Operational Energy Assessment and Selective Retrofit Strategy for a 24-Hour Cafe Using EDGE-Based Scenario Analysis

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ABSTRACT

This research evaluates the energy performance of a 24-hour cafe in a tropical context using the EDGE decision-support platform. Cafe Oregano in Palangka Raya, Indonesia, was selected as a case study due to its continuous operation, refrigeration systems, and kitchen appliances, which generate persistent internal loads that challenge conventional assumptions about commercial building energy use. The EDGE baseline simulation produced a very high Energy Performance Index (EPI) of 778.53 kWh/m²/year, corresponding to a 32.50% relative performance, indicating a mismatch between standardised IFC assumptions and actual cafe operational behaviour. After parameter refinement and validation using monthly electricity bills, performance improved to 674.55 kWh/m²/year (+13.36%), reducing annual electricity consumption from 420,858 to 275,215 kWh. Sensitivity analysis showed that HVAC efficiency and zoning delivered the greatest performance gains, followed by envelope and lighting improvements, while refrigeration loads remained structurally dominant. To evaluate real-world feasibility, a selective retrofit scenario based on local Indonesian market costs was developed. The resulting package—roof and partial wall insulation, LED retrofitting, high-efficiency 1 HP HVAC replacement, and basic zoning controls—requires an estimated capital investment of IDR 310–320 million and achieves a simple payback of 1.5–2 years. Overall, the findings confirm that while EDGE effectively identifies relative performance trends, achieving meaningful energy efficiency in cafe typologies requires calibrated scenarios, realistic operational assumptions, and economically grounded interventions.

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1. INTRODUCTION

The rapid growth of the cafe industry worldwide has led to the intensive use of resources, including continuous air conditioning, kitchen activities, refrigeration, and lighting. Unlike other commercial buildings, cafes often operate outside of standard business hours or even continuously for 24 hours, thus creating persistent internal and latent loads [1] that increase the energy demand of such buildings [2]. In tropical regions, this condition is further exacerbated by high ambient temperatures and humidity, resulting in a heavy reliance on mechanical cooling. In most cases, the sustainability assessment of cafes relies on generalised assumptions developed from residential or office building typologies [3]. These assumptions undervalue the internal gains [4] from refrigeration units, food preparation equipment, occupant density, and exhaust systems. As a result, traditional efficiency measures, such as envelope insulation or efficient lighting, may yield minimal improvements if they are not calibrated against real operational conditions [5].

The EDGE (Excellence in Design for Greater Efficiencies) tool offers a standardised base from which energy performance [6], water efficiency, material savings, and other metrics can be quantified through parametric comparisons. Although EDGE has been widely used to support early design decisions, its various modelling modules do not account for dynamic operational variables or hourly energy behaviour. Thus, the gap between the outputs of simulations generated by EDGE and actual cafe performance should be considered a methodological challenge that must be addressed in the real operation of buildings. This paper presents the energy performance [6] assessment of Cafe Oregano, a 24-hour operating cafe in Palangka Raya, Indonesia, which was conducted by using the EDGE application. Unlike previous cafe studies, which focus on branding, consumer perception, or waste-based sustainability, this research addresses operational energy and mechanical system behaviour in a continuous 24-hour business model. A comparison has been made between baseline and post-scenario simulations, with monthly electricity bills used to validate the model. Moreover, this study examines the feasibility of implementing selective efficiency measures, including roof and wall insulation, LED retrofitting, HVAC upgrades [7], and simple control zoning, based on locally sourced capital cost estimates. This research contributes to practical strategies related to resource-efficient cafe design under tropical conditions, emphasising the alignment of digital assessment tools with real operational behaviour.

2. METHODOLOGY

2.1 Case Study and Operational Context

This research applies a single-case study approach to analyse energy performance [6] in a 24-hour cafe located in Palangka Raya, Indonesia. The building operates continuously, featuring indoor dining areas, beverage preparation zones, and kitchen facilities with uninterrupted refrigeration. Such conditions generate persistent sensible and latent thermal loads [8] that differentiate cafes from standard commercial buildings, typically assumed in generic building performance evaluations. The case was selected because its full-time operation enables the observation of intensive energy behaviours and the interaction between envelope, internal loads, and mechanical cooling.

