The Way Forward For Building Energy Benchmarking in India

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ABSTRACT

India is witnessing unprecedented urban growth with 30% of its population already residing in urban areas. With forecasts that this rate will increase in the near future, the energy demand of the country will be enormous. In order to meet the national and international energy targets, it is crucial that India focuses on its energy policies across sectors. A proven way forward is to introduce energy benchmarking in the policy mainstream for all sectors. In this paper, we discuss the challenges, opportunities and the strategic way forward for energy benchmarking, particularly in the building sector. We look into the existing situation concerning public governence, awareness, regulations, and energy certification and propose the way forward in terms of business oportunities, and synergistic collaboration between stakeholders. Finally, we introduce *The Collective Voices for Buildings in India (CVBi)* and present the strategic plans going forward.

CCS CONCEPTS

• **General and reference** → **Surveys and overviews**; • **Information systems** → **Decision support systems**; • **Social and professional topics** → **Computing / technology policy**.

KEYWORDS

Future of Buildings, India, Energy benchmarking, Digitize buildings, Decarbonize building sector, Collaboration, Open datasets, Rating systems, Energy policy

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NOMENCLATURE

BEE	Bureau for Energy Efficiency
C − Cube	The Climate Centre for Cities
CII	Confederation of Indian Industry
CVBi	The Collective Voices for Buildings in India
DMEO	Development Monitoring and Evaluation Office, GoI
ECBCR	Energy Conservation Building Code for Residential Buildings
EPI	Energy Performance Index
EUI	Energy Use Intensity
GIS	Geographical Information System
GoI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
IEQ	Indoor Environmental Quality
IGBC	Indian Green Building Council
IUDX	Indian Urban Data eXchange
KPI	Key Performance Indicator
MLR	Multiple Linear Regression
MNES	Ministry of Non-Conventional Energy Sources
MoHUA	Ministry of Housing and Urban Affairs, GoI
NICMAR	National Institute of Construction Management and Research
NIUA	National Institute of Urban Affairs
NUDM	National Urban Digital Mission
NUIS	National Urban Innovation Stack
TNIHIS	Tamil Nadu Integrated Housing Information Management System
UPYOG	Urban Platform for deliverY of Online Governance

1 INTRODUCTION

India is witnessing rapid urbanization, with more than 30 per cent of population residing in urban areas, projected to rise to 40 per cent in 2030 [1]. The total floor space in India was reported to be 12 billion sq. metre as of 2011 (one billion in commercial and

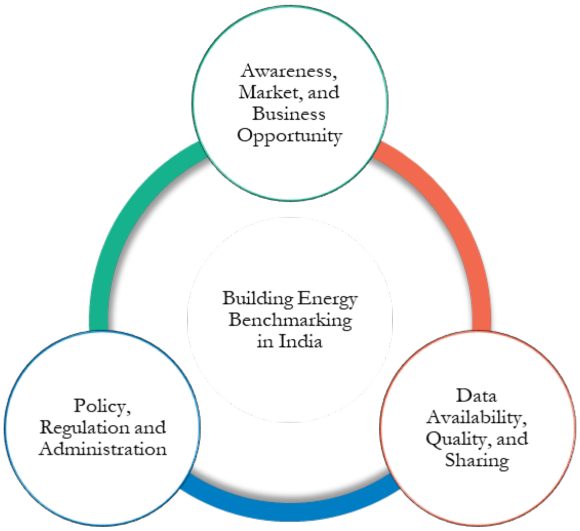

Figure 1: Nexus of challenges and opportunities in benchmarking building energy use in India.

eleven billion in residential) [2]. It has also been estimated that India will add about 90 billion square meters of new building stock between 2011 and 2050 at a growth rate of 5% and 9% per year for residential building and other buildings respectively [3]. Thus, next three decades presents a promising opportunity to decarbonize building sector, either by retrofit or design/construction of high-energy performance buildings.

According to the International Energy Agency, there will be an exponential growth in the energy demand in India between 2019 and 2040, a significant proportion of which shall come from rising building stock in the country. Currently, the building sector in India accounts for more than one-third of the total energy consumption in India, and is projected to rise at a rate of 8% per year [4] owing to the improvement in quality of life [5]. It is also projected that by the year 2050 the average Energy Use Intensity (EUI) of commercial buildings will reach 130 kWh/sqm/yr from the current 70 kWh/sqm/yr and for residential buildings it will increase from 60 kWh/sqm/yr to 96 kWh/sqm/yr [6]. Additionally, the rural to urban transition is expected to have a significant impact on the projected emissions, accounting to up to 10 percentage of national emissions [7]. With the rising trends in urbanization, population, and income, meeting energy demand for the building sector will come at huge costs. Thus, reducing carbon footprint and energy demand from India's existing and up-coming building stock is an eminent opportunity space for energy benchmarking.

