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Energy audit in the industrial sector of the beneficiary or cure of cocoa

Auditoría energética en el sector industrial del beneficiado o cura del cacao

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Abstract

In the state of Tabasco, a first-level energy audit was carried out on a rural production company dedicated to the beneficiation or cure of cocoa, as part of the project "Design, integration and start-up of an online digital platform for energy self-diagnostics of first level in the PyME of manufacture". The objective was to analyze the processes of fermentation, drying and packaging of cocoa, the energy flows of the equipment used (Samoa and rotary type dryers, electric motors, etc.), energy consumption (electric and thermal), electrical parameters, as the opportunities of energy efficiency and short-term or immediate economic savings. The thermal system depends to a greater extent on the consumption of LP gas and a minimum use of the available solar radiation. By means of the electric and LP gas billings for the years 2016-2017, graphs of the system's energy performance were obtained. An AEMC power pad 3945-B power analyzer was used in the 45 kVA transformer to monitor the main electrical parameters resulting in: low charge factor. Therefore, based on the results obtained, the possibilities of economic savings were proposed.

Audit, Energy, Cocoa

Resumen

En el estado de Tabasco se realizó una auditoría energética de primer nivel a una sociedad de producción rural dedicada al beneficiado o cura del cacao, esto como parte del proyecto “Diseño, integración y puesta en marcha de una plataforma digital en línea para realizar autodiagnósticos energéticos de primer nivel en las PyME de manufactura”. El objetivo consistió en analizar los procesos del fermentado, secado y envasado de cacao, los flujos de energía de los equipos empleados (secadoras tipo Samoa y rotativas, motores eléctricos, etc), consumos de energía (eléctrica y térmica), parámetros eléctricos, así como las oportunidades de eficiencia energética y ahorro económico a corto plazo o inmediatos. El sistema térmico depende en mayor medida del consumo de gas LP y de un mínimo aprovechamiento de la radiación solar disponible. Mediante las facturaciones eléctricas y de gas LP de los years 2016-2017 se obtuvieron graficas del comportamiento energético del sistema. Se utilizó un analizador de redes AEMC power pad 3945-B en el trasformador de 45 kVA, para monitorear los principales parámetros eléctricos dando como resultado: bajo factor de charge. Por lo tanto, con base a los resultados obtenidos, se propusieron las posibilidades de ahorros económicos.

Auditoría, Energía, Cacao

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Introduction

The costs of fossil fuels to generate electricity every day higher in world markets, as well as the high polluting emissions has caused our country to adopt new policies to implement renewable energy sources. Therefore, it is crucial that in the future our country does not depend on fossil fuels for the generation of electricity to a greater extent and the consequent reduction of generation costs. In the prospective of renewable energy 2016-2030, Secretariat of Energy (SENER, 2016) affirms:

> In recent years, the development of energy sustainability has been sought in order to include the environment as one of the elements of competition that contribute to the economic and social development of the population. Hence, there is a clear commitment, derived from the Energy Reform: to foresee the gradual increase of the participation of Renewable Energies in the Electricity Industry, in order to meet the established goals in terms of clean energy generation and emission reduction. (p.131)

The cocoa sector in Mexico is at a disadvantage compared to the same business sector in other countries, this lack of innovation in the way they conduct their production processes, in the acquisition of new technologies, implementation of renewable energy and training of personnel in matters of energy saving awareness, therefore it is necessary to optimize the production costs in order to obtain more profits and the company can be profitable, it is for that reason that by applying a correct methodology to be able to diagnose the Real energy status of the company, may be offered, economic studies of the implementation of renewable energy as well as measures and actions to achieve energy efficiency (Manrrero, S., y González, I., 2006).

Performing an energy audit of the production process of traditional cocoa drying of a company or rural production society, dedicated to the benefit or cure of cocoa, allows us to identify all forms and energy sources to obtain the overall energy balance of the plant, analyze the potential areas of energy saving opportunities and implement a permanent program of actions and good use of energy.

