A Radical Rethink on Building Energy Codes: The G20 Experience

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ABSTRACT

This paper takes a cue from Bureau of Energy Efficiency's 'Strategic Plan for Advancing Energy Efficiency Across Demand Sectors by 2030' published during India's G20 Presidency in 2023, which has identified 'Rethinking Energy Codes for a Net-Zero Energy World (RENEW)' as a high-impact energy efficiency opportunity for the G20 towards the realization of the global target of doubling energy efficiency improvements by 2030. While energy codes are adopted widely as a regulatory measure for enhancing the energy efficiency of buildings, their effectiveness depends on robust enforcement and high compliance rates. Unfortunately, there is a massive gulf between the development and implementation of building energy codes, even in some developed countries. Resource and capacity constraints exacerbate the problem in the Global South. This paper offers (i) a comprehensive overview of the status of building energy codes in G20 countries including residential and commercial building codes with mandatory and/or voluntary provisions, including breakthrough examples of embodied carbon and net zero considerations; (ii) evaluation of code compliance procedures in G20 countries based on key parameters such as type of enforcement, provision of certification, on-site inspections, penalties, and incentives, etc.; (iii) best practices, transferable learnings, and actionable recommendations; and (iv) a framework for building performance standards.

Background

In 2021, the G20 accounted for over 89% of the world's electricity demand (IEA 2023). Buildings were identified as a major contributor to this demand across different sectors, wherein the electricity used in residential and commercial buildings accounted for over 34% of the total final electricity consumption in the G20 (IEA 2023). Various regulatory measures have been adopted by G20 countries to enhance buildings' energy efficiency. Among these, building energy codes are widely adopted. Implementing building energy codes from the outset ensures proper construction practices and integrates cost-effective energy-saving measures, which are more economical than retrofitting later. Therefore, building energy codes are considered a highly impactful solution to address energy and carbon inefficiencies in construction practices (National Institute of Urban Affairs and RMI 2022). For example:

- **United States:** According to the US Department of Energy, implementing building codes could lead to around $138 billion in energy cost savings and prevent the emission of 900 million metric tons of CO_2 within the US in 2010-40. These savings are equivalent to the yearly emissions of 195 million passenger vehicles, or the output of 227 coal power plants, or the energy consumption of 108 million homes (Tyler et al. 2021).
- **Saudi Arabia:** A study conducted within the Gulf Cooperation Council projected significant energy savings of 22.7% to 39.5% in Saudi Arabia if building energy codes are effectively implemented. Moreover, considering the hot and arid climate of Saudi

Arabia, the study estimated a 16.4% decrease in the annual cooling load for residential buildings with thorough implementation of building codes (Elnabawi 2021).

Building Energy Code Development in the G20

At present, 18 G20 members, including the European Union, have implemented building energy codes, although the scope and strictness of these codes vary. The stringency of the codes also differs, with some countries adopting voluntary, mandatory, or a combination of both approaches where certain aspects are mandatory while others remain voluntary. Brazil and Argentina have introduced building performance labels, a practice also observed in several other countries alongside building energy codes. For instance, India has the BEE Star Label for commercial buildings (voluntary), while Australia mandates National Australian Built Environment Rating System (NaBERs) for buildings larger than 100 m^2 and uses Nationwide House Energy Rating Scheme (NatHERs) to determine the obligatory minimum energy performance requirements outlined in their National Construction Code.

Table 1. Status of building energy code development in G20 countries[1]
Source: Authors' analysis compiled from various sources such as Building Codes Assistance Project (n.d.), and GBPN (2015).