Energy use benchmarking is the process of assessing the energy performance of a building with respect to a peer group that shares similar physical and operational characteristics. It is one of the proven techniques to improve the overall energy performance of a country's building stock because it helps create awareness about building energy use, identify energy-saving opportunities, and prioritize retrofitting plans. Many cities worldwide have reported that energy use benchmarking has resulted in 3%–8% reductions in energy use [8].

The Figure 1 summarizes the key concepts reviewed and proposed in this study. It begins with the review of historical developments, benchmarking methods and approaches in India in Section 1.1 and 1.2. Some strategic way forward from public policy and administration perspectives to decarbonize building sector in India through energy benchmarking is discussed in Section 2.3. Leveraging India's digital transformation journey the Section 2.2 presents several opportunities on how building industry as a whole can be digitized overcoming some key challenges such as availability, quality and exchange of data? However, the authors recognize a need to build a strong synergy to mature the energy economics within the built-environment in India. This is discussed in Section 2.1. Last but not the least, the authors put-forth strategic action plans to carry out building energy benchmarking across the country in detail in Section 3.2.

1.1 Historical Developments on Energy Benchmarking in India

Post-independence, India's rapid growth largely defined the course for energy policy development pertaining to all sectors, including buildings. Here, the focus was solely to meet the supply-demand adequacy. Eminent institutions like the Planning Commission of India, Ministry of Energy, and Ministry of Non- Conventional Energy Sources were constituted. The importance of "Sustainable Power System" was also underscored with the Electricity Supply Act of 1948 [9, 10]. Driven by the global energy crises of the 1970s,India integrated its energy policy into the national development goals. With the growing concerns over the scarcity of fossil fuels, the Indian Law Institute was commissioned in 1987 to prepare a draft Energy Conservation bill to oversee an appropriate use of energy resources [11].

It was during the 1990's liberalization of the Indian economy that the country's energy scenario underwent a drastic change. A separate Ministry of Non-Conventional Energy Sources (MNES) was established in 1992, which was later renamed to the Ministry of New and Renewable Energy (MNRE) in 2006. Ten years since the liberalization, the Energy Conservation Act was passed in 2001. It stressed energy consumption norms and facilitated the establishment of the Bureau of Energy Efficiency (BEE) under the Ministry of Power in 2002 [12]. It was during this time that the first green rating framework for buildings was introduced in India. It was developed by the Indian Green Building Council (IGBC), a part of the CII (Confederation of Indian Industry)-Sohrabji Godrej Green Business Centre. In 2005, the GRIHA rating system was developed by TERI (The Energy and Resource Institute). It is based on local climatic conditions and national codes of India. A year later in 2006, the US-based LEED rating system was introduced by the IGBC [13]. GRIHA was adopted as the national rating system in 2007 by the Government of India. In the same year, BEE issued the ECBC (Energy Conservation Building Code) which was the first standalone national building energy code [14]. These codes were later revised in 2017 to include additional priorities. ECO- Niwas Samhita, an Energy Conservation Building Code for Residential Buildings (ECBC-R) was subsequently released in 2018 to further propel the nation's energy conservation efforts.

Table 1: BEE Star Rating for office buildings. Source [28]

BEE Star Rating	Energy Performance Index ($kWh/m^2/year$)	
	Less than 50% AC	More than 50% AC
1	80–70	200–175
2	70–60	175–150
3	60–50	150–125
4	50–40	125–100
5	Below 40	Below 100

1.2 Review of Benchmarking Methods and Approaches

A fair energy benchmarking system requires normalizing building's energy use for differences in building operations, before making peer-group comparison. There are many factors that influence building's operational energy use, including, physical attributes such as size, age, geometry, and operational characteristics such as occupancy, schedule, weather, among others [15]. However, to enable easy comparison of building's energy performance, several Key Performance Indicators (KPI) have been proposed, aligning with specific building types and operations. The EUI, expressed as $kW\mathbf{h}/Sq.m^2/year$, is a widely used measure that accounts for differences in building size. Though EUI is easy to calculate and interpret, it overlooks other factors such as occupancy and operational hours [16, 17]. To address these limitations, data-driven predictive models are widely adopted [16–18]. For example, the *Energy Star* system [19] for the USA and Canada uses different Multiple Linear Regression (MLR) model configurations to benchmark different building types. Similarly, other data-driven models have been adopted in China [20],Taiwan [21, 22], Hong Kong [23], Singapore [24, 25], Brazil [26], and UK [27]. A comparison of data-driven energy benchmarking methods across the world is summarized in Table 2. (Source: [15]).