The process of curing or benefiting of cocoa (post-harvest handling) is fundamental to achieve the quality required by the consumer market, it is the final process of cocoa production, where fermentation and drying takes place, therefore, it is a labor important and determinant of the organoleptic characteristics (color, aroma and flavor) of the grain (National Federation of Cacao Growers (FEDECACAO), 2004). The process of beneficiation or cure of cocoa consists of:

1. Harvesting: Only mature and healthy fruits should be harvested.

2. Parting of corncobs and shelling.

3. Fermentation: In the fermentation the flavor and aroma of the grain is developed, the newly extracted grains are deposited in wooden boxes and covered with sacks to maintain a constant temperature of fermentation, the fermentation time varies from 3 to 8 days depending on the type of cocoa and desired final product, you have to move it every 24 hours to achieve a uniform fermentation.

4. Drying: There are two types of dried, the natural taking advantage of the available solar radiation, which is the most economical and artificial drying using fossil fuels, both methods must be performed slowly and at low temperatures, until a moisture content between 6 and 8%.

5. Cleaning, sorting and packing.

The process that most consumes non-renewable energy resources is undoubtedly the drying process, which consumes large quantities of LP gas and electricity from the CFE network.

The importance of implementing solar dryers for cocoa beans, responds to the need to look for alternative and sustainable technologies, which allow to protect the grains of adverse weather conditions, obtain a product that has quality and achieve drying even with diffuse solar radiation, but above all, to reduce the consumption of LP gas and electricity of the CFE network in the drying process, with the consequent economic benefits for the cocoa sector.

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An adequate awareness or energy culture among the cocoa population contributes to a sustained economic development of the sector and the country.

Having technical and economic studies on production expenses in terms of electricity, heat, etc., against the profits obtained, will allow us to obtain a vision of future growth of the company, avoid uncertainty and achieve energy efficiency.

In addition, the use of photothermal and photovoltaic solar energy in the national cocoa sector will reduce the demand for fossil fuels and electricity in the national electricity system, as explained in section 2.

Section 3 describes the activities carried out during the audit. Then section 4 details the production process of the company. Section 5 describes all the information surveys carried out by each of the systems found.

Section 6 analyzes the electrical system in detail, as well as the analysis of the electric billing provided by the company and the report of the substation obtained by monitoring the network analyzer.

Section 7 analyzes the thermal system and the lp gas billing used as fuel. Section 8 shows the total amounts of energy used during the production process of the company, as well as their percentages. Finally, section 9 shows short and long-term energy saving measures, as well as good practices in energy saving.

Current situation

Cocoa producers in Mexico lack investment, training and future projection in their production processes, this causes stagnation or closure of the company.

The costs of fuels, the increase in electricity tariffs has a huge impact on the company's profits, the low implementation of renewable energies means that it depends exclusively on fossil fuels and on the electric power of the national electric interconnected system, this to the long will cause serious problems of over-demand of energy. "In 2015, energy consumption in Mexico exceeded, for the first time, the production of primary energy with a 3.2% difference" (National Energy Balance, SENER, 2016, p.136).

The low productivity of cocoa at the national level, the low prices given by the international fluctuations of the stock market, added to the incidence of the moniliasis of cocoa, made this activity of agricultural production an unattractive and low incentive for the farmers (Quintero, M. L., y Díaz, K. M, 2004).

The traditional drying of cocoa, consists of removing the humidity of the grain and by means of evaporation to transfer it to the environment. The amount of moisture that the air can absorb depends on its temperature, as the air heats up, the water particles evaporate from the grain and these are absorbed by the air, therefore, the consumption of LP gas and electricity is predominant in the process.

That is why once detected one of the main problems faced by cocoa producers in Mexico, which corresponds to the low profitability in the process of transformation of their raw materials towards the final product, compared to the increasingly expensive costs of the energy (electrical, thermal, etc.) that were used in said production, it is of significant importance to promote actions that benefit their development in terms of energy efficiency, for which an energy audit was carried out to a traditional cocoa drying company, to know its real energy situation and to be able to propose saving measures that directly benefit the economic profitability of the company.

