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Journal Electrical Engineering

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The works must be unpublished and refer to topics of Electromagnetism, electrical distribution sources, electrical engineering innovation, signal amplification, electric motor design, material science in power plants, management and distribution of electrical energies and other topics related to Engineering and Technology.

Presentation of the content

As the first article we present, *Proposal for an energy sustainability strategy for the Universidad Tecnológica de Aguascalientes*, by CASTILLO-ZÁRATE, Ma. Alicia, with affiliation at the Universidad Tecnológica de Aguascalientes, as the next article we present, *Analysis and diagnosis of electric power quality at ITSH facilities,* by TELLEZ-CUEVAS, Pedro, HERNÁNDEZ-SÁNCHEZ, Juan Fernando and GARCÍA-MÁRQUEZ, Kevin, with affiliation at the Instituto Tecnológico Superior de Huauchinango, as next article we present, *Analysis of the electrical power generated by a thermoelectric system for application in the Ingenuity drone from a nuclear heat source*, by RODRÍGUEZ-ÁVILA, Jesús, VALLE-HERNÁNDEZ, Julio and GALLARDO-VILLARREAL, José Manuel, with affiliation at the Universidad Politécnica Metropolitana de Hidalgo and Universidad Autónoma del Estado de Hidalgo, as last article we present *Lighting study at the Universidad Tecnológica de Aguascalientes*, ACOSTA-GONZÁLEZ, Yanid, DELGADO-GÓMEZ, Gilberto, SALAS-DOMÍNGUEZ, Mario Iván and HERRERA-RODRÍGUEZ, Samanta, with affiliation at the Universidad Tecnológica de Aguascalientes.

Content

Article	Page
Proposal for an energy sustainability strategy for the Universidad Tecnológica de Aguascalientes CASTILLO-ZÁRATE, Ma. Alicia *Universidad Tecnológica de Aguascalientes*	1-8
Analysis and diagnosis of electric power quality at ITSH facilities TELLEZ-CUEVAS, Pedro, HERNÁNDEZ-SÁNCHEZ, Juan Fernando and GARCÍA-MÁRQUEZ, Kevin *Instituto Tecnológico Superior de Huauchinango*	9-14
Analysis of the electrical power generated by a thermoelectric system for application in the Ingenuity drone from a nuclear heat source RODRÍGUEZ-ÁVILA, Jesús, VALLE-HERNÁNDEZ, Julio and GALLARDO-VILLARREAL, José Manuel *Universidad Politécnica Metropolitana de Hidalgo* *Universidad Autónoma del Estado de Hidalgo*	15-24
Lighting study at the Universidad Tecnológica de Aguascalientes ACOSTA-GONZÁLEZ, Yanid, DELGADO-GÓMEZ, Gilberto, SALAS-DOMÍNGUEZ, Mario Iván and HERRERA-RODRÍGUEZ, Samanta *Universidad Tecnológica de Aguascalientes*	25-31

Article **Journal Electrical Engineering**
December 2022, Vol.6 No.17 1-8

Proposal for an energy sustainability strategy for the Universidad Tecnológica de Aguascalientes

Propuesta de estrategia de sustentabilidad energética para la Universidad Tecnológica de Aguascalientes

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Abstract

Due to the high consumption of electrical energy that the Technological University of Aguascalientes has had during the last 5 years and the interest of moving towards a sustainable university campus, a strategy with an environmental approach is presented that addresses this problem, to reduce the consumption of electrical energy from campus. The work is developed from a meeting with representatives of the Rectory, the Directorate of Administration and Finance and the undersigned, in academic representation of the Renewable Energies career Solar Area of the Institution, to identify the impacts derived from this problem. From the investigation process of the Energy Reform regarding the tariff scheme of the Federal Electricity Commission (CFE) network as of 2017, as well as the calculation procedures for the cost of energy consumed in the High Demand Medium Voltage Hourly rate (GDMTH), an analysis is carried out and the behavior of the costs generated by the energy demand in base, intermediate and peak hours, as well as the consumption for summer and winter hours, is identified. The information from the Single Line Diagram of the Institution allows detecting the supply network and the areas with the highest energy consumption in the Institution. Based on this internal analysis and following the SR-Sustainable methodology, the strategic plan of the proposal is drawn up in the lines of action efficient energy, infrastructure for energy sustainability and Alternatives for energy generation: Sizing, design and installation of sources power generators.

Sustainability, Strategy, Energy

Resumen

Debido al elevado consumo de energía eléctrica que la Universidad Tecnológica de Aguascalientes ha tenido durante los últimos 5 años y, al interés de transitar hacia un campus universitario sustentable, se presenta una estrategia con enfoque ambiental que atiende esta problemática, para disminuir el consumo de energía eléctrica del campus. El trabajo se desarrolla a partir de una reunión con representantes de Rectoría, de la Dirección de Administración y Finanzas y quien suscribe, en representación académica de la carrera de Energías Renovables Área Solar de la Institución, para identificar los impactos derivados de esta problemática. Del proceso de investigación de la Reforma Energética respecto al esquema tarifario de la red de Comisión Federal de Electricidad (CFE) a partir del 2017, así como los procedimientos de cálculo para el costo de energía consumida en la tarifa Gran Demanda Media Tensión Horaria (GDMTH), se realiza un análisis y se identifica el comportamiento de los costos generados por la demanda de energía en horario base, intermedio y punta, así como el consumo por horario de verano e invierno. La información del Diagrama unifilar de la Institución permite detectar la red de suministro y las áreas de mayor consumo de energía en la Institución. A partir de este análisis interno y siguiendo la metodología de RS-Sostenible se elabora el plan estratégico de la propuesta en los ejes de acción Energía eficiente, Infraestructura para la sustentabilidad energética y Alternativas para la generación de energía: Dimensionamiento, diseño e instalación de fuentes generadoras de energía.

Sustentabilidad, Estrategia, Energía

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Introduction

Although the trend of the history of electricity consumption over the years, at the Technological University of Aguascalientes (UTA) follows the same pattern, consumption costs tend to increase due to the constant updating of the price of energy stipulated by the Federal Electricity Commission (CFE) in its tariff scheme, especially for micro and small businesses.

Statistical data for 2018, show an average 54,243 kW/month per year with a maximum consumption of 61,494 in the month of October and a minimum of 44,726 kW/month during April. For 2019, the average consumption was 55,097 kW/month per year with a maximum consumption of 63,192 in the month of October and a minimum of 48,491 kW/month during December. In both years, the consumption ranges ranged between 44 and 63 kW per year.

Subsequently, in February 2020, an interconnected photovoltaic system (SFV-I) with a capacity of 48,380 kW was installed and from March onwards the trend (see Figure 4) shows a decrease with a consumption of 45,422 kW, lower than the minimum consumption of the previous year. At the end of March 2020, due to the suspension of academic activities at the Institution due to the pandemic, in the months of April and May the trend be even lower, i.e., 38,073 kW and 32,877 kW respectively.

For the year 2022, the on-site academic activities are regularized and the consumption trend in the first five months continues with the same pattern as in other years, except that consumption continues to fall with an average of 35,579 kW/month and in the month of May with a maximum consumption of 43,937 kW, lower than the energy consumption before the installation. Despite this decrease, there is still an economic impact due to the costs of this consumption, therefore, considering that the investment to install another photovoltaic generation system is high and, given the Rector's interest in the transition of the Institution towards a sustainable campus, this document describes the development of a strategy based on the methodology proposed by RS-Sostenible with an environmental approach, which reinforces the results of the SFV-I and addresses the problem of energy consumption, as a starting point for this transition.

The article describes the energy problem, the proposed attention, the objective, the development of the energy sustainability strategy based on the methodology of the company RS-Sostenible, the lines of action and the strategic planning of activities.

Theoretical framework

Sustainable development

In 1983 (UN, 1987), the United Nations (UN) created the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, Prime Minister of Norway. In October 1984, this Commission met in response to an urgent call to establish a global agenda for change, and carried out studies, lectures, analyses, debates and public consultations throughout the world. As a result of this work, in 1987 it published and disseminated the report "Our Common Future", which describes the need for society to modify its lifestyle and habits in order to prevent the social crisis and the degradation of nature from spreading irreversibly. The report raises the possibility of obtaining economic growth based on sustainability policies that will extend the capacity of the environment to meet present and future needs. The concept of sustainable development is defined as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (Ramírez, 2002).

Beyond pretending to be a futuristic prediction, this represents an urgent call to adopt decisions that will ensure the resources to sustain this and the following generations.

Since then, in many countries there has been a commitment to maintain, through strategic actions and policies, a balance in the economic, social and environmental dimensions of sustainable development, seeking the viability of using environmental resources for economic growth, ensuring that economic and social growth is equitable, and that available environmental resources support social growth.

In this context, the integration and conjugation of these three dimensions will be the basis for the functionality and growth of the Organization under a Sustainability scheme.

ISSN-2523-2517

To this end, it is important for the Organization to define the key aspects to be addressed in each dimension and to establish the appropriate sustainability strategy for their fulfillment.

Given this scenario and the commitment to contribute to the fulfillment of the Sustainable Development Goals (SDGs) and the recent agreements of the 2030 Agenda, efforts to define and establish sustainability policies and strategies have become increasingly widespread within the Organizations of the participating countries.

Figure 1 Dimensions of sustainable development
Source: http://cidecame.uaeh.edu.mx/lcc/mapa/PROYECTO/libro3/21_definicin_de_desarrollo_sustentable.html

Sustainability strategy

According to (González López, Benítez, Loreto, & Aranda Sánchez, 2015) "Sustainable development supposes the harmoniously viable articulation in time and space of the social with the environmental" therefore the sustainability strategy must provide the university environment with social, environmental and consequently economic value.

There are several methodologies to develop sustainability strategies, in the course called Sustainability Manager given by the company RS-Sostenible.[1] and CAMEXA, the following steps are considered:

a) Context analysis

The organization analyzes the internal and external context to identify the challenges and trends in the environmental, social and economic aspects.

It includes the identification of the type of organization, the problems to be addressed, environmental trends (some actions for the preservation and care of natural environmental resources), social trends (some actions for social coexistence among members of the community) and economic trends (planning and appropriate use of economic resources for physical infrastructure and personnel training) that are developed in the company.

In addition, it includes the review of compliance with the national and international legal framework, reports on sustainability trends of organizations and the review of sectoral sustainability reports (national and international).

b) Stakeholder mapping

Stakeholders are the key groups or individuals with an interest in the organization's issues, decisions and activities, who are involved to inform decisions and support the management of sustainability strategy activities. This process identifies the interested parties, their expectations, and the criteria for prioritization in sustainability.

c) Materiality

Materiality is the resources that can be counted on for the strategy's activities. This is the initial aspect that allows defining and prioritizing environmental, social, economic and governance issues that matter most to the organization and its stakeholders.

d) Action Plans

To implement the sustainability strategy, the different actions are planned with clear objectives, defined scope, execution period, description of indicators and their measurement, responsible team and available resources (budget, training, platforms, etc.).

[1] https://www.rs-sostenible.net/acerca-de

Rates of the Federal Electricity Commission (CFE) for businesses

The consumption cost rates for companies stipulated by CFE[2] are as follows:

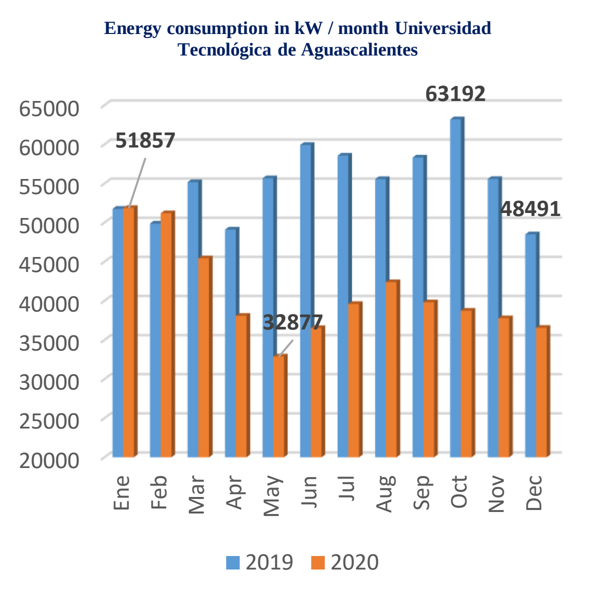
- PDBT rate up to 25 kw for small to medium businesses and commerce.

- GDMTO rate for consumption less than 100 kilowatts per month and has the same cost for energy 24 hours a day.

- GDMTH rate. Generally, the highest of the rates for business and industry, although this varies depending on the characteristics of the load. It is for a voltage ranging from 1000 V to 36000 V and for consumption equal to or greater than 100 kilowatts per month.

Problem

In the year 2019, before the pandemic, the Technological University of Aguascalientes (UTA), shows a high consumption of electrical energy, with an annual average of 55,097 kW per month, a minimum value of 48,491 kW/month and a maximum value of 63,192 kW/month.



Graphic 1 Electricity consumption during 2019 and 2020 in UTA
Source: Own elaboration

As shown in the graph, for the year 2020, despite the fact that, due to the pandemic, academic activities at the Institution decreased and, at the same time, an interconnected photovoltaic installation was installed in February, the annual average consumption decreased to 40,895 kW/month with a minimum value of 32,877 kW/month and a maximum value of 51,857 kW/month; however, this was not significant for the cost of energy.

