depends on the fuel utilization in boilers and varies broadly depending on their design, manufacture, control and mode of operation. Efficiency can also be improved by implementing several measures to reduce the loss of heat from the boiler and related systems. (Ireland-SEAI, 2010)

4.1.1.2 Industrial Electric Power System

"Electric power systems provide clean and convenient energy to light homes, drive motors, run manufacturing plants and business and power our communication and digital systems". (Ray, 2007)

According to Morvay & Gvozdenac (2008) an industrial electric power system normally starts from one or more medium voltage transformers located within a company's perimeter. Some companies may be connected to the grid on high voltage or low voltage, and some may have their own power generation or co-generation.

Anyway, an industrial distribution network ramifies to form the busbars of a transformer substation. The feeders will take electricity flows to the main departments and units of an organization, where local electrical installations will branch out further to reach every end-user. (Ray, 2007)

A set of an electric motor and the attached mechanical device is frequently identified as an electric motor drive, due to their usage as sources of power for driving some mechanical devices.

4.1.1.3 Compressed Air System

According to Vesma (2009) the usage of compressed air includes, among others, the delivering of mechanical power, pneumatic controls, sorting and separating small items on production lines, blowing dust or swarf in manufacturing workshops, transporting powder, atomizing water in humidification systems and agitating the contents of tanks and vats.

It is considered as a safe and reliable power source, since it is generated on-site, giving users greater control over usage and air quality. This also contributes to the fact that it is widely used throughout industry.

Compressed air systems include compressor, after-cooler, air receiver (which works like a buffer), air dryer and distribution system, as represented in the Figure 39.

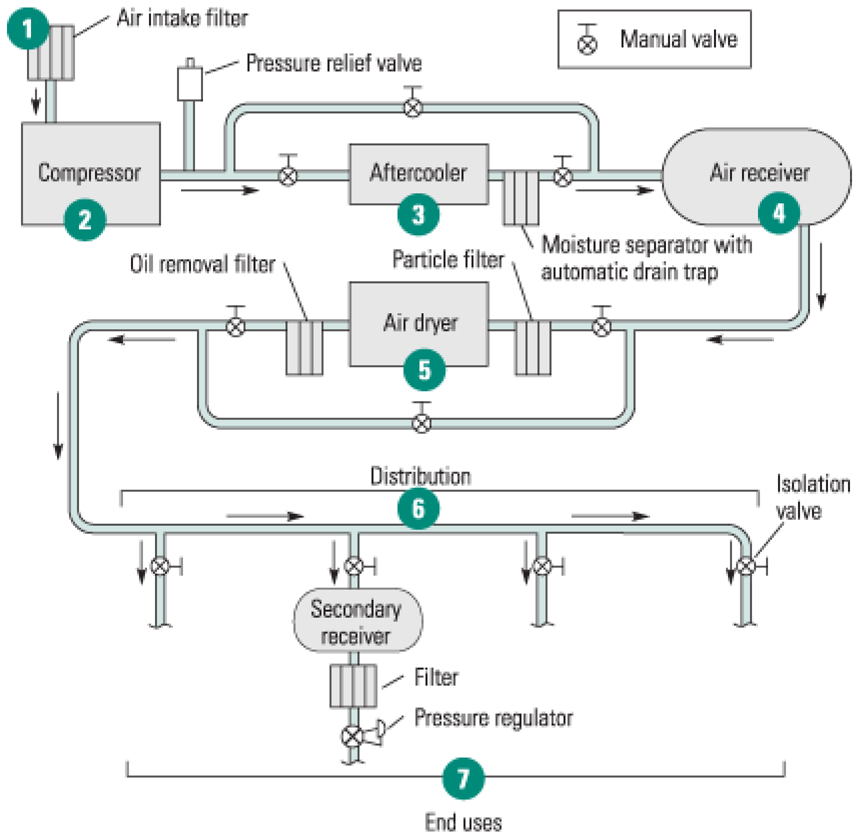

Figure 39: Compressed air system diagram (Source: Scales Air Compressor Corp.)

"The total cost of compressed air over a ten-year period can be estimated as 75% energy, 15% capital and 10% maintenance, representing the relevance of measuring and monitoring of its energy consumption." (Morvay & Gvozdenac, 2008)

From electricity to compressed air, much loss of energy may be identified, to assess this information power, pressure, flow rate and temperature values, shall be monitored.

Measuring power the annual electricity consumption of the compressed air system is assessed. Pressure is measured in order to provide feedback for control adjustments and to determine pressure drops throughout the system.

Flow meters help to determine air consumption and temperature measurements are needed to indicate whether equipment is operating properly. (Doty, 2009)

Apart from the measurements cited above, it is extremely important to determine compressed air leakages, which are responsible for high volume of air losses, they can occur due to small holes in the pipes, when a drain valve is left open or excessive pressure is lifting safety valves, to name but a few.

Is fair to say that through the measurement of energy consumption of a compressed air system it is possible to identify increased uncontrolled leakages, changes in price of electricity, increased maintenance costs and significant changes in the volume of production. (Morvay & Gvozdenac, 2008)

4.1.1.4 Industrial Refrigeration System

Morvay & Gvozdenac (2008) stated that a "… refrigeration system is a combination of components, equipment and piping, connected in a sequential order to produce a refrigeration effect." A refrigeration effect is the process of removing heat from a lower temperature heat source, a substance or cooling medium and transferring it to a higher temperature heat sink, commonly atmospheric air and surface water, in order to maintain the temperature of the heat source below that of the surroundings.

They can be classified in two categories:

- Chilling and chilled storage. The temperature normally varies between 0 to 10°C.
- Freezing, deep freezing, cold storage and deep cold, where the temperature ranges from 0 to minus 40°C.

A mechanical refrigeration system encompasses compressors, condensers, expansion devices, evaporator coils and fans. The refrigerant compressor requires the most of the energy of the system and the overall efficiency of the system can be improved by reducing the work the compressor does.

The heat discharged by the compressor can be used to heat water for domestic use or for heating the halls.

4.1.1.5 Heating, Ventilating and Air Conditioning (HVAC)

"HVAC is an important technology for the conditioning of spaces in modern buildings. It can represent 25–30% of the energy use in a typical building in warm climates." (Ireland-SEAI, 2010)

Heating is normally used in cold climates to heat buildings. There are different heating systems, such as central heating, which normally contains a boiler, a furnace, or heat pump to heat water, steam or air, all in a central location; or heating units located around the building to provide heating when necessary.

Ventilating is the practice of replacing air in any space to control temperature or remove moisture, odours, smoke, dust, airborne bacteria, carbon dioxide, and to refill oxygen, it can be both the exchange of air to the outside or circulation of air within the building.

Air conditioning is provided through the removal of heat, an air conditioning system provides cooling, ventilation and humidity control for a certain space.

In the HVAC system, Vesma (2009) suggests the installation of heat meters capable to assess the fuel used against heat generated and heat generated against degree days. This assists discriminating between faults within the boiler house and waste in the delivery of heat.

4.1.1.5.1 Building Envelope

The building envelope is the interface between the interior of the building and the outdoor environment, comprising walls, roofs and foundation, works as a thermal barrier and plays an important role in determining the amount of energy necessary to maintain a comfortable indoor environment.

According to Vesma (2009) "The significance of building fabric to the energy manager lies in the opportunities that could present themselves to reduce heat loss from buildings in cold weather."

4.1.1.6 Lighting

Lighting is mostly not one of the largest energy consumers in industrial companies, but it draws attention of most employees, it is one of the first points to be raised when suggestions for saving energy are requested. (Vesma, 2009)

Most buildings usually provide opportunities to reduce the electrical energy use of lighting systems. Savings are generally achieved by improved fixture efficiency, reduced operating hours and reduced lighting levels.

However it should be considered that the objective of a lighting system is to provide illumination at the times it is required, where it is required, at an appropriate level of illumination, without causing distractions and without compromising safety, it means that the overall lighting levels and colour of the light provided by the upgraded lighting systems must be suitable for the tasks or objects being illuminated in each case.

4.1.1.7 Hot Water Services

According to Vesma (2009) the most costs in hot water services are directed to its utilization in process applications, more common in drink, food, paper, plastic, chemicals and textile industries.

Domestic hot water services (DHW) are essentially those needed for hygiene and catering, they are not supposed to incur major costs.

Fossil fuels are used to generate hot water in boilers, such as natural gas, fuel oil, coal and peat. The choice of fuel depends on availability and cost.

Hot water services also entail energy costs and should be evaluated in cases of energy savings plan.

4.1.1.8 Industrial Cogeneration

Cogeneration is generally described as the simultaneous generation of combined heat and power (CHP).

Morvay & Gvozdenac (2008) explain that it "…refers to the recuperation of waste heat when electricity is generated and using it to create high temperature hot water or steam or hot gases."

The Figure 40 shows how an industrial cogeneration usually works.

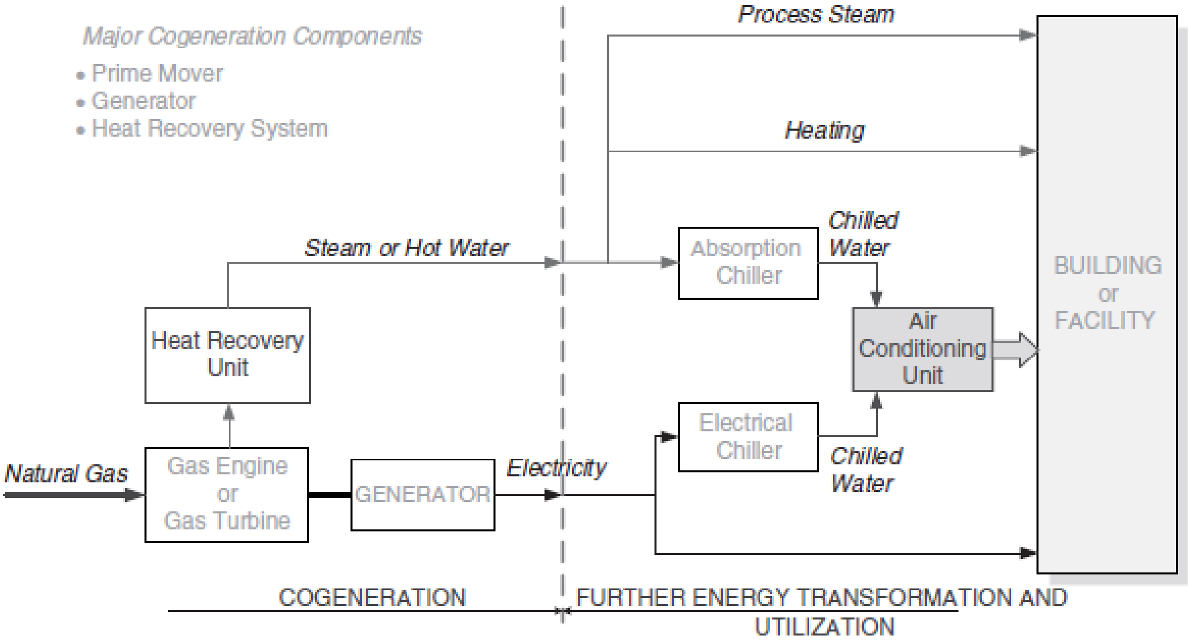

Figure 40: Conceptual Scheme for Cogeneration System (Source: Morvay & Gvozdenac, 2008)

Cogenerated power is usually in the form of mechanical or electrical energy, while the recovered heat is typically steam, hot water or hot gases, which can be used for some production processes, space heating, producing sanitary hot water, or powering absorption chillers for chilled water production.

The basic difference between cogeneration and CHP is that the first one is generally identified with district heating and large utility owned power plants or industrial power production and plant operation, while CHP is generally associated with smaller scale energy units. (Patrick et al., 1993)

The best cogeneration situation is when there is a correspondence between power and thermal demands, what not always happens, due to different reasons, like in the case of seasonality where the consumption of space heating decreases in summer.

4.1.2 Basics for energy measuring and monitoring

In this part of the analysis some terms related to energy consumption are described, in order to elucidate the concepts used in the paper.

4.1.2.1 Energy Baseline

Energy baseline is a quantitative reference that provides a basis for comparing energy performance. (ISO 50001:2009 draft version)

The baseline defines the energy consumption of an organization before any energy saving project, it is necessary for later comparisons and to quantify the benefits of the projects.

4.1.2.2 Factors affecting Energy Baseline

“Some operational variables will have a significant impact on energy use in a particular process while other variables will have only a minor impact.” (Australian Government, 2008)

These aspects that affect the energy consumption must to be regarded when establishing the energy baselines, they can be identified as:

- Ambient conditions: like humidity and temperature, they can be compensated with degree days;
- Production rate: fixed energy overheads spread over greater production;
- Product mix: some products are more energy intensive than others;
- Raw materials: changes can increase or decrease energy consumption;
- Occupancy: increasing number of employees raises energy consumption.

4.1.2.3 Degree Days

Is a measure of the variation of outside temperature and enable building designers and users to determine how the energy consumption of a building is related to the weather.

It is calculated though the sum of the product of the difference in temperature between the average outdoor and hypothetical average indoor temperatures and the number of days the outdoor temperature is below 15.5°C. (Thumann, 2008)

That means: $DD = \Delta T \times t$

The daily data can then be totalled for any required period – a week, month or year etc and compared directly with energy data.

“Degree days divided by the total number of days on which degree days were accumulated will yield an average ΔT for the season, based on an assumed indoor temperature of 15.5°C.” (Thumann, 2008)

4.1.2.4 Energy Efficiency

Energy efficiency refers basically to a ratio between useful energy or final energy services and input energy. (Morvay & Gvozdenac, 2008)

According to McLean-Conner (2009) energy efficiency can also be considered as an investment with a focus on reducing energy waste.

Energy efficiency can be improved in several ways, Moeller (2002) gives examples suggesting technical changes in devices, which will enable the device to produce more energy from the same amount of fuel, or provide the same service while using less energy.

The factors below tend to improve energy efficiency:

- Increasing production levels;
- Production of components from lower energy intensity materials;
- Improving plant-running efficiency;
- Reduction the fixed energy component of the plant;
- Decreasing reject or scrap levels.

4.1.2.5 Energy Performance Targets

Energy performance targets can be established in different levels, they may be presented to the top management as a general result from the organization, or may be required by each line manager in the company in a more detailed level.

“The energy performance of an activity is expressed by the ratio of energy units and the quantified results or aspects of this activity.” (Morvay & Gvozdenac, 2008)

The main consideration is that the targets should be realistic rather than theoretical. Wherever possible, historical data are collected and energy utilization performance is evaluated and targets are set.

4.1.2.6 Measurement Frequency

Measurement frequency has to be established for an accurate data collection, excessively frequent data recording can overload operator with analysis requirements and lack of data leads to errors. (Morvay & Gvozdenac, 2008)

To establish the moment of data reading is also important, a routine enable the impartial assessment of energy performance.

For example, in a three-shift production site, the optimal meter reading can be set up for the beginning of each shift.

Still according to Morvay & Gvozdenac (2008) all of the meters must be read at the same time in order to ensure that the energy used corresponds to the amount of products produced.

4.1.2.7 Seasonality

It is normally expected that energy consumption increases at the same time that production volume increases, however seasonality is a parameter that makes this pattern change.

The graph below represents the trend lines of energy consumption and production, it is possible to verify that the energy consumption increases during the months 5 and 6, while the production decreases. (Morvay & Gvozdenac, 2008)

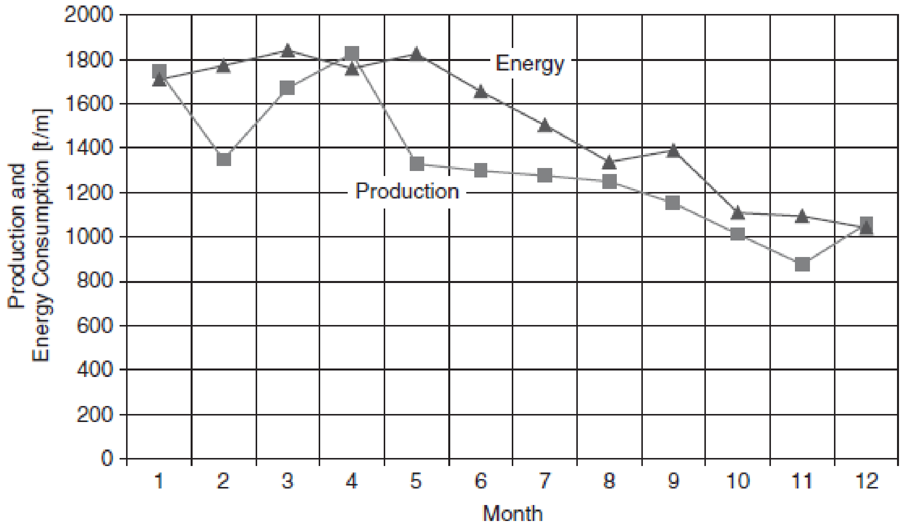

Figure 41: Example of seasonality (Source: Morvay & Gvozdenac, 2008)

This occurrence can be related with the increase of heating costs in the winter time, or the air conditioning system in summer time. There are possible points of seasonality.

4.1.2.8 Metering Instruments

According to document from Australian Government (2008) "… metering is the hardware that enables the measurement of energy consumption and savings."

In other words, "A measuring instrument is simply a device used to determine the value of a quantity, a condition of operation, a physical variable or some other phenomenon." (Patrick et al., 1993)

In some appliances instruments may be permanently attached to a system component, while in others it may be used to perform temporary measurements, normally system operations rely on permanently attached instruments, whereas test instruments are usually temporarily attached to system components to evaluate specific operating conditions and to make adjustments. (Patrick et al., 1993)

There are different measurement tools, appropriate to the various variables that need to be measured, such as temperature, humidity, pressure, light level, airflow and electrical power.

These variables must be measured and evaluated periodically to maintain the system at its peak level of efficiency, instrumentation and measurement are designed to perform this function. (Patrick et al., 1993)

Energy metering technologies provide solutions for energy management by the use of emerging technology advances in metering and communication systems. (EEOA - Australian Government, 2008)

4.1.2.8.1 Temperature Meters

Temperature is one of the most common and most important measurement made in evaluation of building equipments nowadays. Comfort heating equipment, air-conditioning system operation, hot water equipment operation all demand some type of temperature assessment. (Patrick et al., 1993)

For example, when measuring the temperature of an environment and it appears that it is being heated more than necessary, it may indicate an energy waste, where more energy is being used to achieve a heat level above than the desired one.

Two kinds of temperature meters can be identified: electrical or electronically and nonelectrical meters.

4.1.2.8.2 Humidity Meters

"Control of the moisture content of air is a very important consideration in the evaluation of air-conditioning equipment and heating system effectiveness." (Patrick et al., 1993)

Dry air can cause eye, nose, and throat irritation to people and employees may feel uncomfortable, to improve the quality of the environment, in this case, it is generally necessary to raise the room temperature. This obviously demands for longer equipment operation cycles and increased energy consumption.

Not only people bear with the incorrect air moisture, it can also result in static electric discharge, which can damage electronic equipments.

4.1.2.8.3 Pressure Meters

"Measurements of this type are used to evaluate equipment performance, operational efficiency testing, and in routine maintenance procedures. Some pressure measurements are performed on a continuous basis, whereas others are made temporarily." (Patrick et al., 1993)

For measure pressure equipments like Pressure Gauges and Manometers are used.

