An Assessment on the Electrical System Design and Facilities of a Pottery Company in Pampanga, Philippines

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Abstract: - Energy audit is a term that is frequently used, and it can have a variety of meanings depending on the energy service provider. It not only identifies energy use among various services and opportunities for energy conservation, but it also serves as an important first step in establishing an energy management program. The audit will generate the data that will form the basis of such a program. This paper aimed to assess the current electrical system design and facilities of a pottery company in Pampanga through energy audit. The study revealed various technical findings in lighting system, mechanical system, and electrical system, utilities and electrical equipment/motors. Recommendations from this study can help the company to reduce energy consumption as well as to represent significant cost savings.

Key Words: — ***Energy audit, energy efficiency, electrical system design and facilities, energy savings, efficiency opportunities.***

I. INTRODUCTION

Energy is a critical component in the advancement of modern society; it promotes economic growth and improves quality of life. Global population growth has contributed to rising energy consumption, and demand levels are expected to be 45 percent higher in 2030 than they are now [1]. As a result of our reliance on energy, there is growing concern about energy availability and its environmental consequences. Much of our electricity is still generated from carbon-based sources such as coal, oil, and gas, which contributes to more than half of global greenhouse gas emissions [2].

The profile of energy efficiency has gone up significantly as a result of growing concerns about the local and global environmental impacts of energy use.

Manuscript revised May 17, 2022; accepted May 19, 2022.
Date of publication May 21, 2022.

This paper available online at www.ijprse.com

ISSN (Online): 2582-7898; SJIF: 5.59

Energy security issues have also brought energy efficiency to the forefront, as it directly contributes to lower energy consumption. This has led the government to enact a slew of environmental legislation, energy auditing, and accreditation standards. As a result, energy demand and rationalization are gaining prominence in modern manufacturing businesses. Improving energy efficiency is not only one of the most important ways to reduce overall environmental impacts, but it may also represent significant cost savings and competitive advantages [3].

The energy process is a systematic approach to identifying energy waste in a facility and determining how to eliminate this waste at a reasonable cost and within a reasonable time frame. Energy audit is a term that is frequently used, and it can have a variety of meanings depending on the energy service provider. A building's energy audit can range from a quick walkthrough to a comprehensive analysis. It not only identifies energy use among various services and opportunities for energy conservation, but it is also an important first step in establishing an energy management program. The audit will generate the data that will serve as the foundation for such a program.

This paper aimed to assess the current electrical system design and facilities of a pottery company in Pampanga through energy audit. The following are the goals of the energy assessment:

- To determine the current operating conditions of the facility's selected energy-consuming equipment.
- To identify energy conservation improvement opportunities and efficiency options, as well as possible ways to reduce operating expenses.
- And to assist in the capability development of the facility's personnel in energy management.
- The working performance of the facility's lighting, mechanical system, and electrical systems is evaluated in this assessment.

II. Literature Review

Global energy consumption is expected to increase by 50% between 2010 and 2040, owing primarily to increased energy use in the industrial sector, which accounts for approximately 37% of global energy consumption [4] and 25.1 percent of energy consumption at the European Union (EU) level [5]. In this scenario, energy efficiency can make a significant contribution to reducing industrial energy consumption and improving industrial firms' competitiveness [6]. It would also compel industrial companies to prioritize energy management on a strategic level, thereby contributing to the world's transition to more sustainable development [7].

The Energy Efficiency Directive establishes a set of legally binding measures to assist EU countries in meeting the 20% energy efficiency target by 2020. Among the various areas of intervention, the EED advocates for the implementation of high-quality energy audits, which are defined as systematic procedures used to identify, quantify, and report existing energy consumption profiles and energy-saving opportunities in buildings, industrial or commercial operations or installations, and private or public services. The goal of any energy audit, then, is to enable the realization of EEMs by analyzing all aspects of energy consumption and use in a facility. According to the EED, energy audits are required for large enterprises, defined as those with more than 250 employees or an annual turnover of more than € 50 million. Furthermore, the European Commission [8], in support of the agreement reached at the United Nations Conference on Climate Change [9], has emphasized the importance of effective energy audits and EEMs in enhancing industrial companies' competitiveness.

