Journal of Environmental Protection, 2016, 7, 14-26
Published Online January 2016 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2016.71002

Energy Audit in the Meat Processing Industry—A Case Study in Hermosillo, Sonora Mexico

Nora Munguia[1,2*], Luis Velazquez[1,2], Tania Poom Bustamante[1], Rafael Perez[1], Johannes Winter[3], Markus Will[3], Bernd Delakowitz[3]

[1]Sustainability Graduate Program, Industrial Engineering Department, University of Sonora, Hermosillo, Mexico
[2]Work Environment Department, University of Massachusetts Lowell, Lowell, MA, USA
[3]Faculty of Mathematics and Natural Sciences, University of Applied Sciences Zittau/Gorlitz, Zittau, Germany
Email: *nmunguia@industrial.uson.mx, Luis_Velazquez@industrial.uson.mx

Received 18 November 2015; accepted 4 January 2016; published 7 January 2016

Abstract

The meat processing industry, due to its high energy consumption, needs to be assessed in an energy usage basis. This paper reports the results and implications of an energy audit in a 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 can determine a possible transition to sustainable patterns of electricity consumption. The paper described the application to energy auditing, developed by AFNOR (2014) for efficient energy management along with ISO 50001 (energy management systems). For a more specific energy auditing the guide described by Dall "O" (2013) was used. In this case, a study of an integrative characterization of the company's energy consumption is 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 allow 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 is performed. Altogether, this work gives guidance on the implementation of energy auditing in industries within its geographical and industrial sector limitations.

*Corresponding author.

How to cite this paper: Munguia, N., Velazquez, L., Bustamante, T.P., Perez, R., Winter, J., Will, M. and Delakowitz, B. (2016) Energy Audit in the Meat Processing Industry—A Case Study in Hermosillo, Sonora Mexico. *Journal of Environmental Protection*, **7**, 14-26. http://dx.doi.org/10.4236/jep.2016.71002

Keywords

Energy Efficiency, Energy Audits, Energy Consumption, Industrial Buildings

1. Introduction

Climate change is a very complex topic. It is mainly caused by interactions of multiple variables which are influencing factors for climate systems [1]. The modification of single element has the potential to affect the global climatic situation, for example an increase of the greenhouse effect [2]. Because of an enormous environmental impact, the focus of many scientific researches discusses the topic of greenhouse-gas-emissions. Many of these gases like CO_2, methane or ozone are responsible for creating an imbalance of the natural atmospheric conditions leading to climate change [3]. The generation of electricity can be considered as the baseline of this increase, in order to provide overcoming production needs for society [4]. The assessment and following management of resources, particularly electricity, in order to diminish the environmental impact of production processes, empowered by social claiming, are getting important and it has to be taken in consideration for many industrial sectors [5]. The meat processing industry needs to be assessed on the basis of the energy consumption. In this type of industrial sector, there are many enterprises which can be considered as high energy consumers. Among the different energy types which are used in meat processing facilities, the use of electricity is figured out as the dominating one [6].

Highlighting the necessity to assess and manage the energy consumption is required in order to reduce the environmental impact, such as its equivalent in carbon dioxide emissions [7].

In general, meat-processing companies need to comply with regulations established for the food industry, which means in this case that the conventional use of energy will be directed to maintain the cold and preserving the meat during the whole production process [8].

In this paper, an analysis about the characterization of the energy consumption within a meat processing company located in Hermosillo, Sonora is included. In addition, a proposal for strategic energy management focusing on high consumer types of facilities is presented. The results aim to create a systematic approach on energy management more suitable to processes in the food industry. The paper is organized as follows: Section 2 discusses the methodological approach. Section 3 introduces the results obtained and Section 4 evaluates opportunities for sustainable energy management. Section 5 provides discussions and conclusions and finally Section 6 presents future work needed.

2. Methodology

For a facilitated comprehension of the energy consumption and in order to derive improvement measures an explorative case study was conducted. Basically an energy audit was performed in a meat processing industry, located in northwest region of Mexico, hereinafter referred as Company A.

Energy audits are defined as an inspection, survey and analysis of energy consumptions of an industrial site, its buildings and processes aimed at reducing the amount of energy input without negatively affecting the outputs [9], *i.e.* improving energy efficiency.