4.1.2.8.4 Power Measuring Instruments

Electricity meters are devices for measuring and recording the electricity flow and consumption. Electrical power meters are known as wattmeter.

Not only electricity flow can be measured, Patrick et al. (1993) explains that the power factor and power demand may also give important information.

> Power factor is described as ratio of true power to apparent power. True power, which is measured in watts (W), is an indication of the actual power being converted into work by a particular component of system. Apparent power, which is measured in volt-amperes (VA), is an indication of the power being delivered to a system. It is important to monitor the power factor of an electrical system in order to examine its efficiency. This has a great deal to do with the amount of power that is being turned into work and that which is actually being supplied by the system.

Power demand meters aim to measure the peak power (kW) used as compared with the average power (kW) being used. This ratio of power consumption is an indication of the amount of power that the utility company must supply above its predicted average value for a particular building.

“The reading of a kilowatt-hour demand meter is similar in many cases to that of the kilowatt-hour power meter.” (Patrick et al., 1993)

4.1.2.8.5 Flow Measuring Instruments

The understanding of flow instruments helps to recognize malfunctions and evaluate the system consumption.

“Totalized flow measurement, instruments are designed primarily to respond to the total amount of flow that moves past a given point during a specified period of time.” (Patrick et al., 1993)

The measurement of liquid fuel, gas, and water all respond to some type of totalized flow instrumentation.

4.1.2.8.6 Automated Meter Reading Systems (AMR)

Automated meter reading technique replaces the existing manual meter reading operation, transferring meter reading data automatically to a central station or operator for billing and monitoring purposes. (Shibu, 2009)

As stated by Shibu (2009) the meter reading data may be transferred over a wireless communication channel or a wired communication medium. In the case of a wireless channel it can be through radio frequency or power line communication module, radio frequency is normally used with handheld equipments.

4.2 Methods and Instruments: Concept for Implementing or Improving Equipments for Energy Data Collection

To manage energy successfully, it is necessary to measure how much energy has in fact been used, that means collecting information and not simply relying on figures provided by the utility companies.

Neither monitoring nor saving actions can be planned without appropriate metering resources, this assumption defined the starting point for the analysis, the necessity of installation or improvement of energy metering equipments.

Most of the companies do already keep track of their energy consumption numbers, some using daily log sheets, others using manual meter readings and there are also situations where remote metering and automatic recording is done.

Nevertheless, even in companies that already have established some parameters to monitor energy consumption, not all data may be readily available. Usually they do not have enough meters to control at a more detailed level, in these cases some additional meters shall need to be installed on top of the existing ones to complete the performance measurement system.

The higher the level of detail of a measurement system the better the accuracy of the results but also the costs increase significantly.

Cost cutting has always been a subject present in the organizations routine, in this way, even if it is important to have more detailed information about energy consumption, sometimes it is not economically feasible.

Having in mind that a strategy for obtaining accurate energy data supports the estimation, evaluation, measurement and tracking of energy efficiency and potential savings opportunities, and that inaccurate meters are worse than not meter at all, but excessive accuracy is neither required, nor economically justified, this part of the paper describes a concept for guiding in the decision of implementing energy metering equipments in a company, which assists the improvement of the Energy Management System.

The process is divided into six steps, as shown in the Figure 42, the choice of the steps was made based in experience inside the Knorr-Bremse Group, observing the flow of information about energy consumption and complaints about difficulties to collect data.

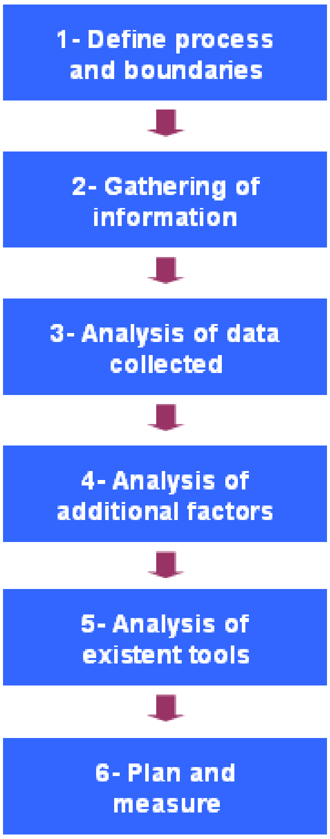

Figure 42: Steps for Implementing an Energy Consumption Monitoring System

The extent of investment in new meters will vary from factory to factory depending on the scope and sophistication of desired meters. Regardless of the data collection system that will be implemented, the critical factors that must be ensured are data adequacy, reliability and accuracy.

4.2.1 Define the processes and their boundaries

For identifying the priorities in positioning metering equipments, it is important firstly to understand the processes, their energy inputs and outputs.

To help in the identification of the processes, the following steps are underlined:

1. Start with a general overview of the inputs and outputs;
2. Divide the possibilities of energy consumption in 'big areas';
3. Divide the 'big areas' in more specific fields.

4.2.1.1 General overview of inputs and outputs

It is not possible to effectively manage what we do not understand, therefore a mapping of general energy inputs and outputs in an organization is required.

The suggestion is to start drawing a sketch or schematic of the energy flow, to have an overview about what is included and what is not included in the analysis, this will help to set up the ways that energy and mass can enter or exit the system and if there are any internal sources or transformations of energy within the scheme.

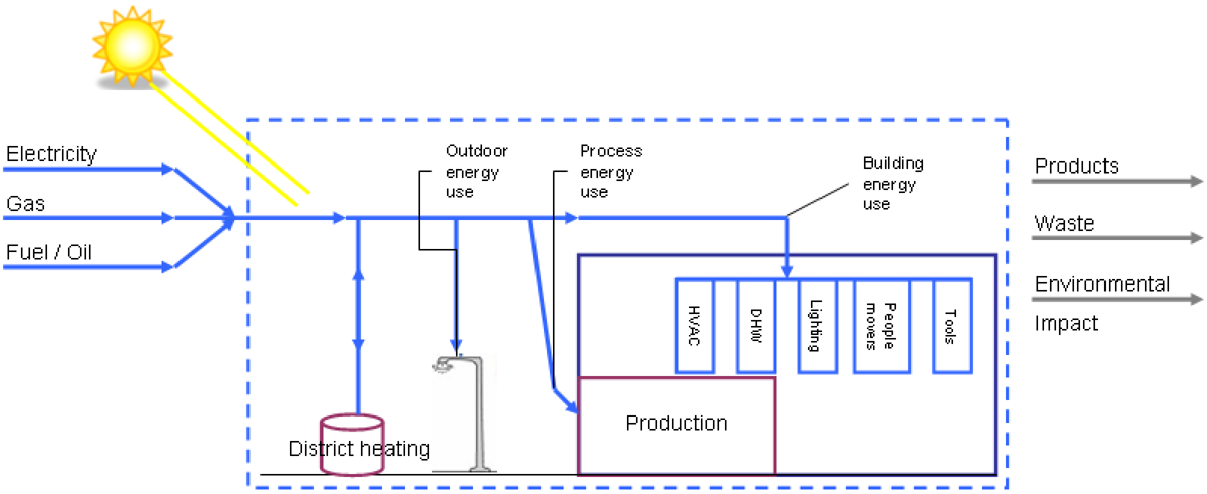

Figure 43: Energy flow diagram

Figure 43 is an example of an energy flow diagram, the types of energy input/ output and the utilization of energy will vary according to each company.

4.2.1.2 Appointing "big areas"

The next step can define the big areas of an industrial company into which the analysis can be split, this can also be considered as the first action that will help defining the level of detail of data that will be analysed.

The following division was made based on the different characteristics that may affect the comparison of performance indicators. (see Figure 44)

Figure 44: Big areas of energy consumption

This means that, in this case, it was considered the fact that it is not recommended to compare an energy performance indicator used for analyse the energy consumption in an office such as 'kW/square meter' with an indicator used for production 'kW/piece produced'.

This is not a pattern, other aspects can be taken into consideration, for example the simple familiarity with the processes, where the choice of the criteria is a matter of interpretation, or purely based in the knowledge of the person who is analysing the system.

4.2.1.3 The level of detail

The level of detail shall help to understand how deep to analyse the data, in some cases it is necessary to go further in the investigation, analysing the energy consumers more specifically and in other cases only a broad view is enough or economically viable.

The level of detail depends on the organization, it does not mean that all measurements have to be in the same level of detail, but the description of the data and the gathering of this kind of information help to have a general view of the energy consumers, their inputs and outputs. It is a document that can be useful in further analysis.

The levelling can be done for each 'big area' identified.

In the example below (Figure 45), the production area is used, initially a second level is defined, where the different activities can be identified.

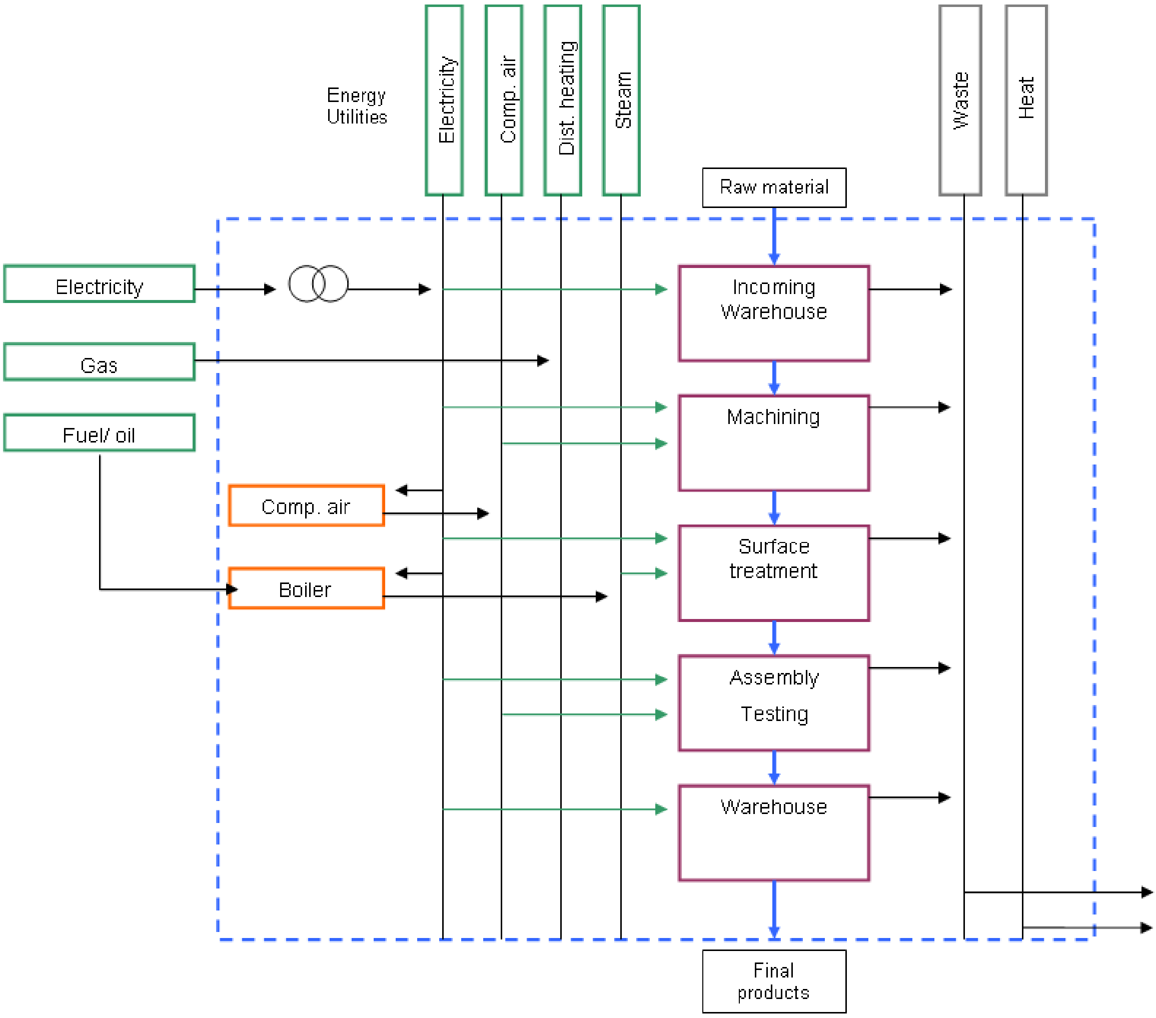

Figure 45: Production – key process identification

After identifying the main activities, a further step can be taken, dividing once more the main activities, detailing the third and more specific level.

The following matrix was developed to help with the identification of activities, their level of detail and their energy input/output, providing a general idea of where data shall be collected. (See Table 10)

The levels indicate how the groups of energy consumers can be divided to facilitate the data collection, they can be divided into process, systems, production line, machines, halls, activities, specific tools, to name but a few.

The energy input part refers to the energy sources that can be measured, through exact values or estimations and direct costs can be analysed.

The energy output part mention the energy that may be lost in each process. In different situations, for example, energy lost due to malfunction of equipments that can be illustrated by lost of compressed air in leakages during the process or energy that could be reused but it is not being, for instance the possibility of reusing the thermal energy (generated by steam processes) for heating halls, in this case it is the lost of a possibility to use energy generated by an internal process.

Energy sources and energy loss were chosen as parameters in order that may indicate potential sources of savings.

Table 10: Identification of Energy Sources and Consumers

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS														
Location: Date:				Identification of energy inputs/ outputs										
				Energy Input						Energy Output				
				Gas	Electricity	Fuel (oil / coal)	Compressed air	Steam	Water	Electricity	Compressed air	Thermal energy	Steam	Water
Level 1	Level 2	Level 3	(...)											

This is an example; the characteristics may change for each different organization.

The choice of quantity of levels depends on accuracy required and the cost of installing and maintaining metering equipments.

4.2.2 Gathering of information

Once having the overview of the energy sources and consumers that can be analysed, the gathering of data about energy consumption can begin, which will help defining where to concentrate efforts and investments.

This paper starts from the assumption that the organization that will use it does not have enough metering equipments or measuring capacity to do a very detailed data collection, in this case, some suggestions about potential sources to find the data are presented in the next points:

Direct performance measurement, where metering equipments already exist;

1. Utility billing analysis;
2. Mathematical models and engineering calculations;
3. Supplier’s classifications;
4. Estimations;
5. Analysis of data from manufacturers, contracts, design, recipes and etc.;

To improve the quality of the captured data, it is important to pay attention in the following considerations:

1. Measurement parameters shall be established;
2. Existent meters and sub-meters shall be calibrated;
3. Measurement points shall be appointed;
4. Reasonable time intervals for collecting data shall be defined;
5. Data shall be collected over a sufficient time period.

External impacts, such as seasonal load, start-up and shut-down transients, weather conditions and other process changes should be observed.

The data gathering is an important step to help quantifying the energy consumption and their relevance, normally the most energy intensive processes are also a big potential in energy savings opportunities.

For assisting the gathering of information, the Table 11 shown below, will be split per energy source what helps to visualize what is required for each source. The fantasy location of Wunderland was used to exemplify the procedures.

Table 11: Energy Consumption Data - Electricity

ENERGY CONSUMPTION						
Location: Wunderland						
Date: 22.10.2010				Electricity		
				Consumption (kWh)	Percentage	Cumulative percentage
Level 1	**Level 2**	**Level 3**	**(…)**			
Production	Machining	M1				
	Machining	M2				
	Machining	M3				
	Machining	M4				
	Machining	M5				
	Machining	M6				
	Assembly	A1				
	Assembly	A2				
	Assembly	A3				
	Assembly	A4				
			TOTAL:			

* theoretical values, just for this example

Different sort of data can be captured in the Manufacturing Sector, the Table 12 presents some examples.

The measurement units mentioned in the Table 12 are:

- T / y: ton per year ;
- M^3 / y: cubic meter per year;
- °C: Degree Celsius
- kWh / y: Kilowatt-hour per year;
- GJ / y: Giga joule per year.

Table 12: Data that can be collected in the manufacturing sector
(Source: Energy Savings Measurement Guide)

Examples of data that can be captured in the manufacturing sector			
Category		Quantifiable parameter	Units
Mass balance	Process streams	Raw material purchased	t / y
		Material flows through each process stage	t / y
		Wasted product	t / y
		Finished product	t / y
	Water	Incoming to site	m^3 / y
		Discharged to sewer	m^3 / y
		Water flows in each process and individual equipm	m^3 / y
Energy balance	Process water	Temperature before heating/ cooling	°C
		Temperature after heating/ cooling	°C
	Process streams	Temperature before heating/ cooling	°C
		Temperature after heating/ cooling	°C
	Electricity	Electricity	kWh / y
	Steam	Steam flow	t / y
	Gas	Gas flow	GJ / y or m^3 / y
	Chilled water	Chilled water load	kWh / y
		Chilled water flow	m^3 / y
	Hot water	Hot water load	kWh / y
		Hot water flow	m^3 / y

After collecting this information, energy flows can be quantified and combined with production inputs and outputs data to define consistent baselines, energy profile and energy performance indicators and start a more accurate monitoring of energy consumption.

4.2.3 Analysis of energy consumption data collected

As soon as the data about energy consumption is pulled together, the next step is to analysis the data to identify the priorities, where the resources should be directed. That means, deciding which are the consumers that need more energy, in order to focus the implementation of metering equipments in those cases, considering that the higher the consume, the greater the saving potentials.

In this case, the Pareto Analysis is used.

Pareto analysis is the method of looking at all the root causes of a problem and trying to determine which ones have the greatest frequency. In this case, it is to look at the energy consumers and identify which ones have the greatest significance.

For using the Pareto chart, the following steps were defined and described in the next chapters:

1- Define the scope;
2- Choose the activities
3- Complete energy consumption information;
4- Start calculations for obtaining the Pareto Chart;
5- Build the Pareto Chart; and
6- Set the focus of the analysis.

4.2.3.1 Define the scope

First of all is important to define the energy source that will be investigated, i.e. if simple information is interesting for the analysis, for example just electricity, or if a combination is required, such as electricity + heating (gas).

Several parameters can be taken into consideration for this decision, one of them is the volume of energy consumed, detected in the previous step, that means the analysis can focus in type of energy source, or sources, most used by the company.

In the case of using more than one type, a conversion of the metrics may be needed, the Table 13 displays values for this conversion.

Table 13: Energy Conversion Factors (Source: British Standard Institute)

Energy source	Measured units	To get kWh multiply by	Observations
Electricity	kWh	1	
Natural gas	m^3	10,7	Depend on pressure, temperature and calorific value
Natural gas	100 cubic feet	30,3	Depend on pressure, temperature and calorific value
Natural gas	kWh	1	Depend on pressure, temperature and calorific value
Natural gas	therm	29,31	Depend on pressure, temperature and calorific value
Diesel or 35-second gas oil	litre	10,6	
Heavy fuel oil	litre	11,4	
Propane	kg	13,78	
Coal	kg	9	Highly variable between types
Steam	tonne	630	Depend on pressure

4.2.3.2 Choose the activities

Using the list of 'Level of Detail', it is possible to identify the processes, lines, activities or machines that will be investigated and which energy sources they consume.

