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Energy Auditing Across Building Types Worldwide: A Review of Methods, Findings and Lessons for Bangladesh

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Abstract

Building energy audits combine utility records, field measurements, and engineering analysis to identify energy-conservation measures (ECMs). This structured narrative review examines international evidence across residential, office, educational, healthcare, hospitality, and public buildings, with particular attention to Bangladesh. Studies published from 2015 to October 2026 are emphasized, alongside foundational methods and standards. Audit priorities vary with climate, occupancy, operating hours, and service requirements. Heating, ventilation, and air conditioning, lighting, controls, and equipment scheduling recur across building types, while hospitals and hotels require additional attention to ventilation, hot water, and continuous services. Comparisons are limited by inconsistent energy boundaries and by the prevalence of estimated rather than measured savings. Bangladesh's 12-building public-sector audit program reported approximately 17% electricity-saving potential, providing a useful starting point for local implementation. Broader evidence remains limited across building categories. The review recommends consistent audit reporting, building-type benchmarks, targeted submetering, lifecycle appraisal, and post-retrofit measurement and verification. International audit methods are transferable, but savings estimates require validation under Bangladesh's climate, operating conditions, and institutional constraints.

Keywords: energy audit; building energy efficiency; energy conservation measures; energy-use intensity; measurement and verification; Bangladesh

1. Introduction and review objectives

Buildings account for a substantial share of global energy demand, making operational efficiency an important demand-side strategy. The 2023 Global Status Report for Buildings and Construction, published in 2024, documents the sector's energy and emissions burden (United Nations Environment Programme [UNEP], 2024). An efficient design alone does not ensure efficient operation: schedules, controls, maintenance, occupant practices, and envelope deficiencies can raise consumption even where individual components are efficient.

An energy audit is not a single test but a structured diagnosis of how, where, and why energy is used. For commercial buildings, ANSI/ASHRAE/ACCA Standard 211 defines consistent procedures and minimum reporting requirements for audit Levels 1, 2, and 3 (ASHRAE, 2023). International Organization for Standardization (ISO) 50002-1:2025 provides a broader international framework for planning, conducting, and reporting energy audits and for identifying energy-performance improvement actions (ISO, 2025). These frameworks differ in terminology and scope, but they converge on the need to define an energy boundary, gather credible consumption and operating data, evaluate significant energy uses, quantify potential improvements, and communicate assumptions and uncertainty.

The distinction between finding an opportunity and proving a saving is central. Audit reports commonly estimate savings using engineering calculations or simulations; these values are conditional on assumed operating hours, weather, occupancy, control response, and equipment performance. By contrast, post-retrofit measurement and verification (M&V) compares normalized baseline and reporting-period performance and is designed to establish what was actually saved. The International Performance Measurement and Verification Protocol (IPMVP) remains a widely used framework for this purpose (EVO, 2022). Long-standing retrofit literature also emphasizes that economic screening, risk assessment, implementation quality, and M&V are integral parts of successful retrofit programs rather than optional additions (Ma et al., 2012).

Cross-building comparison is useful only when it respects functional differences. A hospital that operates 24 hours per day, maintains ventilation and pressure relationships, sterilizes instruments, and powers medical equipment cannot be compared directly with a school that closes overnight and for vacations. Hotels combine guestrooms, kitchens, laundries, hot-water systems, common areas, and highly variable occupancy; offices are dominated by cooling, ventilation, lighting, and plug loads; residential buildings are strongly affected by household behavior. Therefore, the review treats energy-use intensity (EUI) as a contextual indicator rather than a league table. EPA guidance defines EUI as annual energy use divided by building area and distinguishes site and source energy; weather-normalized metrics are intended to improve year-to-year comparability (U.S. EPA, n.d.; U.S. EPA, 2025).

This review has four objectives. First, it compares audit methods, data collection, instruments, baselines, indicators, and economic evaluation approaches across major building types. Second, it synthesizes recurring ECMs and explicitly separates projected, modeled, and measured savings. Third, it examines implementation barriers and the role of M&V. Fourth, it connects international evidence to Bangladesh, where hot-humid conditions, rapid urbanization, growing cooling demand, and uneven metering create a distinctive context. The aim is not to claim statistically representative worldwide performance, but to identify evidence-supported practices and limitations that can inform building-energy policy, research, and facility management in Bangladesh.

2. Literature search and selection approach

This study uses a structured narrative approach rather than a systematic review. The source set was checked through web searches, publisher and DOI records, and official institutional publications, with verification updated on 9 October 2026. Priority was given to primary building studies and authoritative technical reports published from 2015 onward. Older sources were retained for foundational methods, calibration, and retrofit appraisal. Bangladesh evidence was sought in SREDA and GIZ publications and academic case studies.