Although the way how an energy audit is carried out depends on characteristics and approaches of the audited company [10], general elements of an energy audit are:

a) Data acquisition
b) Field work
c) Analysis
d) Report

The energy-related data, which was compiled during the audit, got used for the elaboration of the case study and aims to reduce the gap between the negative environmental impact of production processes and energy consumption.

The energy audit described here pursues the three following main goals.

Identification and assessment of significant correlations between energy consumption and the activities carried out in the processing plant.

1) Compilation of key performance indicators (KPI) to compare the site's performance with similar processing facilities. This company benchmarking were made within the type-specific industrial sector.

2) Determination of opportunities for energy saving measures in Company A and recognizing factors that could determine a possible transition to more sustainable patterns of electricity consumption.

The audit performed can be considered as a Type 1 energy audit according to ISO 50002. Those audits mainly rely on abbreviated walkthrough inspections, brief interviews with operating staff, and analysis of facilities energy/utility bills and additional data from equipment lists, in order to roughly estimate the actual electricity consumption. They serve as preliminary audits for larger facilities. It is the least costly audit, but allows, however, a high-level energy review, *i.e.* the identification of hotspots and areas with significant energy use and estimations of saving potential. Major outputs to be expected from Type 1 audits is a basic understanding of on-site energy consumption and related hot spots as well as a list of low-cost and easy-to-implement energy efficiency improvement measures (see **Chart 9**). For a more detailed and in-depth analyze and on order to legitimate cost-intensive improvement measures, a higher technical resolution and expanded scope of the energy analysis is recommended.

3. Site Description

This facility has the capacity to handle 100 cattle carcasses daily. 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.

The energy audit 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 plant has been made by thermal areas, see **Figure 1**, 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.

The energy audit includes information within the period from 2012 until 2014. Data acquisition in this reference period provides a more or less detailed representation of the energy input and consumption values.

The availability of many comparative data within this reference period gives the possibility to filter out values, which are describing energy consumption factors that were caused by exceptional situations.

3.1. Energy Input

The annual recording and analysis of utilized energy sources includes a usage and cost assessment, the data obtained from the energy billing history can be used to understand the pattern of use and cost of consumption over time. The contribution to climate change is considered here as Global Warming Potential (GWP) given in carbon dioxide equivalents (CO_2-eq.) as energy consumption related. To represent negative environmental impacts derived from the electricity consumption, standard ratios are used to convert the use of kWh into equivalent amounts of CO_2.

Using the methodology based on emission factors, which is the most appropriate and practical method to measure greenhouse gas (GHG) emissions, it estimates the GHG emissions by the multiplication of activity data (e.g., energy consumption) with an emission factor (e.g., grams of CO_2 per kWh) which obtains as a result a CO_2-equivalent.

Activity data * emission factor = CO_2 E.

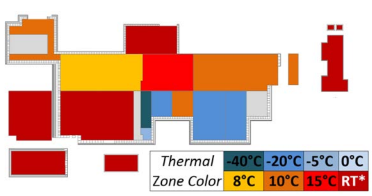

Figure 1. Thermal areas division.

Activity data values are listed on energy bills or energy-related documents of the provider. The emission factor depends on the electricity mix of each country. This value is a quantity number of atmospheric pollution by the use of electricity. Mexico's electricity mix primarily includes the use of oil and gas, non-fossil are composed mainly by large scale hydro power with some contribution from geothermal, which becomes obvious from the representation on in **Figure 2**.

The standard of conversion from KWh to their carbon dioxide equivalents according to the 2014 Climate Registry Default Emission Factors, México has been set with a value of 550.1 CO_2-equation per MWh. In **Chart 1**, the annual consumption of the used energy sources at the company and their detailed carbon equivalent in metric tons are described.

To understand the utilization of energy within the company processes, it is necessary to categorize the energy consumers in order to identify the main consumers. In this case study, the classification was made by thermal areas, which in concordance with the needs of production processes, share similar characteristics such as temperature and isolation. This separation allows the definition of clear and achievable goals in order to improve energy efficiency. **Chart 2** describes the thermal zones defined for this case study and the shared characteristics within the system.