In India, BEE governs and implements energy benchmarking for commercial buildings through its *Star Rating Program* [28]. This program is based on Energy Performance Index (EPI), similar to EUI and expressed as $kWh/m^2/year$. Star ratings are assigned to buildings on a 1-5 scale (from the most inefficient to the most efficient) while considering four climate zones, Warm & Humid, Composite, Hot & Dry, and Moderate. To date, BEE has awarded *Star Rating* to 225 buildings under different categories. Table 1 illustrates the mapping between the *Star Rating* and distribution of EPI based on % of air-conditioning (AC) use in office buildings. Prior to this, the *ECObench* was one of the earliest web-based tool to benchmark the hospital buildings in India [29]. In addition to this, there are a few research studies that developed independent energy benchmarking strategies by leveraging data-driven models. As an example, in a recent study, World Resouces Institute (WRI) has collected data through surveys from 50 offices in the city of Kochi and developed regression based models [30]. It was found out that only 22 offices out of 50 are relatively more efficient.

2 OPPORTUNITIES AND CHALLENGES

This section summarizes potential challenges with respect to energy benchmarking India's building stock. Under each challenge, several open questions were enumerated and opportunistic pathways were identified and discussed with examples. This is illustrated in Figure 1.

2.1 Challenge #1: Awareness, Market, and Business Opportunity

The problem of energy benchmarking of building stocks in India presents several open questions around awareness, market and business opportunity which are listed below.

(1) Is lack of awareness about building energy benchmarking a major bottleneck?
(2) How to create awareness about energy benchmarking and sustainability in the building sector?
(3) Is there a market for energy benchmarking of buildings in India? What is the maturity level? What are the market barriers? What are the allied businesses related to energy benchmarking? How could they collaboratively shape the building energy benchmarking scene in India over the next years?
(4) What is the roleplay of education and engagement to create awareness among key stakeholders incld. facility managers, building owners, tenants, and occupants? How public and private insitutions are encouraging professionals practices in this direction?

Going green has its advantages. They use sustainable materials, has processes that ensure efficient use of natural resources like energy and water, energy use, reduces pollution and uses waste reduction measures during a building's service life. In fact, both building owners and tenants are well informed and aware about the need to be green in terms of operating buildings. The willingness to embrace best practices to operate businesses in such facilities despite higher premium for rental is quite clear from the organizations with the vacancy/leasing rate during and after pandemic [40]. This clearly suggest that lack of awareness is not the bottleneck to roll-out benchmarking at least among commercial office buildings across large urban environments in India. Furthermore, both organizations and tenants report on rational choices they make in the office environment attributing to their own carbon footprint unlike in the past. There is a 13% average rental premium in green-certified IT buildings and a 36% average premium in non-IT buildings. A study by JLL India reported that the real-estate market for Green/Sustainable Buildings, in terms of both leasing and rental premium is reported to 53-56% and 15-54% respectively across major cities in India [40]. Besides rental, another interesting economic value is that only 3-12% of green buildings remain vacant when compared to non-green buildings. All these clearly indicate the general awareness about sustainable practices and market opportunity in India within building sector.

Energy monitoring devices with data analytics capabilities on cloud platform-based dashboards can help visualize the energy costs and provide savings up to 15-20 percent by detecting leaks, breaks and general inefficiencies in HVAC, lighting and other energy intensive equipment [41].

Moreover, adaptive thermal comfort guidelines [42, 43] can help lower the thermal comfort expectations of the occupants by providing stronger capability of physical thermoregulation and also leading to cost savings due to air-conditioning. There exists a nexus

Table 2: Summary of data-driven energy benchmarking methods globally [15].