Search terms combined building categories with “energy audit,” “measured savings,” “benchmark,” and “payback.” Bangladesh searches included “public buildings,” “SREDA,” and “energy efficiency.” Standards were located by title. Full texts were preferred; where access was limited to publisher abstracts, only information visible in those records was used. This review does not claim exhaustive database coverage.

The core synthesis includes studies reporting operational building-energy data, audit procedures, conservation measures, savings estimates, or economic indicators. Industrial process audits were excluded. Simulation-only and organizational studies were retained as contextual evidence and distinguished from measured operational audits. Findings were classified as estimated or modeled potential, observed before–after change, or savings assessed through an explicit measurement-and-verification method. Potentially overlapping publications were treated cautiously to avoid counting the same building twice.

No pooled savings estimate or PRISMA selection count is reported because the search was not designed as an exhaustive systematic review. Differences in climate, energy boundaries, occupancy, and measurement methods limit quantitative comparison. Numerical inconsistencies identified during checking are disclosed or omitted; metadata verification alone is not treated as validation of a study's results.

3. Building energy-audit methods and performance indicators

3.1 Audit depth, boundaries, and planning

Audit depth should match the decision being made. ASHRAE Level 1 is primarily a walk-through and preliminary analysis, Level 2 adds detailed energy surveying and engineering analysis, and Level 3 supports more investment-grade decisions with greater measurement and analytical rigor (ASHRAE, 2023). ISO 50002-1:2025 similarly emphasizes transparent scope, competent auditors, data quality, and prioritized improvement actions (ISO, 2025). In practice, the most important early decisions are often the least visible: whether the boundary includes only purchased electricity or all delivered fuels; whether parking, kitchens, tenant loads, data rooms, or on-site renewable generation are included; and which floor-area definition is used.

A credible audit begins with at least 12 months of utility data where available, tariff structure, peak demand, building area and use, occupancy, operating schedules, equipment inventory, and maintenance information. Longer histories are preferable where weather and operational variability are material. A walk-through identifies obvious mismatches—such as cooling during unoccupied periods, excessive setpoint differences, poor lighting control, equipment left energized, simultaneous heating and cooling, or damaged insulation—but high-confidence measures usually require spot measurements or logging.

3.2 Measurement, monitoring, and model calibration

Common audit instruments include clamp meters, portable power analyzers, lux meters, temperature and relative-humidity loggers, airflow instruments, infrared cameras, combustion analyzers, ultrasonic flow meters, and building-management-system trend data. Submetering is especially valuable in complex buildings because whole-building bills cannot separate chiller, air-handler, lighting, plug-load, kitchen, laundry, hot-water, or medical-equipment performance. The value of measurements is not simply their quantity: duration must be long enough to represent operating modes and should be linked to weather and occupancy.

Simulation can extend short-term measurements to annual estimates, compare retrofit packages, and test interactions among envelope, HVAC, and controls. However, calibration is necessary if simulation is used to make claims about an existing building. Coakley, Raftery, and Keane reviewed methods for matching building energy simulation models to measured data and showed that calibration is essential because real buildings contain uncertain schedules, loads, and control behavior (Coakley et al., 2014). University-building studies in the UAE and Malaysia similarly demonstrate how measurements and calibrated simulation can reveal performance gaps and test combined ECM packages (Alamin et al., 2023; Kim et al., 2021).

3.3 Baselines, EUI, benchmarking, and normalization

The simplest baseline is a historical annual or monthly energy total, but this is often inadequate when weather, occupancy, operating hours, or production-like service intensity changes. Weather normalization commonly uses heating degree days, cooling degree days, or temperature-regression models. Portfolio Manager, for example, provides weather-normalized energy and EUI to support year-to-year comparisons (U.S. EPA, 2025). In hospitals, hotels, and campuses, service-normalized indicators such as kWh/bed/year, kWh/occupied room-night, or kWh/student/year can complement area-based EUI, but they should not replace a clearly defined whole-building energy boundary.

Benchmarking is most useful as a screening device. A high EUI may indicate inefficiency, but it may also reflect long operating hours, intensive equipment, more ventilation, laboratory loads, kitchens, or high occupancy. Conversely, a low EUI can result from under-conditioning or inadequate services. This is why direct ranking across climates and functions is misleading. The same caution applies to cross-country cost comparisons because tariffs, subsidies, currency values, inflation, financing, and equipment prices differ.

3.4 Economic assessment and measurement & verification

Economic screening ranges from simple payback to life-cycle cost, net present value (NPV), internal rate of return (IRR), and sensitivity analysis. Simple payback is easy to communicate but ignores measure life, financing, residual value, tariff escalation, and maintenance effects. Studies of educational and commercial buildings increasingly report NPV or combined payback for packages rather than isolated measures (Ahmed et al., 2023; Alamin et al., 2023). For Bangladesh, where financing constraints may determine implementation more strongly than technical potential, lifecycle analysis should be paired with realistic procurement and maintenance assumptions.

