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Towards effective implementation of building energy efficiency codes in Tripoli, Lebanon: Key actions for enforcement

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Abstract

Energy is vital for human life. However, the increasing global demand for and reliance on fossil fuels are significantly contributing to rising CO_2 emissions. The Building Energy Efficiency Codes (BEECs) are a government initiative aimed at regulating CO_2 emissions. BEECs support both national environmental goals and global climate change initiatives in Lebanon. The study aims to close the gap between the effectiveness of Lebanon's building energy codes and the country's environmental goals. It seeks to identify the key enforcement actions taken by the Trpl-M towards the successful implementation of the Building Energy Efficiency Code (BEEC). Tripoli was selected for its administrative independence and unique authority in enforcing building energy codes, including a dedicated technical department. This autonomy provides a valuable setting to explore compliance strategies and address regional challenges. This is achieved through an approach involving a literature review, case studies, and semi-structured interviews with employees from the Trpl-M Permit Office. The data is analyzed using a thematic analysis approach, providing a nuanced understanding of the implementation challenges within the employees' working environment. Findings suggest considering proactive design integration, third-party inspections, random compliance checks, penalties, and incentives to achieve high standards of energy efficiency and contribute to sustainable urban development and energy conservation in the region.

Keywords: Energy code, Tripoli, Lebanon, BEECs, Policy implementation, Urban sustainability

1. Introduction

Energy is needed in daily life, providing heat, cooling, lighting, enabling mobility, facilitating food preparation, purifying water, and supporting communication [1, 2]. Energy efficiency tools have increased, but over time, global energy demand is rising [3] due to population growth, economic development, as well as the increased use of services and devices such as automobiles, TVs, mobile phones, computing services, and the internet [4]. Fossil fuel-based energy production is the primary source of CO2 emissions, contributing to global warming. The Paris Agreement, signed at COP 21, aims to limit the global average temperature increase to below 2°C above pre-industrial levels, and 1.5°C above pre-industrial levels, with the goal of global peaking.

Major nations have set greenhouse gas reduction targets by the United Nations Framework Convention on Climate Change (UNFCCC) to satisfy the need for lowering GHG emissions in the building sector. Many nations are introducing different building energy regulations aimed at improving the energy efficiency of both new and existing buildings in order to achieve these goals. One of the main tools that governments have used to set minimum standards of energy efficiency for the design and construction of various building types is building energy codes [5, 6]. Helping newly constructed buildings to achieve energy efficiency goals, and lower building energy demand, as well as carbon emissions, is made possible in large part by building energy codes and reducing building energy demand, as well as carbon emissions is made possible in large part by building energy codes [7, 8]. In reference to the Business-as-Usual (BAU) scenario, Lebanon has pledged to increase its target for reducing greenhouse gas (GHG) emissions from 15% to 20%. Additionally, under specific conditions, Lebanon has committed to raising its GHG emission reduction target from 30% to 31% in comparison to the BAU scenario (Lebanese Republic, 2020). Furthermore, Lebanon requires an energy efficiency plan and the implementation of BEECs due to its energy crisis, economic challenges, and environmental concerns. Imported fossil fuels account for 96.8% of the country's primary energy supply, contributing to the increase of both carbon dioxide emissions and public debt [9, 10]. In many parts of the world, the implementation and enforcement of BEECs present significant challenges. The effectiveness of these codes depends not only on their design, but also on how well they are understood, enforced, monitored, and updated. Without proper compliance, the intended energy savings and environmental benefits may not be fully realized [11]. This is greatly important for a country like Lebanon which is currently grappling with an energy crisis, a stagnating economy, and environmental concerns. Lebanon should take critical steps towards its environmental goals, and support the worldwide efforts to respond to climate change. In fact, it is imperative that Trpl-M shows leadership for further enforcement of building energy efficiency codes to confront such challenges and promote a culture of sustainability in the building industry [12].

To address these concerns, the aim of the study is to close the gap between the efficacy of Lebanon's building energy codes and the country's environmental objectives. The research focuses on examining the enforcement capabilities of the Trpl-M, which holds unique administrative power to oversee building energy practices with the following objectives:

1. Examine Global Best Practices: Compare energy efficiency enforcement strategies from other regions, such as California, USA, and Rajasthan, India, to identify solutions applicable to Tripoli.
2. Assess the Trpl-M’s Role in BEEC Enforcement: Evaluate the municipality’s administrative authority and its ability to enforce BEECs during the design, construction, and post-construction phases.
3. Propose Strategies for Effective Enforcement: Recommend measures for improving BEEC compliance in Tripoli, focusing on design integration, third-party inspections, and the use of penalties and incentives.

1.1. Research questions

What actions can be taken by the Trpl-M to improve BEEC enforcement? This question helps to confine the study and enable better recommendations and actionable strategies for increasing the enforcement capacity of a real municipality. The research will finally focus on this single question and therefore give a profound answer to what it takes for BEECs at the Tripoli level to be implemented in practice.

