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Review of Building Data Frameworks across Countries: Lessons for India

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1. INTRODUCTION

Increasing energy efficiency of the commercial building stock is an important aspect of any national energy policy. Understanding how buildings use energy is, therefore, critical to understanding how any new policy may impact the energy use. Data enables decision making and good quality data arms consumers with a tool to compare their energy performance to their peers and allows them to differentiate their buildings in the real estate market on the basis of their energy footprint. Good quality data is also essential for policy makers to prioritize their strategies and track implementation.

India is adding about 4-6% annually to the existing commercial building stock – one of the highest rates of growth in new construction currently in the world. Given this accelerated growth, the buildings sector in the country presents a significant potential to improve its energy performance. The Bureau of Energy Efficiency (BEE) in India developed the Energy Conservation Building Code (ECBC) and launched the Star Labeling for a few energy-intensive building segments as a significant first step. However, a data driven policy framework for systematically targeting energy efficiency in both new construction and existing buildings has largely been missing. There is no quantifiable mechanism currently in place to track the impact of code adoption through regular reporting/survey of energy consumption in the commercial building stock – something that is essential for developing updates to the codes. As part of the effort to bring in a more systematic approach to commercial building energy data collection and reporting, the current study, under the CWF funded "Transforming Commercial Building Sector in India" project, aims to develop a data framework that could be applied to this sector in India.

This report outlines the initial explorations carried out by LBNL on available examples of energy data collection frameworks for buildings. Specifically, this monograph deals with European experience in the buildings sector, the US experience in the commercial buildings sector, and examples of data collection effort in Singapore and China to capture the Asian experience in the commercial sector. The review also provides a summary of the past efforts in India to collect and use commercial building energy data and its strengths and weaknesses. The overall aim of this activity is to help understand the use cases that drive the granularity of data being collected and the range of methodologies adopted for the data collection effort. This review will be a key input and reference for developing a data collection framework for India, and will also clarify general thinking on the institutional structure that may be amenable for data collection effort to match the needs and requirements of commercial building sector in India.

2. U.S. COMMERCIAL BUILDING ENERGY DATA FRAMEWORK

2.1 Executive Summary

There are two key surveys commissioned in the United States that focuses on energy use in the commercial building sector. The Commercial Building Energy Consumption Survey (CBECS) is designed to represent the national commercial building stock and is conducted by the U.S. Energy Information Administration (EIA). The California End-Use Survey (CEUS) is specific to California, and is authorized by the California Energy Commission, and conducted with support from state utilities and other parties. The CBECS and CEUS are both examples of fairly successful and comprehensive commercial building surveys that are conducted with some regularity. Both surveys collect robust information on building characteristics, equipment and building systems (i.e. heating, ventilation, etc.), building activity, end use energy consumption, and energy intensities.

CBECS is a mature program with technical and statistical rigor that collects comprehensive data on parameters relevant to energy use in commercial buildings, and produces results in an effective, user-friendly format. The scope of the survey as well as the approach for data collection have evolved over the years, driven primarily by users of the data and policy needs. CEUS is an excellent example of a resource-intensive approach with a high level of depth and detail through on-site surveys and advanced software modelling component, DrCEUS. Both of these surveys are excellent models for India's long-term commercial building data framework goals. In the near term, however, India may want to focus its efforts on a comparatively simple, yet robust data framework that takes cues from CBECS and CEUS's extensive survey scope, energy modelling efforts, and data outcomes/presentation. A preliminary review of both studies was conducted with specific attention to

- Objective
- Scope
- Policy objectives
- Survey method approach
- Sampling methodology
- Data collection methods, sources and frequency
- Data access
- Derived energy efficiency (EE) indicators, normalization and presentation of data
- Recommendations

Feedback from communities that rely on the data has highlighted critical improvement areas that would make the data more lucrative for a wide range of applications.

Table 2.1 Overview of Systems and Tools Related to EE in Buildings

System	Description
CBECS	• Nationwide (U.S.) commercial building survey that collects detailed data on building shell characteristics (e.g. square footage, wall/roof construction material), building activity (e.g. education, retail), operating schedule (e.g. open hours, estimated occupancy), equipment (e.g. space heating, lighting), and fuel source. • Conducted on a quadrennial basis beginning in 1972; most recent survey is 2012. • Consists of on-site surveys, and energy-supplier survey for selected sites. • Key outcomes include microdata files allowing for custom queries, and summary tables on building characteristics, energy consumption, energy expenditures, and energy intensities, and end-use specific energy consumption estimates based on engineering models.
CEUS	• California-wide commercial building survey that collects detailed data on building shell characteristics, building activities, operating schedule, equipment, and fuel source. • Last conducted in 2006, CSS[1] conducted in 2014. • Consists of on-site surveys, utility billing records, and on-site metering • Key outcomes include DrCEUS simulations (combines features from eQUEST and SitePro, technology and weather data from DOE2.2) using survey and utility billing data, downloadable Excel workbook with simulation data. No microdata available.

2.2 CBECS

2.2.1 Objective

CBECS was commissioned with the goal of developing a repository of statistical information about energy consumption and expenditures in the U.S. commercial building stock, and information about energy-related building characteristics.[1] The CBECS encompasses all 50 states and the District of Columbia. Because CBECS is intended to give a large picture view of commercial building energy use, the geographic granularity is limited; results are broken down only to one of the nine U.S. Census divisions. CBECS is commonly used for benchmarking and rating systems, energy demand forecasting, as a key input to the National Energy Monitoring System (NEMS), tracking efficiency progress, and informing policy decisions, among other things.

2.2.2 Sampling Methodology

The CBECS is conducted every four years (since 1972)- with ten surveys completed to date.
CBECS employs a multi-stage sampling approach. Buildings from the sample frame were sorted into subgroups with similar qualities, optimal sample rates for each subgroup were calculated, and the final sample of buildings was selected using a systematic PPS selection procedure. Each building is also assigned a weight. Larger buildings are represented at a higher rate to capture diversity in energy

[1] California Commercial Saturation Survey.

consumption within that subgroup.[2] The CBECS sample size has continued to grow- the 2012 survey had a sample size of 6,700 buildings, an estimated 28 percent increase from the 2003 survey.[3]

2.2.3 Summary of Data

Table 2.2 CBECS Data Overview

Building Segment	Commercial
Policy Objective	Maintain a database of commercial building energy-related characteristics and energy consumption. Data could be applied for benchmarking, ratings systems (e.g. ENERGY STAR), energy forecasting, tracking industry progress in energy efficiency, as well as other modelling efforts and policy-making.
Country /Scope	• United States (All 50 states & District of Columbia), data presented by U.S. census region & division. • Commercial buildings greater than 1,000 square feet only. • The 2012 CBECS surveyed 6,700 commercial buildings.
Current Status	2012 CBECS building characteristics tables and microdata released in Spring 2015. Consumption and expenditures preliminary estimates, detailed tables, and microdata to be released in February, March, and April 2016, respectively.
Key Energy Indicators	• Measures of energy expenditures, intensity, and consumption by major fuel type, end use, building floor space, principal building activity, year constructed, census region/division, climate zone, number of establishments, occupancy, and more.
Data Collection Method	• On-site surveys to collect building shell characteristics and energy usage data (consumption and costs). • Energy supplier survey to collect energy usage and expenditure data from suppliers (utilities) for buildings that supplied inadequate data in the on-site survey (about 50% of sample). • Engineering models (based on ASHRAE and IESNA) for key end-uses and cross-sectional regressions for additional end-uses
Data Modelling	• Engineering models (based on ASHRAE and IESNA) for key end-uses and cross-sectional regressions for additional end-uses • Modelled end uses include: space heating & cooling, ventilation, water heating, lighting, office equipment, cooking, refrigeration, and "other."
Relevance to India Commercial Building Data Framework	**Medium** Good example for collecting comprehensive data on building type, shell characteristics, building equipment, primary building activities, and fuel source. Particularly useful are the micro-data available for customizable searches, as well as fuel-specific end use energy consumption, expenditure, and intensity estimates.

Type of Data

CBECS data is presented in the form of summary tables as well as microdata. Summary tables provide a wealth of data on building characteristics, principal building activities, operating schedules, energy-consuming equipment, and fuel types. End-use specific energy consumption and intensity estimates are also provided based on survey results paired with engineering models in recent surveys and from Facility Energy Decision System (FEDS) in the prior survey years.[4]

A description of the building characteristics and energy consumption, expenditure, and intensity data is detailed in the table below.[5] Due to the large number of variables captured in the CBECS survey (particularly with respect to microdata), the table below is intended to provide a sample of the types of data available rather than an exhaustive list. The Building Characteristics, Building Activity , and Microdata is representative of CBECS 2012, while the Consumption and Expenditures data has yet to be released. Many of the variables detailed in the table below are cross-tabulated against one another in the CBECS tables. For example, one table indicates the number of employees working at a given building across nearly all of the other variables.

Table 2.3 Data Available in CBECS

Type of Data / Indicator	Description
Building Characteristics Data	
Summary Tables	Provide measures of floor space, number of workers, hours of operation across many key building activity and characteristic variables, including primary energy supply source.
Geographic Region	Indicates census region, division, and climate region.
Size	Indicates the building square footage chosen from 8 different ranges across many key building activity and characteristic variables.
Age	Indicates number of buildings by year constructed from 10 different age range categories.
Energy Sources	Identifies the number of buildings using a certain: • Energy source (i.e. electricity, natural gas, fuel oil, etc.) • Space heating energy source • Primary space heating energy source • Cooling energy source • Water heating energy source • Cooking energy source
Number of Floors/Escalators/ Elevators	Indicates # of floors (5 different categories), # of escalators/elevators (3 different frequency categories).
Establishments	# of establishments in building
Wall Material	# of buildings/floorspace by exterior wall material type
Roof	# of buildings/floorspace by roof material & roof characteristics (roof tilt and cool roof)
Renovations	Renovations (11 different options) occurring in buildings constructed before 2008.
Equipment Replacement	Heating and cooling equipment replaced since 1990.

End Uses	# of buildings to which each of the following energy end use applies: • Space heating • Cooling • Water heating • Cooking • Manufacturing • Electricity generation
Heating Equipment	# of buildings with the following heating equipment: heat pumps, furnaces, individual space heaters, district heat, boilers, packaged heating units, other
Cooling Equipment	# of buildings with the following cooling equipment: central AC, heat pumps, individual air conditioners, district chilled water, central chillers, packaged air conditioning units, swamp coolers, other.
Water Heating Equipment	# of buildings with centralized vs. distributed system, or combination.
Lighting Equipment	# of buildings with specific lighting equipment types: incandescent, standard fluorescent, compact fluorescent, high-intensity discharge, halogen, LED, other.
Refrigeration Equipment	# of buildings with specific refrigeration equipment: walk in unites, cases/cabinets, large cold storage areas, commercial ice makers, residential-type/compact units, vending machines, no refrigeration.
Office/Electronic Equipment	# of buildings with (and the number of units present) for: desktop computers, laptops, dedicated servers, laser printers, inkjet printers, FAX machines, photocopiers, TVs.
Building Activity Data	
Building Activity	Identifies principal building activity (education, food sales, healthcare, lodging, mercantile, office, public safety, religious worship, service, warehouse and storage, other, vacant)
Operating Hours	Weekly operating hours indicated from 1 of 6 categories- from "fewer than 40 hours" to "open continuously."
Employment	Provides measures of building employment from 7 different categories- ranging from fewer than 5 workers to 250+.
Ownership & Occupancy	Identifies the following: • Government vs. non-government owned • Owner occupied, leased, unoccupied, etc. • Party responsible for energy system O&M (e.g. building owner, property management)
Energy Sources & End Uses	Provides measures of energy sources, energy end uses, space-heating end uses, cooling energy sources, water-heating energy sources, and cooking energy sources across key building characteristics including operating hours, number of workers, census region.

Floor Space Heated, Cooled, & Lit	Identifies percent of building floorspace (0%, 1-50%, 51-99%, 100%) that is heated, cooled, lit when open, and lit when closed.
End-Use Equipment	Provides measures of energy sources, energy end uses, space-heating end uses, cooling energy sources, water-heating energy sources, and cooking energy sources across key building characteristics including operating hours, number of workers, census region.
Energy Indicators Data	
Energy Consumption	Provides measures of energy consumption (trillion Btu, billion kWh, billion cubic feet, million gallons,) for all major fuels, electricity, natural gas, fuel oil, and district heat across the following variables[ii]: • energy source • primary vs. site consumption • per building • per sq. ft. • per worker • census region/division • climate zone • building size • year constructed • end use (space heating, cooling, ventilation, water heating, lighting, cooking, refrigeration, office equipment, computers, other)
Energy Expenditures	Provides measures of energy expenditures (million dollars) for all major fuels, electricity, natural gas, fuel oil, and district heat across the following variables: • total • per building • per sq. ft. • per kWh/million Btu/ thousand cubic feet/thousand pounds • census region/division • climate zone • building size • year constructed
Energy Intensities	Provides measures of energy intensity (kWh, cubic feet, gallons, or thousand Btu/ sq. ft.) for all major fuels, electricity, natural gas, fuel oil, and district heat across the following variables: • energy source • per building • per sq. ft. • census region/division

[ii] Not all variables are represented for every energy source type.

	• climate zone • building size • year constructed • end use (space heating, cooling, ventilation, water heating, lighting, cooking, refrigeration, office equipment, computers, other)
Microdata	
Microdata	The 2012 CBECS microdata file contains 6,720 records. Each record corresponds to a single responding, in-scope sampled building. The microdata have too many variables to include in this table. All variables available in the microdata can be found in the variable and response codebook.

Data Access

Results for all CBECS survey years are publicly available on the U.S. Energy Information Administration's (EIA) website. Data are provided in PDF, SAS and CSV format. CBECS provides full access to individual responses through its microdata, enabling easy access for custom queries.