Proposal for attention

Within the framework of the University's interest in a transition to a sustainable campus, a sustainability strategy is presented as a starting point, with an environmental approach that addresses the problem of energy consumption, through the axes Efficient energy, infrastructure for energy sustainability and alternatives for energy generation.

Goal

Reduce electricity consumption through the implementation of a proposed energy sustainability strategy on the university campus.

Methodology

Under the Sustainability approach, an environmental approach proposal called Energy Sustainability Strategy for the Technological University of Aguascalientes, which aims to address the problem of high energy consumption in the institution, which impacts on the cost of consumption, so the intervention is developed in the following stages:

Definition of the scope of the UTA for sustainability.

From a meeting with representatives of the Rector's Office, the Administration and Finance Department and the undersigned, in academic representation of the Renewable Energies Solar Area of the Institution, the main aspects to be addressed by the University in the Economic, Environmental and Social dimensions are proposed.

[2] https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/TarifasCREIndustria/Industria.aspx

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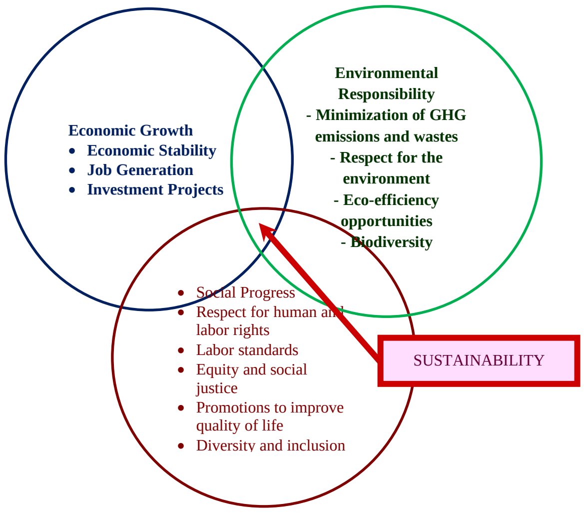


Figure 2 Sustainability approach of the Technological University of Aguascalientes
Source: Own elaboration

Progress in the achievement of the aspects indicated in the three dimensions of sustainability is intended to be gradual, seeking:

a. The viability of the use of environmental resources for economic growth with minimum environmental impact, so for this dimension it is necessary to define and establish policies for an environmental university culture.

b. That the economic and social growth be equitable, therefore it is necessary to define adequate policies focused on the increase of skills for the improvement promotions.

c. That the available environmental resources support social growth, through the use of new and adequate technologies.

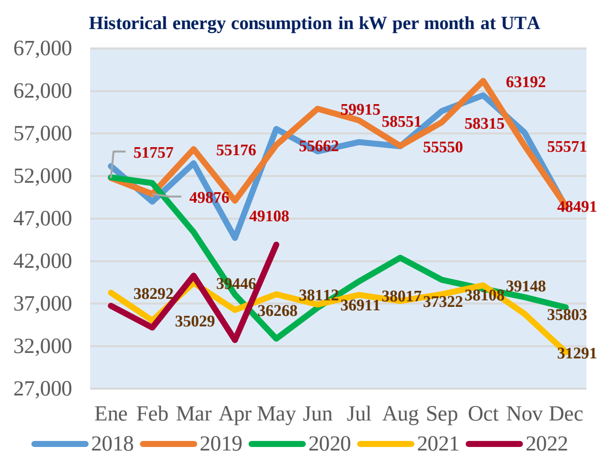
It is important to emphasize that, due to the problems raised, the economic impacts derived from them and the Rector's interest in the transition of the Institution towards a sustainable campus, the development of a strategy with an environmental focus is proposed as a starting point, using the methodology proposed by RS-Sostenible, to address the problem of high electricity consumption.

Context analysis

The problem of high energy consumption begins with the analysis of the procedure used by CFE to calculate the cost of electricity consumption. In this sense, it is detected that the consumption during the year 2021 positions the Institution in the tariff scheme of the Federal Electricity Commission (CFE) as a GDMTO consumer (tariff for consumption less than 100 kW), however, because the contracted demand for electricity of the Institution is greater than 100 kilowatts per month, the tariff that applies to the Institution is GDMTH (Consumption greater than 100 kW).

Despite the fact that in 2020 a SFV-I was installed and academic activities were suspended due to the pandemic, the decrease in consumption reflected in the costs was not significant, probably due to the rate assigned to the Institution (GDMTH) despite the fact that less than 100 kW/month is consumed.

In addition, there are changes in the costs of CFE tariffs, stipulated in the Official Gazette of the Federation throughout the year, and specifically for the GDMTH tariff contracted by the Institution, there is a schedule of Base, Intermediate and Peak levels, where the cost of energy varies depending on the time of day that the energy is consumed. In addition, there are changes due to summer and winter schedules.
In a comparison of consumption during 2019 (before the pandemic) and 2021 (after the pandemic and with a SFV), the decrease in energy consumption is observed.



Graphic 2 Comparison of energy consumption before and after pandemic and installation of photovoltaic system at UTA
Source: Own elaboration

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The analysis of this trend generates awareness regarding energy use, therefore this behavior can be reinforced through the implementation of an energy sustainability strategy.

The analysis of the single-line diagram indicates the areas served by each transformer in the energy supply.

Stakeholder mapping

It shows the stakeholders and their prioritization, on a scale of 1 to 4 (4 being the highest value) to address this problem.

Stakeholder identification and prioritization (IP)						
Categories	Responsibility	Influence	Proximity	Negative effect of the company on IP	Dependence on the company	Priority
Rector	4	4	4	4	4	
Administration and Finance Directorate	4	3	4	4	4	
Maintenance and Services Area	3	1	4	3	4	
Renewable Energies Solar Area	3	1	3	3	4	

Table 1 Identification and prioritization of stakeholders. *Source: RS-Sustainable format and content with own elaboration*

Materiality

The resources with which it is considered feasible to implement the sustainability strategy are:

Basic Subject Matter	Subject Material	Feedback sources	Interested Party	Responsible area
Environment	Energy Management	Energy Receipt	Maintenance	
	Power supplies (light bulbs, wiring, etc.)	External suppliers		
	Management to address energy saving infrastructure	External suppliers		
Community	Training on the topic and scope of sustainability in its three dimensions	Training material on the subject	Energy Staff	Energy Management
	Training and awareness-raising on efficient energy use	Training material on the subject	Maintenance Personnel	Finance
Labor Practices	Efficient use of energy and technological equipment	Definition of energy saving and efficient energy use policies	University community	Rectory
Governance	Commitment of the Institution's leaders	Definition of energy saving and efficient energy use policies	Rector	Rectory

Table 2 Materiality
Source: Own elaboration

Action plans

Based on this internal analysis, three lines of action are defined, each with the following actions:

a. Energy Efficiency: Development of efficient energy use policies, Energy Efficiency Awareness Program, Awareness campaign.

b. Infrastructure for energy sustainability: Change of lighting fixtures, Energy diagnosis by areas.

c. Alternatives for energy generation: After implementing the actions of the previous axes, it is considered relevant to evaluate the reduction of energy consumption to perform sizing (with the results of the energy diagnosis), design and installation of new energy generating sources.

The action plans are shown in the Results.

Finally, in this first step towards sustainability, this proposal considers including the indicators GRI-302-4 Reduction of energy consumption and GRI-305-5 Reduction of GHG emissions, as the first results that can be considered for the future elaboration of Sustainability Reports of the Institution.

Results

Paradigm of the Sustainability concept

As a result of this work, at the management level, the paradigm that the concept of sustainability only includes the care and preservation of environmental resources is broken.

Energy Sustainability Strategy

This strategy is intended to contribute to Sustainable Development Goal SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all (Wu, 2022).

The strategy is outlined in the following illustration.

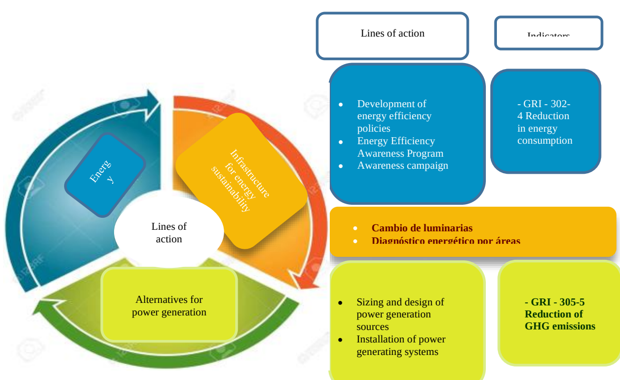

Figure 5 Proposed energy sustainability strategy for the Technological University of Aguascalientes
Source: Own elaboration

Inclusion of Graphs, Figures and Tables

It is worth mentioning that, in this first step towards sustainability, after one year of implementation, the proposal considers making the necessary calculations to show the indicators GRI-302-4 Reduction of energy consumption and GRI-305-5 Reduction of GHG emissions.

Strategic Energy Sustainability Planning for the Universidad Tecnológica de Aguascalientes

Based on the lines of action indicated in the strategy, the following Strategic Planning is carried out.

Lines of action	Description	Shares	Activities	Responsible area	Scope	Resources	Infrestructure	Resource management	Responsible for monitoring	Management schedule 2022											
										J	F	M	A	M	J	JL	A	S	O	N	D
1) Energy efficient	Identification of energy consumption	Energy consumption analysis	Statistical analysis to identify base, intermediate and peak consumption trends in 2021	Renewable Energies	Institution-wide consumption	CFE Receipts EXCEL Software Laptop	UTAgs facilities	NA	NA												
		Energy diagnosis	Perform energy diagnosis by transformer load areas.	Maintenance	Phase A - Rectoría Phase B - Taller 2 Phase B 1- Lab virtual Phase B 2 - Aulas 7 Phase C - PLM	Specialized energy diagnostic service (external provider)	UTAgs facilities	Maintenance Foreman- Subject to budget	Maintenance Manager												
	Efficient energy use and consumption		Desarrollo de: • • • • •		Staff from all areas of the University	Laptop Office Cannon	UTAgs facilities	NA	Rectory												
2) Infrastructure for Energy Sustainability	Replacement of lighting fixtures	Lighting replacement program	Inventory, maintenance and replacement of energy efficient lighting fixtures (energy saving and LED technology).	Maintenance	Luminaires throughout the University	New luminaires and consumables required for changeover	UTAgs facilities	Maintenance manager	Maintenance manager												
	Identification of high energy consuming equipment	Proposal for change, upgrade or maintenance of equipment	Search for suppliers for equipment replacement or maintenance.	Workshop managers	All workshops	Specialized service for equipment maintenance (external supplier)	Workshops	Orders for machinery and equipment in workshops - subject to budget	Maintenance manager												
3) Power generation alternatives	Generation of energy from clean sources	Proposal for PV systems in areas of higher consumption	Photovoltaic system design PV system implementation	Renewable Energy Career	Students and teachers of the Energy career.	Material Components for SFV	Roofs of: Workshop 1 (Phase A - Rectory). Workshop 3 (Phase B - Workshop 2) PLM Building (Phase C - PLM) Classrooms 7 (Phase B2 - Classrooms 7)	Renewable Energy Career	Renewable Energy Career Coordinator												
	Agreement with external institutions	Seeking support from governmental or research institutions.	Search for an agreement to support the purchase of lighting fixtures, equi	Rectory	All areas of the University	NA	NA	Legal Department	Legal												

			pment and PV system components.																		

Strategic planning for energy sustainability for the Technological University of Aguascalientes. Source: Own elaboration

Acknowledgments

Special thanks to the company RS-Sostenible for their support, advice and accompaniment in the development of the energy sustainability strategy.

Financing

This work has not been financed since it is the first strategic proposal that is subject to approval by the Institution's governing authority.

Conclusions

The proposed energy sustainability strategy represents an opportunity to initiate, in the environmental dimension, the transition of the campus to a Sustainable Higher Education Institution.

The successful implementation of this strategy requires the sensitization of stakeholders, with the commitment and responsibility for the execution of the actions proposed.

The commitment of senior management is the fundamental factor to promote the execution of actions through the definition and implementation of institutional policies on sustainability.

As a result of this work, at the management level, the paradigm that the concept of sustainability only includes the care and preservation of environmental resources is broken, hence the importance of training the university community on the scope of sustainability.

It is important to extend the invitation to the different areas of the Institution to form a Sustainability Committee with interdisciplinary personnel. Due to the change of authorities during May 2022, this proposal is left for the consideration of the new authorities for their approval.

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Analysis and diagnosis of electric power quality at ITSH facilities

Análisis y diagnóstico en la calidad de la energía eléctrica en las instalaciones del ITSH

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Abstract

This article presents the study and diagnosis of power quality in the internal electrical network of Building J, within the facilities of the Instituto Tecnológico Superior de Huauchinango that arises from internal research Project in which parameters such as maximum and minimum voltage and current values, frequency, harmonic level are analized, as well as apparent power, active power and reactive power. With the support of the network analyzer of the HIOKI brand, model 3197, the measurements were carried out with the protection protocols (use of gloves, glasses, helmet, etc.), and the results obtained revealed that the values of the electrical parameters of the aforementioned power quality were within the limits allowed by the current standards, also these parameters were plotted with which it was possible to observe the maximum demand of the hours of service, demonstrating that there is a good quality of energy.