Description of the method

On November 27, 2017, an energy audit was conducted in a rural production company located in Cunduacán, Tabasco, belonging to the food industry of the secondary sector in the transformation of goods, dedicated to the benefit or cure of cocoa.

The facilities have a processing area and warehouses where cocoa beans are stored, with and without benefits, as well as an office area, buying and selling and accounting. It has a staff of 25 employees and the services it has are: bathrooms and common area.

To cover all the areas and activities carried out in the facilities of the plant, the work team was divided into two groups, thus speeding up the work of data collection and measurements.

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The activities carried out are listed below:

1. A tour of the facilities was conducted in order to know the different areas of work, the manufacturing process, the raw material, equipment and machinery used.

2. Monitoring of electrical parameters by AEMC network analyzer model: 3945-B (AEMC INSTRUMENTS, 2012). Said equipment was installed on the main board of the electrical installation with the purpose of monitoring the main electrical parameters of the different charges and the most consumed equipment.

3. The data collection of the different equipment installed in the work areas of the plant was carried out. During the survey, force equipment (electric motors), Samoa-type dryers and rotary machines, lighting equipment, office equipment and pumping equipment are taken into account. At the beginning of the activities, Team 1 decided to start with the raw material area: fermentation, drying, bagging and selection, buying and selling area and patio. Team 2 was dedicated to perform data collection in the following areas of the plant: main office, warehouse and warehouse. In the case of offices, miscellaneous equipment (computers, laptops, printers, coffee makers, etc.), air conditioning and lighting equipment are taken into account.

4. Afterwards, after collecting all the information, the network analyzer team was removed and the staff was thanked for the facilities provided.

Productive process

The "big" cocoa harvest is presented annually, between October and May. The raw material used (cocoa beans) comes mostly from the contribution of local partners and farmers, therefore, the process begins with the purchase of these grains, in the plant there is no harvesting, splitting of cobs or shelling.

The villagers of the town take to sell their grains at the doors of the plant. Then, so that cocoa can be converted into chocolate, it must first go through two main processes: fermentation and drying, in which it develops the characteristics of flavor and aroma that define its quality.

Fermented area: Fermentation cleans the seeds and avoids the germination of these. During fermentation, the combined and balanced action of temperature, alcohols, acids, pH and humidity kill the embryo, decrease the bitter taste and produce certain biochemical reactions that form the chocolate (Secretary of Agriculture of Antioquia, 2008).

The fermentation time used in the plant depends on the requests of the clients, but it must not be longer than three days for the white or cotyledon cocoa and greater than eight days for the foreign or purple or purple cotyledon cocoas. The fermentation takes place in wooden boxes, as shown in fig 1.

Figure 1 Fermented area
Source: Own photo

Drying Area: The drying allows the seeds to lose the excess moisture and during this time the changes are finished to obtain the chocolate flavor and aroma. Changes in color also occur, appearing the typical brown color of cocoa. During drying, the ideal is to reduce the moisture content of the seeds from 55% to 6 or 8%. The drying methods they use are:

1. The natural drying in the outdoor patio by taking advantage of the sun, as shown in figure 2, is the most economical since it uses radiant heat from the sun's rays, however, it is used to a lesser extent in the plant.

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Figure 2 Drying in patio
Source: Own photo

2. The Samoa-type dryer, in which a stream of hot dry air is passed through the cocoa arranged on a platform or bed, uses LP gas for the burners and electric power for the fans, as shown in Figure 3.

Figure 3 Samoa type dryer
Source: Own photo

3. Commercial Rotary Dryers, originally designed to dry coffee beans, are used to dry cocoa beans using LP gas burners and electric power, as shown in Figure 4.

Figure 4 Rotary dryer
Source: Own photo

The Samoa and rotary dryer are the main equipment used in the plant for this purpose, after drying the cocoa beans are ready to be packaged and offered to their consumers or customers.

