ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

Deep-Dive Assessment of 250 Buildings in Cambodia

Energy and Carbon Benchmarking to Support Implementation of Low-Carbon Building Solutions

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IKI INTERNATIONAL CLIMATE INITIATIVE

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

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CONTENTS

List of Figures ii
List of Tables iii
Acronyms and Abbreviations iv
Acknowledgement v
Executive Summary vi
1. Introduction 1
2. Building Assessment Approach 2
2.1 Building Selection 3
2.2 Walk-Through Audit 5
3. Key Findings 7
3.1 Energy Audit Results 10
3.2 Energy Conservation Measures 13
3.3 Investment Potential 17
4. EPI Benchmarking 20
4.1 Residential Buildings 21
4.2 Hospitality Buildings 21
4.3 Educational Buildings 22
4.4 Commercial Buildings 22
4.5 Retail Buildings 23
4.6 Comparison of Cambodia's EPI with Regional Countries 23
5. Recommendations and Lessons Learned 25
5.1 Recommended Buildings for Investment 25
5.2 Lessons Learned 26
Conclusion 28
Appendices 29
Appendix I: Methodology to Estimate Bill of Quantities (BOQs) 29
Appendix II. List of energy efficiency suppliers 34
Appendix III: Building Types Suitable for Cambodia 35
Appendix IV: Detailed Energy Conservation Measures 36

List of Figures

Figure 1. Data Collection During Site Visit 1
Figure 2. Data collection process 2
Figure 3. Construction year timeline 4
Figure 4. Life-cycle carbon footprints by building types 7
Figure 5. Energy consumption by building type in Cambodia 8
Figure 6. Average embodied carbon footprints by building type 9
Figure 7. Average annual operational carbon footprints by building type 10
Figure 8. Average investment potential with average GHG savings for various building types 17
Figure 9. EPI of building types in Cambodia 20
Figure 10. EPIs of residential buildings 21
Figure 11. EPI of the hospitality sector 21
Figure 12. EPIs of educational buildings 22
Figure 13. EPIs of office buildings 22
Figure 14. EPIs of retail buildings 23
Figure 15: Inverter-based Air Conditioner. 38
Figure 16: Induction Ceiling Fan. 39
Figure 17: Representative image of a BLDC fan with remote. 39
Figure 18: Installation of occupancy sensor in toilet. 41
Figure 19: Installation of Digital Programmable Timer Switch. 44
Figure 20 - Existing rooftops exposed to sunlight. 46
Figure 21. Potential of using sunlight for illuminations. 47

List of Tables

Table 1. Average carbon footprints, energy consumptions, and saving potential by building type vi
Table 2. Summary of recommendations to reduce operational carbon footprint vii
Table 3. Cambodia's EPI profiles compared with countries in the region viii
Table 4. Key parameters and analyses 3
Table 5. Distribution of 250 buildings by building type 4
Table 6. Grid Emissions Factors 6
Table 7. Emission factors for building materials 6
Table 8. Summary of recommendations to reduce operational carbon footprint 13
Table 9. Total energy savings (kWh) potential by building type (250 buildings) 15
Table 10. Building type-wise investment potential of respective ECMs for 250 buildings 18
Table 11. Comparison of EPI benchmarks across neighbouring countries 23
Table 12. Suitability matrix for selecting buildings for the pilot phase 25
Table 13. Recommended buildings for pilot projects sorted by energy saving potential 25
Table 14. Challenges encountered and resolutions during building assessment in Cambodia 26

Acronyms and Abbreviations

AC	Air Conditioner
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEAT	Building Emission Assessment Tool
BLDC	Brushless Direct Current
BOQ	Bill of Quantities
BUA	Built-Up Area
CSPF	Cooling Seasonal Performance Factor
ECM	Energy Conservation Measure
EDGE	Excellence in Design for Greater Efficiencies
EPD	Environmental Product Declaration
EPI	Energy Performance Index
ESCO	Energy Service Company
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air Conditioning
kWp	Kilowatt-peak (solar capacity)
LCA	Life Cycle Assessment
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MLMUPC	Ministry of Land Management, Urban Planning and Construction
PV	Photovoltaic
RCC	Reinforced Cement Concrete
ROI	Return on Investment
SEER	Seasonal Energy Efficiency Rating
SQM	Square Meter
VFD	Variable Frequency Drive
VRV	Variable Refrigerant Volume
VSD	Variable Speed Drive
WWR	Window-to-Wall Ratio

Acknowledgement

The deep-dive assessment of 250 buildings represents a significant collective effort to advance evidence-based understanding of building energy and carbon performance in Cambodia.

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Technical review and guidance were provided by the Technical Advisory Committee (TAC) of the ALCBT project, with particular contributions from the Ministry of Mines and Energy (MME) and MLMUPC. Embodied carbon analysis benefited from review by HEAT GmbH. Additional technical inputs and data were further enriched by entities active in Cambodia's building sector, including EnergyLab Asia, Sevea Consulting, and WWF Cambodia.

The ALCBT project, through the Cambodia country team of the Global Green Growth Institute (GGGI), led the overall assessment, contributing substantially to data collection, quality assurance, and report coordination.

This report was made possible through the financial support of the International Climate Initiative (IKI) of Germany's Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety.

Executive Summary

This report presents findings from a comprehensive energy assessment of 250 buildings in Phnom Penh and Kandal Province. It identifies viable energy efficiency measures, quantifies payback periods and return on investment (ROI), and estimates carbon emissions using the Building Emission Assessment Tool (BEAT)[1]. The study also evaluates the Energy Performance Index (EPI) and establishes baseline benchmarks for the country. Data collection and operational carbon assessment followed the ASHRAE Level 2 Energy Audit standards[2], including site walkthroughs, utility data review, staff interviews, and detailed technical and financial analysis.

The 250 buildings were segregated by building types based on EDGE[3] (Excellence in Design for Greater Efficiencies) classifications for analysis in this report. Table 1 summarizes the average carbon footprints, energy consumptions, and saving potential by building type.

Table 1. Average carbon footprints, energy consumptions, and saving potential by building type

Building Type	No. of buildings assessed	Average Embodied Carbon/built-up area (BUA) ($kgCO2_e/m^2$)	Average lifetime operational carbon/BUA ($kgCO2_e/m^2$)	Average Annual Liquefied Petroleum Gas (LPG) Consumption per building (litres)	Average Annual Diesel Consumption per building (litres)	Average Annual Electricity Consumption per building (kWh)	Total Electricity Saving Potential (kWh/year)	Total GHG Emission Reduction Potential ($kgCO2_{e/year}$)
Apartment Building	14	291.7	2,217.4	27,975	136	3,069,645	5,266,579	3,212,613
Education – Other Educational Facilities	11	297.9	1,024.1	-	-	81,639	256,729	156,605
Education – School	18	264.2	2,286.7	-	746	605,156	2,756,127	1,681,237
Education – Sports Facilities	7	452.0	2,325.5	-	-	371,654	9,143	5,577
Education – University	4	248.3	2,329.4	-	467	560,322	380,618	232,177
Healthcare – Clinics	4	416.5	2,062.7	-		16,859	955	5823
Healthcare – Dental Hospital[4]	1	405.4	1,057.8	-	-	8,879	-	-
Healthcare – Public Hospital	1	260.7	10,700.3	-	-	841,989	17,502	10,676
Home	12	392.6	1,870.8	874	101	55,457	10,731	6,546
Hotel - 2 star	1	436.3	6,728.6	-	-	992,745	3,421	2,087

[1] Asia Low Carbon Buildings Transition (ALCBT) Project, *Building Emission Assessment Tool (BEAT)*, https://beat-alcbt.gggi.org/
[2] https://www.ashrae.org/technical-resources/bookstore/procedures-for-commercial-building-energy-audits
[3] Green Business Certification Inc. (GBCI). *EDGE: Green Building Certification*. https://edge.gbci.org/
[4] The building was constructed in 2023 and equipped with modern systems which are functioning efficiently. No recommendations are currently necessary.

Hotel – 3 star	3	261.0	5,367.1	-	333	1,176,892	168,846	102,996
Hotel – 4 star	9	248.0	4,739.1	-	-	657,626	17,180	10,480
Industrial – Warehouse	2	349.4	1,385.9	-	50	273,849	39,055	23,823
Mixed Use – Self Defined	12	573.2	3,428.0	7,320	1,535	3,409,730	1,591,993	971,116
Office	112	311.5	2,808.0	-	214	410,753	6,054,916	3,693,499
Pagoda – non-EDGE category	1	369.0	603.0	-	-	5,694	1,734	1,058
Resort[5] – 5 star	1	216.5	8,484.0	-	-	8,000,000	-	-
Retail – Department Store	2	659.1	3,388.3	-	-	142,972	1,732	1,057
Retail – Non-food Big Box Retail	6	366.5	2,188.0	-	-	206,144	2,596	1,583
Retail – Shopping Mall	9	321.4	4,135.8	-	628	705,780	259,869	158,520
Retail – Small Food Retail	12	375.5	8,261.7	1,546	2,684	94,666	76,858	46,883
Retail – Super Market	4	484.8	16,853.8	-	-	666,347	185,887	113,391
Serviced Apartments	4	225.1	5,583.4	100,519	16,508	7,824,700	3,092,366	1,886,343

Across all building types, significant energy-saving measures were identified during energy audits, many of which are readily available in the Cambodian market. Table 2 lists 12 energy conservation measures (ECMs) identified from the assessment and estimates the energy saving potential, simple payback period, and total investment needed across all cases.

Table 2. Summary of recommendations to reduce operational carbon footprint

Energy Conservation Measures	Percentage Energy Saving Potential	Payback Period	Total cases out of 250	Total Investment Potential (USD)
ECM1: Increasing the set temperature of the Air Conditioners (ACs) by 3 degrees	Up to 20%	Immediately	6	No capital cost
ECM2: Retrofit of ACs with Efficient Inverter	Up to 40%	Up to 4 years	57	5,084,110
ECM3: Replacement of Induction Fans with BLDC (Brushless Direct Current) Fans	Up to 50%	Up to 2 years	6	5,312
ECM4: Retrofit of tube lights with LED (Light Emitting Diode) tube lights	Up to 50%	Up to 2 years	66	181,463

[5] The resort is relatively new and has installed systems where retrofitting is not economically viable due to a longer payback period, the assessment recommends that any future investments in HVAC systems should prioritize high-efficiency models.

ECM5: Installation of Occupancy sensors	Up to 60%	Up to 2 years	82	36,580
ECM6: Installation of Variable Speed Drives (VSDs)/ Variable Frequency Drives (VFDs)	Up to 30%	Up to 2 years	1	139,860
ECM7: Applying Sun Control Window Film	Up to 30%	Up to 4 years	25	1,032,628
ECM8: Installation of Timer Switch for Water Dispenser	Up to 50%	Up to 1 year	43	10,170
ECM9: Installation of Rooftop Solar Photo-Voltaic System	Up to 15%	Up to 8 years	9	3,331,274
ECM10: Cool Paint	Up to 15%	Up to 3 years	3	8,192
ECM11: Daylight Integration	Up to 20%	Immediately	1	No capital cost
ECM12: Air Curtain Motion Sensor	Up to 20%	Up to 1 year	2	140

Findings from the energy audits indicate that most buildings, irrespective of type, have opportunities for energy efficiency improvements. Recommended interventions are based on technologies commonly available in the local market. Several energy conservation measures (ECMs) require no capital investment while offering substantial energy-saving potential. Common intervention measures identified across building types include AC retrofits, installation of occupancy sensors, LED lighting retrofits, and installation of timer switches for water dispensers. Other than rooftop solar power systems, which have an estimated payback period of eight years, all other recommended ECMs show a payback period of less than four years.

Based on energy performance comparison across building types (kWh/m²/yr), Cambodia's EPI profile, based on 250 building energy assessments, shows both strengths and clear opportunities relative to its regional peers as summarized in table 3.

Table 3. Cambodia's EPI profiles compared with countries in the region

EPI (kWh/m²/yr)	Residential building	Hospitality building	Educational building	Commercial building - Offices/ Mixed use	Retail Chain building
Cambodia	106.6	171	64.6	131.6	205.5
Thailand[6] [7]	102.4	255	100	225	-

[6] *Christopher Charles Seeley and Shobhakar Dhakal*. "*Energy Efficiency Retrofits in Commercial Buildings: An Environmental, Financial, and Technical Analysis of Case Studies in Thailand*." Energies 14, no. 9 (2021): 2571. https://www.mdpi.com/1996-1073/14/9/2571

[7] Climate Technology Centre & Network (CTCN). *CTCN Project Handbook for Practitioners*. Rev. 02. Copenhagen: Climate Technology Centre & Network, 2021. https://www.ctc-n.org/system/files/dossier/3b/CTCN%20Project_Handbook-2_Practioner_Rev.02_2021.12.30_Eng%20New.pdf

Singapore[8]	64	220	89	143	375
Vietnam[9]	102	182	100	135	200

Overall, Cambodia demonstrates notable strength in educational buildings, while residential, hospitality, commercial, and retail sectors present significant opportunities for targeted energy efficiency improvements. Notably, the comparisons are indicative due to methodological differences across countries.

The ALCBT project in Cambodia, having successfully completed the deep-dive assessment of buildings, is now well positioned to transition into the implementation phase. This next stage will focus on transforming existing buildings to significantly reduce both operational and embodied carbon emissions.

[8] Building and Construction Authority (BCA). *"Building Energy Benchmarking." BuildSG.* https://www1.bca.gov.sg/buildsg/sustainability/regulatory-requirements-for-existing-buildings/bca-building-energy-benchmarking-and-disclosure

[9] Dang, Hoang Anh. "Development of Specific Energy Consumption Profile for Typical Buildings in Vietnam." *Journal of Science & Technology 57* https://jst-haui.vn/media/30/uffile-upload-no-title30665.pdf

1. Introduction

The Asia Low Carbon Buildings Transition (ALCBT) project[10]'s deep-dive building assessment focuses on conducting energy audits and life-cycle assessments of buildings in Phnom Penh and Kandal Province to support and prepare the building sector for low-carbon transition, including reductions in both operational (Figure 1: Data collection at site) and embodied carbon footprints. The project includes the development of a robust building registry database comprising new and existing buildings, energy audits of 250 buildings with corresponding audit reports, and the development of energy-saving recommendations to reduce operational carbon footprints. The life-cycle assessments (LCA) of 250 buildings were conducted using BEAT[11], a web-based LCA platform that quantifies both operational and embodied carbon across a building's lifecycle. The tool was developed by HEAT GmbH as part of the ALCBT project.

