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Energy Efficiency Based on Cleaner Production Approach on an A/C System within a Wire Harness Industry in the State Of Sonora

ESQUER, J.[a*], JUAREZ, B.[a], ZAVALA, A. G.[a]

a. Universidad de Sonora, México

**Corresponding author, jesquer@industrial.uson.mx*

Abstract

This paper shows relevant results on a study conducted into a wire harness industry in the city of Hermosillo, Sonora, about Energy Efficiency into air conditioning (A/C) system. The adaptation of the manual from the UN Programme Environment (UNEP) for a cleaner production program with a focus on efficient use of electricity was used as a guide for the study.

Several options were generated in order to reduce consumption with different solution plans. A compilation of technical data of the equipment used was necessary, thus making crucial the characterization of the electrical energy consumption in the production area in KWH and how the amount of carbon dioxide equivalent would be reduced by the implementation for each of these by taking into consideration the investment and savings plans, leaving top management the decisions for their potential implementation.

Keywords: *Sustainability, Cleaner Production, Energy Efficiency, Air Conditioning.*

1. Introduction

Koike (2010) suggests that global warming and maintaining a secure energy supply are the most serious problems which human beings must overcome to maintain the sustainable development of our civilization. This author notes that, by 2030, the world's energy consumption and CO2 emissions are expected to grow by 40% from 2007 levels. Both substantial decarbonization of energy and drastic improvements in energy efficiency are needed in every possible area, so as to avoid the catastrophic disaster of climate change without constraining economic growth and the standard of living. On the demand side of energy, highly efficient technologies are quite effective to simultaneously solve these problems, for which every one of us is responsible as an energy user and a CO2 emitter.

Furthermore, approximately one-third of the energy consumed globally is used by the industrial sector. A wide variety of energy efficiency policies, programmes, products, services and delivery mechanisms have been implemented in many countries in efforts to improve energy efficiency in industry, with some success (DESA/DSD, 2006). In addition, the electronics industry is one of the most globalized industries, which, from the perspective of sustainable development, less attention has been paid than to other manufacturing industries (Jande, 2007).

In the industrial sector, the economy controls energy efficiency and conservation measures. Manufacturers know that they must keep their costs low to compete in the global economy. Since energy is one of the biggest costs in many industries, manufacturers must use energy efficient technologies and conservation measures to be successful. Their demand for energy efficient equipment drives much of the research and development of new technologies (CAIRF, 2007). Energy efficiency provides multiple public benefits regardless of its carbon emissions impacts. It reduces home and business energy costs, improves productivity, stimulates economic growth, reduces energy market prices, improves energy system reliability, reduces criteria air pollutant emissions, and enhances national energy security (NAPEE, 2009).

Some studies have found that energy efficiency is also profitable in developing countries (Taylor et al., 2008). Furthermore, UNIDO conducted an email survey of 357 industrial firms in 25 developing economies, based on a convenience sample, aimed at obtaining a basic understanding of the rationale behind investing in industrial energy efficiency and at illustrating the key energy-efficiency issues confronted by firms. Of these firms, 261 were followed up; they were also queried about energy-efficiency projects they had decided not to take on. Investments in energy-efficiency projects totaled $613.7 million, and individual investments ranged from $100 to $73 million (UNIDO, 2011).

With energy efficiency programs, there can be benefits from lower energy bills. Studies show that utility or state investment in energy efficiency helps the local economy. By reducing energy use, it can help reduce green house gases, air pollution, water use, and the amount of natural resources (fossil fuels) being extracted from the earth. Energy efficiency also helps protect energy security and using less energy protects the economy and consumers from possible price fluctuations and from energy service disruptions due to natural disasters or other causes (EPA, 2008).

In 2005, emissions related to electricity sector accounted for 35% of gross emissions in the state of Sonora. The energy from the use fuel oil accounted for 71% of total primary energy used, while the remainders were natural gas combustion. The consumption of fossil fuels for electricity generation was responsible for the emission of 6.84 million metric tons of carbon dioxide equivalent of greenhouse emissions in 2005 and is expected to increase up to 12.2 by 2020 (COCEF, 2010).