Lifting charges

The facilities of the company have different types of charges among which are:

- Charges for lighting equipment. The company has compact fluorescent lamps of 26, 45 and 105 W where most are located in the process area, offices, warehouse and drying yard. There are also 75W T12 lamps in the process area.

- Charges for air conditioning equipment. It has a team of 1.5 tons (18,000 BTU) of conventional technology R22.

- Charges for electric motors of alternating current. These engines are located in the drying, fermented areas and the power varies from 0.5 to 10 Hp, where most are standard efficiency.

- Charges for pumping equipment. In what corresponds to pumping equipment, there are 4 centrifugal pumps with capacities of 0.5, 1 and 1.5 Hp.

- Charges by miscellaneous teams. The charge for miscellaneous equipment refers to the various office and laboratory equipment (ventilator, TV, printers, laptop, incubator, coffee makers, etc.) found in their facilities.

According to the survey carried out for connected charges, the total installed power was determined by type of system and the percentage of charge represented by each system with respect to the total installed kW, as shown in table 1 and figure 1.

The lighting and air conditioning system includes all the equipment found in all areas of the industrial warehouse, as well as the AC motor systems (installed in Samoa type dryers and rotary), pumps and miscellaneous equipment.

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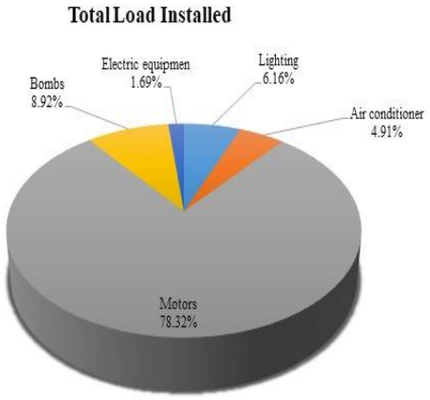
Sistem	Charge [kW]	%
Illumination	2.32	6.16%
Air conditioner	1.85	4.91%
Ac motors	29.487	78.32%
Bombs	3.359	8.92%
Miscellaneous team	0.635	1.69%
Total	37.65	100%

Table 1 Total charges installed by system
Source: Self Made

For a better perception of the charges installed by system, figure 1 shows that the highest installed charge corresponds to 78.32% alternating current motors, then to pumps, lighting and air conditioning and charges for miscellaneous equipment only represent a value of 1.69%.



Graphic 1 Percentages of charges installed by system
Source: Self Made

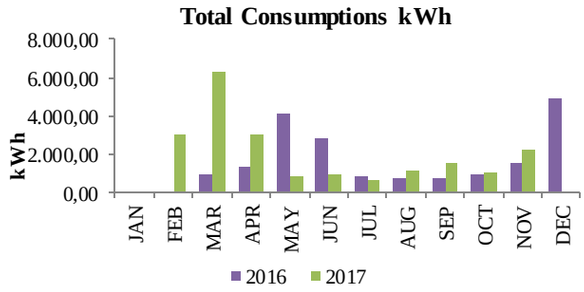
Electric system

The electric power supply service by the Federal Electricity Commission (CFE) is carried out through the ordinary medium voltage (OM) tariff, which has a pole-type substation with a capacity of 45 kVA, a main switch of 100 A and a contracted demand of 21 kW according to billing receipts, so that the company has a 3-phase-4-wire electrical system.

Electric billing analysis

Electric energy billings were processed and the graphs obtained for energy consumption [kWh] and maximum demand [kW] corresponding to the years 2016-2017 were analyzed in the ordinary rate for medium voltage general service with demand less than 100 kW (Rate OM).

The energy consumption in kWh for the different periods of 2016 and 2017 show significant differences as shown in figure 2, which corresponds to the harvest months of October to December and the second harvest of March to May, of each year respectively.



Graphic 2 Behavior of annual energy consumption (2016-2017)
Source: Self Made

The total energy consumption for the year 2017 has increased, compared to the previous year and there is a peak of energy consumption for the month of March 2017 which is much higher than the month of March 2016 and the peak December 2016, so it can be assumed that production increased considerably.