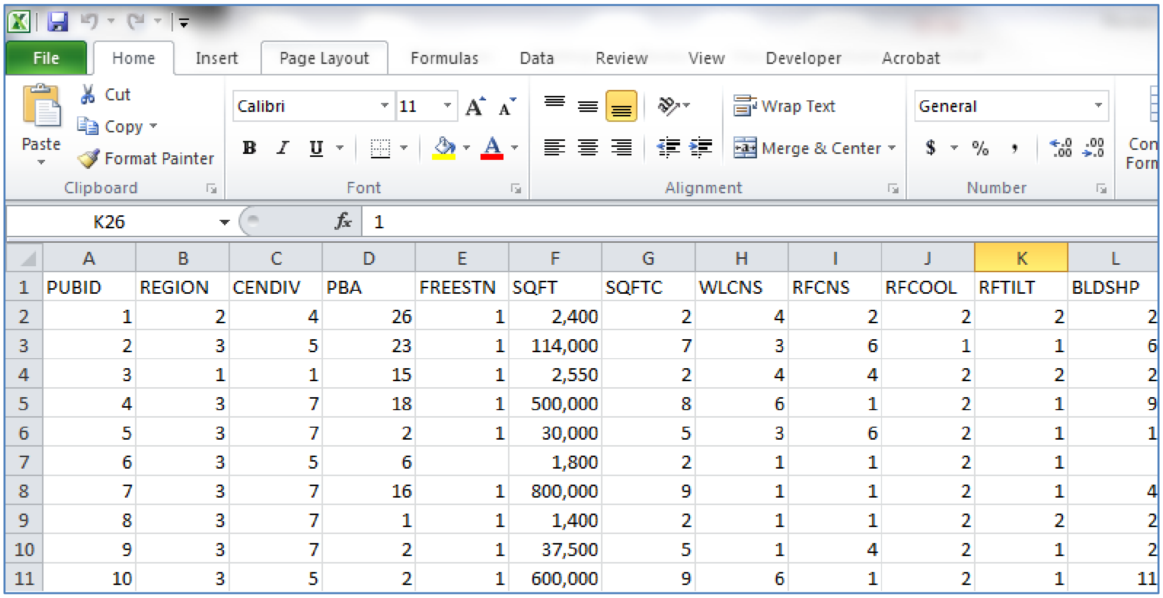
Data Sample

The data samples below indicate a typical CBECS table, as well as a snapshot of the microdata available.

Table E3. Electricity Consumption (Btu) by End Use for Non-Mall Buildings, 2003

	Total Electricity Consumption (trillion Btu)										
	Total	Space Heat-ing	Cool-ing	Venti-lation	Water Heat-ing	Light-ing	Cook-ing	Refrig-eration	Office Equip-ment	Com-puters	Other
All Buildings*	3,037	115	397	384	52	1,143	22	354	64	148	357
Building Floorspace (Square Feet)											
1,001 to 5,000	386	19	43	18	11	93	7	137	8	12	38
5,001 to 10,000	262	12	35	17	5	83	4	56	6	9	35
10,001 to 25,000	407	20	46	44	8	151	3	53	9	19	54
25,001 to 50,000	350	15	55	50	9	121	2	34	7	16	42
50,001 to 100,000	405	16	57	65	7	158	2	29	6	18	45
100,001 to 200,000	483	16	62	80	5	195	1	24	Q	31	56
200,001 to 500,000	361	8	51	54	5	162	1	9	8	19	43
Over 500,000	383	8	47	56	3	181	2	12	8	23	43
Principal Building Activity											
Education	371	15	74	83	11	113	2	16	4	32	21
Food Sales	208	6	12	7	Q	46	2	119	2	2	10
Food Service	217	10	28	24	10	42	13	70	2	2	15

Figure 2.1 CBECS Table Data Sample



	A	B	C	D	E	F	G	H	I	J	K	L
1	PUBID	REGION	CENDIV	PBA	FREESTN	SQFT	SQFTC	WLCNS	RFCNS	RFCOOL	RFTILT	BLDSHP
2	1	2	4	26	1	2,400	2	4	2	2	2	2
3	2	3	5	23	1	114,000	7	3	6	1	1	6
4	3	1	1	15	1	2,550	2	4	4	2	2	2
5	4	3	7	18	1	500,000	8	6	1	2	1	9
6	5	3	7	2	1	30,000	5	3	6	2	1	1
7	6	3	5	6		1,800	2	1	1	2	1	
8	7	3	7	16	1	800,000	9	1	1	2	1	4
9	8	3	7	1	1	1,400	2	1	1	2	2	2
10	9	3	7	2	1	37,500	5	1	4	2	1	2
11	10	3	5	2	1	600,000	9	6	1	2	1	11

Figure 2.2 CBECS 2012 Microdata File Sample Screenshot

2.2.4 Recommendations

Feedback from communities that rely on CBECS data highlights critical improvement areas that would make the data more useful for a wide range of applications. Some of the key recommendations include[6]:

- Increasing the timeliness and frequency of survey releases- possibly through implementing a rotating sample design or revising editing procedures.
- Improving data collection efficiencies by conducting portions of the survey online, partnering with energy suppliers to collect data from centralized sources, or partnering with professional energy auditors to overcome data collection challenges.
- Increasing sample size for more robust customized analyses.
- Increasing geographic granularity and provide more precise building location information, possibly by ASHRAE climate zones.
- Exploring opportunities to partner with other government statistical agencies, organizations, or energy suppliers to collect data on specialized topics without increasing the burden on the current CBECS.
- Periodically reviewing questionnaire content and wording as well as potential new energy end uses.

2.3 CEUS

2.3.1 Objective

The Commercial End Use Survey (CEUS) is a comprehensive study of commercial sector energy use in California. CEUS was first piloted in 1996, with the most recent survey conducted in 2006. CEUS is conducted under the aegis of the California Energy Commission (CEC) with support and partnership from several Utilities (Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, Southern California Gas Company, and the Sacramento Municipal Utility District). While designed primarily to support California's energy demand forecasting activities, CEUS identifies four main objectives: (1) develop estimates of end use saturations, energy use by end use, hourly load profiles for commercial market segments, (2) collect data on end-use energy efficiency to support the design and planning of energy efficiency programs and policies, (3) construct a flexible building energy demand analysis model to support the estimation of the hourly end-use load profiles, and (4) develop a means of estimating the hourly impacts of energy efficiency measures, load management strategies, building standards, alternative rate designs, and other programs and policies.[7]

The scope of data collected in CEUS is similar to that of CBECS. CEUS, however, differs in several key areas. CEUS surveys California commercial buildings only. CEUS also collects highly detailed information for certain topics. For building equipment, CEUS obtains data on the efficiencies and typical operating schedules of energy-consuming equipment, enabling granular end use energy consumption estimates. CEUS also collects more robust data on building activities and schedules- allowing participants to allocate up to 8 different activity areas and three different schedule sets.

Despite the high granularity of survey questions, the utility of this data is somewhat limited in comparison to CBECS as no microdata are released. CEUS does not release any microdata (or individual building responses) due to privacy concerns. Unlike CBECS, CEUS also incorporates a software modelling component (DrCEUS) that enables calibrated building simulations, and graphical views and comparisons of energy information by user-defined segments.[8]

2.3.2 Sampling Methodology

CEUS obtains its sampling data from three California electric investor-owned utilities. CEUS employs a stratified random sampling approach. The sample is stratified by climate, building type, utility area, and size. Some sample sites are selectively replaced with sites that contain interval-metered electricity consumption data in an effort to maximize the number of sites with hourly usage information (which is used to calibrate the energy simulation models).[8]

2.3.3 Summary of Data

Table 2.4 CEUS Data Overview

Building Segment	"Non-residential" (i.e. "Commercial")
Policy Objective	Collect robust data that could support statewide energy demand forecasting efforts. Data also could support the design and planning of energy efficiency programs and policies
Country /Scope	California- ("limited statewide" - only covers the electric service areas of the participating utilities)
Current Status	Latest CEUS released in 2006, CSS in 2014
Key Energy Indicators	• Fuel Shares • Electric and natural gas consumption • Energy-use indices (EUIs) • Energy intensities • 16-day hourly end-use load categories for 12 commercial building type categories. • End-use intensities by major fuels • Monthly and daily load profiles; end-use load profiles
Data Collection Method	• On-site surveys to collect building characteristics data • Monthly utility billing data obtained • Short-term data logging and/or interval metering performed at certain sites.
Data Modelling	• DrCEUS simulations (combines features from eQUEST and SitePro, technology and weather data from DOE2.2) using survey and utility billing data
Relevance to India Commercial Building Data Framework	**Medium** Very extensive data, used for complicated analyses, including calibrated simulations of entire commercial sector or subsectors. Contains useful load profiles (daily, monthly, by end use). The lack of publicly available microdata, however, limits CEUS' usefulness for custom analyses- should CEUS release such data, it would become substantially more useful to its users.

Type of Data

Commercial sector or segment level (based on the utility service area, building type, fuel) results from the CEUS report can be viewed interactively on the CEUS website or as an Excel workbook. This data can be viewed based on up to three simultaneous filters: sector (based on the utility service area), building type (e.g. "all commercial", "restaurant"), fuel type (electric or gas) and result type (e.g. monthly energy use, load profiles by end use). It is important to keep in mind that for each of the data types outlines under "Building Data" and "Energy Indicators", any (or all) of these filters can be applied.[8]

Unless otherwise specified, any reference in the table below to "end uses" can be assumed to include: Heating, cooling, ventilation, water heating, cooking, refrigeration, exterior lighting, interior lighting, office equipment, miscellaneous, process, motors, air compressors, and segment total. No microdata or responses from individual premises are provided due to confidentiality concerns.

Table 2.5 Data Available in CEUS

Type of Data / Indicator	Description
Interactive Results- Filters	
Sector	The "Sector" filter allows results to be generated for specific utilities, utility service areas, or the entire limited state-wide sample.
Building Type	The "Building Type" filter allows results to be generated for 15 different categories including "office", "retail", "all commercial", etc.
Fuel	The "Fuel" filter allows summary table results to be generated for either electric or gas.
Results	The "Results" filter allows users to specify the type of results they seek- for the chosen sector, building type, and fuel. Result types include "Summary", "Monthly", and more. Detail on the contents of each result type are specified below.
Building Data	
EUFS: End-Use Floor Stock	Presents portion of the floor stock in which a specific end use (e.g. heating, lighting, office equipment) and fuel type (electric or gas) is present. Floor stock is indicated in (kSqFt)
EUFS Distribution	For any end use and fuel, the floor stock distribution is the ratio (%) of end-use floor stock where the end use is present to total floor stock in the segment.
Energy Indicators	
EUI: Energy-Use Indices	EUI indicates the annual energy usage for a specific fuel and end use per square foot of end use floor stock (the area served by the end use and fuel in question). EUI is defined in terms of (kWh/EUFS/Year).
EI: Energy Intensity	EI indicates the total fuel-specific consumption per square foot of total floor stock. Can be expressed at the segment or building-level type, at the premise level, or the end-use level. Defined in terms of (kWh/ Segment FS/ Year).
End-Use Energy Distribution (%)	The fraction (%) of the total segment energy that is attributable to a specific end use.
Non-Coincident Peak Loads	The maximum annual hourly load in watts per total segment of floor stock (watts/segment FS) for each end use.
Connected Load	End use connected loads in watts per total segment floor stock (Watts/Segment FS)[iii]

[iii] Heating values presented in sq ft./ kBtu, and cooling sq ft./ ton.

Annual Energy Usage	Annual energy usage (GWh) for each end use.
Monthly	Monthly usage and demand load profiles for electric, usage load profiles only for gas.
Day Type	Stacked hourly load profiles for different end uses[iv] shown for 16 different day types. For each season (winter, summer, fall, spring), profiles are shown for a "typical day", "hot day", "cold day", and "weekend day."
Monthly Day Type	Presents a set of stacked end-use**Error! Bookmark not defined.** hourly load shapes using six day types (Typical, Hot, Cold, Saturday, Sunday, Peak) for calendar months included within the indicated season.
Whole Building	Whole segment end-use hourly consumption graphs for the entire year as one month per panel.

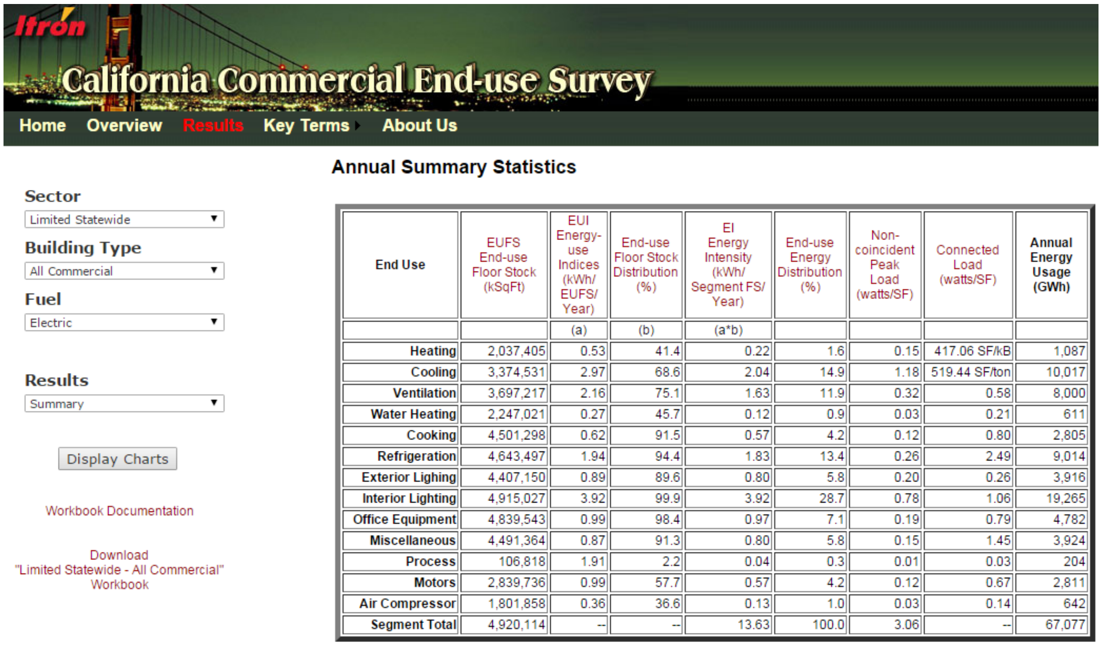
Data Access

The interactive CEUS results are publicly available and can be accessed via ITRON's website.**Error! Bookmark not defined.** Similarly, the Excel workbook is available for public download. While CEUS collects highly detailed information on building equipment efficiencies, operating schedules, activities performed in the building, and much more, because the results are presented in a more aggregated format (even in the downloadable Excel workbook), the usefulness of this data is ultimately lost. Despite the fact that premise-level information may not be available to release due to privacy concerns, the inclusion of more building characteristics, activity, and equipment operation data (even if presented in an aggregated format) could be helpful.