Measurement and verification (M&V) evaluates savings against an appropriate baseline, with adjustments for relevant conditions. The International Performance Measurement and Verification Protocol provides approaches for individual systems and whole facilities (EVO, 2022). A reduction in bills alone cannot establish how much change resulted from a retrofit: weather, occupancy, operating schedules, and on-site generation may also affect the comparison. M&V requirements should therefore be defined before implementation.

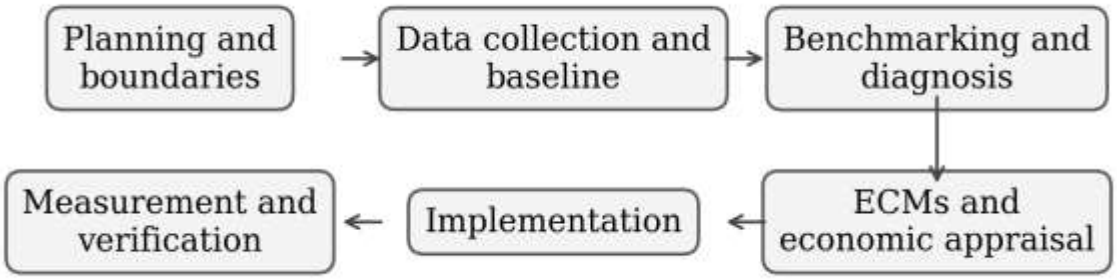


Figure 1 :Building energy-audit and verification workflow

4. International evidence across building types

4.1 Residential buildings

Residential audits are unusually sensitive to occupant behavior because thermostat settings, appliance ownership, cooking, hot-water use, presence patterns, window opening, and room-level conditioning vary among households. Delzendeh et al. showed that occupant assumptions are a major source of uncertainty in building-energy analysis (Delzendeh et al., 2017). Rana et al. monitored two Canadian single-family homes for one year and used calibrated simulations to test upgrade choices for different household profiles, demonstrating that the preferred package can change when occupant behavior and priorities change (Rana et al., 2020). This makes standardized household EUI useful for screening, but insufficient for predicting an individual household's realized savings.

Residential audit case studies also illustrate the value of combining bills with engineering analysis. Solgi et al. evaluated a cold-climate residential building in Iran using actual consumption and simulation, focusing on whether audits remain economically meaningful where energy prices are low (Solgi et al., 2019). Bosu et al. conducted ASHRAE Level 1 and 2 audits in a university residential building in Egypt. Air conditioning represented about 62% of electricity, socket loads 25%, and lighting 13%. Proposed lighting measures were estimated to save 4,432.6 kWh/year, while replacing non-inverter air conditioners with inverter units was estimated to save about 61,194 kWh/year (22.96%) with an 8.6-year payback; PV and solar-water-heating options were evaluated separately (Bosu et al., 2023). These are estimated savings, not reported post-retrofit achievements.

In hot-humid settings, residential audits should prioritize air conditioners, fans, refrigerators, lighting, standby loads, and solar gains, while recording occupancy and appliance use. Envelope measures require local assessment of cooling, ventilation, and moisture conditions.

4.2 Offices and commercial buildings

Office and commercial audits repeatedly identify cooling and ventilation as major loads, followed by lighting and plug loads. An older but still instructive Riyadh office audit found air conditioning accounted for around half of installed power and combined measurements of temperature, humidity, solar radiation, lighting, and equipment loads with engineering evaluation of retrofit options (Al-Ajlan, 2009). More recent academic-office work in the Philippines found air conditioning represented an average 63% of power use across the audited offices, followed by lighting (23%) and plug loads (14%); the authors recommended LED lighting and inverter air-conditioning technologies (Chan et al., 2021).

A Saudi office retrofit illustrates both the value of post-implementation assessment and the need to check reported arithmetic. Asif et al. (2023) reported an EUI decrease from 458.9 to 361.4 kWh/m²/year, implying a baseline-relative reduction of approximately 21.2%. The source's reported 27% does not agree with these values. Ahmed et al. (2023) report identical EUIs and overlapping project characteristics; the two publications are treated here as potentially dependent evidence, not independent demonstrations. Their reported six-year compound payback is case-specific.

4.3 Educational buildings and university campuses

Educational buildings range from intermittently occupied classrooms to laboratories, libraries, data rooms, workshops, and student residences. Academic calendars create long periods of partial occupancy, so schedule errors can produce a large share of avoidable energy use. Zailan and Che Kar reported a Building Energy Index of 98.035 kWh/m²·year for a Malaysian university faculty building, with an air-conditioning index of 73.254 and a lighting index of 11.402 kWh/m²·year. Proposed measures included energy-management practices, air-conditioning maintenance, and LED retrofits; the study targeted roughly 30% annual energy saving, but this was a target rather than verified performance (Zailan & Che Kar, 2018).