Chart 1. Energy input for company A.

Electricity	2012	2013	2014
Quantity [kWh]	4,192,023.0	3,832,094.0	1,660,109.0
Costs [MXN $]	5,850,692.4	6,456,113.8	2,965,192.1
CO_2 E [Metric tons]	2306.03	2108.03	913.22

Chart 2. Thermal zones for company A.

Area	Name	Process	Thermal Zones	Net Area (m^2)	T °C
1	Recollection		6	0	10
2	Gutters		4	428.2	0
		Bone	5		8
3a	Process 1	Package	5	1,639.8	8
		Added value	7		15
		Frozen national	2		−20
3b	Process 2	Fresh national	6	1,422.5	10
		Frozen conservation	2		−20
		Fresh conservation	4		0
		Entry room	4		0
3c	Process 3	Tempered	3		−5
		Blast 123	1		−40
4	Service Building		8	970.1	RT*
5	Outlay Building		8	382.6	RT*
6	Transport Building		8	394.1	RT*
7	Transport Building	Shipment	6	183.5	10
8	Machine room		8	178.4	RT*
9	Archive		8	250	RT*
10	Cardboard Room		8	340.3	RT*
11	Machine room 2		8	104.1	RT*
12	Service Room1		8	30.2	RT*

*RT: Room temperature.

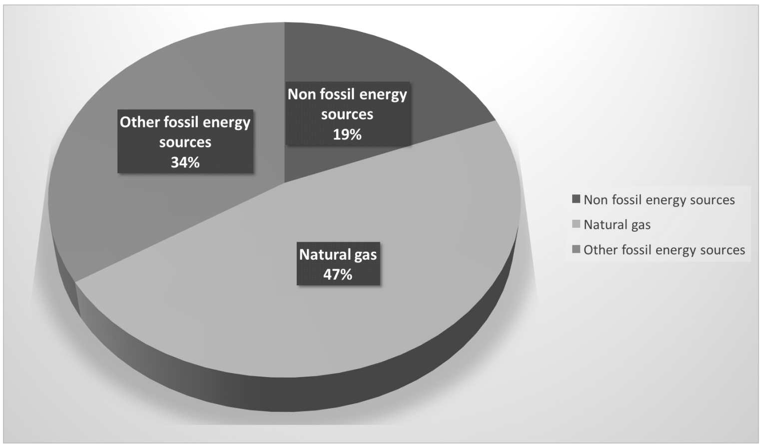

Figure 2. Mexican energy mix 2012 [11].

Several categories were defined according to the main company processes including production, heating, VAC and information technology (IT).

The most valuable information about the energy consumption in each main company process can be delivered by the help of energy meters. Unfortunately are in Company A just meters installed which measure the total energy consumption in the whole production plant.

To allegorize roughly the distribution on a percentage basis of the energy consumption for each process category, it is also sufficient to calculate by the help of the maximum power values from the equipment type plates and the daily operation hours the daily energy consumption per category.

The inventory list, which is organized in terms of their functional application, includes information about the energy consumption. In **Chart 3**, the proportion of daily energy consumption and the environmental impact, expressed as CO_2 equivalents is illustrated.

The daily consumption of Company A was identified in a total as 50,595.6743, 183.42 KWh. By the categorization of the processes, the main energy consumer can be distinguished. The following energy resources are being used in the company:

a. Electricity
b. Natural gas
c. LP gas.

Figure 3 shows that the resource that is mostly consumed is electricity. It is noted that the VAC processes are the most significant consumers of the electricity resource with a share of 7284% from the total consumption. The use of natural and LP gas is destined to heating processes with a share of 14% from the total energy consumption. The computed percentages do not include the consumption in the factory canteen and the laundry, which one of the reasons for share of natural and LP gas on the total amount of consumed energy.

3.2. Systems Description

3.2.1. Electrical System Description

An important step on monitoring the company's electricity consumption is to collect data from the facilities. Reviewing the power rates of the electrical line, transformers and compressors helps with the identification of potential opportunities for an energetic improvement. Company A gets the electrical supply by an integrated three phase electrical system.