G20 country	Commercial building code	Residential building code
Argentina	No code	No code
Australia	Mandatory	Mandatory
Brazil	No code	No code
Canada	Mixed	Mixed
China	Mandatory	Mandatory
EU	Mixed	Mixed
France	Mandatory	Mandatory
Germany	Mandatory	No code
India	Varied	Voluntary
Indonesia	Mandatory	No code
Italy	Mandatory	Mandatory
Japan	Mandatory	Mandatory
Mexico	Mixed	Mixed
Republic of Korea	Mandatory	Mandatory
Russia	Mandatory	Mandatory
Saudi Arabia	Mandatory	Mandatory
South Africa	Mixed	Mixed
Turkey	Mandatory	Mandatory
UK	Mixed	Mixed
US	Mixed	Mixed

[1] Notes: (i) The Energy Conservation Building Code (ECBC) for commercial buildings in India becomes mandatory only upon its incorporation into municipal regulations following notification at the state-level. (ii) India is in the process of drafting new commercial and residential building codes, known as the Energy Conservation and Sustainable Building Code (ESCBC), which include additional elements such as water and waste management and the use of sustainable building materials. (iii) The European Union has implemented a substantial update to the Energy Performance of Buildings Directive (EPBD), mandating member states to notably enhance the energy efficiency of their building inventory (Think Tank European Parliament 2023).

Additionally, some nations have expanded the scope of these codes to include more advanced measures in pursuit of net-zero buildings:

Net zero and net positive energy building codes. Net zero and net positive building codes aim to ensure that buildings either produce the same amount of energy they consume or generate surplus energy, which is fed back into the grid, respectively. While not yet universally embraced, some G20 member nations are leading this transition. For instance, the EU has integrated the Nearly Zero Energy Building (NZEB) requirement into the Energy Performance of Buildings Directive (EPBD), mandating all member states to adopt NZEB codes. Countries like Germany have implemented nearly net-zero energy standards in their building regulations, emphasizing energy efficiency and the use of onsite renewable energy sources, with a goal to achieve virtually carbon-neutral building stock by 2050 (Building Codes Assistance Project n.d.). France, another EU member state, has surpassed NZEB standards by introducing mandatory net-positive energy codes and the Bâtiment à Energie Positive (BEPOS) rating scheme for certifying positive energy buildings (Bordier et al. 2018). Nonetheless, a common challenge in implementing NZEB provisions is the variation in how member states define 'nearly zero' (BPIE 2021).

Net zero / net positive building codes represent a significant step in reducing the carbon footprint of buildings, however, efforts need to be intensified to encourage their adoption. One approach to incorporating net-zero considerations is to enhance building codes gradually, raising minimum performance requirements towards net-zero standards (APEC Energy Working Group 2017). Examples of such gradual improvements include the prohibition of gas connections for new construction in California, New York City, and New York state, starting in 2023, which promotes building electrification (McKenna 2023). However, to effectively reduce building emissions, it's essential to ensure that these incremental changes outpace the rate of urbanization (Ürge-Vorsatz et al. 2020) and are complemented by a holistic systems-thinking approach. This entails integrating policies, capacity building, and penalty/incentive mechanisms. The "Buildings Breakthrough," which was introduced at COP28, is among the most recent initiatives to support step changes to reduce building emissions. Launched by France and Morocco in collaboration with the UNEP, the Buildings Breakthrough aims to accelerate the transition in the buildings sector, with the goal of making near-zero emission and resilient buildings the norm by 2030. Several G20 countries, including Canada, the US, China, the UK, Türkiye, and the EU, have committed to this initiative, signaling a positive step towards reducing emissions from the buildings sector and supporting the goals of the Paris Agreement (Tholot 2023; Wolf 2023).

