THE CITY ENERGY ANALYST IN BRAZIL: practical application and the creation of its first brazilian database[1]

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RESUMO

Este artigo investiga o uso do City Energy Analyst (CEA) no contexto urbano-energético brasileiro e apresenta a criação da primeira base de dados nacional para o *software*. A introdução traz exemplos de aplicações internacionais do CEA, destacando a escassez de estudos com a ferramenta em países em desenvolvimento. A metodologia abrange duas etapas: a construção da base brasileira (BR) e simulações comparativas com uma das bases originais do CEA, de Singapura (SG). A comparação de desempenho entre as bases busca avaliar a relevância de dados locais em análises urbanas e energéticas. As variáveis de saída incluem gráficos de conforto, balanços energéticos e potencial de geração solar. Os resultados indicam que a base BR é robusta e que o CEA tem potencial para representar realidades brasileiras. No entanto, limitações do *software* restringiram a incorporação de características locais relevantes, comuns a diversos países emergentes.

Palavras-chave: Simulações; City Energy Analyst; base de dados; Brasil.

ABSTRACT

This paper investigates the use of the City Energy Analyst (CEA) in the Brazilian urban-energy context and presents the creation of its first national database. The introduction highlights international applications of the software and points to the lack of studies using CEA in developing countries. The methodology involves two stages: building the Brazilian database (BR) and running comparative simulations with one of CEA's original databases, from Singapore (SG). The performance comparison aims to assess the relevance of local data in urban and energy analyses. Output variables include comfort charts, energy balances, and solar generation potential. Results show that the BR database is robust and that CEA has potential to represent Brazilian contexts. However, software limitations restricted the inclusion of relevant local features, commonly found in emerging countries.

Keywords: *Computer simulations; City Energy Analyst; database; Brazil.*

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1 INTRODUCTION

As an excerpt from a Master's thesis (Morais, 2024), this paper examines the use of City Energy Analyst (CEA) in Brazilian urban and energy contexts, pointing out its strengths and limitations in local scenarios. It also discusses the development of the first Brazilian database for said tool, produced in two versions (3.34.2 and 3.37.x), which constitutes the primary contribution of this study. Through the new database, this research sought to bring CEA closer to Brazil without resorting to programming.

1.1 CEA in practice: International applications

This section summarizes some examples of studies where CEA is applied in different territories (Table 1). While this research focuses on testing the software's suitability to Brazilian scenarios, most of the examples below present a different approach locally.

Table 1 – Examples of papers applying CEA in case studies

Authors	Main focus	Location	Examples of findings
Mosteiro-Romero *et al.* (2019)	Analysis of a masterplan proposal using ENVI-met and CEA for simulations.	The Netherlands	Points for climate-related improvement. Highly insulated buildings performed well for heating, but with increased cooling demand.
Mora *et al.* (2021)	Heating demand assessment using an Excel-based method and two software tools, including CEA.	Italy	Dynamic tools, such as CEA, reach more reliable results than Excel spreadsheets, but are considerably more complex to non-specialists, such as policymakers.
Jewell *et al.* (2022)	Union of QGIS, CEA and Urbio to design district energy infrastructure for a greenfield project.	Portugal	The relevance of human behavior to understand energy demands; the need to consider demand changes and expansion potential when designing district heating layouts.
Oraiopoulos *et al.* (2023)	Projection of future energy demands (2040, 2060) in urban and rural archetypes.	Switzerland	Demand linked to population growth, urban density and building use. Higher cooling demand in urban areas; heating demand in rural ones.
Mosteiro-Romero *et al.* (2023)	Impacts of demand-driven control strategies on workplace flexibility and energy use at a university.	Singapore	Slight cooling demand reduction (5–15%) at 25% and 75% occupancy with conventional, centralized operation. Occupancy-and- zone-based control reached higher reduction rates (17–63%).

