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Assessment of Energy Consumption Patterns and Efficiency Opportunities in Government Institutions of Tangmarg, Baramulla

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ABSTRACT: The current study, "Assessment of Energy Consumption Patterns and Efficiency Opportunities in Government Institutions of Tangmarg, Baramulla," examines the energy utilization practices, infrastructural attributes, and potential for efficiency improvements within public sector establishments through a systematically designed questionnaire survey. The analysis encompasses office, educational, and healthcare facilities, highlighting a substantial reliance on outdated infrastructure and traditional utility electricity. Most institutions (87.5%) utilize fewer than 500 units per month, with winter recognized as the highest season for consumption owing to heating demands. Despite recurrent power disruptions, 87.5% of institutions have implemented fallback systems primarily solar-powered—signifying a progressive transition toward renewable energy alternatives. Universal adoption of LED and CFL illumination signifies a favorable trend in the dissemination of energy-efficient technologies, although overall equipment-level efficiency remains constrained. Behavioral assessments indicate a moderate level of awareness; however, the application of energy conservation practices remains inconsistent, with merely 31.25% of institutions having undergone relevant training. Financial constraints, limited awareness, and insufficient government assistance identified as primary obstacles to advancing energy efficiency. The findings highlight the importance of comprehensive policy measures that incorporate financial incentives, capacity development, and technical assistance to enhance energy efficiency and sustainability within government institutions in Tangmarg.

Keywords: Energy consumption, Government institutions, Energy efficiency, Renewable energy, Solar adoption, Energy management practices.

INTRODUCTION

Energy consumption in institutional buildings has become a vital focus within the global dialogue on sustainability, climate change mitigation, and resource efficiency, with government institutions assuming a particularly important role due to their considerable energy demands and their capacity to exemplify best practices in energy management (Pérez-Lombard *et al*., 2008). As countries across the globe confront the dual challenges of satisfying escalating energy requirements and minimizing greenhouse gas emissions and environmental impacts, the necessity to comprehend and enhance energy utilization patterns in public sector buildings has grown more pressing. Government institutions, comprising a wide range of facility types such as administrative offices, educational institutions, healthcare centers, public service buildings, and other governmental facilities, collectively constitute a significant segment of total building sector energy consumption. Estimates indicate that they account for approximately 10-15% of overall building energy use in most developed and developing nations (Chung & Rhee 2014). The importance of energy consumption within these institutions goes beyond simple numerical assessments of energy use and related expenses, encompassing broader implications for the efficiency of public spending, commitments to climate change mitigation, energy security, and the demonstration of governmental leadership in sustainability efforts. The particular context of the Kashmir Valley, especially the Tangmarg area of Baramulla district, offers a distinctive and compelling case for analyzing energy consumption patterns and identifying efficiency opportunities within government institutions. Tangmarg, located in the scenic yet climatically demanding environment of the Kashmir Himalayas, encounters extreme weather conditions marked by harsh winters with temperatures often falling well below freezing, and comparatively mild summers.

These conditions result in unique energy demand patterns that significantly differ from those observed in temperate or tropical areas (Malik *et al*., 2019). The severe climatic conditions require substantial space heating throughout the extended winter period, generally from November to March, leading to heating demands that constitute the primary component of total energy consumption in institutional buildings. This climatic reality, together with the region's distinctive geographical location, historical patterns of infrastructure development, and socio-economic characteristics, produces a complex energy landscape that requires thorough investigation and analysis to formulate suitable and effective energy efficiency strategies tailored to local conditions and limitations. Government institutions in Tangmarg function as vital centers for the provision of public services to both urban and rural communities. These include administrative offices responsible for governance and public administration, educational institutions catering to students from primary to higher education levels, healthcare facilities delivering essential medical services, and various other governmental establishments that constitute the foundation of the public service infrastructure. The energy performance of these institutions has direct consequences not only for government operating budgets and fiscal sustainability but also for the quality and continuity of public services provided to citizens, especially considering the region's historical challenges with energy supply and reliability issues (Gojree *et al*., 2016). The evaluation of energy consumption patterns within these institutions serves as a fundamental step in formulating comprehensive energy efficiency strategies that aim to lower operational costs, enhance service quality, strengthen energy security, and support broader environmental sustainability goals, all while considering the specific constraints and opportunities inherent to the local context.

The methodological approach of utilizing questionnaire-based surveys to evaluate energy consumption patterns and identify efficiency opportunities has gained significant credibility and widespread acceptance in energy research over recent decades, providing notable advantages in terms of cost-effectiveness, scalability, and the capacity to gather comprehensive, multidimensional information on energy use that extends beyond purely technical parameters (Swan & Ugursal 2009). Questionnaire surveys allow researchers and energy analysts to systematically gather comprehensive data on building characteristics, equipment inventories, operational practices, occupant behaviors, organizational policies, perceived barriers to efficiency enhancements, and subjective evaluations of comfort and building performance. This approach offers a holistic understanding of energy consumption patterns that cannot be achieved through technical audits or energy monitoring alone (Guerra-Santin & Itard 2010). The integration of survey-based methodologies with complementary techniques such as physical energy audits, utility bill analysis, and building energy modeling has been shown to produce notably robust and actionable insights. These insights can effectively guide the formulation of targeted, context-specific efficiency interventions with a high likelihood of successful implementation and long-term energy savings.

The justification for concentrating specifically on government institutions in this assessment arises from several considerations that collectively underscore the significance and urgency of this inquiry. First, government buildings in the Tangmarg region are substantial energy consumers collectively, with their aggregate energy usage incurring considerable expenses on public budgets that could otherwise be allocated to improved service provision or other priority governmental functions. Second, the public status of these institutions offers opportunities to implement efficiency measures that can function as demonstration projects and serve as catalysts for wider adoption of energy efficiency in both the public and private sectors, capitalizing on the visibility and credibility of government leadership in sustainability efforts (Lee & Yik 2004). Third, numerous government buildings in the region were erected during earlier periods when energy efficiency was not a primary consideration in design and construction practices. Consequently, the existing building stock exhibits poor thermal performance, inefficient heating systems, outdated lighting technologies, and inadequate energy management practices, thereby presenting significant opportunities for cost-effective efficiency enhancements (Nair *et al*., 2010). Fourth, a systematic evaluation of energy consumption patterns across various government institutions facilitates the identification of shared efficiency opportunities and obstacles, thereby informing the development of programmatic strategies to enhance energy performance on a broad scale, rather than depending on isolated, institution-specific initiatives.