Data Sample

Screenshots of the CEUS results available on ITRON's website are shown in Figure 3.3 through Figure 3.6 below.

[iv] Electric end uses include all 13 outlined above. Gas end uses include: process, water heating, miscellaneous, cooling, cooking, and heating.



Annual Summary Statistics

End Use	EUFS End-use Floor Stock (kSqFt)	EUI Energy-use Indices (kWh/ EUFS/ Year)	End-use Floor Stock Distribution (%)	EI Energy Intensity (kWh/ Segment FS/ Year)	End-use Energy Distribution (%)	Non-coincident Peak Load (watts/SF)	Connected Load (watts/SF)	Annual Energy Usage (GWh)
		(a)	(b)	(a*b)				
Heating	2,037,405	0.53	41.4	0.22	1.6	0.15	417.06 SF/kB	1,087
Cooling	3,374,531	2.97	68.6	2.04	14.9	1.18	519.44 SF/ton	10,017
Ventilation	3,697,217	2.16	75.1	1.63	11.9	0.32	0.58	8,000
Water Heating	2,247,021	0.27	45.7	0.12	0.9	0.03	0.21	611
Cooking	4,501,298	0.62	91.5	0.57	4.2	0.12	0.80	2,805
Refrigeration	4,643,497	1.94	94.4	1.83	13.4	0.26	2.49	9,014
Exterior Lighing	4,407,150	0.89	89.6	0.80	5.8	0.20	0.26	3,916
Interior Lighting	4,915,027	3.92	99.9	3.92	28.7	0.78	1.06	19,265
Office Equipment	4,839,543	0.99	98.4	0.97	7.1	0.19	0.79	4,782
Miscellaneous	4,491,364	0.87	91.3	0.80	5.8	0.15	1.45	3,924
Process	106,818	1.91	2.2	0.04	0.3	0.01	0.03	204
Motors	2,839,736	0.99	57.7	0.57	4.2	0.12	0.67	2,811
Air Compressor	1,801,858	0.36	36.6	0.13	1.0	0.03	0.14	642
Segment Total	4,920,114	--	--	13.63	100.0	3.06	--	67,077

Figure 2.3 Annual Summary Statistics & ITRON Interface

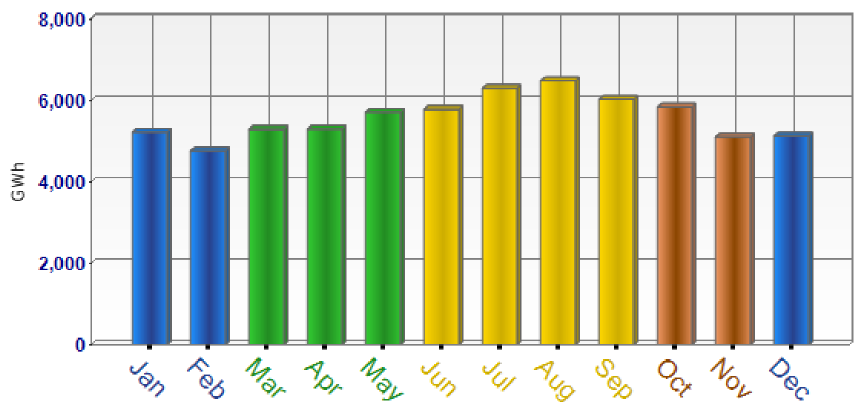


Figure 2.4 Monthly Energy Use

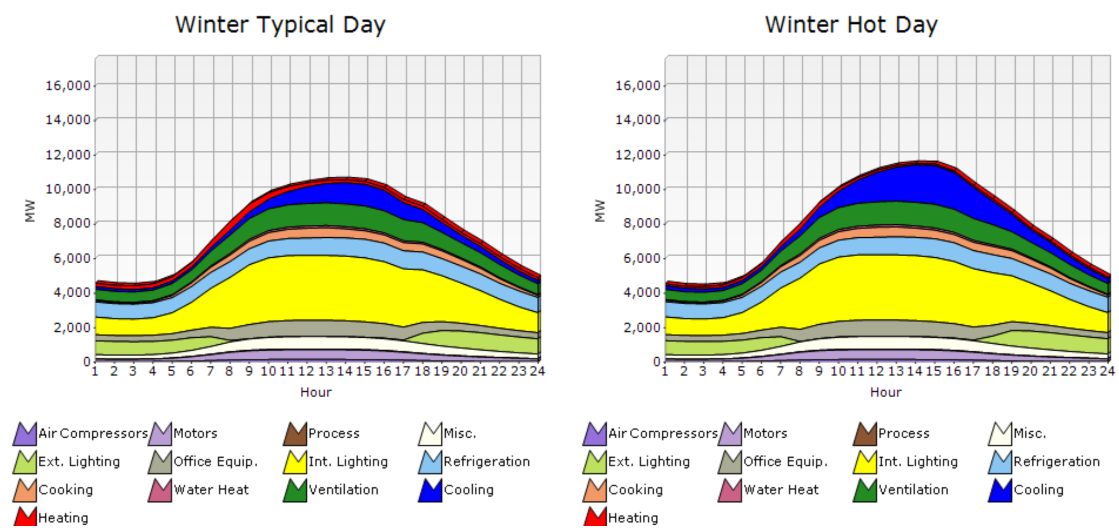


Figure 2.5 Day-Type Load Profiles

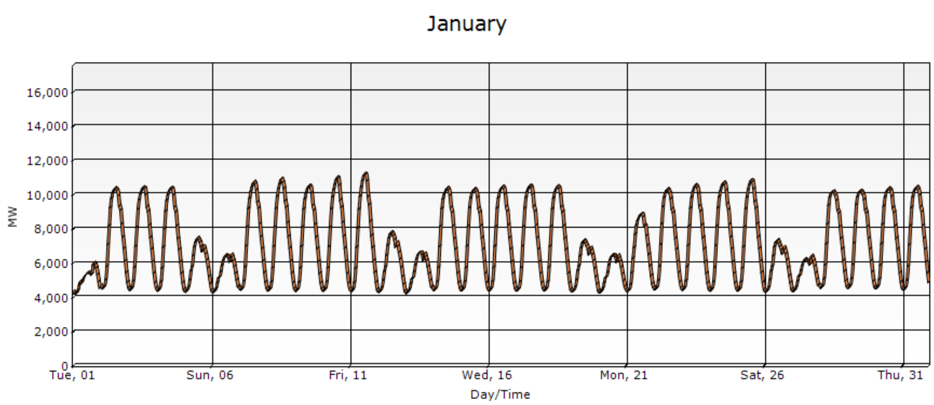


Figure 2.6 Monthly Load Profiles

2.3.4 Recommendations

Recommendations to improve CEUS include:

- Increase the proportion of new construction in the sample
- Improve administrative mechanism for exchanging data between utilities and contractors
- Develop a finer resolution of building types and HVAC end uses
- Increase the amount of field-metering, if possible

3. E.U. BUILDING ENERGY DATA FRAMEWORK

3.1. Executive Summary

This section documents the key aspects of various systems, tools and data available at the Buildings Performance Institute of Europe (BPIE) Data Hub (http://www.buildingsdata.eu/), which are used by

European policy makers, builders and others involved in improving Energy Efficiency of buildings. The aim of this review was to gain insights which may be useful in developing the Commercial Building Data Framework in India.

A preliminary review investigated the following aspects:

- Type of policies, why they were introduced, policy objective, funding for policy
- Type of data collected, volume of data collected
- Data collection methods, sources and frequency
- Derived EE indictors, normalization and presentation of data
- Uses & users of data
- Access levels, Privacy controls
- Building Data maturity level in different countries

The BPIE systems and data are a fairly good source of information in terms of type of data to collect about building structure, energy use and intensity. There is also relevant information on the types of policies in different countries, as well as detailed information on pilot projects to improve the building performance via retrofit projects.

However, in contrast to the aim of the Commercial Building Data Framework for India, most of the EU data, systems, projects and policies are developed for the existing residential building stock, with the aim of improving the energy efficiency of these buildings through retrofits. Though there are some data indicators for "tertiary" or commercial buildings, they are not as well developed. The Commercial Building Data Framework for India is being developed specifically for commercial spaces and is targeted more at new buildings and those built in the last 10-15 years, which will capture recent trend in construction and associated energy use. The BPIE systems have very detailed data on heating systems as most EU projects and policies for improving energy efficiency in buildings are aimed at reducing the energy for space heating and hot water. However, the focus in India will more likely be on reducing energy use for space cooling, both in terms of passive cooling, i.e. improving the thermal efficiency of non-conditioned building stock, and in terms of improving the stock efficiency of cooling systems.

Table 3.1 Overview of Systems and Tools Related to EE in Buildings

System	Description
Tabula	• Contains data of various building typologies (primarily residential) from 13 EU countries • Detailed building data (e.g. type of roofing, windows, walls) and system data (e.g. boiler characteristics) • Set up in 2009-2012 (precursor was **Datamine** in 2006-2008)
Episcope	• This is a building stock monitoring tool which monitors and tracks energy-related refurbishment of buildings • Tracks implementation & impact of energy saving measures • Key outcome is energy performance indicators to be used for policy, education, requirements, etc.

	• Uses data from **Tabula** and feeds data back into **Tabula** • 16 pilot projects in different EU countries in 2013-2016
Mure	• Contains information on EE policies and their impact (where available) for EU 28 • Summary table of all policies based on target end use (e.g. appliance), actor (e.g. utility), target audience (e.g. owners) and type (e.g. regulation)
Odyssey	• Contains data on EE and CO_2 indicators and on energy consumption across several sectors (e.g. industry, transport, households, services) for EU 28 • Used along with **Mure** for monitoring EE trends
Entranze	• Online data and scenario tool across EU 28 (varying levels of detail) • **Data Tool** shows country-wise consolidated data on building characteristics, energy use, energy source, etc. • **Scenario Tool** shows potential demand, consumption, etc. based on BAU (Low), Medium & High levels of policy implementation • Draws on data from **Odyssey**, **Tabula**, **Eurostat**, **UEPC** • Set up in 2012-2014

3.2. Tabula

3.2.1. Objective

Tabula (Typology Approach for Building Stock Energy Assessment) was a project commissioned to develop residential building typologies in 13 EU countries. Funding for the project was provided by the Intelligent Energy Europe (IEE) Programme of the EU. Several project partners from different EU countries participated on a voluntary basis. Each country's national residential building typology includes a classification of residential buildings according to size, age and other parameters and a set of "exemplary" buildings representing typical building types. National typologies are in the country-specific "Building Typology Brochures". The Tabula project was completed in 2009-2012 and the building typology data is being used in the Episcope project (2013-2016).

The Tabula Webtool provides data on each country's exemplary buildings including their estimated energy use, energy costs and CO2 emissions based on the current typology, basic refurbishment and advanced refurbishment. The energy data is calculated using a common reference procedure across the participating countries to enable cross-country comparisons. More information on the detailed building and system data accessible via Tabula web tool can be found on their website.

The typology data consists of:

- The division of residential building stocks in size and age classes
- Data of exemplary buildings: visual appearance, commonly found construction elements and corresponding U-values
- Data of exemplary heat supply systems: commonly found system types and their energy performance indicators
- Typical values for the energy consumption by energy carriers
- Old buildings: energy saving measures on two quality levels and their impact on the energy consumption

- New buildings: examples for realization on three energy performance levels (1) minimum requirements, (2) improved and ambitious, (3) NZEB standard (assumed or announced level of Nearly Zero-Energy Buildings)
- Standard reference calculation procedure based on an agreed data format, user conditions and national climatic data
- Calibration of the standard calculation procedure to the typical level of measured consumption

