UNIVERSIDAD DE SONORA

DIVISIÓN DE INGENIERÍA

DEPARTAMENTO DE INGENIERÍA INDUSTRIAL

SUSTAINABLE ENERGY MANAGEMENT AT A MEAT PROCESSING AND COMERCIALIZATION INDUSTRY

TRABAJO ESCRITO

PARA OBTENER EL GRADO DE:

MAESTRÍA EN SUSTENTABILIDAD

PRESENTA:

TANIA GUADALUPE POOM BUSTAMANTE

DIRECTOR DE TESIS:

DRA. NORA ELBA MUNGUÍA VEGA

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"El saber de mis hijos
hará mi grandeza"

Universidad de Sonora
División de Ingeniería
Departamento de Ingeniería Industrial
Posgrado en Sustentabilidad
Maestría en Sustentabilidad
Especialidad en Desarrollo Sustentable

Hermosillo, Sonora a 12 de Agosto del 2015

Dra. Nora Elba Munguía Vega
Coordinadora de Programa
Maestría en Sustentabilidad
Presente.-

Por este conducto, hago de su conocimiento que estoy de acuerdo que se realice el examen de posgrado del alumno (a) Tania Guadalupe Poom Bustamante con Expediente 213290024, el cual será el día 14 de Agosto del 2015 en el aula "Lozano Taylor" a las 12:30 horas.

Relación de Jurados:

	NOMBRE	FIRMA
PRESIDENTE:	Dra. Nora Elba Munguía	
SECRETARIO:	Dr. Luis Velázquez	
VOCAL:	Dr. Javier Esquer Peralta	
SUPLENTE:	Dr. Nun Pitalúa Díaz	

ATENTAMENTE

MIEMBROS DEL JURADO

"Somewhere, something incredible is waiting to be known."

-Carl Sagan."

"Eigentum verpflichtet. Sein Gebrauch soll zugleich dem Wohle der Allgemeinheit dienen"

-GG Art.14 Abs. 2

The path I choose through the maze makes me what I am. I am not only a thing, but also a way of being--one of many ways--and knowing the paths I have followed and the ones left to take will help me understand what I am becoming."

— *Daniel Keyes, Flowers for Algernon*

It's up to us to be the change. And even though this world needs so much more. There's so much to be thankful for. I will be forever grateful for those who walked with me in the darkest times and for those who have brought light and laughter to my path. Let us meet again and discover incredible things together.

Depende de nosotros ser el cambio .Y a pesar de que este mundo necesita mucho más. Hay tantas cosas que agradecer. Siempre estaré agradecida por los que caminaron conmigo en los tiempos más oscuros y con aquellos que han traído luz y risa a mi camino. Espero nos encontremos de nuevo para descubrir cosas increíbles juntos

ABSTRACT

The meat processing industry, due to its high energy consumption, needs to be assessed in an energy usage basis. This work shows the results and implications of an energy audit in a meat processing industry. Aiming to provide a structured framework for energy auditing in the meat processing industry. In addition, this work provides a comprehensive and practical approach to energy saving measures in the assessed company to recognize factors that could determine a possible transition to sustainable patterns of electricity consumption.

In this case, a study of an integrative characterization of the company's energy consumption was made. The research has been divided in two main sections: the first includes an analysis about the characterization of the energy consumption within a meat processing company in the three sustainable approaches such as: economical, societal and mainly environmental implications. Second, a proposal for strategic energy management measures focusing on high consumer types of facilities.

RESUMEN

La industria de procesamiento de carne, debido a su alto consumo de energía, es necesario evaluar en forma el uso de energía. Este trabajo muestra los resultados y las implicaciones de una auditoría energética en este tipo de industria. Con el objetivo de proporcionar un marco estructurado para la auditoría energética en la industria cárnica. Además, este trabajo proporciona un enfoque integral y práctico a las medidas de ahorro de energía en la empresa evaluada para reconocer los factores que podrían determinar una posible transición hacia patrones sostenibles de consumo de electricidad.

En este caso, se realizó un estudio de una caracterización integral del consumo de energía de la empresa. La investigación se ha dividido en dos secciones principales: la primera incluye un análisis acerca de la caracterización del consumo de energía en los tres enfoques sostenibles como: implicaciones económicas, sociales y sobre todo ambientales. En segundo lugar, una propuesta de medidas estratégicas de gestión energética se centra en tipos altos de consumo de las instalaciones.

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I. INTRODUCTION

The efficient use of resources within industrial systems is a key aspect to consider in order to achieve sustainability, this perspective leads to the necessity to integrate production practices that incorporate economical, ecological and social perspectives limiting the negative impact of industries toward the environment (Blengini and Shields, 2011). In matters of resource efficiency, energy to empower production processes is now a priority, correspondingly, there is a relevance on the reduction of the use of energy and its negative impacts towards the environment such as carbon emissions. Within the food sector and relying on the nature of a company´s processes, many companies can be considered as high energy consumers.

The meat processing industry, due to its high energy consumption, needs to be assessed in an energy usage basis. This work shows the results and implications of an energy audit in a meat processing industry. Aiming to provide a structured framework for energy auditing in the meat processing industry. In addition, this work provides a comprehensive and practical approach to energy saving measures in the assessed company to recognize factors that could determine a possible transition to sustainable patterns of electricity consumption.

In this case, a study of an integrative characterization of the company's energy consumption was made. The research has been divided in two main sections: the first includes an analysis about the characterization of the energy consumption within a meat processing company in the three sustainable approaches such as: economical, societal and mainly environmental implications. Second, a proposal for strategic energy management measures focusing on high consumer types of facilities.

The results obtained allowed the identification of main processes with significant correlations in terms of energy consumption within the company. This data has the potential for energy savings. The data acquisition process prompts the development of practical and accessible energy efficiency measures. In addition, a benchmarking analysis with several tools was performed.

II. STRATEGIC STUDY- GOAL

Prevent, eliminate and/or reduce the alteration of the chemical composition in the atmosphere, causing climate change, caused by inefficient use of electricity in a meat processing industry.

III. SPECIFIC STUDY – GOAL

1. Build a literary analysis on the state of the art of the principles governing the science of climate change; emphasizing the negative environmental impacts prompted by an inefficient use of electricity.
2. Diagnose the usage of electricity in a meat processing plant.
3. Evaluate opportunities for energy management in a meat processing plant.
4. Generate an instrument that optimizes the strategic decision making for sustainable management of energy in a meat processing company.

IV. THEORETICAL FRAMEWORK

4.1 Climate Change Science

Suggesting that climate change (CC) only refers to the temperature change that happens on earth, observed, in relation to prolonged periods of time, is to poorly visualize the concept because it is actually the result of the interaction of multiple variables that collectively integrate climate systems (SC) (Cubasch and Wuebbles, 2013). Some of the elements of such systems are: solar radiation, land surface, gases and aerosols in the atmosphere, which in interaction create certain climate conditions perceptible to humans (Hartmann et al, 2013).

Recognizing that the alteration of any component of the SC results therefore in the alteration of the system itself (Parmesan and Yohe, 2002). Currently, due to the increased amount of gases and aerosols, the atmosphere has changed its composition and caused changes in atmospheric performance as atmospheric inability to release the solar radiation received by trapping heat in the atmosphere (greenhouse effect) resulting in a transition to warmer climates (IPPC, 2005).

The increases in concentrations of greenhouse gases, such as carbon dioxide (CO_2), methane, ozone, etc., are for the most part responsible for creating major imbalances in the natural conditions of the atmosphere leading to climate change (Porrúa, 2001). The first thing to consider is that the turning point for the increase in emissions of such gases was the industrial revolution. From which it can be inferred that the increase in these emissions is a direct result of human activity, see Fig. 1 (IPCC, 2007). However, industrial activity should not be considered as the solely activity causing the change in climatic conditions but also it should be considered the changes in the Earth's crust caused by deforestation, agriculture and especially the dependence on fossil fuels (Forster et al., 2007).

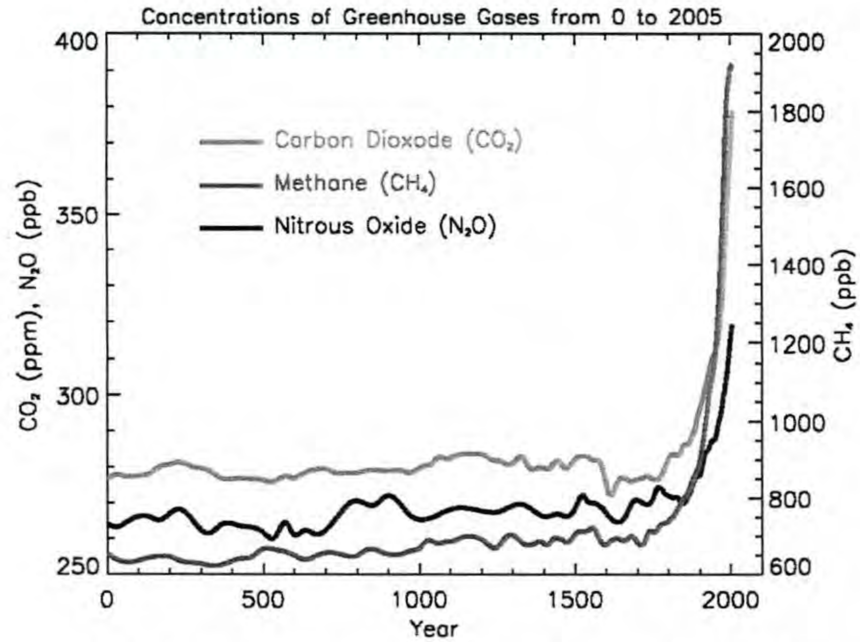

Fig. 1. Concentration of greenhouse gases in the last 2000 years

Source: IPCC (2007)

Maintaining that CC only affects temperatures is also an erroneous view of the problem as it limits the scope of this phenomenon, which has repercussions in the cycles of nature and generally in the environment (NRDC, 2014). Some of the effects that can be described include alterations that occurs in the water cycle leading to droughts and floods (McMichael et al, 2006). From health perspective we can observe air pollution and extreme temperatures (Keatinge and Donaldson, 2004).

It is then essential to understand climate change as a complex phenomenon that has gradually aggrieved because of human activities and has global affectations, which has been making it one of the key points of any agenda that aims to achieve sustainable development (FCCC, 2009). However, despite the integration of policies that enable the reduction of CO_2 emissions to mitigate the negative impacts of CC still can still distinguish some ambivalence about this phenomenon of CC (Honty, 2007). The first blames human activity as the main responsible and on the contrary the second approach ignores the anthropogenic contribution to this phenomenon, under the premise that the various temperature changes that have occurred have occurred naturally throughout history (Lorenzoni and Pigdeon, 2006).

4.2 Generation and use of energy and its contribution to climate change

The contribution to climate change energy use can be seen through the impacts of extraction, transformation, transport and consumption of electricity (USDE, 2014). The magnitude of impacts to the environment depend on the type of resource to be exploited and the technologies used to transform energy (Withagen, 1994). Currently, the most exploited for energy resources are fossil fuels creating a dependency on these, exceeding its ecological limits (Hoel and Kverndokk, 1996).

One of the main negative impacts to observe from the dependence on fossil fuels is its contribution to CC due to the generation of greenhouse gases as a result of the transformation processes needed to generate energy (Manne and Richels, 1990). As shown in Fig. 2, which shows the increase in emissions of greenhouse gases in relation to the annual amount of fossil fuels used during each period, observing visible similarities between historical stage where emissions increase in which greenhouse gas emissions and fuel (Marland et al, 2003).

The production of electrical energy must then be analyzed as a consequence and a factor of development and growth, because energy enables the development of human activities, however an excessive use of fossil fuels used to produce it brings environmental consequences that go beyond exploitation of a resource and ends up becoming the main cause of human origin of climate change resulting CO_2 emissions (Rosenzweig, 2008).