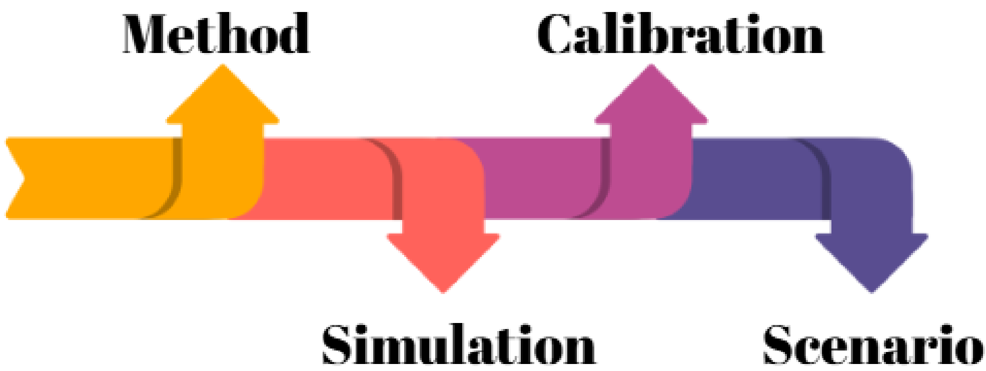

Figure 7. Research Method Framework

Energy performance [6] was assessed using the EDGE platform, version 3.1.0. EDGE provides a reference benchmark derived from IFC datasets [9], which represent standardised assumptions on lighting power density, building envelope performance, HVAC efficiency, infiltration, and internal equipment. These baseline values are predetermined and cannot be altered, thereby ensuring comparability between design alternatives.

In this study, EDGE was used strictly as a decision-support and benchmarking [7] tool rather than a physics-based simulation engine. The software estimates resource performance using static parameters and algorithmic assumptions, without hourly thermal modelling, heat transfer simulation, or refrigeration-HVAC interaction. Accordingly, EDGE outputs are interpreted as comparative indicators rather than absolute representations of actual building behaviour.

Table 1. EDGE Input Parameters for Cafe Oregano

Category	Parameter	Unit	Value (Model)	Source / Note
Occupancy	Operation Hours	h/day	24	Cafe business policy
	Average Occupancy Load	W/person	100	ASHRAE 55 typical cafe profile
Internal Loads	Kitchen electrical load	kW	10.8	Equipment inventory (espresso)
	Refrigerator duty cycle	%	70	Manufacturer catalogue/observation
	Freezer duty cycle	%	75	Manufacturer & observation
Lighting	Lighting power density (LPD)	W/m²	11	EDGE baseline
	Number of luminaires	units	102	Field survey
HVAC System	System type	-	Split DX	As installed
	Cooling capacity per unit	HP	1.0	Nameplate
	Number of units	units	10	Field survey
	COP (nominal)	-	5.7	EDGE baseline/manufacturer data
	Cooling setpoint	°C	25	Owner practice
Envelope	Roof U-value	W/m²·K	2.1	Local construction
	Wall U-value	W/m²·K	1.75	Concrete plaster
	Glazing U-value	W/m²·K	3.2	Single-pane
	Glazing SHGC	-	0.76	Manufacturer/generic data
	Window-to-wall ratio (WWR)	%	35	EDGE geometry input
Ventilation [10]	Infiltration rate	ACH	1.8	Open entrance/door
	Mechanical ventilation	-	Not modelled explicitly	Represented in the EDGE assumptions
Water Fixtures	Basin flow rate	L/min	5	Standard cafe
	WC flush volume	L/flush	6	Standard flush
Schedules	HVAC schedule		24 h no setback	Actual operation
	Lighting schedule		24 h, reduced evenings	Actual operation
	Kitchen equipment schedule		10h peak, 14h idle	Actual operation
Renewables	On-site PV		Not applied	Excluded from retrofit scenario analysis

Building geometry, material composition, operational schedules, and electrical loads were collected through site observation and operational records from Cafe Oregano. The model incorporated actual equipment specifications, including refrigeration units, kitchen appliances, and the operational runtime of air-conditioning systems [11]. All EDGE model parameters were derived from as-built observations, manufacturer data and IFC baseline assumptions. The operational schedule reflects uninterrupted 24-hour business activity, with peak kitchen loads between 8:00 a.m. and 10:00 p.m. and continuous refrigeration duty cycles. HVAC setpoints [12] and equipment capacities were based on actual installations, while glazing, U-values and LPD followed EDGE climate and building-type defaults.