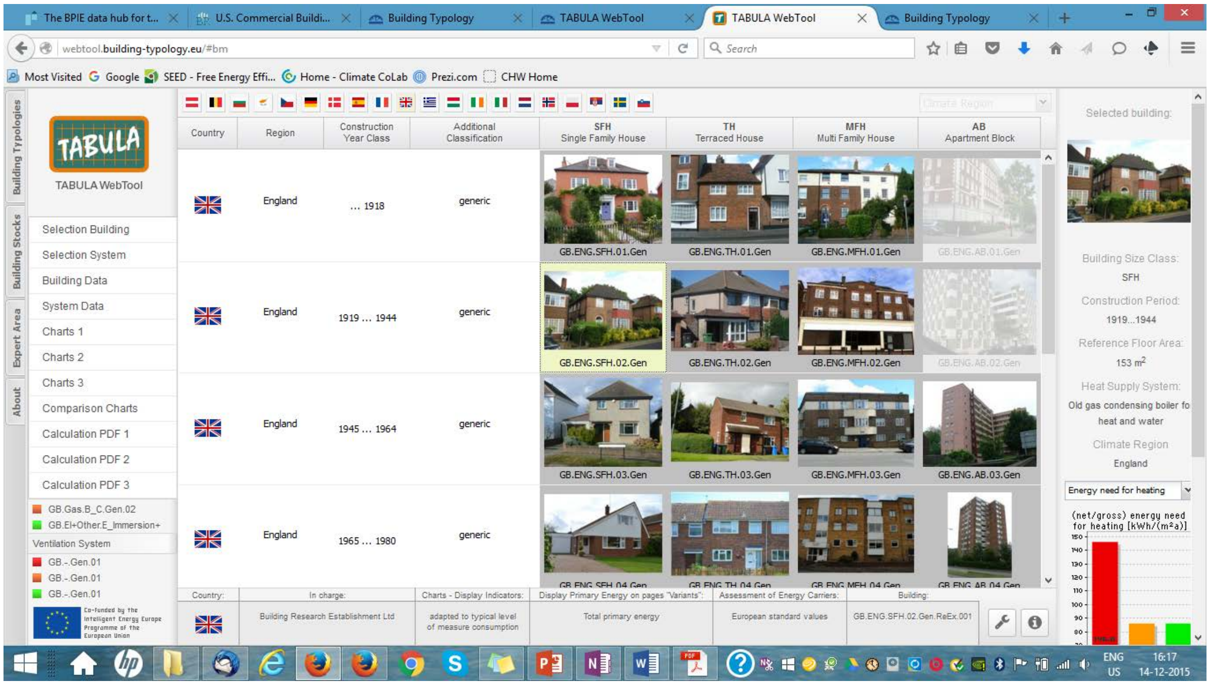


Figure 2.1 Data View for a Type of Single Family Home in the UK

3.2.2. Summary of Data

Table 3.2 Tabula Data Overview

Building Segment	Residential
Policy Objective	Maintain a database of "exemplary" buildings covering the main building typologies in a country and provide estimates of energy use, energy cost and CO_2 emissions based on various levels of building refurbishment. Data could/would be used for policy, building requirements, financial purposes, etc.
Country / EU Scope	EU (country-specific data, EU-wide programme)
Current Status	Project completed in 2012, but data is used & updated via the Episcope project on building stock monitoring (building refurbishment projects & energy monitoring in those buildings)
Key Energy Indicators	• Energy intensity for space heating and hot water (kWh/m^2) • Energy cost for space heating and hot water (€/m^2) • CO_2 emissions for space heating and hot water (kg/m^2)

Data Collection Method	• Existing databases (e.g. Institute of Statistics, Land Registry, Energy Certificate Databases, etc.) on buildings and energy/energy balance; • Housing surveys; Population census; Socio-economic survey • Targeted surveys on energy efficiency in houses • Existing literature (e.g. energy guides, etc.)
Data Modelling	• Country-specific Energy models to calculate energy consumption for space heating and hot water • EU-wide common calculation methodology for energy consumption and CO_2 emissions
Normalization	Common EU-wide reference calculation procedure based on an agreed data format, user conditions and national climatic data. http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf
Relevance to India Commercial Building Data Framework	**Medium** Good reference for building classification, building structural data and key energy indicators, even if only for residential buildings. Report on non-residential buildings also available.

Type of Data

The following table gives a *sample* of the type of raw data and derived data/indicators available in Tabula for residential buildings. The Tabula tool has data only for residential buildings, classified according to specific "exemplary" typologies. The tool has raw data and modelled data and indicators for the existing state of buildings, as well as for two levels of refurbishment (usual & advanced).

Tabula appears to be more of a reference tool based on example buildings with real building structural data from surveys and modelled energy data rather than a LIVE system with actual energy data being updated periodically via meters and utility systems. The data from Tabula is now used in the Episcope tool for ongoing building refurbishment projects.

Data is collected for each country and presented as that country's national typology. However, there is a common structure and format for calculating energy consumption and CO_2 emissions and for presenting the data.

Table 3.3 Data Available in Tabula

Type of Data / Indicator	Description
Building Data	
Building size class	For e.g. single family home, multi-family home, apartment, etc.
Age of building / Construction Period	Based on year of construction; listed as construction period (e.g. 1965-1980)
Reference Floor Area	Measured in m^2
Climate Region	e.g. England
Climate Code	e.g. temperate
Roofing	Type of roofing, surface area in m^2, U-value of material
Walls	Type of walls, surface area in m^2, U-value of material
Floors	Type of floors, surface area in m^2, U-value of material
Windows	Type of floors, surface area in m^2, U-value of material
Doors	Type of floors, surface area in m^2, U-value of material
System Data	
Space Heating System	Type of system, fuel used (gas, oil, electricity, etc.), storage type, distribution type (central, room), energy expenditure coefficient, heat losses
Hot water System	Type of system, fuel used (gas, oil, electricity, etc.), storage type, distribution type (central, room), energy expenditure coefficient, heat losses
Energy Indicators	
Energy for space heating	Measured in kWh/m^2
Energy for space heating & hot water	Measured in kWh/m^2
CO_2 emissions for space heating & hot water	Measured in kg/m^2
Energy Cost for space heating & hot water	Measured in €/m^2

Data Access

Tabula data is publically accessible. Anyone, even outside EU, can obtain information on various building typologies across all the EU countries. Detailed information on building structure and systems for the selected building type can be viewed. Further, country-specific documentation is available in English as a PDF file even for non-English speaking countries.

Data Sample: Country for UK

Table 3.4 Tabula Data Sample[9,10]

Type of Data Collected	• Type of dwelling (e.g. Single Family home (SFH), MFH, etc.); • Age of dwelling based on period of construction (e.g. 1965-1980) • Frequency of dwelling type in national building stock; • Information on insulation level, type of windows, doors, floors, roof and u-values and g-values; • Centralisation of the heat supply; • Heat generation of space heating systems; • Heat generation of domestic hot water systems; • Solar thermal systems; • Control of central heating systems; • Domestic energy consumption
Data Collection Method	• Building & system data taken from English Housing Survey 2009 https://www.gov.uk/government/collections/english-housing-survey Data from 13,300 houses via household interview; further physical inspection of 6,200 houses by a qualified surveyor Analysis done on combined data for two years • Energy consumption data taken from Dept. of Energy & Climate Change
Data Modelling	For Energy Consumption: Secondary Analysis of data from Building Research Establishment & modelling using *Government's Standard Assessment Procedure for Energy Rating of Dwellings: 2009* http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf
Frequency of collection	English Housing Survey is done annually to collect information on people's housing circumstances and the condition and energy efficiency of houses. Tabula tool first updated in 2009.
Volume of "Real" Data Collected	Sample size: 24,642 dwellings
Derived Indicators	Energy needed for space heating in kWh/m^2 per year using energy models
Normalization of Data	Common EU-wide reference calculation procedure based on an agreed data format, user conditions and national climatic data. http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf
Presentation of Data	The final number of sample dwelling types in the Tabula tool is 35. The final number of system measures in the tool is 28.

3.3. Episcope

3.3.1. Objective

The objective of Episcope is to develop a scheme for energy performance indicators for residential building stock. The Episcope tool tracks and monitors energy refurbishment projects in different EU countries. The tool uses data from Tabula and feeds updated information back into Tabula. Like Tabula, funding for the project is provided by the Intelligent Energy Europe (IEE) Programme of the EU.

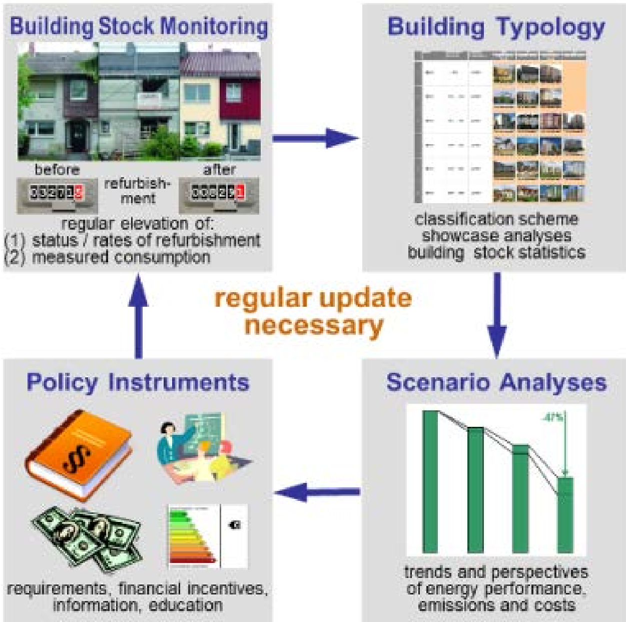


Figure 3.2 Use of Episcope

3.3.2. Summary of Data

Table 3.5 Episcope Data Overview

Building Segment	Residential
Policy Objective	Develop energy performance indicators for residential building stock to increase knowledge of energy saving opportunities. Data could/would be used for policy, building requirements, financial purposes, etc.
Country / EU Scope	EU (country-specific data, EU-wide programme). Based on 16 pilot projects in different EU countries.
Current Status	This is an ongoing project, with a time-frame of 2013-2016. The focus currently is on refurbishments in order to address thermal protection and heating supply in residential building stocks.
Key Energy Indicators	Because the project is still ongoing the energy performance indicators are not yet finalized. Some of the "summary" indicators proposed for the entire residential building stock include: • Annual CO_2 emissions for heat supply (kg/m^2) • Annual total heat demand (kWh/m^2) • CO_2 emission factor for heat supply (kg/kWh)
Data Collection Method	• "Monitoring" indicators which are data on building stock and heat supply systems would be collected via surveys, building registries, etc. • Annual measured energy consumption for residential buildings from national data; would need further analysis to normalise for weather and exclude non-heating related consumption
Data Modelling	Modelling on "basic monitoring data" + "trend indicators (on thermal insulation & heat supply in development projects over a certain period)" to generate current and future/scenario energy balance indicators
Normalization	Common EU-wide reference calculation procedure for building reference area. http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf
Relevance to India Commercial Building Data Framework	**Medium** Good reference for monitoring energy performance and energy-efficiency refurbishments in the building stock of a country. Could help track the impact and effectiveness of policies to promote energy efficiency in buildings.

Type of Data

The Episcope tool uses data from the Tabula tool and is still in the process of being developed. The next release is expected to be in end 2015.

The data is primarily to do with the state of the building stock in a country with respect to various parameters such as distribution by building type, age, type of heating and hot water systems, other technical systems, insulation levels, etc.

A sample of the data that can be viewed for each country is presented in the table below.

Table 3.6 Data Available in Episcope

Type of Data / Indicator	Description
Building Data	
Total area by building type	Indicates the total country-wide gross floor area (m^2) and useful floor area (m^2) per type of building (e.g. single family home, apartment)
Total number of buildings by building type	Indicates the total country-wide count of buildings per type of building (e.g. single family home, apartment)
Total number of dwellings/units by building type	Indicates the total country-wide count of units per type of building (e.g. multi-family house, apartment)
Total area by building age	Indicates the total country-wide gross floor area (m^2) and useful floor area (m^2) by age of building (e.g. 1984-1994, 1995-2001, etc.)
Total number of buildings by building age	Indicates the total country-wide count of buildings by age of building (e.g. 1984-1994, 1995-2001, etc.)
Total number of dwellings/units by building age	Indicates the total country-wide count of units by age of building (e.g. 1984-1994, 1995-2001, etc.)
Building insulation levels	Country-wide % share of dwellings and buildings by level of insulation (level 0, level 1, level 2) for • Wall • Roof • Ground floor • Window
Building insulation improvements	Country-wide % share of dwellings and buildings with insulation improvements for • Wall • Roof • Ground floor • Window
Average thickness of improved insulation	Average thickness (mm) of improved insulation for walls, roofs, ground floor
Average quality of improved windows	% of building stock with double glazing and triple glazing windows
System Data	
Centralisation level for heating	Country-wide % share of dwellings and buildings with • building/apartment heating • district heating • room heating

Centralisation level for domestic hot water	
Heating systems per source	Country-wide % share of dwellings and buildings with heating systems whose fuel source is • biomass • coal • electricity • gas • oil • other
Availability of cooling systems	Country-wide % share of dwellings and buildings with cooling systems
Domestic hot water systems per source	Country-wide % share of dwellings and buildings with hot water systems whose fuel source is • electricity • gas • other
Availability of mechanical ventilation	Country-wide % share of dwellings and buildings with mechanical ventilation
Technical Systems Improvements	Country-wide % share of dwellings and buildings with improved/modernized systems for space heating and hot water
Energy Indicators	Energy Performance Indicators are still being developed. A draft version of the indicators is available in the report *Energy Performance Indicators for Building Stocks (March 2014)*[11]

Data Access

Episcope is also publically available. Anyone, even outside EU, can search and get information on country-wide data in the tool.

Data Sample: Case Study in Ireland

The Irish case study is on monitoring energy refurbishment levels of housing stock on the North side of Dublin City, outlined in the *National Report of the Irish Pilot Action (July 2015)*.[12]

3.4. Mure

3.4.1. Objective

The Mure tool is a data warehouse of energy efficiency (EE) policies and their impact, where available, in various EU countries. (http://www.measures-odyssee-mure.eu/).Funding for the project is also provided by the Intelligent Energy Europe (IEE) Programme of the EU.

The data is categorized by the following sectors: Household, Tertiary (equivalent to commercial buildings), industry, transport.

