A Case Study of Sulam-Driven Energy Audits: Bridging TVET Competencies and Rural SME Sustainability

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ABSTRACT

This case study under the course BELP4853 – Energy Utilization & Conversion examines the integration of energy auditing with experiential learning through the SULAM framework in TVET education. Conducted at Biskut Tongkat Simpang Bekoh, a commercial enterprise under TNB Low Voltage Commercial Tariff B, the audit identified the bakery oven system as the dominant energy consumer (81.45%), followed by lighting (17.11%), plug loads (1.16%), and cooling (0.27%).

Based on these findings, Energy Conservation Measures (ECMs) were proposed across no-cost, medium-cost, and high-cost categories, including techno-economic solutions such as a 1.19-year payback LED retrofit and a 6.0-year payback Solar PV system. The project not only improved energy literacy and sustainability practices for the SME owner but also enabled students to translate theoretical engineering concepts into practical applications, achieving Program Learning Outcomes in technology application, professionalism, and societal responsibility. Overall, the study demonstrates that embedding community-based energy audits within SULAM enhances graduate employability, strengthens rural enterprise resilience, and supports national energy efficiency goals.

INTRODUCTION

The increasing demand for electrical energy in commercial buildings has led to higher operating costs and environmental problems such as greenhouse gas emissions and energy wastage. Commercial buildings such as offices, shopping complexes, universities, and places of worship use a large amount of electricity daily for lighting, air-conditioning, ventilation, office equipment, and other electrical appliances. Inefficient energy usage often occurs due to old equipment, poor maintenance, and lack of proper energy management. Energy efficiency is important to reduce energy consumption while maintaining building comfort and performance. By implementing suitable Energy Saving Measures (ESMs), building owners can reduce electricity costs, improve equipment efficiency, and support sustainable development.

The use of energy-efficient technologies also supports Malaysia's efforts toward energy sustainability and carbon emission reduction.This project is conducted as part of a community service and knowledge transformation program, where a team of electrical energy engineers assists commercial building owners in identifying energy-saving opportunities. The project involves selecting a commercial building and conducting an energy audit to study the building's energy consumption pattern. The audit includes collecting electricity usage data, identifying inefficient systems, establishing an energy baseline, and analyzing areas for improvement.

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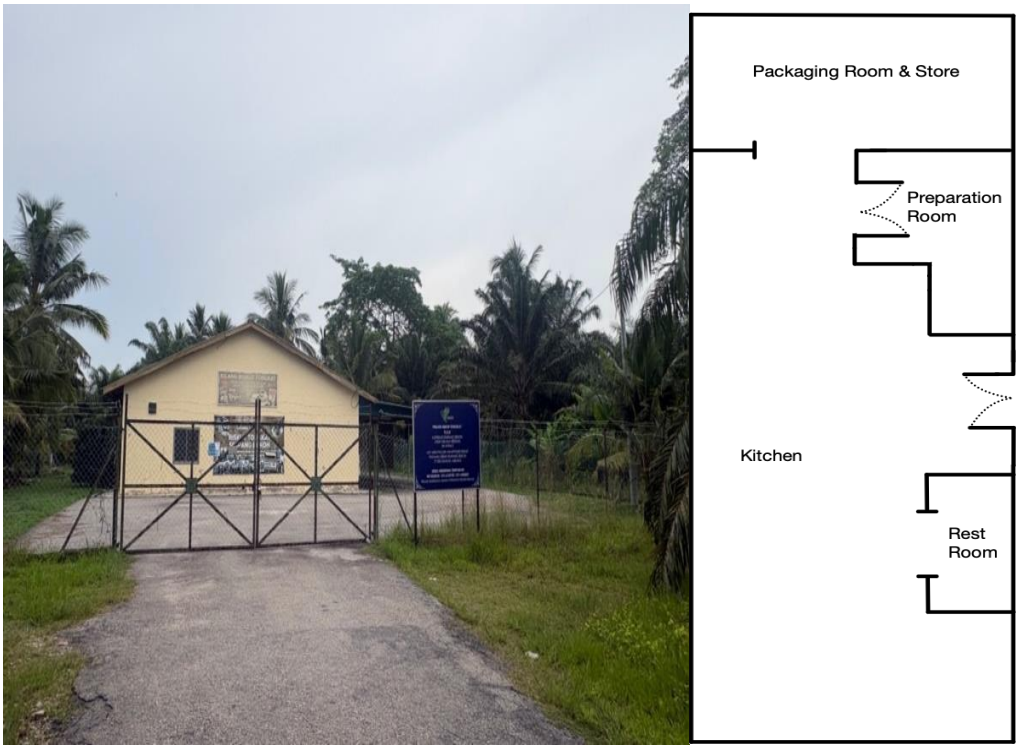


Figure 1 illustrates the commercial building project that operates under Electricity Tariff B and above. Then, preliminary analysis of the building or facility to ascertain the potential for energy savings, pinpoint inefficient areas, and comprehend present energy usage trends. Examining energy bills, visiting potential sites, and gathering information on energy usage may all be part of this project. These can be obtained through MyTNB apps. Other than that, an energy audit to assess the premise's energy efficiency. To find chances for energy savings, this entails analyzing data on energy usage, performing on-site inspections. Based on the findings of the energy audit, developing a set of recommendations and an action plan. This plan outlines the specific ECMs to be implemented, the estimated energy and cost savings, and the associated implementation timeline.