To align simulated values with real consumption, the model was calibrated using monthly electricity bills. Calibration followed the principles of ASHRAE Guideline 14, where the Normalized Mean Bias Error (NMBE) should remain within ±10% and the Coefficient of Variation of the Root Mean Square Error (CV(RMSE)) must remain below 30% for monthly profiles. Parameter adjustments occurred only within documented operational ranges (e.g., refrigeration duty cycles, temperature setpoints [12]) to avoid arbitrary tuning. Calibration ensured that the "base case" model represented actual operational behaviour, enabling interpretable comparison with efficiency scenarios [13].

Calibration was performed using representative billing records and operational load profiles. The simulated energy profile closely matched the measured consumption, yielding a NMBE of −0.46% and a

CV(RMSE) of 2.24%. Both values satisfy the ASHRAE Guideline 14 thresholds for monthly calibration (NMBE ≤ ±10%, CV(RMSE) ≤ 30%), indicating that the model accurately reproduces real operational behaviour.

Table 2. Monthly Calibration of Simulated and Measured Electricity Use

Month	Measured Electricity (kWh)	Simulated Electricity (kWh	Absolute Difference (kWh)	Difference (%)
January	35,280	34,910	370	-1.05%
February	34,120	35,060	940	2.75%
March	36,450	35,980	470	-1.29%
April	34,890	35,220	330	0.94%
May	37,260	36,580	680	-1.82%
June	38,410	36,920	1,490	3.90%
July	39,020	38,040	980	-2.51%
August	38,760	37,880	880	-2.27%
September	37,150	36,980	170	-0.46%
October	36,310	36,590	280	0.77%
November	35,920	36,140	220	0.61%
December	36,870	37,140	270	0.73%
Total	**440,440**	**438,440**	**-**	**-**

2.2 Scenario Construction

Intervention scenarios were developed sequentially to isolate performance contributions and maintain alignment with EDGE logic:

Table 3. Intervention Scenarios

Scenario	Description	Represented Change in Edge	Real-world Implementation
S0	Baseline (EDGE reference)	Fixed default LPD, COP, U-value	n/a
S1	Envelope Improvement	Roof + partial insulation	Passive heat reduction
S2	Lighting Retrofit	LED retrofit	Decrease internal gains
S3	HVAC & Zoning	Inverter 1PK + timer	Demand modulation

Renewable energy was not included in the scenarios, as rooftop photovoltaic systems were not part of the actual operation and would introduce economic distortions that fall outside the observed business model. The scenario set focuses on measures that are realistically applicable to cafes of a similar typology. The energy performance was evaluated through:

1) Energy Performance Index (EPI, kWh/m²/year) [6]
2) Annual electrical consumption (kWh/year)
3) Associated carbon emissions (tCO_2/year)
4) Estimated annual utility cost (IDR/year)

These indicators were selected because they directly reflect operational intensity and allow meaningful scenario comparison under a 24-hour business model. Rather than pursuing EDGE certification thresholds, the study emphasises performance trends, dominant drivers, and economic feasibility of selected interventions.

Table 4. Estimated Capital Expenditure (CAPEX) for the Efficiency Measures

Efficiency Measure	Description	Unit Cost Basis	Quantity	Estimated Cost (IDR)
Roof insulation	50 mm glasswool + aluminium foil, installed	~200,000 IDR/m²	749.2 m²	149,840,000
Partial wall insulation	Interior perimeter retrofit	~150,000 IDR/m²	250 m²	37,500,000
LED retrofit	12W LED lamps, fixtures, labour	~40,000 IDR/unit	100 units	4,000,000
HVAC upgrade	High-efficiency 1 HP inverter split AC	~6,000,000 IDR/unit	10 units	60,000,000
Control & zoning	Digital timer + simple thermostat	~750,000 IDR/zones	10 zones	7,500,000
Subtotal (direct technical)	—	—	—	258,840,000

Design, overhead & contingency (20%)	Contractor margin + unforeseen	0.2 × subtotal	—	51,768,000
Total CAPEX	—	—	—	**310,608,000**

Total investment (rounded) ≈ IDR 310–320 million.