The example in Table 14 was developed to exemplify the procedure:

Table 14: Example, Identification of Energy Sources and Consumers

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS																
Location: Samplecity				Identification of energy inputs/ outputs												
Date: 22.10.2010				Energy Input							Energy Output					
				gas	electricity	compressed air	district heating	fuel/ oil	coal	other (…)	heating	compressed air	vapour	gases	other (…)
Level 1	**Level 2**	**Level 3**	**(…)**												
Production	Machining	M1			x										
	Machining	M2			x										
	Machining	M3			x	x					x	x			
	Machining	M4			x			x							
	Machining	M5			x										
	Machining	M6			x										
	Assembly	A1			x										
	Assembly	A2			x										
	Assembly	A3			x										
	Assembly	A4			x										

In Table 14, it was assumed that the energy consumption data can be assessed per machine, so it was possible to identify three levels until the specific machine.

The crosses associate the name of the machine with the type of energy it consumes and/or the kind of energy output generated by each machine.

4.2.3.3 Complete energy consumption information

In the chapter “4.2.2 Gathering of Information”, general data was collected, all energy consumption related information that could be identified in the company, now this data will be associated to the activity chosen for the analysis.

The energy consumption data will be displayed in the table below (Table 15) for further calculations.

Table 15: Example, Energy Consumption Data

ENERGY CONSUMPTION						
Location: Wunderland				Electricity		
Date: 22.10.2010				Consumption (kWh)	Percentage	Cumulative percentage
Level 1	**Level 2**	**Level 3**	**(…)**			
Production	Machining	M6		32		
	Machining	M5		498		
	Machining	M4		22		
	Machining	M3		302		
	Machining	M2		12		
	Machining	M1		80		
	Assembly	A4		4		
	Assembly	A3		2		
	Assembly	A2		38		
	Assembly	A1		10		
			TOTAL:	**1000**		

* theoretical values, just for this example

4.2.3.4 Start calculations for obtaining Pareto Chart

As soon as the relevant data is chosen, collected and organized, it is possible to start the calculations.

For calculating:

- First organize the values from the highest to the smallest;
- Then, calculate the total of energy consumed;
- Calculate percentages, related to the total amount;

$$\beta = \left(1 - \frac{Mx}{\sum_{1}^{n} M} \right) * 100 \qquad (1)$$

Being:

β = consumption of Machine in %

Mx = consumption of Machine x

- Calculate cumulative percentages; will include the percentage of consumption for that category plus the percentage for all categories preceding it in the list.

The table below exhibits the four steps for calculating, the first column shows the values of energy consumption already organized from the largest to the smallest, the second column is the percentage from each consumer and the third one displays the cumulative percentages.

Table 16: Example, Data for Pareto Analysis

Data for Pareto Analysis						
Location: Wunderland						
Date: 22.10.2010				Electricity		
				Consumption (kWh)	Percentage	Cumulative percentage
Level 1	**Level 2**	**Level 3**	**0**			**0**
Production	Machining	M5	1	498	49,80%	49,80%
	Machining	M3	2	302	30,20%	80,00%
	Machining	M1	3	80	8,00%	88,00%
	Assembly	A2	4	38	3,80%	91,80%
	Machining	M6	5	32	3,20%	95,00%
	Machining	M4	6	22	2,20%	97,20%
	Machining	M2	7	12	1,20%	98,40%
	Assembly	A1	8	10	1,00%	99,40%
	Assembly	A4	9	4	0,40%	99,80%
	Assembly	A3	10	2	0,20%	100,00%
		TOTAL:		**1000**	**100%**	

* theoretical values, just for this example

4.2.3.5 Build the Pareto Chart

After the calculations, it is possible to build the Pareto Chart using the excel, the results can be represented in several forms, such as in Figure 46 and Figure 47.

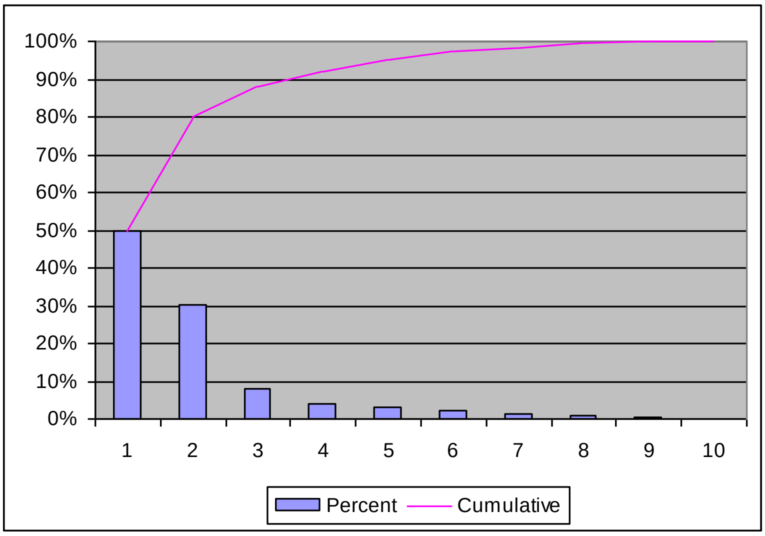

Figure 46: Example, Pareto Chart

The Figure 39 features the percentage and cumulative percentage values, while the Figure 40 trace a curve with the sum.

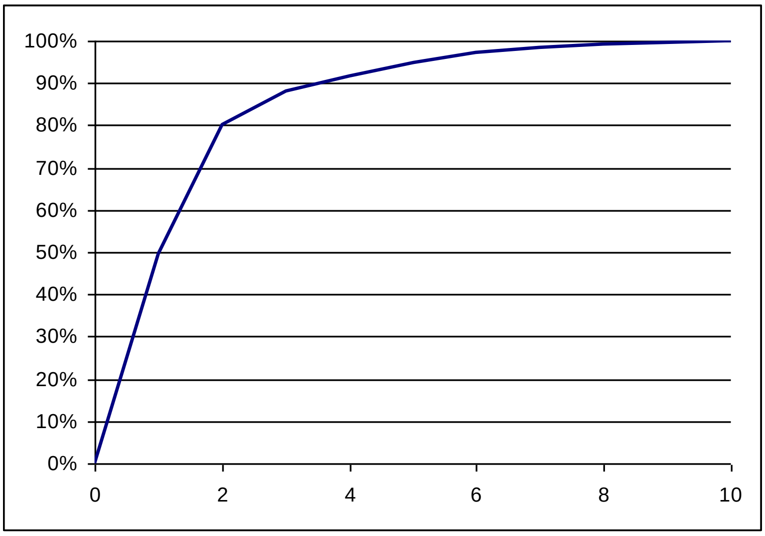

Figure 47: Example, Pareto Chart 2

Knowing that this example was developed with 10 machines, it is easy to see that two of the machines from the third level consume 80% of electricity, while the other eight are responsible for the rest 20%.

4.2.3.6 Set the focus of the analysis

The next step is to analyse the results of the Pareto chart, to define the focus for implementing energy metering equipments.

Dividing the Pareto in areas of impact helps visualising the analysis.

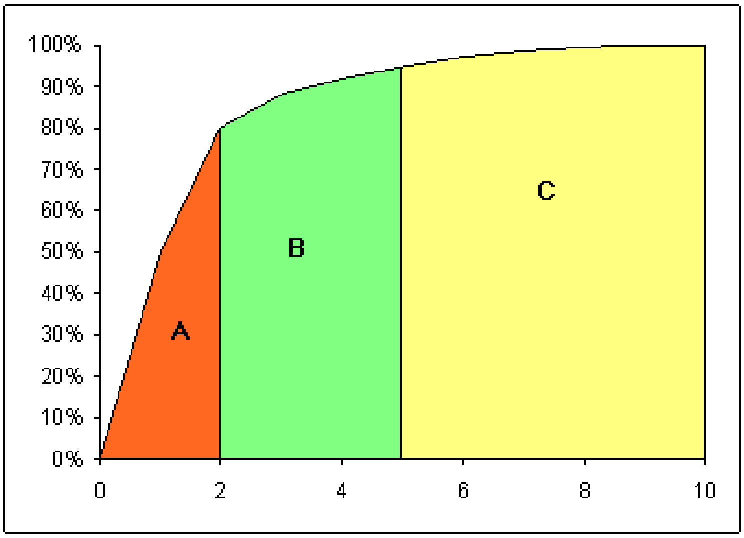

Figure 48: Example, Pareto Analysis

The Figure 48 shows that 20% of the machines/ activities use 80% of energy, 50% consumes 95% and the other 50% utilizes the rest 5%.

Sometimes the actual percentage may differ from 80% - 20%, the important thing is to identify and focus the group of largest energy consumers.

The alternative is to start focusing in the region ‘A’ of the Pareto chart, assuming that for being the largest energy consumers, they will also present the greatest saving potentials.

Part ‘A’ is formed by M5 and M3, both from the Machining process.

It does not mean that the other 80% of the consumers will be totally ignored, it just suggests starting the investigation focusing consumption characteristics.

4.2.4 Identification of other factors that should be taken in consideration

It does not mean that after having identified the largest energy consumers the implementation or improvement of metering system can immediately begin, before starting to define where to take actions, other aspects should be taken into consideration.

In every industry there are recurring problems driving to higher energy consumption rates and costs. If adequately metered, these problems can be actively monitored and prevented, generating quick wins.

An investigation of anomalies in performance should be carried out, with the purpose of removing likely causes of poor energy efficiency performance.

Tracking and reporting the energy use allows itself to prompt intervention in cases where the correction should be required, and will also help to lock in and maintain energy savings that have currently been achieved.

It means that also trend analysis must be performed, where information is available, in the example used in this paper, the M1 is not included in the ‘A’ area of the Pareto chart, however assuming that the analysis of the trends of M1 shows energy consumption ranging during weekends when the factory is shut down. It may indicate an anomaly, showing that even if M1 was not identified as a higher potential for energy savings due to level of consumption, it deserves closer attention.

The Table 17 shows the possible typical problems that can cause anomalies in energy consumption trends.

Table 17: Typical problems that can cause energy waste (Source: Australian Government, 2008)

System	Typical problems
1 Process Operations	incorrect set-points fouled heat exchangers advanced controls switched off poor control timing
2 Boilers	operating conditions hours (on/off) and outputs (low/high) poor air-fuel ratio fouled heat exchangers excessive blow-down incorrect excess air ratio air leakages poor fuel quality
3 Steam	leaks failed traps poor isolation insulation incorrect set-points low condensate return
4 Refrigeration	reduced air flow (e.g. fouled condenser, faulty fan/motor) air in condenser incorrect superheat settings high head pressure settings incorrect compressor selection
5 Compressed air	leaks poor compressor control incorrect pressure
6 Space heating/ cooling	excessive space temperature excessive fun power use overcooling heating and cooling high chilled water temperature
7 Power generation	poor engine performance incorrect control settings poor cooling tower operation fouled heat exchanges
8 Transport	real time driver tracking (idling time, behaviour) traffic congestion engine running hours high (truck maintenance due)

Where a trend analysis is not feasible, the analysis of historical data can be carried out, verifying the relevance and occurrence of these problems. Each of them should be treated separately and their causes should be identified.

4.2.5 Analysis of existing tools

Until this point it was possible to identify:

- Energy sources and energy consumers;
- General values of energy consumption;
- Largest energy consumers;
- Possible anomalies in energy consumption trends, or typical problems.

Based on this information, a list can be prepared, containing the order of priorities for the establishment of energy metering equipments, thus it is possible an overview from the deployment needs.

However, it may be that some of the priorities already have suitable metering equipments, in this case a survey of existing equipments is required. An investment in new equipments where they already exist means unnecessary costs.

For assisting the comparison between what should be implemented and what already exists, it is suggested to use the information that follows.

The identified methods used for metering were divided into five categories:

- Frequency: how often is possible to use the equipment and acquire desired information;
- Mobility: the likelihood of using the equipment in more than one machine;
- Data collection: the ease of collecting data, if it is an automatic meter reading or manual;
- Focus: if it is possible to assemble more than one kind of data;
- History: if the data is recorded.

For each of the categories were given a value in order to simplify the survey:

Table 18: Metering Characteristics

V	Frequency	Mobility	Data collection	Focus	History
3	daily to bimonthly	remote	Wireless AMR	multi indicators	with data storage
2	montly to biannual	portable	AMR		with records
1	annualy	fixed	manual	specific parameters	without records

For sake of simplicity, the punctuation of column ‘V’ can be use to fulfil the table, being 3 the most accurate and complete and 1 the simplest condition.

The Table 19 can assist in the assessment, it was combined with the consumption data table and the fields are to be filled in as follows:

A – Value in the metric chosen (kWh, Btu, m^3, etc);

B – Percentage related to the total amount;

C – Cumulative percentage;

D – Position where the metering equipment is located;

E – Frequency of measuring;

F – Mobility of the metering equipment;

G – The automaticity of data collection;

H – The specificity of the equipment;

I – How the equipment records the data collected;

J – Name or type of metering system or metering equipment used;

K – Type of energy output/ loss;

L – If the output/ loss is measured (yes or no)

M – Total amount of consumption of energy;

N – Location where the data was collected;

O – When the data was collected.

Table 19: Electricity Consumption Analysis (final table)

ELECTRICITY CONSUMPTION ANALYSIS															
Location: N Date: O				Identification of energy inputs/ outputs											
				Electricity - Input										Output	
				Consumption	Percentage	Cumulative percentage	Level	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name of metering equipment	Type of energy output/ loss	Measured (y /n)
Level 1	**Level 2**	**Level 3**	**(…)**												
				A	B	C	D	E	F	G	H	I	J	K	L
Production	Assembly	A1													
	Assembly	A2													
	Assembly	A3													
	Assembly	A4													
	Machining	M1													
	Machining	M2													
	Machining	M3													
	Machining	M4													
	Machining	M5													
	Machining	M6													
			TOTAL	M											

In ownership of such data, one can verify which equipments already exist and what are their characteristics.

4.2.6 Plan metering and measurement

Bearing in hand the information suggested in the previous points, the plan phase can be undertaken. The following table was formulated to clarify the actions that can be taken in planning.

Plan – Metering Equipment Installation/ Improvement	
Reference	To which part of the plant the action will refer
Action	Which action will be taken
Budget (€)	**4.2.6.1 – Budget available**
Resources	Other resources required such as time, personnel, IT, etc.
Current situation	If there is already any meter installed or any other measurement system
Indicators	Target and performance indicators to measure the success of the action
Saving potentials	Activities that will help saving energy and costs
Approval & completion	Management person for approval of the action and ensuring it is completed

Task	Priority	Responsible	Start date	End date	Comments
1. Outsourcing or internal (4.2.6.2 Instruments)					
2. Research of suitable equipment (4.2.6.2 Instruments)					
3. Verification with budget (4.2.6.1 Budget)					
4. Identification of saving potentials (4.2.6.3 Saving pot.)					
5. Definition of targets (4.2.6.4 Targets definition)					
6. Definition of new baselines (4.2.6.5 New baseline adjustment)					
7. Definition of responsible for achievement of targets (4.2.6.6 Responsible)					
8. Definition of next phase (4.2.6.7 Continuous improvement)					

Figure 49: Plan to Introduce Instruments for Energy Consumption Data Monitoring

The field priority is to be filled in with the importance of the activity to achieve the results of the planned action, considering 1 high, 2 medium and 3 low.

4.2.6.1 Budget

The definition of a budget serves as an input to know what measures are possible to be taken, which limits implementation or improvements can reach.

The optimal is a definition of budget made by the top management, where they use the specific parameters established for each case, each organization.

Another option, according to literature consulted, is to define a budget of maximum 1,5%[3] of annual cost of energy. (Australian Government, 2008)

The U.S Department of Energy, in the International Performance Measurement and Verification Protocol of 2002, suggests that the investments should not be higher than 50%

[3] This number was achieved making a comparison with the salary of a worker. Example, considering € 60.000/ year as the salary of the employee. That would mean metering and monitoring at € 60.000 of energy /year, which refers to a motor running continuosly that work out at about 60kW, generating a cost of 10 cents/kWh. Supplying and installing an appropriate sub-meter, communications and monitoring would cost about € 1.000, so we come to around 1,5%.

of the cost-effectiveness of decreasing uncertainty in savings calculations by implementing the new meters, in other words, it is not recommended to spend more than 50% from the value of the guaranteed savings achieved due to improved accuracy obtained by installing new equipments.

4.2.6.2 Instruments

The choice of instruments can be done with the help of a sub-contractor or with an internal research conduced by facility manager, production manager or any other responsible for energy consumption monitoring.

Specification of frequency, mobility, the way the data is recorded, all the characteristics previously mentioned in Table 16, have to be taken into consideration when choosing the most suitable metering equipment.

Specification of the metering points, periods of metering, meter characteristics, meter reading and witnessing protocol, meter commissioning procedure, routine calibration process and method of dealing with lost data, shall be taken into consideration.

The acquisition of the equipment, its installation, its calibration, its handling, the possibility of contracting a third party for assisting choosing and installing and all other costs incurred in this activity, have to be coherent with the budget previously defined.

4.2.6.3 Saving potentials

Just measuring does not help, right after having defined what and how to measure, objectives, targets and performances shall be determined.

Before determining targets, saving potentials should be identified, so targets can be related to them. Saving potential can be identified in all parts of an organization and may represent quick wins.

An example is the case of the company 3M, where investments in different ambits were made, such as heat recovery systems, high efficiency motors, variable speed drivers, computerized facility management systems, steam trap maintenance, combustion improvements, variable air volume systems, thermal insulation, cogeneration, waste steam utilization and shifting to non-hazardous solvents. Such modifications resulted in remarkable improvements in energy efficiency, 3M counts with 3% of energy savings per year for the next 5 years, as results of these improvements. (Capehart, 2008)

4.2.6.4 Targets definition

Knowing where improvements can be done, it becomes easier to recognize where to focus the efforts and consequently measure the results of these efforts.

Energy efficiency goals are set and then the results are measured against a baseline, or set standard, in order to determine the success of the programs.

4.2.6.5 Baseline adjustments

After having the real data provided by the new metering system, an adjustment in the baselines is reasonable, it can be planned from the second year of the new system.

4.2.6.6 Responsible

Holding people responsible for specific results facilitates the achievement of targets, there are different ways to define the person in charge, it may be the operator of the machine, someone that works in the production line or is more familiarized with the process.

The concept of Energy Cost Centre can also be used to support defining the responsibilities

4.2.6.6.1 The Energy Cost Centres (ECC)

"Energy Cost Centre can be a department, a process, or unit of equipment, where the use of raw materials, energy consumption and environmental impacts can be related to ongoing activities and be continuously monitored." (Morvay & Gvozdenac, 2008)

There are no defined rules to arrange an ECC, a good way is by defining parameters, for instance a product, line or type of machine, where it is possible to directly measure the output, define the cost of measurement, designate responsibility to a person working in that area, standardized performance indicators and set realistic targets for improvements.

Thereby the ECC helps to decentralize responsibilities inside the organization and assigns responsibilities centres for energy cost and performance, this enables to allocate the responsibilities to an individual or a team of people.

