XLVI CILAMCE
VITÓRIA - ES - BRAZIL - 2025
XLVI IBERO-LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGENEERING

Integrated Platform for Energy Consumption Management and Efficiency in Public Buildings in the State of Goiás

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Abstract. This paper presents the development of a digital platform for managing and assessing energy performance in public buildings, with a pilot application in the state of Goiás, Brazil. The system, implemented in Python using the Flet framework, integrates three interconnected SQLite databases covering electricity billing, certified equipment performance data from Brazil's National Energy Labeling Program (PBE-INMETRO) and on-site audit records. It enables the automated import and structured extraction of key billing information such as consumption, demand, tariff group and cost from PDF and Excel files, as well as the detailed registration of installed equipment at the room level. All entries are cross-referenced with standardized efficiency data to ensure consistency and accuracy. The platform provides interactive dashboards for consumption analysis, supports both macro-level and micro-level diagnostics and facilitates transparent monitoring of energy use patterns over time. A pilot case study was carried out at the *Secretaria-Geral de Governo de Goiás* (Goiás State Government's General Secretariat – SGG), where the tool replaced manual paper-based data collection with direct digital registration, significantly improving data acquisition efficiency. The results highlight the platform's potential to inform public policy, guide targeted energy efficiency interventions and serve as a replicable and open-access solution for other public institutions. Its structured architecture also establishes a foundation for the analysis of large data repositories through advanced data analytics techniques, enabling large-scale pattern recognition, trend forecasting and enhanced decision-making capabilities. Future developments include advanced dashboard features for year-to-year comparisons, group-based consumption analysis and the integration of performance indicators to evaluate energy efficiency and end-use consumption shares by equipment category.

Keywords: Energy Consumption Database, Energy Efficiency Public Buildings, Electricity Consumption Management, Goiás.

1 Introduction

Energy efficiency in buildings plays a pivotal role in the energy transition, particularly in developing regions facing growing energy demand and limited natural resources. In Brazil, the *Balanço de Energia Útil* (BEU – End-Use Energy Balance) has been developed by the national Energy Research Company (EPE) as an extension of the *Balanço Energético Nacional* (BEN – National Energy Balance). While the BEN accounts for the final energy delivered to each sector, the BEU estimates the portion of energy effectively converted into useful services such as lighting, cooling, and mechanical work, considering the average efficiency of equipment used in each end use [1].

Applying BEU at the building level allows for precise and actionable assessments, complementing macro-level analyses with micro-level diagnostics. Its integration with energy management systems aligns with international standards, including ISO 50001 [2], and performance verification protocols such as IPMVP [3]. Practical implementations in the public sector, such as the case study on the adoption of ISO 50001 in the Court of Auditors of the State of Ceará [4], demonstrate that it is possible to evaluate a building's energy use by identifying the significant energy uses in percentage terms by equipment group, providing indicators for each group. This approach

facilitates energy diagnostics, supports the estimation of efficiency gains from equipment replacement, and establishes energy conservation criteria, highlighting the potential for significant long-term savings and reinforcing the relevance of structured approaches for public administration.

Recent studies have applied structured methodologies to diagnose and enhance energy performance across a variety of sectors and building typologies. These works share the common goal of systematically identifying performance gaps, quantifying potential savings, and supporting decision-making with context-specific data. Approaches range from the development of hierarchical Key Performance Indicators and multicriteria decision models for the industrial sector [5], to advanced simulation and field validation of retrofit measures in government buildings [6], comparative benchmarking analyses for educational facilities [7], and targeted energy audits in agricultural operations [8]. Collectively, they demonstrate that combining quantitative diagnostics with tailored intervention strategies can yield significant efficiency gains, regardless of the sectoral context, and provide valuable insights for the design of flexible, data-driven energy management tools.

In this context, this paper presents the development of a digital platform designed to assess and manage energy performance in public buildings in the state of Goiás, Brazil, emphasizing transparency, replicability, and alignment with both national and international energy efficiency standards. The platform, developed in Python using the Flet framework, enables manual input or automated import of electricity bills in PDF and Excel formats, structured registration of installed equipment, and integration with national efficiency labeling databases from the National Institute of Metrology, Standardization and Industrial Quality (INMETRO) [9]. The system architecture is supported by three interconnected SQLite databases, covering billing, equipment performance data, and on-site audit records, and enabling flexible queries and dynamic visualization.