This report documents observations and presents a summary of data analytics from the 250 building audit reports and emission calculation results, highlighting the following data trends:

- Analyze carbon footprints of buildings
- Quantify embodied carbon using BEAT
- Propose practical building types suitable for the country
- Establish Cambodia's first EPI benchmarks
- Recommend actionable strategies to reduce energy consumption

Figure 1. Data Collection During Site Visit

[10] Global Green Growth Institute (GGGI), *Asia Low Carbon Buildings Transition (ALCBT) Project*, https://alcbt.gggi.org/about/
[11] Asia Low Carbon Buildings Transition (ALCBT) Project, *Building Emission Assessment Tool (BEAT)*, https://beat-alcbt.gggi.org/

2. Building Assessment Approach

A building registry of 1,200 buildings was developed prior the commencement of deep-dive assessment in consultation with the government counterpart – Ministry of Land Management, Urban Planning and Construction (MLMUPC). The registry collected basic building information such as built-up area, energy consumption, year of construction, and building type. Out of the 1,200 buildings, 250 buildings were shortlisted for the deep-dive assessment phase. Site visits were conducted to collect technical specifications of electrical equipment and appliances installed in the buildings, along with energy consumption data from utility bills, to estimate the operational carbon of the building. For embodied carbon calculation, bill of quantities (BOQs) of construction materials are normally required. However, since majority of the buildings did not have available BOQs, a methodology was developed to estimate construction materials to establish the embodied carbon footprint of the buildings.

The building audit process required scheduling site visits in consensus with the building owners as illustrated in Figure 2. In some cases, multiple visits were required to secure participation, and a standardized process was adopted.

Figure 2. Data collection process

The methodology for data collection and evaluation of operational carbon footprint was aligned with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Level 2 Energy Audit standards, which include a basic walk-through assessment, review of utility bills and other applicable operational data, interviews with operations staff, and detailed energy calculations and financial analysis of proposed energy measures. Level 2 audits use utility data over a longer period, enabling auditors to better understand energy usage patterns. The financial analysis is used to develop a business case for implementing energy measures.[12]

The key parameters collected in the building energy audits include building information (occupancy hours), lighting systems, Heating, Ventilation, and Air Conditioning (HVAC) systems, pumping systems, electrical equipment, types of fuel used, diesel generators, and renewable energy systems. These data were used to determine energy consumption by different systems in a building and develop the EPI as summarized in the Table 4.

Based on audit findings and site conditions, suitable energy efficiency measures are recommended for each building, along with a financial analysis of cost benefits and payback periods.

[12] ASHRAE. *Procedures for Commercial Building Energy Audits*. 2nd ed. Atlanta: ASHRAE, n.d. https://www.ashrae.org/technical-resources/bookstore/procedures-for-commercial-building-energy-audits

Table 4. Key parameters and analyses

	Key parameters	Analyses
Operational Carbon	• Building information (occupancy hours) • Lighting systems • HVAC systems • Pumping systems • Peripheral electrical equipment • Types of fuel used • Diesel generators • Renewable energy systems.	• Energy consumption by different systems in the building • Operational carbon emissions • EPI • Energy saving opportunities • Cost benefit analysis • Payback period
Embodied Carbon	• Exterior and Interior wall area, • Windows, • Bricks used, • Steel used, • Cement used, • Roof Area, • Floor area	• Types of material used. • Estimation of excavation • Embodied Carbon of building

The BOQs of construction materials were collected, where available, to estimate embodied carbon using BEAT. BOQs provide information on material types and quantities used in building construction. However, in most of the cases where BOQs were unavailable, material quantities were estimated using architectural drawings, site visit measurements, and other available documentation. Details of the BOQ estimation methodology are provided in Appendix I.

2.1 Building Selection

The 250 buildings were meticulously selected from the extensive database of more than 1200 buildings on the basis of diverse building categories, sizes, ages, and operational characteristics. Selection criteria included:

- Representation of building Types
- Energy intensity of buildings
- Availability of utility bills or BOQs
- Willingness of owners to participate
- Representation of key building functions in Cambodia

The criteria to select the buildings and the list of selected buildings were finalized in consultation with MLMUPC and the Technical Advisory Committee of ALCBT Cambodia. The building types selected are indicated in Table 5 and their construction years are in Figure 3.

Table 5. Distribution of 250 buildings by building type

Building Category with sub-categories		Total Numbers
Apartment		14
Serviced Apartments		4
Homes		12
Hospitality	Hotel - 2 star	1
	Hotel – 3 star	3
	Hotel – 4 star	9
	Resort – 5 star	1
Retail	Retail – Department Store	2
	Retail – Non-food Big Box Retail	6
	Retail – Shopping Mall	9
	Retail – Small Food Retail	12
	Retail – Super Market	4
Industrial – Warehouse		2
Office		112
Healthcare	Healthcare – Clinics	4
	Healthcare – Dental Hospital	1
	Healthcare – Public Hospital	1
Education	Education – Other Educational Facilities	11
	Education – School	18
	Education – Sports Facilities	7
	Education – University	4
Mixed Use		12
Pagoda (non-EDGE category)		1

Buildings were categorized according to EDGE types specific to Cambodia, such as Pagodas. The project ensured representation of dominant building types within the country. Based on findings from this assessment, revised building types suitable for Cambodia are proposed in Appendix III.

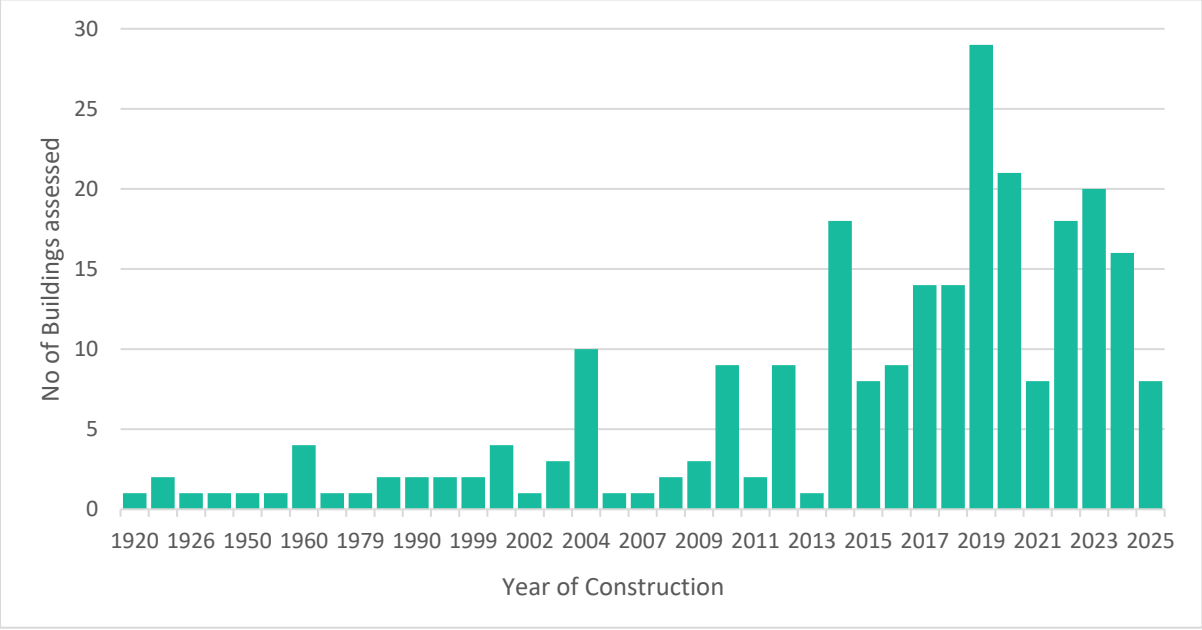


Figure 3. Construction year timeline

The 250 buildings had a combination of 200 existing buildings and 50 new buildings (classified as those constructed in late 2022, 2023, 2024 and 2025). This diversity enables evaluation of energy efficiency practices and operational carbon footprints across different building generations.

2.2 Walk-Through Audit

The walk-through audit aimed to develop a preliminary understanding of building energy performance by observing equipment operation, identifying no-cost and low-cost opportunities, and identifying areas for deeper analysis. The scope covered all buildings within each campus or portfolio (e.g., Block A–D), including all floors and functional areas (office spaces, common areas, utility rooms, server rooms, basements, parking, and rooftops).

From April to November 2025, systematic walk-through audits of 250 buildings in Phnom Penh and Kandal Province were conducted. On average, each site visit required one to three hours per building to complete a comprehensive floor-by-floor assessment, following a standardized checklist aligned with energy auditing best practices. Key steps included:

- **Pre-audit preparation**: Review of building layouts, single-line diagrams, equipment lists, and available utility bills (if provided).
- **On-site walkthrough**: Floor-by-floor inspections during normal operating hours to observe actual usage patterns and controls.
- **Visual assessment of building envelope**: Inspection of building materials, glazing types, shading devices, roof construction, and signs of heat gain/loss.
- **Equipment verification**: Verification of appliances and equipment (lighting, HVAC, pumps, fans, office equipment, kitchen appliances, elevators, server room cooling, etc.), focusing on technical specifications, nameplate data, operational status, and controls.
- **Dimensions and spatial profiling**: Estimation/confirmation of key building dimensions (floor area, ceiling heights, window-to-wall ratios (WWR), conditioned vs. unconditioned areas) to normalize findings and estimate loads.
- **Stakeholder interviews**: Short discussions with operations/maintenance staff to understand schedules, setpoints, maintenance practices, and pain points.
- **Documentation**: Photographs, notes, and preliminary quantification of opportunities for energy savings.

Based on data collected, detailed ASHRAE Level 2 energy audits were developed for each facility. These audits provided comprehensive analyses of the basic building features, operational characteristics, and energy consumption patterns derived from utility bills provided by building owners. The objective was to identify actionable ECMs and quantify their potential impact on energy savings, carbon emission reductions, and financial performance. Each ECM assessment provides:

- Energy Saving Potential: Estimated annual reduction in kWh
- Carbon Emission Reduction: Calculated based on grid emission factors and fuel type
- Investment Requirement: Capital cost for implementation
- Monetary Savings: Annual cost reduction based on current tariffs
- Payback Period: ROI due to monetary savings in years

2.2.1 Estimation of Carbon Footprint

The methodology for estimating the carbon footprint of buildings covered assessments of both operational and embodied carbon emissions.

Operational Carbon

Operational carbon emissions were calculated based on annual energy consumption from electricity, diesel, and LPG. Activity data were obtained from utility records and site information. Energy consumption figures were multiplied by appropriate country- or region-specific emission factors (Table 6) to convert them into carbon dioxide equivalent (CO_2e) emissions.

Table 6. Grid Emissions Factors[13]

Sl No	Energy Type	Emission Factor	Units
1	Electricity	0.61	$kgCO_2e/kWh$
2	Diesel	2.6	$kgCO_2e/Litre$
3	LPG	1.56	$kgCO_2e/Litre$

Embodied Carbon

Embodied carbon emissions were estimated based on the quantities of construction materials used in the buildings, typically documented in the BOQs. However, as detailed BOQs were not available for buildings in Cambodia, a proxy estimation methodology was developed. This involved site visits, visual inspections, stakeholder consultations, and reference to standard construction practices and material specifications commonly used in the local context. Estimated material quantities were multiplied by relevant embodied carbon emission factors to derive total embodied carbon emissions. Table 7 presents the emission factors for different building materials, derived from BEAT (version 1)[14]. The latest version of BEAT may have different emission factor values.

Table 7. Emission factors for building materials

Construction Building Materials	Emission factors as per BEAT tool (kg CO_2e)
C30 Concrete (kg/m3)	445.33
Rebar (kg/kg)	2.6
Mortar (kg/m2)	13.05
Bricks (kg/m2)	6.86
Aluminum (kg/m2)	175
Glass (kg/m2)	33.71
Steel (kg/kg)	5.05
Tiles (kg/m2)	11.03
Plywood[15] (kg/m3)	-1238.69

[13] Grid Emission Factors in Cambodia, Ministry of Environment
[14] BEAT Version One, accessed in Dec 2025, ALCBT Project, *BEAT*, https://beat-alcbt.gggi.org/
[15] The negative values for plywood are primarily due to carbon sequestration and the way biogenic carbon is accounted for during the product's life cycle. This indicates that the amount of atmospheric carbon dioxide absorbed and stored by the trees during growth exceeds the total greenhouse gas emissions generated during the manufacturing and transportation of the product.

Paint (kg/m2)	0.48

3. Key Findings

Cambodia's building stock typically relies on older fixed-speed ACs, legacy refrigerators, induction fans, and fluorescent lighting. Controls are often manual, with limited or no-use of occupancy/daylight sensors, timer automation, or variable-speed drives. Glazing is frequently clear and unshaded, resulting in high solar heat gains and increased cooling loads. Simple operational changes—notably raising AC setpoints—and targeted retrofits (inverter ACs, LEDs, BLDC fans, window films, VFDs, and timers) offer high-impact energy savings with short payback periods in most cases.

Assuming an average building lifetime of 50 years, the average operational and embodied carbon footprints by building type, per unit square meter built up area, are demonstrated in Figure 4. Based on the analysis, retail supermarkets show the highest life-cycle carbon footprint, while pagodas show the lowest in the country.

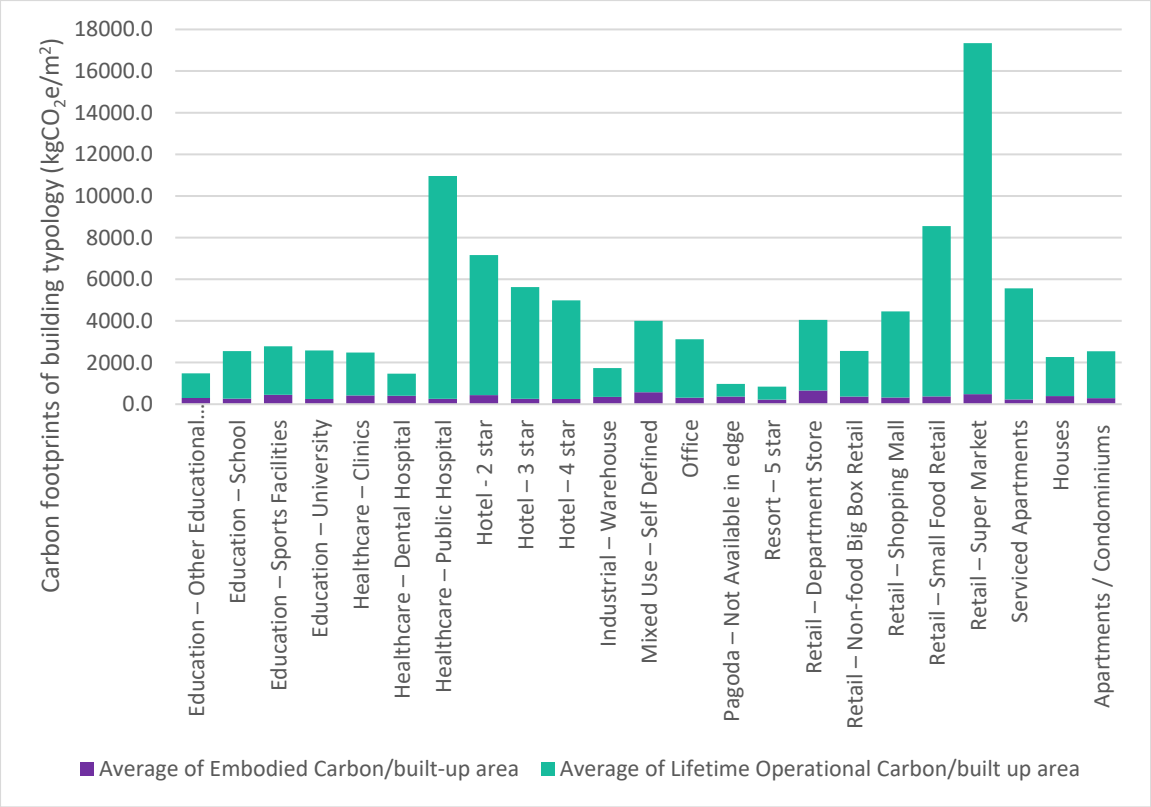


Figure 4. Life-cycle carbon footprints by building types

Based on electricity consumption analysis across the 250 buildings and categorization by type (Figure 5), it was found that the Residential categories, particularly serviced apartments and apartments /condominiums, show the highest consumption levels, with serviced apartments peaking at around 7.5 million kWh annually. Mixed-use developments and large commercial spaces such as offices and retail (especially supermarkets and shopping malls) also exhibit high energy demand, reflecting their continuous and intensive operations. In contrast, smaller facilities such as pagodas, clinics, and certain educational or healthcare buildings consume relatively low amounts of electricity. Hotels display a gradual increase in consumption from 2-star to 4-star categories, indicating higher service levels and amenities driving energy use. Overall, the graph underscores how building function, scale, and operational intensity strongly influence electricity consumption patterns.