MAKLUMAT PRODUK KOPERASI

NAMA KOPERASI	:	KOPERASI SIMPANG BEKOH JASIN MELAKA BERHAD
ALAMAT	:	LOT 4325 PROJEK MEMPROSES BISKUT PADANG LEBAR 77100 ASAHAN JASIN MELAKA
NAMA PRODUK	:	1. BISKUT TONGKAT 100g 2. BISKUT TONGKAT BERGULA 100g
JENAMA	:	BISKUT TONGKAT SIMPANG BEKOH
PEGAWAI KOPERASI UNTUK DIHUBUNGI	:	ENCIK ABD HALIM AB GHANI
NO. TEL. PEJABAT	:	-
NO. TEL. BIMBIT	:	012-6134198
E-MEL	:	ksb_maju@yahoo.com
LAMAN WEB	:	www.facebook.com/biskuttongkatspgbekoh

GAMBAR PRODUK/SKU: BISKUT TONGKAT ORIGINAL



Figure 2: Cooperative Product Information

Koperasi Simpang Bekoh Jasin Melaka Berhad is a cooperative that produces traditional local snacks known as Biskut Tongkat Simpang Bekoh as shown in Figure 2. The factory is located at Lot 4325, Projek Memproses Biskut Padang Lebar, 77100 Asahan, Jasin, Melaka. The cooperative is famous for its traditional biscuits that are popular among local consumers because of their unique taste and nostalgic value. The main products are Biskut Tongkat Original 100g and Biskut Tongkat Bergula 100g.According to the cooperative representative, Mr. Abd Halim Abdul Ghani, the success of Kampung Simpang Bekoh in the Anugerah Desa Sejahtera 1Malaysia (ADS1M) competition helped create opportunities for the local community to improve their economy through small businesses and village entrepreneurship. With financial support from the Ministry of Rural and Regional Development, the cooperative developed a food processing factory with modern machines and facilities. The business was created not only to generate income for the local community but also to preserve traditional food heritage. The products received positive responses from customers, and during the early stage of operation, the factory produced around 200 packets of biscuits per day. The products were sold directly at the factory and through online orders delivered by courier services. To contextualize this educational approach, this study examines the pedagogical structure implemented by the Faculty of Electrical Technology and Engineering (Fakulti Teknologi dan Kejuruteraan Elektrik, FTKE) at Universiti Teknikal Malaysia Melaka (UTeM). The faculty strategically embedded the SULAM framework directly into its academic curriculum through the subject BELP 4853: Energy Utilization and Conservation. Under this course, students are mandated to execute a community-driven project requiring them to apply advanced theoretical energy management principles to solve authentic, localized challenges faced by community stakeholders.

This study evaluates the effectiveness of the SULAM framework executed through the BELP 4853 course as a pedagogical strategy within a TVET engineering program. Using a community-based energy audit conducted by FTKE students for a rural traditional bakery as a case study, this research asks two primary questions: (1) How does the SULAM framework facilitate the practical application of TVET competencies (Program Learning Outcomes) and (2) What is the socio-economic and technological impact of this academic intervention on the participating rural SME. By analyzing both the technical outputs and stakeholder feedback, this paper contributes to the broader discourse on educational sociology, demonstrating how community-engaged TVET can simultaneously solve the community problems and sustainable rural development.

LITERATURE REVIEW

Experiential Learning and Energy Audit

A comprehensive energy audit requires a systematic approach to analyze a facility's energy consumption and identify practical Energy Conservation Measures (ECMs) (Ahmad, 2023). To establish a performance baseline, we profiled electricity usage across hourly to yearly trends using historical utility bills and the MyTNB application, alongside an evaluation of equipment specifications and structural floor plans. To ground our technical findings in real-world operations, we interviewed the facility management at Biskut Tongkat Simpang Bekoh to understand daily workflows, occupant behavior, and machine utilization. Using this combined data, we isolated high-yield ECMs based on cost-reduction potential and short Return on Investment (ROI). These recommendations were strategically categorized into zero-cost, medium-cost, and capital-intensive upgrades to provide the owner with scalable, actionable solutions (Abdullah, 2025). Building on this baseline data, we systematically evaluated the facility to identify practical Energy Conservation Measures (ECMs) (Al-Ghaili A. M.-H., 2020). We isolated high-yield opportunities by focusing on their technical feasibility, cost-reduction potential, and short Return on Investment (ROI). To provide the building owner with a highly actionable roadmap, we then categorized these recommendations into zero-cost, medium-cost, and capital-intensive upgrades. This strategic tiering ensures that the facility can immediately begin saving energy while planning for more substantial, long-term efficiency improvements (Bakar, 2015).

The SULAM Framework and Community Engagement

This energy audit was more than just a technical assessment, but it was driven by Malaysia's SULAM framework (MOHE, 2019), which beautifully bridges classroom learning with real-world community service (MQA, 2020). Following our site visits, we carefully analyzed the data to find practical ways the local facility could save energy. Rather than overwhelming the building owner with endless technical options, we focused

on solutions that made financial sense prioritizing those with significant cost reductions and a quick return on investment (Mohamad, 2021). By organizing these recommendations into simple no-cost, medium cost, and high-cost steps, we were able to hand the owner a realistic, long-term roadmap for lower energy bills, while we as engineering students walked away with invaluable hands-on experience and a much deeper connection to our community (Butin, 2010). From a TVET perspective, service-learning creates an experiential environment where technical competencies are developed through direct engagement with authentic community problems. Energy auditing activities enable students to integrate engineering knowledge, communication skills, ethical responsibility, and sustainability awareness while simultaneously delivering value to community stakeholders. Therefore, the SULAM framework functions not only as a community engagement mechanism but also as a competency development platform aligned with Outcome-Based Education (OBE) principles.

Rural SMEs and the Need for Knowledge Transfer

Small rural food businesses often find it difficult to improve their energy efficiency simply because they rely on older equipment and cannot afford expensive professional audits (Bakri, 2018). By bringing TVET students in through the SULAM framework (Malaysia, 2024), we can bridge this gap by giving local micro-enterprises the technical support they need while allowing students to experience the real-world challenges of grassroots business owners (Bringle, 2009). Taking this community-driven approach to Biskut Tongkat Simpang Bekoh (Stone, 1994), our team rolled up our sleeves to assess the shop's actual energy performance. We did not just crunch the numbers from their past utility bills and equipment specs to map out their hourly and yearly electricity use, but we also sat down with the building manager. Having these open conversations allowed us to look beyond the raw data and truly understand the daily routines, worker habits, and practical equipment usage that drive the shop's real energy footprint (Revichandran, 2022).