Users can search the database by country or EU as a whole, target end use (e.g. appliance, lighting, etc.), actor (e.g. utility, local government, etc.), target audience (e.g. owners, researchers, professionals, etc.) and type of policy implementation (e.g. regulation, financing).

http://www.measures-odyssee-mure.eu/query-energy-efficiency-policy-tertiary.asp

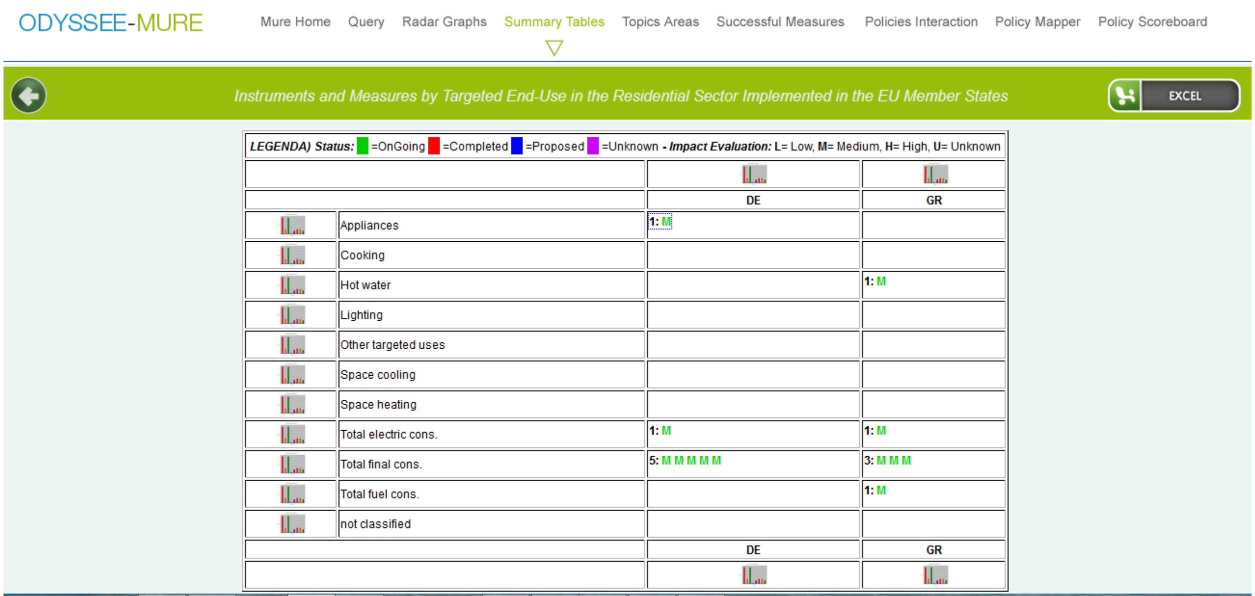


Figure 3.3 Mure Search by Target End-Use in Germany and Greece

3.4.2. Summary of Data

Table 3.7 Mure Data Overview

Building Segment	Residential, Tertiary/Commercial, Industrial
Policy Objective	Data warehouse of energy efficiency policies, their status and impact in EU countries and EU-wide.
Country / EU Scope	EU (country-specific data, EU-wide programme).
Current Status	This is an ongoing project.
Key Energy Indicators	N/A - Specific to each policy
Data Collection Method	Information on policies updated once a year by national teams.
Data Modelling	N/A
Normalization	N/A
Relevance to India Commercial Building Data Framework	**Medium** Good system for tracking policy implementation and results.

Type of Data

The main data in the Mure data warehouse is EE policy documentation which includes the following:

- Detailed information about the policy, including measurements, expected and/or actual results

- Status of policy implementation
- Level of Impact

The policies in the Mure data warehouse are tagged/referenced by several data categories. The table below gives some of the data tags applied to policies for the "Tertiary" sector, which maps to commercial buildings.

Table 3.8 Data Available in Mure

Level 1	Level 2	Level 3, Level 4
Country	Each EU member + Norway	N/A
EU	N/A	N/A
Policy Measure Type	Co-operative Measures	e.g. Technology Procurement for EE Appliances, EE Buildings / Components; e.g. Voluntary Agreements with public or private services
Policy Measure Type	Cross-cutting with sector-specific characteristics	e.g. Eco-tax on electricity/energy consumption or CO2 emissions
Policy Measure Type	Financial	e.g. grants & subsidies, soft loans
Policy Measure Type	Fiscal/Tariffs	e.g. tax exemption
Policy Measure Type	Information/Education/Training	e.g. awards, campaigns
Policy Measure Type	Legislative/Informative	e.g. mandatory annual energy report; e.g. mandatory energy audit in buildings; e.g. mandatory building standards
Targeted End Use	Commercial Appliances	Refrigeration, Washing, Cooking
Targeted End Use	Hot Water	N/A
Targeted End Use	ICT	Office Equipment, Servers
Targeted End Use	Lighting	N/A
Targeted End Use	Motive Power/Electric motors	N/A
Targeted End Use	Space Heating	N/A
Targeted End Use	Total electric consumption	N/A
Targeted End Use	Total fuel consumption	N/A
Actors	Central Government	
Actors	Energy Agencies	
Actors	Manufacturers	
Actors	Financial Institutions	
Target Audience	SME	
Target Audience	Large Enterprise	
Target Audience	Researchers	

Level 1	Level 2	Level 3, Level 4
Tertiary Sectors	Commercial Offices	
Tertiary Sectors	Warehouses	
Tertiary Sectors	Education	
Tertiary Sectors	Health	
Evaluation Method	Deemed Estimate Unit Savings	
Evaluation Method	Direct Measurement	
Impact	Low, Medium, High	
Status	Complete, Ongoing, Proposed	

Type of Policy Measures

The types of policy measures by topic (e.g. buildings, SMEs, vehicles, etc.) can be searched via the "Topic Areas" menu item. A sample of the policy measures for energy efficiency in tertiary/commercial buildings is provided in the following table. The actual policy information listed is a very brief summary rather than details on the policy and how it is to be implemented.

NOTE: Some policies are aimed at several measures and are therefore listed/counted under all those measures.

Table 3.9 Mure Policy Measures

Type of Measure	Availability	Examples
Technology procurement for energy efficient buildings / components	13 measures across 12 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/CZ7.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/EU12.PDF
Financial incentives for architects who integrate EE measures	1 measure in Belgium	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/BEL16.PDF
Energy audits / training / benchmarking activities	21 measures across 13 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/CR17.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/FRA15.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/GER25.PDF
Energy Efficiency Investment	135 measures across most EU countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/GER49.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/LT13.PDF
Mandatory audits in large and small tertiary sector buildings	35 measures across 13 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/GER32.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/POR11.PDF
Mandatory energy efficiency certificates for buildings	32 measures across 17 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/GER33.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/BG9.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/POR15.PDF

Energy performance standards	62 measures across 23 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/EU14.PDF
Minimal thermal insulation standards	46 measures across 19 countries	http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/GER35.PDF http://www.measures-odyssee-mure.eu/public/mure_pdf/tertiary/SPA40.PDF

Data Access

Mure is easily accessible to the public. Anyone, even outside EU, can obtain information on various aspects of policies as given in the above table. Detailed policy documentation is available in English as a PDF file even for non-English speaking countries. SPA37 is an example of a successful policy measure from Spain, which provides details of the regulation of thermal installation in buildings.

3.5. Odyssey

3.5.1. Objective

The primary objective of Odyssey is to monitor energy consumption and energy efficiency trends through Energy Efficiency indicators, CO_2 indicators and on energy consumption across several sectors (e.g. industry, transport, residential and services) for 28 EU countries. Funding for the project is provided by the Intelligent Energy Europe (IEE) Programme of the EU. The project is managed by Enerdata.

The Odyssey tool has several components:

- **Key Indicators,** which has close to 30 energy-related and CO_2-related indicators
- **Market Diffusion,** which has data on the adoption of energy-efficient appliances, equipment, alternative fuel
- **Decomposition,** which indicates change in energy consumption from year to year and the reason for it, i.e. climatic, activities, energy savings, etc.
- **Benchmarking,** which displays a country's energy performance in comparison to another country, across sectors
- **Energy Saving,** which displays energy consumption trends
- **EE Indicator Scoreboard,** which indicates the EE position of each country across different sectors
- **Database,** which has all energy indicators and data

Figure 3.4 Odyssey Key Indicators

3.5.2. Summary of Data

Table 3.10 Odyssey Data Overview

Building Segment	Residential. There are indicators for the "Services" sector which include commercial establishments, but these are given as energy/electricity use per employee or GDP, rather than per building or m^2.
Policy Objective	Monitor energy consumption and energy efficiency trends; use this data in conjunction with policy information in the Mure database to gauge the overall impact of policies.
Country / EU Scope	EU (country-specific data, EU-wide programme)
Current Status	This is an ongoing project, with data being updated by national teams once a year.
Key Energy Indicators	Households: • Total energy consumption per dwelling (toe/dw) • Electricity for lighting & appliances consumption per dwelling (kWh/dw) • Total energy consumption per dwelling scaled to average EU climate (toe/dw) • Heating energy consumption per dwelling (toe/dw) • Heating energy consumption by area (koe/m^2) Service (includes commercial establishments): • Energy consumption per employee (koe/employee) • Electricity consumption per employee (kWh/employee) • Energy Intensity in koe/k€ (€2005 at PPP) • Electricity Intensity in kWh/ k€ (€2005 at PPP)
Data Collection Method	This information is in several reports, accessible via http://www.odyssee-mure.eu/publications/other/
Data Modelling	This information is in several reports, accessible via http://www.odyssee-mure.eu/publications/other/
Normalization	Weather normalization for some energy indicators, primarily applied to space heating metrics.
Relevance to India Commercial Building Data Framework	**Medium** Good reference for high-level indicators for residential buildings. However, the non-residential buildings sector is not covered separately or in detail w.r.t. building parameters. The "Services" indicators could probably be for commercial buildings.

Type of Data

Key indicators are available at the macro level and at sector level for industry, transport, households and service (commercial buildings). The main indicators are given in the table below.

Table 3.11 Data Available in Odyssey

Macro Indicators	• Overall EE gains in % • Final Intensity in koe/k€ (€2005 at PPP) • Primary Intensity in koe/k€ (€2005 at PPP)
Services Indicators	• Energy consumption per employee in koe/employee • Electricity consumption per employee in kWh/employee • Energy Intensity in koe/k€ (€2005 at PPP) • Electricity Intensity in kWh/ k€ (€2005 at PPP)
Market Diffusion Indicators - Efficient Heating	• Share of dwellings with renewable heat pumps measured in % • Sales of renewable heat pumps measured in units/1000 dwellings • Share of dwellings with condensing boiler measured in % • Sales of condensing boiler measured in units/1000 dwellings • Solar water heater installation measured in m^2/habitant • Sales of solar water heaters measured in m^2/1000 habitants • Share of dwellings with solar water heaters measured in %
Market Diffusion Indicators - Efficient Appliances	• Share of refrigerator sales with energy class >= A+ measured in % • Share of freezer sales with energy class >= A+ measured in % • Share of washing machine sales with energy class >= A+ measured in % • Share of dishwasher sales with energy class >= A+ measured in %
Smart Meters	Share of dwellings with smart meters measured in %

There is also an Energy Efficiency Scoreboard based on the following scoring methodology

http://www.indicators.odyssee-mure.eu/php/odyssee-scoreboard/documents/methodology-odyssee-scoreboard.pdf

Data Access

Like the other EU programs described above, data is publically available. Anyone, even outside EU, can obtain information on various indicators for countries and the EU as a whole via the web-based tool. However, access to the main database is restricted.

3.6. Entranze

3.6.1. Objective

The primary objective of Entranze was to provide support for evidence based policy making by providing data, analysis and guidelines to achieve a significant level of penetration of nZEB (nearly Zero Energy Buildings) and RES-H/C (Renewable Heating and Cooling). Entranze draws data from Odyssey, Tabula, Eurostat and UEPC systems, all of which except UEPC are accessible via the BPIE data hub. The project was co-funded by the Intelligent Energy Europe (IEE) Programme of the EU and includes partner organizations in participating countries. A brief project report is available on the Entranze website.

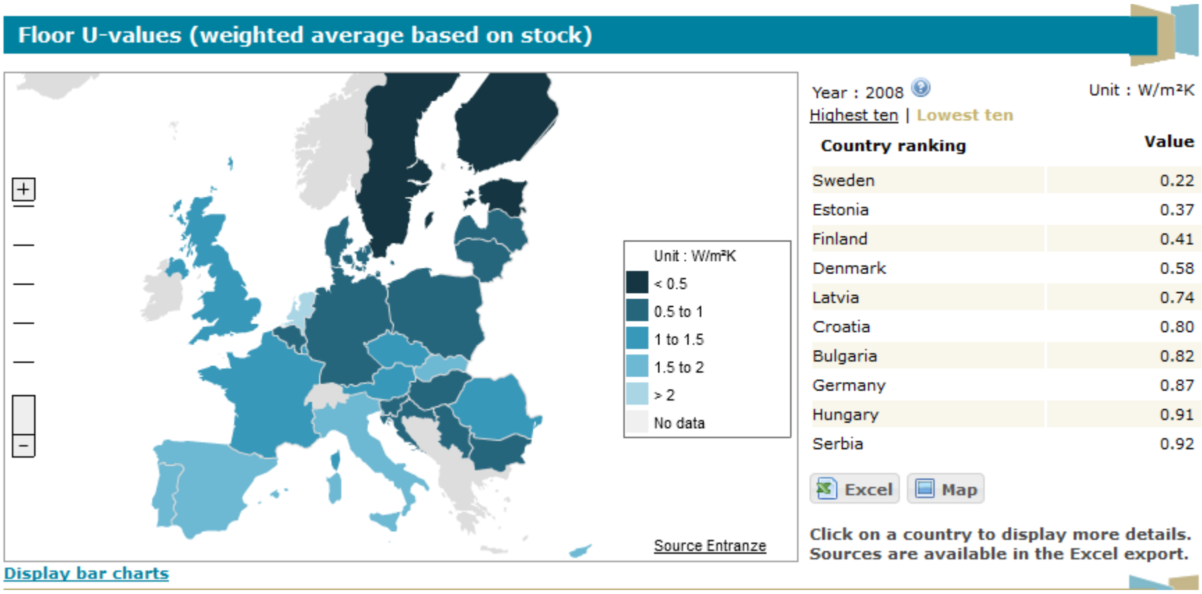


Figure 3.5 Entranze Data Tool

Figure 3.6 Entranze Scenario Tool

3.6.2. Summary of Data

Table 3.12 Entranze Data Overview

Building Segment	Residential, Commercial/Non-residential
Policy Objective	To support evidence based policy making to promote nZEB (nearly Zero Energy Building) and RES-H/C (Renewable Heating and Cooling).
Country / EU Scope	EU (country-specific data, EU-wide programme)
Current Status	The project duration was April 2012 – September 2014.
Key Energy Indicators	For residential buildings, • Total energy consumption by area (kWh/m^2) • Heating energy consumption per dwelling (kWh/dw), broken down by type of fuel • Share of energy consumption for space heating and water heating as % of total energy consumption For non-residential • Total energy consumption by area (kWh/m^2)
Data Collection Method	Data is pulled from Tabula, Odyssey, Eurostat and UEPC.
Normalization	Weather normalization done for total energy consumption by area for both residential and non-residential sectors, as well as for energy consumption for space heating.
Relevance to India Commercial Building Data Framework	**Medium** Good reference for Residential data and for scenario modelling. Can possibly compare with IESS.