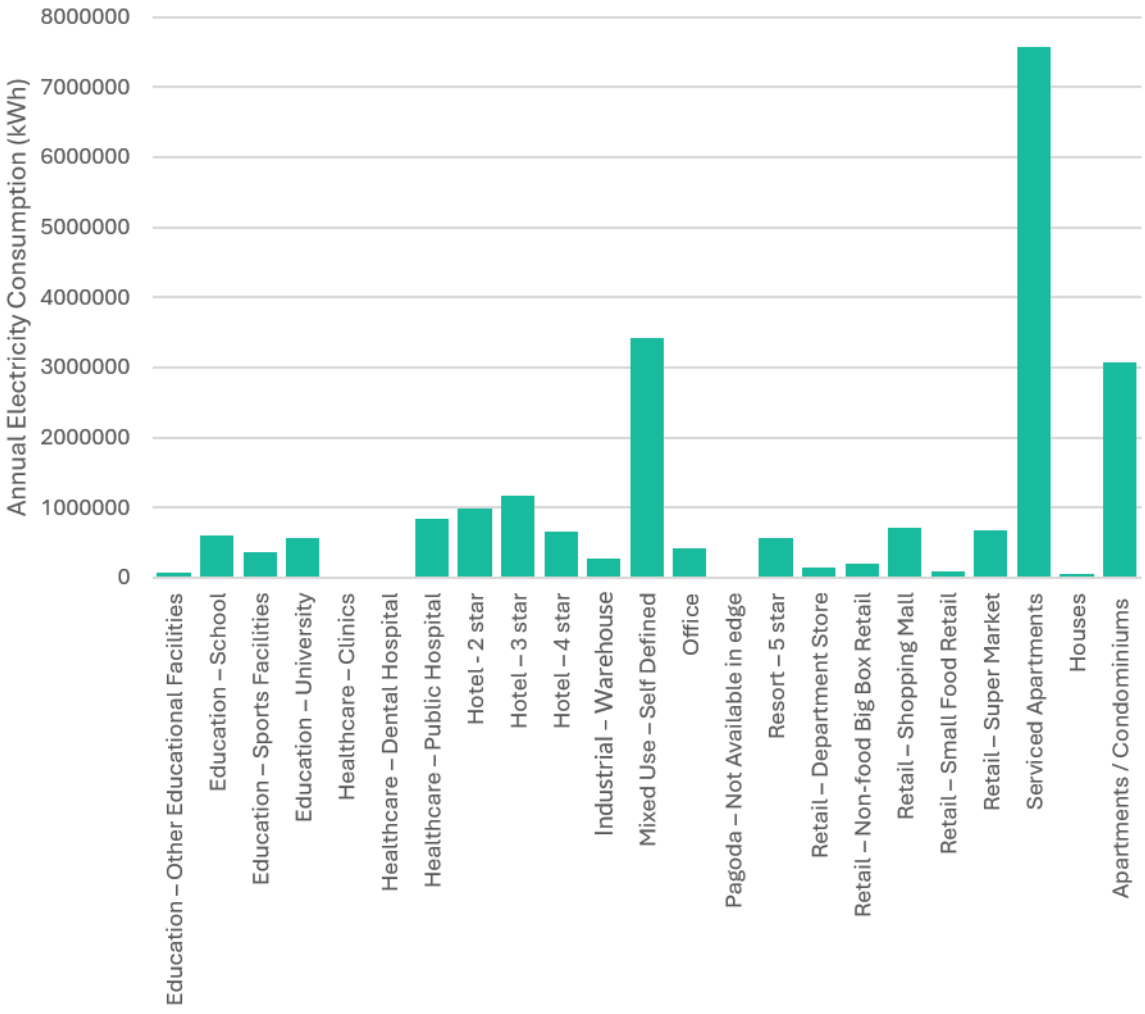


Figure 5. Energy consumption by building type in Cambodia

Embodied Carbon Footprints

Embodied carbon is measured by the quantity and types of construction materials used during construction. During the energy audits, the official BOQs were requested from building owners; however, BOQs were largely unavailable. Hence, embodied carbon was estimated using a proxy methodology based on site visits, visual inspections, stakeholder consultations, and reference to standard construction practices and material specifications commonly used in Cambodia. Material quantities were then estimated and input into BEAT. Two main construction techniques were observed: **steel structures** and **reinforced cement concrete (RCC)** structures. Of the 250 buildings assessed, **22** were constructed using the steel structures and **228** using conventional RCC structures.

The average embodied carbon footprints by building type are indicated in Figure 6. The highest average embodied carbon per unit built-up area (sqm) is in the retail department stores, while the lowest is observed in the 5-star resort (hospitality) building type.

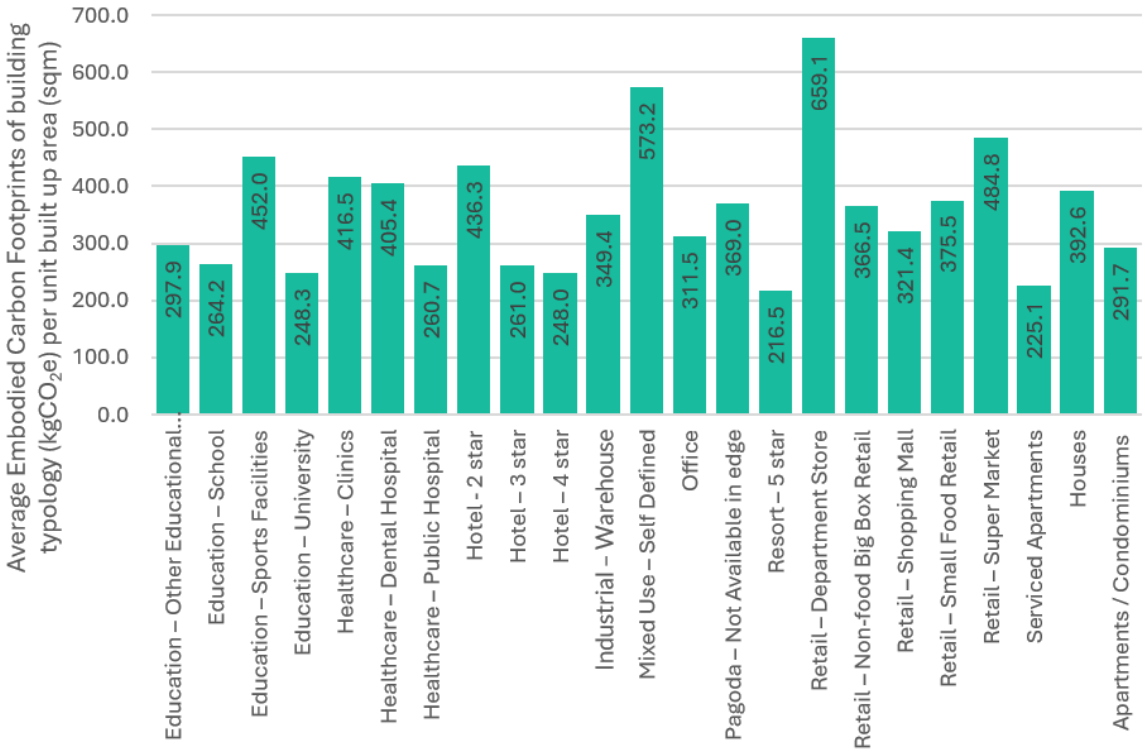


Figure 6. Average embodied carbon footprints by building type

Operational Carbon Footprints

Average operational carbon footprints, including electricity, diesel, and LPG consumption, are indicated in Figure 7. The consumptions of diesel and LPG across the building types were very small attributed by data deficiency during assessment, genset availability in some buildings, and relatively low frequency of blackouts in recent years. The highest average annual combined energy consumption is observed in serviced apartments, while the lowest combined energy consumption (average) usage in a year is in the clinics and dental hospital under the health care category.

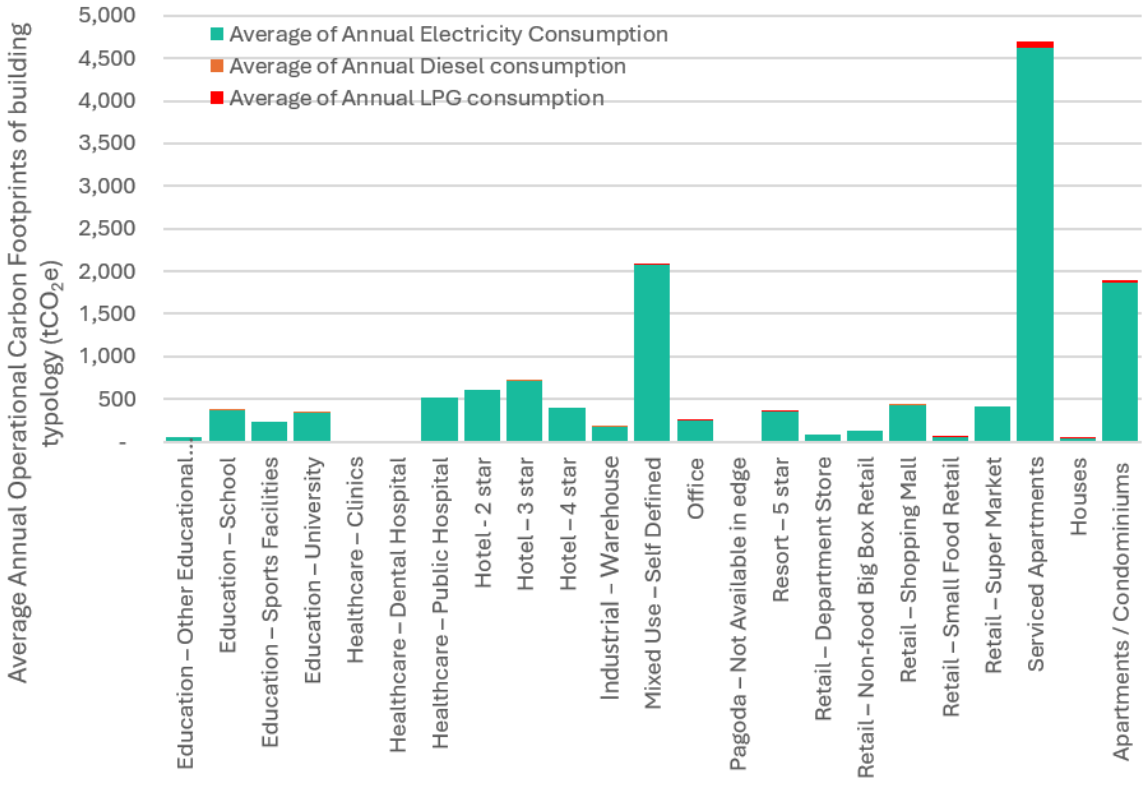


Figure 7. Average annual operational carbon footprints by building type

The audit findings highlight significant opportunities for reducing both operational and embodied carbon. The following sections summarize results by building type and measure.

3.1 Energy Audit Results

Based on the walk-through audits of 250 buildings, common shortcomings in building energy efficiency were observed, as summarized below.

Outdated and Inefficient Equipment

- **Air conditioning**: The building sector still relies heavily on fixed-speed split AC units, many of which use R22 refrigerant[16], and older Variable Refrigerant Volume (VRV)/Variable Refrigerant Flow (VRF) systems installed several years ago. These systems exhibit low Seasonal Energy Efficiency Ratios (SEER) compared to modern inverter-based technologies, meaning they consume more electricity for the same cooling output. Over time, components such as compressors, sensors, and piping further reduces efficiency, causing uneven cooling and extended run-times. This combination of outdated technology and wear leads to higher operational costs, increased energy demand, and elevated greenhouse gas (GHG) emissions. Upgrading or retrofitting AC systems is therefore a high-priority intervention for improving energy performance in buildings.

[16] In 2021, the Royal Government of Cambodia updated its Sub-Decree No. 47 on Ozone Depletion Control. This amendment ensures compliance with the Montreal Protocol by expanding the phase-down schedule for R-22 (Freon 22 or HCFC-22).

- **Appliances and fans**: Conventional refrigerators and induction ceiling fans remain widely used, despite the availability of high-efficiency alternatives such as inverter-based refrigerators and BLDC (Brushless Direct Current) fans. Traditional refrigerators operate with fixed-speed compressors, leading to frequent on-off cycles and higher energy consumption, while induction fans typically draw 60–70 watts of power and lack advanced control features. In contrast, inverter refrigerators adjust compressor speed to maintain optimal cooling with significantly lower electricity use, and BLDC fans consume up to 60–70% less energy than induction models while offering quieter operation and longer lifespan. The continued reliance on these outdated technologies results in unnecessary energy waste, higher utility costs, and increased carbon emissions, underscoring the need for targeted appliance upgrades to improve overall building energy performance.

- **Lighting**: Many buildings in Cambodia still rely on T5 and T8 fluorescent tube lights for illumination, despite the widespread availability of LED lighting solutions that offer superior energy efficiency and performance. Fluorescent tubes typically consume 36–40 watts per fixture, generate heat that adds to cooling loads, and have a shorter operational life compared to LEDs. LED tubes of similar brightness can operate at 18 watts or less, offering around 50% energy savings and lower maintenance costs. The continued use of fluorescent lighting results in higher electricity bills and unnecessary carbon emissions, making the transition to LED technology one of the most cost-effective and impactful measures for improving energy efficiency in the building sector.