The Figure 50 represents an example for different forms of defining ECCs:

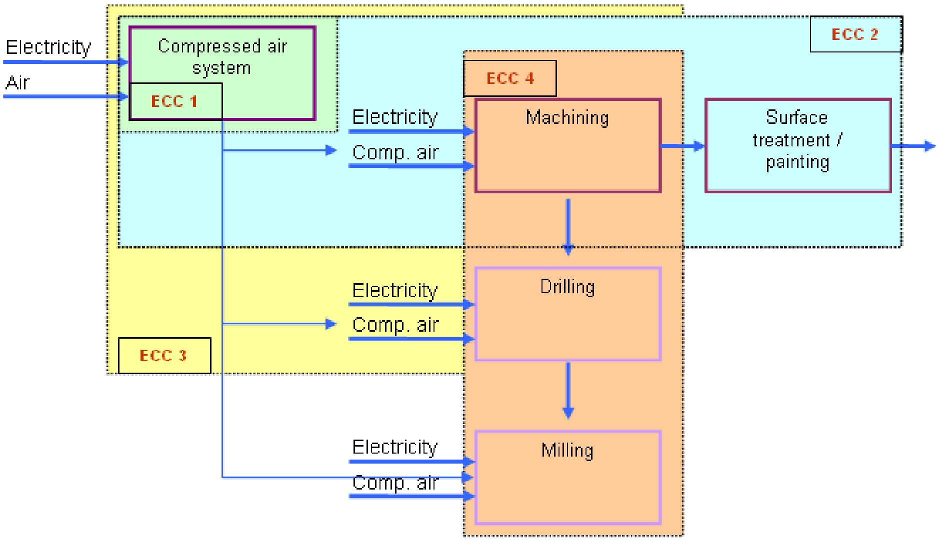

Figure 50: Example of Energy Cost Centres (ECC)

The proposed approach can be changed and adapted in the ways most suitable for any particular case.

4.2.6.7 Continuous improvement

The installation or implementation of energy metering equipments should not be a ‘one time’ activity. The idea is to keep improving until all areas will be covered, something that should take a long time period.

Every year, after the analysis of energy consumption it will be possible to identify new improvement potentials and new implementation plans should start.

4.2.6.8 Communication

Decisions should be reported and communicated, responsible must be recognized by the teams, the status of the budget and resources shall be updated, comments about benefits and failures shall be divulgated as well as both initial setup costs and ongoing costs throughout the adjustment period.

Well-informed employees are more motivated to participate in the results.

The Figure 51 helps to identify the main steps created for this concept, it is a summary of the flow of the activities.

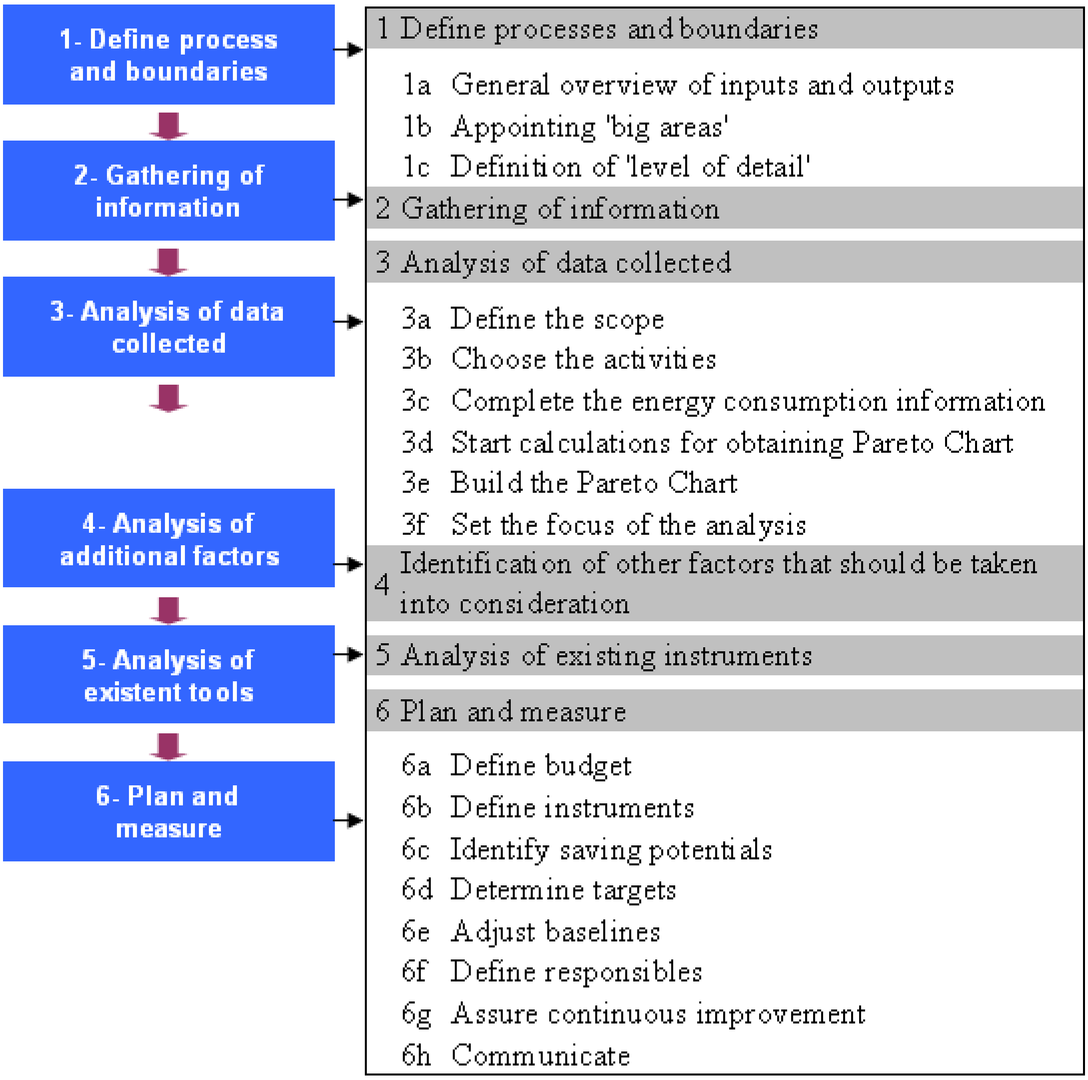

Figure 51: Summary of the flow of the activities

The next chapter presents three examples where the concept was applied, the data was collected with help of the employees from the Health Safety and Environment (HSE) department of each location analysed.

4.3 Analysis of results: Using the Concept for Implementing or Improving Instruments for Energy Data Collection

The process identified in the Figure 51 was applied in three different production sites of Knorr-Bremse Group: Aldersbach (Germany), São Paulo (Brazil) and Bristol (UK). The results are described in this chapter.

4.3.1 Production Site Aldersbach (Germany)

The location of Aldersbach (ALD), with 800 employees, produces mainly disk brakes and electronic air control (EAC), it was chosen due to the size and relevance of its site. A visit to the location was made where the information was collected.

4.3.1.1 Define processes and boundaries (ALD)

First of all the sources of energy were identified together with the potential losses of energy, see Appendix III.

Then the ‘big areas’ were defined, being:

- Production, understanding the energy expenditures directed related to the activities of producing;
- Plant, comprehending the energy costs for facilities in the production, such as lighting and heating;
- Warehouse, being the facilities for the storage area; and
- Office, relating the facilities for the office area.

The ‘big areas’ were further divided according to the rooms, this occurred because the buildings in Aldersbach were constructed in different periods, having different electricity installations.

In this case it was possible to define five levels, because of the information available, this information was not collected by electricity metering equipments, but through estimations.

It was concluded in the meeting that electricity consumption counts the most in Aldersbach, this was the starting point.

4.3.1.2 Gathering of information (ALD)

Data was collected in two ways, first the general electricity consumption obtained in the electricity bills, how presented in Figure 52.

It was identified a representative fall of energy consumption between the years of 2008 and 2009. That does not occur due to planned activities to improve energy efficiency, but because the economical crises of 2008/2009.

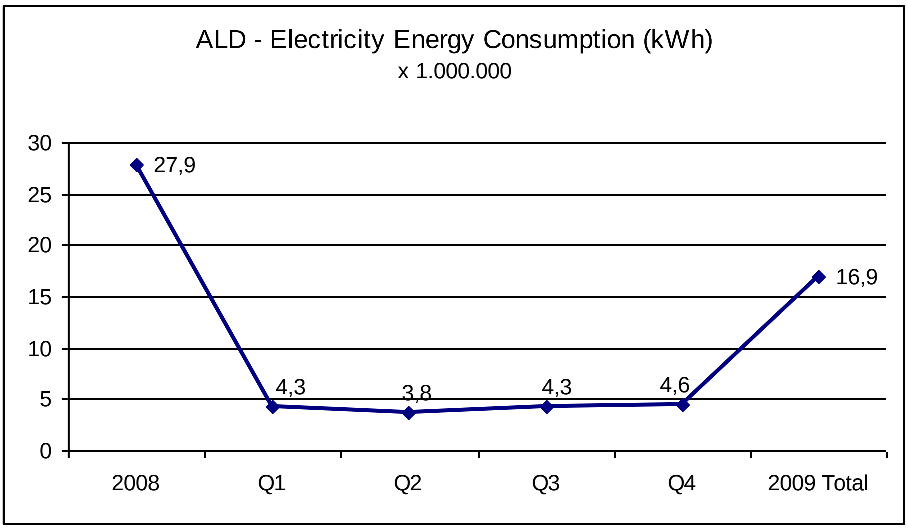

Figure 52: Aldersbach – Electricity Consumption 2009 (Source: KB intranet)

Taking into consideration that Aldersbach does not have the suitable electricity flow meters for measuring specific processes, lines, machines and so on, it was necessary to estimate the consumption.

The data from 2008 was considered for the estimation, since the crisis affected the numbers from 2009 taking from them the characteristics they should have to be appropriate to be used as baseline.

In the second place, it was identified that € 2.858.344 were spend in 2008 in Aldersbach in electricity.

4.3.1.3 Analysis of data collected (ALD)

For sake of simplicity in this paper, the scope was defined before collecting the data, being defined that only electricity consumption would be analysed.

Having the scope defined, the activities and their level of detail were chosen and can be identified in the Appendix IV, together with respective energy consumption information and calculations for obtaining the Pareto Chart.

After the calculations of available data it was possible to draw the Pareto Chart, which is represented in Figure 53:

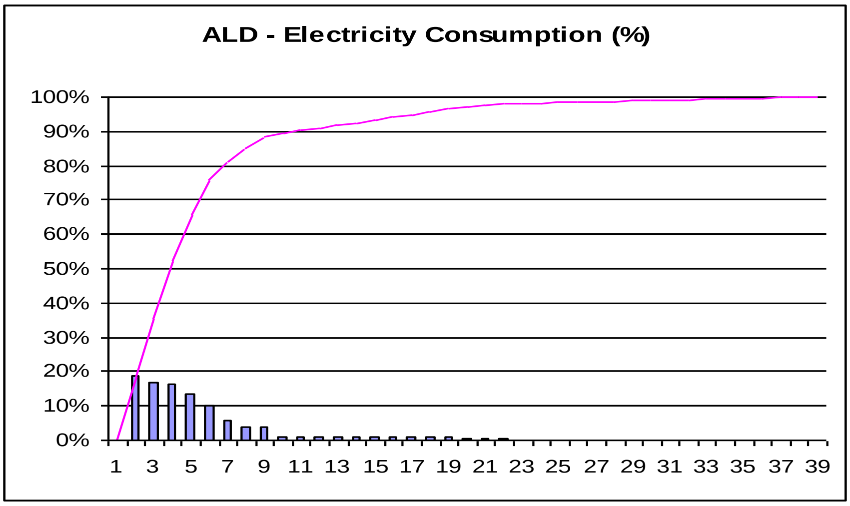

Figure 53: Aldersbach – Pareto Analysis

With the aid of the Pareto Analysis, the identification of largest electricity consumers was made.

Only six (representing 16%) from the 38 estimations account for 81,45% of electricity costs, the main consumers are phosphating, anodizing, comprising all activities from surface treatment and production facilities, finishing 1 and 2 from halls 9.3 and 9.4 that produce disk brakes.

After recognizing the largest electricity consumers, the next step would be to analyse the typical problems that can cause energy waste and consequently, are potential energy savings opportunities.

4.3.1.4 Identification of other factors (ALD)

From the activities that were outside the list of largest consumers, basically assembly, forklift charging and office facilities, it is possible to relate typical problems in process operations, compressed air and transport.

The facility manager and the HSE manager at Aldersbach mentioned the loss of compressed air in the tools from assembly processes, in this case, it would be more reasonable to analyse the losses of compressed air, and not of electricity for generating the compressed air.

The analysis of losses in electricity for generating compressed air shall be done in the beginning of the process, directly by the compressors, there are no data available in this case.

Staying with the analysis of the six largest electricity consumers in Aldersbach and continuing the study, before planning the implementation of new metering equipments, it is necessary to verify which ones already exist.

4.3.1.5 Analysis of existing instruments (ALD)

Some metering equipments were identified in the location, however all of them had only the purpose of measuring the instantaneous capacity, no one of them are suited for assisting the management of data.

The last step is a plan for installing (adapting or improving) electricity metering equipments.

4.3.1.6 Plan and measure

For the definition of the budget, this example will take into consideration the studies from the Australian Government and use the 1,5% of the total energy consumption of the previous year.

In Aldersbach, in 2009, were spent € 2.858.344,00 in electricity, from which 1,5% is equal to € 42.875,16 , considering that implementations will be made in 6 different areas, this value were divided into 6, resulting € 7.145,86 per activity.

The plan for the Phosphating area is represented in the figure below:

Plan: Introduction of Instruments for Energy Consumption Data Monitoring					
Reference	Phosphating				
Action	New metering equipment				
Budget (€)	€ 4.145,86				
Resources					
Current situation	No meter, just estimations				
Indicators	(will be defined in phase 6)				
Saving potentials	(will be defined in phase 5)				
Approval & completion	Industrial Engineering Manager				
Task	**Priority**	**Responsible**	**Start date**	**End date**	**Comments**
1. Outsourcing or internal	1	Internal, facility manager	Jan.2010	Jan.2010	
2. Research of suitable equipment	1	Facility manager	(...)	(...)	
3. Verification with budget	1	Facility manager	(...)	(...)	
4. Identification of saving potentials	1	Engineering manager	(...)	(...)	
5. Definition of new baselines	2	Facility manager	(...)	(...)	
6. Definition of targets	1	Facility manager with responsible	(...)	(...)	
7. Definition of responsible for achievement of targets	1	ECC galvanization worker	(...)	(...)	
8. Definition of next phase	1	Facility manager	Dec.2010	Dec.2010	

Figure 54: Aldersbach, Plan to Introduce Instruments for Energy Consumption Data Monitoring

The figure representing the plan for Aldersbach is just an example about how the process would work, the actual implementation is the next step planned, which requires considerable time.

4.3.2 Location Bristol – United Kingdom

The location of Bristol (BRI) is dedicated to remanufacturing of compressors and brake chambers and count with circa 180 employees, it was chosen due to the high level of organization in terms of quality and environmental management systems.

The production site is divided in two parts, being Kingswood where the remanufacturing factory is and Century House formed by office, warehouse and facility. Both sites are only 7km apart from each other.

4.3.2.1 Define processes and boundaries (BRI)

In this site, the definition of energy consumers was done only until level 4, as shown in the Table 20. The 'big areas' were defined in the level 2 as production, administration, quality, stores, plant, support services, warehouse and offices.

Table 20: Bristol – Identification of Energy Sources and Consumers

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS														
Location: Bristol				Identification of energy inputs/ outputs										
Date:				Energy Input						Energy Output				
				Gas	Electricity	Fuel (oil / coal)	Compressed air	Steam	Water	Electricity	Compressed air	Thermal energy	Steam	Water
Level 1	**Level 2**	**Level 3**	**Level 4**											
Kingswood Site	Production	Remanufacture		X	X		X		X	X	X	X		X
Kingswood Site	Production	Basement Valve Assembly			X		X		X		X			
Kingswood Site	Production	Machine Shop			X		X		X	X	X			X
Kingswood Site	Production	Welding Shop			X		X		X	X	X	X		
Kingswood Site	Production	Assembly Shop			X		X		X	X	X			
Kingswood Site	Administration	Office			X					X				
Kingswood Site	Quality	Standards Room			X					X				
Kingswood Site	Quality	Customer Quality			X		X			X	X	X		
Kingswood Site	Stores	Machine Shop	Raw material storage		X									
Kingswood Site	Stores	Assembly shop	Detail part storage		X									
Kingswood Site	Stores	Basement	Goods receiving		X					X		X		
Kingswood Site	Plant	Facilties		X	X		X		X	X	X	X		X
Kingswood Site	Support services	Maintenance/Labels			X		X		X	X				X
Kingswood Site	Plant	Computer support areas			X					X				
Kingswood Site	Plant	Facilties	Air Compressors		X		X			X	X	X		
Century House	Warehouse	Finished goods storage			X					X				
Century House	Warehouse	Product kitting			X					X				
Century House	Offices	Ground Floor			X					X				
Century House	Offices	First Floor			X					X				
Century House	Plant	Facilties		X	X		X		X	X		X		X
Century House	Warehouse	Service Area	Compressor		X							X		
Century House	Plant	Common rooms	Computer support		X					X		X		

4.3.2.2 Gathering of information (BRI)

The same general electricity consumption data, as Aldersbach, is available for Bristol, the electricity consumption acquired from the supplier's bills, showing the same patterns due to the crisis, as in Figure 55.

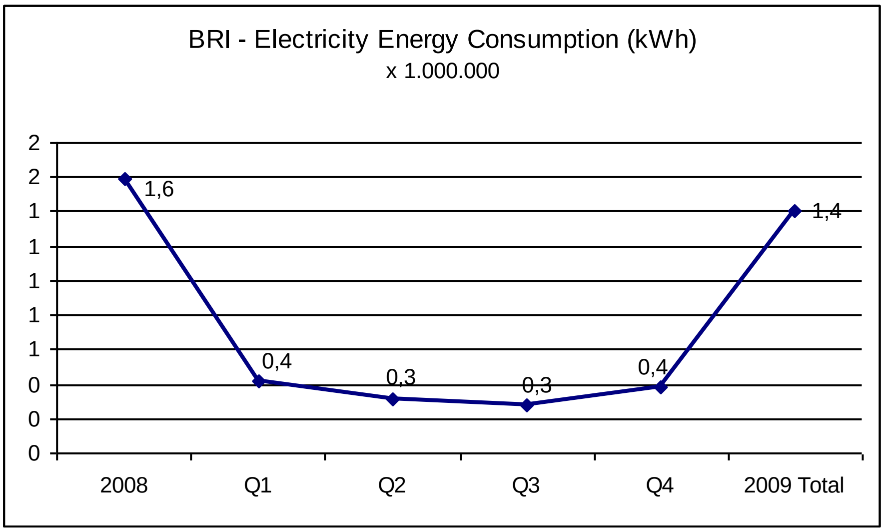

Figure 55: Bristol – Electricity Consumption 2009 (Source: KB intranet)

In 2008, Bristol had expenses of € 205.640,00 in electricity, for both together Century House and Kingswood.

4.3.2.3 Analysis of data collected (BRI)

As in the previous case, to make possible the comparison of analysis, it was chosen the investigation of electricity data.

In this case, however, there are no detailed data, not even gathered through estimations, the only available data were the electricity bills and a resource about electricity consumption by compressors.

This research has been done during the last six months, in the results it was possible to identify that compressors have an average electricity consumption of 1,06% per month over the total amount.

For these reasons, the analysis was divided in two groups of activities: office + production and compressed air.

Having these data in hands, the calculation of consumption was done and is represented in the Table 21, as follows.