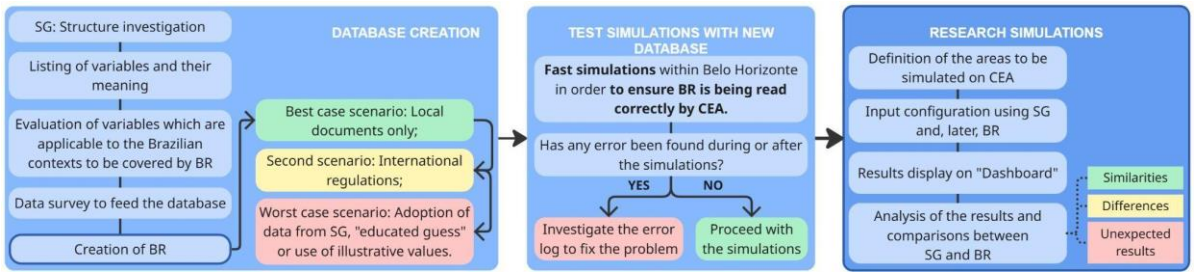
Source: Created by the authors.

The primary locations where CEA has been applied were Singapore, Switzerland and Italy. None of the studies found have considered developing nations, such as Brazil.

2 METHODS

This research was divided into two phases: the creation of the Brazilian database (BR) and the research simulations using both the original SG and BR (Figure 1). These are briefly described in this paper, but more thoroughly covered by Morais (2024).

Figure 1 – Flowchart summarizing path followed during the research



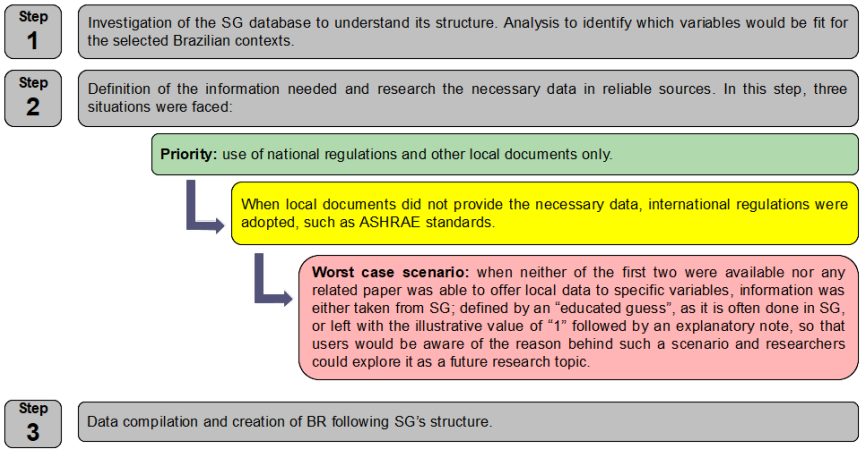
Source: Created by the authors.

The first phase to address is the process of understanding the original SG database in order to shape BR into the correct structure to be read by CEA.

2.1 The creation process of the Brazilian database (BR) for CEA 3.34.2

In order to shape BR's content appropriately, the variables which would be suitable to the studied areas were carefully considered and limitations found in the process were listed. ABNT (*Associação Brasileira de Normas Técnicas*) and EPE (*Empresa de Pesquisa Energética*) are amongst the several institutions that served as sources - the complete list is cited by Morais (2024). Due to the available time frame of a Master's and the large complexity Brazil offers, the first version of BR was destined to Belo Horizonte, Matozinhos and any other city with similar energy and urban traits. However, it could be expanded in the future to cover additional local realities, if needed. The creation process is summarized in Figure 2.

Figure 2 – Summary of the logic behind the creation of BR



Source: Information taken from Morais (2024). Created by the authors.