Limited Automation and Controls

- **Lighting controls**: Toilets, corridors, and other shared spaces lack occupancy and daylight sensors, causing lights to remain switched on even when these areas are unoccupied or naturally well-lit. This results in unnecessary energy consumption and higher electricity bills. Occupancy sensors can automatically turn lights on when movement is detected and off when spaces are vacant, while daylight sensors adjust lighting based on available natural light. The absence of these controls represents a missed opportunity for 20–60% energy savings, achievable with minimal investment and quick payback periods.

- **Always-on small loads**: Small electrical loads such as water dispensers and pumps often operate continuously without any scheduling or load-based control. Water dispensers typically run 24/7, even during non-operational hours, leading to excessive energy use and equipment wear. Similarly, pumps frequently run at full speed regardless of actual demand, wasting energy during off-peak conditions. Installing programmable timer switches for dispensers and VFDs for pumps can optimize operation, reduce energy consumption by 10–30%, and extend equipment life. These measures offer substantial savings with short payback periods, making them highly cost-effective interventions for improving building energy efficiency.

Building Envelope Heat Gains

- Clear glazing on south- and west-facing façades without any shading devices, which significantly increases solar heat gain during peak sun hours. This excessive heat infiltration raises indoor temperatures, forcing AC systems to work harder and consume more energy to maintain thermal comfort. The lack of passive design measures such as external louvers, overhangs, or sun-control films not only elevates cooling loads but also contributes to higher operational costs and GHG

emissions. Implementing simple interventions like solar control window films or shading devices can reduce heat gain by up to 30%, offering substantial energy savings and improved occupant comfort.

- Many modern buildings are designed with a high WWR, often featuring large, glazed areas on façades without adequate shading or thermal protection. While expansive glazing enhances daylight and aesthetics, it also significantly increases solar heat gain, especially on south- and west-facing façades. This excessive heat infiltration raises indoor temperatures, forcing AC systems to operate longer and at higher loads, thereby increasing energy consumption and cooling costs. A high WWR without proper mitigation measures such as low-emissivity glass, external shading devices, or sun-control films undermines building energy performance and occupant comfort. Optimizing WWR during design or retrofitting with shading solutions can substantially reduce cooling demand and improve overall energy efficiency.

Behavioral and Operational Practices

- In many Cambodian buildings, particularly the retails shops and restaurants, ACs are frequently set to very low temperatures, well below the recommended comfort range. This practice significantly increases energy consumption and cooling costs. To counteract overcooling, occupants sometimes leave doors open to allow warmer air to enter, which further reduces system efficiency and forces AC units to work harder. Such habits not only waste energy but also shorten equipment life. Maintaining setpoints within the range of 24–26 °C and ensuring doors remain closed can deliver substantial energy savings without any additional investment.

- A major challenge in the building sector is the lack of awareness about simple operational strategies that can improve energy efficiency. Measures such as setpoint optimization, proper scheduling of equipment, sensor-based lighting control, and leveraging natural daylight are often overlooked. These low-cost or no-cost interventions can reduce energy use by 10–20% or more, yet they are rarely implemented due to insufficient training and awareness among facility managers and occupants.

Renewable Energy in buildings

- The rollout of rooftop solar photovoltaic (PV) continues to face challenges due to an absence of net metering/net billing and the introduction of compensation tariffs for grid-connected systems, which erode project economics. Medium and large grid-connected rooftop systems must pay a compensation tariff designed to account for grid energy exports, losses, and system costs—yet exported energy is not remunerated through net metering, leaving owners effectively uncompensated for surplus generation injected into the grid.

Building Construction Materials

- Building construction in Cambodia is predominantly characterized by conventional reinforced concrete structures, with cement, concrete, fired clay bricks, steel reinforcement, and sand aggregates being the principal materials used.
- Cement- and concrete-intensive elements such as columns, beams, slabs, and foundations account for the largest share of material use and, consequently, embodied carbon emissions,

given the high emission intensity associated with cement production. As per our estimation, percentage share of embodied carbon emissions are columns (7%), Beams (6%), Slabs (12%) and foundation (13%).

- Steel structures are used in some buildings instead of RCC beams and columns; however, these construction practices are rare as the initial cost is high.
- Fired clay bricks, commonly used for walling, also contribute significantly to embodied carbon due to fuel use in kiln firing, while steel reinforcement adds a smaller but notable share because of its energy-intensive manufacturing process.
- The assessment found that the absence of locally available low-carbon alternatives and limited adoption of material efficiency measures further increases embodied carbon levels.

3.2 Energy Conservation Measures

The following ECMs in Table 8 were recommended to reduce energy consumption and operational emissions according to the challenges and opportunities identified during audits.

Table 8. Summary of recommendations to reduce operational carbon footprint

Sl No	Energy Conservation Measures	Percentage Energy Saving Potential	Payback Period	Total cases out of 250	Total Investment Potential (USD)
1.	ECM1: Increasing the set temperature of the ACs by 3 degrees	Up to 20%	Immediately	6	No capital cost
2.	ECM2: Retrofit of ACs with Efficient Inverter	Up to 40%	Up to 4 years	57	5,084,110
3.	ECM3: Replacement of Induction Fans with BLDC (Brushless Direct Current) Fans	Up to 50%	Up to 2 years	6	5,312
4.	ECM4: Retrofit of tube lights with LED tube lights	Up to 50%	Up to 2 years	66	181,463
5.	ECM5: Installation of Occupancy sensors	Up to 60%	Up to 2 years	82	36,580
6.	ECM6: Installation of VSD/VFD drives	Up to 30%	Up to 2 years	1	139,860
7.	ECM7: Applying Sun Control Window Film	Up to 30%	Up to 4 years	25	1,032,628
8.	ECM8: Installation of Timer Switch for Water Dispenser	Up to 50%	Up to 1 year	43	10,170
9.	ECM9: Installation of Rooftop Solar Photo-Voltaic System	Up to 15%	Up to 8 years	9	3,331,274
10.	ECM10: Cool Paint	Up to 15%	Up to 3 years	3	8,192
11.	ECM11: Daylight Integration	Up to 20%	Immediately	1	No capital cost

12.	ECM12: Air Curtain Motion Sensor	Up to 20%	Up to 1 year	2	140

The detailed methodology and calculation for each of the ECMs is listed in Appendix IV.

A summary of suitable ECMs as applicable to building types are listed in Table 9.

Table 9. Total energy savings (kWh) potential by building type (250 buildings)

Row Labels	ECM1: Change Set Temperature	ECM2: AC replacement	ECM3: Fans replacement	ECM4: LED replacement	ECM5: Occupancy /Daylight Sensor	ECM6: VFD Drives	ECM7: Sun-control film	ECM8: Timer Switch	ECM9: RE Integration	ECM10: Cool Paint	ECM11: Daylight Optimization	ECM12: Curtain Motion Sensor
Apartment	-	5,232,043	-	7,156	27,381	-	-	-	-	-	-	-
Education – Other Educational Facilities	-	90,981	-	165,749	-	-	-	-	-	-	-	-
Education – School	-	708,308	4,431	34,625	89,279	-	118,009	10,622	1,747,968	28,994	13,891	
Education – Sports Facilities	-		-	5,779	3,364	-	-	-	-	-	-	-
Education – University	-	281,180	-	46,590	3,928	-	14,845	34,075.2	-	-	-	-
Healthcare – Clinics	-	-	-	-	-	-	955	-	-	-	-	-
Healthcare – Dental Hospital	-	-	-	-	-	-	-	-	-	-	-	-
Healthcare – Public Hospital	-	-	-			-	-	17,502.4	-	-	-	-
Home	-	-	-	10,731		-	-	-	-	-	-	-
Hotel - 2 star	-	-	-	-	3,421	-	-	-	-	-	-	-
Hotel – 3 star	-	112,077	-	54,070	2,698	-	-	-	-	-	-	-
Hotel – 4 star	-	10,494	-	-	-	-	481	-	-	6,205	-	-
Industrial – Warehouse	-		-		1,024	-	34,749	3,281.7	-	-	-	-
Mixed Use – Self Defined	-	24,205	-	96,422	26,596	359,660	1,085,110	-	-	-	-	-
Office	-	2,682,334	85,624	232,925	50,854	-	216,647	238,481.3	2,517,836	30,215	-	-
Pagoda – Not Available in edge	-			1,734	-	-	-	-	-	-	-	-
Resort – 5 star	-	-	-	-	-	-	-	-	-	-	-	-

Retail – Department Store	-	1,094	-	-	638	-	-	-	-	-	-	-
Retail – Non-food Big Box Retail	-	-	-	-	2,596	-	-	-	-	-	-	-
Retail – Shopping Mall	-	221,700	2,365	24,680	11,124	-	-	-	-	-	-	-
Retail – Small Food Retail	42,504	-	-	-	3,121	-	22,119	7,190	0	0	0	1,924
Retail – Super Market	90,590	-	-	95,297		-	-	-	-	-	-	-
Serviced Apartments	-	2,776,436	-	6,177	525	-	309,228	-	-	-	-	-
Total electricity savings (kWh)	**133,094**	**12,140,852**	**92,420**	**781,935**	**226,547**	**359,660**	**1,802,143**	**311,153**	**4,265,804**	**65,414**	**13,891**	**1,924**

3.3 Investment Potential

Investment potential for each building based on the 250 assessments was determined by identifying inefficiencies in operations and technology solutions through the energy audits and estimating the capital costs required to implement recommended ECMs (see Table 10). For each ECM identified, the required capital investment was estimated and aggregated to determine the cumulative investment potential of the building. This assessment helped identify critical gaps where performance, resource allocation, and energy consumption could be significantly optimized.

Based on the energy audit findings, tailored strategies and proposed technology interventions were proposed to address these gaps, aiming to enhance operational efficiency, reduce energy consumption, and ultimately deliver a strong ROI through improved performance and reduced costs.

The energy audits ascertained that retrofits for low-carbon building transformation are feasible across many building types, with significant potential for carbon emissions aversion, as portrayed in the graph below. Figure 8 presents the building types together with their total investment potential and estimated carbon emissions aversion potential.

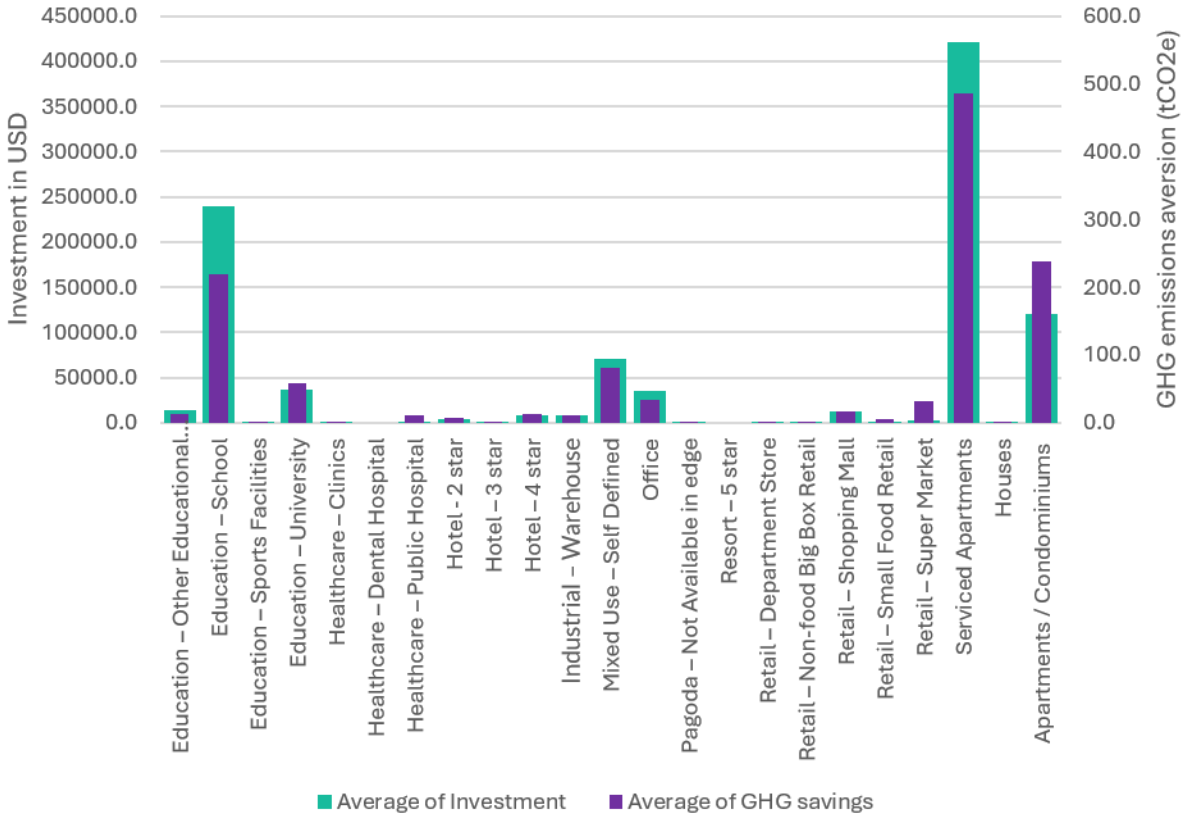


Figure 8. Average investment potential with average GHG savings for various building types

Investment potential is highest in the residential sector, reflecting rapid growth in high-rise housing and low adoption of energy-efficient technologies. This is followed by educational buildings and mixed-use/office commercial buildings.