An energy audit is a study of a plant or facility to determine how and where energy is used, as well as to identify ways to save energy. Energy audits can have different meanings for different people. The scope of an energy audit, the complexity of calculations, and the level of economic evaluation are all issues that each individual auditor may handle differently and should be defined prior to the start of any audit activities [10].

A case study was conducted in a large home appliance manufacturing company in Europe with regards to energy efficiency of the said plant through energy audit. They have concluded that energy audit can be designed and used overcome barriers which hamper the adoption of Energy Efficient Directory [11].

In a study in Sweden, the energy end-use and energy efficiency potential of industrial small and medium-sized businesses taking part in the Swedish Energy Audit Program are examined. The three manufacturing industries studied are wood and cork, food products, and metal products (excluding machinery and equipment). The results of a unique categorization of their production processes' energy end-use are presented, demonstrating that the amount of energy used in various categories of production processes varies between these industries. This also applies to support processes, emphasizing the difficulty of generalizing results in the absence of bottom-up energy end-use data. Furthermore, a calculation of conservation supply curves for measures related to manufacturing processes is presented, demonstrating that there is still energy saving potential among companies participating in the Swedish Energy Audit Program. The study emphasizes the importance of developing energy policy programs that provide high-quality data. The paper adds to our understanding of the complex issues surrounding industrial energy end-use and energy efficiency measures [12].

In Asia, an energy audit was conducted in an Indian yarn manufacturing industry to provide recommendations on reducing energy consumption and significant cost savings. According to the study's recommendations, the industry can save a total of Rs. 8,98,700 per year. This means that by implementing the energy audit program, the industry can save a significant amount of money while also reducing energy consumption [13].

Another study in India was conducted to audit the energy consumption of a tea manufacturing company. The current paper focuses on an energy audit plan for a medium-sized tea manufacturing industry with its own garden in the Jalpaiguri area of North Bengal, which is located in the northern part of West Bengal, India. The audit determines and analyzes the amount of energy used by machines and production processes. The recommendations of the researchers can help the company to bring down the overall use of energy [14].

In the Philippines, Energy usage in industries is one of the significant factors that contribute to industry competitiveness, and as such, it must be properly managed to deliver maximum savings and, ultimately, profits for companies. In general, energy management can be divided into two categories: electrical and mechanical. The goal of this practicum project is to recommend energy conservation measures for the analyzed companies in order to save energy. Thus, the goal of all activities in this practicum project is to reduce energy consumption and, as a result, make the company more competitive. The energy audits of Companies I and II were carried out by the writer and the Energy Management Advisory Services Section of the Department of Energy of the Philippines' Energy Efficiency and Conservation Division. The goal of the practicum project is to provide recommendations for energy conservation by conducting a detailed energy audit and submitting a formal report describing a thorough analysis of energy conservation projects. Company I's monthly potential energy savings are equivalent to Php. 1,690,902.00 with a total investment cost of approximately Php 18,058,888.38, which can be recovered in less than a year, with a monthly total potential monetary savings of Php. With a total investment cost of 244,964.60 and a payback period of Php. 1.02 years and $2,040,000.00 [15].

Another study conducted in the Philippines stated that the inspection, survey, and analysis of energy flows in a building is known as an energy audit. The goal is to identify energy-saving opportunities that will not have a negative impact on the building's output or operations. The study presents a unique case of cleaner production in educational buildings: minimal material flow allows for a focus on energy consumption; robust scheduling provides an advantage; and equipment usage is similar to that of an office and an industrial building. According to energy auditing, air conditioning accounts for the majority of electricity consumption (51%), followed by equipment use (35%), and lighting (35%). (14 percent). Annual CO_2 emissions from electricity consumption are estimated to be 433 tons. Recommendations include using energy-efficient lighting and taking advantage of daylighting, installing a centralized or split-type inverter air conditioning system, and enforcing minimum energy performance standards (MEPS). Finally, it is recognized that scheduling plays a critical role in managing the smart consumption of educational buildings [16].

III. Research Methodology

In this study, the researchers used descriptive research method. Descriptive research involves collections of quantitative information that can be tabulated or can describe categories of information. Observational and survey methods are frequently used to collect data from the study [17].