Power quality, Voltaje, Current, Harmonics

Resumen

Este artículo presenta el estudio y diagnóstico de la calidad de energía en la red eléctrica interna del Edificio J, dentro de las instalaciones del Instituto Tecnológico Superior de Huauchinango que surge del proyecto interno de investigación en el cual se analizan los parámetros tales como los valores máximos y mínimos de voltaje y de corriente, frecuencia, nivel de armónicos, así como la potencia aparente, potencia activa y potencia reactiva. Con el apoyo del analizador de redes de la marca HIOKI, modelo 3197 se llevaron a cabo las mediciones con los protocolos de protección (uso de guantes, lentes, casco, etc.), y del cual los resultados que se obtuvieron revelaron que los valores de los parámetros eléctricos de la calidad de la energía antes mencionados se encontraban dentro de límites permitidos por las normas vigentes, además se logró graficar estos parámetros con lo que se pudo observar la demanda máxima de las horas que se tiene en el servicio, demostrando que se tiene una buena calidad de la energía.

Calidad de la energía, Voltaje, Corriente, Armónicos

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Introduction

Nowadays, energy problems are becoming more and more visible; therefore, new alternatives are being sought every day to save energy and optimize processes, to be efficient in energy expenses, and to be able to reduce the ecological impact of the misuse of resources [1]. The electricity sector must keep pace with this reality since it is a vital input for any industry.

Over the years, awareness of the proper use of energy and the importance of having a quality energy supply began to be raised, added to the development of new technologies with electronic devices sensitive to voltage variations, can cause distortions, contaminating the waveform that affect the power grid and thus its quality, causing deformations in the waveforms in voltages and currents produced by harmonics. The IEEE 1100 standard defines power quality as the process of feeding and grounding electronic equipment so that it is suitable for the operation of such equipment and compatible with the wiring system of the premises and with other connected equipment, but even with this definition all equipment is not exempt from having a failure or not having a proper functioning if they are connected to a contaminated power grid [2]. Another definition states that power quality is a set of electrical limits that allow a piece of equipment to function as intended without significant loss of performance or expected life. [3] Another definition is that power quality is nothing more than a set of characteristics of electricity at a given point in a power system at a given time, which allow the required electrical needs to be satisfied [2]. The efficiency of electric power is generally defined by a condition of its consumption that ensures the availability of the required quality of electric power while the minimum production losses will have been inherent in the process [4].

Poor quality of electric power brings with it increased energy losses, damage to production, economy and business competitiveness. In recent decades with the introduction of nonlinear loads such as computers, variable frequency drives and others, the negative effects on power quality have been manifested more frequently [5].

Nowadays, the analysis and diagnosis of power quality must be strict, measurements of many parameters must be carried out continuously, such as maximum and minimum values of voltage and current, frequency, harmonics and power. To carry out these measurements should be performed with specialized equipment such as network analyzers to analyze the properties of an electrical network with good accuracy and thus measure such parameters as voltage and current, which also graphs us to have a better view of any disturbance and thus solve problems from occasional tripping, harmonics and phase imbalance [6].

Carrying out a diagnosis of the quality of electrical power in the helps to find the affectations in the electrical installations to be analyzed as they determine the variations of voltage and current, based on this it is necessary to perform an analysis of the quality of power in order to eliminate or reduce all kinds of electrical disturbances, avoiding variations in the quality of the power supplied can easily make the equipment in first not work well and second to be damaged [7].

Development

The Instituto Tecnologico Superior de Huauchinango is located in the northern highlands of the state of Puebla and consists of different facilities, including building J which consists of two floors where are located the classrooms of the careers of Electrical Engineering, Industrial Engineering, the Laboratory of time and motion, the offices of School Control, Library, Storage, Psychology, Administrative Services, teachers area of Electrical Engineering, Cashier and toilets, Library, Warehouse, Psychology, Administrative Services, Electrical Engineering teachers' area, cashier's office and restrooms. Inside the building there is computer equipment, machinery, electronic devices, lighting and power systems, as well as computer equipment, machinery, electronic devices. For all these reasons, it is necessary to conduct a study and diagnosis of the quality of the energy supplied to the J building to ensure the safety of students, teachers, administrative staff and visitors; also, preserving the environment; in order to seek alternatives to reduce or mitigate any type of electrical disturbance [8].

The data collection was carried out in the 150 KVA transformer bank that feeds building J. This data collection of electric power quality was done 7 days a week, 24 hours a day.

To carry out the diagnosis, a HIOKI network analyzer, model 3197 Figure (1), which is a portable single-phase and three-phase RMS power quality analyzer, was installed; the equipment has USB communication interfaces; with LCD display. This analyzer measures electrical parameters such as: voltage, current, active, reactive and apparent power, frequency and harmonic distortion, among other electrical parameters. The analyzer compares several data points in real time and builds a complete picture visualizing the electrical energy usage, these data are stored to the PC with the help of the software.

Figure 1 HIOKI power analyzer model 3197

Students and teachers participated in the analysis and diagnosis. The connections were made at the transformer output, taking into account the safety requirements for working with energized electrical equipment, as well as interpreting the data provided by the network analyzer.

The process that was carried out was to connect the three phases of the voltages and then connect them to measure the currents, all this was done with the transformer working.

It is important to follow a protocol in the handling of an electrical network analyzer:

– Verify the safety systems.

– To prepare the measuring equipment.

– Configure the equipment (network topology, date and average frequency).

– Establish the connection of the equipment starting with this order: grounding, voltage clamps and amperimetric probes.

– Switch on the analyzer and check the signal.

– Start recording the measurements (daily, weekly, monthly).

– Disconnection of the equipment and data download.

Figure 2 shows the connection of the network analyzer, where the clamps of the device were placed around the phases and neutral.

Figura 2 Three-phase HIOKI connection

Analysis of results

The data collected with the analyzer were obtained by monitoring in 7 days in a period of 5 hours, Figure 3 shows the behavior of the voltages of each phase.

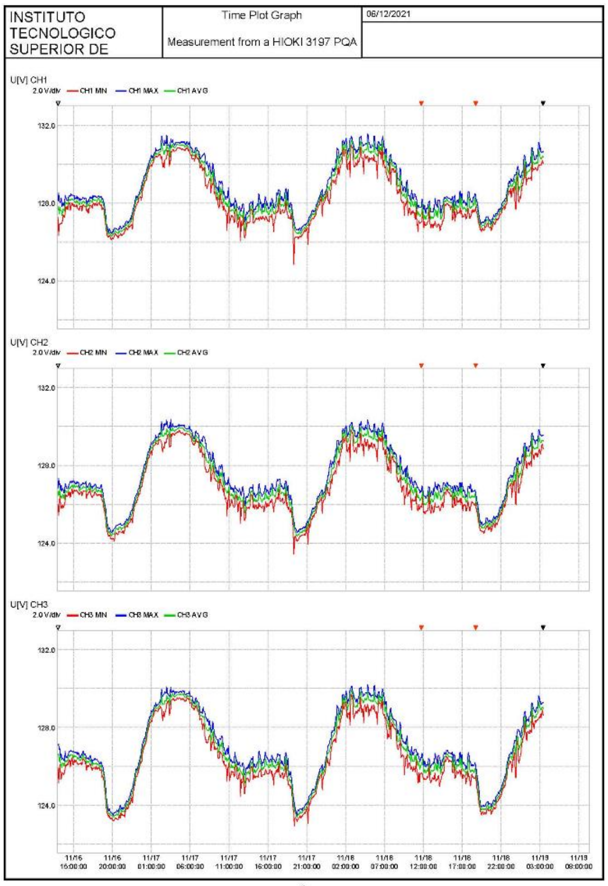

Figure 3 Voltage behavior in each phase

Figure 4 shows the behavior of the current in each phase.

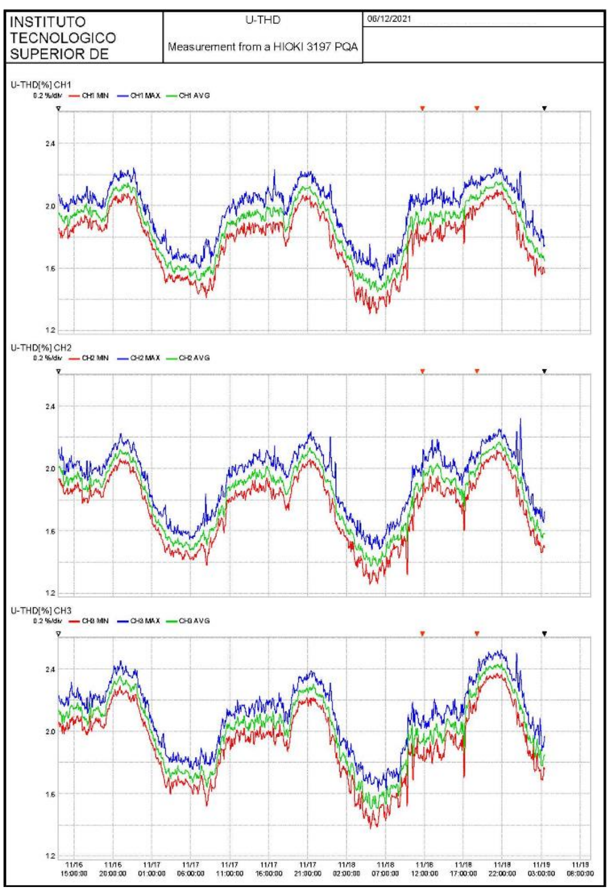

Figure 4 Current behavior in each phase

In 7 days, for 24 hours, the following levels of voltages and currents were obtained, as shown in Figure 4.

V	RMS		
	CH	MIN [V]	MAX [V]
	CH1	124.8	131.6
	CH2	123.4	130.4
	CH3	122.9	130.2
		MIN [A]	MAX [A]
I	CH1	7.3	135.9
	CH2	0	138.9
	CH3	0	114.8
		MIN [Hz]	MAX [Hz]
F		59.89	60.11
	CH	MIN [W]	MAX [W]
P	sum	-0.039M	-0.001M
	CH	MIN [VA]	MAX [VA]
S	sum	0.001M	0.047M
	CH	MIN [VAR]	MAX [VAR]
Q	sum	-0.029M	-0.001M

Figure 5 shows the voltage and current waveform where a deformation in the current waveform can be observed.

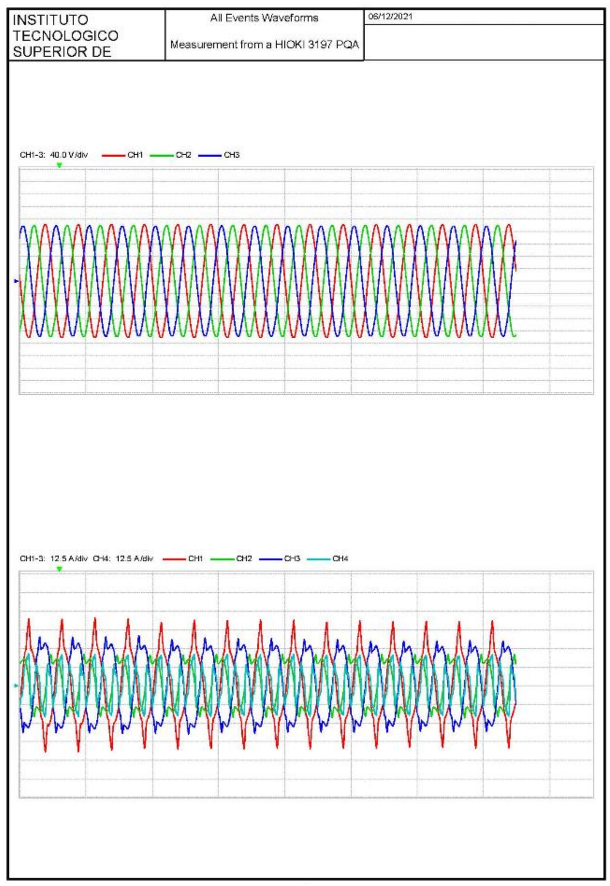

Figure 5 Voltage and current waveforms

Figure 6 shows the maximum active power demand value of 12.7 KW and the average demand value of 5.69 KW.

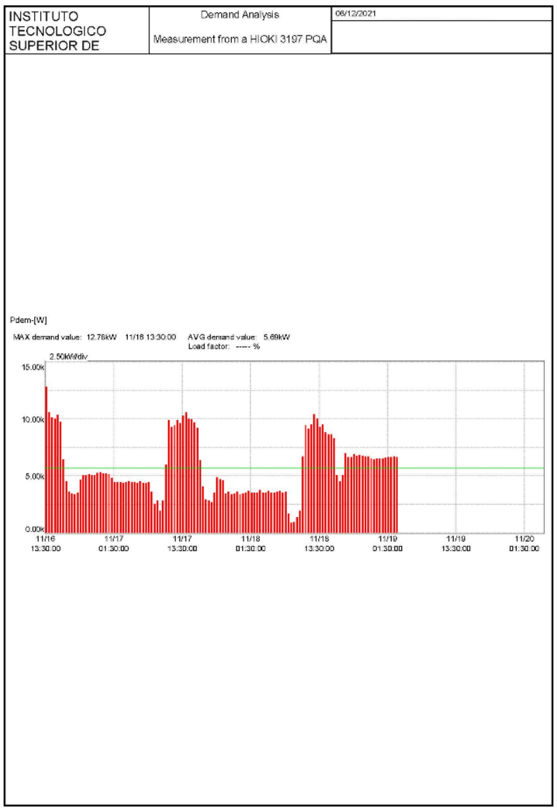

Figure 6 Maximum active power demand

The value of the maximum reactive power demand as well as its average demand is shown in Figure 7, whose values were 5.27 KVAR and 2.994 KVAR respectively.