In 2008, Mexico had 57.2 gigawatts of installed electricity generating capacity. The country generated 239 billion kilowatt-hours (BKWH) of electric power in 2009. Conventional thermal generation represents the overwhelming majority of Mexico's electricity generation, though the mix from these sources is gradually shifting from oil products to natural gas. Mexico consumed 202 BKWH of electric power in 2008 (EIA, 2011).

By 2011, the electricity generated in Sonora accounts for 4% of the national total, that is about 10.056 Gigawatts-hour (GWh) per year. The largest sector in consumption is the industry with 51%, including automotive industry and its suppliers, as well as the aerospace industry, then the domestic sector with a 32%, with 10% agricultural, commercial and services 2 5%. Sonora has a 3.84 megawatts-hour (MWh) per cápita per year, exceeding by almost 50% to the country's average and is well above the global average (COEES, 2011).

During the first quarter of 2012, the performance of the indicators in the electricity industry in Sonora was very positive, the value of sales of electricity stood at 2,741.6 million pesos, accumulating an increase of 22.7 percent over the same period of 2011, bringing the volume of sales expressed in GWh increased 9.7 percent accumulating 1,937.6 units. By type of service, the volume of sales of industrial and service residential were 1,231.1 and 371.3 GWh, respectively. In addition, the number of users increased 1.6 percent, from 841.556 service contracts in March 2011 to 854.858 contracts in March 2012, highlighting the increase in industrial and residential sectors (Sonora, 2012).

2. Methods

Through the postgraduate program of Certificate in Sustainable Development at the University of Sonora (UNISON), an Electrical Energy Efficiency Program was conducted in a Wire Harness Industry in the State of Sonora, based on the manual of a UN Environment Program (UNEP, 2004) that presents an integrated Cleaner Production–Energy Efficiency (CP-EE) methodology addressing strategies that reduce costs and generate profits by reducing energy waste.

The case study was carried out in a company that produces and assembles wire harnesses that is located in the municipality of Hermosillo, Sonora. The case study was developed in a 5-month period covering from July to December 2012. Considering the company's interest, the main focus for this study is in the production area. Furthermore, although issues like consumption of electricity in illumination and equipment were addressed, the emphasis of this paper will be given to the air conditioning system due to space constraints.

The following phases were adapted from the UNEP manual of CP-EE: Top Management Commitment (Support), Planning and Organization, Pre-assessment, Assessment, Feasibility Analysis and Implementation and Continuation, which for the purpose of this study, several proposals are presented, leaving the top management to address the decisions for potential implementation.

3. Results

3.1. Company Commitment

To begin this study of Energy Efficiency based on Cleaner Production, the consent and interest of the company were necessary, which were embodied in an agreement between the company and the institution.

3.2. Planning

The employees were involved, especially the personnel in charge of the maintenance of the electrical equipment including one coordinator, two technicians. Hence according to the program, a team was formed which was designated as CP-EE Team.

The compilation of existing basic information is where the company's Mission, Vision and Values were analyzed and where the following environmental policy was suggested:

> Our company is committed to at least achieve and maintain the standards, laws and regulations that are applied to workplace and environment. Conduct regular audits to assess compliance with these. Consider environmental, occupational hazards and energy conservation projects in the evaluation of existing or newly created in any area or department. Implement programs or procedures that eliminate, control, reduce or recycle waste generation and pollution in the operations of the company to the extent that they are economically and technically feasible. Ensure understanding of all members of this company in the standards and policies that apply, that affect the responsibility of their jobs and tasks.

The graphic below shows historic values of the Total Cost since the company started, in June 2011, up to October 2012, gathered from the electric bills in Mexico. These come from the Mexican governmental agency, the Federal Electricity Commission (CFE by Spanish abbreviation).