3.2.2. Lighting systems Description

The system used by Company A involves two types of lighting: fluorescent and High Intensity Discharge of Metallic Additives (HID). A summary of the lighting system description, including the energy usage for the lighting category, is shown in **Chart 4**.

From the information of the obtained data, HID illumination appliances are revealed as main consumers. The evaluation of the luminance levels in different work areas is a valuable cross reference to identify if the lighting

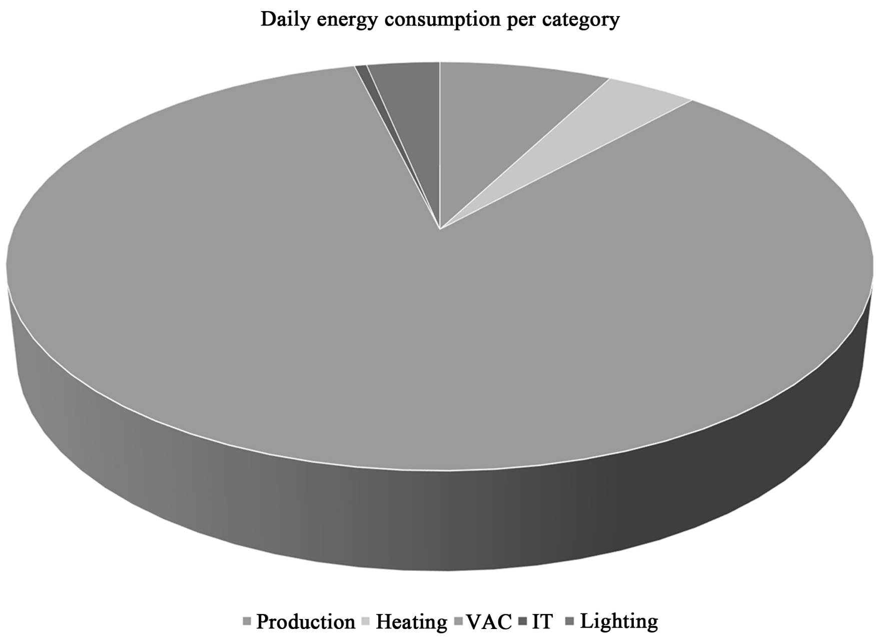

Figure 3. Daily energy consumption by category.

Chart 3. Daily based recording of energy consumers.

	Maximal performance (KW)	Daily energy consumption per category [KWh]	CO_2 emissions [Metric tons]
Production	185.3844	3304.10	1.81
Heating	61.5115	1744.83	0.95
VAC	1296.415	36499.69	20.07
IT	0.96	234.24	0.12
Lighting	2.2582	1400.54	0.77
Total	1546.5291	43183.42	23.75

Chart 4. Lighting system description.

Type	Number of equipment	Daily operation hours	Power [KW]	Consumption [kWh]
Fluorescent	60	13	0.1408	109.824
	57	20	0.1408	160.512
	25	18	0.1408	63.36
	8	13	0.176	18.304
	6	6	0.1738	6.2568
	10	8	0.018	1.44
	8	8	0.018	1.152
HID	21	10	0.25	52.5
	78	20	0.4	624
	22	24	0.4	211.2
	19	20	0.4	152

is appropriate for the correct performance of the operations in each area. This information will enable the detection of improvement opportunities on the visibility conditions and on the other hand to discover energy saving measurements.

For the determination of the average luminance, it is necessary to divide the building parts into a number of equal areas. A lux meter indicates only the luminance in one point and not the average luminance, making it necessary to get an average of the Level of illumination measured in lux at each measured point. This evaluation was made in accordance with the official Mexican standard NOM-025-STPS-1999, referring to illumination conditions on workstations. The purpose of this evaluation consists on making an assessment to detect certain areas that might have deficits or an excessive usage of lights. **Chart 5** describes the current illumination levels compared to the minimal required value of illumination expressed in Lux.

From the acquired data, four thermal zones were detected to be above the required levels of illumination. This visibility assessment also provides information on other thermal zones working with less lighting than needed. The information is useful for the company to improve the quality of lightening and the required illumination levels. It is necessary to conduct measures, which can direct to the reduction on the use of electricity without altering the outcome of the production processes.