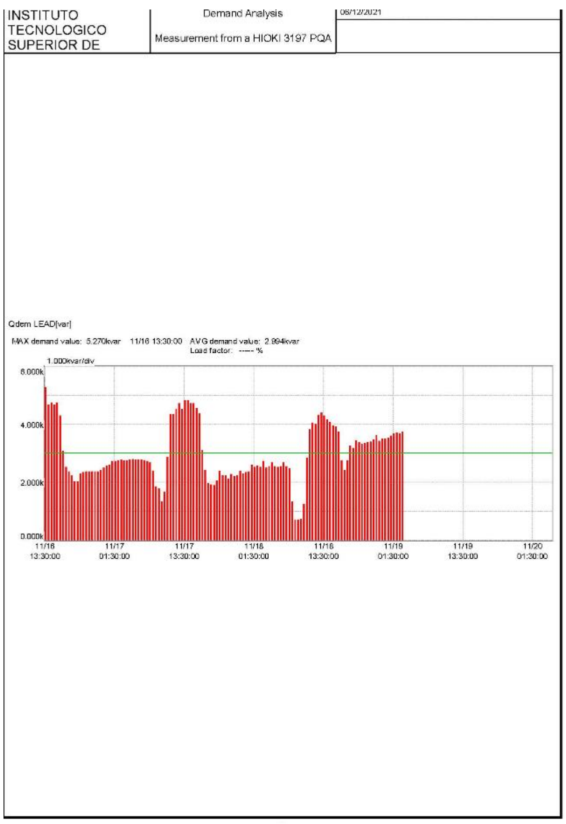

Figure 7 Maximum reactive power demand

Figure 8 shows the maximum value of the active power consumed in KW-H. Finally, Figure 9 shows the behavior of the reactive power in KVAR-H.

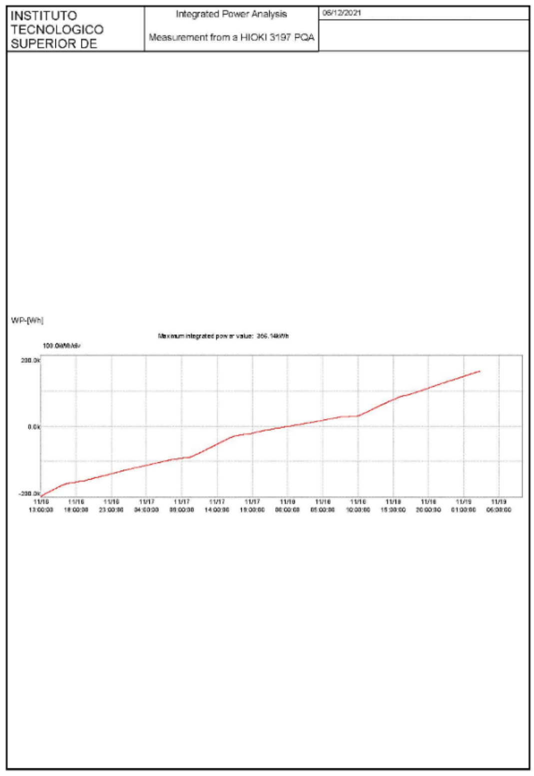

Figure 8 Maximum active power value

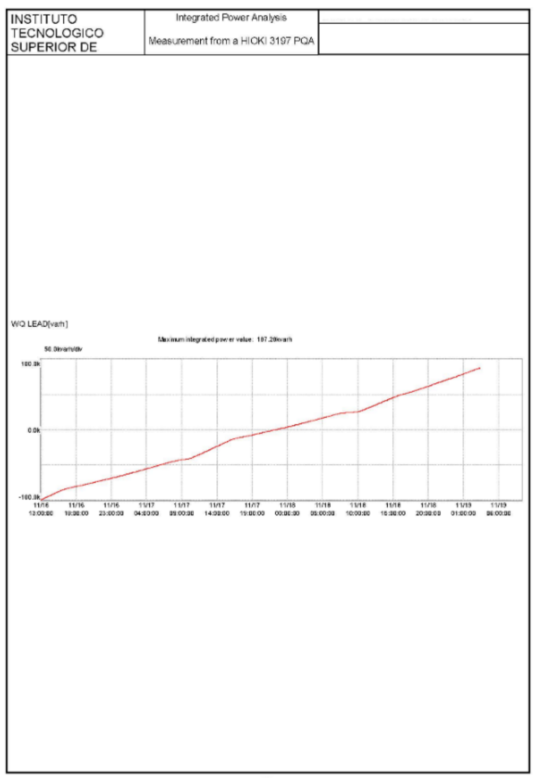

Figure 9 Maximum reactive power value

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The authors wish to express their gratitude to the Electrical Engineering career of the Instituto Tecnológico Superior de Huauchinango for the support and facilities for the development of this work.

Conclusions

In this research it was possible to make a diagnosis of the electrical installations of the ITSH, it was determined that the physical installations where the 150 KVA transformer is located are in optimal conditions, however, it is recommended to perform preventive maintenance in order to prevent failures due to false contacts.

The power system operates at optimal levels, however, it is compromised when harmonic distortion is integrated into the system since it generates a deficient operation of the equipment due to the need to increase power consumption.

The readings obtained establish that the voltage and current ranges are within the normalized values and/or levels.

This type of analysis served to see our type of consumption where there are no disturbances in our network, as this can affect us in what the CFE company does not price values to pay a little high than what our network really has.

In the future we plan to have a wireless electric consumption monitoring system as well as a power quality analyzer.

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Analysis of the electrical power generated by a thermoelectric system for application in the Ingenuity drone from a nuclear heat source

Análisis de la potencia eléctrica generada por un sistema termoeléctrico para su aplicación en el Dron Ingenuity a partir de una fuente de calor nuclear

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Abstract

The aerospace sector has made great strides in the development of electrical power generation in space exploration missions. The ingenity drone is a technological demonstration of flight on the planet Mars, using a solar panel as a source of electrical power generation, however, obtaining power is limited to the atmospheric conditions of Mars and climatic changes such as sandstorms. Thermoelectrics are a good option for power generation in the ingenuity drone since they do not require sunlight to generate electricity, thermoelectrics require a temperature differential to generate a voltage differential this physical phenomenon is known as the seebeck effect. The use of thermoelectrics is exploited by a source of nuclear heat that can reach high temperatures due to the disintegration of radioactive isotopes, so it is necessary that thermoelectrics have a high temperature range. Some thermoelectricals proposed for this work are Bi_2 Te_3, PbTe and SiGe according to their operating characteristics at high temperatures, can be exploited by a source of nuclear heat for the generation of electricity. For this the electrical power required for an axial or stationary flight is calculated, so it is necessary to know some characteristics of the ingenuity drone, as well as the atmospheric conditions of the planet Mars. According to the temperature range of the selected thermoelectrics are determined some properties such as the seececk coefficient, thermal conductivity and electrical resistivity, with these properties is calculated the electrical power required for axial flight and the amount required. According to the electrical power of each thermoelectric is calculated the thermal power required for operation of a source of nuclear heat in its application in the drone.

Drone ingenuity, Thermoelectric, Nuclear heat source

Resumen

El sector aeroespacial ha tenido un gran avance en el desarrollo de generación de energía eléctrica en misiones de exploración espacial. El Dron Ingenity es una demostración tecnológica de vuelo en el planeta Marte, utiliza un panel solar como fuente de generación de energía eléctrica, sin embargo, la obtención de energía se ve limitado a las condiciones atmosféricas de Marte y los cambios climáticos, como tormentas de arena. Los termoeléctricos son una buena opción para la generación de energía en el Dron Ingenuity ya que no requieren de la luz solar para generar energía eléctrica, los termoeléctricos requieren de un diferencial de temperatura para genera un diferencial de voltaje a este fenómeno físico se le conoce como efecto Seebeck. El uso de los termoeléctricos es aprovechado por una fuente de calor nuclear que puede alcanzar altas temperaturas producto de la desintegración de isotopos radiactivos, por lo que es necesario que los termoeléctricos tengan un alto rango de temperatura. Algunos termoeléctricos propuestos para este trabajo son Bi_2 Te_3, PbTe y SiGe de acuerdo con sus características de operación a altas temperaturas, pueden ser aprovechados por una fuente de calor nuclear para la generación de energía eléctrica. Para esto, se calcula la potencia eléctrica requerida para un vuelo axial o estacionario, por lo que es necesario conocer algunas características del Dron Ingenuity, así como condiciones atmosféricas del planeta Marte. De acuerdo con el rango de temperatura de los termoeléctricos seleccionados se determinan algunas propiedades como el coeficiente de Seececk, conductividad térmica y resistividad eléctrica, con estas propiedades se calcula la potencia eléctrica de los termoeléctricos y la cantidad requerida para el vuelo axial. De acuerdo con las potencias eléctricas de cada termoeléctrico se calcula la potencia térmica necesaria de operación para una fuente de calor nuclear en su aplicación para el Dron.

Dron Ingenuity, Termoeléctrico, Fuente de Calor Nuclear

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Introduction

The development of electric power generation in the aerospace sector is one of the most important developing topics due to its technological contribution, where the supply of electric power is sought in missions that require long distance travel, such as satellites, space stations, space probes, rovers and recently drones. The Ingenuity Drone mission is a technological demonstration that aims to test the flight in the atmosphere of Mars, thus becoming the first unmanned aircraft outside the planet Earth. The way of obtaining energy is from a solar panel, placed on top of the propellers, which uses the light it receives during the day, and may vary depending on the seasons and weather changes on Mars such as dust storms that may prevent the operation of the solar panel, so it is important to propose other ways of obtaining energy. Thermoelectric materials are used for the generation of electrical energy through a temperature differential, this physical phenomenon is known as Seebeck effect, thermoelectrics could be a good option for the application in the Ingenuity Drone and in future drone missions, since they do not depend on climate changes, as well as the distance from the sun. The use of thermoelectrics in space missions has its application in the Multimission Radioisotope Thermoelectric Generator (MMRTG), which harnesses the heat generated by radioactive decay from the General Purpose Heat Source (GPHS). The nuclear heat source can reach high temperatures due to decay, so the thermoelectrics selected for this work must have a high operating range. The selected thermoelectrics that meet these characteristics are Bi_2Te_3, $PbTe$ and SiG, making them viable candidates for implementation in the Ingenuity Drone.

The analysis of the electrical power generated by the thermoelectrics, as well as the amount of thermoelectrics needed for the implementation in the Ingenuity Drone could be a starting point in future drone missions, for that reason the Ingenuity Drone is considered for this work since it is the only drone that exists outside the planet Earth. To obtain the electrical power, the drone is analyzed in an axial or stationary flight, so it is important to know some of the characteristics of the Ingenuity Drone, such as the mass of the drone and the diameter of the rotors, as well as the flight conditions in the atmosphere of the planet Mars, such as density and gravity. According to the thermoelectrics proposed for this work, some properties such as the Seebeck coefficient, electrical resistivity and thermal conductivity are obtained. From these properties, the electrical power generated by the thermoelectrics is calculated and the amount needed to generate the axial flight electrical power for the Ingenuity Drone is estimated. With the electrical power generated by the thermoelectrics, the necessary thermal power at which the nuclear heat source must operate is calculated.

Methodology

The present work has the following methodology to be developed:

Review the flight characteristics in the conditions of the planet Mars and the main operating characteristics of the Ingenuity Drone.

- Calculate the mechanical power of the rotors and obtain the electrical energy consumed by the Drone.

- Propose the types of thermoelectrics to convert the thermal power of the nuclear heat source into electricity.

- Calculate the Seebeck coefficient, electrical resistivity and thermal conductivity as a function of the temperature ranges of the thermoelectrics.

- Calculate the electrical power generated by each type of thermoelectric.

- Obtain the thermal power of the nuclear heat source for each of the thermoelectric types.

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Development

Flight conditions on the planet Mars

The possibilities of flight on Mars are dominated by the low density of the Martian atmosphere. The density on Mars is approximately 1% of Earth's, which varies between 0.010 and 0.020 $\frac{kg}{m^3}$ depending on altitude and time of year [I]. The flight dynamics of the Ingenuity Drone are significantly affected due to the low atmospheric density and low gravity (38% of Earth's gravity). In addition, the atmospheric conditions on Mars are colder reaching up to -50°C, resulting in different aerodynamic conditions of in the propellers [II]. Table 1 shows some characteristics of the planet Mars.

Planet Mars conditions	
Density	0.017 kg/m^3
Gravity	3.711 m/s^2
Temperature	-50 °C

Table 1 Flight conditions on the planet Mars

Main operating characteristics of the Ingenuity Drone

The Ingenuity drone has a mass of 1.8 kg in vacuum, which is made up of all mechanical, electrical and electronic components. The drone's battery consists of 6 lithium-ion cells with a nominal capacity of 2 Ah at 4.25V [II]. The rotor system provides the lift for the drone, as well as the forces necessary for directional control of its trajectory. The design uses two coaxial counter-rotating rotors of 1.21 m diameter each. The traction to be generated by the drone is equal to its own weight, so each rotor has to provide a traction of 0.9 kg (3.33 N). Each rotor requires an electrical power to achieve lift on Mars, for this it is important to consider the characteristics shown in Table 2.

Ingenuity Drone features	
Drone Mass	1.8 Kg
Rotor diameter	1.21 m
Batteries mass	273 g
Battery capacity	2Ah a 4.25V

Table 2 Main characteristics of the Igenuity Drone

Calculation of power required for the drone

For the sizing of the amount of electrical power generated by the thermoelectrics for the Ingenuity Drone, the required power is first determined, which is sufficient to meet an axial flight, in a floating state, for which the Rankine and Froude theory is used.