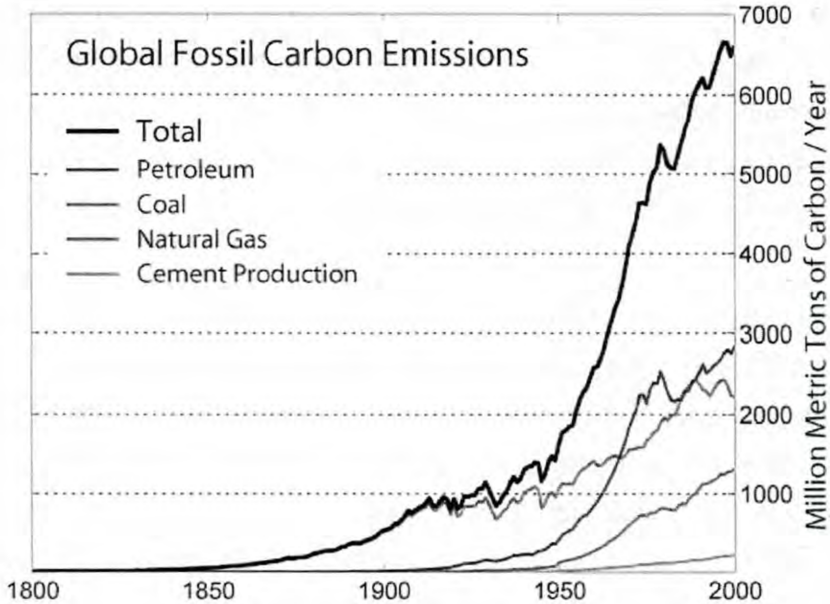

Fig. 2. Global emissions of fossil carbon

Source: Marland, G. et al (2003)

The human being in order to carry out their productive activities transforms fossil fuels in power, making these fuels critical elements for economic development and technological innovation of any nation (Schurr, 1984). Despite being a key element on the prosperity of a country, if looking from an environmental perspective it can be noticeable that the energy industry causes negative impacts; since it represents the largest contributor to emissions of greenhouse gases released into the environment (EPA, 2014).

These emissions result in threats such as global warming (UCS, 2006). Given this situation and to solve the energy problem options to mitigate the negative impact of the generation and use, and to attack these areas allows the transition to sustainable development) are studied (Goldemberg et al, 1987). The solutions at power generation level looks for sources of renewable energy while solutions at the consumption level seeks to implement energy efficiency practices and technology for energy conservation and reducing inefficiencies in the use of this resource (IPCC, 2011).

4.3 Implications of the use of electricity in meat processing plants

Since any production process involves the use of energy, in some form or another, it is imperative to think about the implications of this use from economical, societal and environmental perspectives (Tanaka, 2011). Because of the uniqueness of each production process, the relationship between the impacts of energy use differs in each productive activity; subsequently influencing the decisions involved to address the negative consequences of the use of energy resources (Jorgenson et al, 2014). This makes energy a key element not only for development but for sustainable development (Stern, 2010).

Within the food industry energy use in the supply chain is undeniable, whether in activities such as production, processing, packaging and distribution of food (USDA, 2010). In the case of the food industry in particular the meat processing industry due to the need to maintain low temperatures during the production process, storage temperatures, etc., results that this is one of the industries with energy intensive (Tang, et al, 2013). This dependence on energy consumption is the main cause of interest in the transition to a more energy-efficient industry, this mainly derived from the relationship between energy use and food prices as well as the environmental impacts of energy use as CO_2 emissions to the environment (United Nations Food and Agriculture FAO, 2014).

Specifically, the food industry is one of the sectors with higher energy consumption contributing 33% to the total, and is in the category of meat processing where it has the greatest flow of energy used compared to other subcategories such as canned food, bottled drinks, etc. (USDA, 2010). It is vital to note that energy use in meat processing, as in any food product, is reflected in the prices of food, including greater the use of this greatest resource is the product price (Trosle, 2008). Under this line of thought, consumers seek products that are more energy efficient, where there is a decrease in the use of this resource to not be reflected on prices. This leads companies to consider more efficient processes in creating their products through energy efficiency practices, process substitution or through the replacement of machinery that results in reduced energy consumption processes. Therefore increases on the operation cost of this type of industry due to increments in the prices of energy that have been occurring globally, greater increments on food prices will take place (Emerson Network Power, 2008).

In order to exemplify the environmental implications of high energy consumption metric equivalent of carbon dioxide is used, which represents an amount of a greenhouse gas whose atmospheric impact has been standardized to a unit mass of carbon dioxide based on the global warming potential of the gas (EPA, 2012). In other words, based on their consumption of electricity, described how many emissions of greenhouse gases were released for the operation of an activity (Dalkia, 2014). If we examine the energy we recognize the ecological footprint of plants meat processing have these have a great impact on the environment and in this situation, there is great potential opportunities for better use of energy in this type of facility (Sun and Lee, 2006).

4.4 energy efficiency as a strategy to reduce electricity consumption

Strategies to reduce the amount of electricity consumed in the industry are currently treated as specific solutions limiting the implementation of best practices that result in decreased energy expenditure (Gu, 2013). However, energy efficiency is one of the main techniques for reducing energy consumption because its implementation leads to reductions in operating costs and pollution from the operations of any kind of productive activity (Worrell, 2003).

Particularly, implementing energy efficiency strategies it is not an exact strategy per se but it incorporates several indicators to describe changes in energy efficiency of the systems analyzed (Patterson, 2006). This has resulted in energy efficiency is considered as an ambiguous term; as none of the authors specifically describe this concept and adapts to the context in which it is used (Lovins, 2004). However, most authors agree that, at least at industry level, that energy efficiency can be defined broadly as the ratio of the finished product between the energy that entered the system to process the raw material and turn it into product (Patterson, 1996).

Following this line of thought we can understand energy efficiency as one of the best techniques to reduce energy consumption as it is easy to conceptualize and has low complexity in implementation, providing outstanding results understanding the energy availability for process making and the environmental and economic implications of the use of energy (Tanaka 2008).

The reason that energy efficiency plays an important role is that it not only provides an increase in positive environmental performance of industry but also contributes to more efficient production, increased competitiveness, increase in the innovation capacity and allows companies to comply with government legislation (Schmidheiny, 1992). Within the food industry is that 65% of food processing come from some kind of meat (FAO, 2013). Thus improving the energy efficiency of industrial processes for processing meat through appropriate strategies and implementing adjustments to existing processes is one of the most relevant options to reduce dependence on fossil fuels while costs and emissions of greenhouse gases are reduced (Fritzson and Berntsson, 2006).

4.5 energy Management Systems

Management systems are now a generic term used to designate the number of procedures that an organization needs to follow in order to achieve its objectives (ISO, 2013), seeking to achieve an energy and environmental sustainability of production processes (Vidal et al, 2006).

Thus, energy management systems are very versatile and can focus on each of the specific areas you want; for example, focused on the management of systems such as cooling (Du Plessis, 2013), resource allocation (Bodenstein, 2012) and virtualization (Shuja, 2012).

To promote a methodological unification of energy management systems, in June 2011 the International Organization for Standardization (ISO) released the management system ISO 50001. In regard to indicators, this standard is vague and it does not establish performance goals (Ivanovich, 2011). However, it provides a framework for energy management in any organization (Chiu, 2012).

This standard specifies the basic requirements for energy management without neglecting the systemic approach of continuous improvement typical products of the family of ISO standards (Mckane, 2009). Fig. 3 outlines the ISO 50001 model showing each of its stages. It is noteworthy that runs until June 2013 that the corporate data center to Google and six operational centers obtained the first certification ISO 50001 (Kava, 2013).

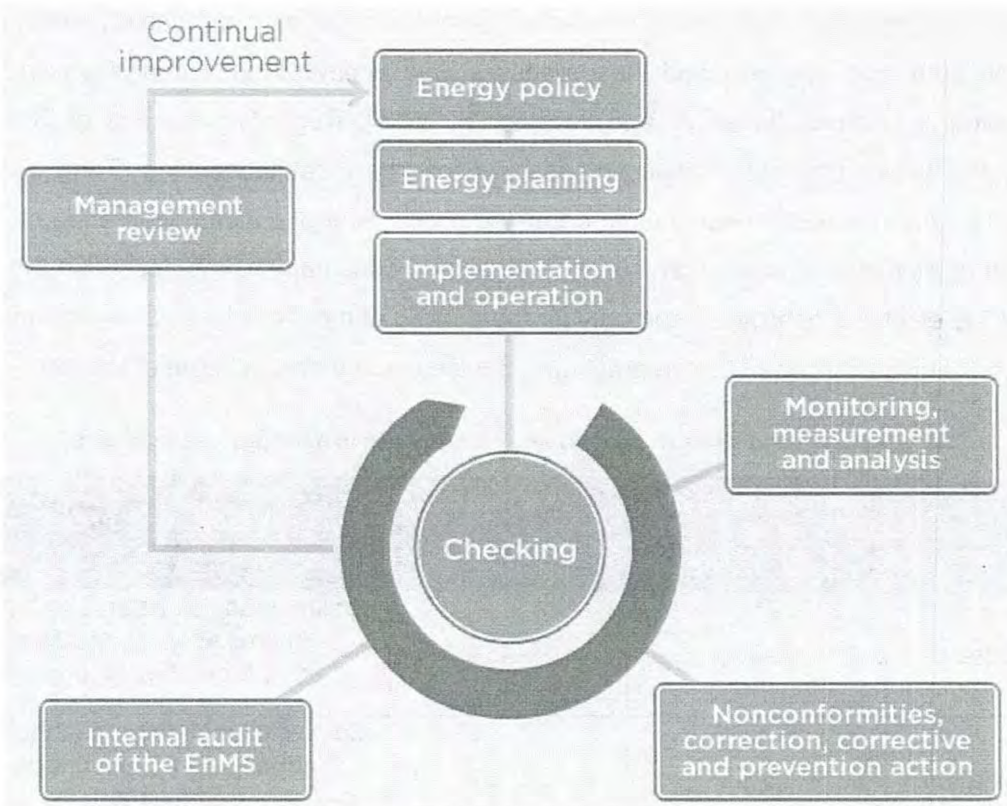

Fig. 3. Diagram of ISO 50001.

Source: ISO (2013)

4.6 Specific metrics in meat processing plants

The ISO 50000 standard provides a framework for all industries and companies interested in managing their energy use (ISO, 2011). However, since industry has specific operations processes and metrics must be adapted to each particular industry (BSR, 2012). Each specific case will have different energy sources and make particular each use, so they must be selected energy performance indicators that establish a profile of specific energy consumption (Chiu, et al, 2012).

In the meat processing industry consumed, mostly, electricity and natural gas (Feliciano, et al, 2014). Most electricity is used for ventilation, cooling, commissioning of equipment (saws, conveyors, etc.) and lighting, cooling step being food which has a more intensive use of energy (Pérez -Lombard, et al., 2008). In this industry the weatherization work areas, is one of the bigger energy consumers in form of the energy consumed by refrigerators and freezers dedicated to the storage of the finished product, in meat processing industries is important to maintain what is known as "cold chain", which is to maintain both raw materials and the process at low temperatures complying with food processing regulations (Likar, K. and Jevsnik, M, 2006). Regarding the use of Thermal energy this is used for sterilization processes within the meat processing (Tang, P. and Johns, M., 2013). Chart 1 describes in detail the profile energy consumption and potential areas of opportunity to make more sustainable energy consumption it is described that 30-40% of the electrical energy is used only for the cooling of meat product, while also lighting processes constitute one of the greatest opportunities to use energy more efficiently.