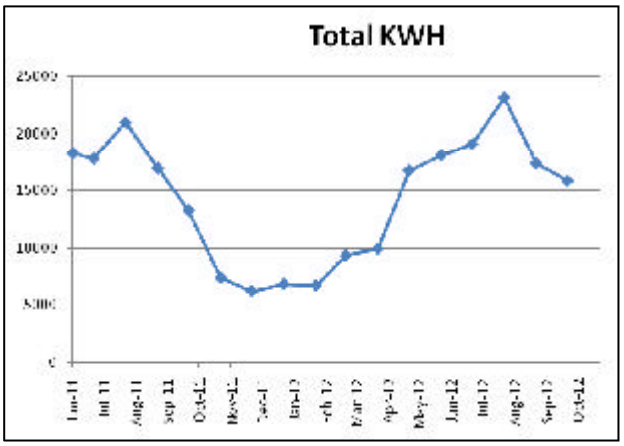

Fig. 1. Total KWH consumption gathered from CFE bills (June 2011 - October 2012)

3.3. Pre-Assessment

The production area has been divided into three main sections (Cutting, Preparation, and Assembly) were most of the electrical equipment is being used. During the Cutting section there is Cutting and Quality Check. After this, it moves on to the Preparation section, which has the following activities: Divest, Tipping, Riveting, Twisting, Tinning and Insertion. The last section is where the Routing, Burning, Electrical Test and Inspection are made to complete the final product. The air conditioning equipment used for this area can be found in the table below, where the main units are hours per day of equipment used, watts per hour (WH), and kilowatts per hour (KWH).

Table 1. Air conditioning equipment used

MFG	DESCRIPTION	VOLTS	AMPS	WATTS	Time in which is turned on - HOURS	Current Daily Consumption WH	Current Daily Consumption KWH
TRANE COMPANY	AC UNIT 2PCS	460	56-70	25760-64400	10	522633.6	522.63
TRANE COMPANY	COMPRESSOR 2PCS	460	17.4-117	16008-107640	10	193003.1	193
TRANE COMPANY	COMPRESSOR 2PCS	460	17.4-117	16008-107640	10	193003.1	193
						Total	908.63

3.4. Assessment

During the evaluation, an issue was that the air conditioning equipment has been on mainly during the months of May until September every year. The following table shows potential waste per equipment:

Table 2. Potential waste per equipment in air conditioning

MFG	DESCRIPTION	WATTS	Time in which is turned on - HOURS	Effective operative time - HOURS	Current Daily Consumption KWH	Daily Consumption Needed KWH	Waste per Equipment KWH
TRANE COMPANY	A/C Unit 2PCS	25760-64400	10	9	522.63	419.59	103.04
TRANE COMPANY	COMPRESSOR 2PCS	16008-107640	10	9	193.00	160.99	32.02
TRANE COMPANY	COMPRESSOR 2PCS	16008-107640	10	9	193.00	160.99	32.02
				Totals	908.64	741.57	167.07
GHG as kilograms of CO2e emitted approximately per year (IEA, 2011): 32,087.46							

The tariff rate from the electric bills that charges this company in Mexico come from the Mexican governmental agency, the Federal Electricity Commission (CFE by Spanish abbreviation), which is "HM" tariff on average (CFE, 2012), where the intermediate cost per KWH is $1.1315 in Mexican pesos (where $1.00 US dollar is equivalent to $12.65 Mexican pesos by March 14, 2013, according to Banamex (2013) Table 3 shows the daily waste from inefficiency:

Table 3. Daily wastes in MXN pesos

Subject	Type of Waste	Total Daily Waste KWH	Cost per KWH in MXN Pesos	Daily Waste in MXN Pesos
Air Conditioning	Electricity	167.072	$1.13	$189.04
GHG as kilograms of CO2e emitted approximately per year (IEA, 2011): 32,087.46				

A fishbone diagram is an excellent tool for cause diagnosis in complex situations where a number of factors are involved. Through this tool, the primary causes of the inefficiency problem were identified as the following figure shows:

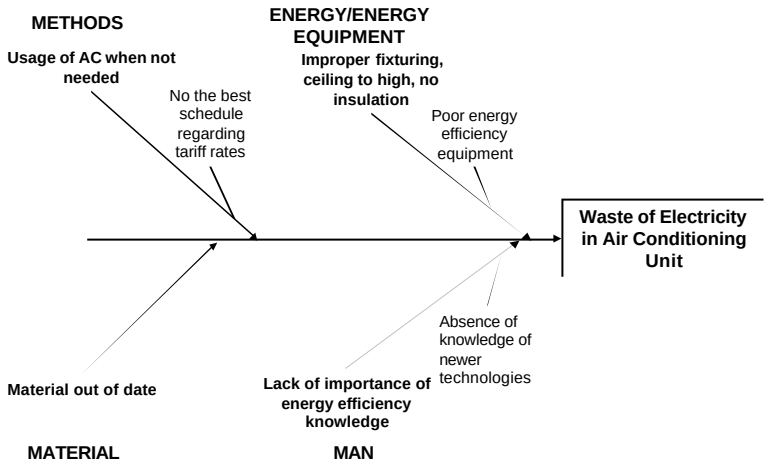

Fig. 2 Cause & Effect of wastage of electricity in Air Conditioning

As a next task, options were generated in collaboration by the CP-EE team and with other associated members of staff personnel. Below are deployed the possible solutions to problems, based on the causes observed earlier concerning waste of electricity in Air Conditioning. Some of the chosen options may require major changes in the equipment. While these solutions may dramatically reduce waste generation, sometimes may also often imply considerable investment.

Table 4. Possible Solutions for Air Conditioning

CATEGORY	CAUSE	POSSIBLE SOLUTION	REFERENCE NUMBER
METHOD	Usage of AC when not needed	Turn off when employees not working	S01
		Reduce fan velocity	S02
		Install timer for automatic shut down when AC not needed	S03
	Not the best schedule regarding electricity tariff rates	Change working schedule to Sunday–Wednesday	S04
ENERGY/ENERGY EQUIPMENT	Improper fixturing, ceiling to high, no insulation	Add panels to lower ceiling	S05
		Seal air ducts	S06
		Add insulation to air ducts	S07
	Poor energy efficiency equipment	Replace air conditioning unit with ENERGY STAR qualified equipment	S08
	Power factor not high enough	Buy and install capacitor bank	S09
MATERIAL	Material out of date	Check expiration dates	S10

MAN	Lack of importance of energy efficiency knowledge	Attend seminars or courses regarding energy efficiency	S11
		Train employees of the importance of energy efficiency	S12
		Contact on a regular basis universities for possible interns in energy efficiency expertise	S13
	Absence of knowledge of newer technologies	Search periodically sources (like internet, suppliers, among others) to identify new technologies, more efficient and environmental friendly.	S14

The team agreed to organize the CP-EE options into two classifications, where implementation priorities and focus efforts are the main concern. These are: Quick and direct implementation (S01, S02, S10, S11, S12, S13, S14), these are practical ideas that can be implemented without investment, leaving the top management with quick decisions; and those that require further analysis (S03, S04, S05, S06, S07, S08, S09), These options may require investment or more detailed studies because it could alter the system or worsen existing conditions.

3.5. Feasibility analysis.

Technical evaluation

Each of the options was analyzed under the major technical areas. To determine the level of impact of every aspect is weighted as follows: high positive impact (3), low positive (1), no significant impact (0), low negative impact (-1), high negative impact (-3). The larger the number in the total result, greater is the benefits in implementing such solution.

Table 5. Technical Evaluation

Option Ref. Number	Technical requirement					Impact (-3/-1/0/+1/+3)					Overall
	Equipment requirement	Instrument or accessories	Manpower	Space availability	Technology availability	Production rate	Product quality	Operation flexibility	Maintenance	Safety	
S03	Timer	NO	NO	YES	YES	0	0	0	1	0	1
S04	NO	NO	NO	YES	YES	0	0	3	0	0	3
S05	Panels	Installation tools	External Advisor	YES	YES	1	1	1	1	0	4
S06	Tape	Installation tools	NO	YES	YES	0	0	0	-1	0	-1
S07	Insulation	Installation tools	External Advisor	YES	YES	0	0	0	0	0	0
S08	AC	Installation tools	External Advisor	YES	YES	0	0	0	-1	0	-1
S09	Capacitor bank	Installation tools	YES	YES	YES	0	0	1	1	0	2

Environmental evaluation

To determine the impact on environmental, health and safety issues and how they would reduce in some way. The harmful aspects to both health and the environmental were observed and analyzed. Values have the same meaning as the scale used for the technical evaluation.