Country	Building types	No. of buildings	No. of attributes	Approach	Rating
EnergyStar, USA [19]	16 types	many	6 to 8	Regression	Point (1-100)
USA [31]	Office	242	5	Regression & Random Forest	
China [32]	Office	88	10	Regression	Point (1-100)
South Korea [33]	Office	1,072	11	DT and ANOVA	5 Grades (A-E)
Taiwan [34]	Hotel	45	6	Regression	
Hong Kong [23]	Office	30	5	Regression	
Taiwan [21]	School and universities	74	4	Regression	
Brazil [26]	Bank branches	1,890		Regression	
Taiwan [22]	Office	47		DEA	Point (1-100)
Ireland [35]	Primary school			Energy Plus	7 Grades (A-G)
Greece [36]	School	320		Fuzzy clustering	5 Grades (A-E)
Hawaii [37]	Office and classrooms	60	10	ANN	
UK [27]	School	7,700	23	ANN	
Greece [38]	Hotel	90		k-means	5 Grades
Italy [39]	Healthcare center	100	11	LMEM and CART	
Singapore [15]	Office, Hotel and Retail	618	10	Ensembling	5 Grades (A-E)
India [30]	Offices	50	3	Regression	1-5 scale

between indoor air quality, thermal comfort and energy consumption in indoor spaces. Measurement of IEQ parameters such as CO_2, air temperature, Rh with energy consumption of spaces can help uncover the sick building syndrome related health effects better. Higher thermal comfort expectations may be associated with higher energy consumption from air conditioning and higher CO_2 levels in a space. With CO_2 also being a proxy for COVID-19 risk, this may help in making a stronger case for energy and IEQ benchmarking.

Studies suggest that behavior change interventions in work places can lead to huge carbon savings too [44]. Some experts working in this area suggest that behavior design has much greater potential in energy savings than technology based interventions in achieving energy efficiency goals. From author's viewpoint, there are islands of research groups and tertiary institutions in India working in siloes, for example, NICMAR's thrust on the Digitalisation of construction, real-estate, infrastructure market segment; CEPT conducts research, consultancy and guidance in a fairly collaborative spirit. As far as role of education is concerned, a good example is the new B.Plan course at the School of Architecture and Planning, Anna University that is funded by the Chennai Metropolitan Development Authority and District and Town Commission Planning.

The authors recognize a void in the innovation ecosystem within Architecture and Engineering Construction sector in India that is independent of institutions and solely concerned about shaping the collective future of our built-environment and markets in a responsible manner. This will spur collaborative industry-led programs to fund and drive research and innovation for sustainable low-carbon transition of the building industry in India in future. Thus, role of smart and sustainable building innovation ecosystem in India equivalent to *BLOXHub*[1] *Copenhagen* is seen as an opportunity to bridge this gap. At present, *C-Cube*[2] is the only closest in spirit to *BLOXHub*. The authors through this article announces a new research and innovation cluster titled *The Collective Voices for Buildings in India* (CVBi) which aims to bring together multiple stakeholders including the building automation *technology partners* (Zenatix, 75F, Kriti Labs), *facility management firms* (SILA, JLL), *prop tech firms* (PropStack, Zapkey), *not-for-profit industry partners* (AEEE, WRI-India), and *academic partners* (IITB, IITD, IITKGP, FLAME) to forge new collaborations addressing the challenge of building energy benchmarking in the Indian context among others topics (For more details refer to Section 3.2).

It is advisable to conduct a critical analysis before arriving at BLOXHub Copenhagen equivalent model for India. It would be relevant if the authors could highlight successful case studies/ models on any industry led approaches in India in the energy sector.

2.2 Challenge #2: Data Availability, Quality, and Sharing

Taking the direction of data-driven approaches (ref. Table 2) to benchmarking building's energy usage in India has several open questions too. Some of them are listed below.

(1) How to collect such data (e.g. frequency, accuracy, scale)? What is the role of open data initiatives in India?
(2) What are the data quality issues and challenges with automated data collection techniques?
(3) How to securely share the data, data privacy issues, etc. using existing nation-wide data initiatives?

Indian Urban Data eXchange (IUDX) is a transformative initiative of the MoHUA, Government of India to provide a data exchange platform to Indian cities [45]. It serves as a seamless interface for data providers and data users, including Urban Local Bodies, to share, request, and access datasets related to cities, urban governance, and urban service delivery. So far, IUDX has managed to partner with 20 cities in India for collecting digital information about a wide range of urban systems including waste, energy, street lights, CCTV cameras etc. Partnering with IUDX is one of the ways forward to collaboratively build datasets pertinent to

[1] https://bloxhub.org/
[2] https://niua.in/c-cube/

buildings and facilities in cities partnering with city municipal authorities and respective smart cities councils. The information about buildings shall comprise of several key attributes of the built-environment across cities including its energy usage (demand), onsite energy generation (supply), usage patterns across building types/seasons/neighborhoods/seasons/income groups (response) and so on. This will eventually allow the collation of large amounts of data to uncover opportunities to improve the building energy efficiency through nation-wide benchmarking efforts. Likewise, Urban Platform for deliverY of Online Governance (UPYOG) [46] is another national reference platform created for the delivery of municipal services online, which utilises the National Urban Innovation Stack principles.