The researchers take a four-stage approach to conducting a complete energy assessment:

- Walk-through and preliminary survey
- On-site Data collection, testing, and measurements
- Data analysis and evaluation, as well as
- Final report preparation and presentation

During the walk-through/preliminary survey, the following activities were carried out:

- Meeting/interview with relevant individuals through the online in connection to the audited systems/equipment
- Identify the key energy-consuming equipment or the area that must be evaluated.
- Determination of sampling points for measurement and on-line meters for monitoring (if applicable);
- And Familiarization with the facility's operation and equipment.

To organize and summarize data gathered from the study, the researchers used descriptive statistics. Descriptive statistics are used to provide and describe the summary of the data collected [18].

IV. Result And Discussion

A comprehensive energy audit was carried out in the facilities of the pottery company being studies by the researchers. The following is a summary of the important technical findings and recommendations for the production plant's energy savings and efficiency opportunities:

4.1 Key Technical Findings

4.1.1 Lighting System

- The production area lighting fixtures were placed correctly and with aluminum reflector.
- Area Comply with the recommended illumination levels of 300 – 750 lux.
- The production fixtures' light outputs were optimized because they were optimized the use of day lighting for maximum illumination.
- The height of installed lamps in all locations has standard recommended mounting height of 1.5 meters, which has an impact on lighting quality.
- Production Area lighting fixture has individual switch as indication of good practice.

4.1.2 Mechanical System

- Majority of the office have undersized ACU system contributes to high energy consumption. And other with oversize cooling loads.
- Older air conditioning units consume more energy.
- ACUs have been installed in the area, but with improper room insulation.
- Majority of the ACU setting between 17-18°C.
- In some places, the actual temperature is higher than the set point. a sign that there is a lot of energy demand
- Parts of the main office are frequently open, allowing extra heat and dust in from the outside.
- Poor building Insulation for some offices.
- A condensing unit in the office in the production area contributes additional heat.
- Dirty air filters are an indication of high dust in the area and frequently left doors open.
- There is no procedure monitoring scheme for how much LPG pressure is used for LPG-fired kilns in particular processes.
- high LPG demand for 3 units of a kiln dryer.
- The wood kiln has exceeded carbon monoxide as per standard.
- The Compressor pipe system leak testing procedure is limited to bubble testing only.
- There is no air capacity regulator from each spray booth. Refer spray gun capacity as recommend for each booth.

4.2 Electrical System, Utilities and Electrical Equipment/Motors

4.2.1 Warehouse:

- There are existing wiring methods which poses hazard and are violation of the Philippine Electrical Code (PEC) for a safe delivery of electricity. These are as follows:
- The Main Panel Board (800 Ampere Main) is located within the vicinity of the Warehouse where Hazardous Material such as Flammable and Combustible substances are stored.
- The Main Panel Board is not easily accessible.
- Working area for MDP is limited due to the orientation of the panel cover**.**

4.2.2 Production Area:

- The approved electrical plan is for construction purposes only. There is a need to provide an actual "As-Built" Plan.
- There exist holes on panel boards. All openings on panel boards, utility boxes, switches gutters and wire ways must be properly sealed to avoid dust accumulation and pest infestation which would cause short circuit and eventually fire on the work station.
- Most of the branch circuits on the panelboard are not properly labelled and/or tagged.
- There are connected "temporary" single phase feeder wire on the PPE3 which may cause overloading on the said panel
- Presence of hot spots PPE3 circuit breaker mains
- The wirings are properly dressed at panel boards. However, additional exposed wirings are not properly terminated.
- There is some electrical equipment such as electric fans/blowers are left operating and unattended.
- On the TSG Batching Area, 3 different power ratings are used. (1hp, 3phase; 1hp, single phase and 1.5hp single phase) which are used or are loaded simultaneously.

4.3 Energy Conservation and Efficiency (EC & E) Options

The potential annual savings for all equipment assessed are summarized in the following table:

Equipment/System	Recommendations	Annual Potential Savings, Php/year
Lighting System	• Majority of the light fixture particular in the production area are installed properly as recommended	TBD
	• Provide proper maintenance, like cleaning fixtures regularly.	
	• Place reminder stickers to switch off the light when not in use.	
	• Turn off lights when not in use.	
Mechanical System	• Use the recommended cooling capacity for each ACU in the offices to prevent running the compressor consciously.	TBD
	• Properly insulate the perimeter/side of the ACU units to prevent heat leaks coming from the production area.	
	• To optimize ACU, avoid setting the ACU setting between 17-18°C and the standard setting to 24-27°C.	
	• Analyze if the older ACU unit needs to be replaced.	
	• To prevent excessive air filter cleaning that goes beyond the usual maintenance, prevent doors from being opened when they aren't needed. Use an air curtain to prevent dust in some busy offices in the production area.	
	• Take time to monitor the actual temperature as indicated in the LPG kiln dryer.	
	• Consider lowering the temperature of the LPG Kiln dryer, optimizing the procedure/time required, and avoiding unnecessary heat up or cool down procedures without affecting output quality.	
	• Take into consideration the wet scrubber to lower the level of carbon monoxide from the wood kiln.	
	• Perform a comprehensive leak test in the compressed air system line. Not limited to bubble test.	
	• Take into consideration the recommended air capacity per spray booth as per the standard by inputting the regulator for each booth.	
Electrical System, Utilities and Electrical Equipment/Motors	• Reduction of 1hr operation per day equipment for machine maintenance. (One hr/day savings for 52 weeks)	TBD
	• Consider the use of Solar Power on the system.	

4.4 Discussion

The following discussion below shows the summary of the observations and findings.

4.4.1 Lighting System:

An accounting of the lamp types and their corresponding wattages is tabulated in Table.1.

Table.1. Summary of Total Installed Lamps

Lamp Type / Wattage	Lamp / Fixture	No. of Fixtures	No. of Lamps
T12 LED 18W	2	355	710
PIN lights 8W	1	57	57
TOTAL		**412**	**767**

Table.2. Summary of the Approximate Electricity Consumption Levels from Lighting for the Different Areas

Location/Area	Total Wattage + Ballast	Usage/day (hours)	Consumption/day (kWh/day)	Consumption/Yr (kWh/yr)	Lighting Cost (PhP/yr)
Production Area	11,376	8	91.008	23,753.09	₱176,485.44
Marketing Office	72	8	0.576	150.336	₱1,117.00
Accounting office	216	8	1.728	451.008	₱3,350.99
Pantry	32	4	0.128	33.408	₱248.22
Production area/Mezzanine Area	1,080	8	8.64	2255.04	₱16,754.95
Administrative area/Mezzanine Area	160	8	1.28	334.08	₱2,482.21
Show room	216	4	0.864	225.504	₱1,675.49
TOTAL			104.224	27,202.46	₱202,114.31

Table.3. Average Illumination Levels for the Different Areas

Location/Area	Minimum Illuminance Level (lux)	Maximum Illuminance Level (lux)	Average Illuminance (lux)	Recommended Illuminance (lux)	Remarks
Production Area	350	400	375	300 – 750	*Within Standard*
Marketing Office	380	420	400	300 – 750	*Within Standard*
Accounting office	350	380	365	300 – 750	*Within Standard*
Pantry	360	375	367.5	300 – 750	*Within Standard*
Production area/Mezzanine Area	375	400	387.5	300 – 750	*Within Standard*

Table.4. Power Density Levels

Location/Area	Area (m^2)	Total Wattage	Total Wattage + Ballast	Lighting Index (W/m^2)
Production Area	7,380	11,376	11,376	1.541463
Marketing Office	17.5	72	72	4.114286
Accounting office	36.4	216	216	5.934066
Pantry	36.4	32	32	0.879121
Production area/Mezzanine Area	144	1,080	1,080	7.5
Show room	208	160	160	0.769231

4.4.2 Mechanical System

The air-conditioning system was operational at the time of the audit and was installed in the main area. Table 5 contains the actual measurement data, which is shown in Table 5 along with a description of each system below.