The main objectives of this work are to design and implement a scalable and user-friendly energy management platform tailored to public buildings, validate the system through a pilot case study at the *Secretaria-Geral de Governo* (SGG – State Government's General Secretariat of Goiás), and provide a replicable and open-access solution to foster energy efficiency improvements in the public sector.

2 Methodology and Database Architecture

The platform follows a modular architecture that separates the user interface, business logic, and data layers. The data layer is composed of three independent SQLite databases connected through relational keys, which allows each dataset to be updated or expanded without affecting the others, while still enabling integrated queries and analysis.

The energy billing database (`dados.db`) stores normalized electricity consumption, demand, and cost records indexed by municipality and client. Automated import routines process PDF and Excel files, extracting fields such as consumption (kWh), contracted demand (kW), billing cycle, tariff group, and total cost. These values are validated against predefined formats to ensure data consistency before being stored for subsequent analysis and dashboard visualization.

The equipment labeling database (`inmetro.db`) contains technical specifications from Brazil's National Energy Labeling Program (PBE-INMETRO), organized in separate tables for each product category (e.g., HVAC systems, lighting, refrigeration). Standardized column naming allows direct retrieval of attributes such as energy consumption, efficiency class, cooling capacity, voltage, and application type. This enables the audit module to associate installed equipment with default performance parameters from the labeling database.

The energy management database (`gestao_energetica.db`) stores detailed information collected during on-site audits at the room level, including physical characteristics, occupancy profiles, and equipment inventories. Each entry links to a specific building and location, allowing multi-site management within the same dataset. Equipment records include fields for quantity, rated power, daily usage hours, and standby modes, and the schema is prepared for future integration with end-use energy modeling.

Integration across the three databases is achieved through unique identifiers, enabling cross-referencing of billing records, technical specifications, and field audit data. This structure supports dynamic queries for performance indicators, facilitates the generation of interactive dashboards, and provides a scalable foundation for future benchmarking and automated efficiency assessments.