Chart. 1. Profile and areas of opportunity in energy use in meat processing plants

Technology	Percentage of total consumption	Percentage of potential savings	Opportunity areas
Refrigeration	15-30%	15-45%	cooling load reduction plant, plant optimization, upgrading equipment, heat recovery
Illumination	3-5	20-50	More efficient lighting technology, lighting controls, voltage optimization.
Compressed air	3	10	Equipment for air quality control and quality of temperature.
High efficiency motors	5	2-4	Refrigeration compressors, tape transportation, processing equipment, hydraulic equipment, fans and pumps
Variable speed	2-5	25-40	Variable speed pumps, fans and compressors

Source: Modified from Tang, P. y Johns, M. (2013)

4.7 Mexican regulations for energy efficiency

The Mexican government through the Ministry of energy (SENER), within the context of the energy strategy for the years 2013 to 2027, seeks to encourage the reduction of operational deficiencies not only in generation but also in the use of energy within the country (SENER, 2013).

Thus, the pillars of the Mexican energy legislation have been described by SENER within the catalog of Mexican Official Standards on energy efficiency (NOM-ENER). In Chart 1, it includes some of the national regulations regarding energy efficiency in order to illustrate the scope of each (National Commission for energy Conservation, 2014).

Chart 2. Mexican Official Standards relevant to energy efficiency.

Norm	Description
NOM-007-ENER-2004	Energy efficiency in lighting systems in nonresidential buildings.
NOM-008-ENER-2001	Energy efficiency in buildings, non-residential building envelope.
NOM-011-ENER-2006	Energy efficiency in air conditioners central rate, packet or divided. Limits, test methods and labeling.
NOM-017-ENER/SCFI-2012	Energy efficiency and safety requirements for self-ballasted compact fluorescent lamps. Limits and test methods.
NOM-018-ENER-2011	Thermal insulation for buildings. Characteristics, limits and test methods.
NOM-023-ENER-2010	Energy efficiency in air conditioners split type, free download without air ducts. Limits, test methods and labeling
NOM-024-ENER-2012	Thermal and optical characteristics of glass and glazing systems for buildings. Labelling and test methods.
NOM-028-ENER-2010	Energy efficient lamps for general use. Limits and test methods.

Source: SENER (2013)

V. METHODOLOGY

5.1 Type of study

The study is quantitative because to estimate the pattern of energy consumption is necessary to use quantifiable and measurable variables that measure the extent of the phenomenon of energy use in meat processing plants.

5.2 Methodological Approach

The methodology described by AFNOR (2014) for efficient energy management in accordance with ISO 50001 (energy management systems), which is adapted to a meat processing plant standard is used, as well as the cleaner production and energy efficiency (CP-EE) presented by UNEP (2004) which follows a systematic approach as the CP methodologies. This work adapts the first three CP-EE methodology steps: Planning and Organization, Pre-assessment and Assessment to compile information about the processes and specifically theirs energy consumption. Aiming to contribute to a cleaner production specifically towards the reduction to GHG emissions of the production processes derived from the energy use. Also, for a more detailed energy audit some tools described in "Green energy audit of buildings a guide for a sustainable energy audit of buildings" by Dall'O' (2013) were taken into consideration to increase the opportunities for the efficient usage of energy.

The union of each methodology core element makes the case for an integrative and adapted approach to energy efficiency and therefore management in a meat processing plant. Due the nature of this work, the implementation steps and validation of the energy management systems are omitted since this work focus on the potential contribution for cleaner production through the reduction of GHG emissions derived from the usage of electricity.

Fig. 4. Methodology

Adapted from UNEP (2004) Guidelines for the Integration of Cleaner Production and energy EfficiencyUnited Nations Environment Programme and AFNOR (2014)

5.3 Research scope

This study was conducted at the processing plant meat Frigorífica Contreras (FRICONSA) is located in the industrial park of the city of Hermosillo, being one of the main enterprises of the Contreras Corporation. The time frame in which this work was developed is November 2013 to June 2015.

5.4 Research Questions

- What is the relationship between energy consumption and the activities carried out in the processing plant?
- Which will be the impacts of the implementation of a sustainable energy management system?
- Which factors could determine a possible transition to sustainable patterns of electricity consumption in the processing plant?

5.5 Aim of study

The power consumption of equipment associated with the operations of the meat processing plant FRICONSA.

5.6 Selection of the study object

The plant selection was determined by convenience due the interest of the company to have a more sustainable use of energy. In order to understand the consumption pattern of the meat processing plant is necessary to fully evaluate all the elements involved in the operation of this plant. Therefore the study was performed on all equipment involved in the operation the meat processing plant.

5.7 Instruments for data collection

Data was collected from measurements to the systems and equipment involved in the operation of the plant's processes. To have a more integrative approach some data will have to be obtained from the company process and politics. In order to characterize the electric energy consumption, the obtained information will be processed with tools for data analysis, such as excel and similes, which enable the calculation and visualization of the electric energy consumption behavior.

The acquisition of equipment related energy consumption data often requires an extra effort. A first approach is to get measurements of equipment and facilities, for example using thermometers, lux meters, infrared cameras to determine the performance and that can be later extrapolated as an influencing factor in energy consumption. In this case study, the equipment necessary for the accomplishment of the energy audits was supplied by the University and includes: thermometer, lux meter, infrared camera, and surface and wall thermometer.

VI. RESULTS

This section features the data obtained for each step on the implementation of the methodology for efficient energy management in accordance with the ISO 50001 standard within the processing plant FRICONSA.

6.1 Planning and organization

This section presents the results of the first stage of the used methodology which is an essential foundation of the efficient energy use within the company. This stage integrates the organization conviction to move toward a more sustainable consumption of energy.

6.1.1 Initial Contact

The first significant change towards sustainable energy management occurs at the very beginning and consists on the single choice of top management to encompass the company to more sustainable energy related practices. The second step on this stage will be data acquisition which will be followed by an integrative analysis will direct the company to the second stage of this methodology.

This section shows the results of the initial contact that enables the communication between the energy auditor and the company and the 1st meeting that shows the request and necessary agreements between auditor and management.

6.1. 2 Top management decision

The first step on the used methodology requires the fully commitment of top management. This decision sets the basis for a proper access to company information, allowing the development of proper evaluation and consequently to a better implementation of an energy management system. In this this case study management commitment was expressed with a collaboration agreement between the University of Sonora and FRICONSA where the production and maintenance manager was appointed by the company as the authority in charge for realizing the fulfillment of the objectives of sustainable management of energy within the plant.

6.1.3 Involvement of staff

Energy management requires a collaborative approach, to enable team work is necessary to create a task force for the achievement of the objectives of efficient energy management. For this work, a multidisciplinary team within the company that includes representatives ranging from company management to academics was assembled, Chart 3 describes an overall look on the team work created at FRICONSA including each member functions within the company.

Chart 3. Work team.

Name	Department	Function
Ing. Eleazar Chuffe	Production	Production and Maintenance Manager
Ing. Geronimo Bernal Sanchez	Personnel	Hiring and Selection Supervisor
Ecol. Carmen Julia Aguirre Solano	Personnel-Environment	Training
Enf. Pastora Felix	Health	Safety and Hygiene Supervisor
Ing. Tania Guadalupe Poom Bustamante	Production	Auditor
Johannes Winter	Production	Auditor

Source: author´s own design.

To achieve best results it is important to open communication channels between all the staff who is involved in the process, requiring that all ideas and suggestions for improvement on topics relating to energy use within the plant will be considered. This horizontal hierarchy will ease the direct communications and ideas, a basic requirement for management systems.

6.1.4 Project Planning

The preparation of a project plan helps to coordinate the activities and scopes of the field work. Leading to a mindful allocation of resources and minding the gap between theory and praxis, Fig. 5 describes the key elements of the project plan for the case study at FRICONSA including elements at timescale, required accuracy and company obligations.

✓	Timescale	✓	Health influences and risks
✓	Required accuracy		
✓	Obligations of the organization	✓	Safety and privacy policies

Fig. 5. Project planning checklist for the project

Source: author´s own design.

6.1.5 Establishing the system boundaries

Frigorifica Contreras is a food-processing and distributing company located in Sonora, Mexico. The system boundaries of this work is mainly focused on the food-processing and packing plant process of this plant. For the purpose of this work the energy input that will be assessed is electricity and its use on the main processes of production, cooling and lighting. The distribution of the finished product is left out of the energy boundaries but could be additionally researched as a new project, see Fig. 6.

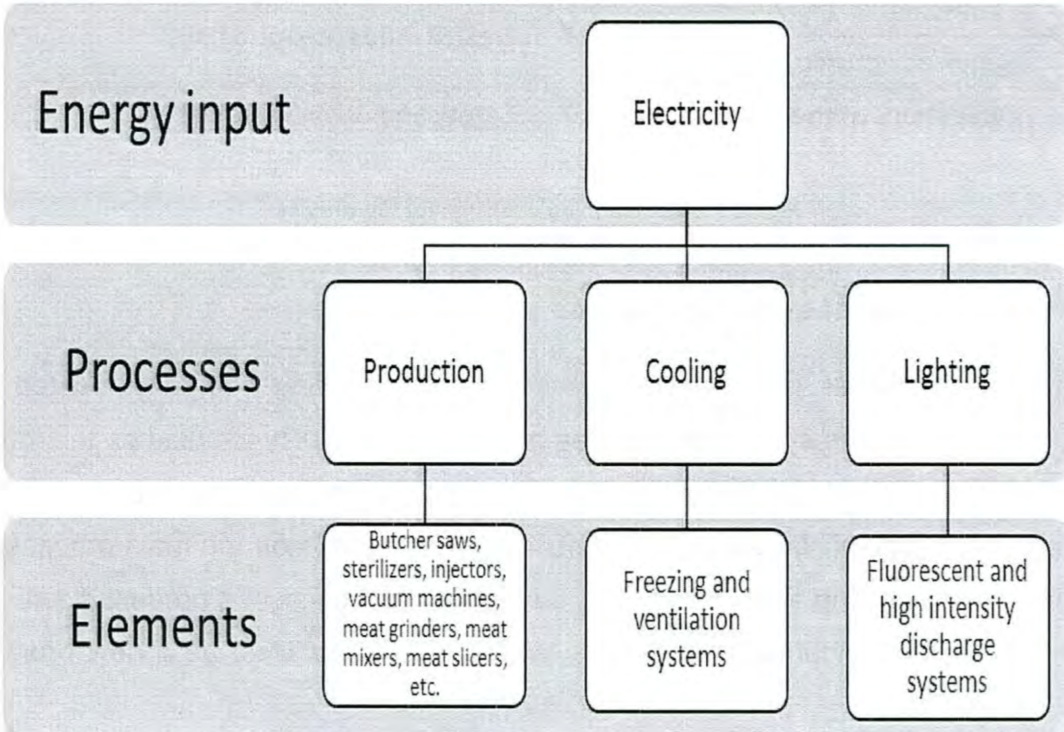

Fig. 6. System boundaries.

Source: author´s own design.

6.2 Data acquisition

In this second stage of the methodology an assessment of the energy situation in the meat processing company is made. For this an energy audit is performed this being the baseline for the obtention of a comprehensive scenario of the energy consumption to later achieve possible energy improvements opportunities for a more sustainable use of the electricity in the company processes.

6.2.1 Facility Overview

The FRICONSA plant is a facility located at the industrial park of Hermosillo, Sonora in Mexico. It serves as a location for the processing and distribution of meat products. This facility is able to process up to 100 cattle carcasses. Depending on the need of production the plant is able to increase or decrease production. The total plant includes several areas and processes in both production and administrative departments, including all the areas the total dimension of the plant is above 6500 square meters. It is important to understand that in concordance with regulations on meat processing facilities some areas of the production process need to comply with certain temperatures in order to keep the food process innocuous. See Fig 7.