More detailed university studies integrate surveys, measurement, and simulation. Alamin et al. proposed eight measures for a Malaysian university building; individual simulated reductions ranged from 2% to 18%, while the combined package was modeled at 41% annual energy reduction with a 3.9-year payback (Alamin et al., 2023). Mohamed et al. studied Princess Sumaya University for Technology in Jordan and estimated an average 12.5% saving from optimized air-conditioner operating times across scenarios; insulation offered higher cost savings but with a long payback (Mohamed et al., 2022). Dyussembekova et al. modeled minor and major retrofit scenarios for the Kazakh-German University, reporting increasingly large annual energy reductions but also highlighting the barrier of high upfront cost (Dyussembekova et al., 2022).

Verification remains important because modeled campus savings can diverge from post-retrofit outcomes. Ligade and Razban simulated HVAC alternatives for a U.S. university health-science building and identified a single-duct VAV system as the most efficient modeled option, with a 28% utility-cost saving relative to the existing system (Ligade & Razban, 2019). By contrast, a later Bosnia and Herzegovina faculty-building case compared pre-renovation bills with post-renovation consumption and reported a much larger measured reduction after envelope and heating-system changes, though the result also reflected fuel switching and should not be generalized to other educational buildings (Peulić et al., 2025).

4.4 Hospitals and healthcare buildings

Hospitals are difficult audit subjects because energy efficiency must not compromise infection control, ventilation, pressure regimes, filtration, thermal comfort, or clinical reliability. They also contain large non-HVAC loads such as imaging, sterilization, laboratories, laundries, kitchens, lifts, UPS systems, and hot water. A 1,250+ bed hospital in India consumed 43,421.15 MWh during April 2019–March 2020 and had an EPI of 290.98 kWh/m²·year; grid electricity represented 64% of site energy (Bhatia & Singh, 2021). The study is useful as a benchmarking case but does not claim verified retrofit savings.

Kapoor and Singhal (2025) identified HVAC, lighting, and uninterruptible power supply equipment as major uses in a southern Indian hospital. Proposed measures had an estimated combined payback of approximately two years. In Pakistan, Habib et al. (2026) attributed approximately 64% of calculated electrical load to air conditioners, chillers, and cooling towers. This kW-based share should not be interpreted as a measured annual kWh share. Apparent unit inconsistencies in that paper's savings calculations further limit quantitative reuse.

Mediterranean hospital research similarly supports integrated envelope and systems assessment, but emphasizes investment barriers and the need to preserve service quality (De Masi et al., 2023). For hospital audits, the most transferable lesson is methodological: end-use metering, ventilation-system performance, plant efficiency, scheduling, setpoints, heat recovery, hot-water demand, and clinical constraints should be evaluated together. Simple lighting measures may have short paybacks, but high-value HVAC measures require coordinated engineering and M&V.

4.5 Hotels and hospitality buildings

Hotels combine guestrooms, common areas, kitchens, laundries, restaurants, domestic hot water, ventilation, pools or spas, and variable occupancy. Useful indicators therefore include kWh/m²·year together with kWh/occupied room-night or guest-night where reliable occupancy data exist. A Portuguese four-star hotel case used a detailed audit to calibrate a DesignBuilder/EnergyPlus model and then evaluated passive, active, and renewable-energy packages for realistic nearly-zero-energy performance (Cunha & Oliveira, 2020). Its main contribution is methodological: detailed measured consumption can anchor hotel retrofit modeling and cost-optimal analysis.

Hospitality evidence also shows that organizational practices matter. A Bali hotel study found positive associations between energy-audit practices, eco-efficiency, and environmental performance, although its cross-sectional survey design could not establish causal energy savings (Saputra et al., 2022). In practical audits, guest-room controls, chiller and pump efficiency, domestic hot-water generation, laundry heat, kitchen exhaust and make-up air, lighting, and occupancy-based control are recurrent opportunities. Because guest comfort and brand standards are commercially sensitive, measures should be tested for comfort, humidity, noise, and service continuity rather than selected only on energy calculations.

4.6 Public and institutional buildings

Lee and Choi (2025) compared electricity bills before and after an envelope retrofit in a South Korean public building. Consumption was 14.7% lower in 2023 and 8.0% lower in 2024 than in 2019, with seasonal differences. These are observed billing changes. Limited operational detail and weather adjustment restrict attribution of the entire reduction to the retrofit. The case supports multi-year monitoring but should not be treated as equivalent to fully normalized savings verification.