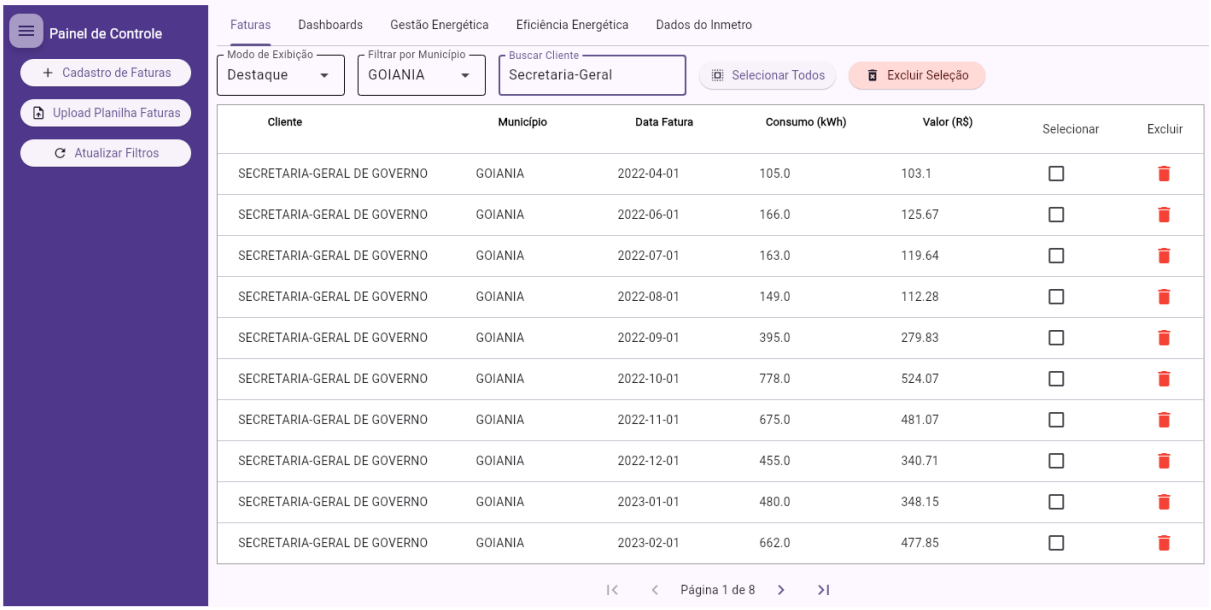
3 Platform Features and Implementation

The digital platform implements the three-database architecture described through a tab-based interface that organizes the energy management workflow into clearly defined stages. Each tab corresponds to operations on one or more databases, ensuring that data import, visualization, equipment registration, and technical referencing occur in a logical and consistent sequence. The main navigation menu includes four functional sections: *Faturas* (Bills),

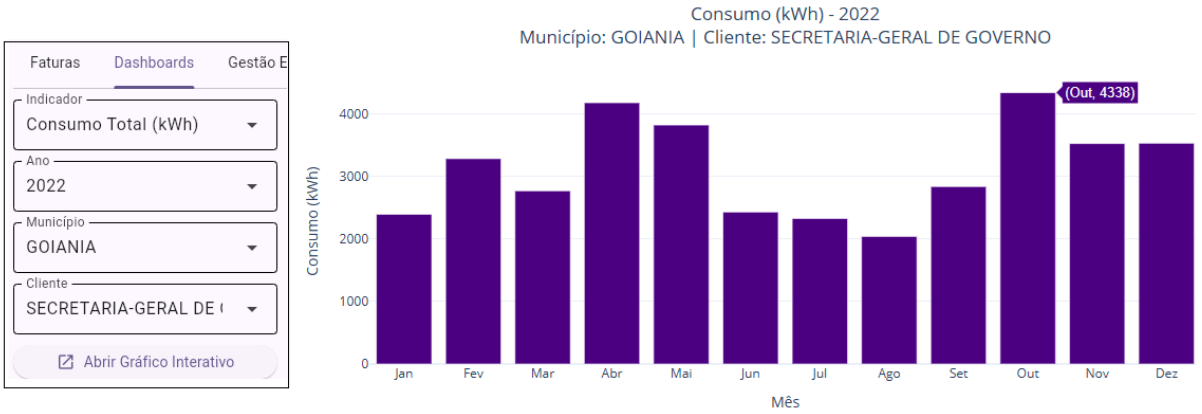
for importing and managing electricity billing data; Dashboards, for interactive visualization of energy indicators; *Gestão Energética* (Energy Management), dedicated to room-level equipment audits; and *Dados do INMETRO* (INMETRO database), which provides access to standardized product performance data. An additional *Eficiência Energética* (Energy Efficiency) section is planned for future integration of BEU-based metrics.

Interactive components such as dropdown filters, searchable tables, and dynamic layout elements allow users to handle large datasets efficiently. A persistent control panel ensures global navigation and real-time feedback across all modules.

The *Faturas* and Dashboards tabs operate directly on the energy billing database (`dados.db`). In *Faturas*, users can import electricity bills in PDF or Excel formats, with automated extraction of consumption, demand, cost, and tariff information. Records can be filtered by municipality or client, sorted, and batch-edited for rapid management. The Dashboards tab complements this functionality with graphical summaries, allowing users to filter by year and consumer unit to identify seasonal variations, detect anomalies, or evaluate the effects of efficiency measures. Figures 1a and 1b illustrate this workflow for the *Secretaria-Geral de Governo de Goiás* (SGG), showing the imported billing records and the corresponding annual consumption profile for 2022.



(a) *Faturas* tab with monthly billing records.



(b) *Dashboards* tab with annual consumption chart.

Figure 1. Example workflow from data import to visualization for the SGG in 2022.