There are success stories from around the world of the use of energy monitoring to assist in energy benchmarking to reduce energy costs for the building owners [41]. In particular, the energy monitoring devices with data analytics capable cloud platform based dashboards aren't commonplace yet in the Indian context where the energy demands are going to rise with the rising building stock and income levels of the citizens.

2.3 Challenge #3: Policy, Regulation and Administration

The role of Public Governance, Regulations, Certifications and Administration is crucial to India's benchmarking trajectory. In many countries, benchmarking and labelling are increasingly becoming mandatory. Such initiatives from public bodies can propel the drive towards energy efficient buildings and environments. Since India has diverse climatic zones, the energy demand modelling in buildings in each climatic zone requires a bespoke approach. Therefore, the regulations and certification bodies should consider crucial normalization factors such as climate. The present certification systems do not take into account the different construction typologies that exist in the diverse scenario of India. Apart from these aspects, a voluntary compliance weakens the influence of all standards and systems.

There are several national missions and bodies that can come together and work for such initiatives. Some of these, such as the MoHUA, NUDM, NIUA, NITI Aayog, Digital India, e-Gov, Smart Cities Mission, Capacity Building Commission, and the DMEO (Development Monitoring and Evaluation Office) already have taken steps in this direction. For example, DMEO has produced an interesting report [47] investigating the development efforts led by the GoI. The crux of this study aims to investigate how 125 Umbrella Centrally Sponsored Schemes in India aligns with state-level programs, thereby breaking the silos and facilitating intergovernmental data sharing across the scheme's life-cycle. These schemes are distributed across multiple Ministries and departments in the government such as the Ministry of Housing and Urban Affairs, Ministry of Environment, Forests & Climate Change.

Another recent development in this regard is that the Lok Sabha passed the Energy Conservation (Amendment) Bill 2022 on August 9th. This bill brings in a list of amendments to the Energy Conservation Act of 2001 to promote energy efficiency and conservation. In particular, this bill focuses on energy transition, favouring renewable energy sources and green hydrogen. It has provisions for regulating energy consumption by equipment, appliances, buildings and industries. The code specifies the standards for energy consumption per square metre. In relation to the building sector, the new code provides standards for energy conservation, utilisation of non-conventional sources of energy and other necessities for green and sustainable buildings.

Moreover, the energy benchmarking framework may need to consider the urban heat island effects which can increase the energy consumption by increasing the cooling demand by upto 20 percent [48]. The avenues for reduction of urban heat island effect may have to be looked at the policy level by city governments which is also related to appropriate land use planning, where a reasonable consideration is given to open spaces in urban areas.

3 DISCUSSION

Digitizing the building stock opens new business and economic opportunities (e.g. building certifications), new models (e.g. transparent/responsible valuation of built-environment driven by data), fostering a sense of innovation to transform the quality of built-environment (e.g. climate-risk resilient, healthier workplaces), identifying interventions for improving sustainability, better adaptation to climate-change, knowing the carbon footprint, and for setting goals for decarbonization, to improve safety and security.

3.1 Our Fore-thoughts

India has pledged to cut its emissions to net-zero by 2070 in COP26 meeting held in Glasgow in 2021. We need to work backwards and start taking steps to reaching that goal. One of the initiatives could be putting minds together in the tertiary institutions focused on higher education, research, development and innovation to become net-zero energy campuses by a certain date. This would involve baselining energy consumption of building within the campus and the continuously benchmark their energy performance over a long-term in order to explore new ways to reduce/optimize energy consumption by combining alternative clean energy sources (e.g. renewables, Power-to-X, energy storage). This can enable learning by doing and gradually scale up from campus/neighbourhood-scale to urban or even regional scales.