Table 21: Bristol – Electricity Consumption 2009

Electricity Consumption 2009 (Analysis)													
Location: Bristol Date: 17.09.2010		Identification of energy inputs/ outputs											
		Electricity - Input										Output	
Level 1	Level 2	Consumption (kWh)	Percentage	Cumulative percentage	Level where metering equipments already exist	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name	Type	Measured (y /n)
Production + Office		1,58	98,94%	98,94%		1		1		1	Estimation		no
Compressed air	Compressed air	0,02	1,06%	100,00%		1		1		1	Estimation		no
	TOTAL	1,6	100,00%								Electricity bill		

The Pareto Analysis makes no sense in this situation, where only two factors are presented, it is possible to skip it and go straight to the analysis of other factors or anomalies.

4.3.2.4 Identification of other factors and existing instruments (BRI)

In this case, the identification of other factors or anomalies will be part of the main final plan.

The next step would be to identify the existing metering equipments, but no meters were identified.

4.3.2.5 Plan and measure (BRI)

Considering that Bristol consumed € 205.640,00 of electricity in 2009, and using the same assumption as the example before, 1,5% of this amount is equal to € 3.084,60, which is the value budgeted for the next period.

The plan for Bristol is shown below in the Figure 56:

Plan: Introduction of Instruments for Energy Consumption Data Monitoring					
Reference	Production				
Action	Start estimations and identification of saving potentials				
Budget (€)	€ 3.084,60				
Resources	IT, etc				
Current situation	Only for compressed air				
Indicators	(will be defined in phase 6)				
Saving potentials	Will be identified during the research				
Approval & completion	Industrial Engineering Manager				
Task	**Priority**	**Responsible**	**Start date**	**End date**	**Comments**
1. Outsourcing or internal	2	Internal	Jan.2010	Jan.2010	
2. Research of suitable equipment	2	To be defined	(...)	(...)	In a further phase
3. Verification with budget	1	To be defined	(...)	(...)	
4. Identification of saving potentials	1	To be defined	(...)	(...)	
5. Definition of targets	1	To be defined	(...)	(...)	
6. Definition of new baselines	2	To be defined	(...)	(...)	
7. Definition of responsible for achievement of targets	1	To be defined	(...)	(...)	Depends on where the activities will be focused
8. Definition of next phase	1	Industrial Engineering Mgr	Dec.2010	Dec.2010	

Figure 56: Bristol – Plan to Introduce Instruments for Energy Consumption Data Monitoring

The plan for Bristol is also just an example, further work in developing an adequate plan is required and considerable time should be dedicated for it.

4.3.3 Location São Paulo - Brazil

The site production of São Paulo has 727 employees and there, practically all sort of Knorr-Bremse products are manufactured, it was chosen randomly.

The construction of a new plant in São Paulo is planned for the next year, in this way the employees that sent the information about the location suggested to start doing the identification of the levels of energy consumers after the plant is ready.

Until this moment the analysis of the electricity consumption in São Paulo is made through estimation and distributed into Rail and Truck (CVS) that are further divided into two 'big areas', office and production.

4.3.3.1 Gathering of information (SAO)

Data found for the year 2008 shows that the whole location consumed 5.500.000 kWh as showed in Figure 57, from which 25% are considered to be spent by the office and 75% by the production, as represented in the Table 22.

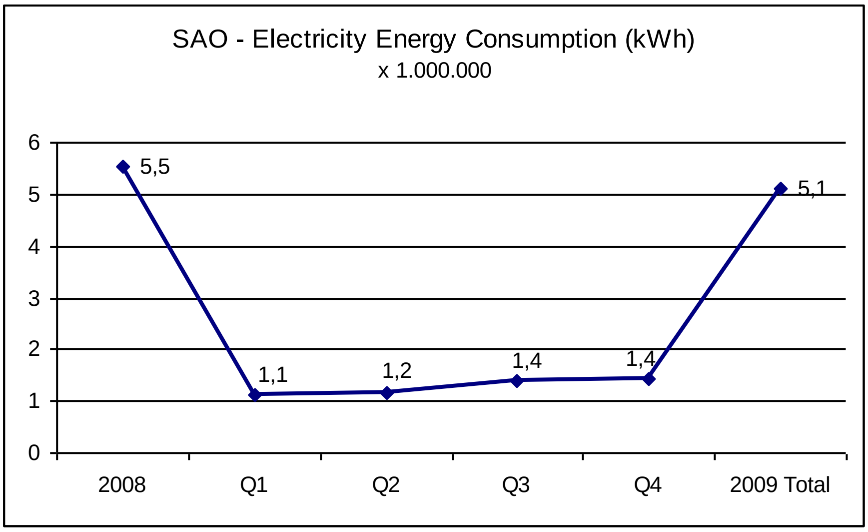

Figure 57: São Paulo - Electricity Consumption 2009 (Source: KB intranet)

4.3.3.2 Analysis of data collected (SAO)

Once again the scope defined was the investigation of electricity consumption and since the location suggested waiting for the new plant to better define the level of detail, the analysis was based dividing the two corporate divisions (Rail and Truck) in two main areas each: production and office, considering the percentages mentioned before.

Table 22: São Paulo – Electricity Consumption 2009

Electricity Consumption 2009 (Analysis)														
Location: Sao Paulo			**Identification of energy inputs/ outputs**											
Date: 17.09.2010			**Electricity - Input**										**Output**	
			Consumption (kWh)	Percentage	Cumulative percentage	Level where metering equipments already exist	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name	Type	Measured (y /n)
Level 1	**Level 2**													
Truck	Production	1	3,5	62,61%	62,61%		**1**		**1**		**1**	**Estimation**		**no**
Truck	Office	2	1,2	20,87%	83,48%		**1**		**1**		**1**	**Estimation**		**no**
Rail	Production	3	0,7	12,34%	95,83%									
Rail	Office	4	0,2	4,17%	100,00%									
	TOTAL		5,5	100,00%								**Electricity bill**		

The percentages were defined through estimations, which were done measuring the electricity consumption in a day that only production was working, then in another day when both production and office were working, later results were compared arriving to the values presented.

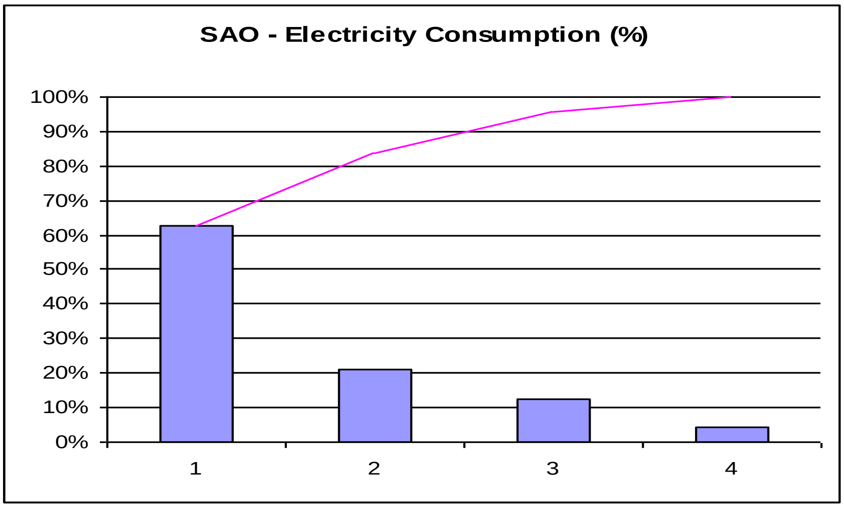

Figure 58: São Paulo – Pareto Analysis

The Pareto Analysis was made (see Figure 58) and the results presented that 83,53% of the electricity consumption is in the CVS division (truck), from which 41,5% is spent in production.

4.3.3.3 Identification of other factors and existing instruments (SAO)

After analysing the data, the anomalies and other factors, according to Table 14, should be identified, as well as the already existing meters.

Considering the fact that a new plant is planed for the next year and assuming that this plant will be already provided with some kind of metering equipments, the focus of the efforts in this case may be in other activities, such as the study of possible anomalies.

4.3.3.4 Plan and measure (SAO)

The focus for this plan was defined as the study of typical problems and possible anomalies, for this activity the budget was stipulated with the same logic as the previous examples, being the electricity consumption of € 635.553,22 in 2008, 1,5% of this amount is equivalent to € 9.533,30.

An example for the plan for São Paulo is represented in the Figure 59.

Plan: Introduction of Instruments for Energy Consumption Data Monitoring					
Reference	Production – Truck				
Action	Study of saving potentials				
Budget (€)	€ 9.533,30				
Resources					
Current situation	No meter, just estimations				
Indicators	(will be defined in phase 6)				
Saving potentials	Main part of this plan				
Approval & completion	Industrial Engineering Manager				
Task	**Priority**	**Responsible**	**Start date**	**End date**	**Comments**
1. Outsourcing or internal	2	Internal	Jan.2010	Jan.2010	
2. Research of suitable equipment	2	To be defined	(...)	(...)	
3. Verification with budget	1	To be defined	(...)	(...)	
4. Identification of saving potentials	1	To be defined	(...)	(...)	
5. Definition of new baselines	1	To be defined	(...)	(...)	
6. Definition of targets	1	To be defined	(...)	(...)	
7. Definition of responsible for achievement of targets	2	To be defined	(...)	(...)	
8. Definition of next phase	1	Industrial Engineering Mgr	Dec.2010	Dec.2010	

Figure 59: São Paulo, Plan to Introduce Instruments for Energy Consump. Data Monitoring

Further analysis are required, the suggestion is to work in the typical problems to avoid them to be present in the new plant and study the metering system in next plans, to keep improving.

5 CONCLUSIONS

It is known that companies prioritize investments where immediate cost reductions can be identified, this may be addressed as one of the main reasons why they are not interested in implementing an Energy Management System.

Usually returns on investments made in energy consumption field are not possible to be predicted, still less likely when referring to investments in metering equipments. Benefits in implementing an Energy Management System are not easily identified, even though the importance in controlling energy consumption and its impacts has been intensified lately.

This paper shows how simple tools can help starting the implementation of an Energy Management System in a company. It is for sure time consuming and requires resources such as people and money, nevertheless it becomes more and more necessary and calls for everyone’s attention.

5.1 Management System Status Evaluation

Management System Status Evaluation part in a first place, identified the similarities between the international standards for energy and environmental management. The Table 23 shows that the energy standard is more detailed as the environmental standard, but even though it does not have many extra requirements.

The main differences identified between the energy and the environmental standards are represented in the Table 23 in blue and orange.

Sentences in blue correspond to the requirements that were only more specifically detailed, for example, while in the ISO 50001:2009 (draft version) the energy aspects were described in 3 points (energy profile, energy baseline and energy performance indicators) in the ISO 14001 this characteristics were grouped under one topic simply called ‘environmental aspects’.

Lines in orange represent the most significant changes. The energy standard recognized the need of highlighting the impact of energy in energy purchasing contracts, in purchasing of goods and services and in designing new plants, production lines, products, etc. To fulfil these specific requirements, processes should be reviewed.

For starting the implementation, it was identified that fulfilling the requirements 4.4.2 energy profile, 4.4.3 energy baseline and 4.4.4 energy performance indicators would involve more efforts. Some energy aspects may already be found in the environmental aspects, but the ISO 50001:2009 demand more detailed energy characteristics.

Table 23: Comparison between the requirements of ISO 50001 and ISO 14001

Comparison between standards			
	ISO 50001:2011 Energy Management		**ISO 14001:2009 Environmental Management**
4.1	General requirements	4.1	General requirements
4.2	Management Responsibility		
4.2.1	Commitment of top management		
4.2.2	Roles, responsibility and authority	4.4.1	Structure and resposibility
4.3	Energy policy	4.2	Environmental Policy
4.4	Planning	4.3	Planning
4.4.1	General		
4.4.2	Energy profile	4.3.1	Environmental aspects
4.4.3	Energy Baseline		
4.4.4	Energy performance indicators		
4.4.5	Legal and other requirements	4.3.2	Legal and other requirements
4.4.6	Objectives, targets and action plans	4.3.3	Objectives and targets
		4.3.4	Environmental management programme (s)
4.5	Implementation and operation	4.4	Implementation and operation
4.5.1	Competence, training and awareness	4.4.2	Competence, training and awarness
4.5.2	Documentation	4.4.4	Documentation
4.5.2.1	Documentation requirements		
4.5.2.2	Control of documents	4.4.5	Control of documents
4.5.3	Operational control	4.4.6	Operational control
4.5.4	Communication	4.4.3	Communication
4.5.5	Design		
4.5.6	Purchasing energy services, goods and energy		
4.5.6.1	Purchasing of energy services and goods		
4.5.6.2	Purchasing of energy		
		4.4.7	Emergency preparedness and response
4.6	Checking performance	4.5	Checking and corrective action
4.6.1	Monitoring, measurement and analysis	4.5.1	Monitoring and measurement
4.6.2	Evaluation of legal/other compliances		
4.6.3	Internal audit	4.5.4	Environmental management system audit
4.6.4	Nonconformities, corrective, preventive and improvement actions	4.5.2	Nonconformities, corrective and preventive actions
4.6.4.1	Nonconformities		
4.6.4.2	Corrective and preventive actions		
4.6.5	Control of records	4.5.3	Control of records
4.7	Review of the energy mgmt system by top management	4.6	Management review
4.7.1	Inputs to management review		
4.7.2	Outputs from management review		

Some actions required by the energy standard can be combined with the ones from the environmental standard, such as communication, control of records, documentation and even the energy policy or the responsible.

The requirement 4.6.1 (monitoring, measurement and analysis) is, in a certain way, connected to the energy aspects, once establishing the energy profile, baseline and performance indicators, the monitoring, measurement and analysis will have the directions to be carried out. For example, every analysis needs a baseline to compare results and energy consumption may be monitored through energy performance indicators.

In the second part of Management System Evaluation section, a checklist was formulated with the aim to identify how far an organization is to implement an Energy Management System, its formulation was based on the ISO 50001:2009 (draft version).

Results showed that sites that already had ISO 14001:2004 certification were closer to the implementation of an Energy Management System, such as the case represented in Figure 60 of Knorr-Bremse Bristol (UK) that has already fulfilled 70% of the requirements.

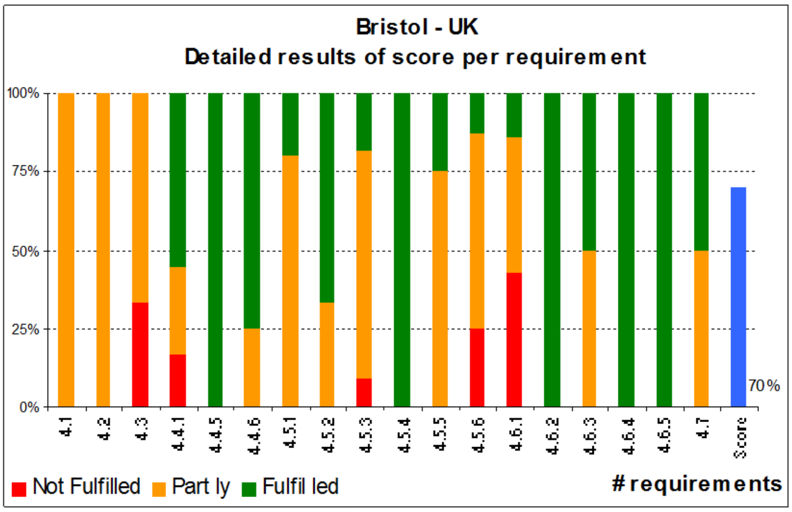

Figure 60: Results per requirement - Bristol

By another hand, the production location of Knorr-Bremse Dalian (China), which is not certificated by ISO 14001:2004 shows to have a long way to go for completing the energy management standard requirements. (Figure 61)

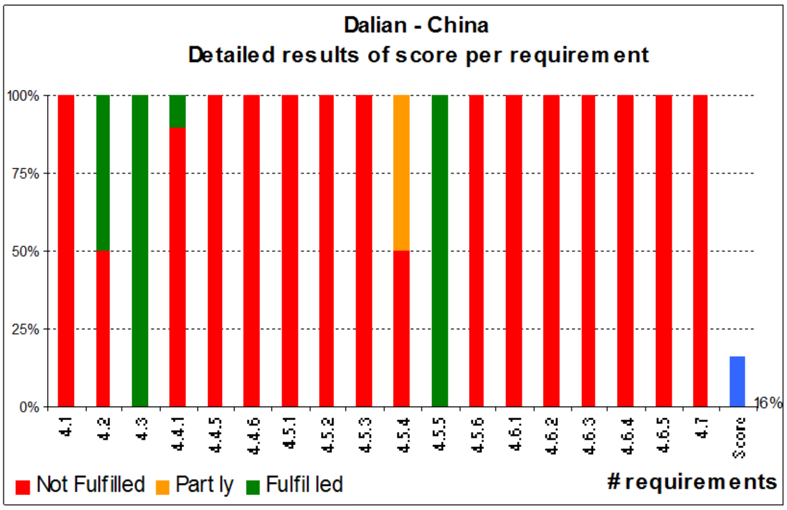

Figure 61: Results per requirement - Dalian

The checklist is a simple tool, but requires attention on the answers, even having direct questions they may be interpreted in different ways, an example is what happened in São Paulo, when receiving the questionnaire, they thought that the case should be treated totally separated from the environmental management system, that an energy management system should start from zero other than using an integrated management system.

Having this point of view their answers did not consider structures already existent, such as the system documentation structure used by ISO 9001:2008 and ISO 14001:2006, that could also be applied for ISO 50001:2009.

Considering cases such as São Paulo, further investigations may be needed, to accurately understand the real situation in each case where the checklist is applied.

In the case of Knorr-Bremse (Region Europe + São Paulo), analysing the results of the status evaluation of Knorr-Bremse, three main weaknesses were identified: competence, training and awareness; purchasing and monitoring, measurement and analysis.

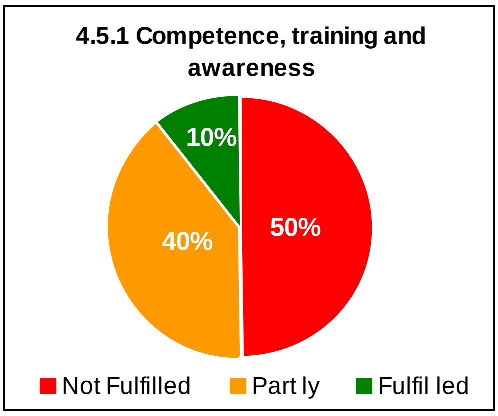

Figure 62: Requirement 4.5.1

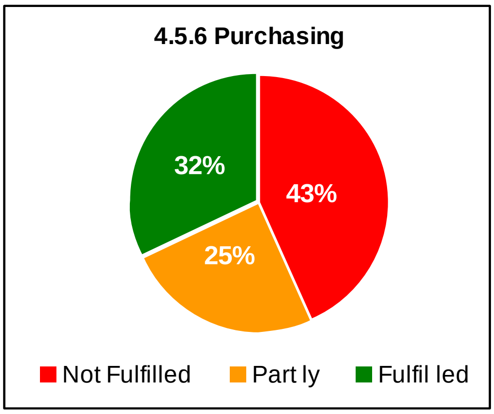

Figure 63: Requirement 4.5.6

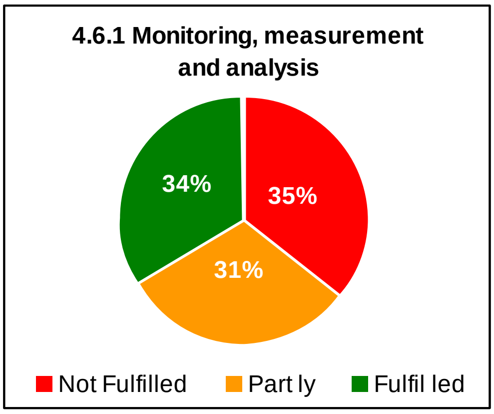

Figure 64: Requirement 4.6.1

The conclusion was that for improving the situation of purchasing a simple action is required, the review of processes to identify where the energy use is relevant and the introduction in the processes where it is relevant.