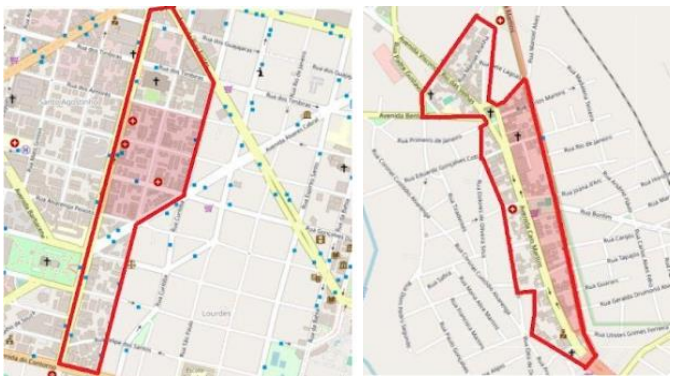
Some variables were less suited to the selected scenarios than to Singapore and thus were either excluded from BR or adapted. Among other data, BR contains schedules

for 9 uses, cooling systems, and both wet and dry construction solutions for building systems. It also offers 15 construction standards varying in use, building technique and WWR (window-to-wall ratio), including one for informal buildings that present neither technical guidance nor approval from local authorities - defined in the research as "atypical settlements" (Morais, 2024). Test simulations were run on a random section of downtown Belo Horizonte using BR's default settings to execute the main CEA utilities, such as solar radiation, energy demand and solar energy production. These tests were not focused on analyzing results, but on identifying and correcting errors, ensuring BR was fully operational before the practical phase.

2.2 Practical application: SG x BR

Conducted using databases, this phase aimed at comparing results and assessing the relevance of a local dataset in urban simulations. The Brazilian cities selected for the original research were Belo Horizonte and Matozinhos, both in Minas Gerais. The selection was based on their geographical proximity, ensuring comparable climate conditions; similarities in building techniques, energy sources and air-conditioning systems, enabling the use of the same database for both areas; and the contrasting urban densities between a metropolis and a small town, allowing promising result comparisons (Morais, 2024). To ensure depth within the scope of this paper, the analysis will address one area in each city. The simulations used "city blocks" rather than "districts" to define study areas and, due to the large data volume and time constraints of a Master's research, each section of the following neighborhoods (Figure 3) included 90-120 buildings (Morais, 2024).

Figure 3 – In red, the studied areas addressed in the present paper: BH1 (left) and MTZ1 (right).



Source: Morais (2024). Adapted by the authors.

- Lourdes (Code: BH1): High-density, central area with high-rise, mixed-use, mid-to-high standard buildings, full infrastructure access, and construction aligned with local regulations. Located in a city with rich data availability;
- Downtown Matozinhos (Code: MTZ1): Moderate urban density with mixed uses and low-rise buildings in most cases (1–3 floors). Visible infrastructure. Compared to Belo Horizonte, Matozinhos lacks enough data to fully describe its area on CEA.

The simulation process is summarized in Table 2.

Table 2 – Summary of the simulation process

Step	Action performed

1	Definition of the areas to be studied on CEA.
2	Selection of databases (SG and BR) and weather files. Both sections were set with the "Belo Horizonte - Carlos Prates" EPW, as Matozinhos lacks its own. The selected file is considered appropriate for urbanized areas (Morais, 2024).
3	Input settings, creating different scenarios with each dataset: BH1_SG, BH1_BR, MTZ1_SG and MTZ1_BR. These settings are detailed by Morais (2024), but they included data such as construction techniques, building heights and uses, HVAC systems, occupancy patterns, indoor comfort definitions, equipment load, solar technologies in place, surrounding buildings and their heights, among others.
4	Simulations: graphs involving comfort; energy balance, energy end-use and final use, and solar energy production (solar collectors, PV and PVT panels) are created.

Source: Morais (2024). Created by the authors.

Each pair of scenarios of the same area were compared to highlight similarities and differences between databases, the existence of any unexpected results and the response offered by CEA to local questions, such as the atypical settlements. The results from each database would be put side by side to enable direct quantitative and qualitative comparisons, investigating if they tracked with the local reality. Some graphs displayed results for the entire section (e.g.: energy final use), while others addressed each building individually (e.g.: energy balance) (Figures 4 and 5).

Figures 4 and 5 – Energy final use of BH1 using BR (left) and energy balance of building B1000 (single-family residence) in BH1 using SG (right).



Note: The meaning of each variable in Figure 5 is explained in the original work.
Source: Morais (2024). Adapted by the authors.