The maximum demand of the years 2016 and 2017 are shown in figure 3, we can see that the maximum demand values coincide with the seasons of high and low production.

The average maximum demand during the period of highest production (March-April) exceeds the contracted demand, this due to the availability of the obtained cocoa harvest volumes, which is variable per year..

There are 4 periods in 2017, where the maximum demand measured exceeds the contracted demand, the above is not a reason for reclassifying the OM rate to the HM rate since it does not exceed 100 kW.

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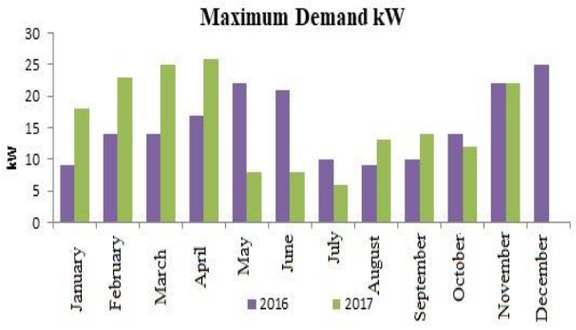


Graphic 3 Maximum demand behavior (2016-2017)
Source: Self Made

With regard to the charge factor, when averaging the values shown in the electricity bill for 2017, it shows a value of 13%. This value indicates that the contracted power is not used in the company because they depend to a large extent on the harvest seasons.

Report of the 45 kva substation

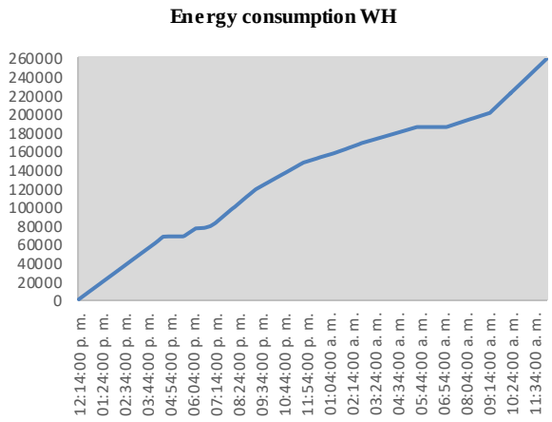
The monitoring was carried out in the main substation of 45 KVA through the electrical power quality and network analyzer brand AEMC 3945-B. Which was installed in the main switch of 100 A.

The readings of the measurements were made in periods of 2 minutes. The total period of the measurement was 24 hours, on November 27, 2017. Next, the parameters are described according to the data obtained.

1. Energy consumption (wh)

The energy consumption measured in the substation is shown in figure 4. Consumption monitoring was recorded for a period of 24 hours from 12:14 pm on day 27/11/2017 to 12:14 pm on day 28/11 / 2017.

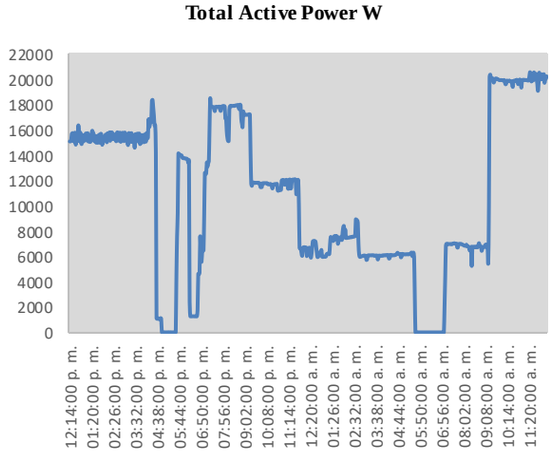
The maximum value of the mentioned measurement period was 259.03 kWh, however, it is important to mention that the production was not 100%.