3.2.3. Infrared Audit and Building Envelope Assessment

a. Infrared audit

An infrared audit, a thermal mapping of a surface, is useful in the process of energy assessment. This non-invasive technique allows to obtain thermographic images with an infrared camera. These images can support energy audits by highlighting energy inefficiencies on buildings and facilities. The thermographic analysis is very useful for evaluating building energy performance, both for envelope and facilities. With correct interpretation, the thermal images can reveal potential problems within the electrical systems and processes. Also, this data can be translated into significant information about energy performance. Which, later on, can be the translated into improvement opportunities that can have significant relevance for the company. The inspection tool used for this evaluation is the FLIR E6 camera. The thermal images obtained with the use of this camera are able to reveal, if existing, problems from sources of energy losses, moisture intrusion and structural issues to overheating electrical and mechanical equipment [12]. **Chart 6** shows a description of the assessed components were thermographic images were obtained.

Chart 5. Lighting system description.

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

Chart 6. Infrared assessment.

Thermal Image Group code	Assessed Component	Temperature Span (˚C)		
		Lower Limit	Average	Upper Limit
G01	Building Envelope	46.6	59.1	69.3
G02	Freezing Systems	−12.5	1.8	12.9
G03	Holders	17.4	43.09	80.6
G04	Control boxes	6.5	40.6	65.7
G05	Controllers	87.2	62.06	45.5
G06	Ventilation Systems	6.2	5.2	4.6
G07	Compressors	152.3	152.3	97.7

As **Figure 4** shows, one of the main improving potentials discovered during the infrared assessment is the energy losses on the refrigeration cameras. Its recognition provides, with a clear picture of the systems, which are the priorities to be improved in order to achieve a higher level of energy efficiency.

b. Building envelope

Part of the infrared assessment is to understand the characteristics of the building isolation materials, calorific capacity and thermal areas. To determine the calorific capacity and to choose the appropriate refrigeration equipment required for the different chambers resp. frozen areas of the plant, the isolation plays an important role. From the company the following descriptions can be made:

• The isolation of the building consists of polyurethane panels of 2, 3 and 4 inches in walls and ceilings.

Different thermal areas are distinguished:

• Recollection, inspection, process and platform processes should keep temperatures of 1.5˚C;
• Gutters need to have a temperature of 2˚C;
• Conservation chambers maintain temperatures below -14˚C;
• In the blast freezers, the temperature is below 5˚C.

4. Performance and Benchmarking

4.1. Benchmarking Assessment

For an analysis of the energy related data, an external benchmarking process will deliver significant results. Energy efficiency can be evaluated in different abstraction levels resulting in some different aggregated indicators [11]. The comparison with other companies of the food-processing industry will give useful information for checking and verifying the company's performance in terms of energetic aspects.

4.2. Defining of a Technical, Geographic and Branch-Specific Area of Validity

Company A, 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 is 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. The extreme climatic conditions in Hermosillo must be taken strongly into consideration for verifying the energetic situation.

4.3. Benchmarking Methodologies

There are several ways for the accomplishment of an energy benchmark assessment. In order to get a comprehensive impression of the current energetic situation and improving potentials of the company, a comparison with data from Australia meat processing industry was the more reliable option for benchmarking key indicators for the production location of company A, especially because of the extreme climatic conditions, it is necessary to choose geographic reference areas with similar characteristics, see **Figure 5**.

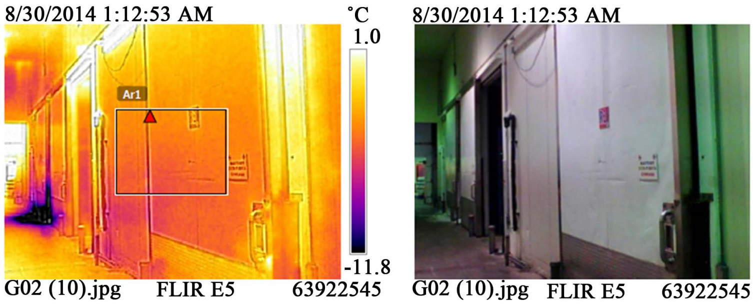

Figure 4. Thermal image.