2. Building energy performance codes

Saving energy in technical systems, buildings, cities, regions, or entire countries can be achieved through energy efficiency. At the micro level, it calculates the amount of energy saved or used for the same amount of useful service, activity, or work [13]. That can be done through research that leads to new technologies [14]. At the macro level, it refers to the ratio between energy consumption and the country's GDP [15]. Although there was an improvement in energy efficiency that reduced energy intensity [16]; [17], energy consumption in developed countries increased at the macro level. In the EU, energy consumption kept on increasing until 2006, when it started to decrease due to the recession and energy policies, until 2014. But since then, energy usage has been

rising again [18]. The BEEC is the minimum level of efficiency that new and renovated buildings must meet, typically guaranteeing consistent decreases in energy consumption and emissions over the life of the building [19]. Studies emphasized the key role of the government code implementation in creating rules and guidelines that bind the stakeholders of green buildings (GB) and in supporting its development financing [20]. Regulating frameworks, enforcement mechanisms, and incentive programs should all be combined to achieve effective implementation of BEEC [21]. Additional research conducted in Singapore, Australia, the United States, and Europe supports the conclusion that homebuyers are ready to pay a premium for energy-efficient homes. Upgrading building efficiency will bring economic benefits, support energy security, and contribute to CO_2 emission reduction. For example, in Italy, over 65% of the 12 million residential buildings were built before the building's performance law was imposed more than 40 years ago. The last two energy performance categories, where nearly 3 million housing units in Italy are located, show that such units require urgent and extensive refurbishment. State laws or regional building regulations can be used by public administrations to encourage interventions to improve the energy efficiency of private buildings [22, 23]. Building codes are being adopted at a higher rate and have been shifted from prescriptive to performance-based to outcome-based. Despite this transition, Britain and Canada permit the Reference Building Approach for small residential buildings [24].

2.1. BEEC stages

Effective implementation of BEEC includes interrelated key stages: publication, familiarity, enforcement, and updating the code. The publication date announces the release of the new code; however, the enforcement date may differ. The period between the publication date and the enforcement date allows stakeholders to gradually become more acquainted with it, a stage referred to as the familiarity stage [12]. Typically, a publication will announce an enforcement date, which marks the beginning of the code enforcement stage. This stage involves verification mechanisms, incentives, and penalties. During the enforcement date, a transitional stage commences to upgrade the new code [12, 25]. The actions of these parties are guided by local ordinances or legislation. As Pan and Garmston [26] discuss, there are two primary stages involved in the implementation of energy efficiency building regulations (Part L) by the United Kingdom Government: the familiarity period and the transitional period. A "familiarity period"—which lasts for six months, three weeks, and five months, respectively—was included with the editions of Part L 2002, 2006, and 2010, and described the time between the publication of Part L and its enforcement. The UK Government has allowed such a time in order to increase practitioners' familiarity with the new building regulations' requirements before they are implemented. During the transitional stage, the key actions of enforcement will begin to take effect, and it will also be time to update the new code edition [26, 27].

Figure 1. BEEC stages, Source: [26]

2.2. BEEC: Enforcing stage

Building energy efficiency codes are only as good as their enforcement. They depend, like most regulations, on successful implementation and enforcement when used as a public policy tool [28]. Enforcing BEEC is a multiphase process that starts with the design phase and continues through the construction phase the commissioning phase, and the after-commissioning phase [29], starting with design inspection. Most building energy codes have two categories of criteria: performance-based and prescriptive [30]. Performance-based criteria for new buildings are being implemented in many countries, including the United States and the European Union countries. These criteria include the energy need and use, primary energy use, and CO_2 emissions, besides the prescriptive criteria, such as air tightness, thermal transmittance, or the basic physical

performance of the building. Other countries start with prescriptive criteria, and then transfer to the performance-based criteria [31]. On-site inspections are carried out to confirm the as-built conditions of the buildings. However, the nature and focus of the field inspections differ. Several studies have exclusively concentrated on the primary systems within buildings, including the building envelope, lighting, and mechanical systems. Others focused on particular building types, or on buildings that were near completion or in the commissioning phase [32].

Third parties play a crucial role in building energy efficiency codes. Some countries endorse codes at both the design and construction phases of a building. During the design stage, the plans of the building are verified by an enforcement agency to check if it meets the energy efficiency requirements specified in the codes. For instance, in Portugal, code compliance at the design and construction phases is verified by energy specialists who work as inspectors and are certified by the National Energy Agency (ADENE). An energy specialist certifies that the plans meet the code and that construction may start. During the building phase, the energy expert snaps pictures and compiles documents to confirm that the structure is compliant and constructed according to schedule. Then, the information is uploaded by an energy expert to a national website. Only after the energy specialist has reviewed and submitted a plan change order, a building can resume. Furthermore, safeguards against conflicts of interest are in place. ADENE, for instance, looks over the papers that the energy expert has posted on the website. Also, the documents are reviewed by the municipality and the head of the construction company [33]. However, there is no one-size-fits-all solution to designing, implementing, and enforcing building energy efficiency policies, and there remains a significant amount of site and industry-specific knowledge sharing and learning in this sector.

2.3. Lebanon BEEC

Lebanon's BEEC primarily follows a prescriptive approach, as indicated by thermal measurements that were presented in 2005, when the UNDP and the General Directorate of Urban Planning under the Ministry of Public Works and Transport requested the adoption of Thermal Standards for Buildings in Lebanon. As Schimschar [34] states, BEECs published under decrees or laws are not required to be revised, but he emphasizes the need for a framework to improve BEECs. Incentive regulation encourages building designers to expand by excluding double walls from the maximum floor area calculation. Buildings above 700 meters above sea level must have thermal insulation, while those below 700 meters do not [35]. Tripoli is in northern Lebanon near Syria (Zone 1), with a coastal altitude below 400 m, and is its climate zone. This zone is characterized by warm, short, and humid winters, and hot summers [36]. Except for Beirut, all the other municipalities in Lebanon have low authority. The research focuses on Trpl-M because it can issue permits, oversee construction until commissioning, and fight violations. The municipality is divided into different departments, of which the Engineering department includes the Possession, Studies and Planning, Implementation, and Building Departments [37].