The specific objectives governing this evaluation of energy consumption patterns and efficiency opportunities in government institutions of Tangmarg, Baramulla, through questionnaire-based survey analysis encompass several interrelated dimensions. The primary objective is to systematically analyze current energy consumption patterns across various types of government institutions within the region, documenting the extent of energy use, the allocation of consumption among different end-use categories such as heating, lighting, and equipment, the types of energy sources employed, and the temporal variations in energy demand over daily, weekly, and seasonal cycles. A secondary objective is to identify and quantify the primary factors impacting energy consumption levels

and patterns, including building attributes such as age, size, construction quality, and envelope performance; equipment and system features such as heating system types and efficiencies, lighting technologies, and office equipment inventories; operational variables such as occupancy schedules, temperature setpoints, and equipment utilization practices; and organizational elements such as energy management frameworks, maintenance procedures, and institutional policies that influence energy usage. A third objective is to evaluate the awareness, attitudes, and behaviors of building occupants and facility managers concerning energy consumption and conservation, acknowledging that human factors are integral to shaping actual energy usage patterns and the receptivity to efficiency enhancement initiatives (Masoso & Grobler 2010).

A fourth objective is to identify particular energy efficiency opportunities relevant to the surveyed government institutions, encompassing low-cost operational and behavioral enhancements that can be applied with minimal investment, as well as more capital-intensive technological upgrades and retrofits that may necessitate substantial financial resources but provide considerable long-term savings potential. This identification of efficiency opportunities must be based on realistic evaluations of technical feasibility, economic viability, and practical implementation, considering the specific constraints and capacities of government institutions in the region, including budget limitations, procurement processes, technical expertise, and competing organizational priorities. A fifth objective is to document the barriers and challenges that have historically hindered energy efficiency enhancements within government institutions in the region, whether these obstacles are financial, technical, informational, organizational, or cultural. Understanding these impediments is crucial for developing effective strategies to address them and promote the accelerated adoption of efficiency measures (Sorrell *et al.*, 2004).

The scope of this assessment includes government institutions of various types and dimensions functioning within the Tangmarg region of Baramulla district, acknowledging that different categories of institutions display distinct energy consumption patterns and encounter unique opportunities and challenges related to efficiency. Administrative offices and government departments overseeing public administration activities constitute a significant category, generally distinguished by daytime occupancy patterns, with heating and illumination serving as the primary energy end-uses, and exhibiting relatively standardized operational protocols. Educational institutions, encompassing schools and colleges, represent another important category characterized by high occupancy densities, diverse spatial configurations with differing energy demands, specialized facilities such as laboratories and computer rooms, and occupancy patterns closely aligned with academic schedules. Healthcare facilities, although potentially fewer in number, constitute particularly energy-intensive institutions owing to extended or continuous operating hours, essential functions that demand dependable environmental regulation, and the requirements of specialized equipment. Other government facilities, such as libraries, community centers, and specialized service establishments, complete the institutional landscape and influence the overall energy consumption profile of the governmental sector within the region.

The questionnaire-based survey methodology utilized in this assessment has been meticulously crafted to encompass the multifaceted aspects of energy consumption in institutional buildings, while ensuring practicality and feasibility within the limitations of available resources and time. The survey instrument comprises multiple sections that examine various facets of energy consumption and building performance, including areas related to fundamental building characteristics and infrastructure, heating systems and operational practices, lighting systems and usage patterns, office equipment and appliances, energy management strategies and organizational frameworks, occupant behaviors and attitudes, perceived obstacles to efficiency enhancements, and willingness to adopt potential efficiency measures (Bartlett *et al.*, 2001). The survey incorporates closed-ended questions that enable quantitative analysis and statistical comparisons among institutions, alongside open-ended questions that permit respondents to convey detailed insights regarding specific circumstances, concerns, and perspectives that may not be adequately represented by standardized response options. The intended respondents for the survey comprise facility managers or administrative officials responsible for building operations and maintenance, acknowledging that these individuals possess the most extensive knowledge of building systems, energy consumption patterns, and institutional practices influencing energy utilization.

The importance of this assessment spans several dimensions and stakeholder groups, each with specific interests in analyzing energy consumption patterns and advancing efficiency enhancements within government institutions. From the perspective of government administrators and policymakers, the assessment offers empirical data regarding energy consumption levels and patterns that can inform budget planning, resource allocation, and the formulation of institutional policies and programs designed to enhance energy efficiency throughout the government building portfolio. The identification of cost-effective efficiency opportunities presents the potential to decrease operational expenses and reallocate resources to other priority areas, while concurrently supporting governmental sustainability commitments and climate action objectives. From the standpoint of facility managers and building operators, the assessment offers benchmarking data that

contextualizes the energy performance of individual institutions in relation to their peers and identifies particular areas where operational enhancements or system upgrades could lead to energy savings and improved building performance (Thollander *et al*., 2007).

From a wider societal standpoint, advancements in energy efficiency within government institutions lead to alleviated pressure on regional energy infrastructure, diminished environmental impacts related to energy production and consumption, and improved energy security through decreased reliance on external energy sources. The capacity of government institutions to act as exemplars and catalysts for the broader adoption of energy efficiency practices enhances the societal importance of this assessment beyond its direct effects on government operations. From an academic and research standpoint, this evaluation adds to the scarce body of empirical studies on energy consumption behaviors in institutional buildings within cold climate developing regions, filling a notable gap in the literature and offering insights that could inform energy efficiency research and practices in comparable contexts worldwide. The methodological approaches utilized and enhanced through this assessment also support ongoing initiatives to develop and validate efficient, practicable survey-based methodologies for energy evaluation in institutional environments (Yun & Steemers 2011).