Codes with embodied carbon considerations. Incorporating considerations of embodied carbon into building codes represents a crucial shift towards addressing total emissions from buildings, going beyond operational emissions alone. G20 countries such as India, and the EU and cities such as California are pioneering this effort. California has set a precedent by adopting building codes that include requirements for embodied carbon, focusing on reducing emissions associated with materials and construction processes. These regulations, effective from July 2024, target limiting embodied carbon emissions in the construction, remodeling, or adaptive reuse of larger commercial buildings and school projects. Additionally, California also plans to roll out programs aimed at promoting zero-net-carbon literacy and educating professionals, both within and outside of the government, on the new code. This marks a crucial step in ensuring adequate buy-in from the buildings' community for the new code (Smolar 2023). Similarly, India has developed new draft codes for commercial and residential buildings, incorporating

provisions for reporting embodied carbon. This approach will help account for the full life cycle carbon footprint of buildings, better aligning the upcoming building stock with a net-zero emissions trajectory. In the EU, the recast of the Energy Performance of Buildings Directive (EPBD) in 2023 introduced mandatory disclosure of embodied carbon for new building construction, further advancing efforts to address embodied carbon emissions within the region (Europa 2023).

Building Energy Code Adoption in the G20

As depicted in Table 1, the majority of G20 nations have embraced energy codes, each with different levels of scope and stringency. Nevertheless, several studies have highlighted that the effectiveness of energy codes relies heavily on robust enforcement mechanisms and high rates of compliance with the code (IEA 2021; Harper et al. 2012; Yu et al. 2013; Evans, Roshchanka, and Graham 2017). Unfortunately, there exists a significant disparity between the quality and rigor of building energy code development and its implementation, as indicated by assessments conducted by the Global Building Performance Network (GBPN 2015). This section assesses the enforcement procedures of building codes across G20 countries, analyzing various parameters such as the type of enforcement, provision of on-site inspections, certification, penalties and incentives, simulations and training and capacity development provisions. The evaluation methodology draws inspiration from approaches utilized by the Global Buildings Performance Network (GBPN et al. 2013) and the APEC Energy Working Group (APEC Energy Working Group 2017). Table 2 provides an overview of the state of compliance procedures in G20 nations. It is essential that the actual implementation and adherence to these measures can vary among countries and even within them.

Table 2. Status of building energy code compliance procedures in G20 countries[2]
Source: Authors' analysis compiled from various sources, including Building Codes Assistance Project (n.d.), GBPN (2015), Moore and Holdsworth (2019), Shui et al. (2009), Li and Shui (2015), Evans et al. (2017), Fayaz and Kari (2009), Leão et al. (2008), Fiener, n.d.; Young, n.d.)

G20 Country	Compliance testing	On-site inspections	Certification	Training and capacity building	Penalties	Incentives
Australia	Local + third party enforcement	Design	EPC present	Resources for code compliance + software training	Loss/ Suspension of license	Subsidies + Public Recognition
California	Local + third party enforcement	Design + pre-occupancy	EPC present	Resources for code compliance + training on code requirement + software training	Refusal of permission to occupy	Subsidies/tax Rebates

[2] Notes: (i) Argentina, Brazil, Indonesia, Italy, Japan, Russia, Saudi Arabia, and Turkey are omitted from the table due to lack of adequate data. (ii) For onsite inspections, India has the provision of HVAC testing post-completion. (iii) In India, while ECBC rules (2018) have the provision of penalty, the states have bypassed and omitted penalties while adopting the code at the state level (Shandilya and Ghorpade 2019) (iv) Code compliance procedures differ across US states. While the table references California due to its advanced standards, it's important to note that California's practices may not represent those of the entire country.

Canada	Local + third party enforcement	Design	EPC present	Resources for code compliance + training on code requirement + software training	Refusal of permission to occupy	Subsidies + Public Recognition
China	Local + third party enforcement	No data	No data	Resources for code compliance + training on code requirement	Refusal of permission to construct	No data
France	Local + third party enforcement	No data	EPC present	Resources for code compliance + software training	Fines	No data
Germany	Local + third party enforcement	Design + pre-occupancy	EPC present	Resources for code compliance	Refusal of permission to construct	Subsidies/tax Rebates
India	Local + third party enforcement	Design + pre-occupancy	EPC present	Resources for code compliance + training on code requirement + software training	None	No data
Mexico	Local + third party enforcement	No data	No data	Resources for code compliance	Fines	No data
Republic of Korea	Local + third party enforcement	Design	EPC present	No data	Refusal of permission to construct	Subsidies/tax Rebates
South Africa	Local enforcement	Design + pre-occupancy	EPC present	No data	Refusal of permission to occupy	Subsidies/tax rebates
UK	Local + third party enforcement	Design + construction	EPC present	Resources for code compliance + training on code requirement + software training	Refusal of permission to construct	Subsidies/tax rebates