The capital expenditure for the proposed efficiency measures was calculated using market prices commonly available in Indonesia. Roof insulation costs were estimated based on 50 mm glasswool and aluminium foil systems, inclusive of labour and installation, using the total roof area of 749.2 m² (approximately IDR 200,000/m²). Partial wall insulation was applied to an effective surface of 250 m², reflecting a more accessible installation process and a lower average cost (IDR 150,000/m²). Lighting retrofit costs were estimated based on commercial LED lamp prices and basic fixture installation, resulting in an average unit cost of IDR 40,000 for 100 points of illumination. HVAC expenditure was calculated for ten 1 HP inverter split units, combining device cost (Daikin/LG/Panasonic commercial range) and installation, resulting in an average cost of IDR 6,000,000/unit. A simple zoning strategy—utilising digital timers and localised thermostats—implemented in 10 service areas at IDR 750,000 per zone. These values represent direct technical costs used to implement an operationally realistic efficiency package. To account for contractor overhead, installation risk, and unforeseen adjustments, a 20% contingency allowance was added to the subtotal. The resulting total investment ranges from IDR 310 to 320 million. This refined estimate is substantially lower than the original EDGE-based incremental cost (IDR 8.98 billion), indicating that context-specific, selective measures provide higher economic feasibility for small-scale tropical cafe operations. All costs represent initial CAPEX and exclude maintenance, operational financing, and subsidy mechanisms; therefore, the calculated payback should be interpreted as a simplified investment indicator appropriate for early decision-making.

3. RESULTS AND DISCUSSION

Oregano Cafe and Resto is a 24/7 coffee shop located at No.120 Kinibalu Street, Palangka Raya City, Indonesia. The Simulation Project for the Oregano Coffee Shop building in the EDGE simulation falls under the light industrial building category with an area of 408 m², located in Palangka Raya, Central Kalimantan.

Figure 8. Cafe Location

3.1 Baseline Performance Characterisation

The original EDGE simulation model indicated severe inefficiency for the existing cafe building. The baseline Energy Performance Index (EPI) [6] reached 778.53 kWh/m²/year, which is significantly higher than typical commercial benchmarks and corresponds to –32.50% efficiency relative to EDGE standard requirements. Annual electricity consumption was recorded at 420,858 kWh, producing an estimated 314.6 tCO_2e. These results reflect the intensive 24-hour operational profile of the case study, driven primarily by continuous refrigeration demands, food-preparation appliances, and uncompartmentalized cooling loads. The performance was not interpreted as a construction deficiency, but as the outcome of applying standardised IFC assumptions to an atypical high-intensity typology. Importantly, this baseline condition does not imply design failure; instead, it highlights a modelling misalignment whereby EDGE's rule-based assumptions treat cafes as low-intensity commercial spaces. Refrigeration duty cycles, thermal exhaust from kitchen equipment, and nighttime cooling are not explicitly captured in EDGE's static baseline. Consequently, the negative performance metric should be interpreted as a limitation of standardised simulation inputs rather than a direct representation of building inefficiency.

3.2 Calibrated Improvement Scenario

After parameter refinement and model calibration against monthly electricity bills, the "after case" demonstrated a measurable improvement in simulated performance [13]. The EPI decreased to 674.55 kWh/m²/year, corresponding to +13.36% relative efficiency. Annual consumption was reduced to 275,215 kWh, resulting in a decrease in CO_2 emissions to 206.4 tCO_2e. These values demonstrate the positive impact of envelope insulation, LED retrofitting, and the implementation of higher-efficiency HVAC systems. Although the improvement is significant, it does not meet the minimum 20% EDGE certification threshold, indicating that cafes have a structural energy intensity that is difficult to offset solely through design-side measures. The continuous thermal gains of kitchen equipment and refrigeration produce latent cooling loads [8] that exceed the typical efficiency of building strategies, even when envelope and lighting measures are implemented.

3.3 Sensitivity of Dominant Energy Drivers

Three subsystems were identified as primary contributors to energy consumption:

(1) HVAC Cooling

Cooling loads are the dominant driver, amplified by:

1) High internal gains from appliances
2) Continuous daytime and nighttime occupancy
3) Weak zoning and temperature setbacks
4) Door-driven infiltration from customer flows

Replacing fixed-speed units with inverter systems allowed partial-load modulation, reducing compressor runtime and improving seasonal performance. HVAC upgrades yielded the most substantial impact among all interventions.

(2) Refrigeration

Refrigeration systems represent persistent base loads, operating at duty cycles of 60–85% regardless of occupancy. Unlike HVAC, refrigeration loads cannot be mitigated through behavioural control or scheduling [14]. Their heat rejection increases the latent load on HVAC systems, thereby compounding energy consumption. This observation explains why envelope measures alone produced limited improvements.