The challenges inherent in conducting comprehensive energy assessments within the specific context of Tangmarg and the wider Kashmir valley warrant explicit recognition, as these challenges influence methodological decisions and inevitably impose certain constraints on the scope and depth of the investigation. The region's intricate political and security landscape may impact access to institutions and influence officials' willingness to engage in surveys and disclose information regarding operations and infrastructure. The historical trends in infrastructure development within the region, frequently marked by resource limitations and conflicting priorities, have led to a wide variation in the quality and condition of existing structures, thereby complicating efforts to establish generalized assessments of energy performance. The reliability and quality of available data on energy consumption, especially for institutions that may lack comprehensive metering or systematic records of energy use and costs, pose challenges for detailed quantitative analysis and often require dependence on estimated or proxy measures in certain instances. The variety of heating systems and practices utilized across institutions, encompassing centralized systems, individual room heaters, and traditional biomass-based heating, introduces complexity in evaluating and comparing energy consumption patterns and in determining suitable efficiency measures (Bansal & Misra 2013).

The expected outcomes of this assessment comprise a detailed characterization of energy consumption patterns within government institutions in Tangmarg, establishing a baseline understanding of current energy usage levels, trends, and practices; the identification and prioritization of targeted energy efficiency opportunities, including estimates of potential energy and cost savings achievable through various interventions; documentation of significant barriers and challenges hindering efficiency improvements, along with recommendations for overcoming these obstacles; and the formulation of actionable strategies for government administrators, facility managers, and policymakers to enhance energy performance in institutional buildings. These outcomes are designed to establish a foundation for the development and execution of targeted energy efficiency programs and policies that can facilitate systematic enhancements in energy performance within government institutional buildings in Tangmarg. Additionally, they may serve as models for comparable initiatives in other areas of the Kashmir valley and beyond. The assessment ultimately aims to contribute not only to immediate enhancements in energy efficiency and operational performance within the surveyed institutions but also to the overarching goals of sustainable development, climate change mitigation, and the improvement of public service quality provided to the region's citizens.

The main aim is to evaluate energy consumption patterns and identify opportunities for efficiency enhancements in government institutions of Tangmarg through comprehensive questionnaire-based surveys. The study seeks to establish baseline data on energy consumption, analyze user behavior and institutional practices influencing energy use, and assess the potential for instituting energy efficiency measures.

Secondary objectives encompass examining the correlation between building attributes and energy usage, identifying obstacles to the adoption of energy efficiency measures, evaluating the level of awareness regarding energy conservation among government personnel, and formulating recommendations to enhance energy management practices. The study will also establish benchmarks for energy consumption across various categories of government institutions and offer insights into seasonal fluctuations in energy use patterns tailored to the region's climatic conditions.

METHODOLOGY

The methodological framework utilized in this study of energy consumption patterns and efficiency opportunities in government institutions of Tangmarg, Baramulla, was developed to systematically gather detailed information regarding energy usage characteristics, building infrastructure, operational procedures, and organizational factors affecting energy performance through a structured questionnaire-based survey approach. The methodology was formulated

with consideration of the distinctive contextual features of the study region, encompassing its severe climatic conditions, heterogeneous institutional environment, and the practical limitations inherent in data collection within government contexts. The research employed a cross-sectional survey design that allowed for the collection of comprehensive data from multiple institutions within a specified period, enabling comparative analysis and the identification of shared patterns and institution-specific differences in energy consumption and management practices.

Study Area and Population

The study was carried out in Tangmarg, a tehsil within the Baramulla district of Jammu and Kashmir, situated in the Kashmir Valley at an elevation that exposes it to frigid climate conditions characterized by harsh winters and moderate summers. Tangmarg functions as a vital administrative and service hub for the neighboring regions, accommodating a wide range of government institutions that deliver essential public services to both local and regional communities. The target population for this study consisted of all government institutions functioning in Tangmarg, including various types such as administrative offices, educational institutions across different levels, healthcare facilities, financial service providers, and other government entities. This deliberate incorporation of various institution types aimed to encompass the entire range of energy consumption patterns within the government institutional sector and to facilitate analysis of differences associated with functional attributes and operational needs. The sampling approach utilized in this study was census-based, indicating that every identifiable government institution in Tangmarg was incorporated into the survey rather than selecting a representative sample. This approach was selected for multiple reasons, including the relatively manageable total number of government institutions within the study area, which rendered comprehensive coverage achievable within available resources and time constraints, and the objective of acquiring complete information on energy consumption throughout the entire government institutional sector rather than depending on sample-based estimates that may not fully represent the diversity of institution types and characteristics within the population. The census methodology also addressed issues related to sampling bias and improved the credibility and completeness of the resultant dataset for guiding policy and programmatic decisions impacting government institutions in the region.

Survey Instrument Development

The main data collection tool was a structured questionnaire explicitly developed to gather comprehensive information regarding energy consumption patterns, building and equipment attributes, operational procedures, and organizational factors pertinent to energy efficiency in government institutions. The questionnaire was created through a systematic process that commenced with a comprehensive evaluation of existing literature on energy assessment methodologies in institutional buildings and an analysis of survey instruments utilized in comparable studies conducted across diverse contexts. This literature review facilitated the identification of essential variables and information categories necessary for a comprehensive characterization of energy consumption patterns and the systematic identification of efficiency opportunities. The process of developing the questionnaire also encompassed an assessment of the particular contextual features of the study area, such as climatic conditions, prevalent building construction methods, commonly utilized energy sources and technologies, and institutional frameworks and practices that may vary from those in other regions.

The questionnaire was organized into several sections, each focusing on particular aspects of energy usage and building efficiency. The initial section concentrated on fundamental institutional and building attributes, gathering data regarding institution type and purpose, year of construction or founding, number of employees or regular occupants, total floor area, and primary energy sources employed. This fundamental information facilitated the classification of institutions and offered essential context for analyzing energy consumption patterns. The second section focused on electricity consumption, which constitutes the main type of commercial energy utilized by most government institutions in the region. It gathered data on monthly or annual electricity usage in units, related expenses, and the availability of backup power sources such as solar systems, diesel generators, or other alternatives employed by institutions to mitigate grid electricity supply reliability concerns.