The general equation of mass flow, momentum and conservation of energy can be applied to a floating rotor. Figure 1 represents the drone rotor in an axial ascent with velocity V_c, for which the hovering condition is obtained at the boundary $V_c \rightarrow 0$, this corresponds to the condition $V_c=0$ as shown in Figure 1. The cross section is 0 in the rotor plane, where in the hovering case the fluid is inactive (i.e., $V_0 = V_c = 0$). Cross sections 1 and 2 are the planes just above and below the rotor, respectively, and the wake (the wake below the rotor) is denoted by the cross section ∞. In the rotor plane, the velocity (the induced velocity or the velocity imparted to the air mass contained in the control volume in the rotor disk) is assumed to be v_i, In the far wake (the current slip), the velocity will increase above that in the rotor plane, and this velocity is denoted by W. The area of the rotor disk is denoted by A. From the assumption that the flow is nearly constant and by the principle of conservation of mass, the mass flow rate $\dot{m}$ must be constant within the limits of the rotor wake control volume.

The actuating disk supports the thrust force generated by the rotation of the rotor blades around the shaft and its action on the CO_2. To generate this thrust, power is required, which is supplied in the form of torque to the thrust shaft. The work done on the rotor leads to a gain of kinetic energy of the rotor wake and this is an energy loss which is called induced power.

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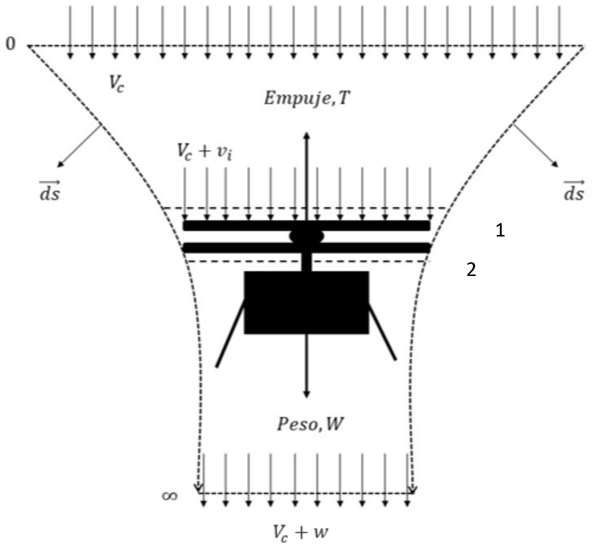

Figure 1 Analysis of the thrust theory of a rotor in axial flight

Stationary flight is a unique flight condition. Here the rotor has zero vertical velocity. The rotor flow field is therefore axisymmetric. In the general approach to the problem, the flow through the rotor will be assumed to be one-dimensional. The momentum theory approach allows to derive a prediction of the thrust and power of the engine. For the calculation of the rotor power it is necessary to know the thrust T generated by the drone which is calculated as follows:

$$T = m * g \quad (1)$$

Where:

T = Thrust $[N]$..

m = Mass of Ingenuity Drone $[Kg]$.

g = Gravity on Mars $\left[\frac{m}{s^2}\right]$.

According to Newton's third law or action-reaction principle, the weight (W) of the Drone has to equal thrust (T) in order to have an axial flight. Momentum theory can be used to relate the thrust of the rotor using the equation:

$$T = 2 * \rho * A * v_i^2 \quad (2)$$

Where:

T = Thrust$[N]$.
ρ = Density on Mars $\left[\frac{kg}{m^3}\right]$.
A = Drone Rotor Area $[m^3]$.
v_i = Induction speed $\left[\frac{m}{s}\right]$.

In the plane of the rotor, the velocity is the induced velocity (vi) or air mass velocity contained in the rotor disk, so it can be obtained that the induced velocity in stationary flight is:

$$v_i = \sqrt{\frac{T}{2 * \rho * A}} \quad (3)$$

Substituting Eq.1 in Eq.3.

$$v_i = \sqrt{\frac{m * g}{2 * \rho * A}} \quad (4)$$

The theory of quantity of motion allows the prediction of rotor thrust and power. For in this way the power is the multiplication of the induced speed and the thrust which generates the following equation.

$$P = 2 * \rho * A * v_i^3 \quad (6)$$

The calculated power is for each of the rotors so it is important to note that the Ingenuity Drone has two rotors that allow axial flight, also the power can be considered as the energy that is transferred to the rotor.

Analysis of selected thermoelectrics.

Thermoelectrics are capable of converting thermal energy into electrical energy, this effect is known as Seebeck. When two different semiconductors are connected to each other, the temperature difference between them causes a potential difference at the point of contact, which generates an electric current in the conductors that form the circuit. For space exploration, the use of thermoelectrics favors the generation of electrical energy without the need to use solar panels. Once the power required by the Ingenuity Drone rotors for an axial flight has been calculated, it is important to know the types of thermoelectrics and their quantity to supply the power required by the drone. Thermoelectrics work under a range of temperatures that can change according to the materials to be used. The dimensions of the thermoelectrics are 8mm long, 10mm wide and 2.5mm thick [III]. The materials selected for the thermoelectric system are:

- Bismuth Telluride (Bi_2Te_3).
- Lead Telluride ($PbTe$).
- Silicon Germanium ($SiGe$)

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They are selected for having a high operating temperature range, so the figure of merit denoted as ZT is used to determine the efficiency of thermoelectrics. The ZT value is a dimensionless index. It increases with the square of the Seebeck coefficient, with the average absolute operating temperature and electrical conductivity. It decreases with the specific thermal conductivity. This can be represented in equation (7).

$$\mathrm{ZT} = \frac{S^2 * \sigma}{k} * T \quad (7)$$

Where:

ZT = Figure of merit.

S = Seebeck coefficient $\left[\frac{V}{K}\right]$.

σ = Electrical Conductivity$\left[\frac{1}{\Omega * m}\right]$.

k = Thermal conductivity$\left[\frac{W}{m * K}\right]$.

T = Absolute temperature$[K]$.

Calculation of thermoelectric power

To calculate the electrical power generated it is necessary to know the thermoelectric properties which are:

- Seebeck coefficient (S, $\left[\frac{V}{K}\right]$).
- Electrical Resistivity (ρ, $[\Omega * m]$).
- Electrical Conductivity (k, $\left[\frac{W}{m * K}\right]$).
- Electrical Resistance ($R, [\Omega]$)
- Electric Current ($I, [A]$).

Bismuth telluride has a low temperature range compared to the other selected thermoelectrics so the values corresponding to the Seebeck coefficient, thermal conductivity and electrical conductivity are taken by means of the following polynomials obtained from the experimental values of reference [III][IV]. The polynomial of the Seebeck coefficient and the electrical resistivity (ρ) of the thermoelectric Bi_2Te_3 is found as a function of the temperature range from 300K to 570K, which is expressed in Eq.8 and Eq.9.

$$\mathrm{S}(\mathrm{z}) = -1.9 * 10^{-6} z^5 - 0.12 * 10^{-6} z^4 + \quad 4.1 * 10^{-6} z^3 - 3.4 * 10^{-6} z^2 + 11 * 10^{-6} z + 1.5 * 10^{-6} \quad (8)$$

$$\rho(\mathrm{z}) = 2.5 * 10^{-7} z^2 + 2.7 * 10^{-6} z + 4.1 * 10^{-5} \quad (9)$$

Where the value of z is expressed in Eq.10.

$$\mathrm{z} = \frac{T - 4.1 * 10^2}{76} \quad (10)$$

In this case the thermal conductivity remains constant for the temperature range used, around $0.85 \frac{W}{m * K}$ [III]. For $PbTe$ material according to a temperature range from 500K to 800K the following polynomials of experimental values were obtained from reference [III][V].

$$\mathrm{S}(\mathrm{z}_s) = -8.2 * 10^{-6} z_s^4 - 7.3 * 10^{-6} z_s^3 - 7.9 * 10^{-6} z_s^2 + 54 * 10^{-6} z_s + 2.8 * 10^{-4} \quad (11)$$

$$\rho(z_r) = 6.4 * 10^{-5} z_r + 5.5 * 10^{-5} \quad (12)$$

$$k(z_k) = 0.23 * z_k^2 - 0.28 * z_k + 1.2 \quad (13)$$

Where the values of z_s, z_r *and* z_k are expressed in the following equations:

$$z_s = \frac{T - 5.3 * 10^2}{150} \quad (14)$$

$$z_r = \frac{T - 5.3 * 10^2}{350} \quad (15)$$

$$z_k = \frac{T - 5.3 * 10^2}{170} \quad (16)$$

For the $SiGe$ thermoelectric, which is in a higher operating temperature range from 750K to 1000K, the polynomials corresponding to its properties are expressed according to experimental values from references [III][VI].

$$\mathrm{S}(\mathrm{z}_s) = -4.5 * 10^{-6} z_s^3 - 9.6 * 10^{-6} z_s^2 + 6 * 10^{-5} \mathrm{z}_s + 0.0002 \quad (17)$$

$$\rho(z_r) = 1/(8.7 * 10^3 z_r^2 - 2.5 * 10^4 z_r + 6.7 * 10^4) \quad (18)$$

Where the values for z_s and z_r are expressed in the following equations:

$$z_s = \frac{T - 6.5 * 10^2}{240} \quad (19)$$

$$z_r = \frac{T - 6.5 * 10^2}{240} \quad (20)$$

The thermal conductivity of $SiGe$in the temperature range used is practically constant, $4.5\frac{W}{m*K}$[III]. With the Seebeck coefficient (S) of each of the thermoelectrics, the voltage produced according to the temperature range of each thermoelectric and the ambient temperature of Mars, the voltage produced by the semiconductors is obtained according to the principle of the Seebeck effect shown in Equation 21:

$$V = S*(T_c - T_f) \quad (21)$$

Where:

V = Voltage $[V]$.

S = Seebeck Coefficient $\left[\frac{V}{K}\right]$.

T_c = Temperature on the hot face $[K]$.

T_f = Cold face temperatura $[K]$.

The electrical resistance of the thermoelectric is determined with Equation 22.

$$R = \rho\frac{e}{A} \quad (22)$$

Where:

ρ = Electrical Resistivity $[\Omega * m]$.

e = Thermoelectric thickness $[m]$.

A = Thermoelectric Area $[m^2]$.

The electrical power generated is calculated using Equation 23.

$$P = S*I*(T_c - T_f) - R*I^2 \quad (23)$$

To obtain the peak current, the electrical power is partially derived with respect to the current and equals zero as shown in Equation 24.

$$\frac{\partial P}{\partial I} = 0 = S(T_c - T_f) - 2RI \quad (24)$$

With the voltage and resistance calculated according to the temperature range of each of the thermoelectrics, the maximum electric current is calculated using Equation 25.

$$I_{max} = \frac{V}{2R} \quad (25)$$

The calculation of the electrical power generated by the thermoelectrics according to their respective temperature ranges, allows to know the amount required for an axial flight and according to the conditions of Mars.

Thermal power required for nuclear heat source

The general purpose heat source (GPHS) is a nuclear source used mainly in space missions, inside it contains a radioactive isotope that serves as nuclear fuel, the heat generated from radioactive decay is used by thermoelectrics to generate electricity, so it is important to know the thermal input and output power of thermoelectrics for the design of a nuclear heat source. To determine the heat input (Q_{in}), at the hot face (T_c), in a thermoelectric generator, heat conduction, Joule effect and power generation by Seebeck effect are considered, as shown in equation 25 [III]:

$$Q_{in} = S*T_c*I - \frac{1}{2}*R*I^2 + \frac{K*(T_c - T_f)}{e} \quad (26)$$

Similarly, the outgoing heat flux (Q_{out}) is calculated, considering the above mentioned effects applied to the wall with the lowest temperature (T_f).

$$Q_{out} = S*T_f*I - \frac{1}{2}*R*I^2 + \frac{K*(T_c - T_f)}{e} \quad (27)$$

This provides the heat range for the design of a nuclear heat source for the Ingenuity drone application for this work.

Results

The obtained results are divided into the subsections of power required for an axial flight, merit graph of the thermoelectrics, Seebeck coefficient for the temperature range, power of the thermoelectrics according to the temperature range, amount of thermoelectrics needed for the Ingenuity Drone and range of thermal power according to the thermoelectrics needed for the nuclear heat source.

Power required for an axial flight

Table 3 shows the results obtained for an axial flight according to the characteristics of the Ingenuity Drone and the conditions of the planet Mars.

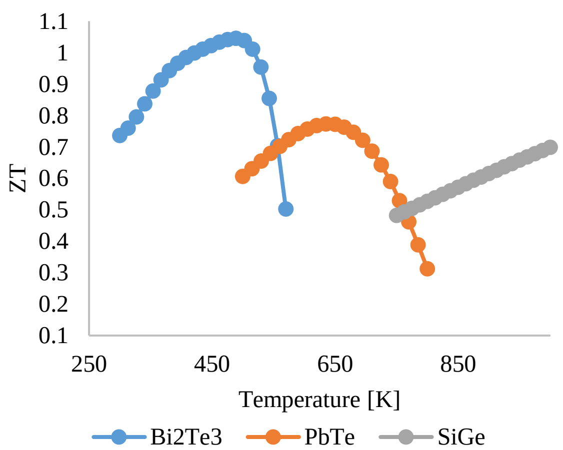
Axial flight results	
Rotor drive	0.9 kg
Rotor disc area	1.1499 m
Induction speed	9.2426 $\frac{m}{s}$
Mass flow	0.1806 $\frac{kg}{s}$
Power per Rotor	30.869 W
Total power in axial flight	61.74 W
Take-off power	370.44W

Table 3 Axial flight results for the Ingenuity Drone.