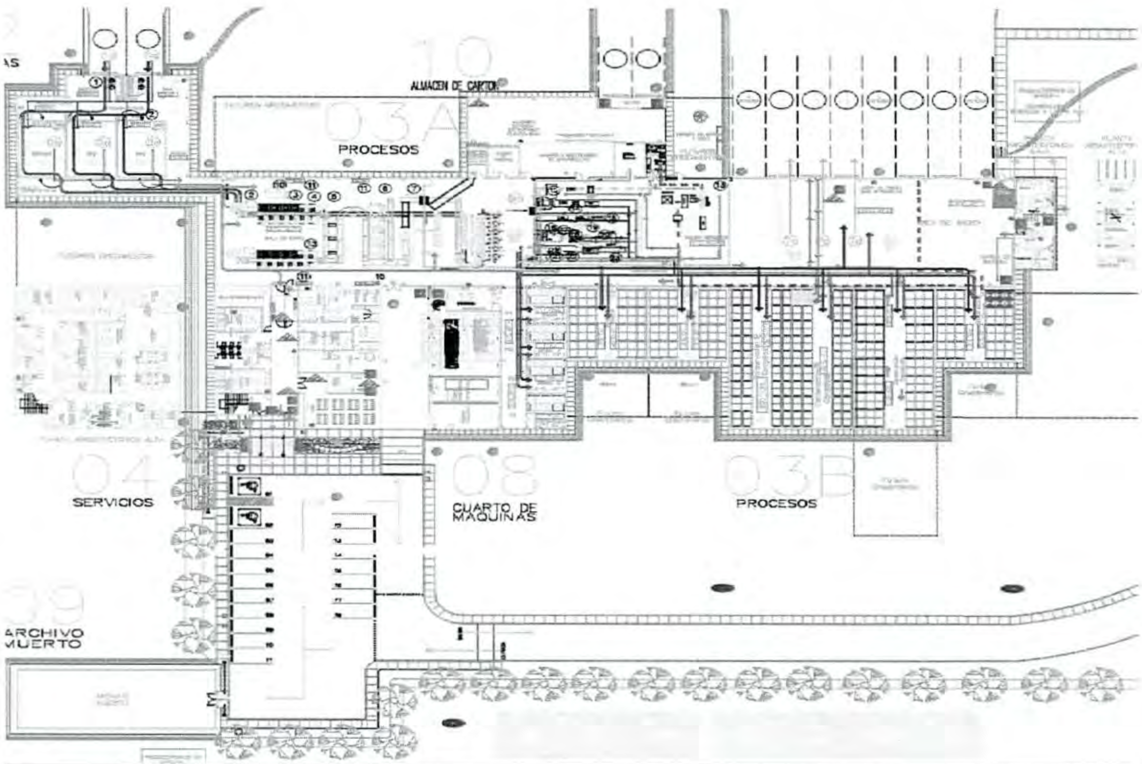

Fig. 7 Plant layout

Source: FRICONSA (2015)

6.2.2 Energy analysis

To obtain the energy status of the company it is necessary to obtain all energy relevant data within the defined system boundaries. This information will determine the energy balance of the company and will compose the basis for a comprehensive analysis of energy consumption.

a) energy input

To start the energy review the values of used energy were obtained through the invoices of the Mexico's electricity provider *Comisión Federal de Electricidad (CFE)* and two other companies in charge of delivering Natural Gas and Liquefied Petroleum (LP) gas to the company. The energy input enlists the sources utilized by the company and the consumption by various consumers. For a monthly review of the company please go to the Annex energy Accounting-EA1.

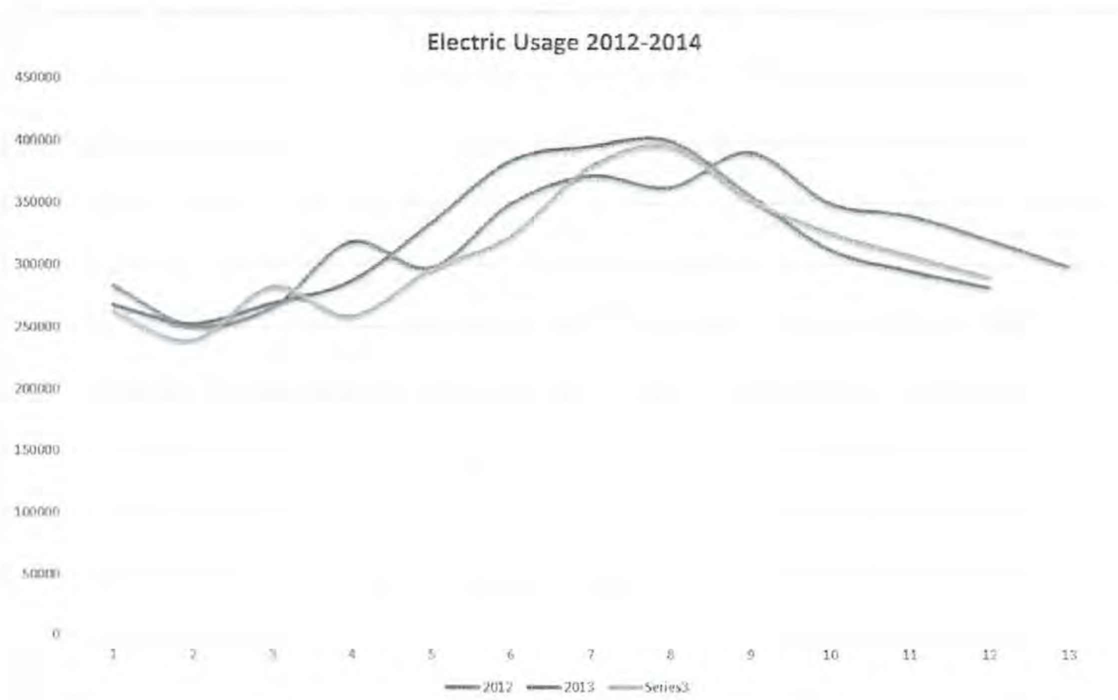

Fig. 8. Electricity Usage 2012-2014

Source: author´s own design.

From Fig. 8, we can see the detailed electricity usage of the FRICONSA Company through the years of 2012 to 2014. The data was categorized monthly and there is a consistency between the three years in an increased consumption during months June to September, which represent the summer season in the desert of Sonora, with temperatures ranging from temperatures that can go higher than 50 Celsius degrees.

To represent the energy consumption in an economical approach the electricity cost from the company was recorded and put together as in Fig. 9. From this graphic we can see the existence of a relationship between energy consumption and cost.

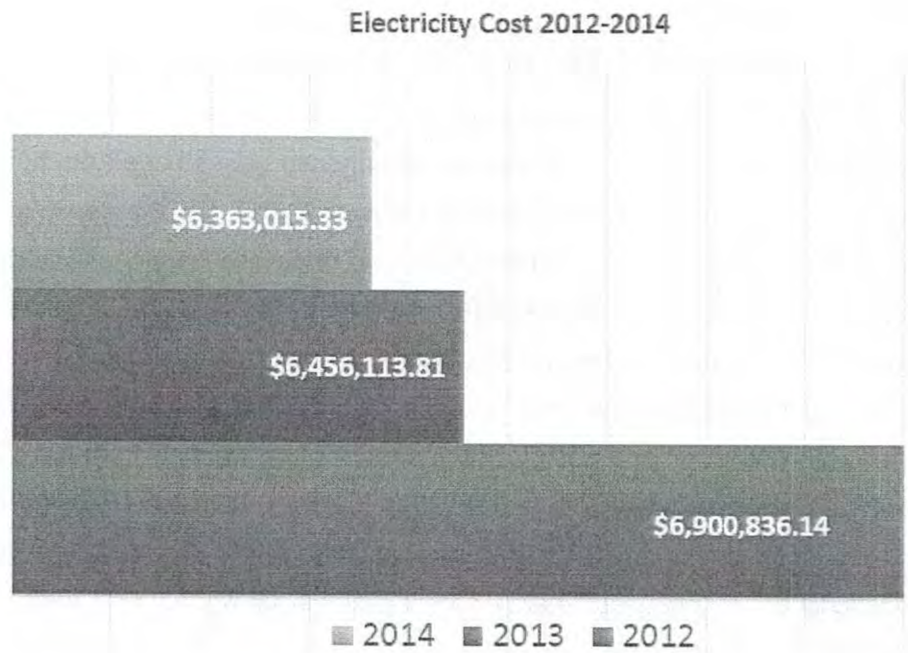

Fig. 9. Electricity Cost 2012-2014

Source: author´s own design.

To obtain a more veridical representation of the energy consumption of the company a record of the annual energy input data was calculated. Chart 5 includes the annual consumption of the three main energy inputs used at the FRICONSA plant. From the obtained data we can understand that energy consumption at the company has the tendency to increase from year to year and also is electricity the most used energy type.

Chart 5. Annual energy input data

Year	Electricity [KWh]	LP Gas [KWh]	Natural Gas [KWh]	Total energy
2012	4192023	2386.63018	905559.749	5099969.379
2013	3832094	1670.602033	1346835.325	5180599.927
2014	1660109	-	608478.1367	2268587.137

Source: author´s own design.

Once that the annual records of energy inputs were analyzed it is necessary, since the generation and therefore consumption of energy causes different environmental impacts, the Annual recording and analysis of utilized energy sources should not only include an usage and cost perspective but should admit at least one indicator of environmental impact.

In this case study energy consumption was translated into their carbon dioxide equivalent. According to the glossary of climate change of the U.S Environmental Protection Agency this metric compares the emission from various greenhouse gases based on their global warming potential. Therefore the Carbon dioxide equivalent (CO_2 E), expressed on Metric tons, describes the potential climate warming capability of several gases on one standard unit. To represent the global warming potential derived from the consumption/generation of electricity standard ratios are used to convert in equivalents amounts of CO_2. This ratios are mostly defined by the electricity mix of each country, the Mexico's electricity mix, primarily entails the use of oil and gas, so the standard of conversion from KWh to their carbon dioxide equivalents according to the *2014 Climate Registry Default Emission Factors* Mexico is defined with a 510.1 CO_2 E by consumed MWh. In Chart 6, we can find the annual description of the used energy sources at the company, and their detailed carbon equivalent in metric tons

Chart 6. Analysis of utilized energy sources

2012					
Energy Source	**Quantity [KWh]**	**Shared of total quantity [%]**	**Costs**	**CO_2 E [Metric tons]**	**Shared of total CO_2**
Electricity	4,192,023.0	82.19	$5,850,692.45	2,306.03	97%
LP Gas	2,386.6	0.04	$172,088.23	1.6	<1%
Natural Gas	905,559.7	17.70	$159,489.27	62.4	>2%
Total	5,099,969.4	100.00	$6,182,269.95	2,370.03	100
2013					
Energy Source	**Quantity [KWh]**	**Shared of total quantity [%]**	**Costs**	**CO_2 E [Metric tons]**	**Shared of total CO_2**

Electricity	3,832,094.0	73.97	$6,456,113.81	2,108.3	69%
LP Gas	1,670.6	0.03	18,82,0666.7	1.2	<1%
Natural Gas	1,346,835.3	25.99	$265,985.08	929.0	>30%
Total	5,180,599.9	100.00	$25,542,765.59	3,038.5	100
2014					
Energy Source	**Quantity [KWh]**	**Share of total quantity [%]**	**Costs**	**CO_2 E [Metric tons]**	**Share of total CO_2 [%]**
Electricity	1,660,109.0	73.18	$2,965,192.10	913.22	68%
LP Gas	0.0	0.00	$0.00	0.0	<1%
Natural Gas	608,478.1	26.82	$141,884.42	420.0	>31%
Total	2,268,587.1	100.00	$3,107,076.52	1,333.22	100

Source: author´s own design.

This collection of the CO_2 E data that is derived from the operation of the company allows to direct energy saving measures towards reducing the environmental impact.

b) energy consumption

The energy review also requires to include the utilization of energy within the system, it is necessary to categorize the energy consumers in a way that the high consumers of energy can be identified, the structure of categorization in the FRICONSA plant has been made by thermal areas, see Fig. 10., in concordance of the processes of the company and more important with the temperature that its needed to comply according to federal and international laws inside food processing industries.