METODOLOGY

Research Design and Context

The complete progression of this methodology is illustrated in Figure 3, which maps the audit from initiation to final reporting (Zailan, 2018). The workflow began with a scoping briefing, team task delegation, and a preliminary site survey to secure formal authorization. Subsequent on site execution focused on extracting architectural data and conducting active field measurements for real-time energy monitoring. Finally, our team synthesized these technical metrics to calculate exact projected energy savings and precise payback timelines, culminating in a comprehensive technical report and final presentation to stakeholders (Tan, 2023).

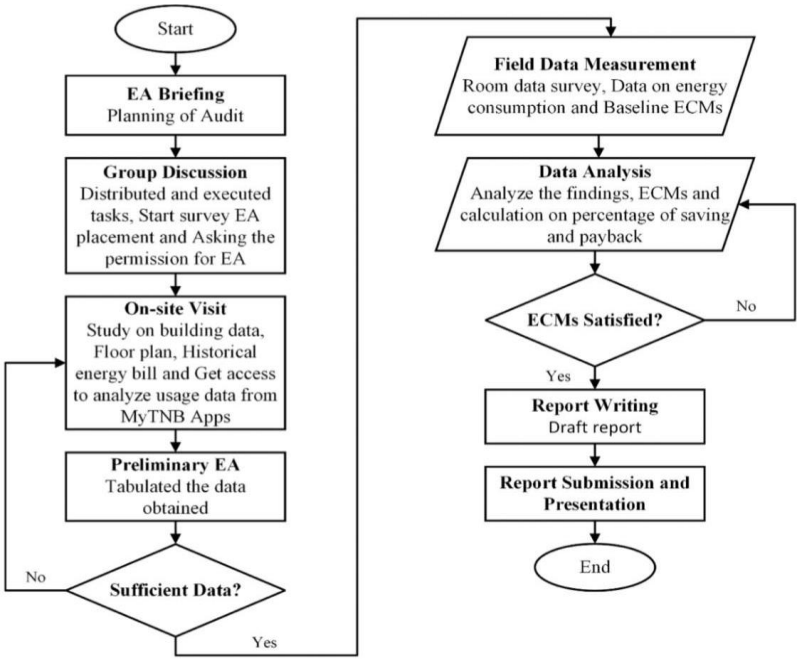


Figure 3: Flowchart for the Process of Energy Audit

Participants and Setting

Participants included a team of four undergraduate TVET students and one primary community stakeholder. The community setting was Koperasi Simpang Bekoh Jasin Melaka Berhad, a cooperative managing a rural food processing factory (Biskut Tongkat Simpang Bekoh) established with government support to generate local income and preserve traditional food heritage.

As part of their SULAM coursework, the TVET students conducted a comprehensive energy audit to assist the business owner in identifying practical energy-saving opportunities (Abdul Aziz, 2020). The students utilized technical instruments, including Kyoritsu clamp-on ammeters, smartphone lux meter applications, and TNB smart metering data, to perform load apportioning and baseline energy profiling as shown in Figure 4.

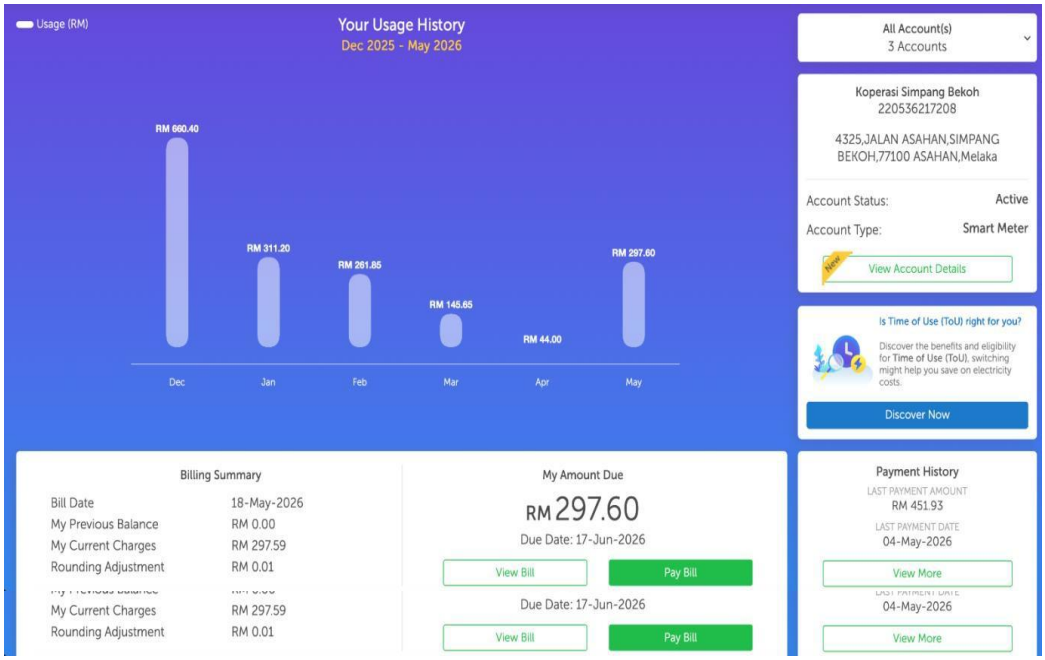


Figure 4: MyTNB Apps

To assess the social and pedagogical outcomes, the study analyzed two primary data streams:

1. Technical Deliverables: The feasibility and techno-economic accuracy of the Energy Consumption and Energy Conservation Measures (ECMs) designed by the students were evaluated as evidence of applied TVET knowledge (Noranai, 2022).
2. Energy Audit Performances: To systematically evaluate the energy efficiency of Biskut Tongkat Simpang Bekoh, a comprehensive energy audit was conducted to assess the facility's baseline performance (Norhisham, 2022). The quantitative methodology involved a rigorous analysis of electricity consumption patterns across hourly, daily, and annual intervals, utilizing historical utility bills and technical equipment specifications to construct a detailed energy profile. To supplement this empirical data, qualitative assessments were undertaken through in-depth discussions with the facility manager. This integrated approach enabled the audit team to correlate raw consumption metrics with actual operational realities, providing a critical understanding of how daily routines, occupant behaviors, and specific mechanical loads collectively dictate the facility's aggregate energy footprint.