As can be seen, the power of each rotor is added to get the total power required for axial flight. With the calculated power, the analysis of the thermoelectrics required for the flight is performed.

Graph of merit

The graphic of merit allows identifying the efficiency of the selected thermoelectric plants, as shown in graphic 1.

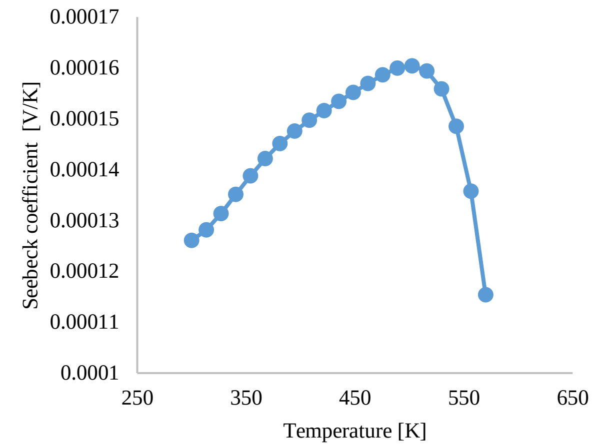


Graphic 1 Figure of merit of thermoelectric plants

The selected thermoelectrics have different efficiencies depending on their temperature range, so the higher the ZT, the higher the efficiency of thermal to electrical energy conversion. It can be observed that the Bi_2Te_3 has the highest efficiency range, but it is also the one with the lowest temperature range of the 3 selected thermoelectrics.

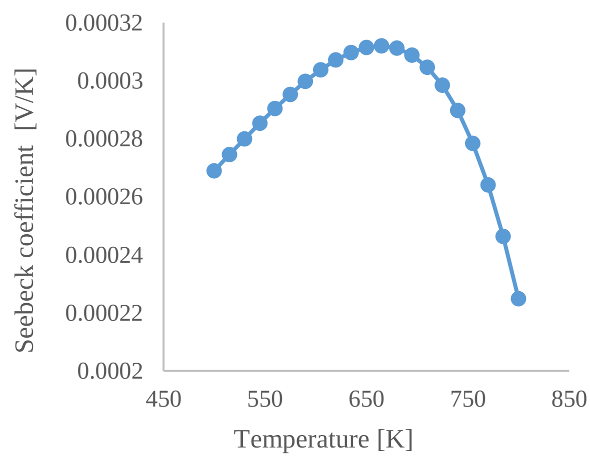
4.3 Seebeck coefficient

With the polynomials obtained from the bibliography, the Seebeck coefficient is calculated with the corresponding temperatures, which can be represented in the following graphs.



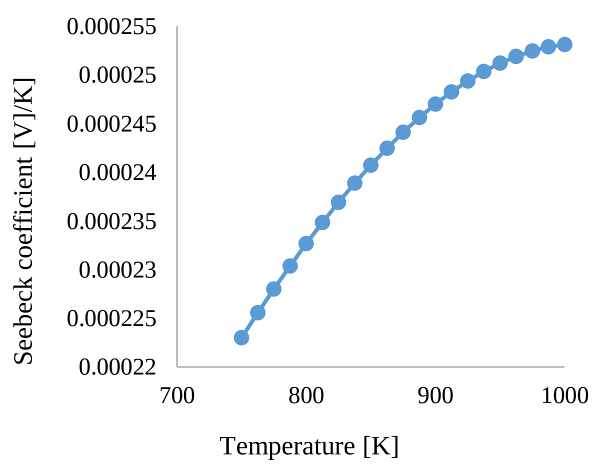
Graphic 2 Seebeck coefficient vs. temperature of Bi_2Te_3

The Bi_2Te_3 despite having a high merit number has the lowest temperature range and a low Seebeck coefficient, but it can be observed that its highest coefficient point is near the middle of its temperature range.



Graphic 3 Seebeck coefficient vs. temperature of $PbTe$

$PbTe$ has the highest Seebeck coefficient, and like the previous material, its highest coefficient is in the central zone of the temperature range.



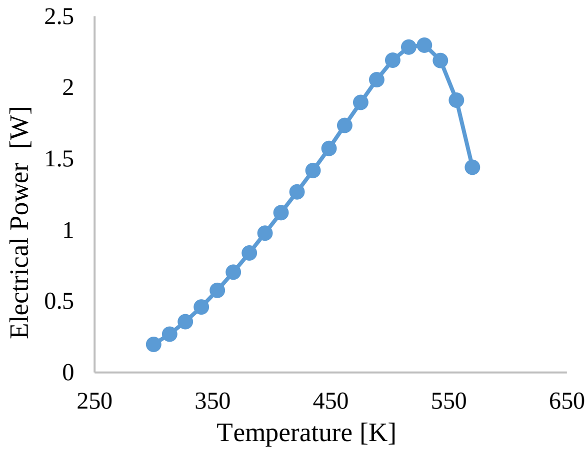
Graphic 4 Seebeck Coefficient vs. Temperature of $SiGe$

December 2022, Vol.6 No.17 15-24

SiGe has the widest temperature range, its coefficient remains relatively high unlike the other thermoelectrics, its highest coefficient is found at the highest temperature and as the temperature decreases the coefficient decreases.

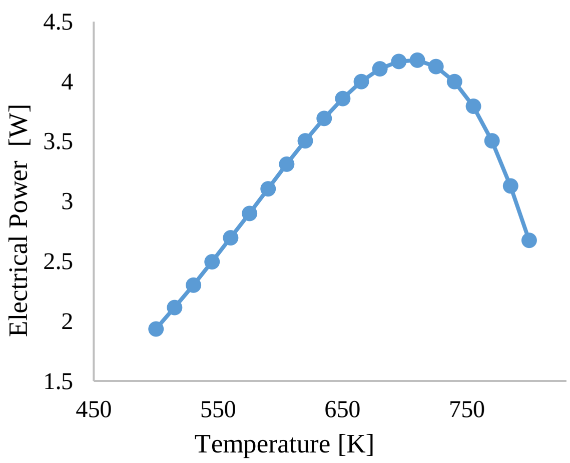
Electrical power of the thermoelectrics

With the values of the Seebeck coefficient, voltage, electrical resistance, electrical current and electrical conductivity of each of the thermoelectrics, the electrical power generated by the thermoelectrics was calculated by taking the ambient temperature of Mars which is -50°C to generate the temperature differential, which can be represented in the following graphs.



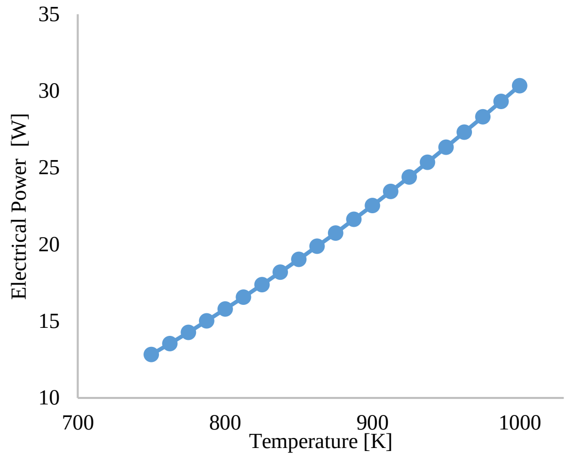
Graphic 5 Electrical Power vs Temperature of Bi_2Te_3

The temperature on the cold side of the thermoelectric is maintained at Mars ambient temperature while the hot side is in the operating range of the thermoelectric. For Bi_2Te_3 the maximum electrical power is reached at 500K, so it is a relatively low power.



Graphic 6 Electrical Power vs Temperature of *PbTe*

The thermoelectric PbTe has a higher electrical power Bi_2Te_3, the highest electrical power it reaches is around 700K. It is a higher power at a suitable temperature for the implementation in the drone.

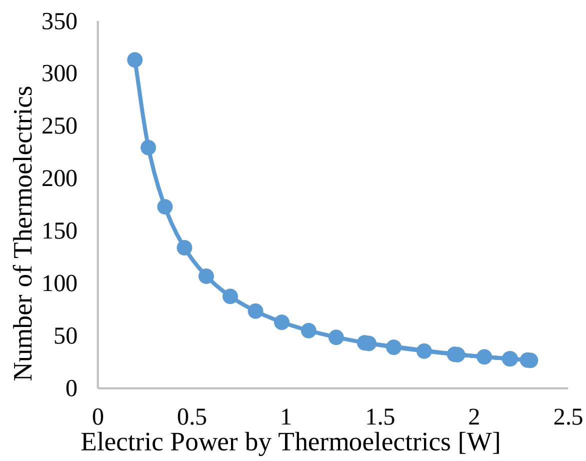


Graphic 7 Electrical Power vs. Temperature of *SiGe*.

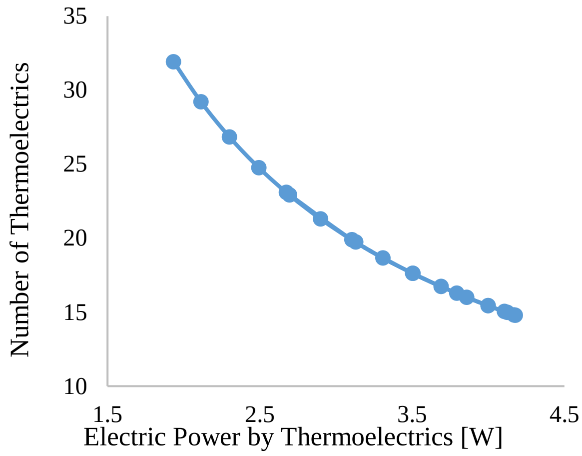
The electrical power of *SiGe*.is by far the highest of the selected thermoelectrics. It reaches its electrical power at the highest operating temperature and decays as the temperature on the hot face decays.

Number of thermoelectrics

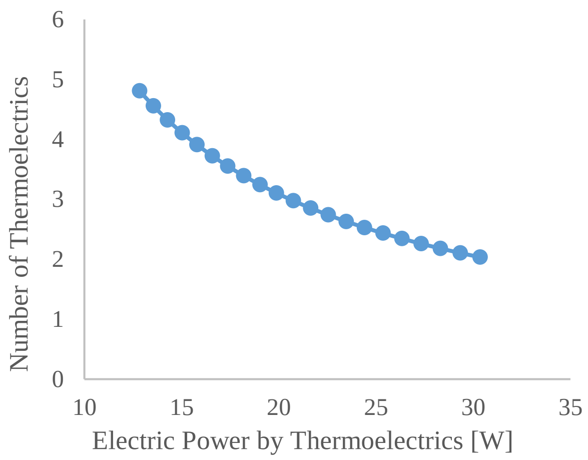
Having knowledge of the electrical power generated by the thermoelectrics we estimate the amount needed to generate the flight power for the Ingenuity Drone.



Graphic 8 Quantity of Thermoelectrics vs Electrical Power of Bi_2Te_3



Graphic 9 Quantity of Thermoelectrics vs Electric Power of $PbTe$

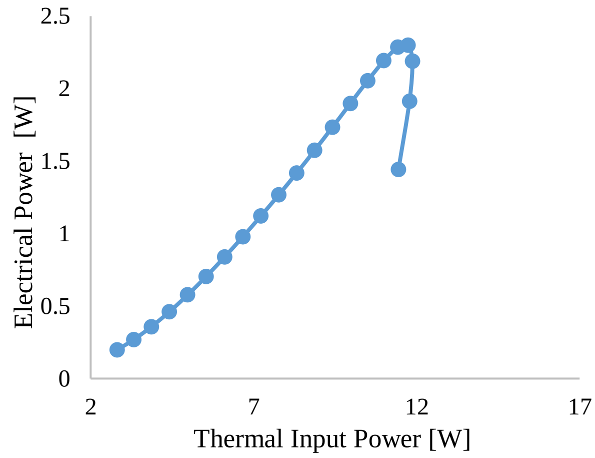


Graphic 10 Quantity of Thermoelectrics vs Electrical Power $SiGe$

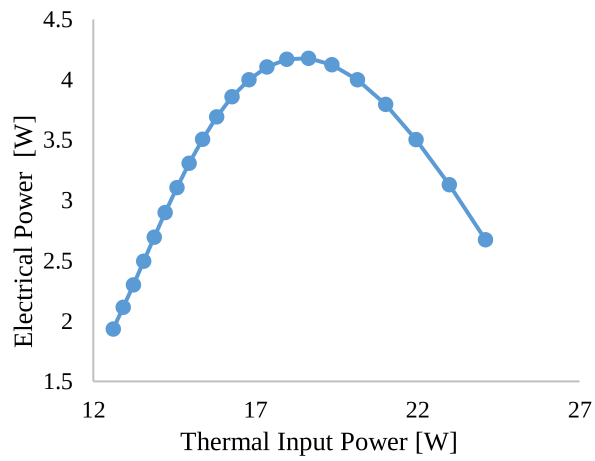
$SiGe$ requires the least amount of thermoelectrics compared to Bi_2Te_3 and $PbTe$, the latter requiring more thermoelectrics to generate the electrical power for axial flight. Despite having a relatively low figure of merit SiGe and having a high temperature range is able to generate more electrical power.