Type of enforcement (local and/or third party). Currently, code enforcement responsibilities rest with local governments across all G20 countries. While countries like Australia, Canada, and China (Bin and Nadel 2012) employ a combination of local government oversight and third-party assessors for ensuring compliance, others like South Africa mandate local government agencies to bear sole responsibility. Furthermore, certain states in India, such as Telangana and Andhra Pradesh, have begun incorporating third-party assessors for enforcing commercial building energy codes (Madan 2023). The choice of enforcement mechanisms significantly influences the effectiveness of compliance. Insufficient funding or resources often hinder local governments from adequately enforcing building codes (Evans et al. 2017). Some experts note that enforcement effectiveness can be influenced by factors such as the size of urban local bodies (ULBs)/municipalities and their demographic composition. In certain cases, smaller ULBs find it easier to monitor new constructions, while larger ULBs face challenges due to their extensive geographical areas. Enforcement disparities also exist between rural and urban jurisdictions, with urban areas generally exhibiting more stringent enforcement measures. Moreover, a lack of understanding of codes among government and non-government building professionals poses further obstacles to enforcement. Additionally, experts from India also highlighted a lack of coordination between departments overseeing general construction activities and those responsible for implementing building energy codes at the local level, leading to inadequate enforcement by local governments. To address these gaps, the introduction of third-party assessors has been proposed to assist local governments in code compliance. While this approach may provide additional impartiality and expertise, sometimes third-party inspections replace

rather than supplement verification by local government, potentially leading to conflicts of interest, malpractices, and increased expenses.

Onsite inspections. Onsite inspections serve as a practical method for verifying compliance with energy efficiency codes in buildings. However, the implementation of these inspections varies widely among countries, occurring at different stages such as during design, construction, or pre-occupancy. Countries like Australia, Canada, Germany, the Republic of Korea, South Africa, the United Kingdom, and several US states conduct inspections during the design stage, followed by additional inspections during construction or pre-occupancy. It is essential to ensure that onsite inspections are robust, adequately funded, and carried out by qualified professionals to uphold the integrity of building codes. For instance, IEA (2021) notes that compliance checks often lack thoroughness due to staff shortages, insufficient training and understanding of the code, limited capacity for building simulations, and sometimes due to malpractice at the local level. This challenge is observed across both developed and developing countries, including Australia, the US, India, and China. Moreover, the timing and frequency of these inspections are crucial for effective enforcement. Traditionally, onsite inspections for energy efficiency have evolved alongside those for health and safety measures and are often conducted concurrently. However, IEA (2021) indicates that these inspections frequently occur at the foundation or completion stages, overlooking essential checks such as insulation and building envelopes. This discrepancy in inspection times for energy efficiency and safety assessments presents challenges in ensuring comprehensive compliance with energy efficiency measures. The need for additional checks can be addressed through the implementation of building performance standards.

Certification. Certification, often in the form of energy performance certificates (EPCs), plays a vital role in verifying compliance with energy efficiency building codes. They are based primarily on energy models and many G20 countries, including the UK, Canada, France, and South Africa, have adopted EPCs. These certificates typically detail the building's energy performance and enable the estimation of its energy demand, providing valuable information on building performance to potential buyers, tenants, and property owners. By doing so, energy performance certificates aim to address information asymmetry regarding building energy performance among stakeholders such as property builders, owners, potential buyers, and tenants (Y. Li et al. 2019). However, several studies have pointed out multiple errors in EPC ratings. A study conducted by Hardy and Glew (2019) on open EPC records in the UK revealed that 27% of EPCs "report at least one flag to suggest it is incorrect." They further estimated the true error rate of the EPC records to be between 36% and 62% (Hardy and Glew 2019; Lees 2024).