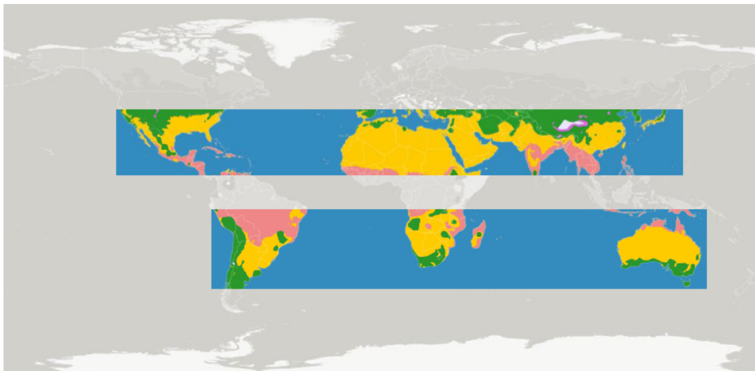

Figure 5. Continental climatic zones.

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.

A significant factor for benchmarking is the size of the company, where also the AMPC review is focused on small and middle-sized enterprises. The analysis of the energetic situation is based on indicators which take into consideration technical and economic aspects, to understand the patterns of energy consumption in the benchmarked company.

4.4. Energy Indicators of the Industrial Sector

In the course for an external 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 7**.

In relation with this indicator and the energy consumption data, specific values can be obtained; **Chart 8**. These indicators are shown in an annual basis in order to benchmark this data with the information of the Australian industry.

One of the key performance indicators for the meat processing industry takes into consideration is the energy 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 **Figure 6**.

In some industries, environmental benchmarks are used extensively to gauge the performance and competitiveness. Because of a non-existing unique production unit, an accurate benchmarking procedure for meat processing companies is just partly achievable.

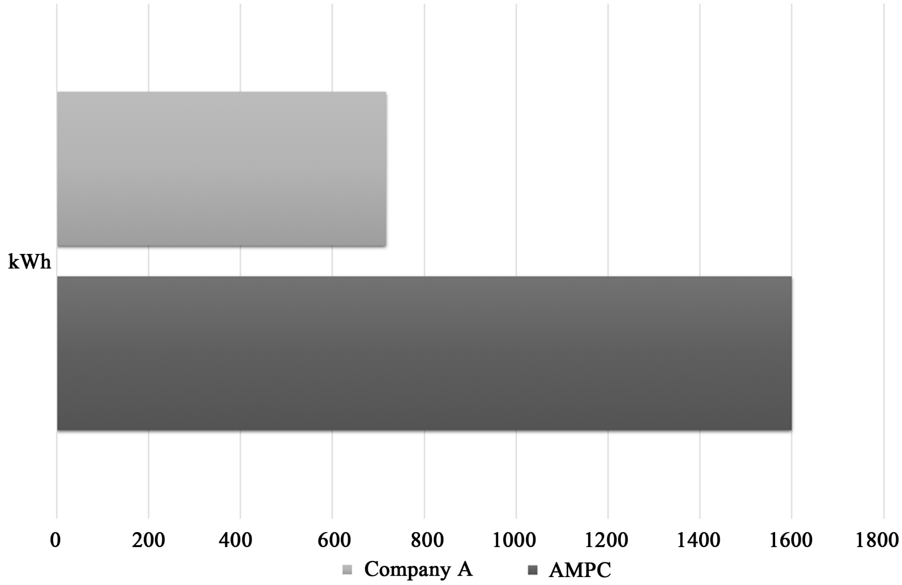

Figure 6. Energy per produced ton.

Chart 7. Performance indicators.

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

*Production quantity = head of livestock slaughtered.

Chart 8. Energy use indicators for company A.

Energy use indicators (2013)	
Total energy use	$5,587,835.9 kWh
Energy per head slaughtered	214.9 kWh
Energy per produced ton	716.3 kWh
Energy per employee	24,724.9 kWh
Energy cost	25,542,765.6 MXN $
Energy intensity by 2013	
Energy intensity electricity	0.73
Energy intensity natural gas	0.26
Energy intensity LP Gas	0.0003

5. Proposed Saving Strategies

The results obtained from the energy audit of company A gives an overall look of the energy consumption in the particular areas and processes, which can be convenient for the identification of energetic improvement potential. This information enables the company management to take decisions, related to areas or processes which may be analyzed in a are more profound way.