Thermal power for the nuclear heat source

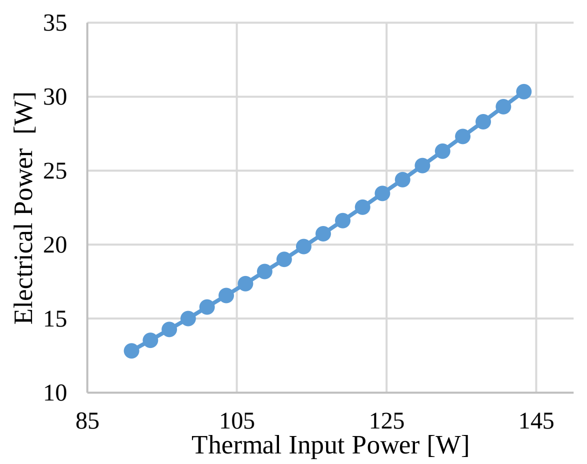
Thermoelectrics in space missions convert the thermal energy generated by nuclear heat sources into electrical energy. In the following results the thermal power at the input of the thermoelectric is shown as this way the thermal power of operation of the nuclear heat source is estimated.



Graphic 11 Electrical Power vs Thermal Power at the input of Bi_2Te_3



Graphic 12 Electrical Power vs Thermal Power at the $PbTe$ input



Graphic 13 Electrical Power vs. Thermal Power at $SiGe$ input

It can be seen that thermoelectrics can work at different thermal input powers, unfortunately not all the thermal power is utilized so only a small fraction is converted, nuclear heat sources leave to operate in high temperature ranges so the $SiGe$ thermoelectric is the best candidate for implementation in the Ingenuity Drone.

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Conclusion

The analysis of the power generated by the thermoelectric systems in the implementation of the Ingenuity Drone, can change according to the thermoelectric to be used. The Bi_2Te_3 requires a large amount to produce the required power, despite having a high number in the graph of merit could not be possible its implementation the drone, while $PbTe$ requires a moderate amount but still remains high, the $SiGe$ does not require large amounts compared to the other thermoelectrics. In conclusion, for implementation in the Ingenuity Drone, he $SiGe$ is the best candidate to supply the required electrical power in its flight, with the least amount of thermoelectrics, also it is the best candidate for a nuclear heat source as they usually work at high temperatures.

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Article
Journal Electrical Engineering
December 2022, Vol.6 No.17 25-31

Lighting study at the Universidad Tecnológica de Aguascalientes

Estudio de Iluminación en la Universidad Tecnológica de Aguascalientes

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Abstract

In the present job, the objective is to carry out an evaluation of the level of illumination in each building of the Technological University of Aguascalientes (UTA), taking as a reference the NOM-025 -STPS-2008 that is focused on ilumination conditions in the work centers. The project has two parts: firsttly counting and verifying the types of lighting, until the last lamp and to determinate, how much watts each building, consumes. Subsequently, an analysis was carried out with the lux meter and to be able to verify versus the parameters indicated in the NOM-025-STPS-2008 to subsequently make recommendations.

Lighting, Evaluation points, Lux, Meter, Nom-025-2008

Resumen

El presente trabajo tiene como objetivo, realizar una evaluación de los niveles de iluminación en los edificios de la Universidad Tecnológica de Aguascalientes (UTA), teniendo como referencia la NOM-025–STPS-2008, referente a las condiciones de iluminación en los centros de trabajo. El proyecto está integrado por dos partes: primeramente, se hizo un registro de los tipos de iluminación hasta el detalle de cada lámpara, y cuantificar el consumo en watts, por edificio. Posteriormente, se realizó un análisis con luxómetro para comparar contra los luxes referencia de la NOM-025-STPS-2008 y emitir recomendaciones.

Iluminación, puntos de evaluación, luxómetro, Norma-25-STPS-2008

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Introduction

Workplaces require a lighting level according to the activities to be performed and in compliance with regulations, which can improve productivity, safety and comfort of workers (Marquínes et al., 2020).

The level of illumination is one of the main factors where the worker can be affected by the level of fatigue and the mental state of the same, to develop their work (Machado Miranda et al., 2020). In this sense, in order to develop work activities better, it is necessary to see their environmental characteristics and vision that complement each other in 50% of the sensory information received by man of visual type, in other words, as a primary source of light. Having an evaluation of the visual aspect, we will have a better safety, comfort and productivity (Paul et al., 2022).

Casbascango Camuendo et al., (2021) mentions, distribution, intensity and balance of artificial and natural light must comply for the type of work to be performed, because if it is not met it can affect vision, irritation, as well as eye fatigue and headaches.

Lighting and ventilation must be in accordance with the needs of workers, complying with the allowed luxes required by the regulations for optimal performance (Torres Julon, 2020).

Mexican Standard 025 of the Ministry of Labor and Social Welfare (STPS) of 2008, refers that a safe and healthy work environment should be promoted in workplaces, to provide a good working environment for the worker, prevent accidents and damage to facilities, have good visibility, identify areas of opportunity; It also obliges the employer to recognize and evaluate the conditions, lighting levels in all areas and work stations, through reports and reports of the study of lighting conditions, as well as the control of the same, the maintenance of lights and luminaries, including emergency lights, among others.

Workers are obliged to notify the employer of unsafe lighting conditions, to use lighting systems appropriately, to participate and observe measures to control lighting levels based on evaluations and to take the eye exams required by the employer (Secretaría del Trabajo y Previsión Social, 2008).

Having this context of the importance of a lighting study, the Technological University of Aguascalientes (UTA), has the interest to perform in all buildings, supporting the department of Maintenance and Facilities, a lighting study.

Description of the problem

The Technological University of Aguascalientes has a quality management system, through which complaints were received from teachers, students and administrative staff about the type of lighting in the areas and workshops.

In the workshops, students practice in two shifts (morning and afternoon) and poor lighting can cause accidents. In the case of administrative areas and classrooms, it can cause visual fatigue (Torres Julon, 2020). Upon reviewing such a claim, the absence of a lighting study of the institution became notorious,

Project objective

To carry out a study of the UTA facilities according to regulation 025-STPS-2008, in order to comply with the lighting according to the activity performed.

Methodology to be developed

There are two methods in the implementation of the project: Deming's circle and NOM-025-STPS-2008.

In the Deming Circle that serves for the analysis and solution of problems and implementation of improvements, considering: Plan, Do, Check and Act (PHVA) (Castillo Pineda, 2019). In the stages of each of them will be implemented as follows:

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1. Planning (Plan); in this stage is to identify the positions to be evaluated as: (a) State of the company and its needs; (b) the type of lamps is identified, (c) the type of activities performed by personnel in each building, this was done in order to identify whether there is poor lighting or excessive lighting that can cause glare (d) description of the tasks performed (Paul et al., 2022).

2. Doing (Do); when the activities are established, work begins on the changes to achieve the objectives that were set. In the Do stage, the analysis of the type of lamps, their height and the study of luxes that exist within the facilities will be carried out.

The lighting study will be supported by the NOM-025-STPS-2008, considering the "appendix A" (evaluation of lighting levels), as well as the reference guide "I" (measurement of lighting levels), both references, which are part of the standard itself.

Within the reference "I", it handles the method to evaluate the average illumination levels, with the purpose of verifying the values corresponding to an installation, precautions must be considered to carry out the study such as: Nominal voltage supply, ambient temperature, choice of lamps, so that the readings of the illuminance meter are corrected taking into account the conditions.

To determine the average illuminance calculation for the building constant method, the following expression is used (Secretaría del Trabajo y Previsión Social, 2008):

$$Ep=1/N\ (\Sigma Ei) \qquad (1)$$

Where:

Ep = Average level in lux.

Ei = Illumination level measured in lux at each point.

N = Number of measurements made.

With this calculation the average will be determined to establish if the work area has the lux required by the standard (Secretaría del Trabajo y Previsión Social, 2008).

Check; in this stage it is verified if the improvements made, serve to achieve an objective; it is verified if the data obtained with the luxmeter are suitable according to the parameters of the norm.

Act; the results obtained in the verification phase allow to determine actions to ensure that the lighting in all UTA facilities comply with the standards indicated in NOM 25.

Project development

The next step was to make the plans of the 20 buildings (See Illustration 1) to identify the measurement points, measurement performed, with a luxmeter (measuring instrument that allows to measure simply and quickly the real and not subjective illuminance of an environment) (PROTEGERI.P.S, 2018) and this compare it with the table of lighting levels mentioned above.

Figure 1 Plan of the Universidad Tecnológica de Aguascalientes

Article
Journal Electrical Engineering
December 2022, Vol.6 No.17 25-31

In accordance with STPS Norm 25, an inventory of all the lamps must be made, which in this case are 20 buildings that the university has: eight classrooms, five storerooms, four administrative areas, a sports area, restroom area and the cafeteria, to identify the number of lamps, their watts consumption, the type of luminaire and consumption (See Table 1).

AULAS 1					
Áreas de estudio	Lamparas	Focos	Consumo total (Watts)	Tipo de luminaria	Consumo unitario por lámpara (Watts)
Pasillos salones	20 PZA (T8)	0	360	Tubos LED	18 w
Salon 1	18 PZA (T8)	0	324	Tubos LED	18 w
Saalon 2	18 PZA (T8)	0	324	Tubos LED	18 w
Salon 3	18 PZA (T8)	0	324	Tubos LED	18 w
Salon 4	18 PZA (T8)	0	324	Tubos LED	18 w
Salon 5	18 PZA (T8)	0	324	Tubos LED	18 w
Salon 6	18 PZA (T8)	0	324	Tubos LED	18 w
Salon 7	18 PZA (T8)	0	324	Tubos LED	18 w
Baños H	4 PZA (T8)	0	72	Tubos LED	18 w
Baños M	4 PZA (T8)	0	72	Tubos LED	18 w
Audivisual	18 PZA (T8)		324	Tubos LED	18 w
Pasillo de oficinas	12 PZA (T8)	0	216	Tubos LED	18 w
Pasillo recepción	8 PZA (T8)	4	180	Tubos LED y downlinght	18 w y 9 w
Sala de maestros	20 PZA (T8)	0	360	Tubos LED	18 w
Oficinas	30 pza (T8)	2 (DICROICOS)	590	LED	18 w y 25 w
Cuarto de limpieza	0	1 (9W)	9	Downlinght	9 w

Note: A part of what was done in the UTA is represented

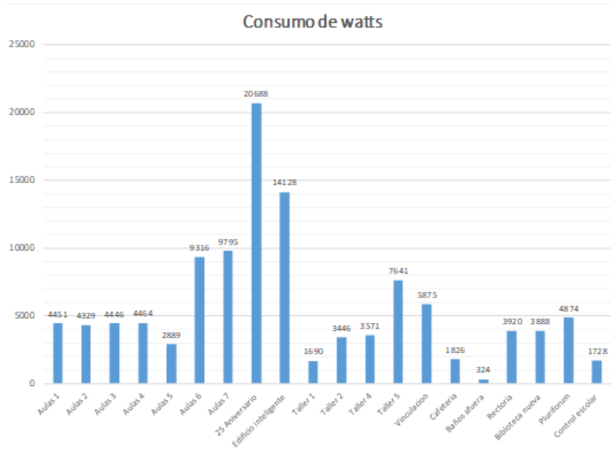
Table 1 Inventory of Classroom Lamps 1

Another area that was evaluated was the workshops, which in this case will represent workshop 1, the inventory of lamps was 14 bulbs and 24 T8 (See Table 2).

Taller 1					
Áreas de trabajo	Lamparas	Focos	Consumo de Wats	Tipo de luminaria	Consumo unitario por lámpara (Watts)
Oficinas	2 T8, 8 T8	0	612	Tubo LED	18 w y 36 w
Baños de M	2 T8	0	36	Tubo LED	18 w
Baños de H	2 T8, 2 T8	0	108	Tubo LED	18 w y 36 w
Laboratorio de química	4 Focos	0	<		105 w
Cafetería de ofina	4 T8	0	72	Tubo LED	18 w
Área de almacén	6 Focos	0	630		105 w
Almacén de química	4 T8	0	72	Tubo LED	18 w
Parte exterior del taller	4 Focos	0	160		40 w
TOTAL			1690 W		

Table 2 Inventory of lamps in workshop 1

Once the data on the areas were available, an analysis of watts consumption was made, where it can be seen that the highest consumption is in building XXV, the second highest consumption is in the intelligent building, and the areas with the lowest consumption are the restrooms, school control building and cafeteria (See Graphic 1)



Graphic 1 Watt consumption of the UTA buildings

The next step was to identify the parameters that will be used later to see if the required lighting according to STPS Standard 025 is met (See Table 3).