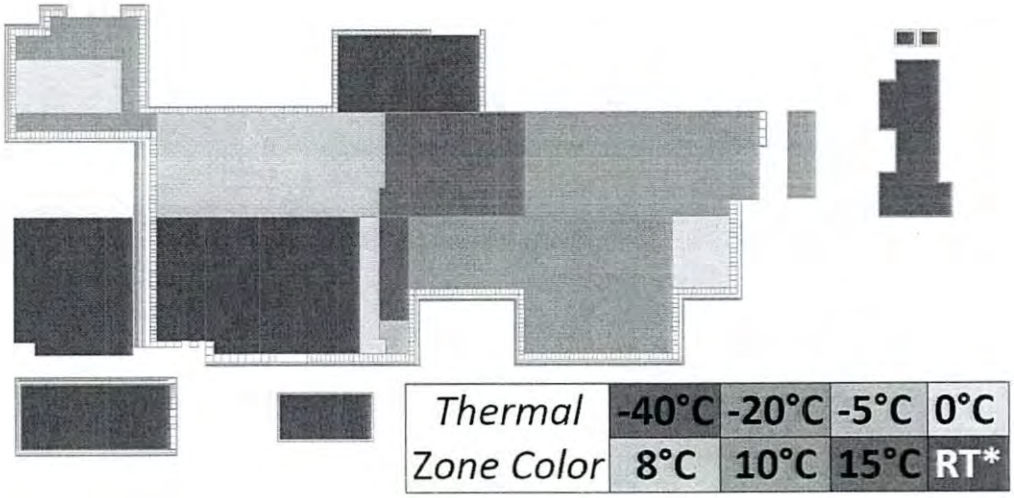

Fig. 10. Thermal zones

Source: author´s own design.

This separation will allow to define and set clear and achievable goals within the efficient management of energy in the company. The total number of thermal zones defined summed up a total of 8 areas that share a similar range of temperature in site and sometimes are part of the same process. Chart 7 shows the areas of the company, the process that is taken place within the areas, the net floor area of this zones and the temperature that it is expected to maintain at all times.

Chart 7. Thermal zones description

Area	Name	Process	Thermal Zone	Net floor Area (m^2)	Temperature (◦C)	E **	LP ***	N ****
1	Recollection		6	0	10			
2	Gutters		4	428.2	0	X		
3a	Process plant	Bone	5	1639.8	8	X		
		Package	5		8	X	X	X
		Added value	7		15	X	X	X
3b	Process plant	Frozen national	2	1422.51	-20	X		
		Fresh national	6		10	X		
		Frozen conservation	2		-20	X		
		Fresh conservation	4		0	X		

3c	Entry room	Conservation	4		0	X		
	Tempered		3		-5	X		
	Blast 123		1		-40	X		
4	Service building		8	970.13	RT *	X		
5	Outlay building		8	382.62	RT *	X		
6	Transport building		8	394.14	RT *	X		
7	Platform building	Shipment	6	183.58	RT *	X		
8	Machine room		8	178.43	RT *	X	X	X
9	Archive		8	250	RT *	X		
10	Cardboard room		8	340.37	RT *	X		
11	Machine room 2		8	104.16	RT *	X	X	X
12	Sanitization and cleaning materials room		8	30.2	RT *	X	X	X

*Room Temperature, **Uses Electricity, ***Uses Natural Gas, ****Uses LP Gas

Source: author´s own design.

To obtain even more detailed information on the main energy consumers within the company process a detailed energy balance was created. In this balance the company's operation was categorized into five categories that separates the energy consumers. Categories as production, heating, ventilation and air conditioning and lighting, each category includes every appliance used to function and it is disaggregated in a daily basis. In chart 8, the daily KWh consumption of each category is described as well as the environmental impact of these categories expressed in CO_2 Equivalents.

Chart 8. Daily based recording of energy consumers

Category	Maximal performance (KW)	Daily energy Consumption per Category [KWh]	CO_2 Emissions [Metric tons]
Production	185.3844	3304.1024	1.81758673
Heating	61.5115	9157.092	5.037316309
VAC	1296.415	36499.696	20.07848277
IT	0.96	234.24	0.128855424

Lighting	2.2582	1400.5488	0.770441895
Total	1546.5291	50595.6792	27.83268313

Source: author's own design.

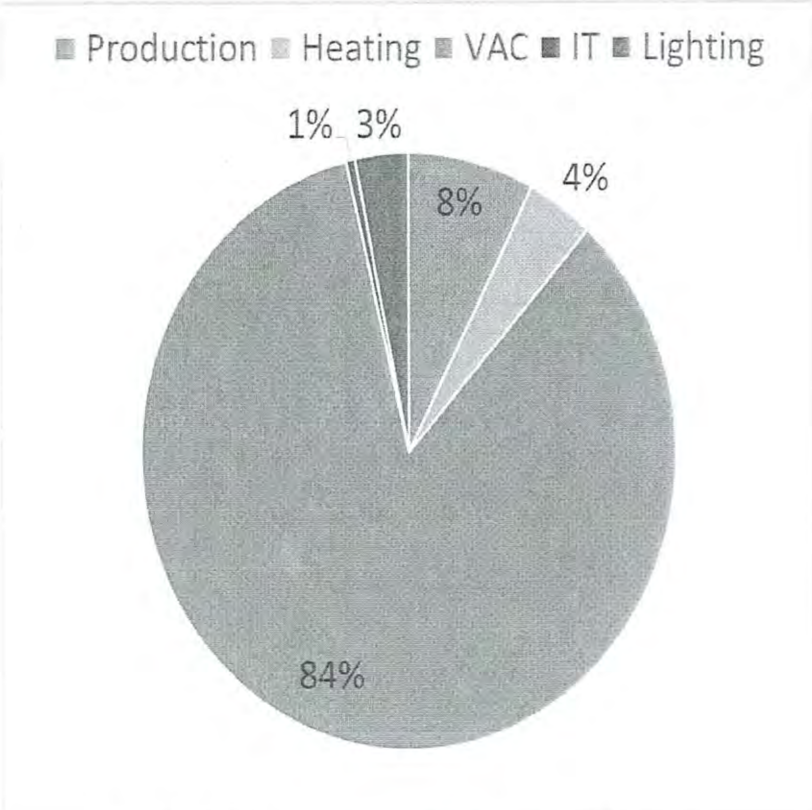

Fig. 11. Daily energy consumption by category

Source: author's own design.

6.2.3 Operating and Technical Information

6.2.3.1 Measurement equipment index

The acquisition of equipment related energy consumption data often requires an extra effort. A first approach is to get measurements of equipment and facilities, for example using thermometers, lux meters, infrared cameras to determine the performance and that can be later extrapolated as an influencing factor in energy consumption. In this case study the equipment necessary for the accomplishment of the energy audits was supplied by the university and will include but it's not limited to: Thermometer, Lux meter, Infrared camera, and surface and wall thermometer.

This information can be used to monitor whether some instruments are subject to inspection and need to be calibrated or certified. Also this review can help to easily identify if the instrumentation used really help to the achievement of practical and structured goals. It can be identified that there is a lack of measuring devices within the company since all the instruments where provided by the Universidad de Sonora.

6.2.3.2 Electrical System Description

An important step on monitoring the company's electricity consumption is to collect data from the electrical systems is important, review the power rating data of the electrical line, transformers and compressors can help with the identification on potential identification of optimization opportunities. In chart 9, we can see a description of the three phasic electrical providing systems at the FRICONSA plant, in this the main components of the electrical system are enlisted and each of them include their electric voltage, electric apparent power and capacity. The electric circuits of the plant have two main components, 2 transformers of different capacity.

Chart 9. Electrical system description

Equipment	Energy Consumption	Receptors
Transformer 1	1000 KVA	Compressor and capacitors bank
Transformer 2	300 KWA	Panel boards for operations management

Source: author´s own design.

6.2.3.3 Lighting systems description

Summarizing the lighting system at the FRICONSA plant can help understand the consumption of energy in this category in chart 11 a detailed description of the lighting system is provided. The FRICONSA lighting needs are satisfied with the use of two types of lighting: Fluorescent and High Intensity Discharge (HID) of metallic additives.

Chart 10. Lighting System Description

Type	Ilumination Zone	Number of Equipment	Daily operation hours	Power [KW]	Consumption [kWh]
Fluorescent	Service Building Upper	60	13	0.1408	109.824
	Service Building Bottom	57	20	0.1408	160.512
	Platform Building (shipment)	25	18	0.1408	63.36

	Cardboard Room	8	13	0.176	18.304
	Transport Building (exterior)	6	6	0.1738	6.2568
	Service Building (exterior)	10	8	0.018	1.44
	Service Building Upper	8	8	0.018	1.152
HID	Exteriors	21	10	0.25	52.5
	Production	78	20	0.4	624
	Shipment	22	24	0.4	211.2
	Freezers	19	20	0.4	152

Source: author´s own design.

a) Visibility

Evaluating illuminance levels in the different work areas will help determine if the light sources are enough for the correct performance of the workers in each area, this activity will enable the detection of improvement opportunities not only on the visibility conditions but could help with the discovering of energy saving measurements. On chart 12

For the determination of the average luminance, it is necessary to divide the space into a number of equal areas. Because a lux meter indicates just the luminance in one point and not the average luminance in the space the results from the measurements each single area needs to get averaged. This evaluation was made in accordance with the NOM-025-STPS-1999, referring to illumination conditions on work stations. In the Annex Visibility-V2 the associated drawings and calculations are attached. The purpose of this evaluation consisted on making an assessment to detect certain areas that might have deficient or exceeding lighting, every lighting type associated to the working areas were analyzed.

The luminance levels resulting from the visibility assessment are described on chart 12, in this chart we can found areas and their respective illumination levels and can have an overall look on how this levels agree with the regulated standards for work stations.

Chart 12. Average Lighting levels

Area	illumination level (Lux)	Minimal required (Lux)	Compliance with official standard	Difference with minimal levels
Cardboard Room 1	151.3	50	Yes	+101.3
Process 1	238.7	300	No	-61.3
Outlay Building 1	28.1	300	No	-278.9
Outlay Building 2	302	300	Yes	+2
Service Building 1	374.1	300	Yes	+74.1
Service Building 2	384	300	Yes	+84
Gutters	190	50	Yes	+140
PB 1	353	50	Yes	+300
PB 2	251	300	No	-49
Process 3	56.6	200	No	-143.4
Process 2	191	200	No	-198
Recollection	269.2	200	Yes	+69.2
Sanitization 1	212.1	300	No	-87.9
Transport Building 1	141	300	No	-159

Source: author´s own design.

6.2.4 Infrared Audit and Building Envelope Assessment

a) Infrared Audit

An infrared audit helps with the process energy assessment. Through the thermo graphic images obtained with an infrared camera, the company can detect potential problems within the electrical systems and processes. The impact of the obtained information in form of improvement opportunities could have significant economical relevance within the company.

The main result after an infrared audit is the characterization of the energy attributes of certain process and systems within the company that can be translated into significant consumption of energy. Therefore finding if there is within systems anomalies that could increase power consumption can be both helpful in matters of sustainability of the company.

In this work the inspection tool used was the FLIR E6 camera. The thermal images obtained with the use of this camera clearly would reveal, if existing, problems from sources of energy losses, moisture intrusion and structural issues to overheating electrical and mechanical equipment (FLIR, 2014). In chart 13 it's stated the summary of results obtained from the infrared audit, for a more detailed description of the results can be founded in the Annex Thermal Images-T3.