FINDINGS AND DISCUSSION

Evidence of Technical Competency and Knowledge Application

The students successfully translated their classroom instruction from BELP 4853 into a professional-grade technical assessment. Figure 5 illustrates the facility's annual load profile, presenting electricity consumption over the verified monitoring period from May 2025 to June 2026. All monthly consumption values were

validated against electricity billing records obtained from the MyTNB platform prior to analysis. The data reveal fluctuations in monthly energy usage, with an average monthly electricity consumption of 759.31 kWh. The highest recorded energy consumption occurred in August 2025, reaching 1,788 kWh

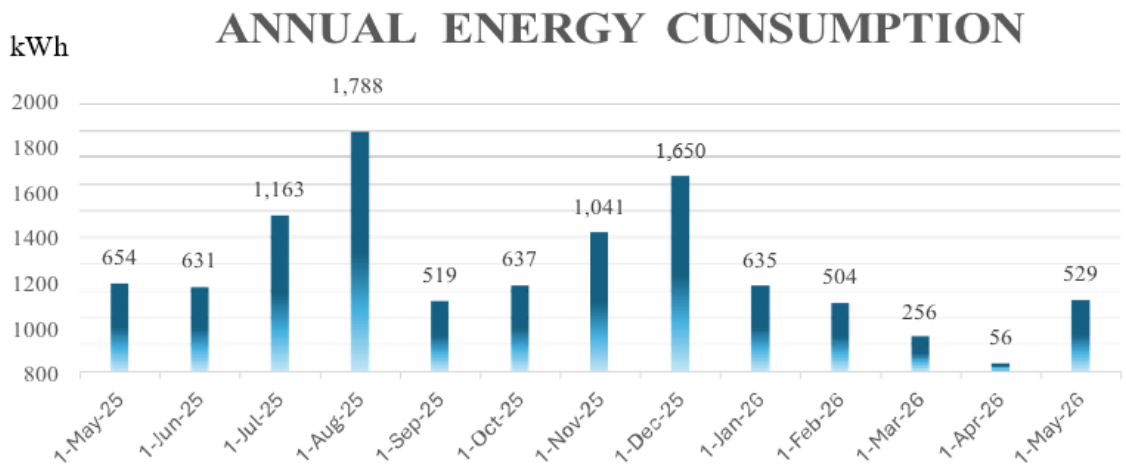


Figure 5: Annual Energy Consumption In 2025-2026

Figure 6 provides a more granular look at daily electricity consumption from May 2025 to June 2026. Because the factory operates strictly on an order-fulfillment basis, energy usage is not consistent throughout the month. Significant consumption spikes align directly with active production days when machinery, equipment, and lighting are fully operational. Conversely, non-production days record little to no electrical usage. The electricity consumption dataset used in this study was obtained from two primary sources, (i) monthly electricity billing records extracted from the MyTNB portal and (ii) short-term field measurements conducted during the site audit using clamp-meter observations and equipment operational records. The monthly billing dataset covered the period from May 2025 to June 2026, whereas the detailed daily and hourly consumption analyses were derived from operational monitoring conducted between 1 June and 7 June 2026. Missing records and periods with zero electricity consumption were retained in the dataset to reflect the actual intermittent production schedule of the factory. Arithmetic averages were calculated only after verification of billing consistency and removal of duplicated entries.

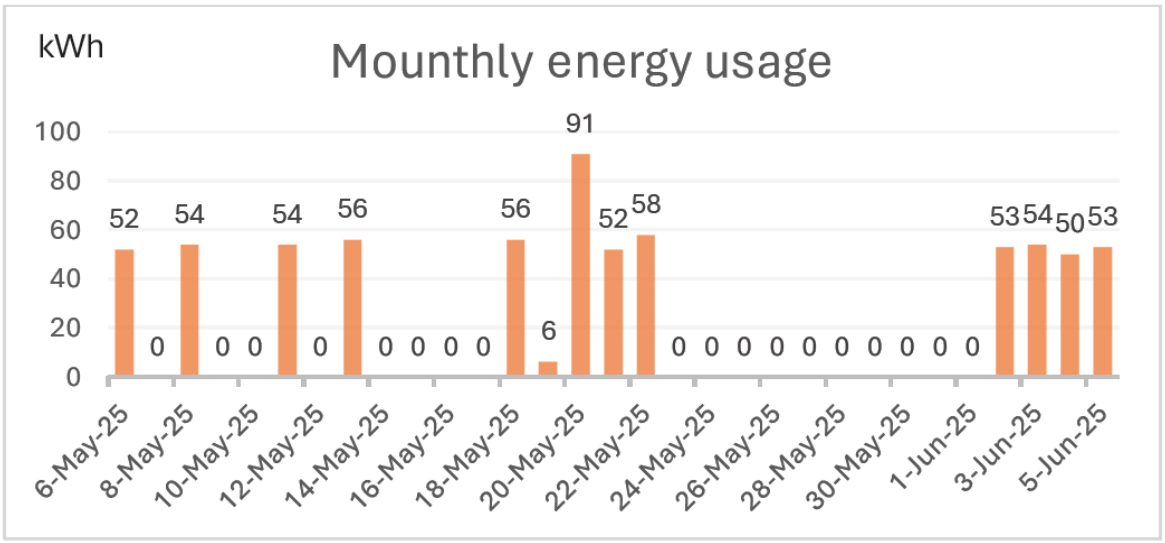


Figure 6: Monthly Energy Consumption (6 May 2025 – 5 June 2026)

Focusing on a micro-level analysis, Figures 7 and 8 depict the weekly and average daily energy consumption profiles from June 1 to June 7, 2026. The data reflects standard operating hours of 9:00 AM to 4:00 PM.