For individual results, each area would have its most representative building uses chosen as reference to allow comparisons between databases, as B1000 exemplifies.

3 RESULTS AND DISCUSSION

3.1 The Brazilian database

To adapt BR to the selected areas, data on construction methods, cooling systems,

building uses, and occupancy were gathered. Several variables were influenced by data availability and local contexts, reflecting contrasts between Brazil and Singapore. CEA's limitations were noted. Figure 6 outlines important information.

Figure 6 – Summary of the adaptations and constraints found during the creation of BR

ADAPTATIONS	LIMITATIONS
• No need for heating systems due to local climate; • Adoption of figures from external sources when a lack of local data was faced; • Adoption of building and city scales following local energy and electricity distribution; • Exclusion of variables dealing with hot water for HVAC systems since the options in BR do not need such supply; • Adaptations in the "Thermal grid" tab, where illustrative values were included alongside an explanatory note, as the current data is not representative for the study areas.	• Inability to incorporate crucial data related to Brazilian energy and electricity demands; • A reduced number of schedules in the "Use_types" due to a lack of data in local regulations; • Embodied emissions data for construction systems: due to unit incompatibility between CEA ($KgCO2/m^2$) and local data ($kgCO2eq$), an illustrative value of "1" and an explanatory note were added to BR; • Constraints in the Feedstocks table, which only supports kWh as a unit. As a result, only SIN (*Sistema Interligado Nacional*, referred to as GRID since CEA does not allow custom naming) and SOLAR were included, focusing on the most representative energy sources for the study areas.

Source: Morais (2024). Created by the authors.

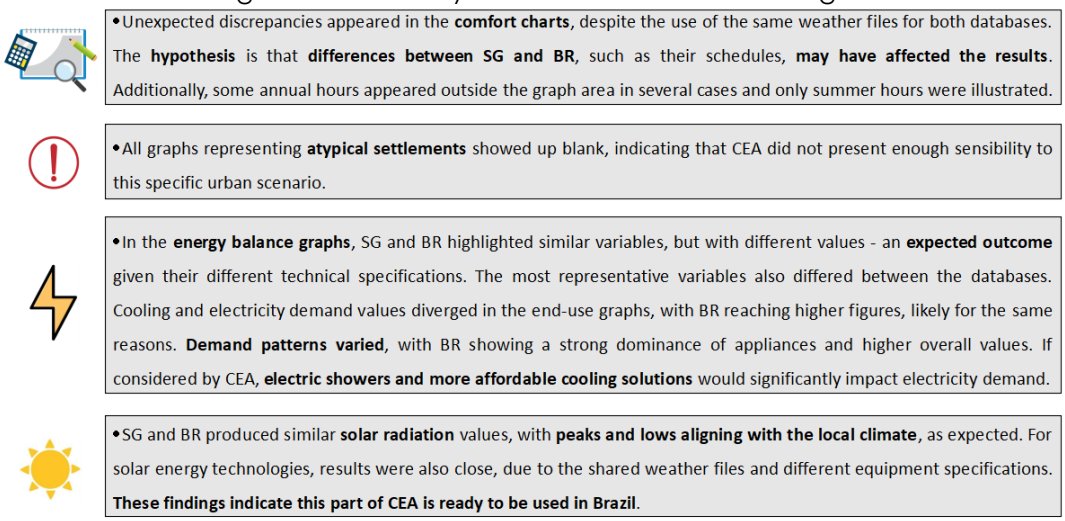
The adaptations made in BR sought to align CEA with local conditions without programming, but some changes were unfeasible due to software limitations. Key issues on CEA and its database involved the impossibility of incorporating relevant elements to Brazil's energy context - electric showers, LPG and wood for cooking, affordable cooling (e.g., fans) and natural ventilation as a passive strategy - as well as weaknesses in emissions data, HVAC-related variables, and limited "Use_types" schedules (partly due to gaps in local regulations). Regulatory shortcomings also involved missing data on key national topics and insufficient information on embodied emissions. Variables with data taken from SG were also a drawback.