Chart 13. Thermal Characterization

Thermal Image Group code	Quantity of images taken	Assessed Component	Temperature Span (°C)		
			Lower Limit	Average	Upper Limit
G01	5	Building Envelope	46.6	59.16	69.33
G02	15	Frezing Systems	-12.5	1.81	12.94
G03	15	Holders	17.44	43.09	80.61
G04	15	Control boxes	6.55	40.61	65.77
G05	10	Controlers	87.22	62.06	45.5
G06	3	Ventilation Systems	6.22	5.25	4.66
G07	6	Compressors	152.3	152.31	97.7

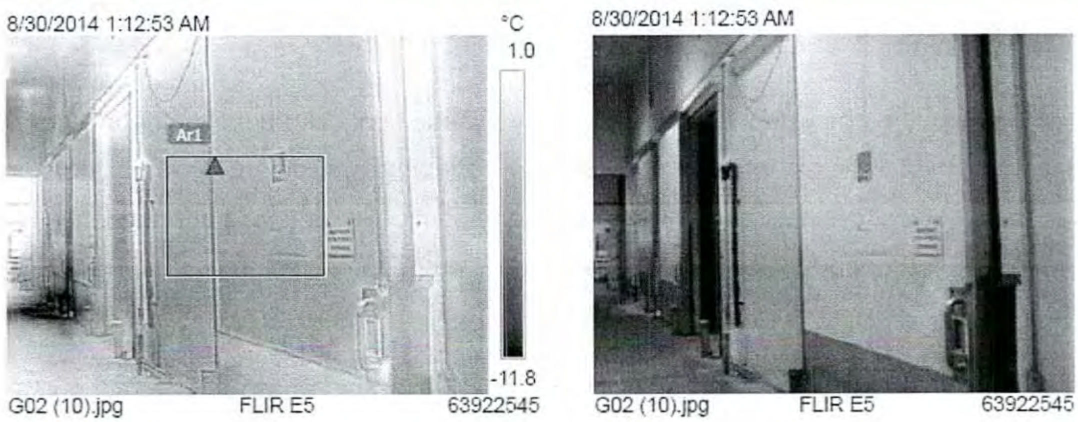

Fig. 10. Infrared assessment at the company

Source: FRICONSA (2013)

Identification of equipment problems can also be determined with the quantification of energy fluxes of the equipment, for this assessment of the consumption hours by each equipment has been made.

Chart 14. Quantification of energy usage on the production process.

Machine	Operation daily hours	Quantity	Daily total consumption (KW)	Cost	CO_2 E	Share of total CO_2 (%)
Machine 1	16	1	2.9	506.2	1.6	2
Machine 2	16	1	2.2	379.6	1.2	1
Machine 3	16	4	1	169.6	0.5	1
Machine 4	16	4	1.5	254.4	0.8	1
Machine 5	16	8	0.7	126.5	0.4	0
Machine 6	16	1	63	10687.9	34.6	34
Machine 7	16	1	1.1	186.6	0.6	1
Machine 8	16	1	0.8	147.5	0.4	0
Machine 9	16	2	8	1357.2	4.4	4
Machine 10	16	1	5.5	949.1	3.07	3
Machine 11	16	1	11	1866.1	6.05	6
Machine 12	16	1	0.7	127.2	0.4	0
Machine 13	16	1	1.8	316.3	1.02	1
Machine 14	16	1	1.1	189.8	0.6	1
Machine 15	16	1	2.6	442.9	1.4	1
Machine 16	16	1	1.4	253.1	0.8	1
Machine 17	16	1	5.5	949.1	3.07	3
Machine 18	16	1	2.2	379.6	1.2	1
Machine 19	16	1	2.2	379.6	1.2	1
Machine 20	16	2	0.4	67.8	0.2	0
Machine 21	16	1	1.5	254.4	0.8	1
Machine 22	16	1	2.2	379.6	1.2	1
Machine 23	16	1	9.4	1594.7	5.1	5
Machine 24	16	1	3.4	576.8	1.8	2
Machine 25	16	1	27	4580.5	14.8	15
Machine 26	16	1	0.7	127.2	0.4	0
Machine 27	16	1	8	1357.2	4.4	4
Machine 28	16	1	9	1526.8	4.9	5
Machine 29	16	1	1.4	240.4	0.7	1
Machine 30	16	1	2.2	379.6	1.2	1
Machine 31	16	1	4.1	695.5	2.2	2
Total			185.3	31450.46	101.9	100

Source: author´s own design.

b) Isolation data of the building envelope

To determine the calorific capacity and therefore choose the exact refrigeration systems required in the different cameras and frozen areas of the plant the following considerations where taken into account.

Chart 15. Building envelope specifications

Area	Dimension (L-A-H) Mts	Isolation	Daily MAX cattle load	Storage capacities	MAX TEMP	MIN TEMP	RH*	CTL**
Cattle inspection	7.20x2.93x6.22/6.13	3" I-PUR*** panel in walls and ceiling	150	-	1.5◦C	10◦C	70%	31,813 Btu/hr
Pork inspection	7.20x2.93x6.22/6.13	3" I-PUR*** panel in walls and ceiling	100	-	1.5◦C	10◦C	70%	33,926 Btu/hr
Recolection area (entrance)	21.37x3.83x6.52/6.32	3" I-PUR*** panel in walls and ceiling	150 in transit	-	1.5◦C	10◦C	-	36,974 Btu/hr
Recolection area (exit)	21.58x2.78x7.17/7.0	3" I-PUR*** panel in walls and ceiling	150 in transit	-	1.5◦C	10◦C	-	33,482 Btu/hr
Gutter #1	8.93x5.83x7.0/6.52	3" I-PUR*** panel in walls and ceiling	50	50	2◦C	0◦C	90%	58,252 Btu/hr
Gutter #2	8.93x5.83x7.0/6.52	3" I-PUR*** panel in walls and ceiling.	50	50	2◦C	0◦C	90%	58,252 Btu/hr
Gutter #3	8.93x5.83x7.0/6.52	3" I-PUR*** panel in walls and ceiling	50	50	2◦C	0◦C	90%	58,252 Btu/hr
Combos Chamber	8.93x2.77x7.0/6.52	3" I-PUR*** panel in walls and ceiling.	10 tons	10 tons	4◦C	0◦C	90-95%	36,673 Btu/hr
Process1 (bone)	30.77x17.62 x6.62/5.73	2" I-PUR*** panel in walls and ceiling	25 people and machines for 10 HP		1.5 ◦C	10◦C	55-60%	230, 220 Btu/hr
Palletizing area	33.04x17.62 x6.62/5.73	2" I-PUR*** panel in walls and ceiling	10 people and machines for 10 HP		1.5◦C	10◦C	55-60%	203,89 0 Btu/hr
Platform	35.80x17.62 x6.62/5.73	2" I-PUR*** panel in walls and ceiling	6 people during 12 hours, 2 electric lifts (8 hours a day) and machines for 5 HP		1.5◦C	10◦C	55-60%	236,14 9 Btu/hr
Chamber 1 Conservation fresh	12.07x9.77x 11.44/10.8	4" I-PUR*** panel in walls, floor and ceiling.	48 toneladas (60 palleta)	384 toneladas (480 pallets)	-14◦c	-20◦c	90%	101,88 5 Btu/hr
Chamber 2 Conservation frozen (season)	23.33x9.79x 12.08/10.8	4" I-PUR*** panel in walls, floor and ceiling..	48 toneladas (60 palleta)	384 toneladas (480 pallets)	-14◦c	-20◦c	90%	166,16 3 Btu/hr
Chamber 3 Conservation	23.33x15.47 x12.08/10.8	4" I-PUR*** panel in walls, floor and ceiling.	96 toneladas (120 palleta)	512 toneladas (640 pallets)	-14◦c	-20◦c	90%	232, 214 Btu/hr
Chamber 4 fresh national	12.03x9.79x 11.44/10.8	4" I-PUR*** panel in walls, floor and ceiling.	38.6 toneladas (48 pallets)	192 toneladas (240 pallets)	4◦c	0◦c	90%	92,762 Btu/hr
Chamber 5 frozen national	12.03x9.79x 11.44/10.8	4" I-PUR*** panel in walls, floor and	38.6 toneladas (48	192 toneladas (240 pallets)	4◦c	0◦c	90%	124,24 3Btu/hr

		ceiling.poliuretano.	pallets)					
Blast freezer (ante camara)	18.84x2.68x6	4" I-PUR*** panel in walls, floor and ceiling.	-	Solo transito	1.5◦C	10◦C	-	14,986 Btu/hr
Blast freezer 1	6.00x5.00x6.00	4" I-PUR*** panel in walls, floor and ceiling.	9 tons	Tiempo de congelación 30 horas	4.4◦c	-18◦c	-	186,683 Btu/hr
Blast freezer 2	6.00x5.00x6.00	4" I-PUR*** panel in walls, floor and ceiling.	9 tons	Tiempo de congelación 30 horas	4.4◦c	-18◦c	-	186,683 Btu/hr
Blast freezer 3	6.00x5.00x6.00	4" I-PUR*** panel in walls, floor and ceiling.	9 tons	Tiempo de congelación 30 horas	4.4◦c	-18◦c	-	186,683 Btu/hr

*RH: Relative Humidity,**CTL: Calculated thermic load,***PUR: Polyurethane Panel, 50 cattles =15 tons

Source: author´s own design.

6.2.5 Key Performance indicators

For a targeted analysis of the energy related data an extern benchmarking process will deliver more significant results. The comparison with other companies of the food-processing industry will give useful information for checking and verifying the own performance in terms of energetic aspects. Frigorifica Contreras, a company belonging to the food industry sector, has the main activity to produce and distribute meat products. Based on the SIEM-database of the Mexican economy ministry it is categorized as a small industry.

For getting dependable results it's necessary to include the geographic information of the company into the benchmarking process, because the weather conditions are a significant factor for energy consumption levels. Especially the extreme climatic conditions in Hermosillo must be taken in consideration for verifying the energetic situation. For the energy assessment three benchmarking databases were selected in order to get a comprehensive impression on the energetic improving potentials.

In particular, meat processing companies have limited available capability, capacity and resources to manage energy cost and consumption. For these facilities, it is important to understand the potential benefits of energy management best practices and technologies, and be able to benchmark the current performance against other similar facilities. In order to get reliable benchmarking key indicators for the production location of FRICONSA, especially because of the extreme climatic conditions, it is necessary to choose geographic reference areas with similar characteristics.

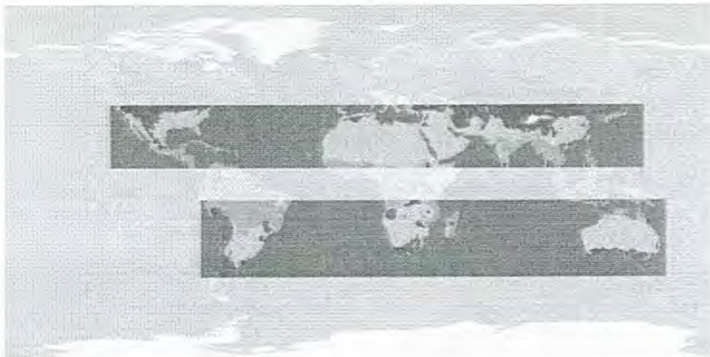

Fig. 11. Continental climatic zones

Source: author´s own design.

For the consideration of this specific benchmark the area of Australia was chosen due to the consistent similarities within the climatic region and the characteristics of the industrial sector. The Australian meat processing industry is structured in similar way like in Mexico.

From the review of energy efficiency utilization benchmarks & technologies for Australian red meat processing (2013) established by the Australian Meat Processor Corporation (AMPC) comparable data can be obtained. The primary energy sources (electricity, natural gas and liquefied petroleum gas) used in the reference meat processing facilities are in accordance with this case example in northern part of Mexico.

Also, a significant factor for benchmarking is the size of the company where also the AMPC review is focusing small and middle-sized enterprises. In the course for an extern benchmark with other companies of the industrial sector there is a need to gather the energy related data into specific energy indicators. These energy performance indicators are expressed in form of several metrics, which are quantitative and comparable. For the analysis of the energy audit data the performance indicators are significant, which are listed in chart 16.