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 since it establishes the structure and discipline to implement technical and management strategies that significantly cut energy costs and greenhouse gas emissions—and sustain those savings over time. Savings can come from no- to low-cost operational improvements.

In the context of the performed energy audit, the advantages are to reveal the options to improve energy efficiency and to give suggestions where an exhaustive, additional research is profitable.

Focusing on general improving measures in the scope of crossover technologies, in **Chart 9**, general strategies are listed.

The main crossover technologies in this context are:

- Illumination
- Pneumatic systems
- Electric drives
- Pumping systems
- Ventilation systems
- Air conditioning and space heating/ cooling systems

Chart 9. Crossover technology improving measures.

Scope	Measures for energy efficiency improvement
Illumination [13]	Installation of more energy-efficient lighting
	Matching of the illuminance and the purpose at the workplace
	Application of light sensors which adjust the illumination
	Installation of motion detectors
Pneumatic systems [14]	Detection and reduction of leaks
	Converting into electric tools where possible
	Usage of variable speed drive compressors
Electric drives [15]	Usage of energy efficient motors (IEC standard 60034-2-1 or CEMEP efficiency category)
	Utilization of variable speed drives (VSD)
	Preferential usage of direct drives to reduce the friction losses
	Switching on or off in a targeted manner of the drives
	Selection of an energy efficient type of transmission
Pumping systems [14]	Reduction of the flows through variable speed drives (VSD)
	Reduction of the flows through effective time control
Ventilation and Air-conditioning technology [14]	Reduction of the air flows through variable speed drives (VSD)
	Reduction of the flows through effective time control
	Usage of air curtains for shuttle doors
	Supply of heat and cooling at the right temperature
	Taking advantage of free cooling
	Maintenance of adequate tire pressure
	Optimization of the storage location to reduce the transport distance

The listed measures integrate a wide action scope in the five main categories to improve energy efficiency. Referring to **Figure 3**, the main consumption of energy is use of electricity. It is target-aimed to pursue energetic improving potentials.

By the analysis of the benchmarking outputs, the used technological systems are weighted differently, in terms of reduction capabilities. It seeks to prioritize the most cost effective opportunities to catch, metaphorically, the low hanging fruits.

The technologies at the center of attention in company A are illumination, ventilation and air conditioning systems. Further measures for improvement include illumination, electric drives, pneumatic and pumping system where an additional research is suggested. For these systems, except illumination, high energy savings can be achieved by the use of variable speed drives (VSD).

Therefore, this ensemble of measures set a useful guideline in the implementation of energy efficiency actions in company A.

6. Conclusions

For a systematic approach to energy auditing, it is essential to calculate the energy impact of the company´s processes. In this case study, an integrative characterization of the company's energy consumption was made. The methodology used in this case study was probed to be helpful and to serve as a basis for the assessment of the energy use within a food processing company.

The main processes with significant correlations in terms of saving energy are ventilation and air conditioning processes. Illumination, as second highest energy consumer, has high improving potentials as well. The achieved results can help develop a more practical and integrative approach for energy management within companies not only in the northwest of Mexico but also in geographical similar regions.

By comparison with energy consumption of the crossover technology, the meat production processes carry no weight. Refrigeration should be still considered as a key element of meat processing. In this type of industry, the compliance with the food safety regulations is inalienable to ensure the meat quality. For that reason, there are fixed minimum temperature levels for the different areas and processes. For securing permanently cooled meat, high amounts of energy get spent in this industrial sector. Being this fact, it is of great significance to figure out improving measures also for the air-conditioning systems. The benchmarking process for meat processing industries proves difficult, because there is no available explicit database in Mexico for a comparison. As a result of non-standardized scale units, which express the amount of produced meat, in this industrial sector it's difficult to determine meaningful energy indicators.