Table 1 : *Selected international building energy-audit case studies*

Study and building	Method and baseline	Measures and findings	Economics and limitations
Bosu et al. (2023), Egypt University residential; hot-arid/coastal	ASHRAE L1/L2; bills, meters, survey AC 62%, sockets 25%, lights 13%	LED/sensors; inverter AC; PV; SWH Projected: AC change 61,194 kWh/y (22.96%); lighting 4,432.6 kWh/y	AC payback 8.6 y; PV 3.77 y; SWH 2.49 y; not post-retrofit M&V
Rana et al. (2020), Canada Two detached homes; different occupancy profiles	1-year intrusive load monitoring + calibrated simulation Profile-specific, not directly comparable	Upgrade combinations chosen by occupant scenario Modeled scenarios	Shows occupant behavior changes optimal package

Study and building	Method and baseline	Measures and findings	Economics and limitations
Asif et al. (2023); Ahmed et al. (2023), Saudi Arabia 7,500 m² office; hot-arid	Detailed audit + IPMVP Option B EUI 458.9 kWh/m²·y pre-retrofit	Five EEMs + rooftop PV Reported EUI 458.9 → 361.4 kWh/m²/year; calculated reduction 21.2%. Source reports 27%; discrepancy unresolved.	Reported 6-year compound payback; publications apparently overlap.
Alamin et al. (2023), Malaysia University educational building; hot-humid	Measurements, survey, simulation Building-specific modeled baseline	8 envelope/HVAC/lighting/control measures Modeled: 2–18% each; 41% combined	Combined payback 3.9 y; not measured post-retrofit
Zailan & Che Kar (2018), Malaysia University faculty building	Internal audit; comfort/IAQ, lighting BEI 98.035; ACEI 73.254; LEI 11.402 kWh/m²·y	SEMS, AC maintenance, LED Target/projected ~30% annual saving	Estimated annual cost saving RM48,551.20; no M&V reported
Bhatia & Singh (2021), India 1,250+ bed hospital; composite climate	1-year operational energy assessment 43,421.15 MWh/y; EPI 290.98 kWh/m²·y	Benchmarking-focused No retrofit saving verified	Grid electricity 64%; useful benchmark, not an intervention trial
Kapoor & Singhal (2025), India Tertiary hospital; humid tropical; 24/7	Detailed audit, end-use monitoring, load profiling HVAC, lighting, UPS dominant	LED, HVAC, solar, operations Estimated only	Accessible abstract indicates ~24-month payback; currency detail not used here
Cunha & Oliveira (2020), Portugal 4-star hotel	Detailed audit + calibrated DesignBuilder/EnergyPlus Measured hotel energy used for calibration	Passive, active, renewable packages Modeled scenarios	Cost-optimal/nZEB analysis; no simple measured retrofit % used here
Lee & Choi (2025), South Korea Aging public building	Utility bills: 2019 baseline, 2023–2024 post Whole-building electricity	Wall, roof, window retrofit Observed bills: −14.7% in 2023 and −8.0% in 2024 versus 2019.	Limited weather and operational adjustment; seasonal variation.

Study and building	Method and baseline	Measures and findings	Economics and limitations
Peulić et al. (2025), Bosnia & Herzegovina University/public educational building	Pre bills 2013–15 vs 2022 post-renovation Heating/final-energy comparison	Envelope + heating optimization; coal to biomass Measured bills: 94.18 kWh/m² (74.96%) reduction reported	Fuel switch and long comparison interval limit direct transferability
Chan et al. (2021), Philippines Academic office; tropical	Audit of 8 representative offices AC 63%, lights 23%, plug loads 14%	LED; inverter AC Recommendations; no measured savings	Pilot scale; office subset only

Note: Modeled and recommended savings are not achieved savings. EUIs are not ranked because building functions, climates, and measurement boundaries differ.

5. Critical comparative discussion

The case evidence does not support a single "typical" building saving. The same measure can perform differently because climate, internal loads, operating hours, maintenance quality, and baseline efficiency change the marginal benefit. Cooling-dominated offices in tropical and Gulf climates often show large HVAC shares (Asif et al., 2023; Chan et al., 2021), while heating-dominated public or educational buildings may respond more strongly to envelope and heating-system measures (Lee & Choi, 2025; Peulić et al., 2025). Residential performance is particularly sensitive to occupant behavior (Rana et al., 2020). Thus, cross-study synthesis should compare methods and mechanisms before comparing percentages.

Across building types, recurring ECMs fall into five groups: operational and control improvements; lighting retrofits and controls; HVAC plant or room-unit upgrades; envelope measures; and on-site renewables. Operational measures usually have low capital cost but can decay if staff practices change. Lighting is comparatively straightforward to quantify, yet its total-building impact depends on how large lighting is in the baseline. HVAC upgrades can generate large savings, especially in cooling-dominated buildings, but interactions with ventilation, humidity, and controls require careful engineering. Envelope improvements have long lives but often longer paybacks and strong climate dependence. Renewables reduce grid purchases but should be reported separately from demand-side efficiency to avoid confusing lower purchased energy with reduced building demand.