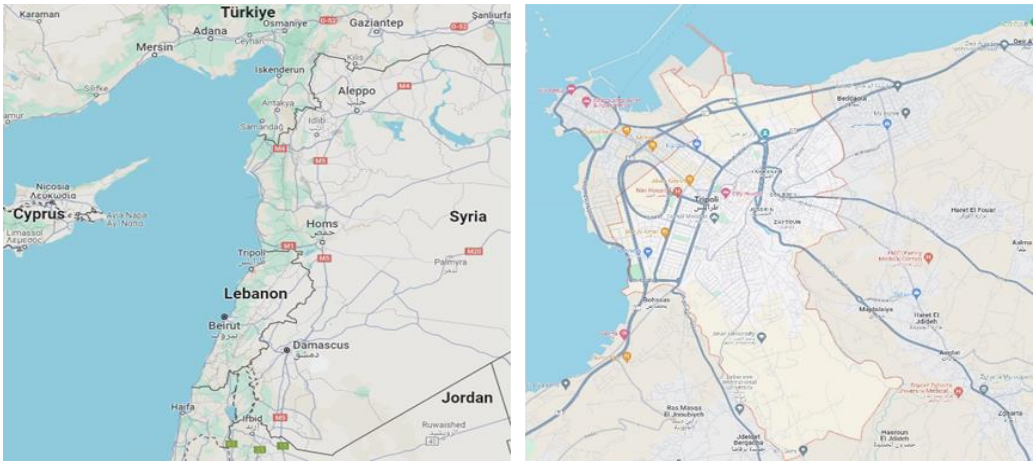

Figure 2. The left side portrays the geographic location of Lebanon, while the right side depicts the geographic location of Tripoli; Source: Google Earth

3. Case study

Governments use preventive, correct, and punitive enforcement mechanisms. Inadequate implementation of the codes and compliance processes is one of the primary reasons why the calculated or designed savings of energy are often debilitated. The code ordinances, institutional capacity, training of the indexers, and the users of the code on the need for compliance are very essential to enable sustained success. The general public and the builders are not always concerned with energy savings; their main interest is in ensuring that they acquire the building at the lowest cost while meeting the requirements for the building. Common reasons for not enforcing the codes mainly include corruption in the local authorities, ignorance or resistance, non-financial benefits that are greater than compliance with the codes, and technological, financial, or social factors.

The case studies of Rajasthan, India, and California, USA, were carefully selected for their relevance to Tripoli's context. Rajasthan-India mirrors Tripoli-Lebanon in that both regions than are in a country in an early stage that faces difficulties related to the enforcement of building energy codes and the retrofitting of older infrastructure. Rajasthan provides valuable lessons on overcoming limitations that Tripoli may encounter, especially in developing effective enforcement mechanisms and raising awareness of energy efficiency standards. On the other hand, California, USA, and Germany were chosen for their advanced, well-enforced energy codes. These regions showcase mature regulatory frameworks that can serve as models for Tripoli to adopt proven strategies to enhance code compliance and enforcement.

Rajasthan, India relies on the proactive measures taken by local governments, in accordance with state policies and guidelines. According to Tan, et al. [38], Rajasthan, India employs a hybrid approach to energy codes, combining prescriptive standards for straightforward compliance and performance-based evaluations for larger projects, the assessment is done during the planning and design phase. The state and local government employ certified third-party assessors to verify compliance in the construction phase; compliance checks are conducted during the post-construction phase, in accordance with the regulations set by the state and local government. These assessors are regularly audited. Compliance with the regulations is encouraged by offering additional floor area ratios and the opportunity to be recognized through the prestigious Rajasthan Energy Conservation Award. Failure to comply with regulations is subject to severe penalties, such as monetary fines and, in extreme cases, the termination of utility services to the building [39].

In California, USA, local jurisdictions play a crucial role in the implementation of state-wide energy codes, backed by strong support from state energy commissions. Extensive energy efficiency plans are mandated at the design stage and have to be verified by third-party certifiers. Regular checks for compliance are carried out at the construction and operational stages; the latter is conducted by state agencies on a regular basis. Many certified third-party agencies participate in enforcement and compliance checks. There are many financial incentives and awards to buildings that surpass energy efficiency requirements. These are provided through either standalone state programs or federal incentives. Non-compliance is subject to heavy fines and may require the forced implementation of energy efficiency measures, including retrofitting, in cases of failure [40].

In Germany, local authorities enforce building codes rigorously, supported by clear mandates and national regulations. During the planning stage, detailed planning for energy efficiency in new buildings is mandated, with a strong emphasis on integrating renewable energies and high-efficiency systems from the initial design phase. During the construction and operational phases, regular audits and compliance checks are conducted by authorized inspectors, ensuring stringent enforcement and monitoring [41]. The compliance process also involves a combination of third-party auditors and governmental inspectors, operating within a detailed regulatory framework to ensure adherence. Germany offers subsidies and financial incentives for energy-efficient constructions and renovations, including support for the incorporation of renewable energy sources. Penalties for non-compliance include fines and mandatory compliance measures, with severe violations potentially resulting in legal consequences [42].