Regardless of the benchmarking process limitations, the information obtained from the chosen benchmarking tools is expedient to understand the energy consumption of company A. The tools are selected in a way to guarantee a widespread consideration of the issue, which enables to make a further comprehension of the energy performance.

For the company A, a set of measures to enhance energy efficiency is developed, whereby main energy saving potentials get proposed. In this connection, it exists a major opportunity to reduce the energy costs and the environmental impact, without changing the productivity of company A. While energy efficiency means the reduction of energy inputs of production systems while keeping or enhancing the level of production, it represents a major opportunity to reduce greenhouse gases in a cost efficient way.

7. 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.

References

[1] Cubasch, U., Wuebbles, D., Chen, D., Facchini, M.C., Frame, D., Mahowald, N. and Winther, J.-G. (2013) Climate Change 2013: The Physical Science Basis. In: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M., Eds., *Contribution of Working Group I to the* 5*th Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge and New York, 119-

158.

[2] Parmesan, C. and Yohe, G. (2003) A Globally Coherent Fingerprint of Climate Change Impacts across Natural Systems. *Nature*, **421**, 37-42. http://dx.doi.org/10.1038/nature01286

[3] Marland, G. (2003) The Climatic Impacts of Land Surface Change and Carbon Management, and the Implications for Climate-Change Mitigation policy. *Climate Policy*, **3**, 149-157. http://dx.doi.org/10.3763/cpol.2003.0318

[4] Rosenzweig, C., Karoly, D., Vicarelli, M., Neofotis, P., Wu, Q., Casassa, G., Menzel, A., Root, T.L., Estrella, N., Seguin, B., Tryjanowski, P., Liu, C., Rawlins, S. and Imeson, A. (2008) Attributing Physical and Biological Impacts to Anthropogenic Climate Change. *Nature*, **453**, 353-357. http://dx.doi.org/10.1038/nature06937

[5] Schmidheiny, S. (1992) Changing Course: A Global Business Perspective on Development and the Environment. MIT Press, Cambridge.

[6] Canning, P., Ainsley, C., Huang, S., Polenske, K.R. and Waters, A. (2010) Energy Use in the U.S. Food System. http://www.ers.usda.gov/media/136418/err94_1_.pdf

[7] Dalkia (2014) Guide Equivalences CO_2. http://www.dalkia.ie/ireland-energy/ressources/documents/1/20202,Guide-equivalences-CO2.pdf

[8] Tang, P. and Jones, M. (2013) Energy Consumption Guide for Small to Medium Red Meat Processing Facilities. http://www.ampc.com.au/site/assets/media/reports/ENV/Energy/ENERGY-CONSUMPTION-GUIDE-FOR-SMALL-TO-MEDIUM-RED-MEAT-PROCESSING-FACILITIES.pdf

[9] Dall'O (2013) Green Energy Audit of Buildings a Guide for a Sustainable Energy Audit of Buildings. Springer, London.

[10] Tyagi, A.K. (2003) Handbook on Energy Audits and Management. The Energy and Resources Institute.

[11] Secretaría de Energía (2013) Estrategia Nacional de Energía 2013-2027. http://www.sener.gob.mx/res/PE_y_DT/pub/2013/ENE_2013-2027.pdf

[12] Flir Systems Inc. (2014) Thermal Imaging Cameras. http://www.flir.com/uploadedFiles/Thermography_USA/Products/Product_Literature/flir-thermography-family-brochure.pdf

[13] Hesselbach, J. (2012) Energie- und Klimaeffiziente Produktion: Grundlagen, Leitlinien und Praxisbeispiele. Vieweg+ Teubner Verlag, Kassel.

[14] Thollander, P. and Palm, J. (2013) Improving Energy Efficiency in Industrial Energy Systems: An Interdisciplinary Perspective on Barriers, Energy Audits, Energy Management, Policies, and Programs. Springer-Verlag London. http://dx.doi.org/10.1007/978-1-4471-4162-4

[15] Müller, E., Engelmann, J., Löffler, T. and Jörg, S. (2009) Energieeffiziente Fabrikenplanen und Betreiben. Springer Berlin Heidelberg, Berlin. http://dx.doi.org/10.1007/978-3-540-89644-9