The third section of the questionnaire addressed the equipment and appliances available within the institution, acknowledging that the variety, quantities, and operational patterns of energy-consuming devices are essential factors influencing overall energy consumption. This section utilized a checklist format enumerating typical equipment categories, such as LED/CFL bulbs, tube lights, ceiling fans, room heaters, computers and laptops, air conditioners, geysers, and other appliances, enabling respondents to specify which equipment types were available in their institution. This method enabled a systematic comparison of equipment profiles among institutions while also permitting respondents to specify additional equipment types not encompassed by the predefined categories. The fourth section examined operational characteristics and usage patterns, gathering data on standard daily operating hours, peak consumption periods, and other temporal trends in building occupancy and energy utilization that substantially impact overall energy consumption and load profiles.

The fifth section concentrated on energy management practices and behaviors, examining whether the institution consistently monitors electricity bills, maintains detailed records of energy consumption, implements energy conservation measures, and regularly turns off lights and equipment when not in use. This section was developed to gather information concerning the organizational and behavioral aspects of energy consumption, acknowledging that management practices and occupant behaviors can significantly influence energy use independently of building and equipment attributes (Masoso & Grobler 2010). The sixth section examined cognizance and attitudes toward energy efficiency, inquiring whether respondents were cognizant of energy-saving technologies and whether they would be inclined to implement energy efficiency measures given appropriate support. The concluding section of the questionnaire concentrated on identifying perceived obstacles to energy efficiency enhancements. Respondents were presented with typical barrier categories, including insufficient funding, limited awareness, lack of technical expertise, minimal government support, and other factors, and were prompted to specify which barriers were applicable to their institution.

The questionnaire predominantly utilized closed-ended questions with predetermined response options to enable standardized data collection and subsequent quantitative analysis. Response categories were formulated through a comprehensive literature review and an initial comprehension of the study context to ensure they effectively encompassed the spectrum of conditions and practices likely to be encountered. For specific variables such as building age, floor area, electricity consumption, and operating hours, response categories were established as ranges rather than requesting exact values, acknowledging that respondents may not possess precise information readily available and that range-based responses would be more practical while still yielding valuable data for analysis. The questionnaire also incorporated limited open-ended components, notably in the equipment section where respondents could specify supplementary equipment types, and in the barriers section where a "other" category permitted the identification of barriers not encompassed by the predefined categories.

Data Collection Process

The data collection procedure was conducted through the direct administration of the questionnaire to representatives of each government institution participating in the study. The intended respondents comprised facility managers, administrative officers, or other officials responsible for and knowledgeable about building operations, maintenance, and energy utilization. These individuals were selected as the most suitable respondents due to their extensive knowledge of building characteristics, equipment inventories, operational procedures, and institutional policies related to energy consumption. Additionally, they possess the authority and perspective necessary to provide insights into organizational factors and barriers to efficiency enhancements. Before initiating data collection, formal approvals were secured from the appropriate authorities to contact government institutions and solicit their participation in the survey, ensuring adherence to administrative procedures and promoting respondent cooperation.

The questionnaire was conducted via in-person visits to each institution, during which trained data collectors engaged with the designated respondents to clarify the study's objectives, secure informed consent for participation, and assist them in completing the questionnaire. The in-person administration method was selected over self-administered surveys for several reasons, including the capacity to clarify questions if respondents found them unclear or ambiguous, the opportunity to seek more detailed information when initial responses were vague or incomplete, the ability to verify and cross-check information through observation of building conditions and equipment, and the generally higher response rates associated with in-person administration compared to mail or electronic survey methods. During each institutional visit, data collectors also recorded observational notes regarding observable building features such as apparent construction quality, window types, presence of insulation, and equipment conditions that could supplement and corroborate the information supplied by respondents.

The data collection process was carried out within a specified timeframe that facilitated comprehensive coverage of all institutions while maintaining acceptable temporal consistency in the collected data, acknowledging that certain attributes, such as electricity consumption, may exhibit seasonal fluctuations. Before commencing comprehensive data collection, a pilot test of the questionnaire was carried out with a limited number of institutions to detect any issues related to question phrasing, response options, or questionnaire design that could hinder efficient data gathering. The pilot test identified minimal concerns regarding terminology and response category definitions, which were rectified through questionnaire revisions prior to the commencement of the full survey. Data collectors received training in questionnaire administration techniques, encompassing methods for establishing rapport with respondents, posing questions in a neutral manner that did not imply preferred answers, and managing common challenges such as respondents' uncertainty regarding specific information or hesitance to disclose certain details**.**

Data Management and Quality Assurance

The finalized questionnaires were meticulously examined for thoroughness and coherence immediately after each institutional visit, enabling prompt follow-up with respondents if clarification or supplementary

information was required to resolve incomplete or ambiguous responses. This quality assurance procedure contributed to maintaining the integrity and comprehensiveness of the dataset while reducing the extent of information loss resulting from incomplete survey responses. The data from the completed questionnaires were input into a digital database utilizing spreadsheet software, with each institution represented as a row and each questionnaire item as a column variable. The data entry procedure adhered to standardized coding schemes that converted response categories into numerical codes appropriate for subsequent statistical analysis, while ensuring comprehensive documentation of each code's meaning to avoid confusion during the analysis. Data quality assurance procedures encompassed double-entry verification for a subset of questionnaires to evaluate data entry accuracy and detect any systematic errors in the data entry process. Logical consistency assessments were conducted on the submitted data to detect potentially erroneous or inconsistent responses, such as institutions reporting unusually high electricity consumption alongside very small floor areas, or institutions indicating the operation of equipment types that appear incompatible with their functional attributes. Cases identified by these consistency checks were examined and, when required, corroborated with the original questionnaires or through subsequent contact with respondents to address any discrepancies. Missing data were explicitly coded to differentiate between instances where respondents were unaware or unable to provide information and instances where queries were unintentionally omitted during survey administration.