Competence, training and awareness requirement is a matter of adding references to energy use in the already existing plans.

Monitoring, measuring and analysis requirement demands a deeper investigation, since may involve the acquisition of new equipments to enable the energy data consumption collection and it will the basis for establishing objectives, targets and action plans.

Having the results acquired in Knorr-Bremse (Region Europe + São Paulo) in mind, it was decided to develop a concept that helps introducing or implementing energy consumption data monitoring equipments, to create a solid basis for the energy management system.

The checklist turned out to be a simple tool that helps companies to identify where to start focusing attention in an energy management system implementation. It was also observed that a company ISO 14001:2004 certificated it is very close to the completion of the requirements of ISO 50001:2009, this fact reduces the amount of resources required for the implementation of the new standard.

Different companies will have different results applying the same checklist, but in any case it is possible to identify the strengths and weaknesses of the management system, simply by looking at the graphs generated by answering the questions.

5.2 Implementing or Improving Energy Consumption Data Instruments

Another objective of this paper is to create an approach that helps the fulfilment of the gaps identified in the status analysis, for accomplish with this objective it was chosen the topic monitoring, measurement and analysis, since it was considered of great relevance when starting the energy management system implementation.

It is necessary to know if the efforts made managing the energy system are leading to the expected results. It is not possible to manage what can not be measured

A concept for guiding the implementation or improvement of energy consumption metering equipments was developed, the concept is quite simple and embraces two main characteristics that affect energy consumption, which are volume of energy consumed and the typical problems that cause energy waste.

The analysis of these two characteristics gives the directions about how to focus the further implementations.

The concept created has 6 main steps, for supporting the completion of step '1-Define process and boundaries', the tool 'Identification of energy sources and consumers' was created (see the example of Appendix III), for helping the steps '2-Gathering of information' and '3-Analysis of data collected' the tool 'Energy consumption analysis' was developed, as seen in appendix IV.

For the step '6-Plan and measure' the instrument 'Plan: metering equipment installation/ improvement' was built, as shown in appendix VIII. The Figure 65 represents the summary of the concept.

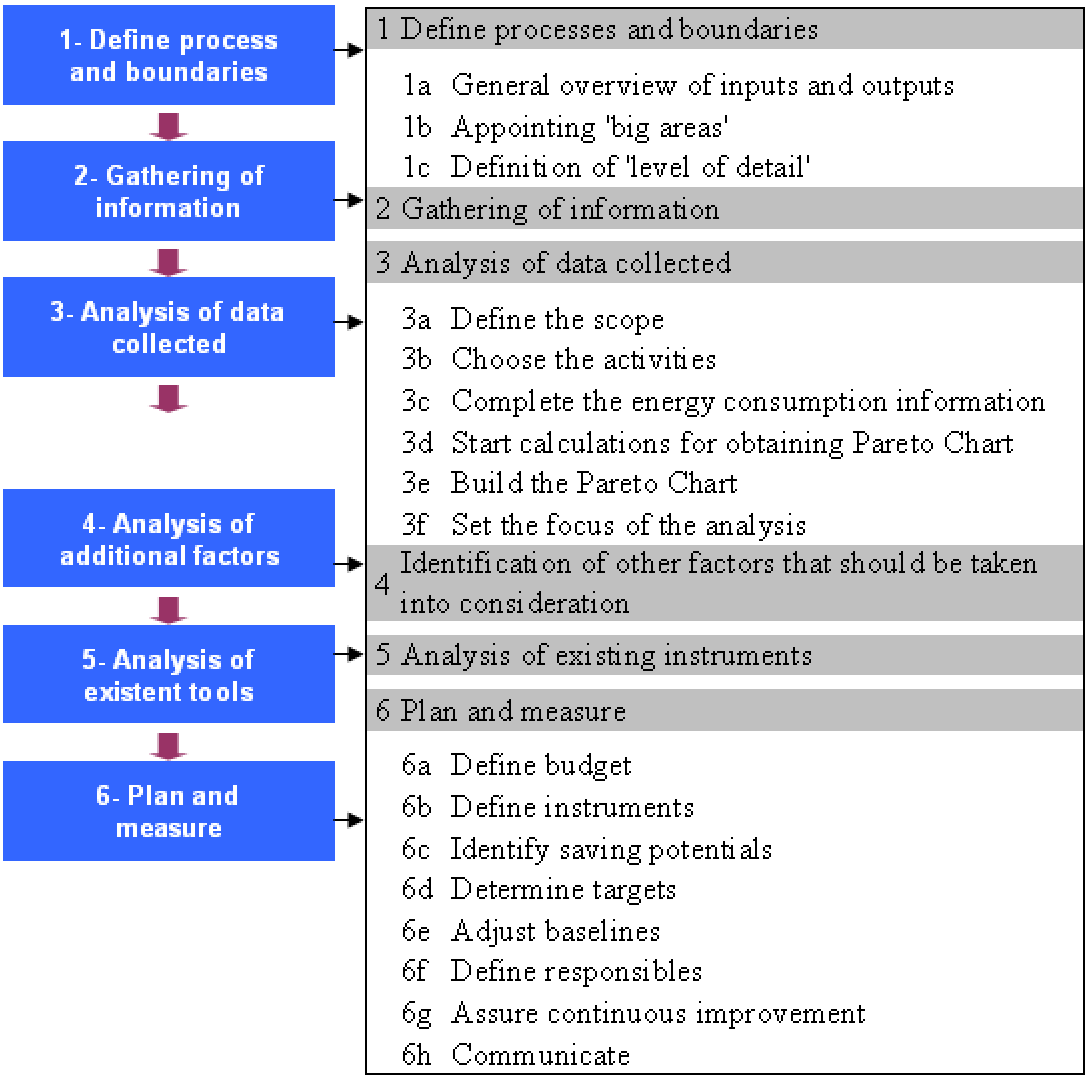

Figure 65: Summary of the flow of the activities

The concept was applied in three production sites: Aldersbach (Germany), Bristol (UK) and São Paulo (Brazil) and observing their results it is possible to conclude that despite of the differences such as organization of processes, size, volume of energy consumed and particular characteristics of each production site (for example, the moment of building a new plant as in São Paulo), the tool developed in this paper can still be applied.

In the case of Aldersbach the information received was more complete, allowing a definition of an action plan for each of the largest electricity consumers founded.

Bristol does not have estimations in the same level of detail as Aldersbach, for this location the action plan suggested was to start doing more detailed estimations, so that a better analysis will be possible in the near future.

São Paulo did not accept the fact of spending time looking for metering equipments in a plant that will be deactivated. It does not mean that any action can be taken, so the suggestion was to investigate typical problems that occur in this kind of manufacturing system in the way to avoid their occurrence in the new plant.

There are three different directions found, each case with its particular results, the main idea is to start doing something with the aim to continuous improve the processes.

The concept for implementing or improving instruments for energy data collection turned out to be useful in order to give a direction about how to enrich a measuring and monitoring system and to sustain a continuous improvement process.

5.3 Exploration of Possible Benefits Implementing an Energy Management System

Since this work was developed in an industry, some conclusions came with the experience, observing the system, the behaviour of workers and their response to the issues of an Energy Management System.

As a result, benefits of the implementation of an Energy Management System were raised. These benefits can be recognized into different scopes, for instance: cost of energy usage, cost of energy contracts and image of the organization.

Several flaws responsible for misuse of energy fail to be identified due to lack of investments in measurement equipments, in some cases, these problems are not avoided only because they can not be detected.

The identification and management of such failures can turn continuous sources of waste into quick wins. Through a permanent measurement system, these sources of waste become evident and possible to be eliminated.

These sources can be leakages in compressed air system, lack of adjustments in temperatures, absence of heat recover, flooded heaters, poor feed water heater performance, unnecessary usage of compressors, etc.

The cost reduction, in this case, may not occure only by reducing energy consumption, but also in reducing costs related to the production, such as decrease of number of scraps generated due to wrong adjustments in the machine.

Simple actions can be taken to change the scenario, such as improving plant utilization, reducing material inputs, improving efficiency of existing equipments, reducing capacity requirements, to name but a few. All of them lead to the energy efficiency improvement.

The benefits, brought by focusing on these issues, are the control of rising energy costs as well as their reduction.

A good understand of energy contracts can bring a cost reduction in the cases where the contracts and the way that energy is billed are carefully examined. Contracts may contain penalties for reducing energy demand, or annual pricing linked to periods of peak demand, i.e. to make a closer alignment of energy procurement with actual energy needs of the company.

The concern about energy consumption brings up also the matter of global warming, and the company starts to introduce a sustainable thinking among the employees, engaging staff in programs to identify energy efficiency opportunities can make them feel more involved in decision making and contribute to improved levels of job satisfaction.

It provides a nicer environment, improving work conditions for personnel, in cases such as reducing heat from process, improving lighting or reducing noise. It also presents the possibility to direct the attention to health and safety issues related to risks using high temperatures and steam.

Energy efficiency improvements contribute directly to an organization's greenhouse gas (GHG) reduction performance and carbon costs, providing access to external funds for energy efficiency and GHG projects.

The employees' awareness and apparent concern with the environment, improve corporate reputation and image.

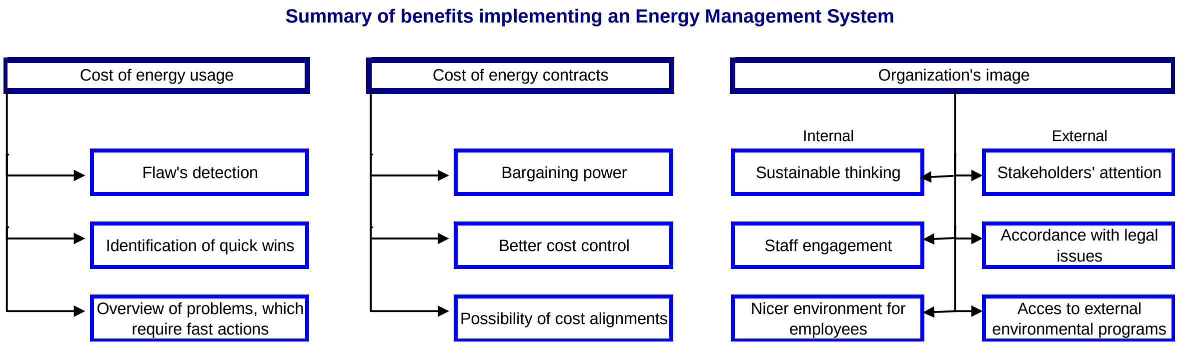

Figure 66: Summary of benefits

Apart from the benefits, some barriers to implement an Energy Management System and consequently improve industrial energy efficiency were identified during this research, the most common include lack of information or energy data, limited awareness of the benefits arising from energy efficiency measures, lack of knowledge from the employees, deficiency in communication about the topic, capital constraints and corporate culture leading to more investment in production capacity rather than energy efficiency.

Nevertheless, an energy management system will deliver significant benefits by reducing energy usage and simple actions often identify problems, a simple spreadsheet based on basic information, such as a nominal motor size and estimated running hours, gives a lot of information, the matter is, it always needs to start somehow.

For continuing the implementation of an energy managment system, further work is suggested, first the development of models to perform cost-benefit assessment of energy metering practices for energy efficiency, based on such model values can be better estimated and directed to investments in process improvements.

Having in mind the results of the gap analysis, another suggestion is in the purchasing aspect, investigating if all process that affect energy consumption are taken into account and developing a concept to introduce the suitable changes.

The implementation of an energy management system may be a hard work, that demand resources and in a first sight increases cost, it also does not bring visible results immediately and savings are hard to be accurately calculated. It is, anyway, a subject of increasingly importance and work has to start to be done in order to begin understanding the energy consumption impacts and turn them into actual advantages inside an organization.

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7 APPENDIX

7.1 Appendix I – Checklist

KNORR-BREMSE
Systeme für Nutzfahrzeuge

Please use 'x' in evaluation box

Status evaluation for the implementation of an Energy Management System according to ISO 50001 draft

LOCATION: *please enter here location name*
DATE: *DD.MM.YYYY*
NAME: *please enter here contact person*

Req. No	Element Requirement / Questions	Evaluation: Not Fulfilled	Evaluation: Partly	Evaluation: Fulfilled	Evaluation: not applicable	Comments to explain the evaluation i.e. evidences	rating score and inter-mediate results (%)
4.1	**General requirements**						0%
1	Has the organization defined an Energy Management System accordingly to ISO 50001?						0
4.2	**Management responsibility (4.2.1/ 4.2.2)**						0%
1	Has the organization defined an energy management representative (energy manager) and defined their roles, responsibilities and authorities?						0
2	Are the specialized skills, human, financial and technological resources necessary for energy management identified and provided by the board?						0
4.3	**Energy policy**						0%
1	Has the board defined in writing a policy, which includes also a commitment to continuous improvement of energy efficiency?						0
2	Does the policy show a commitment to achieve the energy management objectives and to reduce energy related emissions?						0
3	Is the policy available to internal and external public?						0

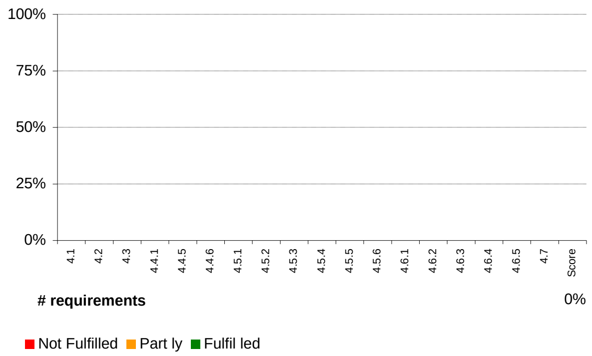
4.4	**Planning**						
4.4.1	**Energy profile/ baseline/ Energy KPI (4.4.2/ 4.4.3/ 4.4.4)**						0%
1	Have you identified the past and present information of energy consumption in the relevant activities/processes of the site?						0
	Have you checked this information for all inputs:						
2.A	electricity?						0
2.B	gas?						0
2.C	district heating?						0
2.D	fuel (oil)?						0
3	Have you made an analysis showing significant changes in energy consumption out of this data?						0
4	Is there an estimate of the energy consumption for the following periods?						0
5	Have you identified operations/processes, whose actions may lead to significant changes in energy consumption?						0
	Have you identified opportunities for improving energy efficiency? Such as, reduction of consumption of energy in:						
6.A	ventilation and air conditioning?						0
6.B	compressed air?						0
6.C	illumination?						0
6.D	heating?						0
6.E	manufacturing processes?						0
6.F	cold production?						0
6.G	electrical drives?						0
6.H	IT?						0
6.I	Other? Which?						0
7	Is there a register of identified energy saving potentials?						0
8	Are the energy saving potentials reviewed in predefined intervals?						0
9	Are the significant energy issues prioritised for further analysis?						0
10	Are the carbon emissions identified and calculated?						0
4.4.5	**Legal obligations and other requirements**						0%
1	Does a procedure exist in order to identify current applicable legal obligations and other requirements related to energy usage/consumption on site?						0
2	Does a register of applicable energy related legal obligations and other requirements exist,which is updated in regular intervals?						0
4.4.6	**Objectives, targets and action plans**						0%
1	Has the organization defined an objective related to consumption of energy; eg. increasing of energy efficiency?						0
2	Are specific and measurable targets, and related specific indicators, defined for significant energy usages?						0
3	Has the organisation defined an action plan for achieving objectives and targets?						0
4	Has the organization put in documented action plans, the responsabilities, times and means for their achievement?						0

4.5	**Implementation and operation**						
4.5.1	**Competence, training and awarness**						0%
1	Is the energy management representative (energy manager) appropriate, competent and qualified?						0
2	Are the training needs identified, for those activities that may have an effect on the energy efficiency?						0
3	Are the special energy management related training included in the local training plan?						0
4	Are any information/training given to temporary workers and subcontractors' personnel working on site so that they are aware of the energy management system of the company?						0
5	Are there any events performed to promote awarness for employees about energy usage and consumption, as well as climate protections? (quizz, energy day, etc)						0
4.5.2	**Documentation (requirements and control; 4.5.2.1/4.5.2.2)**						0%
1	Is the system documentation structured for energy management and the interaction between documents defined?						0
2	Are the core elements of the energy management system identified? (eg. Enery related requirements in purchasing, production planning, product development processes, etc)						0
3	Are any existing energy related documentation integrated into the documentation management system? (eg. energy saving concepts, guidelines, standards, procedures, etc)						0
4.5.3	**Operational control**						0%
	Do exist guidelines/ concepts for basic and detailed analysis of high energy consuming processes in order to identify saving potentials, (optimization in general or based on any changes of operations) on site, in the fields:						
1.A	compressed air system?						0
1.B	heating/ cooling of buildings?						0
1.B	illumination?						0
1.D	machines?						0
1.E	Other? Which?						0
2	Do the rules to improve energy efficiency cover the maintenance of the equipment?						0
3	Is the use of equipment included in the rules to improve energy efficiency, including start up and shut down stages?						0
4	Do the rules to improve energy efficiency cover building works and equipment modifications?						0
5	Does the organization plan monitoring and measuring of all significant energy consumption and energy factors?						0
6	Are any energy efficiency assessments undertaken in the identificated activities?						0
7	Are energy load trends monitored?						0
4.5.4	**Communication**						0%
1	Does the company communicate internally the policy, targets, actions and results concerning energy efficiency?						0
2	Does a procedure exist which manages communication about the energy issues inside the organization, and to and from outside?						0

4.5.5	**Design**						0%
1	Is there any guideline/procedure that takes into account the energy efficiency when designing/ modifying a new plant/ building?						0
2	Is there any guideline/procedure that takes into account the energy efficiency when designing/ modifying a production/ assembly line?						0
3	Is there any guideline/procedure that takes into account the energy efficiency when designing/ modifying a manufacturing process?						0
4	Is there any guideline/procedure that takes into account the energy efficiency when designing/ modifying a new product?						0
5	Does the design FMEA take into account energy aspects ?						0
4.5.6	**Purchasing (4.5.6.1/ 4.5.6.2)**						0%
1	Is there any rule, procedure, instruction that takes into account the energy efficiency when evaluating a purchase?						0
2	Is there any guideline/procedure that takes into account the energy efficiency when purchasing a new equipment?						0
3	Is there any guideline/procedure that takes into account the energy efficiency when purchasing services?						0
4	Is there any guideline/procedure that takes into account the energy efficiency when purchasing products?						0
5	Is there any energy use over lifetime assessed when purchasing a new product or equipment?						0
6	Is there any guideline/procedure to guide the purchasing of energy?						0
7	Are there any bundling energy contracts? (with another company or KB-location)						0
8	Are energy prices monitored?						0
4.6	**Checking performance**						
4.6.1	**Monitoring, measurement and analysis**						0%
	Do you have appropriate equipments to measure the energy consumption of:						
1.A	ventilation and air conditioning?						0
1.B	compressed air?						0
1.C	illumination?						0
1.D	heating?						0
1.E	manufacturing processes?						0
1.F	cold production?						0
1.G	electrical drives?						0
1.H	IT?						0
1.I	Other? Which?						0
2	Are the monitoring and measurement systems, existing on site, appropriate to facilitate the analysis of detailed energy consumption (on points 1.A to 1.I), variations over time, achievement of targets, etc?						0
3	Are the measurement tools calibrated at regular intervals?						0
4	Do calibration records exist?						0
5	Are the measurement results and consumption trends reviewed in regular intervals?						0
6	Are the significant energy consumers (areas or equipments) separatelly monitored and measured?						0
7	Do any records kept of significant deviation from expected energy consumption, their causes and remedies?						0
8	Are there any benchmark with similar companies (whenever possible) carried out?						0