Table 1. Enforcement strategies for building energy efficiency: A Comparative analysis of Rajasthan, California, and Germany; Source: [39, 40, 43] [42] and Google Maps

Feature	Rajasthan, India	California, USA	Germany
Location			
Local Role	Local inspection with State-supported enforcement.	Local inspection with State-coordinated implementation.	Local inspection with Nationally backed enforcement.
Approach To Energy Codes	Hybrid Model	Performance-Based Approach	Performance-Based Approach
Design Stage	Requires third-party assessments.	Local department inspects Plans that need third-party verification.	The Government inspects the BIM model and focuses on integrating renewables from the site
Construction Stage	Third party inspection.	State-enforced regular inspections.	Federal audits and enforcement.
Third-Party Role	Extensive reliance on assessors.	Broad third-party involvement.	Mix of third-party and government inspectors.
Incentives	Awards and area bonuses.	Financial incentives and awards.	Subsidies for efficient practices.
Penalties	Severe, including utility cut-offs.	Heavy fines and retrofit requirements.	Stringent fines, legal consequences and corrective actions

The significance of the case study conclusions is that in India, local inspections during the planning and construction stages require the involvement of third parties, with support from national or state coordination. In contrast, the governments of Germany and California have their own inspection tools and involve third parties primarily for inspecting plans or BIM models during the planning stage; however, during the construction stage, the government itself conducts inspections. It is also notable that India heavily relies on third parties for inspections, whereas Germany and California have their own inspection tools. In conclusion, all countries in the case study utilize incentives and penalties, despite their inspection practices.

4. Research method

This study uses a comprehensive approach to examine Lebanon's Tripoli Building Energy Efficiency Code (T-BEEC) implementation challenges and strategies. A variety of data collection methods were employed to gain a complete understanding of the topic.

4.1. Methods of data collection

4.1.1. Literature review

To contextualize the study, academic literature on global climate change, energy efficiency, BEECs, and Lebanon's building sector were reviewed. Insights from global and regional studies on BEECs guided the study's

approach to assessing enforcement strategies, particularly in the context of Tripoli, Lebanon. This comprehensive background provided a basis for exploring effective implementation methods for BEECs that align with Lebanon's environmental and regulatory goals.

4.1.2. Case studies

The study compared energy efficiency projects in Rajasthan, India, and California, USA, to identify effective strategies and common challenges in implementing BEECs. Tripoli and Rajasthan share resource limitations and are in the early stages of energy code development thereby offering an opportunity to explore modes of compliance strategies. However, California and Germany offer a mature regulatory framework with compliance mechanisms in place and therefore provide an opposite opinion that brings forward potential options for Tripoli to improve energy efficiency enforcement. Together, these cases enable the study to identify both successful tactics and challenges common to the local adoption of building energy efficiency codes at different but intensive levels within a single country.

4.1.3. Semi-structured interviews

Five in-person interviews were run with Trpl-M Permit Office employees in their offices. The five key personnel individuals selected are directly responsible for reviewing building licenses and enforcing the BEEC and its incentives. This sample of participants was chosen to capture essential insights from key personnel directly involved in BEEC enforcement within Tripoli's Permit Office. Each participant represents a unique perspective from relevant departments, including licensing, compliance, and enforcement, ensuring a comprehensive understanding of implementation challenges. The permit officer and office head were interviewed as well. Each interview was designed to discuss building energy efficiency code implementation experiences, challenges, and perspectives in depth. The researcher requested an appointment before scheduling the interview and explained the study, its goals, and the expected interview length. The interviews were conducted in the employees' offices. They lasted for about 40 minutes, where interviewers responded to open-ended questions about the familiarity implementation.

To ensure data accuracy, interviews were audio-recorded in Arabic, the participants' native language, for clear responses. Five key department heads' interviews illuminated BEE planning, operational, and compliance phases. The interviewees include Engineer Rana Zahra, Head of the Building Department, Engineer Azzam Naoushi, Head of the Possession Department, Engineer Zaher Skaff, Engineer Rida Bakri, and Saeed Abed, Head of the Building Violations Unit. The data was analyzed using a thematic analysis approach, categorizing each answer according to the implementation stage, to provide a nuanced understanding of the obstacles and perspectives associated with T-BEEC implementation. This approach ensured a detailed exploration of the implementation challenges within the context of the employees' working environment.

5. Results and discussion

In this section, a case study compares BEEC implementation strategies during enforcement in Rajasthan and California, followed by a thematic analysis of Trpl-M employee interviews highlighting key challenges and perspectives.

5.1. Thematic analysis of interviews with Trpl-M employees

In qualitative research, interviews start with the design of efficient questions and the choice of suitable participants. Following this, a thematic analysis is conducted to identify and report on patterns within data, enhancing the systematization, traceability, and verification of analysis. As mentioned before, writing questions and selecting participants in the design and execution of qualitative research, as well as the sequence of designing the survey is dependent on the research type. Authors [44] discuss the considerations of interviewer and participant characteristics in qualitative research, highlighting the importance of understanding the dynamics between interviewers and participants. It is important to address questions tailored to the specific

context and the characteristics of those concerned in an interview setting. As Pinsky [45] suggests, that might involve defining the research questions at the beginning.