In the *Gestão Energética* (Energy Management) tab, the user selects a consumer unit from the billing module and registers the equipment installed in each room of the building. Categories include HVAC systems, lighting devices, computers, monitors, and other appliances. All entries are cross-referenced with the INMETRO labeling database to ensure consistency of power consumption and efficiency values. Each room record includes metadata such as built area, occupancy level, operational schedule, and equipment usage profile. Conditional input fields

adapt to user selections, maintaining both flexibility and data integrity.

Once a consumer unit is selected, the platform displays a list of all registered rooms, including their basic characteristics and installed equipment. Figure 2 illustrates this interface for the *Secretaria-Geral de Governo de Goiás* (SGG), showing part of the registered rooms for energy management.

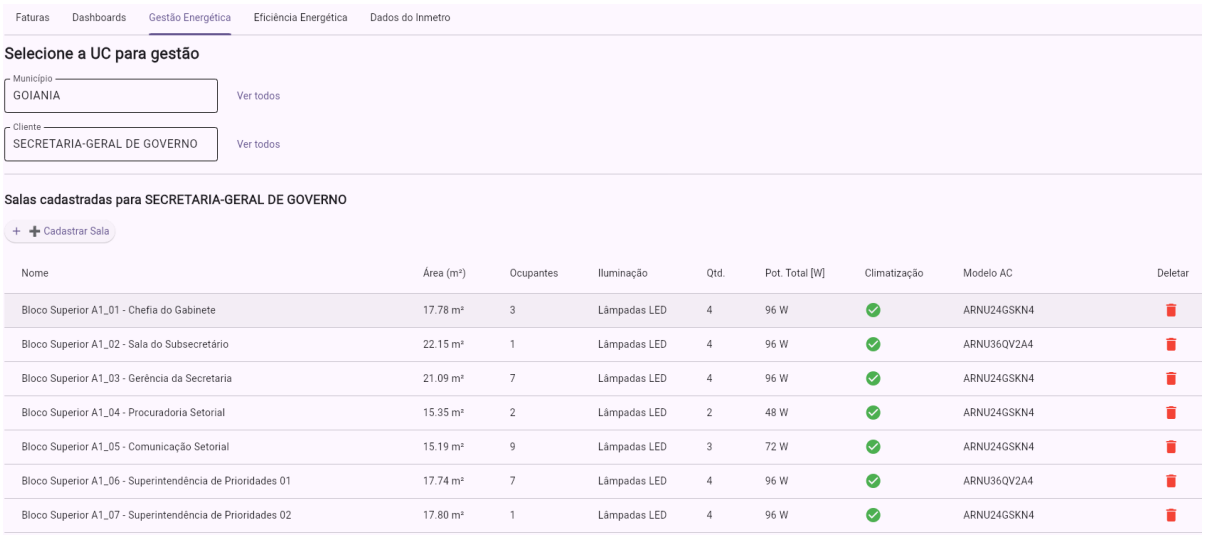


Figure 2. Example of the *Gestão Energética* tab showing registered rooms for the SGG consumer unit.

The *Dados do INMETRO* tab provides access to a local copy of the National Energy Labeling Program (PBE) database, stored in `inmetro.db`. Users can browse products by category, search by brand or model, and view attributes such as energy consumption, efficiency class, capacity, and voltage. The database can be updated from the most recent datasets made available through the *sou.gov* portal, ensuring alignment with official records. Administrative tools allow further manual edits to adapt entries to field survey needs. Integration with the energy audit module ensures that equipment registered during on-site assessments is automatically matched with standardized performance data.

Figure 3 shows the *Dados do INMETRO* interface in "highlight" mode, where only the most relevant fields for the selected equipment category are displayed. In the example, several Samsung-brand air conditioners are listed, showing description, efficiency class range, annual energy consumption, nominal cooling capacity, and function. Each category in the database presents its own set of relevant attributes. A "full" mode is also available, which displays all specifications provided by the PBE dataset.