Embracing the principles of National Urban Innovation Stack (NUIS), we foresee developing a strong synergistic collaboration with Centre for Digital Governance (CDG). This shall provide the impetus to drive digitizing building stocks gradually and progressively and allow exploring digital innovation at the nexus of built-environment, standardization, and decarbonization to revolutionise urban governance as part of the National Urban Digital Mission. For instance, embracing the existing NUIS to explore applications of emerging digital technologies (e.g. IoT, cloud, AI) and investigate scientific approaches in order to develop standards to collect, process, visualize data efficiently about building energy-use intuitively, provide insights to make proactive decisions that guide stakeholders, and finally conduct building energy benchmarking autonomously through-out the lifecycle of buildings in an urban-scale across the nation will be the initial steps. Thus, uncovering new opportunities to better deliver municipal and urban governance in a proactive and responsible manner.

Another potential application beyond individual building-level metering is to use of wide-range techniques such as GIS or thermal imaging cameras to conduct rapid building energy benchmarking at the urban-scale. In addition, we need to take advantage of the concept of work from home and work from mountains becoming commonplace due to COVID-19 pandemic and look for ways to decongest our cities to reduce urban heat island effect and improve quality of life for people living in cities. GIS-based analyses could be performed to find the more sustainable habitats for people to dwell in from minimal energy consumption point of view and make those places attractive for people to move to. Behavioral design could also help in redefining sustainable ways of living and simpler lifestyles and make it a norm to consider in energy benchmarking framework.

3.2 Our Appeal

Way forward Through *CVBi* authors envisage the following strategic action plans for this cluster with the sole objective to guide a nation-wide collective research, engagement, and innovation activities around transforming built-environment over the next decades. Some preliminary initiatives of this cluster are.

1. Mission MEGA The initial focus of this collaborative activity is to digitize buildings in 4 mega cities strategically located North-East-West-South within India, namely New Delhi, Kolkatta, Mumbai, and Chennai. This is our first collective mission which we began.

2. Mission 36 Based on our first collaborative outcome, we lay the foundations to expand our work and activities through engagements with other academic and local partner institutions in India, by hand-holding them to advocate digitizing buildings across 28 States and 8 Union Territories, while focusing on emerging cities.

3. Forging New Strategic Partnerships Specifically, one of our next steps is to partner with IUDX. The authors reckon that IUDX is a synergistic partner in the proposed initiative owing to the fact that we have a shared agenda to *digitizing urban socio-technical systems*, thereby delineating new value-chains for multiple stakeholders. We will collaborate with cities willing to digitize their building stocks; provide guidance to instrument, monitor, measure, collect key building information continuously in order to conduct baselining/benchmarking of building's energy use throught-out its life cycle. By partnering with us, IUDX can expand their portfolio into building sector and develop more proven use cases, and for us the benefit to partner with them is to employ their scalable frameworks and schemas to build open datasets. Thus, it is a strategic win-win partnership for both. From authors perspective, this will transform buildings in the cities into 'sandboxes' that catalyzes innovation, particularly in the intelligent energy management within the emerging smart building market segment in future smart cities [49]. In fact, this is synergistic to the vision of NUDM to envision U-Box as the one-stop-shop that offers Innovation-Support-as-a-Service for the urban development sector.

4. Forging Convergence One of the strengths of our focused working group is to include global best practices that we bring to guide the sustainable development of buildings and facilities with a clear long-term strategic vision, structure discussions with a clear foresight into the landscape of urban development, and build synergistic activity and engagement plans with key stakeholders. Such strategic goal-driven action plans are catalytic pathways that enable nation-wide capacity building and provide opportunities that stimulate behavior change to improve healthy collaboration between partners to address the grand challenges (such as decarbonizing building stocks pan-India). The authors introduce an example case that exemplifies how a proposed strategic activity plan shall enable convergence between the state-wide urban development efforts with one of NUDM's national mission. Recently, the Tamil Nadu Urban Habitat Development Board has proposed to develop a new Tamil Nadu Integrated Housing Information System (TNIHIS) with a huge capital budget of USD 715 Million [50] with a main specific objectives to allow informed decision-making by administrators and authorities about housing sector. However, the question on whether this project at the State-level aligns with National schemes' as articulated by DMEO still remains to be answered [47]? In this specific context, our strategic approach recognizes TNIHIS as a key funding instrument to first digitize existing building stocks in the State, and then explore its role to establish a firm baseline to enable continuous benchmarking of buildings within the Greater Chennai Corporation through the Digital Chennai project and responsibly guide decarbonizing and future-proofing the building sector in the coming years. Thus, our proposed way-forward approaches not only allows identifying strategic action plans but creates pathways to collaborate, foster innovation and achieve better convergence.

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