This research question focuses on: How can TBEEC effectively integrate a dynamic enforcement framework to ensure high levels of adherence and continuous improvement in building energy efficiency code implementation?

Thematic analysis is a widely used qualitative research method that involves identifying, analyzing, and reporting patterns within data sets. It is a purposeful approach that aims to systematize and increase the traceability and verification of the analysis [46]. It is composed of six phases as developed by Braun and Clarke [47]. The researcher employs a systematic methodology in which they carefully read the interview and subsequently provide a concise summary or initial code. The process of thematic analysis involves several key phases, and, in the next section, the researcher follows the following stages to analyze the interview: I-Familiarization with the data, II-Initial code generation, III- Themes searching, VI-Themes revision, V- Themes defining and naming, VI-writing report [46].

5.1.1. Familiarization with the data

This is the initial step of engagement with the data collection. It involves researchers reading and rereading, immersing themselves in the data to gain a good understanding of it. This stage assists individuals in determining the nature and quantity of themes that may arise from the data. The researcher thoroughly engages with the data by carefully reading and reviewing the transcripts multiple times and examining the interviews conducted with the facilitators. The transcripts are carefully examined, line by line, multiple times to ensure a thorough understanding. As shown in Figure 3, different colors of highlighters are used to highlight different parts of answers, and each sentence is copied. While the questions are focused on the theme, the interview dialogue may diverge into other topics. The dialogue is segmented into sentences (interview answers) and then compiled to align with the theme. Note that the color selection has no relation with the theme; it is only selected to make different contexts appealing.

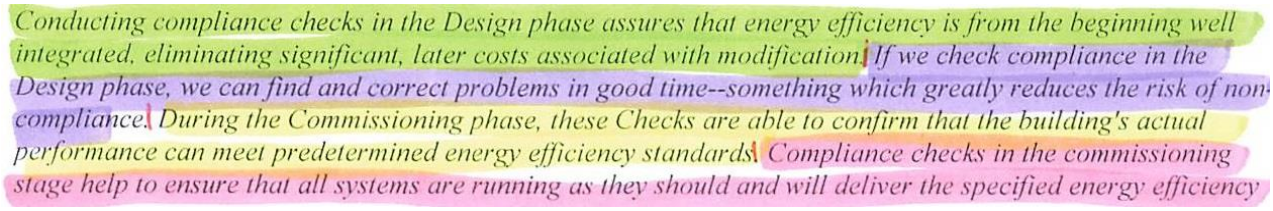

Figure 3. Sample of familiarization with the data, Source: Author interview thematic analysis

5.1.2. Initial code generation

In this phase [48] suggests starting this phase with a comprehensive list of identified codes in the data set. The primary goal of this phase is to identify patterns and relationships in the entire data set [48], which suggests analyzing codes to create a cohesive theme. Hence, this step emphasizes theme analysis over code analysis. A theme represents a patterned response or meaning within the data set. Using codes as building blocks and combining them to generate themes related to research questions is suggested. Table 2 shows a sample of initial code generation. Each sentence was summarized into an initial code to help find the theme for each interview answer in the next step.

Table 2. Sample of initial code generation; Source: Author interview thematic analysis

Initial code generation	Interview Answer
Necessity of third-party lab inspections.	"Unable to establish and then maintain specialized laboratories for energy compliance testing, which makes third-party inspections a necessity."

Initial code generation	Interview Answer
Unbiased, fair third-party evaluations.	"Third-party inspections provide an independent point of view on performance and give impartial, objective evaluation."
Essential for unbiased evaluations.	"Third-party inspections are an impartial, objective assessment that provides new ideas and thoughts on compliance and performance definitions."
Minimizes conflict, and enhances trust.	"Third-party inspectors minimize possible conflicts with in-house inspections that enhance confidence in the compliance results."
Access to advanced inspection tools.	"Third-party inspectors often have access to higher-quality, specialized tools and technologies for proper assessment."

5.1.3. Theme searching: Codes analyzed, themes formed, data patterns understood

Braun and Clarke [48] note that this phase starts with a list of all the codes that were discovered in the data set. Chamberlain [49] states that the main goal of this phase is to find the patterns and connections across the whole set of data. It is necessary to look at the codes and think about how they can be put together to make a bigger theme [48]. In other words, this step is mostly about analyzing themes rather than codes.

Braun and Clarke [48] assert that "a theme captures something important about the data in relation to a research question and represents some level of patterned response or meaning within the data set" (p.10). Consequently, it is essential to conceptualize these codes as foundational elements and amalgamate analogous or multiple codes to formulate potential themes pertinent to the research questions.

Table 3. Theme searching; Source: Author interview thematic analysis

Analyzed Code	Initial code generation	Interview Answer
Resource Limitations	Necessity of third-party lab inspections.	Unable to establish and then maintain specialized laboratories for energy compliance testing, which makes third-party inspections a necessity
Objectivity and Fairness	Unbiased, fair third-party evaluations.	Third-party inspections provide an independent point of view on performance and give an impartial, objective evaluation
Necessity of Third-party	Essential for unbiased evaluations.	Third-party inspections are an impartial, objective assessment that provides new ideas and thoughts on compliance and performance definitions
Objectivity and Fairness	Minimizes conflict, enhances trust.	third-party inspectors minimizes possible conflicts with in-house inspections, that enhances confidence in the compliance results
Resource Limitations	Access to advanced inspection tools.	Third-party inspectors often have access to higher-quality, specialized tools and technologies for proper assessment
Large-Scale Project Expertise	Third parties handle complex inspections.	Our employees are limited in resources and cannot inspect large-scale projects. Many of these projects demand a high level of detail and therefore unskilled work

5.1.4. Themes revision: Refined themes checked for coherence and consistency

During this stage, the researcher makes sure that the themes are consistent and coherent. Several steps can be taken in order to ensure that the preliminary themes align with the objectives of the research. These steps include reviewing the coded data and checking that the themes are consistent.