Table.5. Summary of the recommended cooling Capacity

Room	ACU Type	No. of units	tal Cooling Capac		Floor Area (m2)	Volume (m3)	Recomended cooling Capacity				Remarks
			Tr	Kj/hr			1TR=12m2	1TR=28.34m3	Btu/hr	kj/hr	
Area before Show room	Split Wall Mounted	1	1.89563	24,000	45.8	117	3.9	4.128440367	49,541.28	52,269.03	UnderSize
Show Room	Split Wall Mounted	2	3.81496	48,300	163.8	409.5	13.65	14.44954128	173,394.50	182,941.60	UnderSize
office beside show room	Window Type	1	_	_	35.1	87.75	2.925	3.096330275	37,155.96	39,201.77	No name plate
Marketing office	Split Wall Mounted	1	1.35459	12,150	17.5	43.75	1.458333	1.543754411	18,525.05	19,545.04	UnderSize
Accounting office	Split Wall Mounted	1	1.89563	24,000	36.4	91	3.033333	3.211009174	38,532.11	40,653.69	UnderSize
Pantry	Window Type	1	_	_	36.4	91	3.033333	3.211009174	38,532.11	40,653.69	No name plate
MAC office	Window Type	1	_	_	22.5	56.25	1.875	1.9848271	23,817.93	25,129.34	No name plate
Production mezzanine area/QC area	Window Type	1	_	_	24	60	2	2.117148906	25,405.79	26,804.63	No name plate
Production mezzanine area/Production office	Window Type	1	_	_	25.8	64.5	2.15	2.275935074	27,311.22	28,814.98	No name plate
Production mezzanine area/Conference room	Split Wall Mounted	1	_	_	22.8	57	1.9	2.011291461	24,135.50	25,464.40	No name plate
Production mezzanine area/PPC office	Window Type	1	_	_	22.8	57	1.9	2.011291461	24,135.50	25,464.40	No name plate
Production mezzanine area/I.O.B office	Window Type	1	_	_	18	45	1.5	1.58786168	19,054.34	20,103.47	No name plate

Table.6. Electrical System, Utilities and Electrical Equipment/Motors

[illegible]

4.5 Recommendation

4.5.1 Lighting System

Lighting system energy savings can be obtained by either reducing the time of use or lowering the lighting system's power. Reducing use time without sacrificing productivity requires little investment and can be implemented right away. The following are some proposals that could be put into action to save energy:

- *Turn off lights in unoccupied areas*
  - ✓ Place reminder stickers around the area to remind people to switch off lights as they leave.
  - ✓ Provide individual switches to the high-wattage lighting, for example, so that one switch does not control all fixtures for numerous work areas.
- *Follow a regular maintenance schedule*
  - ✓ Establish a routine for inspecting and cleaning lighting and fixtures. Lamps' light output can be reduced by up to 50% when they are dirty. Lamps and fixtures should be cleaned on a regular basis to keep their light output.
  - ✓ Dispose of any broken or flickering lamps, as they continue to consume electricity while providing no light.
  - ✓ Although walls, ceilings, and floors are not part of the lighting system, they must be kept clean to maintain the high level of illumination

due to their surface reflectivity. The goal of good lighting is to improve the pattern of light, shade, color, and contour such that important items are clearly visible and inconspicuous objects are not.

4.5.2 Mechanical System

Air-Conditioning System:

Energy savings for Air-Conditioning System might be accomplished by both monitoring and properly maintaining the equipment and proper cooling capacity it's critical to account for the effect temperature has on the unit's cooling capacity performance. The capacity of an air conditioner diminishes as the ambient temperature rises. Depending on the unit's design qualities, this behavior can occur. This would not require any investment and could be implemented right away. The following are recommendations.

that could be implemented to achieve energy savings:

- Measure the Required Capacity
  - ✓ Use the recommended cooling capacity for each ACU area to prevent running the compressor consciously.
  - ✓ It's important to make adequate allowance for the effect temperature has on the cooling capacity performance of the unit.
  - ✓ Refer to the table 5 for recommended Cooling Capacity
- Make good air circulation
  - ✓ Used fan for more Air Movement
  - ✓ Make proper Air Movement in the Area by increasing outdoor Air intake.
- Location
  - ✓ Prevent the ACCU expose to the direct sunlight
  - ✓ Maintained proper air flow of the ACCU
- Perform regular maintenance
  - ✓ Clean the air conditioner filter at least once a month. A clogged air filter reduces airflow and may cause the unit to malfunction. Clean filters enable the unit to cool down quickly and use less energy.
  - ✓ Ensure that the doors separating the conditioned and unconditioned spaces are always kept shut.