Graphic 4 Behavior of the total energy consumption of the day 27-11-17
Source: Self Made

2. Active power (kw)

By means of the demand data that we obtained from the analyzer we can observe in graph 5 the maximum and minimum demand behavior obtained in the monitoring period.



Graphic 5 Behavior of the active power of the day 27-11-17
Source: Self Made

The demand for average active power under normal working conditions has a value of 18 kW, according to figure 5. Around 5:00 pm on November 27 and at 5:30 am on November 28, demand decreases drastically, which corresponds to the change of employee shift.

The power remains stable between 18 and 20 kW from 9:00 a.m. to 5:00 p.m. of each working day during the strong harvest period, which coincides with the morning work schedule and because in the day is when the partners take to sell their cocoa beans to the cooperative.

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The substation has a capacity of 45 KVA, and according to measurements recorded by the network analyzer, the maximum value measured was 29.79 KVA.

From the above it is concluded that 66.2% of the transformer capacity is being used, which is within the operating limits of the transformer efficiency.

Thermal system

The thermal system used depends to a greater extent on lp gas consumption for the drying of cocoa and a small percentage on the use of solar radiation in the outdoor drying patio.

Gas billing analysis lp

The following table 2 shows the consumption in liters of LP gas, the energy in megajoules MJ and the cost in pesos, according to the invoices provided for the year 2017, as we can see the lp gas purchases correspond to the months of production and the annual consumption for 2017 was 49,479.

2017	GAS LP Liters	MJ	Cost $
Jan	8,479.00	224,201.72	$63,399.52
Feb	10,874.00	287,530.31	$81,473.29
Mar	16,493.00	436,107.91	$124,313.11
Apr	1,692.00	44,739.86	$12,673.08
May	0.00	0.00	0.00
Jun	0.00	0.00	0.00
Jul	0.00	0.00	0.00
Aug	0.00	0.00	0.00
Sep	4,728.54	125,032.05	$37,384.08
Oct	1,788.11	47,281.20	$15,332.07
Nov	5,424.80	143,442.56	$50,125.15
Dec	No disponible	No disponible	No disponible
Total annual	**49,479.45**	**1,308,335.62**	**$384,700.31**

Table 2 2017 LP gas consumption
Source: Self Made

Where the PCS of LP gas equals 26,442 MJ / l

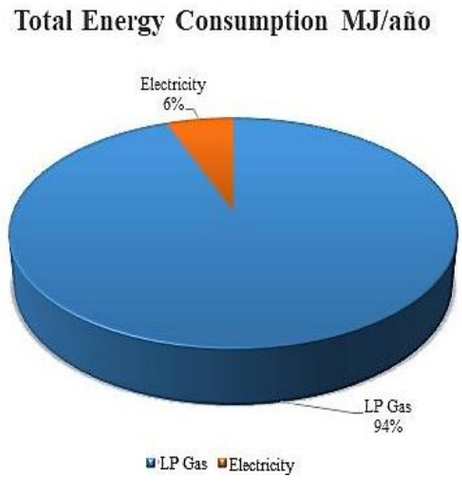
Total energy used in MJ / year

In the company two types of energy are used for the development of activities during the year 2017, electric power, which is charged with feeding the electric motors that are required during the processes and the thermal energy that is used for the drying of cocoa.

Total Energy Consumption 2017		
Gas LP	1,308,335.62	MJ / year
Electricity	80,794.80	MJ / year
Total	1,389,130.42	MJ / year

Table 3 Total energy consumption of 2017
Source: Self Made

In figure 6, you can see the percentages of distribution in the consumption of the energy used.



Graphic 6 Total energy consumption in MJ / year of 2017
Source: Self Made

For all this we can conclude that lp gas consumption is the predominant and that the most money costs the company, only until the month of November 2017 represented an expense of $ 384,700.31 which is why it is important to reduce consumption.

Energy saving measures

Short-term measures

Lighting: A decrease in electricity billing will be obtained, using natural lighting during the day through the use of translucent sheets or turning off the lamps in those areas that are left without activity, this applies to the drying and fermentation area, where you have some translucent sheets, which require cleaning and maintenance.