Table 10. Building type-wise investment potential of respective ECMs for 250 buildings

Row Labels	Sum of ECM1: Change Set Temperature	Sum of ECM2: AC replacement	Sum of ECM3: Fans replacement	Sum of ECM4: LED replacement	Sum of ECM5: Occupancy /Daylight Sensor	Sum of ECM6: VFD Drives	Sum of ECM7: Sun control film	Sum of ECM8: Timer Switch	Sum of ECM9: RE Integration	Sum of ECM10: Cool Paint	Sum of ECM11: Daylight Optimization	Sum of ECM 12 Curtain Motion Sensor
Apartment	-	1,668,598	-	1,720	4,260	-	-	-	-	-	-	-
Education – Other Educational Facilities	-	64,000	-	66,860	-	-	-	-	-	-	-	-
Education – School	-	322,000	250	6,990	7,840	-	46,722	1,260	1,351,632	3,440	-	-
Education – Sports Facilities	-		-	1,494	560	-	-	-	-	-	-	-
Education – University	-	126,500	-	11,635	1,520	-	3,740	510	-	-	-	-
Healthcare – Clinics	-	-	-	-	-	-	480	-	-	-	-	-
Healthcare – Dental Hospital	-	-	-	-	-	-	-	-	-	-	-	-
Healthcare – Public Hospital	-	-	-		-	-	-	120	-	-	-	-
Home	-	-	-	3,500	-	-	-		-	-	-	-
Hotel - 2 star	-	-	-	-	440	-	-	-	-	-	-	-
Hotel – 3 star	-	51,000	-	10,220	600	-		-	-	-	-	-
Hotel – 4 star	-	7,150	-	-	-	-	520	-	-	400	-	-
Industrial – Warehouse	-		-		340	-	16,000	60	-	-	-	-
Mixed Use – Self Defined	-	58,750		19,250	3,400	139,860	607,800		-	-	-	-
Office	-	1,170,362	4,662	46,774	14,320	-	171,116	8,070	1,979,642	4,352	-	-
Pagoda – Not Available in edge	-	-	-	220	-	-	-	-	-	-	-	-

Resort – 5 star	-	-	-	-	-	-	-	-	-	-	-	-
Retail – Department Store	-	650			120		-	-	-	-	-	-
Retail – Non-food Big Box Retail	-		-	-	920	-	-	-	-	-	-	-
Retail – Shopping Mall	-	112,700	400	2,360	1,220				-	-	-	-
Retail – Small Food Retail	-	-	-	-	840	-	6,250	150	-	-	-	140
Retail – Super Market	-	-	-	9,360				-	-	-	-	-
Serviced Apartments	-	1,502,400	-	1,080	200	-	180,000	-	-	-	-	-
Grand Total (USD)	**No capital cost**	**5,084,110**	**5,312**	**181,463**	**36,580**	**139,860**	**1,032,628**	**10,170**	**3,331,274**	**8,192**	**No capital cost**	**140**

4. EPI Benchmarking

Data analytics from the energy audits of 250 buildings provide an indicative Energy Performance Index (EPI) for different building types in the country. Figure 9 shows the average EPI by building type with respect to the average occupied building floor area (sqm).

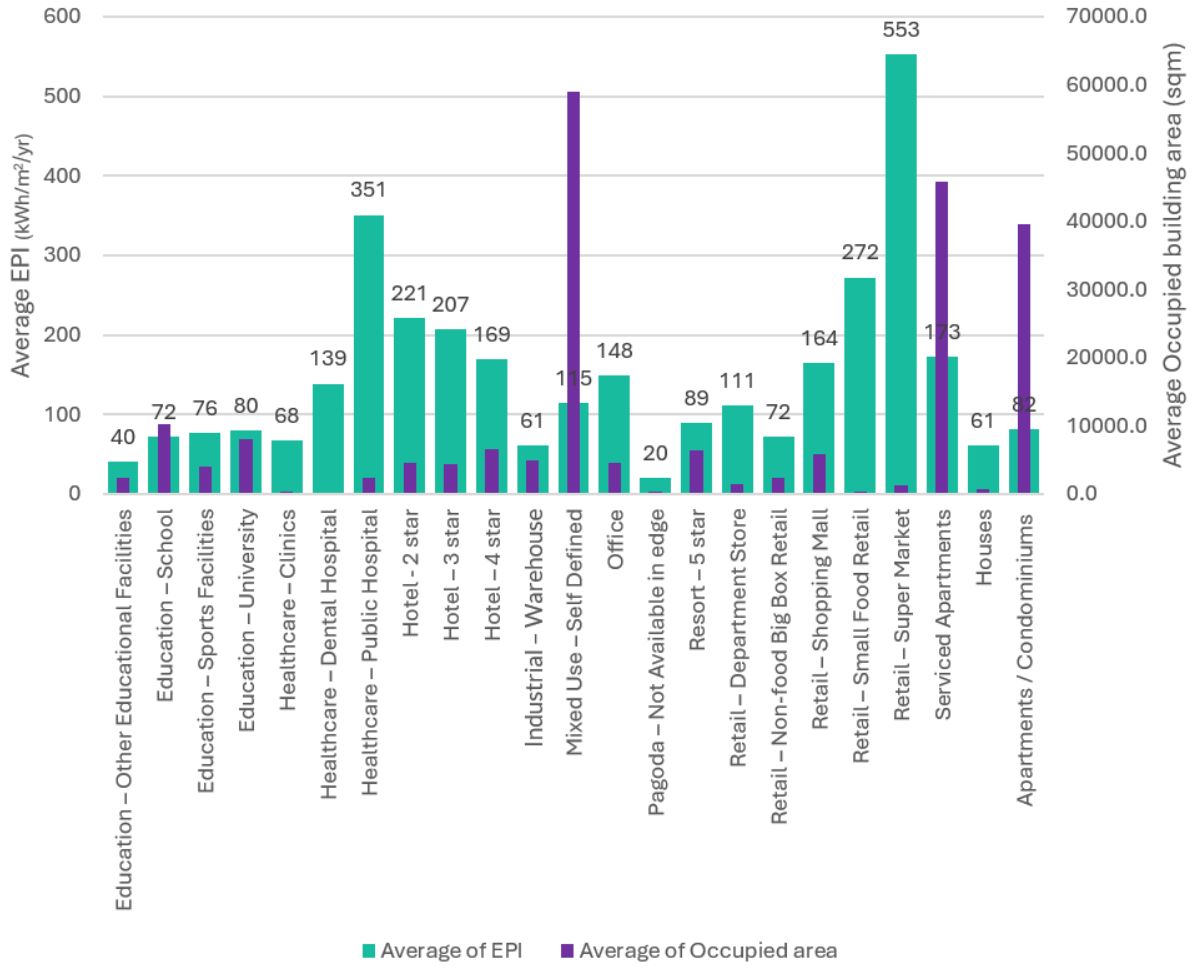


Figure 9. EPI of building types in Cambodia

The results indicate that **supermarkets** (retail) record the highest average EPI in the sample (approximately 553 kWh/m²/yr), despite having a relatively low occupied floor area, driven primarily by its 24/7 operations and high cooling load and refrigeration. **Public hospitals** (EPI 351 kWh/m²/yr) and **small food retail** buildings (EPI 272 kWh/m²/yr) emerge as the next most energy-intensive categories in building sector.

In the subsequent sections, EPIs are further analyzed and compared by building function (in addition to type), and average EPIs of the buildings segregated are estimated.

4.1 Residential Buildings

Within the residential sector, key differentiation includes **independent houses** and **multi-storey apartments**. In addition, some residential buildings operated as hotels fall under the **serviced apartment category**. The average EPI for the residential sector is **106.6 kWh/m²/yr**.

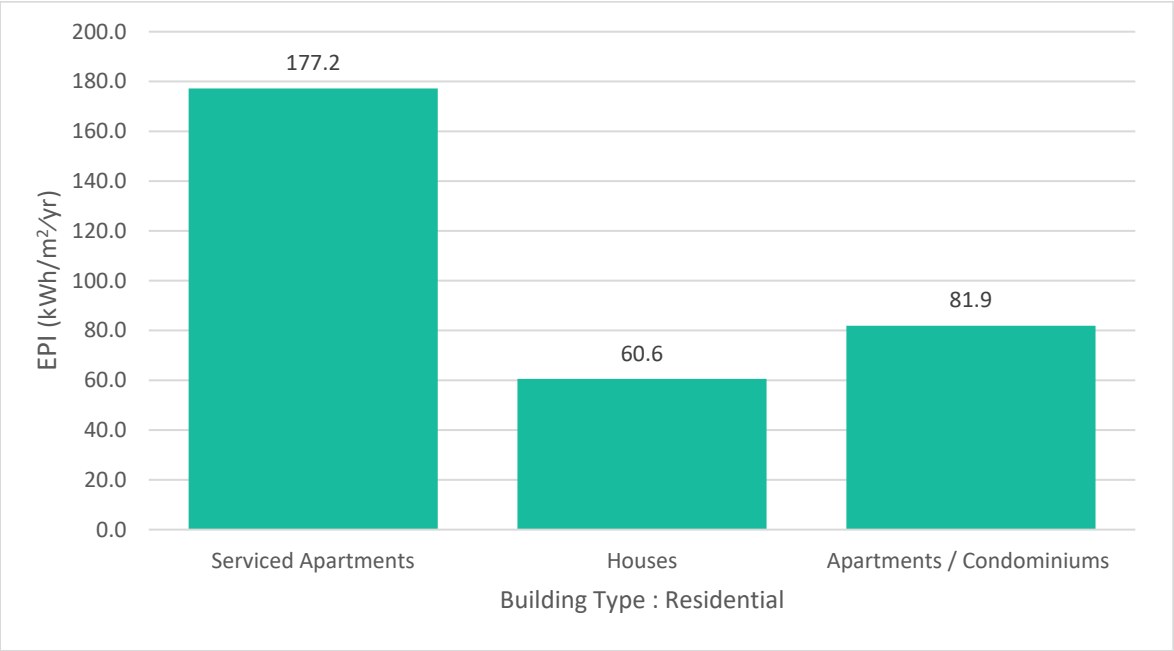


Figure 10. EPIs of residential buildings

4.2 Hospitality Buildings

The average EPI for the hospitality sector (mainly hotels, without categorization by star rating) is **171.2 kWh/m²/yr**.

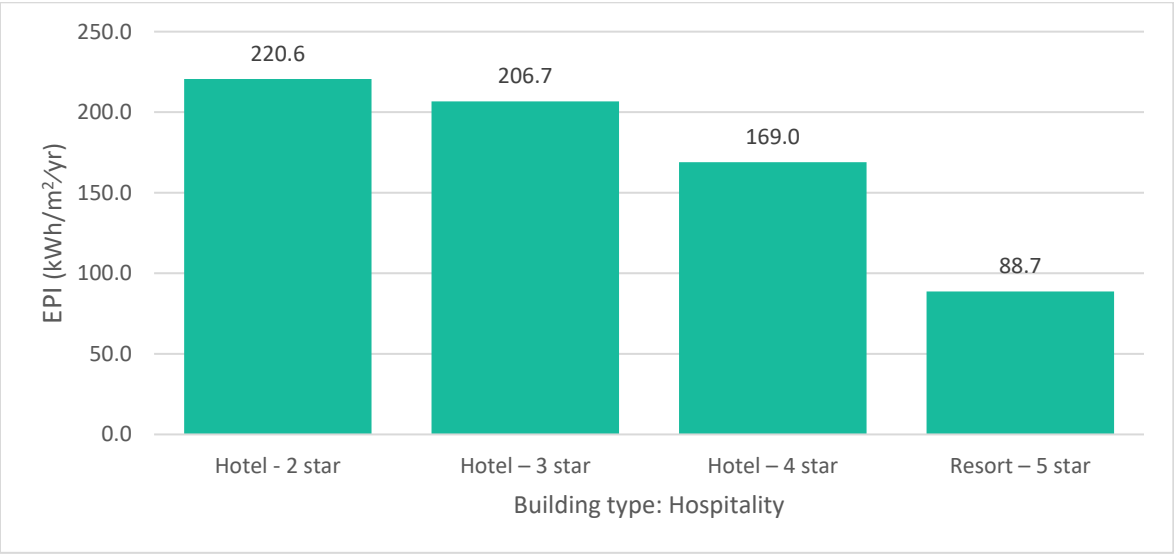


Figure 11. EPI of the hospitality sector

4.3 Educational Buildings

Education buildings were categorized into **schools**, **universities**, **sport facilities**, and other **educational facilities**. The average EPI of the educational building is **64.6 kWh/m²/yr**.

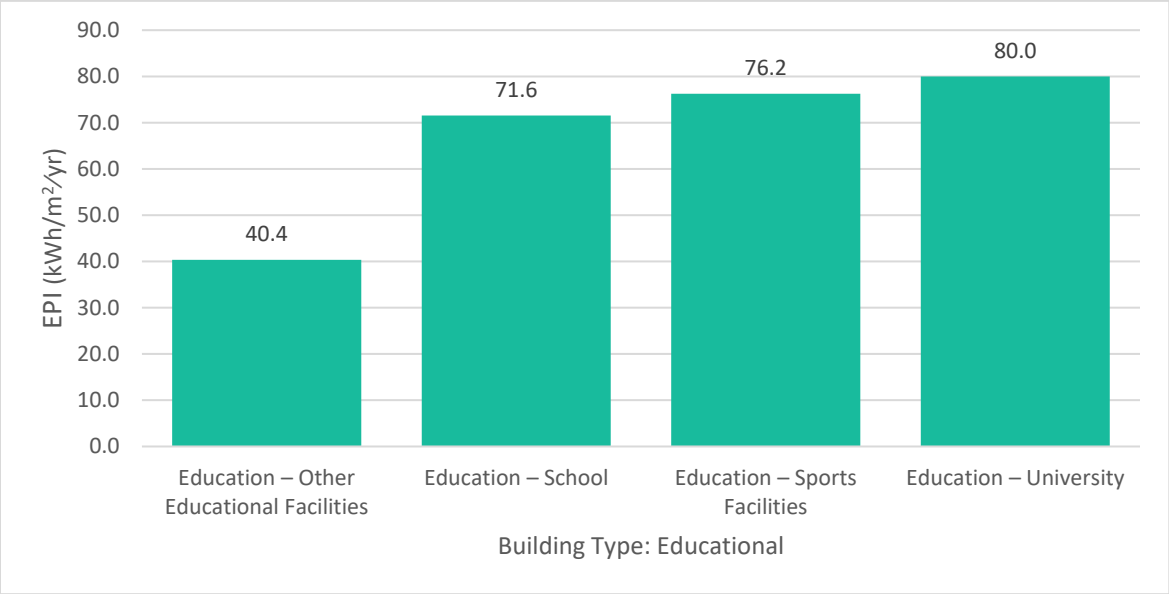


Figure 12. EPIs of educational buildings

4.4 Commercial Buildings

Commercial buildings mainly fall into two categories: **office** and **mixed-use**. Mixed-use commercial buildings are very common in Cambodia, where majority of the building space is used for offices, lower floors for retail, and top floors often for restaurants. The average EPI for commercial office/mixed-use buildings is **131.6 kWh/m²/yr**.