Compressed Air System:

Energy savings for compressed-air systems might be accomplished by both monitoring and properly maintaining the equipment and optimizing these systems can improve energy efficiency by 20% to 50%. Depending on the unit's design qualities, this type of behavior is possible. This would not necessitate any financial outlay and could be implemented immediately. The following are some proposals that could be put into action to save energy:

- Fix Leaks
  - ✓ CONNECTIONS SHOULD BE TIGHTENED. Anything that has the potential to loosen is ripe for an air leak. It's a good idea to go around your compressed air system on a regular basis and tighten any connection points. If any loose components are visible or felt, tighten them as well. The less compressed air you lose, the more secure your system is.
  - ✓ REPAIR OR REPLACEMENT OF PARTS, another key area where you're likely to uncover a few air compressor leaks is old, replacement parts. Air compressor leak points include old filters, lubricators, regulators, flanges, and leaking drains.
  - ✓ REPLACE THE HOSE AND TUBE PARTS AS NEEDED. Another major source of air compressor leakage is air hoses and tubes. These leaks are a little more difficult to spot, but if you hear a leak and can't pinpoint where it's coming from, dab a little soap on the area where you suspect a leak. When your compressor turns on, bubbles will appear around the air leak. Replace the leaking hose or tube with a new one, and your air compressor will be in good working order.
- Proper, regular maintenance and others
  - ✓ SET UP A MAINTENANCE PROGRAM, Air compressors must be serviced on a regular basis. Regular oil changes and maintenance are required for an air compressor.
  - ✓ In addition to a regular repair schedule, having one of your own maintenance or facilities employees evaluate your compressors on a

regular basis is a smart idea. Even a simple weekly walk around your compressed air system might help you detect air leaks early. The more money you save, the faster you can stop air compressor leaks.

- ✓ UTILIZE COOLER INTAKE AIR, Cooler intake air requires less energy to compress because it is denser. Though most compressors are housed within a plant structure, the suction can often be ducted to pull air from outside the structure. The ambient air around the compressor will be cooler in general, and in some situations, much cooler. According to some calculations, decreasing the intake air temperature from 90 to 70 degrees Fahrenheit will save about 3.8 percent in operational costs.

Other System (LPG and Wood Kiln):

- ✓ Check for wear and damage on the burners, regulators, and control valves. Burners can decay in addition to the wear and tear suffered by mechanical equipment.
- ✓ Overheated furnace casings, corrosion of casings or other furnace elements, increased maintenance expenses, and lost production time are all possibilities if the kiln insulation is not maintained.
- ✓ Examine the air/fuel control mechanisms for excessive hysteresis or variability. Process temperature and air/fuel ratio setpoints are more difficult to maintain due to coarse positioning resolution, lack of synchronization, and nonlinear response.
- ✓ Provide proper level of exhaust fumes as per standard figure 1 below.

* Wet Scrubber diagram TBD*

4.5.3 Electrical System

Energy savings for electrical systems could be achieved by either reducing the time of use or by reducing the power rating of the equipment. Reduction of the time of use without sacrificing productivity does not entail investment and could be implemented immediately. The following are recommendations that could be implemented to achieve energy savings:

Production Area

- *Installation of PV panel based on measured kW power consumption during the audit with a recommended rating of 60kW or more depending on the Roofing Carrying Capacity.*
    - For the above stated PV capacity, savings amounting to Php 60,000 or more can be generated.
    - With an Estimated ROI is 4.16 years.
- *Switch- off idle machines.*
    - ✓ Post reminder stickers to turn off machine when leaving the area
    - ✓ Install proximity switches or sensors so as to reduce machine consumption time.
    - ✓ Usage of machines must be maximized to reduce idle time. A good working schedule for the usage of equipment must be properly plan.
- *Follow a regular maintenance schedule*
    - ✓ Establish a regular inspection and preventive maintenance schedule of electrical equipment.
    - ✓ Presence of pest on circuit breakers, panel boards poses electrical hazards. These may cause the breakers to tripped off which may cause power outages within the site.
- *Strictly follow provisions of the Philippine Electrical Code (PEC) for the safety of personnel and equipment.*
    - ✓ Inspect all possible sources of short circuit such as jumpers and circuit protection bypass.
    - ✓ Seal all possible entries of pest and dust which accumulates on the panelboards and controllers.
- *Strictly follow provisions of the Philippine Electrical Code (PEC) for the safety of personnel and equipment.*

4.5.4 Compliance in Energy Efficiency and Conservation Act (Republic Act No. 11285)

In compliance in R.A. No. 11285, the company is mandated to prepare and evaluate further its Energy Conservation Program to secure sufficiency and stability of their energy supply.

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