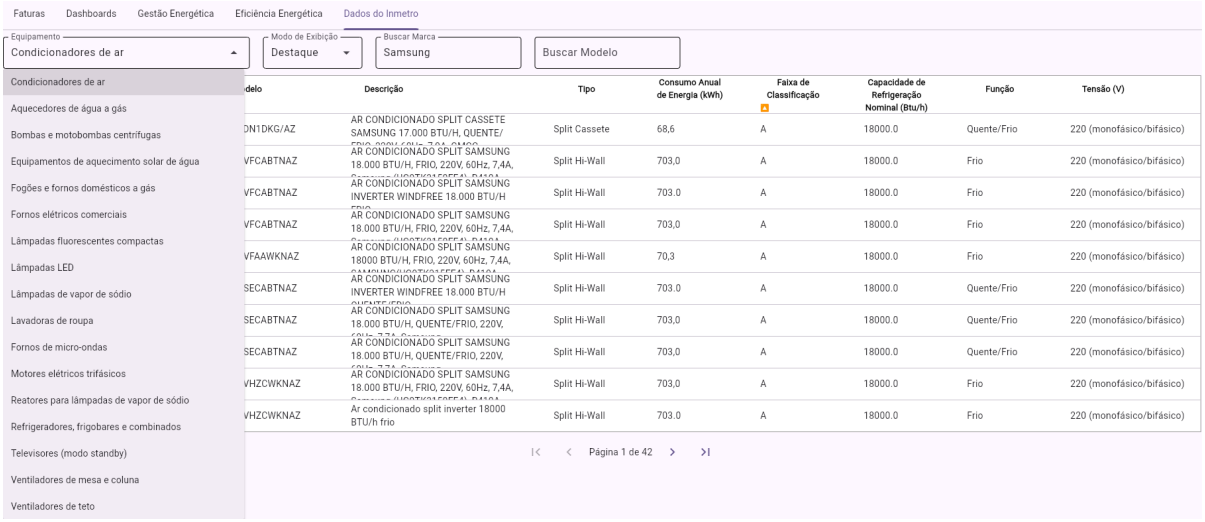


Figure 3. Example of the *Dados do INMETRO* tab showing registered air conditioners in highlight mode.

4 Case Study: Goiás State Government's General Secretariat

A preliminary site visit to the *Secretaria-Geral de Governo de Goiás* (SGG) allowed researchers to record initial information about the installed equipment in several rooms of Block A. At first, data were collected on paper, but this approach proved to be inefficient, as it required a second manual transcription into the digital platform. To streamline the process, a new feature was implemented in the platform's *Gestão Energética* (Energy Management) tab, enabling direct room registration through the *Cadastrar Sala* (Register Room) interface.

Figure 4 shows the room editing interface, where users can update the `gestao_energetica.db` database in real time. Each record includes the built area, number of occupants, type of lighting, HVAC system, computing equipment, and other appliances. For every equipment entry, brand and model can be selected from the `inmetro.db` database, ensuring consistency with the official PBE-INMETRO dataset. Dropdown menus and search tools facilitate quick selection, while conditional fields adapt dynamically to the selected equipment type.



Figure 4. Room editing interface in the *Gestão Energética* tab, showing the configuration of lighting, HVAC, computing devices, and other equipment.

With the aid of the architectural floor plans for Blocks A, B, and C, as well as the lighting design project, all 53 rooms were registered with their respective dimensions, lighting fixtures (type, quantity, and power), and other relevant attributes. Figure 5 illustrates the upper floor plan of Block A as an example, where each room is identified by a unique code.