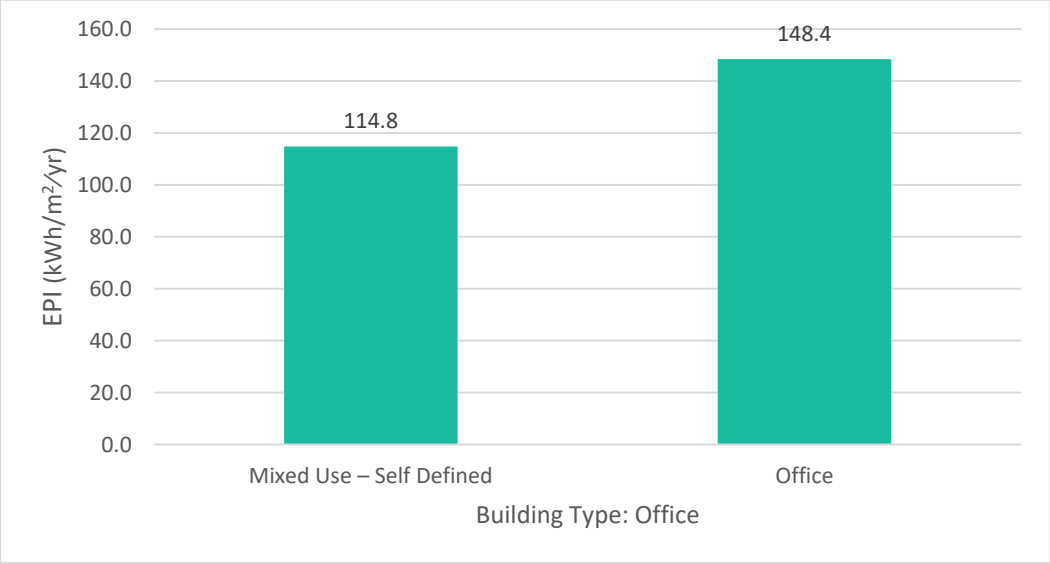


Figure 13. EPIs of office buildings

4.5 Retail Buildings

The average EPI for retail chain buildings, including shopping malls, retail stores, supermarkets, and warehouses is **205.5 kWh/m²/yr**.

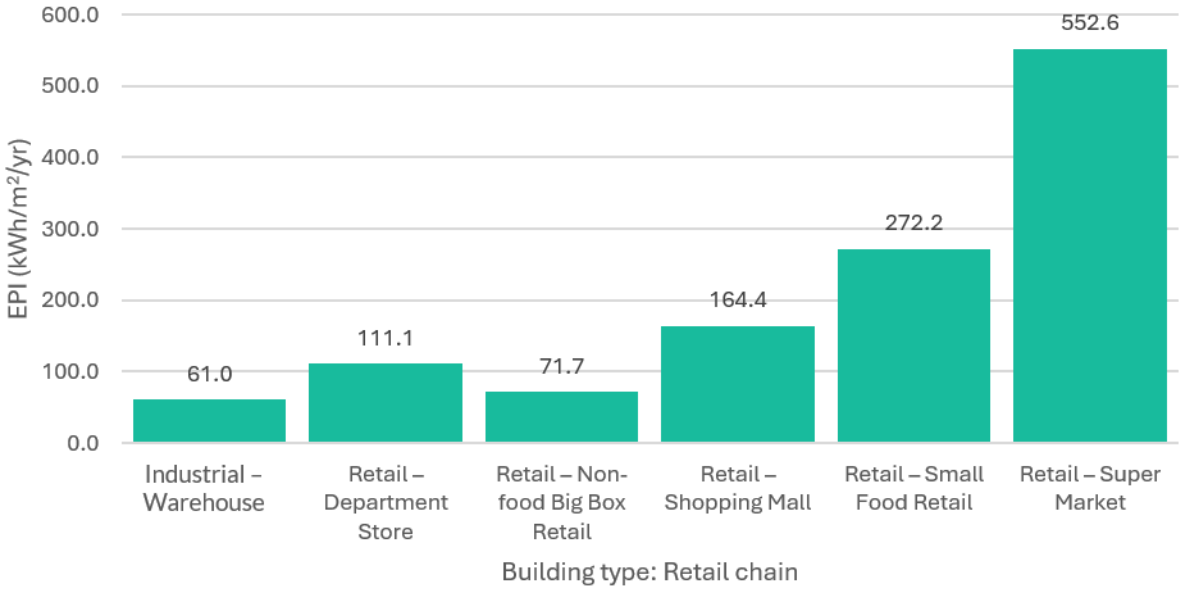


Figure 14. EPIs of retail buildings

4.6 Comparison of Cambodia's EPI with Regional Countries

In summary, the EPI values by broad building category, based on the deep-dive assessment, are summarized in Table 11 alongside reference values for neighboring countries. Regional comparison of EPI values provides a useful benchmark for evaluating the effectiveness of national energy policies and building codes.

Table 11. Comparison of EPI benchmarks across neighbouring countries

EPI (kWh/m²/yr)	Residential building	Hospitality building	Educational building	Commercial building - Offices/ Mixed use	Retail Chain
Cambodia	106.6	171	64.6	131.6	205.5
Thailand[17] [18]	102.4	255	100	225	-

[17] *Christopher Charles Seeley and Shobhakar Dhakal. "Energy Efficiency Retrofits in Commercial Buildings: An Environmental, Financial, and Technical Analysis of Case Studies in Thailand." Energies 14, no. 9 (2021): 2571.* https://www.mdpi.com/1996-1073/14/9/2571
[18] Climate Technology Centre & Network (CTCN). *CTCN Project Handbook for Practitioners*. Rev. 02. Copenhagen: Climate Technology Centre & Network, 2021. https://www.ctc-n.org/system/files/dossier/3b/CTCN%20Project_Handbook-2_Practioner_Rev.02_2021.12.30_Eng%20New.pdf

Singapore[19]	64	220	89	143	375
Vietnam[20]	102	182	100	135	200

Cambodia's EPI values highlight clear differences in energy intensity across major building types, reflecting climate conditions, construction practices, and typical operational patterns. Residential buildings show a moderate EPI (106.6 kWh/m²/year), while educational facilities perform more efficiently (64.6 kWh/m²/year), likely due to shorter operating hours and lower cooling demand.

By contrast, hospitality buildings exhibit significantly higher EPI (171 kWh/m²/year), driven largely by extended operating hours and continuous need for air-conditioning, ventilation, and hot water systems. Retail chain buildings also display elevated energy use (205.5 kWh/m²/year), consistent with long operating hours, intensive lighting, and cooling loads. Commercial offices and mixed-use buildings fall between these extremes (131.6 kWh/m²/year).

Overall, the results suggest that in Cambodia, energy consumption is particularly high in sectors with heavy cooling demands and extended occupancy, highlighting strong opportunities for targeted efficiency improvements in hospitality, retail, and commercial building operations.

[19] Building and Construction Authority (BCA). "Building Energy Benchmarking." *BuildSG*. Last updated November 28, 2025. https://www1.bca.gov.sg/buildsg/sustainability/regulatory-requirements-for-existing-buildings/bca-building-energy-benchmarking-and-disclosure

[20] Dang, Hoang Anh. "Development of Specific Energy Consumption Profile for Typical Buildings in Vietnam." *Journal of Science & Technology 57* (Special issue, November 2021): 21–25. https://jst-haui.vn/media/30/uffile-upload-no-title30665.pdf

5. Recommendations and Lessons Learned

5.1 Recommended Buildings for Investment

Following the assessment of 250 buildings, a set of criteria (see Table 12) was developed to shortlist building for pilot project. Those criteria include the techno-commercial feasibility of the proposed technology solutions. For each solution, investment potential, energy savings, and carbon emission aversion potential were estimated. Based on this assessment, the candidate buildings were identified and recommended for pilot projects, as listed in Table 13.

Table 12. Suitability matrix for selecting buildings for the pilot phase

Filter	Description	
Building owners	Interest in implementing low carbon interventions in the building	
GHG Emissions Aversion Potential	Potential carbon savings from energy saving interventions	Higher value will be prioritized
Investment Mobilization potential	Required investment to implement ECMs	Higher value will be prioritized
Category of Building	Commercial/ Residential/ Hotel/ Apartment/ Healthcare	Buildings from each type to be selected
Energy Consumption (Annual)	kWh/year	Highest energy consumers prioritized
Occupancy Hours	Buildings with higher occupancy rate will be preferred	If above mentioned filters are not sufficient

Table 13. Recommended buildings for pilot projects sorted by energy saving potential

Sl No	Building ID	Building type	ECM - Investment Potential (USD)	Energy Savings Potential (kWh)	GHG Emission Aversion Potential (tCO_2e)
1.	Building 0022	Apartments / Condominiums	940,800	3,286,483	2,070
2.	Building 0013	Serviced Apartments	1,502,880	2,779,725	1,751
3.	Building 0073	Office	1,287,800	1,662,630	1,014
4.	Building 1286	Education – School	1,164,070	1,508,909	920
5.	Building 0035	Apartments / Condominiums	479,388	230,180	795
6.	Building 0012	Mixed Use – Self Defined	528,900	896,148	547
7.	Building 0058	Office	575,900	763,174	466
8.	Building 1284	Education – School	380,712	592,836	362
9.	Building 0014	Apartments / Condominiums	171,420	45,450	275
10.	Building 1307	Office	273,580	385,007	235
11.	Building 0005	Mixed Use – Self Defined	140,860	366,760	224

12.	Building 0051	Office	139,100	355,486	218
13.	Building 0034	Office	168,358	335,111	208
14.	Building 0041	Serviced Apartments	180,000	309,228	189
15.	Building 1334	Education – School	103,660	299,516	183
16.	Building 1247	Education – University	87,800	233,152	142
17.	Building 1325	Apartments / Condominiums	75,000	230,960	140
18.	Building 1113	Retail – Shopping Mall	112,700	221,700	135
19.	Building 1266	Office	80,400	220,098	134
20.	Building 1237	Office	125,470	182,264	111
Total			**8,350,440**	**14,904,817**	**10,119**

The above recommendations are subject to the willingness of building owners to implement energy efficient solutions. Selected buildings may proceed to the next phase, which will involve Investment Grade Energy Audits. These audits will utilize instruments and data loggers to ensure that ECMs are based on measured energy performance data collected from the building site.

5.2 Lessons Learned

Key challenges encountered during the building energy and carbon assessment in Cambodia, along with the corresponding resolutions, are summarized in Table 14. These challenges reflect limitations in data availability, stakeholder engagement, documentation of building characteristics, and benchmark development. The resolutions highlight adaptive strategies, methodological adjustments, and engagement approaches used to ensure that the assessment remained robust, credible, and context appropriate.

Table 14. Challenges encountered and resolutions during building assessment in Cambodia

Challenges	Resolution
Building registry not available in secondary domain or with project stakeholders	Redundant information excluded
Energy audit reports of buildings were not available in the country	Conducted primary data collection through site visits, stakeholder consultations, and utility data requests
Many building owners were hesitant to share building information, including utility bills, due to concerns over potential financial penalties	Built trust through repeated engagement, ensured confidentiality, and explained the non-regulatory, capacity-building nature of the assessment
Single utility bill covering multiple buildings	Applied allocation methods based on floor area, building function, and estimated operational intensity to divide utility consumption across buildings
BOQs for all buildings were not available	Estimated material quantities using site inspections, engineering judgment, and standard construction practices commonly used in Cambodia
Utility bills did not reflect actual carbon footprints because many buildings (especially	Normalized energy consumption based on actual occupancy levels and adjusted EPI calculations to reflect typical operational scenarios

residential and commercial) were not fully occupied	
Multiple site visits were required to convince building owners, leading to project delays	Created a structured stakeholder engagement plan and consolidated visits to maximize efficiency and minimize delays
Limited small sample size for EPI benchmarking	Acknowledged this limitation and positioned the results as indicative benchmarks, recommending future studies with expanded datasets.
Building owners were unable to commit to energy-efficient retrofits due to lack of business models and execution plans	Provided guidance on potential retrofit opportunities and suggested development of investment-ready business models for future phases
Building types were not well defined and most buildings were mixed-use	Categorized buildings based on dominant functional use and applied mixed-use allocation techniques to improve comparability

Conclusion

The energy audits of 250 buildings were successfully completed despite the challenges related to limited publicly available data. These challenges were addressed through targeted data collection and sustained coordination with building owners during site visits. The engagement process also helped raise awareness among building owners regarding the objectives of the ALCBT project.

The assessment highlighted the need to refine national building types. In particular, urban buildings should not be broadly classified as mixed-use but rather classified according to their dominant function, enabling more accurate benchmarking and performance comparisons. The audits further revealed that many building owners continue to adopt technologies based on market availability rather than selecting the most energy-efficient options, limiting opportunities for long-term efficiency gains.

At the same time, the assessment identified several zero or minimal cost interventions that can be implemented immediately, including:

- Increasing AC setpoint temperatures to align with occupant thermal comfort requirements
- Installing smart plugs or timer-based controls to regulate power use according to operational schedules.

These measures can deliver measurable reductions in energy consumption without requiring significant capital investment.

The presence of high-rise buildings using VRV systems also indicates a significant increase in refrigerant volumes compared to water-cooled chiller systems, highlighting an important environmental consideration. Addressing structural, behavioral, and market barriers will therefore be critical to enabling a more energy-efficient and climate-responsive building sector in Cambodia.

Appendices

Appendix I: Methodology to Estimate Bill of Quantities (BOQs)

1. Material Types and Quantities

- **Accurate material type identification is paramount** - All Environmental Product Declarations (EPDs) in BEAT are categorized by specific material types.
- **Important**: There are NO composite EPDs in BEAT. Each material must be listed separately:
    - For reinforced concrete structures: List BOTH concrete type (e.g., M25, M30) AND steel reinforcement (e.g., Fe 415, Fe 500D) separately
    - Example: Foundation = Ready-mix concrete M30 (500 m^3) + Reinforcement steel Fe 415 (40 tons)
- Material categories include:
    - Concrete types (Ordinary Portland Cement, Ready-mix M25/M30/M50, etc.)
    - Steel types (TMT bars Fe 415/500D/550D, reinforcement steel)
    - Bricks (Fly ash, Red brick, AAC blocks)
    - Finishes (Ceramic tiles, Vitrified tiles, Granite, Marble, etc.)
    - Wood, aluminium doors, windows

2. Building Elements Breakdown

Quantities are required for all major structural and non-structural elements, as detailed below:

2.1. Foundation: Material types + quantities

Select the appropriate foundation type based on the number of storeys.

- **Isolated Footing (G to G+3)**

No. of Storeys	Foundation Type	Required footing area	Length footing	Breadth Footing	Height RCC	Height PCC	Trench length	Trench breadth	Trench height	Steel
G	Isolated Footing	1.2	1.34	0.89	0.45	0.15	2.24	1.79	1.5	[1]0.8% of total volume
G+1		2.4	1.90	1.26	0.45	0.15	2.80	2.16	1.8	
G+2		3.6	2.32	1.55	0.45	0.15	3.22	2.45	2.1	
G+3		4.8	2.68	1.79	0.45	0.15	3.58	2.69	2.1	

Calculations

For isolated footing foundation = {No of Columns * (Length*Breadth* $Height_{RCC}$)} + (Floor Area * $Height_{PCC}$)

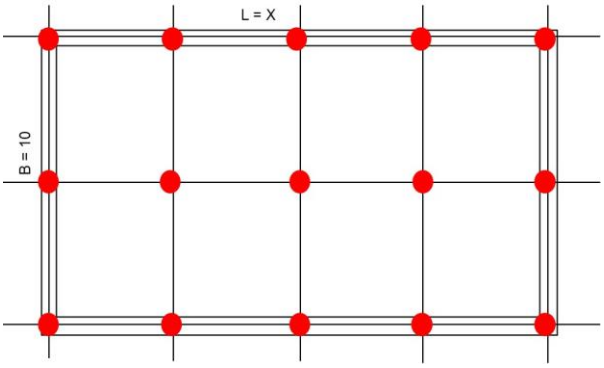
- **Raft Footing (G+4 and above)**

No. Storeys	Foundation Type	Height of RCC	Height of PCC	Height of sand filling	Trench height	Trench width/length extensions	Foundation extension	Steel
G+4 and Above	Raft footing	0.6	0.15	0.45	3	1.6	1	0.8% of total volume[1]

Calculations

For Raft footing: Concrete Volume= Floor *Area* × ($Height_{RCC}$ + $Height_{PCC}$)

2.2. Columns and Beams: Concrete grade + steel reinforcement quantities



- **Example with Available data:**

  Building height=3.2 m (For all commercial building ht.)