Energy demand steadily climbs starting at 9:00 AM and reaches its highest peak between 10:00 AM and 12:00 PM, the facility's most intensive production period. Following this peak, consumption gradually tapers off until the factory closes at 4:00 PM. Notably, during the specific week studied, the facility only operated for four days, which aligns with the manager's explanation that production schedules are heavily dictated by current market demand.

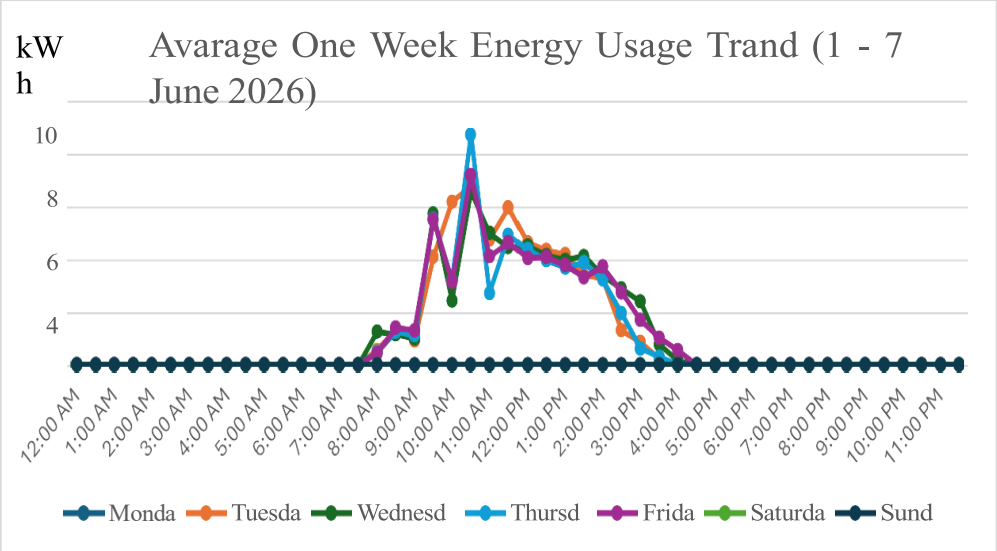


Figure 7: Weekly Energy Consumption (1 – 7 June 2026)

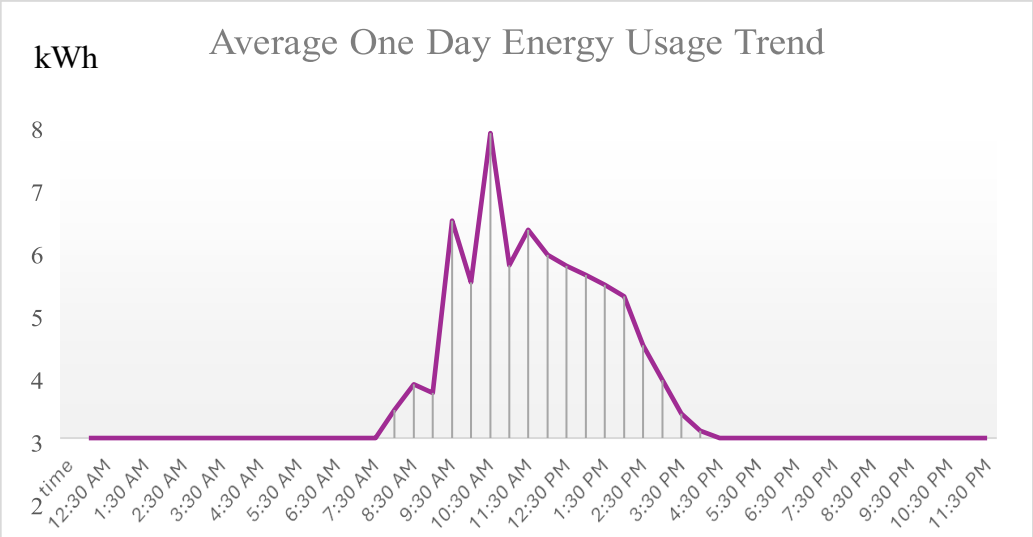


Figure 8: Average One Day Energy Consumption (1 – 7 June 2026)

A highly positive finding from this usage data is that the factory does not consume electricity outside of its 9:00 AM to 4:00 PM operating window. All lighting, machinery, and electrical equipment are entirely powered down when production halts. Base Load ≈ 0 (Negligible) This demonstrates excellent operational practice. By eliminating phantom loads and standby energy waste during non-operating hours, the facility ensures that its electricity expenditures remain strictly proportional to actual manufacturing output.

Socio-Economic Impact and Community Satisfaction

The electrical load schedule from the facility's energy audit reveals that its energy footprint is overwhelmingly driven by the primary production zone in the kitchen, which houses highly energy-intensive thermal and inductive equipment. The bulk of the power demand originates from heavy-duty resistive heating elements,

specifically a mechanized baking infrastructure that includes three 26,000 W 3-deck ovens, three 13,200 W 2-deck ovens, a 6,600 W 1-deck oven, and a 2,500 W bread proofer. This thermal load is compounded by high torque mechanical loads from a 5,600 W spiral dough mixer and a 2,200 W automatic dough sheeter, alongside auxiliary refrigeration and extensive fluorescent lighting as shown in Table 1. In stark contrast, peripheral support zones such as the porch, restrooms, preparation room, and packaging store contribute minimally to the total capacity, relying solely on basic fluorescent lighting and low-wattage ceiling fans. Consequently, to maximize the impact of any Energy Conservation Measures (ECMs), strategic upgrades and operational optimizations must prioritize the high-wattage thermal and mechanical production assets in the kitchen, as these dictate the facility's peak demand and overall energy consumption.