Table 4. Themes revision

Themes	Sub Theme	Analysed Code	Initial code generation	Interview Answer
Third-party	Resource Limitations	Resource Limitations	Necessity of third-party lab inspections.	Unable to establish and then maintain specialized laboratories for energy compliance testing, which makes third-party inspections a necessity
	Objectivity, Fairness, and Trust	Objectivity and Fairness	Unbiased, fair third-party evaluations.	Third-party inspections provide an independent point of view on performance and give an impartial, objective evaluation
	Objectivity, Fairness, and Trust	Necessity of Third-party	Essential for unbiased evaluations.	Third-party inspections are an impartial, objective assessment that provides new ideas and thoughts on compliance and performance definitions
	Objectivity, Fairness, and Trust	Objectivity and Fairness	Minimizes conflict, enhances trust.	Third-party inspectors minimizes possible conflicts with in-house inspections, that enhances confidence in the compliance results.
	Resource Limitations	Resource Limitations	Access to advanced inspection tools.	Third-party inspectors often have access to higher-quality, specialized tools and technologies for proper assessment

5.1.5. Defining and naming

This phase follows the theme revision. During this phase, a clear definition of each theme is developed, explaining how the theme relates to the research question. Then, themes are named in a way that they capture the main idea. As shown in Figure 3, initial codes were analyzed, grouped then connected to sub-themes.

5.1.6. Writing report

This step is the final stage of thematic analysis. Interview report results are drafted to highlight key findings. After designing questions, selecting participants, familiarizing with data, initial code generation, theme searching, theme revision for coherence, and theme definition and naming, a systematic analysis for dynamic building energy efficiency code enforcement in Tripoli is ensured. At this stage, the results of the interview analysis are presented in the simplified Insight Map shown in Figure 4, offering a detailed account of the challenges and perspectives on BEEC enforcement, as well as recommendations based on identified themes.