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Niveles de iluminación		
Tarea visual	**Área de trabajo**	**Niveles mínimos de iluminación (luxes)**
En exteriores: distinguir el área de transito, desplazarse caminando, vigilancia, movimiento de vehículo.	Exteriores generales: patios y establecimientos.	20
En interiores: distinguir el área de transito, desplazarse caminado, vigilancia, movimiento de vehículos.	Interiores generales: almacén de poco movimiento , pasillo, escaleras, establecimientos cubiertos, labores en minas subterráneas, iluminación de emergencia.	50
En interiores	Área de circulación y pasillos; salas de espera; salas de descanso; cuarto de almacén; plataformas; cuarto de calderas.	100
Requerimiento visual simple: inspección visual, recuento de piezas, trabajo en banco y máquina.	Servicios al personal: almacenaje rudo, recepción y despacho, casetas de vigilancia, cuartos de compresores y pailería.	200
Distribución moderada de detalles : ensamble simple, trabajo medio en banco y maquina, inspección simple, empaque y trabajo de oficina.	Talleres: áreas de empaque y ensamble, aulas y oficinas.	300
Distribución clara detalles: maquinado y acabado delicado, ensamble de inspección moderadamente difícil, captura y procedimientos de información, manejo de instrumentos equipo de laboratorio.	Talleres de precisión: salas de computo, áreas de dibujo, laboratorios.	500
Distribución final de detalles: maquinado de precisión, ensamble e inspección de trabajo delicados, manejo de instrumento y equipo de precisión, manejo de piezas pequeña.	Talleres de alta precisión : de pintura y acabado de superficies y laboratorios de control de calidad.	750
Alta exactitud en la distinción de detalles: ensambles proceso e inspección de piezas pequeñas y complejas, acabado con pulidos finos.	Proceso: ensamble e inspección de piezas complejas y acabados con pulido fino.	1000

Table 3 Lighting levels

Results

A table was made where information is concentrated according to NOM-025-STS-2008 such as: Incident light, permissible level, lux reflected at the approximate height (E1), incident light (E2, lux reflected at the approximate height, incident lux among other things, in order to see if the allowed luxes were met or if they are deficient, an example of an area is attached (See Table 4), in order to avoid physical risks with vision, since they can cause occupational diseases, such as asthenopia, since one of the most relevant risks is lighting (Martínez Martínez Danna, Ramírez Torres & Yiseth, 2021).

For the case of the four workshops, a representation of the results of workshop 1 is shown, detailing the 64 points that were evaluated depending on the work areas (See Illustration 2).

Taller 1																		
							Plano						Pared					
punto	Lado	Área donde se encuentra	Luz incidente	Nivel permisible	Cumple Si	Cumple No	Lux reflejada a la altura aproximada	Lux incidente (E2)	Kf= E1/E2 *100	Nivel permisible	Cumple Si	Cumple No	Lux reflejada a la altura aproximada (	Lux incidente (E2)	f= E1/E2 *100	Nivel permisible	Cumple Si	Cumple No
1	L1	Oficina 1 Ing. Sergio Nájera	88.3	300		x	0	83	0	50		x	38.1	111.2	34.2625899	60		x
	L2		141.5	300		x	0	116.8	0	50		x	59.9	99	60.5050505	60	x	
	L3		161.5	300		x	0	175	0	50		x	47.2	110.7	42.6377597	60		x
2	L1	Escritorio 2 Ramon	93.7	300		x	0	48	0	50		x	41	67.1	61.1028316	60	x	
	L2		178.2	300		x	0	114	0	50		x	43.1	106.9	40.3180543	60		x
	L3		125	300		x	42.3	120	35.25	50		x	53.8	97.2	55.3497942	60		x
3	L1	Escritorio 3 Ing. Juan Carlos	194	300		x	59.6	195.9	30.423686	50		x	42	136.8	30.7017544	60		x
	L2		209	300		x	0	89.9	0	50		x				60		
	L3		200	300		x	0	295	0	50		x				60		
4	L1	Escritorio 4 Leti	160	300		x	36.8	214	17.196262	50		x				60		
	L2		159.3	300		x	47.7	206	23.15534	50		x				60		
	L3		208	300		x	57	166.7	34.193161	50		x				60		
3	L1	Cafeteria oficina	712	300	x		291	800	36.375	50		x				60		
	L2		845	300	x		170	1003	16.949153	50		x				60		
	L3		850	300	x		180	643	27.993779	50		x				60		
5	L1	Área de almacén	554	200	x		417	364.3	114.4661	50	x					60		
	L2		122.9	200		x	0	63.2	0	50		x				60		
	L3		212	200	x		0	69.4	0	50		x				60		
	L4		270	200	x		0	49.1	0	50		x				60		
	L5		336	200	x		0	51.6	0	50		x				60		
	L6		85.3	200		x	36.8	79.5	46.289308	50		x				60		
	L7		109	200		x	39	84.4	46.208531	50		x				60		
	L8		84.2	200		x	0	80.1	0	50		x				60		
	L9		106	200		x	0	86.4	0	50		x				60		
	L10		55	200		x	0	37.7	0	50		x				60		
	L11		123.7	200		x	38.2	165.5	23.081571	50		x				60		
	L12		173.1	200		x	55.1	183.3	30.060011	50		x				60		
	L13		130.2	200		x	0	10	0	50		x				60		
	L14		158.3	200		x	0	41.6	0	50		x				60		
	L15		173.6	200		x	0	61	0	50		x				60		
	L16		259.1	200	x		0	38.9	0	50		x				60		
	L17		225	200	x		39	70	55.714286	50	x					60		
	L18		280	200	x		75.3	111.5	67.533632	50	x					60		
	L19		265	200	x		0	39.7	0	50		x				60		
	L20		386	200	x		37.8	89.4	42.281879	50		x				60		
	L21		149.9	200		x	64	191.5	33.420366	50		x				60		
	L22		101.2	200		x	0	36.3	0	50		x				60		
	L23		126.3	200		x	0	54	0	50		x				60		
	L24		170.3	200		x	58	70.8	81.920904	50	x					60		
	L25		85.1	200		x	0	46	0	50		x				60		
6	L1	Lab. Quimica	88.1	500		x	0	40	0	50		x				60		
	L2		119.7	500		x	0	45	0	50		x				60		
	L3		115.1	500		x	0	76.9	0	50		x				60		
	L4		89.4	500		x	0	89.8	0	50		x				60		
	L5		94.7	500		x	0	56.5	0	50		x				60		
	L6		101.3	500		x	0	65.3	0	50		x				60		
	L7		102.2	500		x	55.7	94.5	58.941799	50	x					60		
	L8		172	500		x	36.1	60	60.166667	50	x					60		
	L9		107	500		x	43.6	103	42.330097	50		x				60		
	L10		94	500		x	36.2	93.4	38.75803	50		x				60		
	L11		101.4	500		x	0	73.6	0	50		x				60		
	L12		188.3	500		x	47	105.6	44.507576	50		x				60		
	L13		95.8	500		x	0	46	0	50		x				60		
	L14		61.2	500		x	0	58.8	0	50		x				60		
	L15		58.1	500		x	42.9	44.1	97.278912	50	x					60		
	L16		58.3	500		x	46.3	54.8	84.489051	50	x					60		
	L17		53.7	500		x	0	54.8	0	50		x				60		
	L18		87.9	500		x	0	44.4	0	50		x				60		
	L19		71.2	500		x	0	60	0	50		x				60		
7	L1	Almacén de quimica	109.5	200		x										60		
	L2		119.2	200		x										60		
	L3		136.8	200		x										60		
	L4		222.4	200	x		0	30	0	50		x				60		
8	L1	Baño M	326.2	200	x											60		
	L2		456	200	x											60		
	L3		164	200		x										60		
9	L1	Baño H	250	200	x											60		
	L2		180	200		x										60		
	L3		280	200	x											60		

Table 4 Evaluation of lux level in Workshop 1

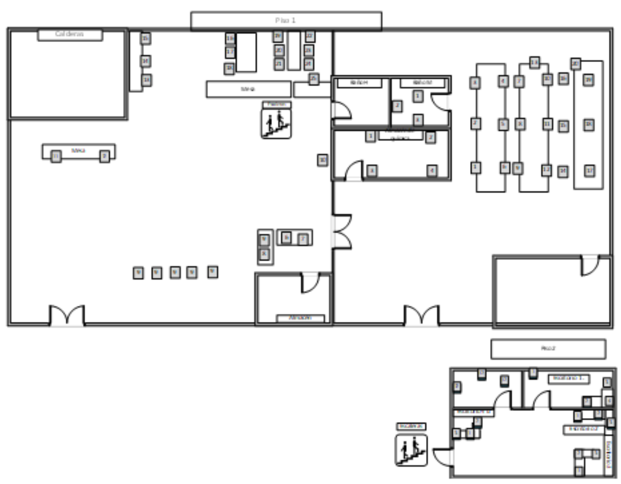
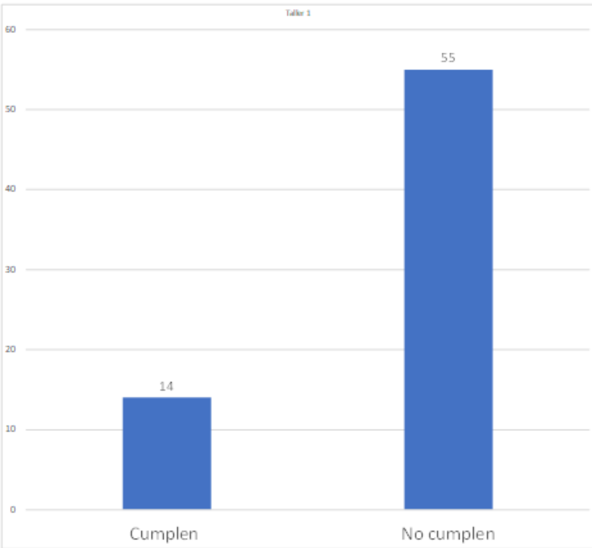


Figure 2 Evaluation of lux in workshop 1

Workshop 1

In workshop 1, the lighting of 14 points only complies with the luxes, and 55 points are below the permissible level of NOM 025 STPS 2008 (See Graph 2). It can be concluded that of the workshops (1, 2, 3 and 5), 27.14% of a total of 409 points were complied with.



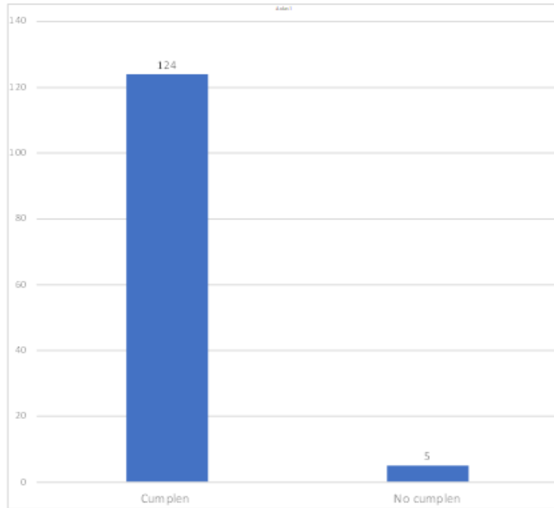
Graphic 2 Luxes of Workshop 1

Classrooms 1

With regard to the classrooms, one is presented as "type" because they all have the same dimensions; the sampling points were determined for the lighting in the classrooms, cubicles, audiovisual, offices, teachers' lounge (See Figure 1).

Figure 3 Evaluation of lux in Classrooms 1

In classrooms 1, of a total of 129 points, 124 points complied with the luxes (See Graph 3). It can be concluded that 66.63% of the classrooms (1-6) complied with the lighting, that is, out of a total of 911 points that were taken.



Graphic 3 Classroom Luxes 1

Acknowledgements

We would like to thank the Universidad Tecnológica de Aguascalientes for the opportunity to carry out the study in their facilities. We also highlight that this study had a zero cost, since it was carried out with our own resources, and as a reference it would have had a cost of $30,000, with an external consultant.

Conclusions

The recommendations in a very general way is to replace the luminaires in poor condition, and change the type of luminaires in the areas where the lighting levels indicated by the standard are not met, it is also required to make a maintenance and cleaning plan for the entire lighting system, in order to promote work environments that can improve productivity, safety and comfort of employees, also the design of natural lighting systems will reduce energy consumption by the combination of systems that regulate it according to the internal and external environment (Marquínes et al., 2020).

The performance and learning of students is significantly influenced by the ergonomic conditions of lighting in classrooms, furniture, chair size and table height, which will be important to consider in order to make improvements in logistics (Martínez Martínez Danna, Ramírez Torres & Yiseth, 2021).

Regarding the workshops where students perform practices, it will be necessary to adapt the workplace to avoid accidents and health problems (Cabascango Camuendo et al., 2021).

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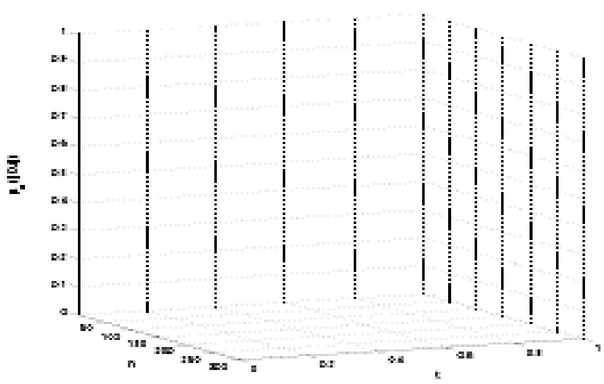

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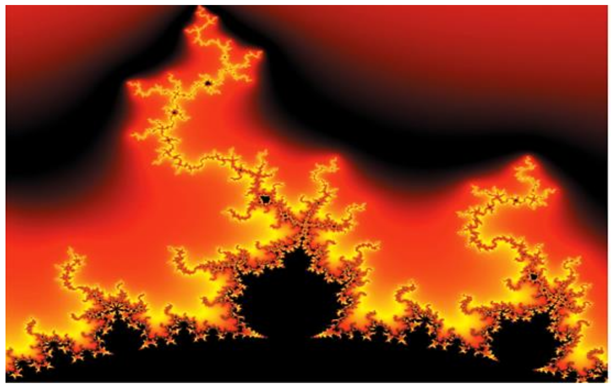

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