Table 2.13 Data Available in Entranze

Non-residential Buildings	• % share of non-residential area in total building area • % share of non-residential area broken down by sub-sector (e.g. education, office, hotel, etc.)
Residential Buildings	• U-values (weighted average based on stock) for floor, wall, ceiling, windows for each country • % share of building stock by dwelling type • Average floor area (m^2) per type of dwelling
Heating / AC systems	• % share of dwellings by type of heating (e.g. central, room, district, etc.) • % share of dwellings by heating source (e.g. oil, gas, electricity, etc.) • % share of dwellings with air conditioning
Energy Use	Residential buildings: • Total energy consumption by area (kWh/m^2) • Heating energy consumption per dwelling (kWh/dw), broken down by type of fuel • Share of energy consumption for space heating and water heating as % of total energy consumption Non-residential buildings: • Total energy consumption by area (kWh/m^2)

Data Access

Anyone, even outside EU, can view all indicators country-wise and EU-wide.

4. SINGAPORE BUILDING ENERGY DATA FRAMEWORK

4.1. Executive Summary

Building Energy Submission System (BESS) is a recent initiative of the Government of Singapore. The system requires reporting of building energy related data by building owners, and thus, the system enables the owners to compare their building EUI with those of their peer group. Though the building energy consumption details are made available only to building owners, the Building and Construction Authority (BCA) releases an annual report highlighting energy consumption patterns among commercial buildings, as well as a comparison of green-rated building performance to the rest of the building stock. BESS is particularly successful at collecting data that that affect building energy consumption.

BESS has significant relevance to the Indian data framework as Singapore has tropical climate and most of the commercial building energy demand is driven by space cooling, similar to India. Since it will be critical for India to capture those variables that impact the cooling demand, a comparison of the data framework may prove useful. Additionally, as a fairly recent initiative, BESS gives India the opportunity to examine an evolving program in a similar environment.

4.2. BESS

4.2.1. Objective

BESS was launched in 2013 by the BCA to monitor the energy efficiency of the existing commercial buildings in Singapore and to formulate the national energy benchmark. BCA is an agency under the Ministry of National Development, Singapore. Under Section 22FJ of Building Control Amendment Act 2012, starting in 2013, building owners are required to submit building information and energy consumption data relating to their buildings to the BCA annually. BCA's objective is to present a snapshot of evidence based energy performance of commercial buildings in Singapore.

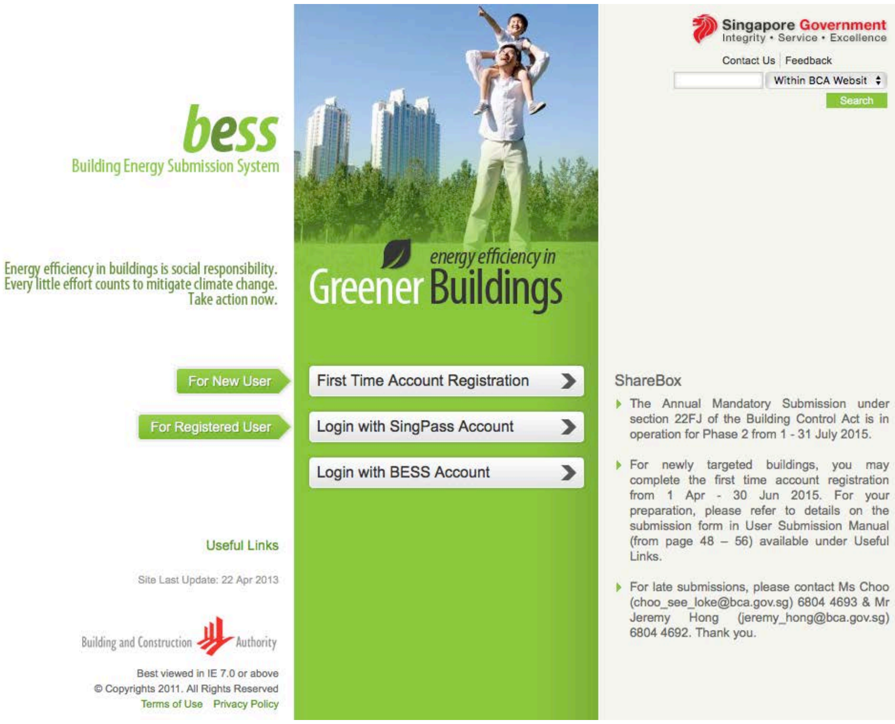


Figure 4.1 BESS Submission Panel

4.2.2. Sampling Methodology

BESS analyzed 884 buildings in 2013 and 1018 buildings in 2014. A total of 783 comparisons were conducted in the 2014 analysis. Individual building owners (with the help of building submission representative/officer) submit building information directly to BESS. The BCA Building Energy Benchmarking Report was first published in 2014 and then again in 2015. Post publication, an outreach workshop is conducted with building owners.

The benchmarking data is made available to the building owners so that they can pro-actively improve their building energy performance/ energy consumption behaviours of users. With comparative energy consumption information being available, building owners of offices, hotels, retail buildings and mixed development are better equipped to understand the performance of their buildings.

4.2.3. Overview of System

System	Description
BESS	• Nationwide existing commercial building detailed data collection on ownership and activity (building occupancy type/ activity type/ green mark labelling), building data (gross floor area, carpark area, number of rooms, major retrofitting), building services information (lifts/ ACMV/ lighting/ hot water systems/ building electricity and other fuels consumption. • Launched in 2013 and is conducted annually. • Key outcomes include summary tables on building total annual energy demand, monthly energy demand and EUI

4.2.4. Summary of Data

Table 4.1 BESS Data Overview

Building Segment	Commercial (Offices, Hotels, Retail Buildings, Mixed use developments)
Policy Objective	To present a snapshot of evidence based energy performance of existing commercial buildings and to formulate the national energy benchmark. Encourage buildings owners to pro-actively engage to improve their building energy performance/ energy consumption behaviours of users.
Country/ Scope	Singapore, Existing commercial buildings, In 2014 1018 buildings energy performance was analysed
Current Status	BESS was launched in 2013 and since then buildings energy performance analysis is carried out annually and published. BCA Building Energy Benchmarking Report released in 2014 & 2015
Key Energy Indicators	Information on Building energy consumption compared to similar building types is provided to building owners. Key energy indicators provided are: Total annual energy consumption (kWh) Energy Utilisation Index (EUI-kWh/m^2/yr) Monthly Energy Consumption graph (kWh) Yearly Energy Consumption graph (kWh)
Data Collection Method	Submitted by building owners with the help of building submission representative and building submission officer on BESS website, annually

Relevance to India Commercial Building Data Framework	**Medium** Good reference for high-level indicators for commercial buildings and implementation of firm level actions (Section 22FJ of Building Control Amendment Act 2012) to improve building energy efficiency. Extensive data has been used for analysis; however, data is not publically available.

Type of Data

Table 4.2 Data Available in BESS

Type of Data / Indicator	
Ownership & Activity	
Building Ownership Type	Building Owner, Developer, MCST, REITs, Others
Building Ownership Setup	Single Individual, Multiple Individual, Single Corporation, Multiple Corporation, Individual & Corporation, Others
Building Occupancy Type	Owner Occupied, Single Tenant, Landlords + Multi Tenants, Others
Building Activity Type	Public Sector Building/ Facilities, Commercial & Residential, Commercial (Bank, Cinema, Clinic, Commercial School, Convention/ Exhibition centre/ Entertainment, Foreign Trade Mission/ Chancery, Market/ Food Centre/ Restaurant, Medical Suite, Mixed Uses (Office/ Shopping/ Cinema/ Hotel/ Flat), Offices, Recreation Club)
Green Mark Building	Year of Rating, Rating achieved, Green Mark Incentive Schemes, Building Retrofit Energy Efficiency Financing scheme (BREEF)
Building Data	
Gross Floor Area (GFA) Exc. Carpark area (approx.)	total floor area excluding carpark area (m^2)
Gross Lettable Area	gross lettable area, this excludes common service areas like lifts, stairs etc. (m^2)
Average Building Occupancy Rate	[(Total area occupied/Total area available)/12]*100
Air-conditioned Floor Area (Approx.)	Total Air-conditioned floor area (m^2)
Number of Blocks	Total number
Number of Hotel Rooms	Total number
Data Centres/ Server Room Area	Area (m^2)
Carpark Area	Area (m^2)
Carpark Type (You may choose more than one types where applicable)	Open/ Surface Carpark Multi-storey/ Elevated Carpark Basement Carpark
No. of Carpark Lots	Total number

No. of Carpark Storey Above Ground	Number
No. of Carpark Storey Below Ground	Number
Type of Carpark Mechanical Ventilation (MV) systems (you may choose more than one type where applicable)	Natural Vent/ Exhaust Only/ Supply and Exhaust, Ducted, Ductless Fan
Carpark MV system with CO sensors	Yes/ No
Date of last major renovation/ retrofitting works (Works on envelope, extension, lighting, ACMV etc.)	Date
Type of major renovation/ retrofitting	Change of façade, replacement of chiller systems, building extensions, replacement of lift systems/ escalators, others
Building Service Information	
Lifts, Escalators & Travellators	Type of Lift (Geared, Gearless, Regenerative lift, Others) Type of Motor used (VVVF motors and without VVVF motors) Type of mode used (sleep mode, without sleep mode) Types of escalators and travellators systems (constant speed, sensor based)
ACMV (Air conditioning and mechanical ventilation)	Type of Centralised Air-Conditioning System (District Cooling System, Water Cooled Central Chilled Water, Air Cooled Central Chilled Water, Water-Cooled Central Chilled Water, Water-Cooled Packaged Units) Total Cooling Capacity (RT) Total number of Chillers (Individual chiller capacity, years in operation, average peak running load per day) Air-con system efficiency (kW/RT) Number of Fan Coil Units Number of Air Handling Units Type of Air Distribution System (Constant Air-Volume and Variable Air Volume) Average Building Operating Hours/ Week
Lightings	Select from list lighting types and indicate their type of space and percentage used in buildings
Hot Water Systems	Electric Water Heaters Gas Storage Water Heaters Gas Instantaneous Water Heaters Oil Storage Water Heaters

	Oil Instantaneous Water Heaters Hot Water Supply Boilers- Gas and Oil Hot Water Supply Boilers – Gas Hot Water Supply Boilers – Oil Others
Building Energy Consumption	
Building Energy Consumption	Monthly Electricity Consumption (kWh)
Fuel Type	Annual Fuel Consumption (Diesel (litres), Natural Gas (kWh) & Town Gas (kWh))

Data Access

Data from BESS does not appear to be accessible to the public, government agencies, researchers, or businesses. Through their registered channels, individual building owners can access the information about their building. The Annual report which provides an overview of the energy consumption by existing commercial buildings, however, is published for public access.[v]

Recommendations

BCA could consider including more details on other end-uses, including energy consumption due to building water pumping/ waste water treating systems (if any).

5. CHINA BUILDING ENERGY DATA FRAMEWORK

5.1. Executive Summary

China's commercial building energy use data collection efforts are considerably more fragmented than those of the U.S. or Europe. Until recently, there had been no centralized effort to regularly collect such data through a system-level approach. Most data collection efforts in China are conducted on a local level, with a series of energy use monitoring platforms (EUMPs) and databases in key provinces and municipalities. In more recent years, the Ministry of Housing and Urban-Rural Development (MOHURD) has sought to centralize this data under a national EUMP, but has found little success.

The general lack of transparency regarding type of data collected and methodology, as well as limited data accessibility makes it difficult to assess the relevance of China's efforts for establishing a data framework in India. As in the case of China, India could potentially consider approaching data collection both at a national as well as sub-national level. One key takeaway is that if a country-wide, unified data framework is the ultimate goal, it is best to begin with a centralized, uniform approach. While effective

[v] http://www.bca.gov.sg/GreenMark/others/BCA_BEBR_Abridged_FA_2015.pdf
http://www.bca.gov.sg/GreenMark/others/BCA_BEBR_Abridged_FA.pdf
https://www.bca.gov.sg/BESS/

locally, autonomous regional efforts that are not standardized will create a fragmented and inconsistent data network that is difficult to effectively reconcile.

Table 5.1 Overview of Systems and Tools Related to EE in Buildings

System	Description
Sub-National-Level Programs	• EUMPs have been established in Beijing, Tianjin, Shenzhen, Shanghai, Hangzhou, Qingdao, Nanning, Nanjing, and Chongqing. • Initiated in 2007 • No standardized methodology, energy information systems, components, or reporting strategies known. • Focus on using metering and sensing technologies to obtain building energy consumption data. • Many of these EUMPs have been highly successful
National-Level Programs	• MOHURD currently employs a national database for real-time, online energy monitoring, and is working to connect local efforts to its platform. • National platform considered to be unsuccessful, largely due to gaps in the data. • Project underway with the World Bank and Global Environment Facility (GEF) to unify localized platforms to a national Chinese building energy performance benchmarking methodology, platform, and tool.