Chart 16. Performance indicators

Performance indicators	Formula
Total energy use	Absolute
Units of energy consumed (in kWh or MJ for example) per head of livestock slaughtered	$\frac{Total\ energy\ consumption}{Production\ quantity*}$

Units of energy consumed (in kWh or MJ for example) per ton of live carcass weight (tLCW) produced	$\frac{Total\ energy\ consumption}{Production\ in\ tons}$
Units of energy consumed (in kWh or MJ for example) per number of full time employees (FTE).	$\frac{Total\ energy\ consumption}{Total\ number\ of\ employees}$
Total energy costs	Absolute
Energy intensity	$\frac{Consumption\ per\ energy\ source}{Total\ energy\ consumption}$
*production quantity =head of livestock slaughtered	

Source: author´s own design.

In relation with this indicators and the energy consumption data specific values can be obtained. These indicators are shown in an annual basis in order to benchmark this data with the information of the Australian industry.

Chart 17. energy use indicators

Energy Use indicators (Annual)	
Total energy use	7,993,397.6 KWh
Energy per head slaughtered	307.4 KWh
Energy per produced ton	1,024.7 KWh
Energy per employee	35,369.01 KWh
Energy cost	25,542,765.6 MXN $
Energy intensity 2013 Reference Year	
Energy intensity electricity	0.73 KWh
Energy intensity natural gas	0.26 KWh
Energy intensity LP Gas	0.0003 KWh

Source: author´s own design.

One of the key performance indicators for the meat processing industry takes into consideration the energy which is needed to produce one ton of processed meat. The indicator has a value by the AMPC rank of 1600 KWh per produced ton. In comparison Company A encounters itself beneath this mark with a value of 1024 KWh per produced ton, see Fig.12.

Fig. 12. energy per produced ton

Source: author's own design.

In some industries, environmental benchmarks are used extensively to gauge the performance and competitiveness. Because of a not existing unique production unit, an accurate benchmarking procedure for meat processing companies is just partly achievable.

6.3 Analysis

This third stage is relevant for the determination of significant consumers and influencing factors. At this step it's important in order to focus in what is essential: efficiency and compliance since the determination of the major energy consumption will make it possible to define priorities for actions and use resources and tools in a more purposeful manner.

6.3.1 Significant energy factors influencing energy consumption

A significant influencing factor on the energy balance can be major energy consumer or a circumstance that has a major effect, for example: maintenance intervals, capacity, and utilization of equipment, legal frameworks, climate conditions and level of production. For this research two significant factors are recognized:

- Climate conditions,
- Level of production,

The following charts enlist the consumers which are sorted according to consumption amount. This will provide with the necessary information to identify which consumers have the most consisting and the most fluctuating consumption derived of the significant factors that influence energy consumption so changes can be can be made quickly and with little effort.

Chart 18. Significant factors evaluation

	Criteria									
	Consumption	Consumption fluctuation	Planned consumption	Cost	Potential savings	Legal compliance	Environmental Impact	Implementation	Deviation from benchmark	Possibility to influence consumption
Influencing factors	VAC	3	3	3	3	3	2	3	1	3
	Lighting	1	2	2	2	1	2	3	1	1
	IT	1	1	1	2	1	2	2	1	1
	Production	2	1	1	2	1	2	2	1	1
	Heating	2	1	1	1	1	1	1	1	1
	Legal requirements	2	1	2	1	1	2	1	1	1
	Maintenance	1	2	2	2	1	2	1	1	1
	Annual mean temperature/ degree days	3	3	3	3	3	3	3	3	3

3= strong influence, 2= medium influence, 1, little or no influence

A semi-quantitative analysis using a matrix representation is sufficient to evaluate the significant factors. All energy uses are entered in the vertical column, and all criteria are entered in the horizontal row. The criteria with the strong influence is indicated with the number 3. Each field of the matrix is assessed recognizing the energy uses with the highest as the most significant ones. In this exercise it is particularly important to focus on the climate conditions and it can be highlighted as a significant factor. Also, an important highlight that can be assessed from this matrix is the influence of the VAC energy usage in the total consumption of energy of the company.

6.3.2 Potential energy savings and potential energy improvements

The results obtained from the energy audit of FRICONSA gives an overall look of the energy consumption in the particular areas and processes, which can be convenient by the identification of energetic weak spots. This information enables the company management to make decision related to which areas or processes are more profound reasonable investigations.

To develop concrete strategies on how to improve the current energetic situation a differentiation of behavioral and technical factors is advisable. For the realization of behavioral improving measures, the implementation of an energy Management System, according to the ISO 50001 standard, is highly recommended.

6.3.3 Definition of energy targets

There are numerous energy efficiency opportunities and best practices that can be implemented at red meat processing facilities. These range from simply improved housekeeping through to upgrade or replacement of existing equipment.

Energy efficiency opportunities can be broadly categorized in four categories; (1) energy efficient technologies (crossover technologies), (2) alternative energy systems, (3) maintenance, and (4) behavioral and Procedural. In this work, due the characteristics of the company, the main opportunities will be explored on the areas of crossover technologies, maintenance and behavioral and procedural.

6.3.3.1 Crossover technologies

A technical energy efficiency measure involves physically altering some aspect of the building or equipment to get more out of the energy used, for example, installing cavity wall insulation in a home or buying a more energy efficient washing machine. In the industrial context, energy use can also be reduced by the use of crossover technologies such as variable speed drives in a motor operated system, high efficient motors, efficient nozzles in compressed-air system, waste heat recovery system in boilers, etc. In the context of the performed energy audit, the focus is to reveal the energetic weak spots and give suggestions where an exhaustive, additional research is profitable. Themed on general improving measures in the scope of crossover technologies are, in chart 19, general strategies listed. The main crossover technologies in this context are: illumination, pneumatic systems, electric drives, pumping systems, ventilation systems, air conditioning technology and space heating/ cooling systems. This list is compiled from an extensive analysis of energy efficiency strategies, proposed by several authors.

Chart 19. Measures for energy efficiency

Scope	Measures to improve the energy efficiency
Illumination (Hesselbach, 2012)	- Installation of more energy-efficient lighting engineering
	- Reduction of the wattage of lights
	- Pale painted walls, ceilings and floors reflecting the light in a better way
	- Matching of the illuminance on the purpose of the workplace
	- Application of light sensors which adjust the illumination
	- Installation of motion detectors which are noticing if persons entering into an area or room and the light gets switched on
	- Intelligent time management and formation of zones depending on usage
	- With a control system can every employee control the illumination from his own computer
Pneumatic Systems (Thollander and Palm, 2013)	- Reduction of air leaks
	- Decrease of the air pressure
	- Converting into electric tools where possible
	- Usage of variable speed drive compressors
	- Consideration of the possibility to use the compressor's cooling output for space heating purposes
Electric drives (Müller et al., 2009)	- Usage of energy efficient motors (IEC standard 60034-2-1 or CEMEP efficiency category)
	- Regular maintenance of the drives
	- Minimization of ration radii, accelerations, displaced mass and velocities
	- Regeneration of braking energy
	- Utilization of variable speed drives (VSD)
	- Preferential usage of direct drives to reduce the friction losses
	- No oversizing of the electromagnetic drives
	- Switching on or off in a targeted manner of the drives
	- Selection of an energy efficient type of transmission
Pumping Systems (Thollander and Palm, 2013)	- Reduction of the flows through variable speed drives (VSD)
	- Improvement of gears and transmission
	- Reduction of the flows through effective time control
Ventilation and Air-conditioning Technology (Thollander and Palm, 2013)	- Reduction of the air flows through variable speed drives (VSD)
	- Reduction of the flows through effective time control
Space heating and cooling	- Heat recovering from hot exhaust air flows

systems (Thollander and Palm, 2013)	- Usage of ceiling fans
	- Shutdown of the heat circulation pumps in the summer
	- Usage of air curtains for shuttle doors
	- Reduction of the indoor temperature during heating season
	- Improvement of the roof and wall insulation
	- Supply of heat and cooling at the right temperature
	- Better insulation of pipes, heat exchangers etc.
	- If possible converting from steam into waterborne systems
	- Usage of heat pumps
	- Taking advantage of free cooling
Internal Transport (Thollander and Palm, 2013)	- Improvement of the production planning to reduce transport distance
	- Optimization of the storage location to reduce the transport distance

6.3.3.2 Behavioral measures for energy efficiency

Although energy efficiency can be highly improved through technology measures, efficient energy use also has a behavioral component (Gosman, 2012). energy efficiency through behavioral measures in the industrial sector mainly involves a consumer, in this case primarily the employees, changing their habitual behavior to get more out of the energy used, for example, turning the heating down by one degree or turning off electrical equipment not in use (Department of energy and Climate Change DECC, 2012).Typical behaviors such as turning off lighting in unused areas is a demonstration that changing behavior can be an inexpensive and an immediate way of saving energy and in certain times

it can be comparable to installing technical energy efficiency measures. For example, according to UK studies from the DEEC, turning the thermostat down or up by one degree could achieve about 90 per cent of the energy savings that cavity wall insulation achieves. In this case study, for the FRICONSA meat processing plant, the behaviors that should be modified must focus the attention to the comprehensive use of illumination, ventilation and air conditioning systems.

Chart 20. Typical Behavioral energy measures

Typical behavioral energy measures	Approximated energy saved [KWh]
Turn thermostat down by 1 degree	1500
Delay start of heating	600
Turn off lights when not in use	150

Source: DEEC (2012)

6.3.3.2.1 energy efficiency courses

Another way to increase energy efficiency is by the implementation of energy efficiency courses and training programs which are very important to increase the awareness of people who are involved in the daily operations of the company. This courses can be relevant to engineers, management and overall to all employers, mainly they can be particularly useful for the decision makers within the company.

6.3.3.2.2 energy saving by housekeeping

Another approach to energy efficiency can be observed with the overlap of efficient production and good working environment. This concept is referred to "good housekeeping", which can be defined as the elimination of inefficiencies and accident hazards caused by unfavorable conditions in the workplace which is essential in getting the job done efficiently and safely. A concept that matches with the cleaner production approach, which is very important for the industry nowadays (Dufort V. and Infante-Rivard, C., 1999).

Housekeeping involves all stages of industrial operations and goes beyond clean workspaces. In FRICONSA, especially in matters of energy efficiency, housekeeping can help to reduce energy consumption in the following ways.

Chart 21. energy efficiency through housekeeping

Housekeeping actions that can lead to energy efficiency	
Lighting	Paint the walls: Light-colored walls reflect light. Dirty or dark-colored walls absorb light. Maintain the light fittings: Dirty lamps and shades, and lamps whose output has deteriorated with use, deprive employees of essential light. It's been found that lighting efficiency may be improved by 20–30% simply by cleaning the lamps and reflectors.
Maintenance	Regular maintenance allows management team to repair machinery, broken windows, damaged doors, defective plumbing, and leaking, broken floor surfaces. A good maintenance program will make provision for the inspection, lubrication, upkeep and repair of tools, equipment, machines and processes.

Check	A sound method to ensure that housekeeping is done is for management to prepare a check list to suit the requirements of the workplace.

Recalling the previously presented data about energy consumption, it can be remembered that the main consumption of energy at the FRICONSA plant is by the use of electricity, it is target-aimed to pursue energetic improving potentials. Taking into consideration the analysis of the benchmarking outputs, the used technological systems are weighed differently, in terms of reduction capabilities. It seeks to prioritize the most cost effective opportunities to catch, metaphorically, the low hanging fruits.

Therefore, this ensemble of measures, set a useful guideline in the implementation of energy efficiency actions in the company since the listed measures integrate a wide action scope in both, technical and behavioral measures, to improve energy efficiency. Nonetheless, for each potential measure, a deeper analysis with possible measurements, associated costs and time requirement is presented.