Training and capacity building of government officials. One of the bottlenecks that hinders building energy code enforcement is the lack of understanding of the code by the local government officials. Several studies have indicated that key stakeholders tasked with building code enforcement often find it difficult to understand the technical components of building energy codes (IEA 2021; Evans et al. 2017). An expert consultation also revealed that such a lack of capacity of government officials in code enforcement, especially, in running or rechecking software simulations, often lead to inadequate cross-checks on simulation designs submitted from private third-party assessors. Such a gap in understanding necessitates resources dedicated to training and capacity building of government officials to enforce the code (IEA 2021). This includes floating resources on building energy code implementation, training government officials on code enforcement and building capacity to run software simulations of

building design. Most countries have such programs to support building energy code implementation. There are varied approaches for the same – countries such as Mexico have the provision of rolling out resources for code compliance, while countries such as India, Canada and USA also have the provision for conducting training on code requirements as well as for software to support code implementation. However, per expert consultations, training programs often remain at a cursory level and a lack of code understanding persist.

Penalties and incentives. Penalties and incentives serve as powerful tools for bolstering compliance with building energy codes. While many countries like Germany and the UK impose fines or withhold construction or occupancy permits as penalties for non-compliance, others such as Japan employ a combination of strategies like withholding permits, publishing the building owner's name, and imposing fines (Evans et al. 2017). Incentives are also extensively utilized to encourage the adoption of building codes. They operate as market-based mechanisms, facilitating compliance beyond the minimum requirements and encouraging market adaptation, thus easing compliance efforts (IEA 2021). While incentives are typically offered for certified buildings that meet minimum performance levels, several countries are introducing stretch codes, where higher performance levels qualify for incentives. G20 members employ various approaches to incentivize compliance with energy codes, including tax exemptions, low-interest loans, subsidies, and public recognition of high-performing buildings. For instance, industry associations like the Energy Efficiency Council in Australia grant public recognition to buildings demonstrating exemplary energy efficiency or sustainable design practices, while Canada has a rating program for recognizing high-performing buildings publicly. However, according to some experts, it is more effective to target incentives towards high achievers, as incentivizing minimum performance may convey the message that compliance is not mandatory. In addition to monetary or public incentives, benefits such as prioritized permit application processing can also positively influence developers' behavior.

Simulations. Several G20 countries have implemented supplementary measures to bolster compliance with energy efficiency and sustainability criteria. For example, France requires computer simulations for all projects to ensure that energy efficiency is considered from the initial design phase. Such measures often supplement conventional enforcement methods and play a crucial role in advancing sustainability objectives. In the US, ASHRAE has developed a database that enables building designers to select simulated designs that comply with building codes (ASHRAE 2021). This extensive database covers a diverse array of potential buildings, significantly reducing compliance expenses and ensuring precise simulations.

Recommendations

The implementation of building energy codes is a multifaceted process that involves various stakeholders interacting at different stages of building construction, from design to commissioning. Each stage requires specific resources for effective code enforcement. Therefore, to successfully implement building energy codes and ensure compliance, it's essential to adopt a systems-thinking approach, as suggested by many experts and practiced by some G20 countries. This approach involves streamlining the enforcement and compliance process and identifying systemic barriers that hinder compliance at different stages. These barriers may include inadequate communication among different departments involved in plan approval and a lack of resources for implementing building codes. Once these barriers are identified, they can be

addressed using technology, improved communication strategies, and other measures. In this context, this section presents recommendations on enhancing building energy code compliance, based on different stages of building energy code enforcement.