(3) Lighting

LED retrofits produced modest but consistent reductions in energy and internal heat gain. While lighting is not a dominant load, replacing outdated fixtures reduces the cooling penalty and, therefore, indirectly contributes to improved HVAC performance [14]. The sensitivity findings reinforce that cafes must prioritise demand control (insulation, zoning, HVAC selection) over generic equipment additions. Efficiency must begin by reshaping load behaviour rather than adding capacity to compensate for it [15].

Table 5. Base Case and After Case

Scenario	Model Basis	EPI	Total kWh/year	CO_2	Annual Cost	CAPEX
Base Case	EDGE Default	778.5	420,858	314.6	Rp714M	—
After Case (Selective)	Envelope + LED + HVAC + controls	674.5	275,215	206.4	Rp506.9M	Rp310-320M

Note: After Case refers to S3 (selective interventions) & PV not included

3.4 Economic Feasibility of Selective Efficiency Measures

To evaluate the real-world feasibility, the improvement scenario was translated into a selective retrofit package based on market prices in the Indonesian market. Instead of implementing all EDGE-suggested measures, the study focused on four targeted interventions:

a) Roof insulation (749.2 m²)
b) Partial wall insulation (250 m²)
c) LED retrofitting (100 fixtures)
d) Replacement of 10 non-inverter 1 HP AC units with high-efficiency inverter units
e) Basic control and zoning strategy

Using local vendor pricing and installation estimates, the total capital cost was approximately IDR 310–320 million, including a 20% contingency for overhead and unforeseen installation conditions. When compared to the simulated annual electricity cost savings (IDR 207 million/year), the selective package yields a simple payback period of 1.5–2 years, which stands in sharp contrast to the earlier EDGE investment estimate, whose payback time exceeded 50 years.

This finding demonstrates that realistic retrofit strategies must be based on localised costs and operational priorities [16] rather than uniform EDGE formulations. In small hospitality businesses, rapidly amortising measures—such as HVAC zoning, insulation, and LED retrofits—offer significantly greater adoption potential than capital-intensive interventions [17].

3.5 Limitations of Simulation-Based Assessment

EDGE offers a structured and accessible benchmark [7] for building performance; however, its computational framework limits applicability to high-intensity cafes. The tool does not model:

a) hourly thermal mass behaviour,
b) refrigeration-heat coupling,
c) night-time setback strategies,
d) kitchen ventilation or exhaust kinetics,
e) compressor cycling and HVAC staging.

These omissions are critical in cafe environments, where latent loads [8] are driven by internal processes rather than climatic factors. Therefore, EDGE should be positioned as an early decision-support instrument rather than a definitive diagnostic tool [18]. For high-intensity food-service facilities, detailed building energy simulations or monitored performance data are necessary for accurate system-level optimisation.

4. CONCLUSION

This study demonstrates that the energy demands of 24-hour cafes differ significantly from those of typical commercial buildings and that performance assessments must account for continuous refrigeration, kitchen heat gains, and uncontrolled night-time cooling. The EDGE baseline model identified the case study cafe as highly inefficient; however, this outcome reflects standardised IFC assumptions rather than poor construction quality. Once operational profiles, internal loads, and setpoints [12] were calibrated, simulated performance improved, confirming that energy intensity in cafes is primarily driven by service equipment and HVAC behaviour. The improvement scenario revealed that cafe efficiency can be achieved through targeted interventions rather than comprehensive technology packages. Envelope insulation reduces conductive heat gain, LED retrofitting lowers internal lighting loads, and high-efficiency inverter HVAC units modulate cooling demand more effectively than fixed-speed systems. When translated into a localised investment scenario using Indonesian market pricing, these measures form an economically viable package with an estimated payback period of 1.5–2 years. This result stands in contrast to generic EDGE incremental-cost projections, demonstrating the importance of aligning performance strategies with real operational constraints.

More generally, the results suggest that EDGE is best employed as a decision-support framework for identifying trends and prioritising measures, rather than as a standalone simulation engine for high-intensity commercial typologies. For cafes and similar service facilities, calibrated inputs, scenario-based assessment, and economic feasibility studies are required to transform digital assessments into actionable building design strategies. In contrast to certification-oriented simulations, the selective retrofit analysis pursued in this work was not targeted at maximising EDGE scores, but at contextualising the platform's decision-support logic within realistic economic constraints commonly found in small-scale cafes. This approach safely maintains EDGE as a valuable analytical tool without imposing unrealistic investments in renewables or relying on template-based assumptions. The mismatch observed between EDGE baseline assumptions and actual cafe performance is a direct consequence of applying static benchmarks to a typology with continuous internal loads.

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