Due to the facility's inconsistent operating schedule throughout the month, we based our findings on a representative sample of data collected from June 1 to June 7, 2026. Analyzing the electrical appliances during this period provided valuable insights into the building's true energy consumption patterns. By identifying the most energy intensive equipment, highlighting peak demand periods, and pinpointing specific areas for improvement, this data establishes a strong foundation for the audit. Ultimately, these insights allow us to develop targeted, practical energy saving strategies designed to significantly reduce both overall power usage and daily operational costs.

Table 1: List of Load Appliances

Location	**Load Appliances**	**Quantity**	**Load in Watt (W)**
Porch	Fluorescent Light	7	40 W
Kitchen	2-door Display Refrigerator	1	650 W
	3-Deck Bakery Oven	3	26000 W
	2-Deck Bakery Oven	3	13200 W
	1-Deck Bakery Oven	1	6600 W
	2-Door Bread Proofer cabinet	1	2500 W.
	Spiral Dough Mixer	1	5600 W
	Automatic Dough Sheeter	1	2200 W
	Fluorescent Light	32	36 W
	Continuous Band Sealer (small)	1	500 W
Rest Room 1 & Preparation Room	Fluorescent Light	8	72 W
	KDK Celling Fan	2	36 W
Packaging Room & Store	Fluorescent Light	2	36 W

To ensure consistency throughout the audit, equipment ratings reported in Table 1 represent manufacturer rated capacities. However, actual operational energy calculations presented in subsequent analyses are based on estimated operating demand during normal production conditions. Therefore, rated power and operating demand are presented separately to avoid misinterpretation of equipment energy use.

Table 2: Total Average for One Day Power Consume of Appliances

Load Appliances	**Quantity**	**Operation Hour**	**Average Total Energy Consumption Power/Quantity**	**Daily Total Energy Consumption (kWh)**
3-Deck Bakery Oven	3	3	15000W	45
2-Door Bread Proofercabinet	1	1	500 W.	0.50
Spiral Dough Mixer	1	0.25	1200 W	0.3
Automatic Dough Sheeter	1	0.5	400 W	0.20
Fluorescent Light	38	7	36 W	9.58

Continuous Band Sealer (small)	1	7	100 W	0.15
KDK Celling Fan	2	7	36 W	0.50

As clearly outlined in Table 2, when we break down the shop's daily energy consumption, it is incredibly easy to see exactly where all the power is going. The real heavy hitters on the production floor are undoubtedly the three large 3-deck bakery ovens. Although each 3-deck bakery oven has a manufacturer rated capacity of 26,000 W, site observations and discussions with facility operators indicated that the heating elements do not operate continuously at full rated capacity throughout the baking cycle. Consequently, an estimated operating demand was used for daily energy calculations. Future studies should incorporate direct power logger measurements to validate the actual demand profile of the baking equipment.

Table 3 & Figure 9 illustrates the daily electrical load apportionment for the facility, clearly breaking down where energy is consumed by category. The overwhelming majority of the facility's daily energy usage is driven by the Oven and Bakery System, which consumes 45.5 kWh, accounting for a massive 81.45% of the total load. The second largest consumer is Lighting, which uses 9.56 kWh, representing 17.11% of the daily total. The remaining categories have a negligible impact on overall consumption: the Plug Load accounts for just 0.65 kWh (1.16%), and the Cooling systems consume a mere 0.15 kWh (0.27%). This stark distribution indicates that any effective energy-saving strategy must primarily target the bakery equipment, followed by the lighting system, to achieve meaningful cost reductions.

Table 3: Load Apportioning

Time	**Total Power Consumption (kWh)**	**Percentage (%)**
Oven and Bakery's System	45.5	81.45
Lighting	9.56	17.11
Cooling	0.15	0.27
Plug Load	0.65	1.16

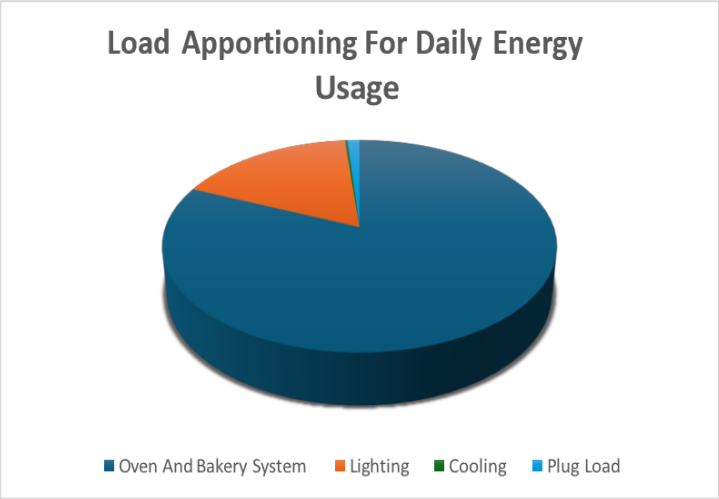


Figure 9: Load Apportioning Pie Chart

Figure 9, it is obvious that the shop's energy goes almost entirely into baking, with basic comforts like cooling barely registering at all. Looking ahead, if the bakery gets busier and ramps up production, their electricity bills will climb right alongside those extra batches. This is where the SULAM framework truly shines, by having students look at this real world data, we can give the owners practical ECM as advice like tweaking their baking schedules or adding better insulation so they can successfully grow their local business without letting their overhead costs get out of hand. Prior to ECM evaluation, all billing records, equipment inventories, and operational schedules were reviewed and cross-checked with information provided by the facility representative. The verified dataset was subsequently used to develop the energy baseline and determine the load apportionment presented in this study. The calculated energy consumption values should

therefore be interpreted as engineering estimates based on available operational information rather than long-term monitored measurements.