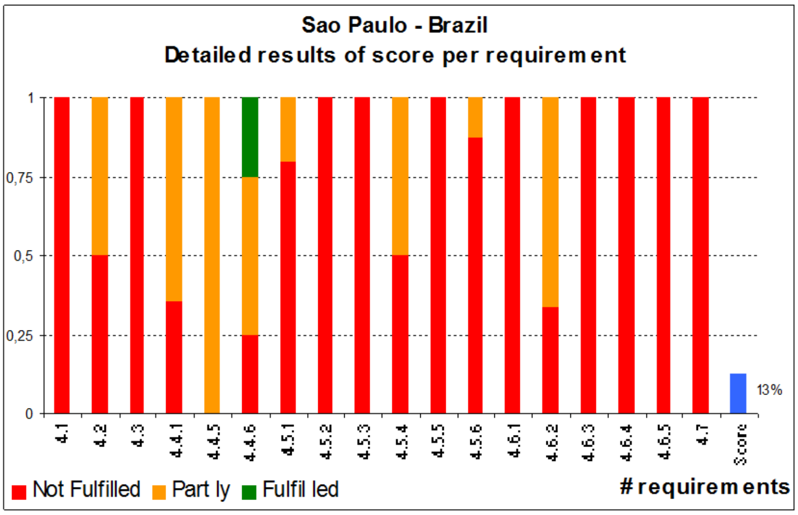
	Evaluation of legal/other compliances						0%
1	Does a procedure exist for evaluation of the compliances of the energy management system with legal obligations and other requirements, relating to the significant energy consumption?						0
2	Is this evaluation periodically performed?						0
3	Are records kept from the results of this evaluation?						0
4.6.3	**Internal audit**						0%
1	Are there internal audits, at planned intervals, carried out to review that the measures regarding energy management are implemented and effective?						0
2	Does the plan take into consideration the significant energy issues?						0
3	Are the results recorded and communicated?						0
4	Are the audits performed by impartial and trained personnel?						0
4.6.4	**Nonconformities, corrective, preventive and improvement actions (4.6.4.1/ 4.6.4.2)**						0%
1	Do procedures exist which define responsibilities and authority in order to manage and analyse the non-conformities?						0
2	Does a procedure exist that identifies non-conformities of the energy management system and their causes?						0
3	Are the changes, resulting from corrective/preventive actions recorded?						0
4.6.5	**Control of records**						0%
1	Are records related to energy (eg. Invoices, measurements, etc) integrated in the documentation management system?						0
2	Are records legible, identifiable and treaceble to the relevant activity, product or service for the established retention period?						0
4.7	**Energy Management Review (4.7.1/ 4.7.2)**						0%
1	Has the local top management defined the review interval for the energy management system?						0
2	Are the actions following to this review recorded?						0
						Overall score (%)	**0%**

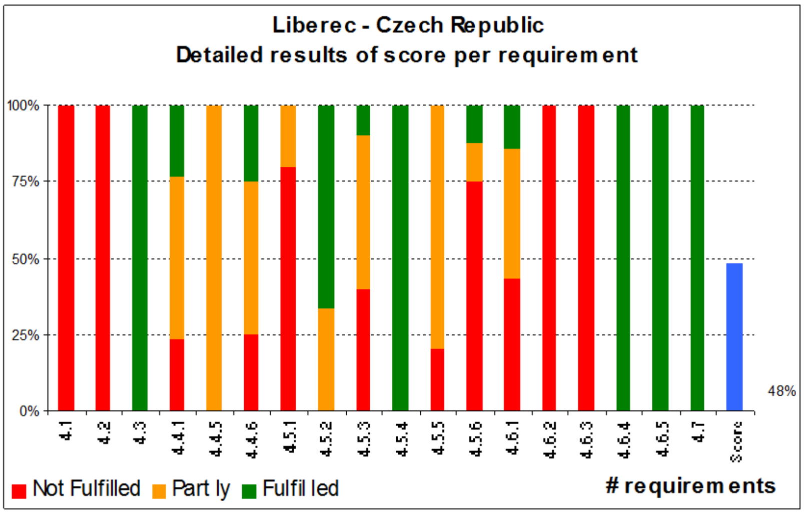
Detailed results of score per requirement

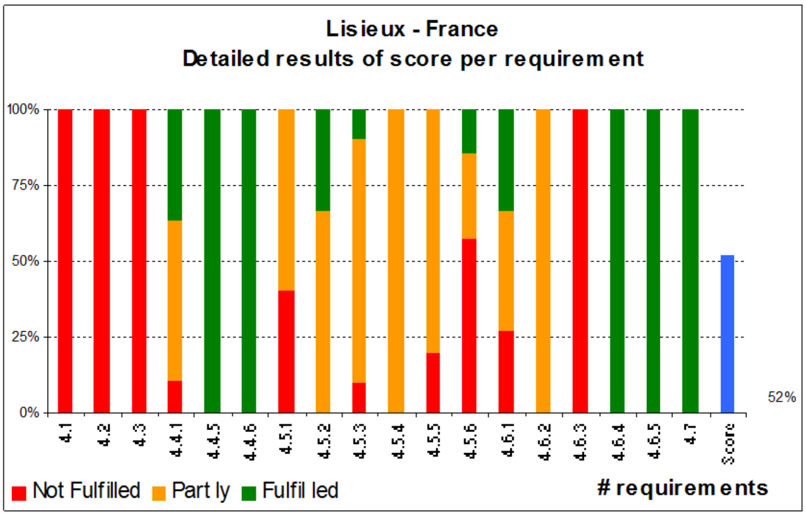


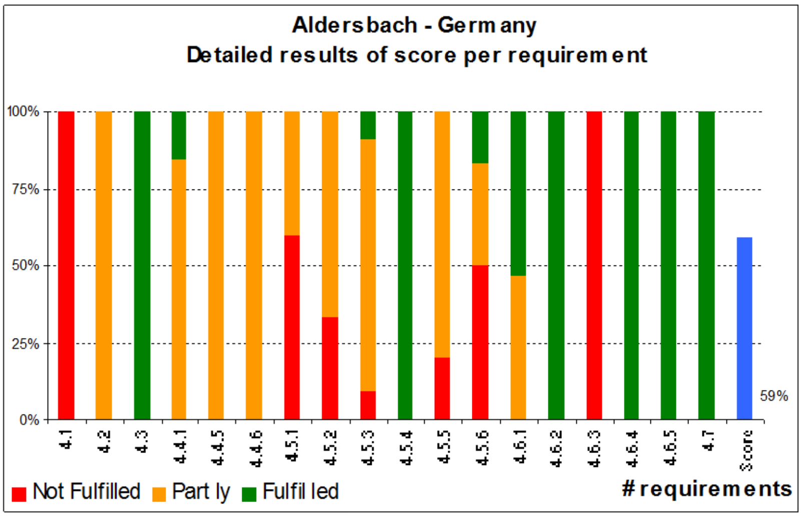
	Requirements ISO50001 draft
4.1	General requirements
4.2	Management responsibility (4.2.1/ 4.2.2)
4.3	Energy policy
4.4.1	Energy profile/ baseline/ EnPI (4.4.2/ 4.4.3/ 4.4.4)
4.4.5	Legal obligations and other requirements
4.4.6	Objectives, targets and action plans
4.5.1	Competence, training and awarness
4.5.2	Documentation (requirements and control; 4.5.2.1/4.5.2.2)
4.5.3	Operational control
4.5.4	Communication
4.5.5	Design
4.5.6	Purchasing (4.5.6.1/ 4.5.6.2)
4.6.1	Monitoring, measurement and analysis
4.6.2	Evaluation of legal/other compliances
4.6.3	Internal audit
4.6.4	Nonconformities, corrective, preventive and improvement actions (4.6.4.1/ 4.6.4.2)
4.6.5	Control of records
4.7	Energy Management Review (4.7.1/ 4.7.2)

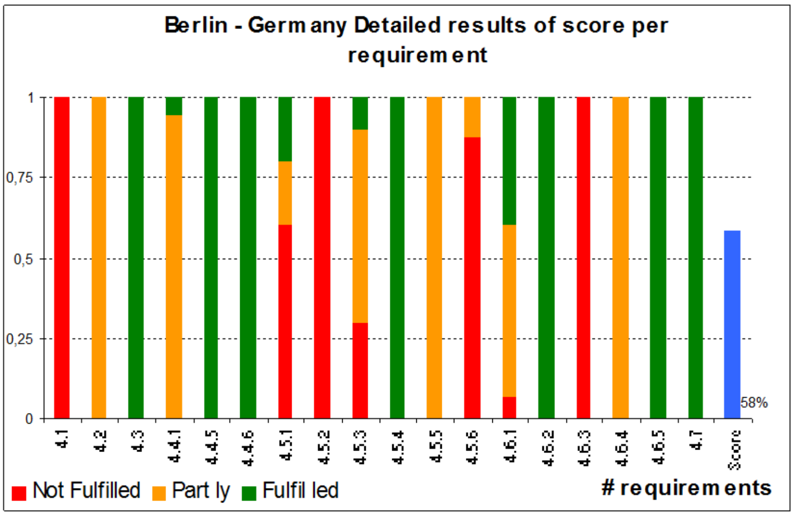
7.2 Appendix II - Checklist Results

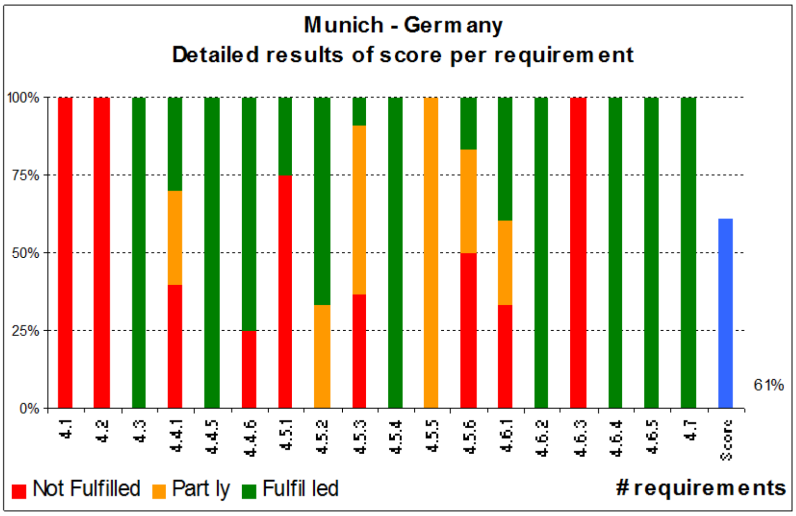







Aldersbach - Germany
Detailed results of score per requirement
100%
75%
50%
25%
0%
59%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Berlin - Germany Detailed results of score per requirement
1
0,75
0,5
0,25
0
58%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Munich - Germany
Detailed results of score per requirement
100%
75%
50%
25%
0%
61%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
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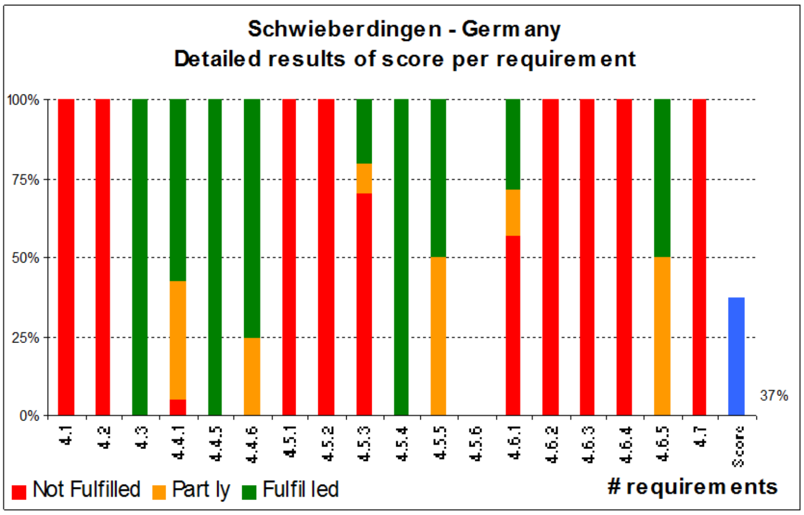
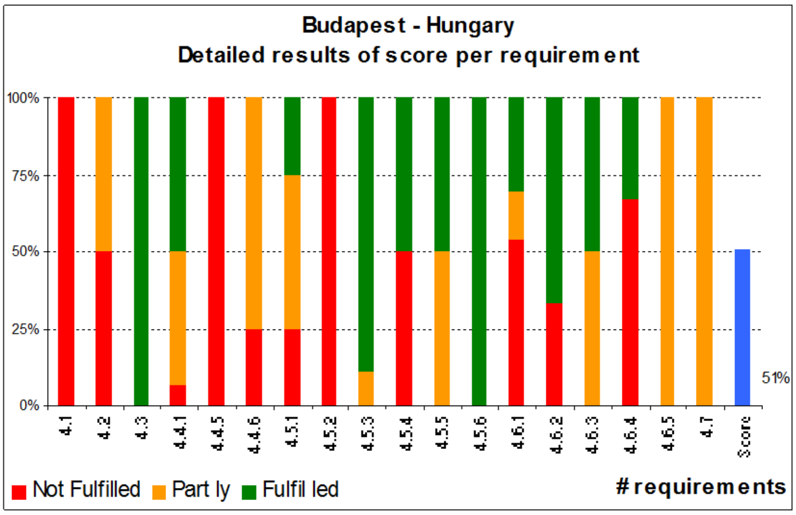
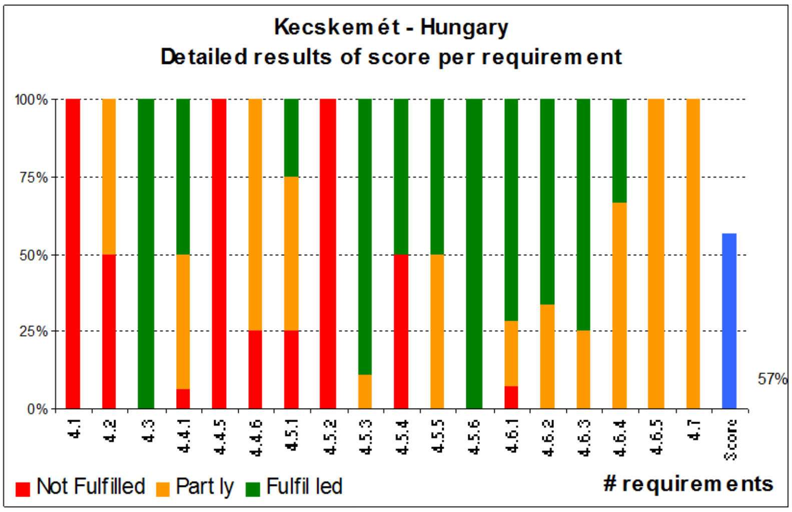
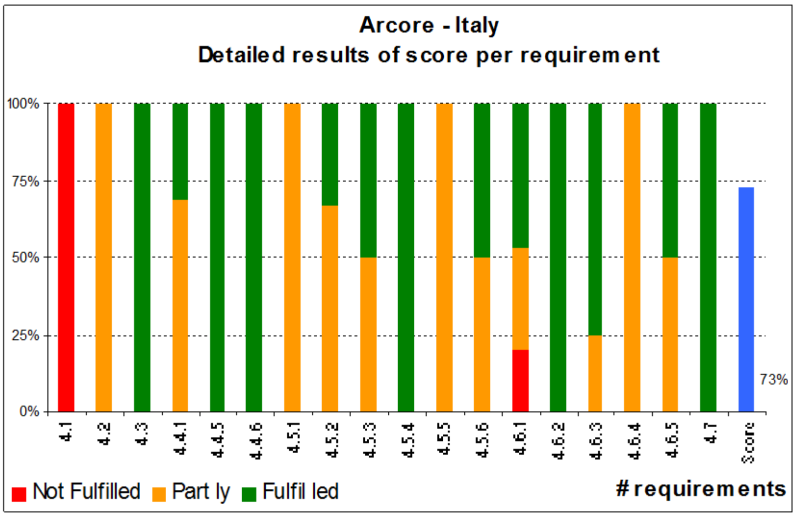
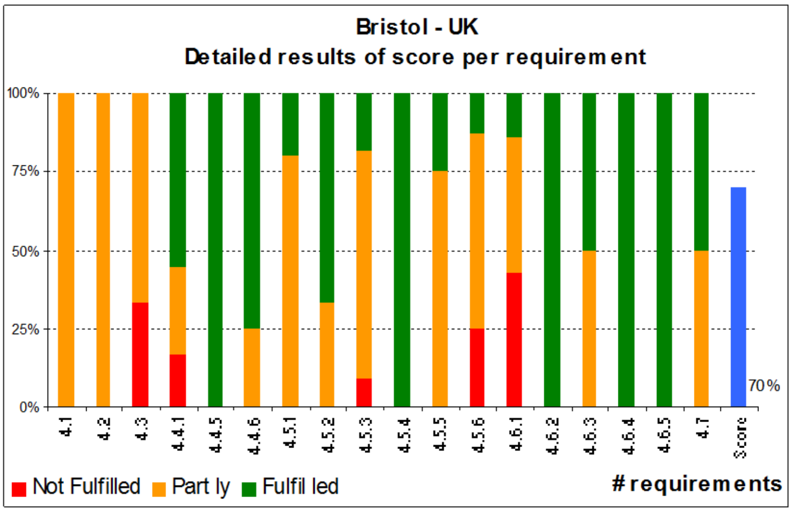
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements