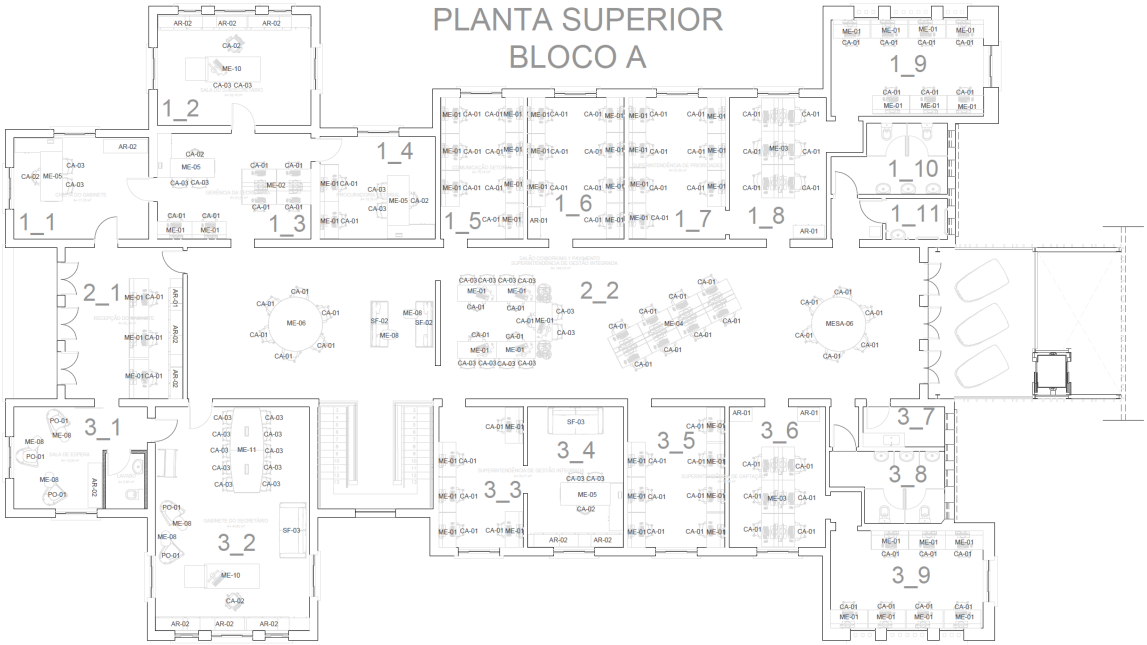


Figure 5. Upper floor plan of Block A at the SGG headquarters, showing the coded layout of the rooms.

After the initial registration, the remaining equipment data were collected during a second technical visit. This updated workflow significantly improved efficiency, as the platform allowed direct entry and instant synchronization of field observations with the central database, eliminating the need for intermediary manual transcription.

5 Conclusion and Future Work

The development of the proposed digital platform represents a significant step toward modernizing energy performance management in public buildings, offering a transparent, replicable and scalable tool. By enabling both macro-level and micro-level analyses, the system facilitates the monitoring of overall consumption trends while also providing detailed diagnostics at the room and equipment level. This dual perspective empowers decision-makers to identify inefficiencies, prioritize interventions and track the impact of implemented measures with greater precision.

From an implementation standpoint, the project demonstrated the value of integrating multiple data sources including electricity bills, equipment inventories and certified performance data into a unified interface. The transition from manual paper-based data collection to direct on-site registration within the platform significantly improved efficiency and reduced the risk of transcription errors. Moreover, the case study at the *Secretaria-Geral de Governo de Goiás* (Goiás State Government's General Secretariat – SGG) revealed the importance of user-friendly design and flexible data structures to accommodate diverse building typologies and operational contexts.

The adoption of the platform by SGG underscored the relevance of having a centralized digital environment for tracking electricity consumption and managing building accounts across the state. In light of these benefits, SGG has recommended the implementation of new functionalities in the billing module, including advanced interactive dashboards with year-to-year comparisons, group-based consumption visualizations and additional custom filtering options. These enhancements are planned as part of the next development phase.

Importantly, the platform's modular architecture and structured database design create the groundwork for the analysis of large data repositories through advanced data analytics techniques. Such capabilities could enable large-scale pattern detection, trend forecasting and more robust evidence-based decision-making to support public sector energy management policies.

Following this work, the case study at SGG will continue with an in-depth evaluation of energy efficiency through performance indicators and the estimation of consumption shares by equipment group. This ongoing effort aims to not only optimize resource use within SGG facilities but also serve as a replicable model for other public institutions, supporting the formulation of evidence-based policies and long-term energy conservation strategies.

Acknowledgements. The authors acknowledge the financial support provided by the Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG), through research scholarships granted under the *Chamada Pública FAPEG nº 02/2024 – Seleção de Bolsistas de Desenvolvimento Científico e Tecnológico para Atuação na Secretaria-Geral de Governo do Estado de Goiás (SGG)*, which made this work possible.

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