Employ integrated policymaking principles during code development/amendment and adoption to ensure greater buy-in at later stages. In nearly all G20 countries, the national government primarily holds responsibility for code development. Some nations, like Australia, integrate their building code into their primary construction regulations, while others, such as India, maintain a separate code specifically focused on building energy efficiency. However, when it comes to code adoption, local governments typically play a more significant role. Even in countries where the national government has the authority to adopt the code, local governments often provide support in the adoption process. The code adoption process involves multiple stakeholders. For instance, in India, following code development by the central government, state-level departments of energy or urban development typically facilitate code notification. The energy departments are responsible for energy code amendments, while urban development departments handle amendments to town and country planning regulations and building byelaws to incorporate building energy code provisions post-notification and amendment at the state level. Although the state energy department leads the code amendment process, involving urban development departments has proven beneficial during later stages of code adoption. This collaborative approach streamlines the incorporation of building energy code provisions into building byelaws, simplifying the overall process. However, the lack of inter-ministerial coordination in some cases has affected code enforcement and led to delays in code adoption across certain states in the country (AEEE et al. 2017).

Introduce supplementary materials such as implementation rules for building code enforcement agencies and user guides for demonstrating compliance. To enhance building energy code enforcement, clear guidelines are essential for both code enforcement agencies and stakeholders. Implementation rules outline the operational aspects of enforcement, defining roles and responsibilities for all stakeholders involved in building energy code implementation. This ensures uniformity and consistency in the enforcement process. Similarly, user guides are vital for stakeholders directly engaged in compliance, providing step-by-step instructions and insights into meeting code requirements for building developers. An exemplary case from the G20 countries is observed in the states of Telangana and Andhra Pradesh in India. Through stakeholder engagement, it was discovered that professionals in the building community encountered challenges in meeting code requirements, particularly regarding building materials, testing, and mechanical system modeling due to the technical nature of the code. Responding to this, the governments of both states developed multiple technical resources to address this capacity issue (Government of Telangana et al., 2017). This challenge was also noted at the national level, prompting the Bureau of Energy Efficiency to introduce ECBC Rules in 2018, as outlined by the Ministry of Power. These rules delineated the operational elements of the code, significantly contributing to code compliance. In fact, expert consultations revealed that states with poor performance in code compliance often failed to notify the ECBC rules, leading to a lack of defined responsibilities for specific actors, thereby impacting compliance verification.

Develop online single window clearance systems. An online single window clearance system simplifies the approval process for building energy code compliance, making compliance easier for builders. This system should offer a centralized platform where builders/developers can

submit, track, and receive approvals for their applications. It streamlines the bureaucratic procedures, enhances transparency, and reduces processing times, contributing to more efficient code enforcement. Such single window systems are usually implemented at subnational levels – and while many local governments are following suit, incorporating elements such as helpline number/chat box to assist with the application process, and adding links to application for incentives on the same page to enhance the user experience, can help ease the compliance process for varied stakeholders. There are multiple countries following this practice. For example, in India, the states performing well in "Ease of Doing Business" rankings have implemented online single window systems for building construction permits. Examples include Uttar Pradesh's Nivesh Mitra (Government of Uttar Pradesh, n.d.), and Telangana's TS-bPASS (Telangana State Building Permission Approval & Self Certification System - Government of Telangana, n.d.). Similarly, local governments such as Council in the City of Greater Sudbury in Ontario, Canada also implemented a 'Pronto' online portal to ease the process of applying for building permits. Additionally, they have also developed a helpline number to assist the users in submitting their building permit applications online – thereby easing the transition from in-person application submission process (Greater Sudbury 2023).