  Total BUA =10,000 sqm.

  No. of Floors= G+7= 8 floors

  Per floor Built up**= 10,000/8=1,250** sqm.

  (assuming all floors have equal BUA and building as rectangular shape)

Parameters	Calculations
Building Dimensions	
(B)Width of building identified	25 m say (As per Google maps).
(L) Calculated Length	1250 (per floor area) /25= 50m
Number of Columns calculations	
Assuming 5 m c/c distance (for this case)	
No. of columns per width	= (Width/centre to centre dist)+1 = (25/5)+1= 6 **Nos.**
No of columns per Length	= 50/5=10+1= 11 **no.s**
Total No. of columns:	= 6*11=66 no.s
Column Size:	**= c/c span (say 7000 c/c)/12**

(250mm can be minimum, 450 width is considered for safety purpose)	**= 583.33** approximately 0.600 X 0.450 mm
Total No. of Beams:	= (No. of columns per length – 1) * No of columns per Width * (No of columns per Width - 1) * No of Storeys of the building **= 11 * 6 * 5 * 8** **= 2640**
Beam Size: (250mm can be minimum, 450 width is considered for safety purpose)	**= c/c span (say 7000 c/c)/12** **= 583.33** approximately 0.600 X 0.450 mm

- **Column Design Parameters**

Building Height	Height in Meters	Column Size	Column C/C
1-3 Stories	10m	0.450 x 0.300	5 m C/C
4-5 Stories	16m	0.500 X 0.300	6 m C/C
6 floors and above	16m above	0.600 X 0.450	7 m C/C

In Column we are considering TMT bars/steel as Fe500 = 2.5% of the total volume

- **Beam Design Parameters**

Building Height	Column C/C	Height in Meters	Beam Size
1-3 Stories	5 m C/C	10m	0.450 X 0.300
4-5 Stories	6 m C/C	16m	0.500 X 0.300
6 floors and above	7 m C/C	16m above	0.600 X 0.450

In Beam we are considering TMT bars/steel as Fe500 = 2% of the total volume

2.3. Floor Construction: Bottom floor, intermediate floors, roof

In case the roof material is different, it will not be considered in the calculation of concrete volume. The ground floor will not be considered in the calculation as it will be considered in the foundation.

Volume of Concrete for floor construction = (Area of one floor) *(No of floors) *Thickness

Thickness of a floor = 150 mm - 200 mm

2.4. Walls: Exterior and interior walls with material specifications

External Wall volume	= 2 (length + Width) *wall thickness* No. of floors*Floor height
Internal Wall	Inner wall volume is considered as 80% of outer wall volume

- **Exterior Walls**
  - Brick (Common or Cored) with Plaster
  - Clay/Honeycomb Blocks
  - Hollow or Solid Concrete Blocks
  - Autoclaved Aerated Concrete (AAC)

  - Precast Panels
  - Stone Blocks
  - Metal or Aluminum Cladding
  - Curtain Walling
  - Steel-Clad Sandwich Panels

- **Interior Walls**
  - Brick, Clay, or Concrete Block Walls
  - Precast Panels
  - Cement Fiber Boards (on Metal/Timber Studs)
  - Plasterboards (with or without insulation)
  - In-situ Reinforced Walls
  - Stone Blocks
  - Precast Concrete Sandwich Panels

- **Doors, Windows, Staircases**.
  - Door and Windows cover 5% of the internal wall

2.5. Finishes: Floor finishes, wall finishes

Tiles = Floor area * No of storeys

Painting = (2*Internal wall area) / 8 since liter of paint covers 8 sqm area

2.6. Additional Element (If data exists)

- Insulation types and thicknesses
- Window specifications (frame type, glazing type, areas)
- Door specifications and quantities
- Staircases and ramps details

3. Operational Energy Data –

From Utility bills documented in energy audit report.

- Energy consumption by type (electricity, diesel, gas, etc.)
- Annual consumption values from utility bills
- Units must be specified (kWh, litre, kg, etc.)

4. Operational Details

- Operating hours and schedules
- Typical cooling/heating temperatures
- HVAC system and other building appliance type and capacities

5. Basic Building Information

- Building type and primary use
- Total built-up floor area
- Number of floors
- Construction year (if known)

GOOD-TO-HAVE DATA (Enhances Accuracy)

- Waterproofing materials
- Anti-termite treatments
- Special coatings or additional finishes

Data Format Recommendations

- **From Bill of Quantities (BOQs)**:
    - Extract material quantities with clear material identification
    - Use standard BOQ units: m^3 for concrete, kg or tonnes for steel, m^2 for tiles / finishes
- **Material Naming**: Use specific grades and types rather than generic terms.:
    - ❌ "Concrete" → ✅ "Ready-mix concrete M30"
    - ❌ "Steel" → ✅ "TMT Steel bars Fe 500D"

Key Points to Remember

- **Material accuracy is crucial**: Since EPDs are material-specific, incorrect material identification will lead to inaccurate carbon calculations.
- **Separate composite materials**: Always break down composite elements into individual materials.
- **Focus on major contributors**: Prioritize accuracy for high-volume materials (concrete, steel, bricks, glass, wood…)
- **Construction techniques**: While useful for context, these are not required for BEAT calculations.

Appendix II. List of energy efficiency suppliers

System	Organization Name	Email	Phone Number
Lighting	EGAL Lighting	info@egalgroup.org	(+855) 69 282 757
	MSKE Investment Co., Ltd.	mesacambodia@gmail.com	(+855) 70 979 824
	Maxk Lighting	info@maxklighting.com	(+855) 87 969 669
	Paragon Lighting Cambodia	support@paragon.com.vn	(+855) 10 319 717
	Bright & Eternity Trading Co., Ltd	kem.kep@betcambodia.com	(+855) 66 376 666
Power	ATS	e-mail@ats.com.kh	(+855) 93 716 333
	PATech	info@patech-eng.com	(+855) 61 222 409
	MAUSO	info@mauso-kh.com	(+855) 81 227 779
Air Conditioning and Ventilation	A.M.E.E	Thavyrin.borda@gmail.com	(+855) 12 920 858
	GAGE&C	info@gagec.com	(+855) 23 222 990
	CEMP Engineering Co., Ltd.	info@cem-engineering.com	(+855) 12 676 849
	EZ Build	info@cem-engineering.com	(+855) 69 836 896
	Sam hak Cooling system (JK&L United Co. Ltd.)	keang1633@yahoo.com	(+855) 70 422 356
	ET&S Engineering Import Export Co., Ltd.	info@etsengineering.com.kh	(+855) 16 928 929
	Taikisha (Cambodia) Co. Ltd	p-chanroth@taikisha-kh.com	(+855) 10 791 119
Pump	TEM Trading	Sales@tem-trading.com	(+855) 95 414 045
	LEO Pump Cambodia	info@leopump.com.kh	(+855) 85 888 363
	Dayuan Pump	dayuanpumpscambodia.assistant@gmail.com	(+855) 12 855 990

Appendix III: Building Types Suitable for Cambodia

Sl No	Building Type	Sub Type
1.	Residential Buildings	i) Villa ii) Multi Storied Apartments
2.	Commercial Buildings	i) Hotel ii) Market Place / Shopping Mall /Shophouse iii) Restaurants / Coffee Shops
3.	Institutional Buildings	i) Government Offices ii) Educational Buildings iii) Museums iv) Library
4.	Hospital Buildings	i) Clinic ii) Hospital
5.	Assembly buildings	i) Auditorium/Hall ii) Stadium
6.	Industrial	i) Manufacturing ii) Storage and Logistics
7.	Pagoda	-

Appendix IV: Detailed Energy Conservation Measures

ECM 01: Increasing the set temperature of the ACs by 3 degrees

Issue	It has been observed across restaurant chain that the set-temperatures of the ACs are low, due to which at times the staff leave the door open to infuse outdoor air to increase the inside temperature, particularly during the monsoon.
Solution	The adaptive thermal comfort of people supports a wide range of temperature hence increasing the temperature of the restaurant will not disturb thermal comfort and lead to energy savings. As per testing methodology, 1 degC rise in AC temperature leads to 6% of energy savings[21] hence increasing the set temperature by 3 degrees will lead to saving of 18%
Resource Saving	Energy Saving/AC: (3.78*.6) * 4,958 hrs * 18% = 2,024 kWh / year
Financial Investment	No capital cost
Financial Saving	Total Saving: 2,024 kWh *0.182 = 368 USD/year/AC
Return on Investment	0.1
CO_2 Saving	2,024 kWh / year x 0.61 kgCO2e/kWh /1000 = 1.2 tCO2e /year

[21] Press Information Bureau, Government of India, Ministry of Power. "Frequently Asked Questions on BEE Recommendations on Temperature Setting of Air Conditioners." June 29, 2018. https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=180281

ECM 02: Replacing Old/Energy Inefficient AC

<table>
<tr><td>Issue</td><td>Older air conditioning systems often suffer from low energy efficiency, refrigerant leaks, sensor issues, uneven cooling, extended run times, and difficulty maintaining the set temperature. Additionally, improper insulation of outdoor AC piping could further impact system performance and energy consumption.</td></tr>
<tr><td>Solution</td><td>Replacing the old inefficient fixed speed air conditioners with efficient inverter-based air conditioner will lead to savings.

As per the Thailand star rating system, a 1.5 TR Fixed Speed AC will have a best SEER of at least 13.00 whereas an efficient 1.5 TR Inverter AC will have a SEER of at lease 21.50.

<table>
<tr><th colspan="7">Energy Efficiency Level Criteria for Air Conditioners (Fixed Speed)</th></tr>
<tr><th rowspan="2">AC Capacity</th><th colspan="6">Efficiency Value: SEER (BTU/hr/W)</th></tr>
<tr><th>Base</th><th>★</th><th>★★</th><th>★★★</th><th>★★★★</th><th>★★★★★</th></tr>
<tr><td>Not exceeding 8,000 W (< 27,296 BTU/hr)</td><td>13.17 - 13.70</td><td>13.71 - 14.23</td><td>14.24 - 14.77</td><td>14.78 - 15.30</td><td>15.31 - 15.84</td><td>15.85</td></tr>
<tr><td>More than 8,000 - 12,000 W (27,296 - 40,944 BTU/hr)</td><td>12.56 - 13.12</td><td>13.13 - 13.69</td><td>13.70 - 14.25</td><td>14.26 - 14.82</td><td>14.83 - 15.39</td><td>15.40</td></tr>
<tr><td>More than 12,000 - 18,000 W (> 40,944 - 61,416 BTU/hr)</td><td>10.00 - 10.59</td><td>10.60 - 11.19</td><td>11.20 - 11.79</td><td>11.80 - 12.39</td><td>12.40 - 12.99</td><td>13.00</td></tr>
<tr><th colspan="7">Energy Efficiency Level Criteria for Air Conditioners (Variable Speed/Inverter)</th></tr>
<tr><th rowspan="2">AC Capacity</th><th colspan="6">Efficiency Value: SEER (BTU/hr/W)</th></tr>
<tr><th>Base</th><th>★</th><th>★★</th><th>★★★</th><th>★★★★</th><th>★★★★★</th></tr>
<tr><td>Not exceeding 8,000 W (< 27,296 BTU/hr)</td><td>17.06 - 18.55</td><td>18.56 - 20.05</td><td>20.06 - 21.55</td><td>21.56 - 23.05</td><td>23.06 - 24.55</td><td>24.56</td></tr>
<tr><td>More than 8,000 - 12,000 W (27,296 - 40,944 BTU/hr)</td><td>16.04 - 17.15</td><td>17.16 - 18.27</td><td>18.28 - 19.38</td><td>19.39 - 20.50</td><td>20.51 - 21.62</td><td>21.63</td></tr>
<tr><td>More than 12,000 - 18,000 W (> 40,944 - 61,416 BTU/hr)</td><td>14.00 - 15.49</td><td>15.50 - 16.99</td><td>17.00 - 18.49</td><td>18.50 - 19.99</td><td>20.00 - 21.49</td><td>21.50</td></tr>
</table>

In the solution, Thailand Star Rating Table is considered because Cambodia has no star rating table in the public domain for ACs and the installed brand is an import.</td></tr>
</table>

	 Figure 15: Inverter-based Air Conditioner. PS – Cambodia has launched its own star labelling for split ACs (< 27,297 BTU/hr) in April 2025 and the Government has given time of 1 year for all manufacturers and importers to comply to the Star labelling regulation. The star labelling is based on Cooling Seasonal Performance Factor (CSPF) which requires the energy performance of ACs to be tested as per the temperature conditions mentioned in ISO 16358-1:2013 and ISO 5151:2017. Since, the installed ACs imported from China, Thailand majorly has rated energy efficiency mentioned in the name plate and not the CSPF, hence for recommendations, owing to lack of sufficient information on CSPF - we are using international star rating table for energy saving estimation
Resource Saving	Average Power Rating of Fixed Speed AC: (1.5*12000)/13.7 = 1313.8 W Average Power Rating of Inverter AC: (1.5*12000)/24.56 = 733 W Energy Savings/AC: (1313.8 - 733) W * 1980 hrs = 1151 kWh/year
Financial Investment	650 USD
Financial Saving	1151 kWh/year * 0.182 USD/kWh = 209.6 USD
Return on Investment	3.1 years
CO_2 Saving	1151 kWh * 0.61 kgCO_2e/kWh /1000 = .7 tCO_2e

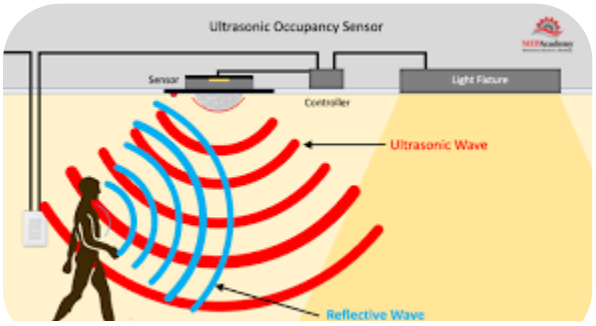
ECM 03: Replacement of Induction Fans with BLDC Fans