Figure 3. Defining and naming; Source: Author interview thematic analysis

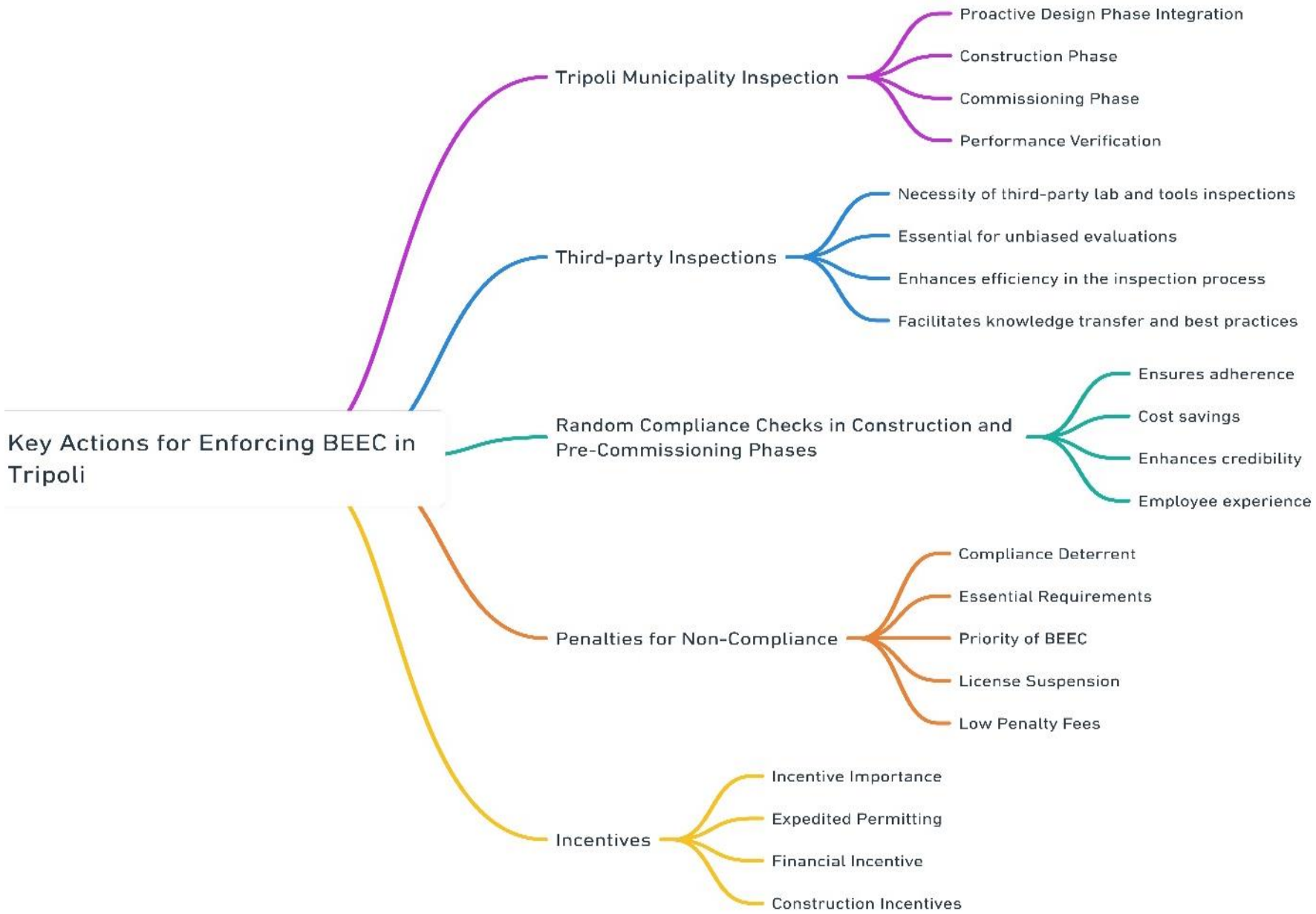

Figure 4. Simplified Insight Map, Source: Author interview thematic analysis

5.2. Interview report results

This section will present the interview findings related to the stage of enforcement. Table 2 shows an interview with the heads of departments from the municipality of Tripoli, which was analyzed by thematic analysis. The themes enumerated include Trpl-M inspection, third-party /inspections, random compliance checks in the construction and pre-commissioning phases, penalties for non-compliance, and incentives.

5.2.1. Trpl-M inspection

Conducting compliance checks during various phases of a building's lifecycle is crucial for ensuring energy efficiency, as shown in Table 2. This proactive approach ensures that energy efficiency is well integrated from the beginning. However, during the commissioning phase, compliance checks verify that the building's actual performance meets the predetermined energy efficiency standards. These checks confirm that the systems are well functioning and that they will deliver the specified energy efficiency targets, ensuring that the building operates efficiently from the start. However, inspection capabilities during the construction phase are limited. This limitation highlights the need for third-party inspection.

Table 5. Trpl-M inspection; Source: Author interview thematic analysis

Sub Theme	Summary	Sample of Interview Answer
Proactive Design Phase Integration	"Integrates efficiency in the design phase."	Conducting compliance checks in the design phase assures that energy efficiency is well integrated from the beginning, eliminating significant, later costs associated with modification."
Construction phase	“Limited inspection capability”	“Due to a lack of tools, vehicles, laboratories, and insufficient staff to conduct proper on-site assessments.”
Commissioning phase	"Verifies efficiency in the commissioning phase."	"During the Commissioning phase, these checks can confirm that the building's actual performance can meet predetermined energy efficiency standards."
Performance Verification	"Ensures system functionality and efficiency."	"Compliance checks in the commissioning stage help to ensure that all systems are running as they should and will deliver the specified energy efficiency targets."

5.2.2. Third-party inspections

Third-party inspections are evaluations carried out by certified inspectors or agencies not concerned with building design, construction, and operation. These inspections help ensure that the building meets the energy efficiency standards and codes at key stages of a project. The third parties could be private or governmental [5] [50] [51]. The Lebanese decree 14293 introduced optional private licensed inspectors or agencies in four phases: initial design documents review, review of execution documents, site inspection of the building, and inspection of work completed after completion in the guarantee period [52]. The necessity of third-party involvement in the enforcement stage, is shown in Table 3. Due to the lack of laboratories, tools, and transportation methods in Trpl-M, these reports are submitted at the design phase. They give an objective assessment providing new ideas and thoughts on compliance and performance definition. Additionally, engaging third parties speeds up the inspection, provides new ideas, and creates learning opportunities.

Table 6. Third-party inspections; Source: Author interview thematic analysis

Sub Theme	Summary	Sample of Interview Answer
Resource Limitations	Necessity of third-party lab and tools inspections.	“Unable to establish and then maintain specialized laboratories or tools for energy compliance testing, which makes third-party inspections a necessity.”
Objectivity, Fairness, and Trust	Essential for unbiased evaluations.	"Third-party inspections are an impartial, objective assessment that provides new ideas and thoughts on compliance and performance definitions."
Cost-Effectiveness and Efficiency	Enhances efficiency in the inspection process.	"Third parties can conduct a faster inspection in comparison to the actual conduct of operations. This is as a result that they give evaluations that have no distractions from internal task assignment."
Learning Opportunity	Facilitates knowledge transfer and best practices.	"Engaging with third parties allows internal parties to learn new things about the industry and best practice success and mistakes."

5.2.3. Random compliance checks in construction and pre-commissioning phases

While it may be challenging to conduct thorough checks during the construction and pre-commissioning phases due to the limited availability of laboratories, vehicles, and tools as mentioned by Al-Sukkari, et al. [12], Table 4 shows that implementing random checks could potentially provide Trpl-M with the opportunity to enhance the experience of Trpl-M employees who wish to take on additional responsibilities. This approach would also contribute to various aspects, such as ensuring strict adherence to codes and achieving cost savings through early detection. For the purpose of ensuring adherence to regulations, random compliance checks will be conducted throughout the construction and pre-commissioning stages.