The reviewed evidence spans engineering estimates, calibrated simulations, and post-retrofit measurements. These categories answer different questions. Simulation tests potential measures under stated assumptions; measurements reveal actual consumption, while adjusted baselines support attribution of savings. Calibration reduces uncertainty but does not establish that a proposed package has been implemented (Coakley et al., 2014). The apparently overlapping Saudi publications should not be counted as two independent cases, and the Korean billing comparison retains weather and operational limitations (Ahmed et al., 2023; Asif et al., 2023; Lee & Choi, 2025).

Economic interpretation requires similar caution. Simple payback values from different countries and years are not directly comparable because tariffs, labor, equipment prices, taxes, exchange rates, discount rates, and subsidies differ. The most defensible use of international economics is qualitative: low-cost controls and lighting frequently pay back faster than envelope retrofits; deeper packages may need longer horizons or concessional finance. Local investment appraisal should use current Bangladesh tariffs, procurement costs, maintenance resources, equipment lifetimes, financing terms, and sensitivity ranges rather than imported payback values.

Implementation barriers are partly technical and partly institutional. Auditors may identify measures that facility teams cannot maintain; meters may not isolate major loads; procurement may select lowest first cost rather than lifecycle value; and building managers may lack authority over tenants or departments. These

barriers explain why audit programs should include implementation responsibility, commissioning, operator training, and M&V from the outset. ISO 50001 provides a management-system context in which energy review, performance indicators, objectives, monitoring, and continual improvement can institutionalize audit findings (ISO, 2018).

Table 2: *Comparison of energy-audit priorities across building types*

Building type	Energy uses and audit priorities	Indicators and measures	Constraints
Residential	Room AC/heating, fans, appliances, hot water, lighting Occupancy, appliance stock, thermostat/window behavior, envelope	kWh/m²·y; kWh/household/year; end-use shares Efficient AC/heat pumps, fans, LEDs, envelope/shading, hot-water efficiency, controls	High behavioral variability; bills may omit fuels
Office/commercial	HVAC, ventilation, lighting, plug loads, lifts Schedules, chiller/AHU performance, controls, after-hours loads	Site/source EUI; peak demand; load factor Scheduling, VFDs, setpoint reset, LED, sensors, efficient chillers/AC	Tenant split incentives; changing occupancy
Educational/campus	HVAC, lighting, labs, IT, plug loads Academic calendar, labs, lecture-room schedules, dormitories	kWh/m²·y; kWh/student/year; building-level EUI Schedule optimization, LEDs, HVAC, envelope, submetering	Mixed functions; long unoccupied periods
Hospital/healthcare	HVAC/ventilation, medical equipment, hot water, sterilization, laundry, kitchen Air changes, pressure control, chiller/boiler efficiency, 24/7 baseload	kWh/m²·y; kWh/bed/year; peak demand HVAC optimization, heat recovery, LEDs, efficient plant, controls	Patient safety, IAQ/infection control constraints
Hotel/hospitality	Guest HVAC, hot water, kitchen, laundry, common areas Occupancy, room controls, chiller/hot-water plant, laundry/kitchen	kWh/m²·y; kWh/occupied room-night Key-card/occupancy control, efficient chillers, heat recovery, SWH, LED	Guest comfort; variable occupancy; mixed services

Building type	Energy uses and audit priorities	Indicators and measures	Constraints
Public/institutional	HVAC, lighting, plug loads, lifts, public-service equipment Shared meters, schedules, maintenance, procurement constraints	kWh/m²·y; peak demand; weather-normalized EUI LED, AC/HVAC upgrades, controls, submetering, envelope	Budget cycles, maintenance gaps, weak incentive alignment

Note: Indicators should be used only with consistent area, energy boundary, climate, and operating definitions.

6. Bangladesh: evidence, challenges, and applicable lessons

6.1 Policy and institutional context

Bangladesh's institutional framework centers on the Sustainable and Renewable Energy Development Authority (SREDA). The Energy Efficiency and Conservation Master Plan up to 2030 targets a 20% improvement in national primary-energy intensity per unit of GDP relative to 2013 (SREDA, 2016). This is an intensity target, not a 20% reduction in absolute energy consumption. The applicable rules, audit requirements, and implementation notices should be consulted directly when designing a compliance program. SREDA's energy-audit webpage reported 189 designated consumers when checked in October 2026 and describes auditor certification and energy-management activities (SREDA, n.d.). Its building initiatives include the Building Energy Efficiency & Environment Rating guideline and a draft government-office benchmark listed in 2025 (SREDA, 2024; SREDA, 2025). These initiatives provide an institutional basis for auditing, but a policy document or draft benchmark is not itself evidence of achieved savings.

Cooling and electricity use are prominent in the public and institutional buildings considered here. Fans, room air conditioners, solar heat gains, and humid conditions make operating schedules, maintenance, and cooling-system selection important. The EEPB technology assessment identifies cooling and lighting as major intervention areas (GIZ, 2021). Findings from these buildings should not be generalized to the entire national building stock, which includes different services, fuels, and occupancy patterns.