Table 6. Environmental Evaluation

Option Ref. Number	Non Toxic Residues	Green House Gases	Organics (COD)	Toxic Residues	Consumption of Non Renewables	Noise Level	Unpleasant Odor	Risk Area Level	Overall
S03	0	1	0	0	3	0	0	0	4
S04	0	3	0	0	3	0	0	0	6
S05	0	3	0	0	0	1	0	0	4
S06	0	1	0	0	1	0	0	0	2
S07	0	1	0	0	1	1	0	0	3
S08	0	3	0	0	1	1	0	0	5
S09	0	3	0	0	0	0	0	0	3

Economic Evaluation

For each proposed solution, the cost of materials and their proper installation are being considered below. Some notes are added to these costs that will be important later in the selection of options. To determine the level of impact, every option is weighted as follows: lowest positive impact (0) up to highest positive impact (10). The larger the number, greater is the benefits in implementing such solution. The recommended overall has been selected from the economic point of view of the company, this means that higher the positive impact is, the more feasible it is to be implemented.

Table 7. Economic Evaluation

<table>
<tr><th>Option Ref. Number</th><th>Investment (MXN Pesos)</th><th>Annual savings (MXN Pesos)</th><th>Payback Period</th><th>Recommended Overall</th></tr>
<tr><td>S03</td><td>-</td><td>$28,072</td><td>Each electricity bill the AC unit is on</td><td>9</td></tr>
<tr><td>S04</td><td colspan="2">0</td><td>$10,500</td><td>10</td></tr>
<tr><td>S05</td><td colspan="3" rowspan="4">Reducing the ceiling will help the air conditioner to work efficiently. Buying newer air conditioner with SEER rating will reduce KWH but due to the climate in Hermosillo, sealing and insulating ventilation ducts is also needed. Since this can be done together the investment is variable due to different suppliers and materials</td><td>3</td></tr>
<tr><td>S06</td><td>4</td></tr>
<tr><td>S07</td><td>4</td></tr>
<tr><td>S08</td><td>1</td></tr>
<tr><td>S09</td><td colspan="2">$2,010</td><td>$6,327</td><td>8</td></tr>
</table>

The evaluations described above help to identify options that are more viable in order to be prioritized for implementation. The team discussed the total score obtained from the sum of the three aspects and assigned a rank where 1 is for the highest priority, 2 for the second, and so on.

Table 8. Economic Evaluation

Option Ref. Number	Option	Technical feasibility	Environmental impact	Economic feasibility	Total Score	Rank
S04	Change working schedule to Sunday -Wednesday	3	6	10	19	1
S03	Install timer for automatic shut down when AC not needed	1	4	9	14	2
S09	Buy and install capacitor bank	2	3	8	13	3
S05	Add panels to lower ceiling	4	4	3	11	4
S07	Add insulation to air ducts	0	3	4	7	5
S06	Seal air ducts	-1	2	4	5	6
S08	Replace air conditioning unit with ENERGY STAR qualified equipment	-1	5	1	5	7

4. Discussion

At first glance, the processes done in the production area seemed efficient in spite of the vast products being manufactured. After several visits, the creation of the CP-EE team and identifying the equipment used, it became noticeable the impacts of not having an energy efficiency program. Some of these impacts were seen in the air conditioning equipment throughout the production area, ranging from simple tasks, like leaving equipment on when not being used, to more complex but still being applicable.

Most of the literature review that was shown here was regarding energy efficiency and with this comes energy efficiency programs; where there can be benefits from lowering energy bills. Studies show that utility or state investment in energy efficiency helps the local economy. Energy efficiency relies on companies and retailers to provide energy management services and energy-saving products, which many have been selected as potential alternatives and solutions for the causes found during this study.

The air conditioning system was the area with major concern to the company, by having an energy efficiency program properly running, the efficiency in the company will be improving continuously.

5. Conclusions

From the first approach to the company, it was observed that there was interest in energy efficiency and cleaner production programs, in spite of not having policies regarding sustainability. This study helped the company to find opportunities for improvements in different areas, as well as to search for newer and more efficient technologies; this in return will help reduce costs and GHG gases.

The creation of the CP-EE team was indispensable in order to map the processes flow diagram and where the efficient use of electrical energy can be applied throughout the company. As seen above, there are several potential solutions that may be applied in the air conditioning equipment. Some of these solutions can be implemented with ease and others may need external intervention.

Developing such program has been an eye-opener since the company had little energy efficiency knowledge. Also, with this study the company has been aware that energy efficiency programs can help with its economy while still being friendly with the environment.

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