Air conditioning: During the tour in the facilities Minisplit type air conditioning equipment was observed, it is important to mention that air conditioning equipment requires a minimum of preventive maintenance twice a year, in order to avoid increases in energy consumption of the teams (Sanz, J. G., Cuadros, F., y López, F., 2011).

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Engines: Motors require preventive maintenance due to cocoa residues preventing the correct heat dissipation of the motor, as well as cleaning of connection boxes, bearings and bands.

Samoa type dryers: Samoa type dryers should be thermally insulated in a proper way to avoid heat transfer to the outside.

Long-term measures

The proposals for long-term energy savings involve the replacement of technologies as shown in the guide to develop an energy diagnosis in real estate (SENER, 2013).

Lighting: The lighting system in the different areas of your company consists of outdated technology T12 75 W tubular lamps and compact fluorescent lamps of 26, 45 and 105 W. For the above, it is proposed to use more efficient technologies such as lamps led to reduce energy consumption providing the necessary lighting conditions for the performance of the different activities.

Air conditioning: In the facilities there is a minisplit air conditioning system, of conventional technology, therefore it is proposed to consider the use of minisplit inverter equipment.

Dryers: The use of dryers for hybrid greenhouse cocoa is proposed, alternating renewable energy (solar thermal and photovoltaic) and conventional energy to a lesser extent (LP gas and electricity from the CFE network). These dryers allow the cocoa beans to be dehydrated by means of a heat transfer process by convection between hot water generated by the solar collectors and a forced ventilation system. (Maupoey, P., Andrés, A., Barat, J. y Albors, A., 2001).

The renewable energy system consists of a photothermal system that allows to heat the water necessary to reach an air temperature inside the drying chamber at 60 ° C and a photovoltaic system that is charged with generating the energy to power the equipment. pumping and heat exchanger, all this without affecting the sensory properties and quality of cocoa.

Good practices

Air conditioner:

1. Create and implement a preventive maintenance plan that allows maintaining a correct level of service in the equipment.
2. Replacement of damaged or damaged thermal insulation.
3. Verify the absence of unwanted heat sources in the air conditioning areas.

Lighting:

1. Have an inspection and maintenance program to obtain an efficient operation and avoid unnecessary energy consumption.
2. Check for false contacts, hot spots and dust accumulation.
3. Implement a program for changes in lighting schedules, uses and customs of the staff.
4. Avoid over lightening, as well as unnecessary sources of light.
5. Replace obsolete T12 technologies with T5 or LED.

Bombs:

1. Check the alignment between motor and pump, avoiding stresses that reduce the service life of the bearings.
2. Prevent the pump from operating without fluid.
3. For motors greater than 1 Hp, it is recommended to use an independent electric circuit.
4. Place flexible joints to prevent the propagation of vibrations and stress from the pipe to the pump and vice versa.

Motors:

1. To the extent possible make use of high efficiency engines.
2. For large capacity motors, the use of a starter is recommended since it improves the operation and extends the useful life of the motor.
3. The motors have an average lifespan between 15 and 20 years. Replacement is recommended after that period.
4. Check the accessories that are attached to the motor for the purpose of replacing said parts (belts, chains, bearings, etc.)

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5. Verify that the engine ventilation system is free of dust

Substation:

1. Create a preventive maintenance plan that allows to keep the transformer in optimal conditions.
2. Maintain ground connections of equipment in good condition.
3. Maintain the area of the substation in orderly and clean conditions.

Conclusions

One of the main problems faced by cocoa producers in Mexico is the low profitability of the way in which they transform their raw materials into their final products, against the increasingly expensive costs of energy (electric, thermal, etc.) that were used in said production process.

Cacao growers in Mexico, being an important part of the country's economy, economic development and generating jobs, it is of significant importance to promote actions that benefit their development in terms of energy efficiency, so perform an energy audit in the company of cocoa drying, allows us to know your real energy situation and to propose saving measures that directly benefit the economic profitability of the company.

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