RESULTS AND INTERPRETATION

Based on the survey data collected from sixteen government institutions in Tangmarg, Baramulla, the following tables present a systematic analysis of energy consumption patterns, infrastructure characteristics, and energy management practices.

Table 1: Institutional Characteristics and Infrastructure Profile.

Characteristic	Category	Frequency (n)	Percentage (%)
Type of Institution	Office	9	56.25
	School	6	37.50
	Hospital	1	6.25
Year of Establishment	Before 1970	2	12.50
	1970-1989	7	43.75
	1990-2009	4	25.00
	2010 and after	3	18.75
Number of Staff	Below 20	7	43.75
	21-50	7	43.75
	51-100	2	12.50
Daily Users/Visitors	Less than 100	5	31.25
	100-500	4	25.00
	500-1000	6	37.50
	Above 1000	1	6.25

Table 1 delineates the demographic and infrastructural profile of the government institutions surveyed in Tangmarg. The data indicates that offices represent the predominant portion (56.25%) of surveyed institutions, followed by educational establishments (37.50%) and healthcare facilities (6.25%). A considerable proportion (43.75%) of buildings were erected between 1970 and 1989, reflecting aging infrastructure that may demonstrate subpar energy efficiency owing to obsolete construction standards and declining building envelope integrity. The staff distribution indicates a balanced division between smaller institutions with fewer than 20 employees and medium-sized institutions with 21-50 employees, each accounting for 43.75%. Conversely, only 12.50% of institutions have larger staff complements exceeding 50 personnel. The daily user traffic exhibits significant fluctuations, with educational institutions and banks accommodating markedly greater numbers of visitors in comparison to administrative offices, reflecting their respective functional roles and service delivery demands.
Table 2 delineates the electricity consumption patterns and corresponding costs observed among the surveyed institutions. All institutions (100%) depend solely on grid electricity as their main power source, demonstrating complete reliance on the public electricity supply system. The consumption data indicates a predominantly uniform pattern, with the majority (87.50%) consuming less than 500 units per month, which corresponds to expenditures below Rs 5000. Only two institutions J&K Bank Tangmarg and Sub District Hospital Tangmarg demonstrate

significantly higher consumption levels (501-1000 and 1001-2000 units respectively), due to their extended operating hours and increased equipment burdens. The daily operating hours indicate that 75% of institutions function between 6 and 12 hours each day, reflecting the typical working hours for most government agencies. Notably, 62.50% of institutions indicate winter as the peak consumption season, highlighting the prominence of heating demands in the cold climate conditions of the Kashmir Valley. Conversely, schools primarily identify summer as the peak season, likely influenced by examination periods and summer activities when heating is unnecessary. Table 3 analyzes the prevalence and classifications of reserve power systems utilized by government institutions to mitigate challenges related to the reliability of the grid electricity supply. An immense majority (87.50%) of institutions have allocated resources to reserve power facilities, underscoring the essential importance of uninterrupted energy supply for government functions and service provision. Solar energy has become the primary fallback solution, with 56.25% of institutions relying solely on solar systems and an additional 25% employing solar in conjunction with diesel generators or LPG. This significant adoption of solar backup systems indicates both the decreasing costs of solar photovoltaic technology and the possible insufficiency of utility supply during essential times. Only three institutions utilize fossil fuel-powered generators (diesel or petrol) without solar components, indicating a preference for renewable alternatives driven by environmental consciousness or cost considerations.

Table 2: Electricity Consumption and Cost Profile.

Parameter	Category	Frequency (n)	Percentage (%)
Primary Electricity Source	Grid Electricity	16	100.00
Monthly Consumption	Below 500 Units	14	87.50
	501-1000 Units	1	6.25
	1001-2000 Units	1	6.25
Monthly Expenditure	Below Rs 5000	14	87.50
	Rs 5001-10000	1	6.25
	Rs 10001-20000	1	6.25
Daily Operating Hours	Less than 6 Hours	2	12.50
	6-12 Hours	12	75.00
	13-18 Hours	1	6.25
	More than 18 Hours	1	6.25
Peak Consumption Season	Winter	10	62.50
	Summer	6	37.50

Table 3: Backup Power Systems and Alternative Energy Sources.

Parameter	Response/Type	Frequency (n)	Percentage (%)
Backup Power Availability	Yes	14	87.50
	No	2	12.50
Alternative Energy Sources	Solar Only	9	56.25
	Diesel Generator Only	1	6.25
	LPG + Solar	2	12.50
	Solar + Diesel Generator	2	12.50
	Petrol Generator	1	6.25
	No Backup	2	12.50

Table 4: Equipment Inventory and Technology Adoption.

Equipment Type	Frequency (n)	Percentage (%)
LED/CFL Bulbs	16	100.00
Tube Lights	16	100.00
Ceiling Fans	16	100.00
Room Heaters	16	100.00
Computers/Laptops	16	100.00
Geysers	3	18.75
Air Conditioners	2	12.50
Other Appliances	3	18.75
Energy-Efficient Appliances Use	Yes	16