The structure of CEA databases and traits of Brazil's energy and electricity matrices posed challenges for BR's development. For instance, as a large-scale, multi-source electricity production and transmission system, the SIN's complexity could not be fully captured through the GRID tab. Previously mentioned issues also hindered accurate representation of Brazil's energy demand, especially in atypical settlements, affecting results. Bridging these gaps may require programming-based adaptations and more time to expand BR. On a positive note, the gaps related to emissions and hot water demand are already being addressed by researchers at UFMG. As an additional development, BR 3.34.2 was duplicated and adapted to create a second database compatible with CEA 3.37.x, the latest version at the time, for the same urban and energy contexts. Both datasets were registered by CTIT-UFMG.

3.2 The simulations

The analysis of the results focused on evaluating the suitability of CEA to Brazilian contexts. Simulations were conducted for 112 buildings in BH1, creating 52 charts, and 101 buildings in MTZ1, producing 44 charts. Figure 7 outlines some of the findings.

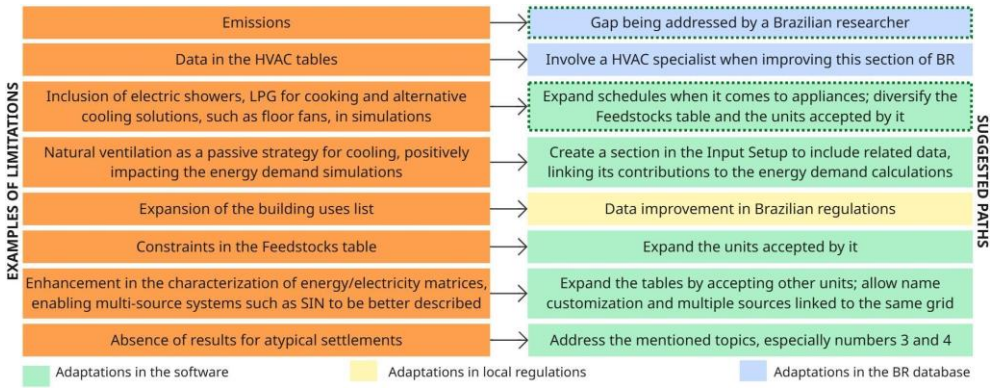
Figure 7 – Summary of the main research findings



Source: Morais (2024). Created by the authors.

BH1 used 3 standards from SG and 6 from BR, while MTZ1 used 4 from SG and 7 from BR, indicating that BR's 15 standards were better tailored to local scenarios. The strongest assets BH1 presented were data availability for simulations and solid urban infrastructure. In contrast, MTZ1 showed greater flexibility for implementing future urban and energy strategies, which is valuable when applying CEA in real-life decisions. Located in a small town, MTZ1 lacked data during input setup. Figure 8 suggests paths to seek solutions for some limitations found in this research.

Figure 8 – Roadmap linking detected limitations to possible solutions



Source: Morais (2024). Created by the authors

As topics for future investigations, most of them are linked to programming on some level. Boxes with dotted borders indicate ongoing research at UFMG.

4 CONCLUSION

Results revealed CEA's potential, particularly when using local data, which improved accuracy. Some values aligned with Brazilian realities, such as solar radiation, while others require further investigation. Key limitations involved the description of the energy and electricity matrices, as well as the absence of vital elements for building energy demand, including atypical settlements. This research sought to bring CEA

closer to local scenarios without programming, and the findings indicate the need to adapt the tool to start considering those aspects. From an urban and social perspective, the lack of results regarding atypical settlements represented a limitation that is expected to be overcome if the identified gaps are addressed. Alongside the aforementioned findings, the Brazilian database is considered to be the main contribution of this research. BR proved to be valuable in representing local scenarios, supporting its adoption by public agencies. While data gaps had a negative impact, BR can be propelled further by researchers, as seen with current work on emission-related data. The HVAC section, for instance, is a promising area for improvement. Overall, the research underscores the importance of urban-scale simulation tools that can reflect diverse - especially emerging - contexts to better support planning and energy transitions.

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