Discussion on Energy Conservation Measure (ECMs)

The findings of this case study strongly validate SULAM as an effective experiential learning pedagogy within engineering TVET programs. By shifting the learning environment from the university laboratory to a rural cooperative under the BELP 4853 course, the students were forced to navigate authentic constraints such as the SME's limited capital and lack of technical literacy. The proposed energy-saving strategy goes beyond simply lowering the shop's monthly electricity bills, but it also aims to encourage the business owners to adopt long-term, energy-conscious habits. This structured approach relies on Energy Conservation Measures (ECMs) targeted recommendations designed to decrease the facility's overall power consumption based on our energy audit findings. To ensure these strategies are practical and financially viable for the micro-enterprise, the ECMs are carefully analyzed and divided into no-cost, medium-cost, and high-cost categories. By calculating the projected percentage of savings and the simple payback period for each proposed measure, we can provide the owners with a clear, step-by-step roadmap for upgrading their operations.

As a highly effective, low cost starting point, ECM 1 recommends replacing the facility's existing 40W fluorescent lights with modern LED lighting systems as stated in Table 4 and Figure 10. Conventional fluorescent tubes draw significantly more electricity, generate excess heat, and burn out much faster than their LED counterparts. By making this simple switch, the bakery can immediately reduce its daily lighting load while improving overall brightness and workspace visibility. Ultimately, this straightforward retrofit requires minimal upfront investment but delivers long term value by cutting down on maintenance frequency and steadily lowering the shop's monthly utility costs. Replacing 38 units of 36 W fluorescent lamps with 18 W LED lamps can reduce lighting energy consumption from 9.58 kWh/day to 4.79 kWh/day. This results in an energy saving of 4.79 kWh/day, approximately 50% reduction in lighting energy consumption while maintaining adequate illumination levels as mentioned in Table 5.

Table 4: Comparison Before And After ECM

Load Appliances	**Quantity**	**Operation Hour**	**Average Total Energy Consumption Power/Quantity**	**Daily Total Energy Consumption (kWh)**
Fluorescent Light (before ECM)	38	7	36 W	9.58 kW
LED Light (After ECM)	38	7	18 W	4.79 kW



Figure 10: Recommended LED Light

Table 5: Comparison Before And After ECM

Item	Calculation	Value
Number of LED Lamps	-	38 units
Daily Energy Saving	9.58 − 4.79	4.79 kWh/day
Annual Energy Saving	4.79 × 365	1,748.35 kWh/year
Electricity Tariff	-	RM 0.365/kWh
Annual Cost Saving	1,748.35 × 0.365	RM 638.15/year
Cost per LED Lamp (Assumed)	-	RM 20.00
Total Investment Cost	38 × RM 20.00	RM 760.00
Simple Payback Period	RM 760.00 ÷ RM 638.15	**1.19 years**
Payback Period (Months)	1.19 × 12	**14.3 months**

The proposed LED retrofit assumes replacement of 38 existing fluorescent lamps with 18 W LED tubes providing equivalent illumination levels for industrial workspace applications. The investment cost estimate includes lamp procurement only and excludes electrical rewiring costs because the existing fixtures are expected to remain operational. Actual project implementation should include illumination verification using calibrated lux meter measurements to ensure compliance with workplace visual comfort requirements.

The Execution of ECM 2 is more significant, long-term investment, installing a rooftop Solar Photovoltaic (PV) system is one of the most effective ways for the bakery to permanently cut its utility bills. Because the shop operates heavily during the daytime, it is perfectly positioned to use solar energy exactly when it is generated, drastically reducing its reliance on the main power grid (TNB). While the upfront cost is higher, tapping into free, renewable sunlight pays off steadily over time, offering a strong return on investment while making the business much more environmentally friendly.

Looking practically at the Biskut Tongkat Simpang Bekoh facility, the building has an available rooftop space of about 15 by 22 feet, which can comfortably fit around 18 solar panels. Given Malaysia's strong sunlight averaging 4.5 to 5 peak sun hours a day this 18-panel setup could generate anywhere from 24.3 to 45.0 kWh of electricity daily, depending on the specific wattage of the panels chosen. Over a year, that adds up to between 8,869 and 16,425 kWh of clean energy, which would take a massive bite out of the shop's operational costs and protect them against future energy price hikes as mentioned in Table 6.

Table 6: Estimated Output for 18 Panels

Panel Wattage	Total System Size	Estimated Daily Output	Estimated Annual Output
300W Panels	5.4 kWp	24.3 – 27.0 kWh	8,869 – 9,855 kWh
400W Panels	7.2 kWp	32.4 – 36.0 kWh	11,826 – 13,140 kWh
500W Panels	9.0 kWp	40.5 – 45.0 kWh	14,782 – 16,425 kWh

The proposed PV system sizing was evaluated based on the available roof area of approximately 15 ft × 22 ft. Assuming an average panel footprint between 1.9 m² and 2.3 m² per module, the installation of 18 PV modules is considered physically feasible subject to detailed structural assessment and shading analysis. The energy yield estimation assumes average solar irradiation of 4.5–5.0 peak sun hours per day and overall system losses of approximately 15–20% due to inverter inefficiencies, temperature effects, cable losses, and module degradation.

The Return on Investment (ROI) for the proposed solar photovoltaic (PV) system can be estimated based on the installation cost, annual electricity savings, and energy generated by the system. Although the installation of solar panels requires a high initial investment, the long-term savings on electricity bills can help recover the cost within several years. For an 18-panel solar system installed at the Biskut Tongkat Simpang Bekoh factory, the estimated ROI is as in Table 7.