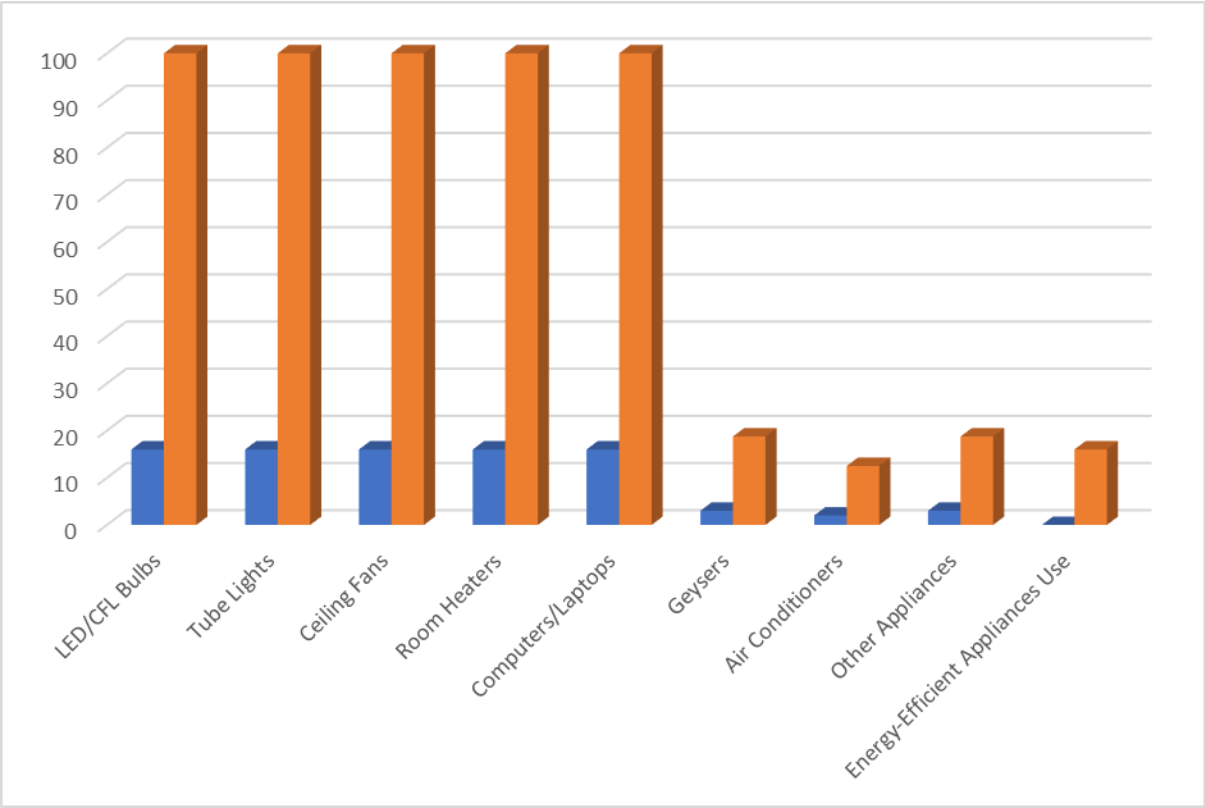

Fig. 1. Equipment Inventory and Technology Adoption.

The two institutions, Treasury Office Tangmarg and Government Primary School Tangmarg, lack alternate power supply posing potential risks to service continuity during power disruptions, which are reportedly frequent in the region. Table 4 and Fig. 1 present the inventory of electrical equipment and appliances across the surveyed institutions, highlighting significant patterns in technology adoption and equipment profiles. Universal adoption (100%) of LED/CFL bulbs indicates successful integration of energy-efficient lighting technologies across government institutions in Tangmarg, signifying a positive advancement in energy efficiency, as LED/CFL technologies utilize 50-80% less electricity compared to conventional incandescent bulbs.

Table 5: Energy Management Practices and Barriers to Efficiency.

Parameter	Response	Frequency (n)	Percentage (%)
Regular Equipment Maintenance	Yes	15	93.75
	No	1	6.25
Equipment Switch-Off Practice	Always	12	75.00
	Sometimes	4	25.00
Natural Lighting/Ventilation Use	Rarely	6	37.50
	Sometimes	10	62.50
Energy Conservation Training	Yes	5	31.25
	No	11	68.75
Willingness to Adopt Renewables	Yes	14	87.50
	Maybe	2	12.50
Barriers to Energy Efficiency			
Lack of Funds	12	75.00	
Lack of Awareness	8	50.00	
Limited Government Support	6	37.50	
Lack of Technical Expertise	0	0.00	
Other	1	6.25	

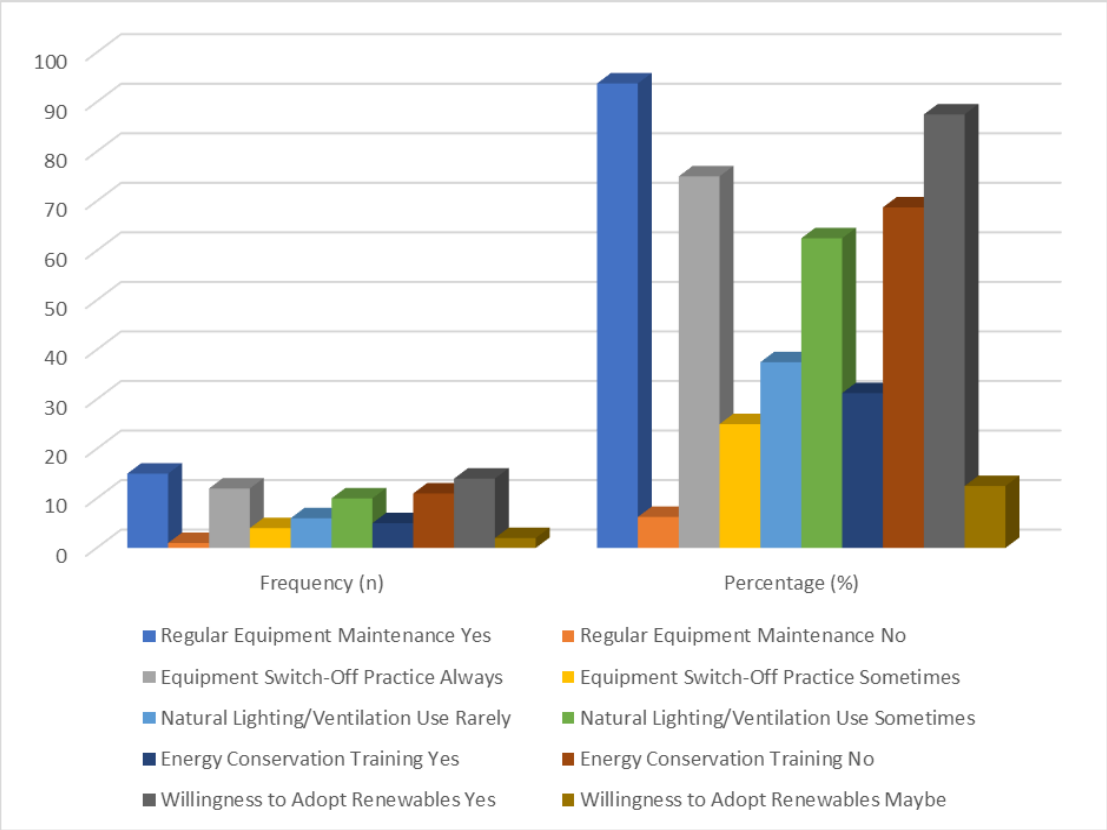

Fig. 2. Energy Management Practices and Barriers to Efficiency.