6.2 Evidence from public buildings

The Energy Efficiency in Public Buildings in Bangladesh (EEPB) project provides a substantial local audit dataset. Its December 2021 executive summary describes 12 buildings audited using ANSI/ASHRAE 211-2018 Level 2 procedures. It reports approximately 1.06 million kWh of annual electricity-saving potential, around 17% of consumption, with investment of approximately BDT 8.5 crore and paybacks of 5–12 years (Deloitte Touché Tohmatsu India LLP, 2021). These are identified opportunities rather than measured portfolio-wide savings. The figures refer specifically to this executive summary; aggregate estimates in other EEPB summaries should not be combined without reconciling their assumptions.

The same executive summary identifies suitable rooftop space at 10 buildings and estimates 534 kW of photovoltaic (PV) capacity producing approximately 0.87 million kWh/year across nine buildings (Deloitte Touché Tohmatsu India LLP, 2021). The companion technology assessment discusses efficient cooling, lighting, and PV (GIZ, 2021). Electricity saved through efficiency and electricity generated by PV should remain separate reporting categories.

Public-building retrofit programs should link procurement to documented baselines, commissioning, and normalized post-retrofit monitoring. Whole-building M&V may suit combined measures, while equipment-level measurement may suit isolated retrofits.

6.3 Educational and other building evidence

Evidence beyond the public-building program is less consistent in coverage and verification. Educational buildings provide opportunities to study classrooms, laboratories, libraries, and residences, but simulation and field auditing must be distinguished. The present synthesis omits subsystem savings percentages from sources whose detailed calculations could not be independently checked.

Hasan and Islam (2026) modeled a library building in Gulshan-2, Dhaka using Revit, Autodesk Insight, and Green Building Studio, reporting an EUI of 94.8 kWh/m²/year. This is contextual simulation evidence rather than a measured operational benchmark or a demonstration of retrofit savings. Its practical value is in identifying parameters for subsequent field measurement and model validation.

The lack of published evidence should not be mistaken for lack of opportunity. It means that savings percentages from Saudi Arabia, Malaysia, Europe, or other climates cannot be transferred directly. Bangladesh needs local baselines for room-air-conditioning performance, fan efficiency, occupancy schedules, humidity control, envelope solar gains, appliance density, and maintenance quality. Hospitals and hotels are particularly important research priorities because cooling, hot water, kitchens/laundries, and 24-hour services create load profiles unlike government offices.

6.4 Barriers to implementation

Bangladesh faces four linked barriers: shared meters and incomplete records weaken baselines; decentralized equipment and limited diagnostic tools complicate maintenance; upfront costs and first-cost procurement constrain investment; and divided responsibility for equipment, schedules, and utility budgets weakens implementation.

6.5 Transferability of international practices

Technology selection requires local appraisal. LED savings depend on existing lamp efficiency, operating hours, and the lighting share of annual energy use; installed power shares alone are insufficient. Inverter air conditioners should be assessed against actual baseline efficiency, sizing, part-load operation, maintenance, and comfort requirements. Envelope changes require attention to shading, moisture, ventilation, and latent cooling. Hospital and hotel projects also need service-specific evaluation of indoor air quality, hot-water demand, and continuity of operation.

Table 3: *Bangladesh building-energy evidence matrix*

Source and context	Method	Main finding	Evidence status and gap
Deloitte Touché Tohmatsu India LLP (2021), EEPB executive summary 12 public buildings, multiple locations	ANSI/ASHRAE 211-2018 Level 2 audits	~1.06 million kWh/y, ~17% electricity-saving potential; BDT 8.5 crore investment; 5–12 y payback; rooftop PV assessed	Projected/identified potential, not reported portfolio M&V Need implementation and normalized post-retrofit data
GIZ BAT assessment (2021) Public buildings	Technology assessment linked to EEPB	Efficient cooling, lighting, and solar PV identified as priority technology areas	Technology recommendations Need measured field performance and lifecycle cost under local maintenance

Source and context	Method	Main finding	Evidence status and gap
Hasan & Islam (2026) Educational library, Gulshan-2, Dhaka	BIM/Autodesk Insight/Green Building Studio simulation	Modeled EUI 94.8 kWh/m²·y; HVAC, plugs, lighting major modeled contributors	Simulation-only contextual evidence Needs measured operational validation
SREDA program and benchmark pages Commercial/designated consumers and government offices	Regulatory and benchmarking program	189 designated consumers reported; government-office draft benchmark listed in 2025.	Institutional evidence, not a building-saving study Need public benchmark dataset and consistent reporting
BEEER (2024 circular) New/existing building efficiency framework	Rating/guideline framework	Links energy efficiency and environmental performance; supports M&V/energy management concepts	Policy framework Need wider operational adoption and published performance outcomes

Note: "Projected" means estimated from audit calculations or modeling; it is not equivalent to verified savings.