6.3.4 energy Policy

With the evaluated data and taking into consideration the legal, social, economic and environmental requirements for the company´s operations, a series of energy objectives to achieve an efficient energy use can be elaborated. For this reason, it is important to first elaborate an energy policy that works with the company values and objectives. A proposal, for energy policy at FRICONSA is elaborated in the next paragraph.

"At FRICONSA, we recognize that our daily operations have a significant impact on the environment. Therefore, assuming the commitment to reduce its ecological footprint and contribute to the improvement of the quality of life of our community. Having the compromise to reduce the negative impact towards the environment and incorporating the dimension of sustainability on our processes."

For the company, the majority of actions are focused on the improvement of the lighting and refrigeration systems. These actions are also ranked with the highest ROI, which can lead the management to take measures toward an improvement of the systems.

a) Technical energy objectives

The priority areas for energy savings are lighting and refrigeration. The main objectives of the plant should be to reduce the consumption of energy in these key areas. To achieve that, it's necessary to define several actions that become objectives for energy savings. In the following chart, a total of seven objectives are defined by categories. Also a representation of the level of return of investment is displayed.

Chart. 22. Technical energy objectives.

End Use	Action	ROI
Lighting	Reduce Indoor Power Density by 25%	Medium
Lighting	Reduce Indoor Power Density by 10%	High
Lighting	Reduce Indoor Power Density by 15%	High
Motors, Ventilation	Install Premium Efficiency Motor for Fans	High
Refrigeration	Change Air-Cooled Condensers to Evaporative-Cooled	Medium
Refrigeration	Convert to Multiplex Compressor	High
Refrigeration	Change all Condensers to Oversized Condenser	Medium

Source: author´s own design.

b) Operational energy objectives

This objectives seeks to achieve a more comprehensive use of energy and a reduction of electricity use prompted by the dissemination of knowledge about energy efficiency from the employers at FRICONSA. This will enable technological skills in energy, environment and health & safety aspects to professionals for the industrial development of the company.

6.4 Report

This final step is dedicated to the presentation of the key elements for a sustainable transition to energy consumption. In this stage a report of all the potential opportunities for energy efficiency and energy management are presented and evaluated. This stage aims to provide the company management with a comprehensive tool for decision making in matters of energy management.

6.4.1 Saving opportunities

A description of the strategies for energy efficiency and their actions is described in the following section.

i. ***Strategy 1: Lighting opportunities***

a) Reduce indoor power density by 15 %

Action 1. Cleaning of lamps and reflectors.

ii. ***Strategy 2: Refrigeration opportunities***

a) Change to energy efficient refrigeration equipment.

Action 1. Change air-cooled condensers to evaporative cooled

Action 2. Convert to multiplex compressors

Action 3. Change all condensers to oversized condensers

b) Temperature control

Action 1. Automatically adjust temperature from thermostat in function of the productive area.

Action 2. Maintenance to the freezers chambers.

Action 3. Continuous maintenance to the entrance to the refrigeration's chambers will reduce the leakage of cold air. Therefore, It will reduce the leakage of energy.

iii. ***Strategy 3: Behavioral and operational opportunities***

This strategy seeks to o impart technological skills in energy, environmental, health and safety aspects to professionals for industrial development and a reduction of electricity usage prompted by knowledge about energy efficiency from the employers at FRICONSA:

a) Diminish energy consumption by office equipment

Action 1. Enable the energy saving mode in all the computers.

Action 2. Disconnect all at the voltage regulators at the end of the work day.

b) Housekeeping action for energy efficiency

a. Color walls in light tones to reduce energy consumption.

c) Stablish a policy for equipment maintenance

d) Integrate an energy efficiency training program in which all the company employees are considered

6.4.2 Evaluation of proposed saving strategies

With all the possible measures to obtain better energy efficiency at FRICONSA and with the energy objectives already defined it is necessary to evaluate and assess with measures for energy efficiency that will be applicable in order to achieve significant reductions in the electricity bill in the company.

At FRICONSA, it is distinguishable that the main focus for reducing electricity consumption should be through the maximization of the benefit of accomplishing operational objectives. However, some technical measures will fit the company objectives to reduce energy consumption.

In terms of energy efficiency measures, the production category, as it has no significant high energy consumption, will not reflect a significant change towards the reduction of energy consumption. Therefore, change in the process will not have a significant impact on the reduction of the company overall consumption of electricity within the plant.

The priority areas to apply energy efficiency measures at FRICONSA are those of illumination and in the attitudinal change of energy use. The first entails a degree of technical requirements while the second is an operational and behavioral strategy oriented towards the employees and their resourceful use of energy. In the next section, the proposed saving strategies are evaluated in matter of implementation viability within the company resources and availability for the implementation of each selected proposed strategy for energy efficiency.

6.4.3 Energy saving measures analysis

In Chart 23, the analysis of the proposed energy efficiency measures are evaluated in matter of consumption, cost and potential of reduction if the measure is implemented. To calculate cost and potential savings the official rate of electricity, from CFE, for this company is defined as in the official electricity bills as 169.65 Mexican pesos per kilowatt of billable demand. It can be observed that the technical measures imply an investment from the company. However, the return of investment can be shown not only as an economic indicator but can be observed from an ecological perspective as in the reduction of carbon dioxide emissions. For the FRICONSA case, if all the measures listed in the previous chart will mean a reduction of the CO_2 E emitted to the environment.Chart. 23 Analysis for energy saving measures

	Saving goal	Measures	Consumption [% of total]	Cost of consumption [MXN]	Potential savings [%]
Illumination	Reduce indoor power density by illumination	Cleaning of lamps and reflectors	9	$469,902.7	20-50
		Change to more energy efficient bulbs			
Refrigeration	Refrigeration	Change to more energy efficient refrigeration	89	4,664,165	15-40
	Temperature control	Automatically adjust temperature from thermostat in function of the productive area.			
	Maintenance	Schedule maintenances regularly to avoid cold losses			

Information technology	Diminish energy consumption by office equipment	Enable the energy saving mode in all the computers	1	39,738.82	
		Disconnect voltage regulators			
Operational and behavorial	Housekepping	Light colored walls	-	-	NA
	Maintenace	Create policies for equipment maintenance	-	-	NA
	Training	Implement an integrative training program on energy efficiency	-	-	NA

Source: author´s own design.

VII. ANALYSIS

It is a known fact that the functioning of organizations is decided on the basis of greatest benefit with minimal use of resources. The plant activities reflect this notion and are focused on minimizing the use of resources for the lowering of costs, displacing to the background the protection and control of negative environmental impact; focused only to compliance. In this research, energy consumption is used to gauge the use of this resource in each of the activities carried out within the processing plant of meat, it is through this work that you can get an overview of the implications have studied administrative and production processes.

The information obtained through the characterization of energy consumption of the different processes of the plant is useful to discover opportunities in sustainable energy use. Resulting in strategies that are based on policies, resources and capabilities of the company to be implemented have maximum impact on the sustainable use of energy within the company, thereby contributing to the reduction of the environmental impact of its activities by improving their contribution the maintenance of the environment.

Following the completion of this research it is clarified that the management of energy, given the particular situation of the FRICONSA, can only be achieved if use of strategies is done with multiple approaches, integrating elements of both technical and behavioral as it is at the intersection of these concepts where there is the opportunity to reduce costs and the negative environmental impact of the company without changing its productivity. Applying this type of multidimensional energy management will allow the company to integrate a frame of reference and understanding for comprehensive energy management with positive results.

In FRICONSA the impacts of the implementation of energy management strategies will have different implications for the performance of the company having different ranges. For example, from an economic perspective energy efficiency strategies for sustainable management of energy will have an impact on the monetary resources of the company since the shift to more efficient technologies involves an investment in the company. However, it should be emphasized that the options presented to FRICONSA are those most economically viable cost-benefit ratio so the company must remember that the resources invested in the long run will produce higher profits.

Watching from a different perspective, having no care with the implementation of energy management strategies can be result in the phenomenon of Javons paradox within the company. This paradox indicates that further introduction of energy efficient technologies can be increased, in reality, the power consumption. Because the management of the company may find that it is reducing the consumption and also the cost of energy use in their processes and decide to increase their production levels and thus found using more energy.

A positive mention of the implementation of strategies for managing energy impacts, is that employees develop skills beneficial for saving energy. It can be seen that strategies for a more sustainable energy consumption implicate the creation and strengthening of positive patterns of behavior in the company employees. This, combined with the company policies that the company will have a better performance in terms of sustainable use of energy. However, these behaviors will not be limited to the geographical confines of the company but also the employees can carry them out in their homes.

Given the above arguments, it may be determined that the main factors that contribute to the transition to sustainable patterns of energy consumption are:

- Knowledge on the part of management, economic and social effects of energy management projects.
- Understanding of the responsibility for ecology and environment for all members of the company,
- The cooperation of employees with the company.

Of the various questions that served as research guides very interesting elements to address emerge, not only in this research but in similar projects, for example and very especially the need to reduce the gap between knowledge and industry highlights in order to strengthen and benefit as sustainable development must strike a balance between the costs in the implementation of a project (feasibility and feasibility within the industry) and environmental management (knowledge of the ways of mitigating the negative environmental impacts) within organizations.

This study provides elements that allow the description of the transition from an industry to a sustainable energy, explaining the technological and social context of organizations. In turn this research is to contribute to broaden the field of knowledge about power management similar to those of the geographical area of northern industries.

IX. CONCLUSIONS

Following the completion of this research the following is concluded:

The methodology used in this case study was recognized as useful and serves as the basis for the evaluation of energy use in a meat processing company. The main processes with significant correlations in terms of energy saving processes are ventilation and air conditioning. Also the lighting, as the second largest energy consumer, has high potential to be better. Compared to the energy production processes of meat no weight in energy consumption due to its manual nature. Because of this, the results can help develop a more practical and comprehensive for energy management within companies approach, not only in northwest Mexico, but also in similar geographic regions.

The implementation of an energy audit provides the basis for describing the power consumption of the meat processing industry in Sonora. Thus promoting the development and implementation of strategies for energy management to conduct a more sustainable use of energy, favoring the reduction of negative environmental impacts, such as global warming.

An important part of this research was to identify and disseminate within the company the existence of different management practices for energy while at the same time there are different technologies that can reduce energy costs and improve business performance. Following an analysis of the implications of the results it can be understood that each company needs specific strategies for energy management.

The process of benchmarking (benchmarking) for the meat processing industry is difficult, because an explicit data base (in Mexico) for a comparison is not available. As a result of the lack of non-standard scales, which express the amount of meat produced in this industry, it is difficult to determine significant energy indicators.

The implementation of strategies to improve energy performance generated in this document will enable the company has increased its energy efficiency and reducing carbon emissions.

Finally, it should be noted that human resources will be essential for the transition to more sustainable energy consumption, since it is through employees and their awareness that management strategies energy will be accepted at the company since they are responsible for implementing them in their work areas. That's why the first step towards a more sustainable industry can only be given if there is support and cooperation from employees FRICONSA.

X. RECOMMENDATIONS AND FUTURE WORK

Future work includes developing a methodological framework that can be useful for the meat processing industry located in the Mexican northern region. Concerning the importance of this industry in this region, it is important to focus directly on the energy intensive industries for a reduction and mitigation of the environmental impacts

After the completion of this work, the following recommendations are made:

- Suggest the management of FRICONSA to integrate not only an energy management system but also to enable the environmental management system that takes into consideration the creation of pollution prevention programs with the final objective to improve the environmental performance of the company towards the environment.
- Keep the relationship of this company with the university, as a way for students to put into practice their knowledge by the creation of innovative processes that can enhance the performance of the company.

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XII. ANNEX

Annex energy Accounting-EA1. .

Annex Visibility-V2

Annex Thermal Images-T3