Table 7. Random compliance checks in construction and pre-commissioning phases; Source: Author Interview thematic analysis

Sub Theme	Summary	Sample of Interview Answer
Ensures adherence	Ensure strict application of codes	"Random checks ensure strict application of those codes, underscoring to stakeholders the importance of compliance."
Cost savings	Cost savings through early detection.	"Early detection through random checks saves future rectifications that are even more expensive, stressing that observance pays."
Enhances credibility.	Cost savings through early detection.	"Random checks confirm the integrity of the energy program, which benefits code compliance."
Employee experience	Provides training opportunities	"May lead to giving Trpl-M the ability to give more experience to Trpl-M employees if they want to take over"

5.2.4. Penalties for non-compliance

The implementation of penalties for non-compliance with BEEC is crucial in ensuring adherence. Compliance deterrents are identified as highly effective, with Zahra emphasizing that penalties act as a key deterrent against ignoring energy-efficiency requirements. These penalties reinforce essential requirements, making energy efficiency measures mandatory rather than optional suggestions, as Skaf notes. Furthermore, the threat of penalties ensures the prioritization of BEEC throughout all construction phases, as highlighted by Naoushi. A significant measure is the halting of the occupancy license process for violations, which Bakri states will pause the acquisition of an occupancy license, with small infractions resulting in small penalties for non-compliance. These measures collectively emphasize the importance of strict enforcement to achieve energy efficiency goals.

Table 8. Penalties for non-compliance; Source: Author interview thematic analysis

Sub Theme	Summary	Sample of Interview Answer
Compliance Deterrent	Effective compliance deterrent	Penalties to not comply with this standard are key, they're an effective deterrent to those who ignore energy-efficiency requirements."
Essential Requirements	Reinforces essential requirements	"Penalties make energy efficiency measures are not merely seen as suggestions but as essential requirements."
Priority of BEEC	Ensures BEEC prioritization	"The threat of penalties ensures that builders and developers prioritize BEEC in all phases of construction."
License Suspension	Halts occupancy license process	“BEEC adherence violation will pause the prevailing acquisition of an occupancy license. Small quotas shall incur small penalties for non-compliance”
Low Penalty Fees	Low penalty fees for minor violations	“here are low penalties and fees for low level of regulation violation”

5.2.5. Incentive

Energy efficiency in building projects is greatly aided by incentives. Incentives can be financial through banks reducing or eliminating interest in using energy-efficient building materials, or expedited permitting, which can also be considered as a financial incentive where decreasing time will lead to more profit margin, according to Zahra. By motivating building owners to keep up their efforts, rewards for progressive improvement in energy efficiency create a climate where continuous progress can be maintained. Also, building area incentives for construction can improve energy efficiency.

Table 9. Incentive; Source: Author interview thematic analysis

Sub Theme	Summary	Sample of Interview Answer
Incentive Importance	Incremental achievements	“By motivating building owners to keep up their efforts, rewards for progressive improvement in energy efficiency create a climate where continuous progress can be maintained"
Expedited Permitting	Faster approval processes.	"Expedited permitting for energy-efficient projects accelerates the development process, serving as a strong incentive for builders to comply with or exceed standards."
Financial incentive	Makes borrowing affordable	” Low-interest financing options for energy efficiency projects reduce the cost of borrowing, constituting a break for property owners to fund the necessary upgrades that will make them conform to energy codes
Construction incentives	Additional building area	“Trpl-M is unable to afford any financial incentives, but it is able to permit additional building up area as previous laws permitted.

6. Conclusions

This paper examines the implementation of the Building Energy Efficiency Codes (BEEC) in Tripoli, Lebanon, through a literature review, comparative case studies, and interviews with key personnel from Tripoli Municipality (Trpl-M). The case studies are from Rajasthan (India), California (USA), and Germany, demonstrating how BEEC best practices can be adapted. Interviews with key personnel of Trpl-M were conducted to assess the implementation of BEEC. Although specific to its geographic and temporal context, the findings offer insights that could inform broader applications in similarly resourced municipalities.

Trpl-M faces many obstacles to effective BEEC enforcement. Due to limited resources and the insufficient inspection infrastructure. Additionally, the case studies' findings revealed that Tripoli's approach to energy codes is a perspective approach where it is advised to start a hybrid model as Rajasthan, India and then transfer to performance-based as California and Germany.

As per the findings of the study, it was concluded that Tripoli is facing many obstacles in applying energy-efficiency programs. These hurdles include limited resources and insufficient inspection infrastructure.

Additionally, the case studies' findings revealed that Tripoli's approach to energy codes is a perspective approach where it is advised to start a hybrid model as Rajasthan, India, and then transfer to performance-based as California. This approach will help Tripoli to enforce its learning capabilities while learning from advanced mature systems.

To address these challenges, it is recommended to further invest in the inspection technologies and tools and prioritize the allocation of resources to establish specialized laboratories inspector training programs. These programs should target the third-party inspectors and the municipality's employees in the first place, to further expand their knowledge and understanding of energy-efficiency codes. Also, awareness campaigns about the importance of BEEC should be raised. This must include initiatives to inform all stakeholders about the importance of BEEC to have better engagement in this field.

In conclusion, Tripoli can effectively pave the way for a more sustainable building energy efficiency framework by following a multifaceted approach that acknowledges the limitations of the current study while actively pursuing practical recommendations. A multifaceted approach that includes proactive design integration, third-party inspections, random compliance checks, penalties, and incentives is critical for achieving and maintaining high standards of energy efficiency in Tripoli and will significantly enhance sustainable urban development and contribute to broader energy conservation efforts across the region.

Declaration of competing interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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