Table 7 : Estimated Return of Investment (ROI)

Panel Wattage	System Size	Estimated Annual Output	Estimated Annual Savings	Estimated ROI Period	Estimated Energy Cost Reduction
300 W	5.4 kWp	8,869 – 9,855 kWh	RM 3,500 – RM 4,000	6 – 8 years	20% – 30%
400 W	7.2 kWp	11,826 – 13,140 kWh	RM 4,700 – RM 5,300	6 – 7 years	30% – 45%
500 W	9.0 kWp	14,782 – 16,425 kWh	RM 5,900 – RM 6,600	5 – 7 years	45% – 60%

The 500 W panel systemprovides the highestenergy generation and electricity savings,making it suitable for factories with high daytime electricity usage. Although the initial installation cost is higher,the system can reduce long term operating costs and provide better energy efficiency.Overall, the solar PV system is considered a practicallong term investment because it reduces electricity expenses, supports sustainable energy practices, and improves the overall energy performance of the factory.

Table 8 : Average Payback Period

Item	Calculation	Value
Number of Panels	-	18
Panel Wattage	-	500 W
System Size	18 × 500 W ÷ 1000	9.0 kWp
Annual Energy Generation	-	14,782 – 16,425 kWh
Average Annual Savings	(RM 5,900 + RM 6,600) ÷ 2	RM 6,250
Estimated Installation Cost	-	RM 37,500
Payback Period	RM 37,500 ÷ RM 6,250	**6.0 years**

Table 8, provides a clear financial and technical breakdown for installing the high capacity solar PV system at the bakery. By utilizing 18 high-output 500W panels, the shop would effectively install a robust 9.0 kWp system. Over the course of a year, this solar setup is projected to generate between 14,782 and 16,425 kWh of clean electricity. When converted into financial terms, this renewable energy generation translates to an average annual savings of RM 6,250 on their utility bills. While the initial estimated installation cost is a significant investment at RM 37,500, the long-term financial viability is highly favorable. By dividing the total upfront cost by the projected annual savings, the system yields a straightforward payback period of exactly 6.0 years. From a practical business perspective, this means the solar panels will completely pay for themselves in just six years, after which the ongoing energy savings will directly increase the bakery's operational profit margins.

The financial analysis assumes that all generated solar energy is self consumed within the facility during operating hours. Annual maintenance costs, inverter replacement costs, electricity tariff fluctuations, and future production variability were not explicitly modelled. Therefore, the estimated six-year payback period should be interpreted as an indicative value rather than a guaranteed financial outcome. Sensitivity analysis indicates that changes in tariff structure and production schedules may influence the actual savings achieved.

Sustainable Energy Management System Practice

As a result of the energy audit that was carried out at Biskut Tongkat Simpang Bekoh, several Energy Conservation Measures (ECMs) have been found. These ECMs have the potential to make a considerable contribution to energy savings and to promote environmentally responsible activities. These ECMs, such as replacing Fluorescent Lamp are in line with the bakery's commitment to sustainability and contribute to a greener future. Biskut Tongkat Simpang Bekog may see significant energy savings, cost reductions and environmental benefits as a result of the implementation of the sustainable energy management system practices that have been advised based on the findings of the energy audit. Table 9 shows the suggested sustainable energy management practice for Biskut Tongkat Simpang.

Table 9 : Sustainable Energy Management System Practice

SEM System Practice	List of Action	Application For	Remarks
A. Energy Conservation Manager (ECMs) Implementation	A1: Turn off sockets of unused appliances. A2: Regular maintenance on appliances. A3: Install window tinted. A4: Replacement of 36W Fluorescent Lamp to LED 18W.	1. Owner 2. Staff	After implementation of ECMs, the annual energy usage of Biskut Tongkat Simpang Bekoh can save more than 10 percent from the before EMCs annual energy usage.
B. Net Efficiency Consumption And Sustainable	B1: Every single component of the ECM system's implementation is supervised and recorded. B2: Conduct an analysis of the results of the activities taken to make improvements. B3: Conduct awareness and training to educate staff about energy-saving practices.	1. Own 2. Staff	To achieve this objective, all staff members must assume responsibility.
C: Renewable Energy Integration	C1: Install solar panels as the source of electricity for the building's energy system.	1. Owner	Evaluate the viability of integrating renewable energy sources such as solar panels into business operation

While this case study provides deep ECM insights into the mechanics of a successful TVET service-learning project, it is limited by its single-case design. The SULAM implementation was evaluated through observation of student participation, completion of technical deliverables, reflective discussions, and feedback obtained from the community stakeholder. Students demonstrated competency in energy auditing, load profiling, data interpretation, techno-economic assessment, and professional communication. The community stakeholder indicated that the audit report increased awareness regarding energy consumption patterns and potential conservation opportunities. However, because the recommended ECMs had not yet been fully implemented at the time of reporting, the projected energy and cost savings presented in this paper should be regarded as anticipated benefits rather than verified outcomes.

CONCLUSION AND RECOMMENDATIONS

The integration of the Service Learning Malaysia (SULAM) framework into TVET engineering curricula represents a powerful synergy between academic instruction and community development. This case study demonstrates that deploying TVET students from the Fakulti Teknologi dan Kejuruteraan Elektrik (FTKE) through the BELP 4853 (Energy Utilization and Conservation) course to conduct real world energy audits

successfully bridges the gap between theoretical knowledge and practical, socio-technical problem solving. Educationally, the project served as a robust mechanism for competency development, allowing students to achieve critical learning outcomes related to technology application, professional communication, and environmental responsibility in a highly authentic context. The findings indicate that SULAM-based energy audit projects provide a meaningful platform for integrating technical learning with community engagement. The study demonstrates the potential of TVET students to apply engineering knowledge in addressing real world energy challenges faced by rural SMEs. While the projected energy and cost savings remain subject to future implementation and verification, the project successfully enhanced student competency development and provided practical recommendations to support more sustainable energy management practices. Future work should evaluate the long-term implementation outcomes of the proposed ECMs using validated energy performance measurements.

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