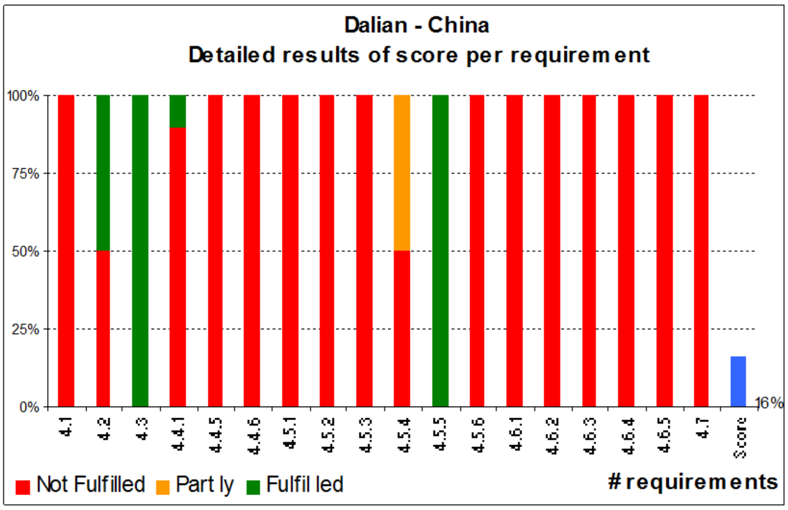

Schwieberdingen - Germany
Detailed results of score per requirement
100%
75%
50%
25%
0%
37%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements

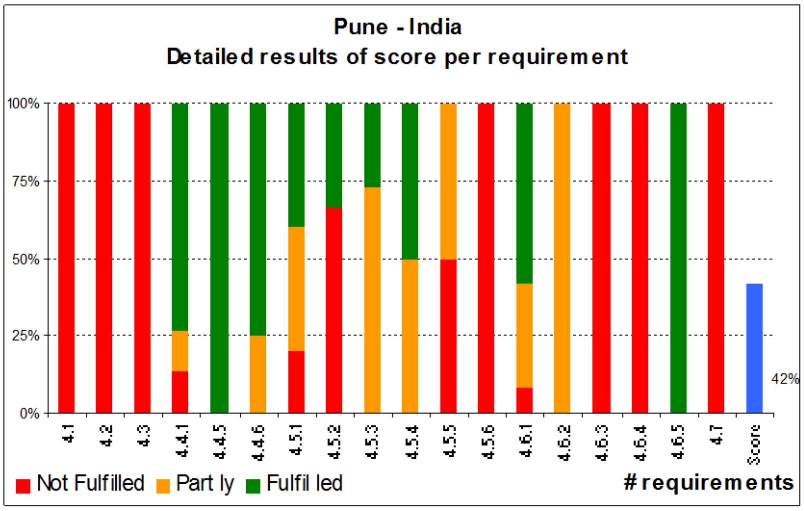

Budapest - Hungary
Detailed results of score per requirement
100%
75%
50%
25%
0%
51%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements

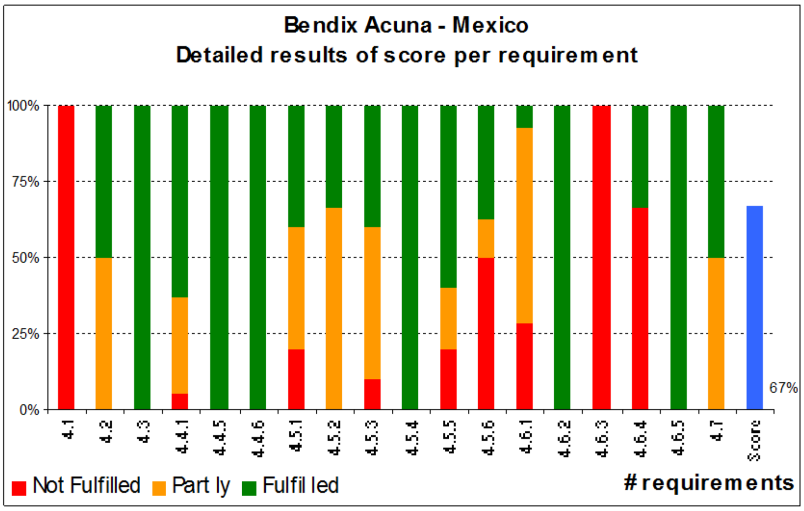

Kecskemét - Hungary
Detailed results of score per requirement
100%
75%
50%
25%
0%
57%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements

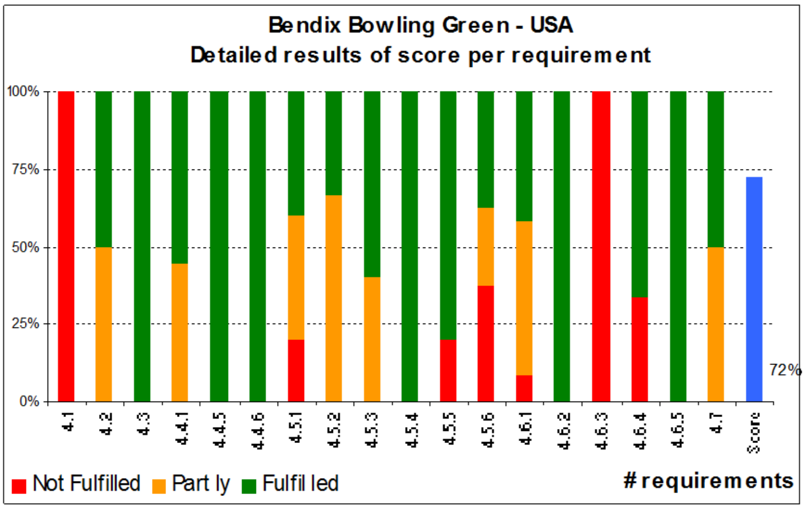

Arcore - Italy
Detailed results of score per requirement
100%
75%
50%
25%
0%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
73%
Not Fulfilled
Part ly
Fulfil led
requirements

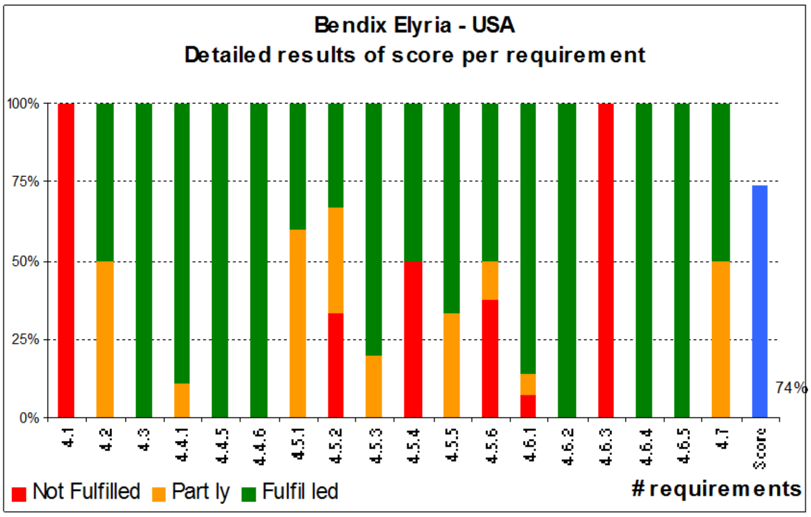

Bristol - UK
Detailed results of score per requirement
100%
75%
50%
25%
0%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
70%
Not Fulfilled
Part ly
Fulfil led
requirements

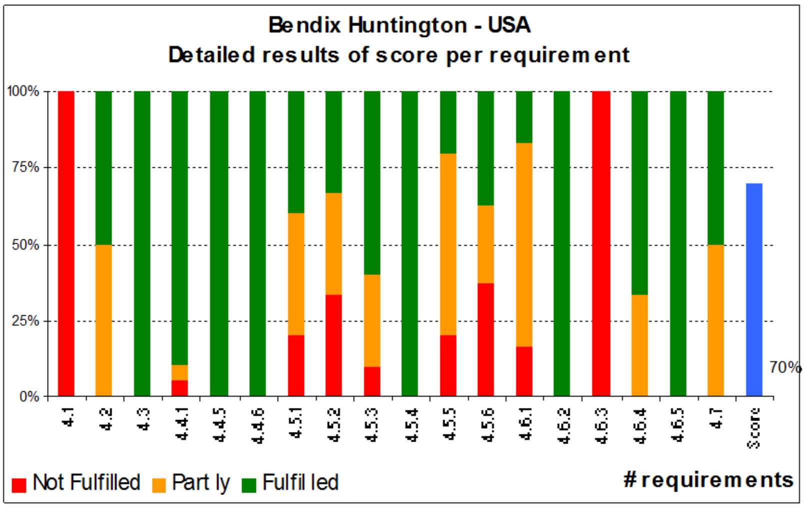

Dalian - China
Detailed results of score per requirement
100%
75%
50%
25%
0%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
16%
Not Fulfilled
Part ly
Fulfil led
requirements


Pune - India
Detailed results of score per requirement
100%
75%
50%
25%
0%
42%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Bendix Acuna - Mexico
Detailed results of score per requirement
100%
75%
50%
25%
0%
67%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Bendix Bowling Green - USA
Detailed results of score per requirement
100%
75%
50%
25%
0%
72%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Bendix Elyria - USA
Detailed results of score per requirement
100%
75%
50%
25%
0%
74%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements


Bendix Huntington - USA
Detailed results of score per requirement
100%
75%
50%
25%
0%
70%
4.1
4.2
4.3
4.4.1
4.4.5
4.4.6
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5
4.5.6
4.6.1
4.6.2
4.6.3
4.6.4
4.6.5
4.7
Score
Not Fulfilled
Partly
Fulfilled
requirements

7.3 Appendix III - Energy Sources Identification, Aldersbach

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS

Location: Aldersbach
Date: 16.09.2010

					Identification of energy inputs/ outputs										
					Energy Input						Energy Output				
					Gas	Electricity	Fuel (oil / coal)	Compressed air	Steam	Water	Electricity	Compressed air	Thermal energy	Steam	Water
Level 1	**Level 2**	**Level 3**	**Level 4**												
Production	Hall 9.1	Assembly	Disk brake	LSW 6		x		x			x	x			
Production	Hall 9.1	Assembly	Disk brake	LSW 7		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 1		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 2		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 3		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 4		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 5		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 6		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 7		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 8		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 9		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 10		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 11		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 12		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 13		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 14		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 15		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 16		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 17		x		x			x	x			
Production	Hall 9.1	Assembly	EAC	Station 18		x		x			x	x			
Production	Hall 8	Assembly	Disk brake	LSW 1		x		x			x	x			
Production	Hall 8	Assembly	Disk brake	LSW 3		x		x			x	x			
Production	Hall 8	Assembly	Disk brake	LSW 4		x		x			x	x			
Production	Hall 8	Assembly	Disk brake	LSW 8		x		x			x	x			
Production	Hall 8	Assembly	Disk brake	Kleinserie A6		x		x			x	x			
Production	Hall 9.2	Surface treatment	Disk brake	Phosphatierung		x				x	x				x
Production	Hall 9.2	Surface treatment	Disk brake	Anodisierung		x				x	x				x
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing		x		x		x	x	x			x
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing		x		x		x	x	x			x
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing		x		x		x	x	x			x
Plant	Plant			Litghting		x					x				
Plant	Plant			Facility - lighting	x	x				x	x		x		x
Plant	Plant			Forklift charging		x					x				
Production	Hall 7	Testing				x		x			x	x			
Warehouse	Hall 9.2	Stock				x					x				
Production	A	Assembly	Disk brake	LSW 2		x		x			x	x			
Production	A	Assembly	Disk brake	LSW 5		x		x			x	x			
Warehouse	Hall 4	Stock/ Testing	Disk brake			x					x				
Production	Hall 7	Technical testing				x		x			x	x			
Production	Hall 7	Quality				x				x	x				x
Plant	Hall 10	Compressors				x		x			x	x			
Production	Hall 8	Assembly	Disk brake	Retro montage		x		x			x	x			
Warehouse	Hall 8	Assembly	Disk brake			x		x			x	x			
Production	Hall 8	Assembly	Disk brake	Sample montage		x		x			x	x			
Warehouse	Hall 13			Empty goods		x					x				
Office	Hall 11				x	x				x	x		x		x

7.4 Appendix IV - Electricity Consumption Analysis – 2009 Aldersbach

Electricity Consumption 2009 (Analysis)

Location: Aldersbach
Date: 17.09.2010

Identification of energy inputs/ outputs — Electricity - Input (Consumption (kWh) to Type/ Model/ Name); Output (Type, Measured (y / n))

Level 1	Level 2	Level 3	Level 4		0	Consumption (kWh)	Percentage	Cumulative percentage	Level where metering equipments already exist	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name	Type	Measured (y / n)
								0,00%									
Production	Hall 9.2	Surface treatment	Disk brake	Phosphating	1	5.274.003	18,94%	18,94%		1		1	1		estimation		no
Plant	Facility			Facility - lighting	2	4.670.439	16,77%	35,72%		1		1	1		estimation		no
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing 1	3	4.598.586	16,52%	52,23%		1		1	1		estimation		no
Production	Hall 9.2	Surface treatment	Disk brake	Anodizing	4	3.750.722	13,47%	65,70%		1		1	1		estimation		no
Plant	Facility			Litghting	5	2.802.263	10,06%	75,77%		1		1	1		estimation		no
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing 2	6	1.580.764	5,68%	81,45%		1		1	1		estimation		no
Production	Hall 7	Testing			7	1.005.941	3,61%	85,06%		1		1	1		estimation		no
Plant				Forklift charging	8	1.005.941	3,61%	88,67%		1		1	1		estimation		no
Warehouse	Hall 9.2	stock			9	215.559	0,77%	89,45%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	Disk brake	LSW 6	10	215.559	0,77%	90,22%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	Disk brake	LSW 7	11	215.559	0,77%	90,99%		1		1	1		estimation		no
Production	Hall 8	Assembly	Disk brake	LSW 1	12	215.559	0,77%	91,77%		1		1	1		estimation		no
Production	Hall 8	Assembly	Disk brake	LSW 3	13	215.559	0,77%	92,54%		1		1	1		estimation		no
Production	Hall 8	Assembly	Disk brake	LSW 4	14	215.559	0,77%	93,32%		1		1	1		estimation		no
Production	Hall 8	Assembly	Disk brake	LSW 8	15	215.559	0,77%	94,09%		1		1	1		estimation		no
Production	Hall 9.3/ 9.4	Assembly	Disk brake	Finishing 3	16	215.559	0,77%	94,86%		1		1	1		estimation		no
Production	Hall	Assembly	Disk brake	LSW 2	17	215.559	0,77%	95,64%		1		1	1		estimation		no
Production	Hall	Assembly	Disk brake	LSW 5	18	215.559	0,77%	96,41%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 15	19	179.632	0,65%	97,06%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 14	20	143.706	0,52%	97,57%		1		1	1		estimation		no
Production	Hall 8	Assembly	Disk brake	Kleinserie A6	21	86.223	0,31%	97,88%		1		1	1		estimation		no
Office	Facility				22	43.115	0,15%	98,04%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 12	23	43.112	0,15%	98,19%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 1	24	35.926	0,13%	98,32%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 2	25	35.926	0,13%	98,45%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 3	26	35.926	0,13%	98,58%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 4	27	35.926	0,13%	98,71%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 6	28	35.926	0,13%	98,84%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 7	29	35.926	0,13%	98,97%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 8	30	35.926	0,13%	99,10%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 9	31	35.926	0,13%	99,23%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 10	32	35.926	0,13%	99,35%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 11	33	35.926	0,13%	99,48%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 16	34	35.926	0,13%	99,61%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 17	35	35.926	0,13%	99,74%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 18	36	35.926	0,13%	99,87%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 5	37	28.741	0,10%	99,97%		1		1	1		estimation		no
Production	Hall 9.1	Assembly	EAC	Station 13	38	7.185	0,03%	100,00%		1		1	1		estimation		no
					TOTAL	27.843.001	100,00%								**Electricity bill**		

7.5 Appendix V - Energy Sources Identification, Bristol

IDENTIFICATION OF ENERGY SOURCES AND CONSUMERS

Location: Bristol
Date:

Level 1	Level 2	Level 3	Level 4	Energy Input: Gas	Energy Input: Electricity	Energy Input: Fuel (oil / coal)	Energy Input: Compressed air	Energy Input: Steam	Energy Input: Water	Energy Output: Electricity	Energy Output: Compressed air	Energy Output: Thermal energy	Energy Output: Steam	Energy Output: Water
Kingswood Site	Production	Remanufacture		X	X		X		X	X	X	X		X
Kingswood Site	Production	Basement Valve Assembly			X		X		X		X			
Kingswood Site	Production	Machine Shop			X		X		X	X	X			X
Kingswood Site	Production	Welding Shop			X		X		X	X	X	X		
Kingswood Site	Production	Assembly Shop			X		X		X	X	X			
Kingswood Site	Administration	Office			X					X				
Kingswood Site	Quality	Standards Room			X					X				
Kingswood Site	Quality	Customer Quality			X		X			X	X	X		
Kingswood Site	Stores	Machine Shop	Raw material storage		X									
Kingswood Site	Stores	Assembly shop	Detail part storage		X									
Kingswood Site	Stores	Basement	Goods receiving		X					X		X		
Kingswood Site	Plant	Facilties		X	X		X		X	X	X	X		X
Kingswood Site	Support services	Maintenance/Labels			X		X		X	X				X
Kingswood Site	Plant	Computer support areas			X					X				
Kingswood Site	Plant	Facilties	Air Compressors		X		X			X	X	X		
Century House	Warehouse	Finished goods storage			X					X				
Century House	Warehouse	Product kitting			X					X				
Century House	Offices	Ground Floor			X					X				
Century House	Offices	First Floor			X					X				
Century House	Plant	Facilties		X	X		X		X	X		X		X
Century House	Warehouse	Service Area	Compressor		X							X		
Century House	Plant	Common rooms	Computer support		X					X		X		

7.6 Appendix VI - Electricity Consumption Analysis - 2009 Bristol

Electricity Consumption 2009 (Analysis)

Location: Bristol
Date: 17.09.2010

Level 1	Level 2		Electricity - Input: Consumption (kWh)	Percentage	Cumulative percentage	Level where metering equipments already exist	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name	Output: Type	Measured (y /n)
Production + Office			1,58	98,94%	98,94%		1		1		1	Estimation		no
Compressed air	Compressed air		0,02	1,06%	100,00%		1		1		1	Estimation		no
		TOTAL	1,6	100,00%								Electricity bill		

7.7 Appendix VII - Electricity Consumption Analysis - 2009 São Paulo

Electricity Consumption 2009 (Analysis)

Location: Sao Paulo
Date: 17.09.2010

Level 1	Level 2		Electricity - Input: Consumption (kWh)	Percentage	Cumulative percentage	Level where metering equipments already exist	Frequency	Mobility	Data collection	Focus	History	Type/ Model/ Name	Output: Type	Measured (y /n)
Truck	Production	1	3,5	62,61%	62,61%		1		1		1	Estimation		no
Truck	Office	2	1,2	20,87%	83,48%		1		1		1	Estimation		no
Rail	Production	3	0,7	12,34%	95,83%									
Rail	Office	4	0,2	4,17%	100,00%									
		TOTAL	5,5	100,00%								Electricity bill		

7.8 Appendix VIII – Plan: Metering Equipment Installation / Improvement

Plan: Introduction of Instruments for Energy Consumption Data Monitoring					
Reference					
Action					
Budget (€)					
Resources					
Current situation					
Indicators					
Saving potentials					
Approval & completion					
Task	**Priority**	**Responsible**	**Start date**	**End date**	**Comments**
1. Outsourcing or internal					
2. Research of suitable equipment					
3. Verification with budget					
4. Identification of saving potentials					
5. Definition of targets					
6. Definition of new baselines					
7. Definition of responsible for achievement of targets					
8. Definition of next phase					

7.9 Appendix IX – Comparison of results between groups