Embrace the third-party assessor (TPA) model for inspections and bolster their reliability by instituting official government accreditation for TPAs. Supplement this with periodic random checks conducted by government officials to ensure thoroughness and accountability in the inspection process. After submitting the building plan for approval, the next step in the construction and code enforcement process is compliance verification. Countries utilize diverse methods for verifying code compliance, including local government verification, third-party verification, or a combination of both. In regions where local governments conduct compliance verification, they may review the plans themselves or require a document confirming adherence to the building energy code by a registered architect. However, this approach encounters two main challenges: capacity constraints, as code officials often lack the necessary training for energy efficiency checks, and resource constraints, due to an insufficient number of officials to oversee new construction and ensure compliance. To address these challenges, Third Party Assessors (TPAs) have been introduced, though this method raises concerns about potential malpractices since TPAs are usually hired by developers to review their plans (Yu et al. 2013). Enhancing the robustness of this process can involve having government-accredited third parties to verify compliance and achieving a balanced approach between third-party and local government inspections. This may entail utilizing government-trained inspection bodies or recruiting government-appointed officials (such as "designated confirmation bodies" in Japan or "BEE empanelled building energy auditors" in India) (IEA 2021) (BEE 2010). The existing infrastructure of TPAs under building rating programs like Leadership in Energy and Environmental Design (LEED) can aid in establishing strong TPA programs in countries. Utilizing individuals experienced in energy efficiency inspections helps address capacity constraints, though they may require training on the country's energy code requirements before receiving government accreditation for building energy code inspections (Yu et al. 2013). Establishing official government accredited TPAs allows for more rigorous inspections by enhancing the TPA model's robustness. One strategy is to randomly assign TPAs to buildings, compensate them from a common pool, and conduct random retests for accuracy, overseen by government officials to minimize instances of malpractices in inspections. Instances of malpractice can result in the revocation of certification or licensure for the third party. This

approach, tested with environmental auditors in Gujarat, India, can enhance compliance rates without increasing regulatory burdens (J-PAL 2018).

Strengthen enforcement checks. Enhancing code compliance requires robust enforcement checks, particularly in ensuring energy efficiency standards. Currently, enforcement checks prioritize health and safety measures over energy efficiency requirements, leading to gaps in compliance. To address this, integrating energy code language with life safety code priorities can underscore the importance of energy efficiency in mitigating emissions from buildings amidst the climate crisis. Moreover, establishing specific rules for conducting construction checks at crucial stages of the building process for energy efficiency requirements would enhance inspection effectiveness. Clear guidelines should dictate when these checks occur, facilitating timely interventions and corrections. For instance, inspections could align with critical construction milestones like foundation laying, insulation installation, and HVAC system installation. This strategic approach not only fosters compliance with energy efficiency standards but also streamlines the inspection process, promoting a systematic and accountable implementation of energy codes.

Incorporate a hybrid approach to inspections by combining remote assessments with on-site inspections where feasible and appropriate. Virtual inspections, increasingly utilized for enforcing building codes, initially garnered attention for their potential to reduce time and expenses. However, their adoption surged during the COVID-19 pandemic. These inspections offer various advantages, particularly in saving time and money, especially when construction sites are located far away. For instance, First Nations communities in northern Canada have found virtual inspections beneficial, reducing travel costs and time. Integrating remote inspections with onsite ones can effectively address resource constraints, such as staff shortages (IEA 2021).

Implementing building performance standards (BPS). Each of the measures discussed above plays a vital role in enhancing overall compliance with existing building codes, thereby moving us closer to ensuring the energy efficiency of new constructions. However, the construction phase represents just one aspect of the entire building lifecycle. Ensuring energy-efficient building operations is equally essential, and this is where BPS come into play. These standards are regulations or policies that stablish specific building performance benchmarks or targets typically related to energy efficiency ratings or energy/carbon intensity (Hinge and Brocklehurst 2021). Through this, BPS offer greater flexibility in achieving energy efficiency targets, promoting innovation and adaptation to various building types and contexts. This flexibility ultimately contributes to higher compliance rates. The significance of adopting BPS is particularly evident when addressing the challenge of evaluating the effectiveness of prescriptive codes in real-world scenarios. Several progressive cities in G20 nations, such as Tokyo in Japan, Boulder and Washington DC in the US, and various cities in the UK, have already implemented BPS for diverse building types, showcasing their effectiveness (Nadel and Hinge 2020). The key elements of a BPS policy are as follows:

<u>Backend infrastructure for BPS</u>

- Metering and monitoring: Robust metering to capture energy consumption is crucial for implementing BPS. Accurate measurement and monitoring are critical for tracking performance (Evans et al. 2014).