Similarly, all institutions are equipped with tube lighting, ceiling fans, room radiators, and computers or laptops, illustrating the fundamental operational necessities of government establishments. The widespread use of room heaters highlights the essential role of space heating in frigid climate conditions, and these devices probably constitute the majority of electricity usage during the winter season. Geysers and air conditioners demonstrate limited adoption rates (18.75% and 12.50% respectively), predominantly found in upscale establishments such as J&K Bank and institutions with specialized needs. The universal affirmative response regarding the use of energy-efficient appliances should be approached with caution, as it probably indicates the adoption of LED/CFL lighting rather than overall energy efficiency across all equipment categories, and may also be affected by social desirability bias in self-reported survey data.

Table 5 and Figure 2 synthesize information regarding energy management practices, behavioral patterns, and perceived obstacles to efficiency enhancements in the surveyed institutions. The data indicates varied patterns in energy conservation practices and notable deficiencies in institutional capacity. Although 93.75% of institutions indicate that they conduct regular equipment maintenance and 75% assert that they consistently turn off equipment when not in use, these self-reported practices should be regarded with appropriate caution due to the potential for response bias. What is more concerning is the inadequate adoption of passive energy conservation measures, with 62.50% indicating they only "sometimes" utilize natural illumination and ventilation, highlighting missed opportunities for cost-free energy savings. The fact that merely 31.25% of institutions have undergone energy conservation training indicates a substantial capacity deficiency that potentially hampers the success of efficiency initiatives. The strong willingness to implement renewable energy systems (87.50%) reflects positive attitudes toward sustainable energy; however, this enthusiasm must be balanced with the identified obstacles. Financial limitations constitute the primary obstacle, with 75% identifying insufficient funding, followed by a lack of awareness at 50% and limited government support at 37.50%. Notably, no institution cited a deficiency in technical expertise as a barrier, which may indicate either sufficient technical capacity or a lack of awareness regarding the technical aspects of energy efficiency. The barrier profile indicates that successful energy efficiency programs must concurrently address multiple aspects by integrating financial support mechanisms, awareness-raising initiatives, and strengthened government technical assistance programs.

DISCUSSION

The results from sixteen government institutions surveyed in Tangmarg, Baramulla, offer a

comprehensive overview of current trends in energy utilization, infrastructural features, and energy management practices among small- to medium-sized public sector organizations in a cold-climate area of Jammu and Kashmir. This discussion analyzes the results in the context of energy efficiency theory, regional climatic conditions, and prevailing policy frameworks. The analysis emphasizes the interaction among institutional frameworks, operational practices, and socio-technical limitations that influence energy consumption and management within government facilities.

The dominance of administrative offices (56.25%) and educational institutions (37.5%) illustrates the functional structure of the public sector in Tangmarg, where service provision and governance constitute the primary institutional functions. The comparatively limited proportion of healthcare facilities (6.25%) indicates a restricted diversification within the public service infrastructure. However, this composition has direct implications for energy demand profiles—offices and schools generally display consistent daytime operational patterns with moderate equipment loads, whereas healthcare facilities, although fewer in number, exhibit sustained energy demand driven by medical equipment and patient care needs.

The age of infrastructure serves as a vital factor influencing energy performance. Approximately 44% of institutions were built between 1970 and 1989, a timeframe prior to the implementation of contemporary energy efficiency standards and thermal insulation practices. These historic structures are likely characterized by significant heat loss, inadequate insulation, and ineffectual heating systems, leading to increased energy consumption during the winter months. The balanced staff distribution between tiny (fewer than 20 staff) and medium-sized (21–50 staff) institutions further underscores the modest scale of operations, which may constrain financial capacity for energy retrofits or renewable energy investments. Nonetheless, these institutions can function as essential hubs for testing community-scale energy efficiency initiatives owing to their accessibility, prominence, and public service functions. A notable finding of the study is the exclusive dependence (100%) on grid electricity as the primary power source, with no institution indicating the utilization of decentralized, grid-independent systems. This highlights the susceptibility of public service continuity to grid disruptions, which are common in the hilly regions of Baramulla district, especially during the winter season. The pattern of low-to-moderate electricity consumption (below 500 units for 87.5% of institutions) indicates either limited supply, low appliance penetration, or intentional conservation measures in response to cost considerations. However, the consumption peaks observed in particular institutions such as the Sub-District Hospital and J&K Bank Tangmarg indicate functional heterogeneity—extended operating hours, increased equipment utilization, and the provision of essential services contribute to their elevated consumption profiles. Data on seasonal variation further corroborate the climatic dependence of energy consumption. With 62.5% identifying winter as the peak consumption season, the predominance of space heating demands is apparent. In frigid climatic conditions such as those in Tangmarg—where winter temperatures frequently drop below freezing—electrical room heaters and geysers markedly elevate demand. Conversely, educational institutions and financial institutions displaying summer maxima are likely to encounter increased occupancy and operational activity during examination and business periods. This seasonal variation underscores the importance of implementing tailored energy management strategies—such as thermal efficiency improvements in winter and demand-side management during summer. The high prevalence of reserve systems (87.5%) indicates a pragmatic institutional response to an unreliable grid supply. Solar energy has become the primary fallback solution, with 56.25% of institutions exclusively utilizing solar systems and an additional 25% combining solar with LPG or diesel generators. This signifies a promising transition toward the integration of renewable energy within public infrastructure. The substantial adoption of solar energy in Tangmarg, despite limited institutional resources, can be attributed to several factors: the availability of government subsidies for rooftop solar through programs such as PM-KUSUM and JAKEDA, the declining costs of photovoltaic panels, and the growing awareness of the advantages of renewable energy. Nevertheless, the presence of fossil-fuel-powered generators (diesel or petrol) in a minority of institutions highlights the continued reliance on traditional energy security measures, especially in facilities that demand continuous power supply. Diesel-powered systems, while dependable, are linked to substantial operational expenses and greenhouse gas emissions, underscoring the importance of a gradual shift toward hybrid or entirely renewable alternatives. The two institutions lacking any alternative support (Treasury Office and Government Primary School) constitute significant points of vulnerability. In rural Kashmir, even brief power disruptions can interrupt administrative and educational functions, underscoring the urgent necessity for a fair distribution of renewable energy installations across all institutions.