5.2. Sub-National and National Data Collection Efforts

Sub-National

Historically, universities and other organizations (primarily building research institutes) have largely been left to collect commercial building energy use data via their own means. Tongji University, the Fujian Academy of Building Research, the Wuhan University of Science and Technology, the China Academy of Building Research (CABR), and Chongquing University have all pioneered large metering projects.[13] The CABR also constructed its own successful web-based benchmarking tool for hotels based primarily on CBECS and ENERGY STAR (see table 5.3).[14] While disjoint, these private and local efforts have proven to be more successful and exemplary than national ones. In 2007, MOHURD and the Ministry of Finance (MOF) jointly initiated pilot project EUMPs in key provinces and municipalities. Programs have since been established in Beijing, Tianjin, Shenzhen, Shanghai, Hangzhou, Qingdao, Nanning, Nanjing, and Chongqing.[13] These city-level monitoring platforms have consistently provided accurate, reliable, and granular data that has proved useful in a variety of applications- from ensuring building code compliance to identifying audit opportunities.

National

China recently launched an initiative to link these local data collection efforts onto a single national platform. Currently, MOHURD "employs a centralized national platform for real-time, online energy monitoring which accesses data for thousands of buildings." MOHURD is working to connect these provincial and city-level platforms to its national platform with the cooperation of local building research institutes and MOHURD offices.[13] This effort has not yet met expectations, however, with MOHURD CSTC and Tsinghua University both noting it has failed to provide large-scale, reliable, real-time energy data sets. If successfully implemented, a national real-time online monitoring platform would be a robust and useful resource.

Further, in In 2013 MOHURD launched a project (Urban-Scale Building Energy Efficiency and Renewable Energy Project: Energy Performance Benchmarking & Disclosure in Large Public and Commercial Buildings) with the World Bank and Global Environment Facility (GEF). The project plans to create a national Building Energy Performance and Disclosure Program (EPB&D) for large and commercial buildings, developed at the national level, with mandatory adoption by select cities. The project will strive to unify the localized EUMPs already in place to a national Chinese building energy performance benchmarking methodology, platform, and tool. The project is slated to be completed in 2018.[15]

5.2.1. Objective

Sub-National

The objectives of the city and provincial-level data collection efforts are not well documented, but are certainly driven by the desire to obtain data on building energy consumption, and gain insights into energy efficiency best practices.

National

Connecting the local EUMPs under a national platform was initiated with the intention of streamlining access to the data, as well as expanding the dataset for peer to peer building comparisons. MOHURD's recent project with the World Bank and GEF to establish a national EPB&D program for large public and commercial buildings has several primary objectives[16]:

- Develop a building energy performance benchmarking methodology, tool, and national platform for China under the guidance of MOHURD;
- Prepare guidelines for energy performance benchmarking and disclosure (EPB&D) for public and large commercial buildings at the national level and city level;
- Support pilot implementation and expand city-level mandatory EPB&D programs in Beijing and Ningbo, under the supervision of BHURDC and NHURDC.

5.2.2. Methodology

Sub-National

There was limited information available (particularly in English) regarding the approach and methodology used by cities and provinces for their EUMPs. The ICF study (ICF 2015) provided some insight into the energy information system (EIS) platform used by Tsinghua University. Tsinghua employs the iSagy system, which is a Building Energy Monitoring System (BEMS), uses an integrated software platform which obtains real-time energy usage data for buildings and provides data acquisition through metering/sensor devices, as well as enables data processing and mining.[13]

National

Little information was available on the methodology to unify the local EUMPs under a national platform. The project plans to draw on domestic and international expertise to develop a Building

Energy Performance Benchmarking methodology and tool, and to test them with inputs from the pilot cities. The China Academy of Building Research (CABR) will develop an interface that links the city-level EUMPs to the national-level EUMPs, a national online benchmarking platform and tool, as well as a national EBP&D database. The consolidation efforts also will provide technical advisory support to each city's survey and audit methodologies- implying that they may remain heterogeneous. Further, it was reported that a building energy performance typology and database would be established for Beijing. It is possible that this typology might be applied country-wide for consistency. [13]

The data collection initiatives in China appear to place emphasis on energy metering technology to collect data as opposed to partnering these efforts with large-scale surveys. The CABR Hotel and Office Benchmarking tool utilizes a survey as a primary data collection method, but little additional details are known. While it is possible that individual institutions are pursuing survey research efforts, it does not appear to be a significant component of the national data platform plans. The ICF study indicated that expanding these types of efforts would be a useful supplement for energy data analysis. [13]

5.2.3. Summary of Data

Given the fragmented data collection efforts and limited availability of information in English, the following summary presents an overview of the range of data being collected through these efforts on the subnational or national level, however, the effort itself is evolving and may take a different form as it moves forward. More detailed information on the EUMP organized by the Shanghai Research Institute for Building Science (SRIBS) and Tsinghua University is available in the ICF report. The table below may not be representative of all data collection efforts, and is intended only to provide an example of some of the data being collected in the subnational EUMPs for Shanghai and Beijing.

Table 5.2 Sample Sub-National EUMP Data Overview

Building Segment	Commercial and government
Policy Objective	To provide energy information on a large proportion of large commercial and government buildings.
Country /Scope	• 17 district-level EUMP, which all roll-up to a city-level online monitoring platform • Data for approximately 100 buildings is also transferred from the city-level platform to the MOHURD national platform.
Key Energy Indicators	• Equipment and system level energy consumption by fuel type • Yearly, monthly, weekly, daily, or hourly analysis of energy consumption for whole buildings or system levels (i.e. lighting). • User-defined comparison of different equipment or system level energy consumption. • Ranking and proportional analysis for equipment or system level energy consumption. • Benchmarking and indexing of total weekly energy consumption of a building or equipment/subsystem.

Data Collection Method	• Metering/sensing technology implemented (not disclosed)
Data Modelling/Other Capabilities	• Comparisons of building energy performance to Shanghai's 2013 energy performance standard • Identification of buildings for audits and retrofits (based on projected magnitude of savings) • Monitoring energy savings of retrofitted buildings • Monitors performance of green certified buildings • Integrated power software platform utilizes reference models to monitor buildings of different scales and purposes in a unified way for whole building energy use or subsystem (i.e. lighting) comparisons.
Relevance to India Commercial Building Data Framework	**Limited/Medium** Good example for EIS options and capabilities, not a comprehensive approach to commercial building energy use data collection.

Table 5.3 CABR Hotel and Office Benchmarking Survey Data Overview[17]

Building Segment	Hotels, offices
Policy Objective	Annual Energy Benchmarking Survey conducted to provide access to data for 700 hotels annually.
Key Energy Indicators	• Energy consumption measured based on utility bills • Source & primary energy use measured
Data Collection Method	• Survey (details not disclosed) • Utility bills used for energy consumption
Data Collected	• Star category (for hotels) • Number of rooms • Number of workers • Location (HDD/CDD) • Gross floor area • Annual operating hours • Floor area (heated & cooled) • Building characteristics (e.g. building envelope, windows) • Equipment characteristics (e.g. HVAC, lighting) • Occupant tendencies (e.g. lighting control habits)
Relevance to India Commercial Building Data Framework	**Limited/Medium** Similar to CBECS, but does not appear to be quite as thorough or have easily accessible documentation.

Type of Data

It's not clear whether data other than direct metered energy consumption is collected through sub-national EUMPs, or exactly what data will be available through the EPB&D Project. MOHURD indicated that due to incomplete data in the national EUMP, the only data useful for analysis is the energy consumption data.

The ICF study noted that China needed to "increase the magnitude and variety of data points it collects, including collecting data on human behavior and its impact on building energy performance, cooling and heating volume, and climate and weather patterns."[13] It also calls for more transparency on the building auditing process- which coupled with data analysis, can support the identification of energy-saving opportunities.

Based off of CBECS and ENERGY STAR, CABR's hotel and office benchmarking tool collects similar information on building occupancy, climate, etc. For example, the survey component collects data on the number of workers, building operation hours, occupancy tendencies, and cooling degree days. The survey also collects data on various building and building equipment characteristics (see Table 5.3).

Data Access

Subnational and national EUMP databases don't appear to be publically available, or at least not easily accessible. With the expansion of the national level EUMP database, as well as the impending completion of the national EPB&D project, it is likely that the transparency of and access to commercial building energy consumption data will improve.

Data Sample

Data samples of the iSagy user interface were provided by Xia Jianjun of Tsinghua University in the ICF study.[13] The screenshots depict commercial building energy use examined by hour, week, subsystem, as well as comparisons between buildings, among other variables.

Figure 5.1 iSagy Building Energy Use Trends Comparison

Figure 5.2 iSagy Total Building Electricity Use by Subsystem

5.2.4. Recommendations

The ICF study makes a number of recommendations for China's commercial building energy data collection efforts. While it highlighted the need to connect and centralize the current-city level energy monitoring platforms and create a national database for peer-to-peer data comparisons between buildings, it also forewarned that the format of China's EUMP was not an exemplary model. This may be due to the fact that local-level EUMPs preceded plans for the national-level EUMP, and thus they were not optimally designed for larger-scale integration. Additional recommendations included[13]:

- Define the roles and responsibilities of key stakeholders in data acquisition and analysis processes.
- Develop regulations to establish a standard approach for developing energy use monitoring platforms.
- Develop standard methodologies and definitions for reporting energy use data
- Improve data quality through quality assurance and increasing data precision. MOHURD indicated the data is full of holes due to missing meters, etc.
- Use extensive data mining to identify best practices that can inform building energy efficiency data collection programs and policies.
- Improve systems to support data download, storage, and transmission.
- Improve public access to enhance data utility.

6. PAST EFFORTS ON INDIAN COMMERCIAL BUILDINGS ENERGY BENCHMARKING SUMMARY

This section summarizes the efforts towards collecting building sector data in India spanning the years since the formation of the Bureau of Energy Efficiency in 2002. The efforts documented here comprise activities that have been purely data collection efforts as well as activities that included data collection on commercial buildings, as part of a project. This review will also serve to highlight some of the use cases in India that have looked for a potential data source for undertaking the project tasks.

The cases presented cover details on data collection source and methodology, calculation/ modelling approach, and normalization methods adopted so far. Data collected as part of a project have generally followed their own data framework. The different energy efficiency key performance indicators captured in these cases have not been an attempt to track impact energy efficiency policies/measures in India, with the exception of data collected on green buildings. However, the indicators may have some relevance in the ongoing effort to develop a data framework.

Situation Analysis of Commercial Buildings by Spatial Decisions for BEE

The study was one of the first attempts in India to assess the size and distribution of the commercial building stock and its energy consumption.

Table 6.1 Situation Analysis of Commercial Buildings in India[18]

Year	2008
Carried by	Spatial decisions with support from BEE
Data Collection Methodology	Secondary Survey: The survey attempted to gather information on 1066 buildings from electricity supplying authorities and building sanction authorities; however, the building area details were available for 269 buildings. No details were provided on the organizations which were approached for electricity consumption and floor area data.
Data set size	The information was collected on 1066 buildings, which includes Office buildings, Shopping Malls, IT Parks, Hotels, Hospitals, Hotel cum Office, Commercial cum Residential, Residential Complexes, Office cum IT Park, Education Institute, Golf Course, Stadium, etc. Since most buildings did not include data on covered area, only 269 of the 1066 commercial buildings were analyzed
Parameters collected	The parameters collected in the study are not fully disclosed, however, the survey results indicated building level data was collected which includes building monthly energy consumption and building covered area. System level information was not collected. The questionnaire used for the study is not available.
Analysis methodology	No details are provided on the methodology used for analyzing data.

<table>
<tr><td>Result</td><td>The survey highlighted average EPI of the 269 analyzed buildings The average EPI of each of the building type is presented in the attached table.
<table>
<tr><td>S. No.</td><td>Building Type</td><td>No. of Buildings</td><td>Annual kWh consumption per sq.ft. of covered area</td></tr>
<tr><td>1</td><td>Office Buildings</td><td>85</td><td>1 - 374</td></tr>
<tr><td>2</td><td>Shopping Malls</td><td>85</td><td>10 - 895</td></tr>
<tr><td>3</td><td>IT Parks</td><td>63</td><td>0 - 190</td></tr>
<tr><td>4</td><td>Hotels</td><td>27</td><td>2 - 340</td></tr>
<tr><td>5</td><td>Hospitals</td><td>9</td><td>3 - 120</td></tr>
<tr><td></td><td>Total</td><td>269</td><td></td></tr>
</table></td></tr>
<tr><td>Challenges</td><td>The survey faced major challenge in collecting the covered area of the government buildings and thus energy benchmarking of selected Government buildings could not be completed. The study does not discuss the challenges faced in the data analysis,</td></tr>
<tr><td>Area of Improvement</td><td>Data collection methodology is not discussed in detail, however; the analysis indicates an absence of detailed data collection framework. Following are the recommendations for building data analysis:
1. The range of annual kWh/sq. ft. data for each of the building type is too large. Various factors can be responsible for such anomaly in the data set. These factors may be a) single shift or multiple shift operations; b) Mixing of AC or non-AC spaces; c) climate zone in which building is located; d) efficiency of building envelope and HVAC system, Lighting, etc.
2. Normalizations (after accounting for climate, building type, # of shifts, service levels, etc.) needed to come up with acceptable benchmarks</td></tr>
<tr><td>Lessons</td><td>1. Data collection framework should be comprehensive and clearly spell out general building characteristics as well as performance related variables.
2. Various data analysis methods must be considered, in order to differentiate the effect of building design and systems on the overall building energy consumption.</td></tr>
</table>

Performance Based Rating and Energy Performance Benchmarking for Commercial Buildings in India by ICMQ and ECO3

The study carried out under USAID's ECO3 project was a joint effort of ICMQ and ECO3. The data collection was carried out by ICMQ team, whereas the ECO3 performed the analysis. The study provided BEE with energy benchmarks for various commercial buildings like office buildings, hospitals, hotels and shopping malls.