- Data disclosure and benchmarking: Energy usage disclosure and benchmarking involve comparing a building's performance with similar buildings or simulated performance. Standardized protocols for data measurement, monitoring, and reporting are necessary for consistency (National Centre for Disease Control 2023). An example is the Super Low Energy Building (SLEB) Smart Hub in Singapore (BCA 2020).
- Defining performance metrics: Choosing the right performance metric is essential. It must align with existing policies and goals, and be clear and simple (ASHRAE 2023).

BPS policy elements

- Defining policy scope: Identifying building types and setting size thresholds based on jurisdictional data is important. Thresholds can vary by building type and decrease over time to include smaller buildings.
- Defining performance targets: Establish clear, quantifiable targets tailored to building types, adjusted for function, size, climate, and operations. Targets should be periodically revised to remain relevant and achievable (ASHRAE 2023).
- Enforcement mechanisms: Beyond issuing a certificate of occupancy (CO), alternative enforcement methods include temporary COs, annual inspections, fee-bates, public disclosure, utility rate adjustments, and mandatory retro-commissioning (Frankel 2012).
- Awareness and capacity building: Raising awareness and building capacity among stakeholders are vital. Educational campaigns for building owners and industry professionals can enhance compliance.
- Integration with prescriptive codes: Combining traditional building energy codes with BPS can maximize energy savings. Prescriptive codes ease compliance and encourage the use of sustainable components.

Conclusion

The journey towards effective enforcement and compliance with building energy codes across G20 nations presents a multifaceted challenge marked by varied scopes, rigor, and effectiveness. This paper underscores the significant gap between the development and implementation of these codes, with studies, including those from the Global Building Performance Network, highlighting discrepancies that need urgent attention. Key obstacles such as inadequate funding, resource constraints, and varying enforcement capacities between urban and rural areas persist, often undermining the intended benefits of these codes. Onsite inspections, a cornerstone for ensuring compliance, face hurdles such as staff shortages, inadequate training, and limited resources, which compromise their thoroughness and effectiveness. Energy performance certificates (EPCs) offer transparency but are frequently marred by inaccuracies, calling for more rigorous quality control mechanisms. The role of government officials in this ecosystem is pivotal; thus, comprehensive training and capacity-building programs are essential to bridge the technical knowledge gap and enhance enforcement.

Incentives and penalties emerge as critical tools in driving compliance. Countries like Germany and Japan exemplify diverse strategies that blend penalties with incentives such as tax exemptions and low-interest loans, which could serve as models for broader adoption. Moreover, the integration of simulations in the design phase, as seen in France and the US, underscores the importance of leveraging technology to ensure compliance from the outset. The Indian context

offers valuable insights, particularly the role of state-level departments and the development of supplementary materials like implementation guides, which aid in overcoming compliance challenges. Online single-window clearance systems and third-party assessor (TPA) models further illustrate innovative approaches to streamline processes and enhance accountability.

Moving forward, a systems-thinking approach that involves integrated policymaking, robust enforcement mechanisms, and effective incentives is crucial. The development of building performance standards (BPS), which ensure energy-efficient operations throughout a building's lifecycle, is a promising complement to traditional codes. Progressive cities in G20 nations that have adopted BPS policies demonstrate their potential in achieving substantial energy savings and higher compliance rates. Ultimately, the collective efforts of national and local governments, combined with technological advancements and strategic incentives, can foster an environment where building energy codes not only exist on paper but translate into tangible energy efficiency improvements, contributing significantly to global goal of doubling energy efficiency progress by 2030.

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