The data demonstrate widespread implementation of essential electrical appliances, including LED/CFL bulbs, tube lamps, ceiling fans, radiators, and computers—indicating that fundamental electrification requirements are fulfilled across all surveyed institutions. The full adoption of LED and CFL lighting signifies a significant milestone in institutional energy efficiency, decreasing lighting-related electricity

consumption by as much as 70% in comparison to traditional bulbs. This indicates the successful execution of government-led efficiency initiatives, such as the UJALA (Unnat Jyoti by Affordable LEDs for All) program.

However, the restricted utilization of high-energy-consuming appliances such as geysers (18.75%) and air conditioners (12.5%) indicates both infrastructural limitations and adaptive behavioral responses to local climatic conditions. Although the frigid climate requires heating instead of ventilation, the limited availability of effective heating options such as heat pumps or solar water heaters continues to pose a challenge. Overall, although lighting efficiency has attained maturity, significant unexploited potential persists in heating and office equipment efficiency, particularly through the procurement of Bureau of Energy Efficiency (BEE)-rated devices and the implementation of intelligent energy management systems. The examination of energy management practices uncovers promising behavioral patterns, yet highlights ongoing systemic deficiencies. Nearly all institutions (93.75%) indicate that they perform regular maintenance, and three-quarters (75%) report consistently turning off unused equipment, reflecting a foundational awareness of effective energy management practices. However, the inconsistent application of passive design elements — with 62.5% "sometimes" employing natural illumination and ventilation — indicates an under exploitation of cost-free energy conservation opportunities. Given Tangmarg's climatic and daylight conditions, a greater emphasis on natural ventilation and window design in architecture could substantially decrease the reliance on artificial illumination and heating during moderate seasons.

The limited proportion (31.25%) of institutions that have undergone formal energy conservation training highlights a significant capacity deficiency. Training and awareness initiatives serve as the fundamental basis for the successful implementation of energy efficiency measures. The absence of formalized training mechanisms likely hampers both the recognition of energy-saving opportunities and the implementation of advanced management practices such as energy audits or monitoring systems.

Obstacles to energy efficiency identified by respondents underscore the inherently structural nature of the challenge. Financial constraints, reported by 75% of institutions, continue to be the primary obstacle—aligning with observations from developing regions where energy efficiency is weighed against more pressing operational costs. Insufficient awareness (50%) and restricted government support (37.5%) exacerbate the problem, highlighting the necessity for comprehensive policy measures that incorporate financial, informational, and regulatory strategies. Interestingly, none of the institutions cited technical expertise as a barrier, which may either indicate an overestimation of their internal capabilities or a lack of awareness concerning the technical complexities associated with energy optimization.

Addressing these obstacles necessitates comprehensive systemic reforms—including the establishment of dedicated energy efficiency funds, the implementation of mandatory energy assessments for public structures, and the incorporation of energy management into administrative training programs. The demonstrated willingness of 87.5% of institutions to implement renewable systems offers a promising opportunity for policy initiatives, contingent upon the development of supportive financing mechanisms and technical assistance frameworks.

Policy and Practical Implications

The findings hold multiple implications for policymakers and institutional administrators. Initially, the prevalence of aging infrastructure requires the implementation of targeted retrofitting initiatives emphasizing thermal insulation, energy-efficient heating systems, and enhancements to building envelopes. These interventions have the potential to generate substantial energy savings and enhance occupant comfort.

Second, the deployment of renewable energy—particularly solar photovoltaic systems—should be expanded across all government facilities through mechanisms such as capital subsidies, low-interest financing, or performance-based contracting models like Energy Service Companies (ESCOs). Considering Tangmarg's moderate solar potential, even limited solarization of public buildings could significantly decrease reliance on the grid and improve resilience to power outages.

Third, the development of institutional capacity must be given priority. Forming energy management cells at district or block levels, implementing regular training initiatives, and incorporating behavioral incentives such as feedback dashboards or reward systems can promote sustained cultural transformation towards efficiency.

Finally, the data from this study can serve to guide the development of a localized energy efficiency strategy for government institutions in hilly regions, aligning with the overarching national goals outlined in the National Mission for Enhanced Energy Efficiency (NMEEE) and the National Solar Mission.

CONCLUSIONS

In summary, the discussion highlights a complex energy landscape characterized by:

-Complete dependence on grid electricity, moderated by widespread adoption of solar backup systems;

-Predominantly old building stock with limited thermal efficiency;

-Strong lighting efficiency performance but lagging progress in heating and overall energy management;

-Behavioral awareness but insufficient institutional training; and
-Significant financial and policy barriers that impede full realization of energy efficiency potential.

These findings collectively emphasize that improving energy performance in Tangmarg's government institutions requires an integrated approach — combining infrastructural retrofits, renewable integration, behavioral interventions, and supportive governance mechanisms. Addressing these multidimensional challenges is essential not only for operational sustainability but also for demonstrating leadership in the region's transition toward cleaner, more resilient energy systems.

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