Issue	Some buildings have installed induction ceiling fans of 70-80 Watts **Figure 16: Induction Ceiling Fan.**
Solution	BLDC (Brushless Direct Current) fans are preferred over induction fans due to their superior energy efficiency, longer lifespan, quieter operation, and advanced control features. BLDC motors consume significantly less power, often 60-70% less than induction motors, leading to lower electricity bills and reduced environmental impact. They also have a longer lifespan due to the absence of brushes and lower heat generation, resulting in fewer maintenance needs. BLDC fans offer precise speed control, timer functions, and sleep mode, enhancing user comfort and convenience. **Figure 17: Representative image of a BLDC fan with remote.**
Resource Saving	**Energy Savings/fan**: (70 W - 34 W) * 2880 hrs = 103 kWh / year
Financial Investment	40 $/BLDC fan
Financial Saving	18.8 USD/yr
Return on Investment	2.1 years
CO_2 Saving	103 kWh / year x 0.61 kgCO_2e/kWh /1000 = 0.063 tCO2e /year per fan

ECM 04: Retrofit of tube lights with LED tube lights

Issue	Many buildings have fluorescent tube lights installed in many locations for their illumination requirements
Solution	Replacing the T5 tubelights with LED tube light can help to save energy. The LED bulbs which are of 9W or LED tubelights which are of 18 W can be used to retrofit the existing T5 tubelights which are of 36 - 40W
Resource Saving	**Energy Savings/tube light**: (36 -18) W * 1825 hrs = 32.9 kWh / year
Financial Investment	Cost of LED tube-light – 9.6 USD
Financial Saving	Cost Savings/tube light: 32.9 kWh/year * 730 riels/kWh = 24,017 riels/ year or 6 USD
Return on Investment	1.6 years
CO_2 Saving	32.9 kWh / year x 0.61 kgCO_2e/kWh /1000 = 0.02 tCO2e /year per tube light

ECM 05: Installation of Occupancy sensors

Issue	In most of the buildings, the toilets are not equipped with occupancy sensors, leading to energy loss. For each toilet at least 2 units of sensors would be required, which cost USD 10 each. Occupancy sensors can save about 20 – 60% of energy consumption depending upon the usage of toilets.
Solution	Occupancy sensors in toilets can significantly save energy by automatically turning lights on when someone enters and off when the space is unoccupied. This reduces unnecessary energy consumption, ensuring lights are only used when needed. Additionally, these sensors can help lower electricity bills and contribute to a more sustainable environment. Automatic detection sensors save energy by automatically turning off lights when no people are detected in the target space. Typical movement-detecting sensors include infrared, ultrasonic, and Doppler sensors. This is one of the most efficient energy-saving systems.  **Figure 18: Installation of occupancy sensor in toilet.**
Resource Saving	**Energy Savings/toilet**: (6 x 12) W * 4320 hrs * 20% = 62 kWh / year
Financial Investment	20 USD/toilet
Financial Saving	**Cost Savings/toilet**: 62 kWh/year * 640 riels/kWh = 11.2 USD/yr
Return on Investment	1.7 year
CO_2 Saving	142 kWh / year x 0.61 kgCO_2e/kWh /1000 = 0.086 tCO2e /year

ECM 06: Installation of VSD/VFD drives

Issue	It is observed in many buildings the pumps are running at full load capacity even when there is no requirement for them to run on full load conditions leading to energy wastage. If the pumps and motors can run or drive as per the load conditions, then energy savings can be achieved.
Solution	Installing Variable Frequency Drives (VFDs) or VSDs on motors and pumps can lead to significant energy savings. These drives adjust the motor speed to match the actual load requirements, reducing energy consumption by 10-30%. Although the initial cost is around USD 10000 per unit, the long-term savings on energy bills and the reduction in energy waste make it a worthwhile investment. VFDs/VSDs operate by varying the frequency and voltage supplied to the motor, allowing it to run at different speeds. This means the motor only uses the amount of energy needed for the specific task, rather than running at full speed all the time. This not only saves energy but also reduces wear and tear on the equipment, extending its lifespan.
Resource Saving	**Energy Savings/motor**: 1.73 * 150 A* 440 V* 0.9 (power factor) * 2500 hrs * 10% (least energy saving potential) = 25,690 kWh / year
Financial Investment	Cost of VFD for 90 kW: 40,000,000 riels | 9990 USD
Financial Saving	Cost Savings/motor: 25,690 kWh/year * 0.182 $/kWh = 4,688 USD
Return on Investment	2.1 years
CO_2 Saving	25,690 kWh / year x 0.61 kgCO_2e/kWh /1000 = 15.8 tCO2e /year

ECM 07: Apply Sun Control Window Film

Issue	In majority of buildings, window glazing is of clear glass. The east, south, and north façades lack any shading devices to block direct sunlight. As a result, indoor spaces with large window areas—particularly on the south and west façades—experience excessive heat gain, leading to increased cooling energy demand.
Solution	Applying sun control window films can help reduce solar heat gain in the building by approximately 10 - 30%, particularly on the south- and west-facing façades.
Resource Saving	**Energy Savings 30% of cooling load**: 460.8 kW * 1,460* 10% = 67,276.8 kWh / year
Financial Investment	Cost of Sun Control Window Film: 20$/sqm * 2,208sqm =44,160 USD
Financial Saving	Cost Savings: 67,276.8 kWh/year * 0.182 USD/kWh = 12,244 USD
Return on Investment	3.6 years
CO_2 Saving	67,276.8 kWh / year x 0.61 kgCO_2e/kWh /1000 = 123 tCO2e /year

ECM 08: Installation of Timer Switch for Water Dispenser

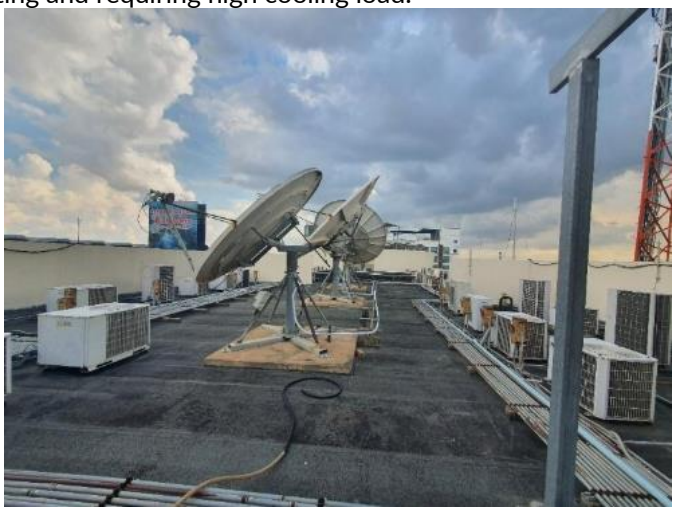
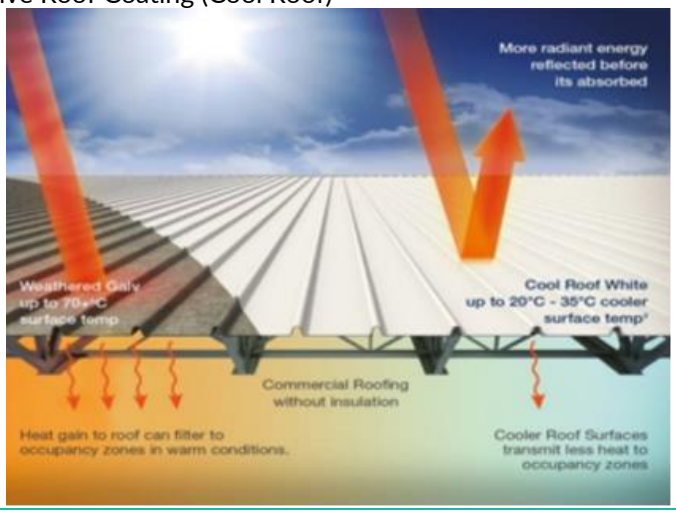
Issue	The water dispenser is turned on 24 hours a day or unoccupied hours, which causes unnecessary electricity consumption, increases energy costs, and puts continuous stress on the heating and cooling systems. This constant operation can lead to a shorter lifespan of the appliance and potential overheating, especially during times when the dispenser is not in use (e.g., overnight or weekends).
Solution	Install a timer switch to automatically turn the water dispenser on and off according to your daily usage schedule. A digital programmable timer (like the TM619) allows you to set specific on/off times, ensuring the dispenser only runs when needed. This helps save electricity, reduces wear on internal parts, and lowers the risk of overheating, all while maintaining user convenience. **Figure 19: Installation of Digital Programmable Timer Switch.**
Resource Saving	**Energy Savings**: (500-0.5) W * 1980 hrs = 989 kWh / year
Financial Investment	30 USD/dispenser
Financial Saving	**Cost Savings/toilet**: 989 kWh/year * 0.182 USD = 180 USD
Return on Investment	<1 month
CO_2 Saving	989 kWh / year x 0.61 kgCO2e/kWh /1000 = 0.6 tCO2e /year

ECM 09: Rooftop Renewable Energy System

Issue	Available space on the roof of the building which has potential for installing rooftop solar PV system.
Solution	The average horizontal irradiation at the location is about 5.1 kWh/m²/day. At this level, an assessment for generating electricity from rooftop solar system is conducted to evaluate the reduction in electricity cost and GHG emission reduction for the building. The available roof space is approximately 300 sqm. Additional areas like parking and free areas can also be used for solar installation. Therefore, total usable space for solar installation is approximately 400sqm.
Resource Saving	Standard solar panels typically produce around 200 W/m² (0.2 kWp/m²). At condition of solar panel efficiency of 20%, the total capacity of rooftop solar system is 400 m2 * 0.2 kWp/m2= 80 kWp. For on grid rooftop solar system, the annual energy generation is defined below. Energy generation: 80 kWp * 5.1 kWh/m² * 0.9 * 238 days = 87,393 kWh/year PS – 238 days are used in the calculation according to office operation days. The grid supplier do not provide net metering to consumers which could allow selling renewable energy in excess or during off days in which the building have minimal consumption. In Cambodia, it's a common practice to install zero export device due to lack of net metering facility and compensation tariff.
Financial Investment	System cost per kWp: USD 1,080[22] Total investment: USD 1,080 * 80 kWp = USD 86,400
Financial Saving	Cost Savings: 87,393 kWh/year * 0.182 USD/kWh = 15,905 USD/year Compensation tariff: 0.047 USD/kWh * 87,393 kWh/year = 4,107 USD/year Total saving: 15,905 USD/year – 4,107 USD/year = 11,798 USD/year
Return on Investment	7.3 years
CO_2 Saving	87,393 kWh/year * 0.61 kgCO_2e/kWh /1000 = 53.3 tCO2e/year

[22] EAC decision on compensation tariff, ref: 101SR-25 EAC

ECM 10: Cool Paint on rooftops

Issue	The building's roof is a major source of heat transfer to the floor below, which houses offices, causing overheating and requiring high cooling load.  **Figure 20 - Existing rooftops exposed to sunlight.**
Solution	Applying Reflective Roof Coating (Cool Roof) 
Resource Saving	**Energy Savings**: 544sqm * 0.1kWh *1,944hrs /3.5 = 30,215.3 kWh / year
Financial Investment	8 USD * 544sqm = 4,352 USD
Financial Saving	Cost Savings/Unit: 30,215.3 kWh/year * 0.164 USD/kWh = 4,955.3 USD/ year
Return on Investment	0.87 years
CO_2 Saving	30,215.3 kWh / year x 0.61 kgCO_2e/kWh /1000 = 18.43 tCO2e /year

ECM 11: Daylight optimization

Issue	Most of the indoor spaces are accessible to natural light. However, the blinds are pull down and blocking the sunlight. The artificial lights are used to light up the room. **Figure 21. Potential of using sunlight for illuminations.**
Solution	Maximize daylighting. After all, sunlight is free! Open or close blinds to make the best use of natural daylight and take advantage of skylights or other natural daylight sources to reduce lighting during daytime hours.
Resource Saving	10%-20% of lighting power consumption of the building: 277,820kWh * 20% * 20% = 11,112kWh/year
Financial Investment	Low to zero cost
Financial Saving	Occupancy Cost Savings: 11,112 kWh/year * 0.182/kWh = 2,022 USD/year
Return on Investment	Immediately
CO_2 Saving	11,112 kWh / year x 0.61 kgCO_2e/kWh /1000 = 6.778 tCO2e /year

ECM 12: Air Curtain Motion Sensor

Issue	In the common area, such as the entrance, an air curtain is installed and operates continuously. However, it is often left running even when not needed, which can lead to unnecessary energy consumption and energy waste.
Solution	Occupancy sensors at the entrance can significantly reduce energy consumption by automatically turning air curtain on when someone enters and off when the space is unoccupied.
Resource Saving	Energy Savings/unit: 440 W * 4,958 hrs * 20% = 436 kWh / year
Financial Investment	Occupancy Sensor: 20 USD/sensor
Financial Saving	Total Saving: 436 kWh *0.18=78.5 USD/year
Return on Investment	0.2 year
CO_2 Saving	436 kWh/year x 0.61 kgCO2e/kWh /1000 = 0.3 tCO2e /year

About ALCBT Project

The Asia Low Carbon Buildings Transition (ALCBT) Project seeks to significantly reduce GHG emissions by catalyzing nationwide transition towards low-carbon buildings in Cambodia, India, Indonesia, Thailand, and Vietnam. The project is led by the Global Green Growth Institute (GGGI), in partnership with the ASEAN Centre for Energy (ACE), Energy Efficiency Services Limited (EESL), and HEAT GmbH. It is funded by the Government of Germany's Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) via the International Climate Initiative (IKI).

In Cambodia, the project is implemented in partnership with the Ministry of Land Management, Urban Planning, and Construction (MLMUPC). It conducts assessments and develops tools and measures for low carbon buildings, focusing on Phnom Penh, and designed for replication in other Cambodian cities.

About GGGI

Global Green Growth Institute (GGGI), headquartered in Seoul, Republic of Korea is a treaty-based international, inter-governmental organization dedicated to supporting and promoting strong, inclusive and sustainable economic growth in developing countries and emerging economies.

About ACE

The ASEAN Centre for Energy (ACE) is an intergovernmental organization within the Association of Southeast Asian Nations' (ASEAN) structure that represents the 11 ASEAN Member States' (AMS) interests in the energy sector.

About EESL

Energy Efficiency Services Limited (EESL) is a super energy service company under the India's Ministry of Power. It seeks to unlock energy efficiency market in India through innovative business models and has expanded its operations in other Asian countries.

About HEAT International

HEAT International is an independently acting consulting firm with 30 years of experience in the field of climate, heating & cooling, and transport. HEAT's goal is to support countries in their effort to mitigate emissions and to implement transformative pathways towards zero GHG emission solutions.

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant.

ASIA LOW CARBON BUILDINGS TRANSITION
Life Cycle Assessment for Transitioning to a Low-Carbon Economy | **PROJECT**

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