Table 4: *Applicability of international audit practices to Bangladesh (review synthesis)*

Practice	Evidence base	Local prerequisites and barriers	Priority
Standardized audit levels and reporting	ASHRAE 211; ISO 50002; EEPB	National template aligned with SREDA regulations; trained auditors Barrier: Inconsistent datasets and scopes	High
12–24 month utility baseline + weather normalization	EPA/Portfolio Manager; M&V literature	Reliable bills, floor area, weather and operating data Barrier: Shared meters; missing records	High
Submetering major HVAC/electrical loads	International office, hospital, campus audits	Metering plan; data ownership; maintenance Barrier: Capital cost and data management	High for large buildings
Post-retrofit M&V	IPMVP; Saudi retrofit publications	Baseline lock, commissioning records, trained analysts Barrier: Projects often end at recommendation/installation	High

Practice	Evidence base	Local prerequisites and barriers	Priority
HVAC control optimization	Tropical office/university and hospital evidence	Functional controls, trained operators, comfort/IAQ limits Barrier: Overrides and maintenance	High
LED + occupancy/daylight controls	Common across building types; EEPB	Lighting inventory and lux checks Barrier: Smaller benefit where lighting share is already low	Medium–high
Envelope retrofit	Korea, Europe, cold/mixed-climate cases	Local hygrothermal and cooling-load validation Barrier: Long payback; moisture/comfort trade-offs	Medium, case-specific
PV after demand-side efficiency	EEPB; residential audit literature	Roof suitability, interconnection, separate generation accounting Barrier: May mask inefficient demand if reported only as net grid use	Medium–high

Note: Authors' review synthesis. Priorities indicate implementation importance, not expected savings.

7. Research gaps and practical recommendations

The first research priority is a Bangladesh building-performance database with transparent definitions. Each record should identify building type, gross and conditioned floor area, location, energy carriers, billing period, occupancy, operating hours, major systems, and whether on-site generation is netted from consumption. Without these fields, EUI comparisons will reproduce the same ambiguity seen internationally. SREDA's emerging government-office benchmark provides a logical starting point (SREDA, 2025), but the framework should expand to hospitals, hotels, universities, offices, and representative residential categories.

Second, audits should be linked to implementation and M&V. Public programs can require an M&V plan at the investment-approval stage, with a reporting period long enough to capture seasonal cooling and occupancy. Small measures can use simplified measurement; large packages should use IPMVP-compatible methods (EVO, 2022). This would gradually convert Bangladesh's evidence base from "identified potential" to measured performance and help calibrate local savings assumptions.

Third, cooling research should compare room-AC sizing, part-load efficiency, thermostat practices, maintenance, fan energy, and humidity outcomes. The EEPB technology assessment provides a starting point for selecting locally relevant systems (GIZ, 2021). Demonstration projects should report indoor conditions alongside energy use so that apparent savings are not achieved through inadequate cooling or ventilation.

Procurement should assess lifecycle value, service support, spare parts, technician capability, warranties, and tariff sensitivity. Combining short-payback controls and lighting with longer-life envelope or plant measures can improve portfolio economics.

University campuses offer varied building types under shared governance and can support submetering, calibrated models, behavior studies, and post-retrofit verification. Partnerships could extend this approach to hospitals and hotels.

Policy evaluation should report energy by carrier, EUI, peak demand, renewable generation, costs, and emissions separately, because improvements in one indicator need not imply improvements in the others.

8. Review limitations

This narrative review is selective and does not claim global statistical representativeness. Geographic coverage is uneven, audit terminology varies, and studies use different energy carriers, floor areas, and operating periods. Some sources were available only through abstracts or publisher records. The review therefore cannot establish a universal savings percentage or rank buildings by EUI.

Post-retrofit evidence is limited and not uniformly normalized for weather or service levels. Potential duplication and source-level numerical inconsistencies further constrain comparisons. Bangladesh evidence is concentrated in public buildings and a small number of contextual academic studies. Reported gaps describe the material located for this review and do not establish that no other audits exist.

9. Conclusion

Across building types, credible audits combine utility records, operating data, field measurements, normalization, and engineering analysis. HVAC and controls are recurring opportunities; priorities for lighting, plug loads, hot water, and envelopes depend on function and climate.

Evidence strength varies from modeled potential to observed consumption changes and explicitly adjusted savings. Transparent baselines, measurement periods, and uncertainty statements are essential to distinguish these results. International examples support better monitoring and appraisal, but their savings percentages should not be transferred directly to other buildings.

For Bangladesh, the 12-building EEPB executive summary reports approximately 17% electricity-saving potential, providing a practical starting point for implementation rather than a national savings estimate (Deloitte Touché Tohmatsu India LLP, 2021). Priority actions are consistent audit datasets, local benchmarks, targeted metering, lifecycle appraisal, and post-retrofit verification across a wider range of building types.

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