Table 6.2 Performance Based Rating and Energy Performance Benchmarking For Commercial Buildings in India reference

Year	2010
Conducted by	ICMQ and ECO3
Data Collection Methodology	Primary Survey: The survey gathered complete information for 760 buildings which primarily included offices, hotels, hospitals and retail malls. Data collected is fairly representative as it covered all the five climatic zones. The dataset also included both public and private sector buildings. The survey covered the buildings in metropolitan cities, Tier II and Tier III cities, as well as smaller towns. Copy of questionnaire was not provided in the review.
Data set size	760 buildings which primarily included offices, hotels, hospitals and retail malls. 197 office buildings out of 760 had information about all the key variables that are likely to affect energy consumption in a building. This smaller set was used to conduct the multi-variate regression analysis.
Parameters collected	Building Level and System Level: The questionnaire included information such as connected load, electricity generated on site, electricity purchased from the utilities, built up area, conditioned area, number of people working, number of floors, type of air-conditioning and the load, climatic condition, operating hours, etc.
Analysis methodology	Study compares the whole building energy consumption of the building under consideration with a benchmark building of similar characteristics. The study used the following three step methodology • Estimate energy consumption of the benchmarked building • Compute performance index with respect to the benchmarked building - calculated as the ratio of actual electricity consumed by the candidate building to estimated electricity use by the benchmarked building. • Compute performance score based on the relative performance of other buildings in the sample - The Building Performance Index (BPI) of all buildings in the sample is used to create a distribution profile of relative performance.

Result

The study provided performance rating through peer group comparison for office buildings. The study also provided BEE with energy benchmarks for various commercial buildings like: Office buildings, hospitals, hotels and malls.

A look up table for office buildings to determine percentile score based on BPI. This table is estimated from the gamma distribution given in equation 2. E.g. If the BPI for a building is 0.4, it ranks in top 10 percentile amongst its peers.

BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)
0.14	1	0.6	21	0.92	41	1.29	61	1.83	81
0.19	2	0.62	22	0.94	42	1.31	62	1.86	82
0.23	3	0.63	23	0.95	43	1.33	63	1.9	83
0.26	4	0.65	24	0.97	44	1.35	64	1.95	84
0.29	5	0.67	25	0.99	45	1.37	65	1.99	85
0.31	6	0.68	26	1.01	46	1.4	66	2.04	86
0.34	7	0.7	27	1.02	47	1.42	67	2.09	87
0.36	8	0.71	28	1.04	48	1.44	68	2.14	88
0.38	9	0.73	29	1.06	49	1.47	69	2.2	89
0.4	10	0.74	30	1.08	50	1.49	70	2.26	90
0.42	11	0.76	31	1.09	51	1.52	71	2.33	91
0.44	12	0.78	32	1.11	52	1.54	72	2.41	92
0.46	13	0.79	33	1.13	53	1.57	73	2.49	93
0.48	14	0.81	34	1.15	54	1.6	74	2.59	94
0.5	15	0.82	35	1.17	55	1.63	75	2.71	95
0.52	16	0.84	36	1.19	56	1.66	76	2.85	96
0.53	17	0.86	37	1.21	57	1.69	77	3.02	97
0.55	18	0.87	38	1.23	58	1.72	78	3.27	98
0.57	19	0.89	39	1.25	59	1.76	79	3.68	99
0.58	20	0.91	40	1.27	60	1.79	80	Inf	100

Number of Buildings	Building Type	Floor Area (m^2)	Annual Energy Consumption (kWh)	Benchmarking Indices	
OFFICE BUILDINGS				kWh/m²/year	kWh/m²/hour
145	One shift Buildings	16,716	20,92,364	149	0.068
55	Three shifts Buildings	31,226	88,82,824	349	0.042
88	Public Sector Buildings	15,799	18,38,331	115	0.045
224	Private Sector Buildings	28,335	44,98,942	258	0.064
10	Green Buildings	8,382	15,89,508	141	-
HOSPITALS				kWh/m²/year	kWh/bed/year
128	Multi-specialty Hospitals	8721	24,53,060	**378**	**13,890**
22	Government Hospitals	19,859	13,65,066	**88**	**2,009**
HOTELS				kWh/m²/year	kWh/room/year
89	Luxury Hotels (4 and 5 Star)	19,136	48,65,711	**279**	**24,110**
SHOPPING MALLS				kWh/m²/year	kWh/m²/hour
101	Shopping Malls	10,516	23,40,939	**252**	**0.05642**

Source: Building Energy Benchmarking study undertaken by the USAID ECO-III Project

Challenges

Data Collection: Data collected is for the total energy consumption at the building level, with associated building characteristics. There is no specific information available to understand thermal comfort, indoor air quality or other basic amenities, etc.

Area of Improvement	• The survey informs us about the percent of space that is conditioned in a building. However, it does not tell us about the operation schedule of HVAC system, thermal comfort levels, and indoor air quality. • The impact of climate is not easily discernable from the regression equations. Impact of urban heat island effect, level of service, building schedule and equipment load are very different in semi-urban and rural settings.
Lessons	• Providing building owners with peer review will help them in enhancing the EE of their building. • Detailed analysis is very important to understand the various parameters related to the building energy consumption.

Market Assessment of Public Sector Energy Efficiency Potential in India by LBNL

The purpose of this study was to assess the potential for improving energy efficiency in public buildings by providing preliminary estimates of the size of the public sector buildings market, the patterns of energy use in public buildings, and the opportunity for reducing energy use in this sector. The study estimates the size of this market and the potential for carbon savings with conservative assumptions requiring moderate investment towards efficiency improvement in public sector buildings.

Table 6.3 Market Assessment of Public Sector Energy Efficiency Potential in India[19]

Year	2009-10
Conducted by	LBNL
Data Collection Methodology	Primary Survey: The survey gathered complete information on185 buildings which primarily included offices, hotels, hospitals, educational and retail establishments. Data collected was fairly representative as it covered all the four climatic zones, public as well as private sector buildings. The survey covered buildings in metropolitan cities, Tier II and Tier III cities.
Data set size	The survey gathered complete information on185 buildings which primarily included offices, hotels, schools, hospitals and retail establishments. 50% of the buildings included data on key attributes impacting energy use such as type of space conditioning equipment, efficiency rating, and lighting levels. The data set was used to establish baseline efficiency in the building stock for specific end-uses.
Parameters collected	Building Level and System Level: The questionnaire included information such as connected load, electricity generated on site, electricity purchased from the utilities, built up area, conditioned area, number of people working, number of floors, type of air-conditioning (including capacity, and number of units) and the load, operating hours, lighting type and lighting design levels etc.
Analysis methodology	The study used summary statistics to estimate the EUI's and developed weighted estimates using the range of distribution of building size.
Result	The study provided EUI estimates of commercial buildings by principal building activity, and some understanding of end-use level energy consumption.
Challenges	Limitations arising out of a small data set, and not being statistically representative.
Area of Improvement	• The current survey informs us about the percent of space that is conditioned in a building. However, it does not tell us enough about the thermal comfort levels, and indoor air quality that is maintained. • Information on other envelope/building shell related parameters

	will help in improving efficiency of building performance
Lessons	• Provided some understanding of the energy footprint of commercial buildings in the existing stock and opportunities for efficiency improvement. • The building sample was not selected through a sampling plan and therefore was not statistically representative of the entire commercial building stock in India.

Graduated Energy Benchmarking for Hotels and Hospitals by CBERD

These reports are example of a fairly rigorous exercise carried out in India to understand the key energy consumption parameters in Indian Hotels and Hospitals. Data was collected by ECO3 and analysis was performed by CBERD. Fairly comprehensive questionnaires were prepared for both – the hotel study as well as hospital study.

Table 6.4 Graduated Energy Benchmarking for Hotels and Hospitals

Year	2015
Carried by	CBERD India team analyzed the data, whereas data collection task was carried by ECO3
Data Collection Methodology	Primary Survey: The survey gathered complete information on133 hotel buildings and 67 hospital buildings. Fairly detailed questionnaires were prepared bot both building types. The copy of questionnaire is not provided in the report, however is available for the review.
Data set size	The data set consist of details from 133 hotel and 67 hospital buildings.
Parameters Collected	Buildings Level and System Level HOTEL: The data set consist of details from 133 buildings. Core fields include building size, location, energy use, hotel type, star rating, no. of rooms, occupancy. It also includes various measures of area: total built up, ex. Parking, carpet, service, etc. Many additional fields on system and use characteristics were also collected which includes- AC capacity, installed loads for lighting, AC, plugs, EMCS, Audit, number of banquets, conference attendees, restaurants, Laundry service on site and so on, a total of 131 variables were collected. HOSPITALS: 67 hospitals surveyed across all five climate zones of India. Broadly, the data collected were sub-categorized under general information, area, use intensity, energy management, and energy loads. Eighty-nine different variables were recorded, of which core fields include building size, location, energy use, hospital type number of beds, and number of outpatients per year. Various measures of area—such as total built up, area excluding parking, carpet area, non-active area, and others—were recorded. Occupancy-related variables included numbers of outpatients, number of meals and laundry per year, numbers of operation theatre beds and number of private and general ward beds, and more. System data included installed air conditioning, lighting loads, and plug loads. Many additional fields on system and use characteristics regarding operations, maintenance, and audits were also collected.
Analysis Methodology	A three-tier graduated benchmarking approach, structured as follows: • Level 1: 1–3 variables that are significant and easy to collect, with

	reasonable data quality. • Level 2: 2–3 additional variables that increase the robustness of the benchmarking. • Level 3: 1–2 additional optional variables to address special loads or uses. Based on the preliminary analysis, the following eleven variables were further explored for their ability to predict the dependent variable (i.e., energy use in a graduated approach), considering correlation, regression coefficients, and elasticity. Based on this, the first five (in bold) were included in the development of the graduated models, while the remainder were dropped because they had almost no significance. • Number of rooms • Star rating of hotel • Built up area per room - area excluding parking or Built up area per room - total area • Number of restaurants per room • Climate • Percentile ratio of room occupancy • Number of overnight guests/room • Average conference and weddings per year • Average room tariff • Building Indoor Environmental Quality (IEQ) monitored Three regression-based methods—using Independent models, Constrained Regression models, and Single models—were considered and analyzed for the graduated benchmarking approach.
Result	HOTEL: Exploratory Data Analysis of Indian Hotel Benchmarking, on the ECO III dataset gives an insight into the various aspects of the variables under consideration. Univariate and Bivariate analysis helps asses the relationship between the variables. Climate zone, Service star level, Number of rooms, and Built-up area per room are the major variables that should be considered for hotel benchmarking. • Recommendations: Use room-based EPI rather than area-based EPI • Must include electricity and fuels in calculating EPI, given extent of fuel use • Star rating and climate should be included as core independent variables • Need further analysis to determine if usage variables should be included as independent variables – number of guests, room occupancy rate, number of restaurant covers, and number of conferences HOSPITAL: The diagnostics indicate that: (1) number of beds and built up area per bed of a hospitals are the two most critical variables, and (2) the lowest-level model in the graduated benchmarking approach should include these two

	variables at a minimum.
Challenges	The studies have carried detailed data collection exercise and fairly extensive analysis has been carried to arrive at conclusions. However, challenges faced during data collection and analysis has not been discussed in the report.
Area of Improvement	• The report highlights the rigorous efforts carried, however, the linkages of this exercise to have evidence based and data driven policy have not been discussed.
Lessons	• Provided extensive information on the hotel and hospital buildings energy consumption parameters. It is very crucial to understand and collect the right information. • It is importance to understanding the critical variables driving the building energy demand.

Report on Energy Benchmarks for Commercial Buildings Prepared by Darashaw and Submitted to BEE

This is a recent study on the status of commercial building energy use in India, however the study lacks the technical and statistical rigor compared to the other past efforts.

Table 6.5 Report on Energy Benchmarks for Commercial Buildings

<table>
<tr><td>Year</td><td>February 2016</td></tr>
<tr><td>Conducted by</td><td>Bureau of Energy Efficiency with support from UNDP-GEF appointed Darashaw to undertake the study on “Benchmarking of commercial Buildings” across all climatic zone for different categories i.e., Offices, Hotels, Hospitals, Shopping Malls, Institutes, BPO’s and IT.</td></tr>
<tr><td>Data Collection Methodology</td><td>Secondary Data: Various rounds of interviews (both in-person and telephonic) were conducted with the concerned officials at Urban Local Bodies (ULBs), Development Authorities, Housing Boards, Power Distribution Companies (DISCOMs), and State Designated Agencies (SDAs) etc.
Primary Data: A comprehensive questionnaire was designed to collect the required information. The target sample consisted of the following-
Data collection from buildings that have a connected load of 100 kW and above, or contract demand of 120 kVA and above;
Data collection of existing and new commercial buildings for a period of one year;
For new buildings, data collection was based on building plan approvals and its connected load from different departments;
Covered all climate zones for most building types.</td></tr>
<tr><td>Data Set</td><td>1160 commercial buildings surveyed for the study. Star rated buildings were omitted from the study to get a clearer picture of the energy consumption in regular office buildings.
<table>
<tr><th>S. No.</th><th>Category</th><th>Warm & Humid</th><th>Composite</th><th>Moderate</th><th>Hot & Dry</th><th>Cold</th><th>Total</th></tr>
<tr><td>1</td><td>Office Building</td><td>99</td><td>117</td><td>33</td><td>51</td><td>4</td><td>304</td></tr>
<tr><td>2</td><td>Shopping mall</td><td>35</td><td>44</td><td>32</td><td>30</td><td>-</td><td>141</td></tr>
<tr><td>3</td><td>BPO</td><td>41</td><td>30</td><td>24</td><td>2</td><td>-</td><td>97</td></tr>
<tr><td>4</td><td>Hospital</td><td>60</td><td>69</td><td>42</td><td>39</td><td>6</td><td>216</td></tr>
<tr><td>5</td><td>Hotel</td><td>70</td><td>93</td><td>35</td><td>55</td><td>27</td><td>280</td></tr>
<tr><td>6</td><td>Institute</td><td>28</td><td>48</td><td>23</td><td>14</td><td>9</td><td>122</td></tr>
<tr><td></td><td>Total</td><td>333</td><td>401</td><td>189</td><td>191</td><td>46</td><td>1160</td></tr>
</table></td></tr>
<tr><td>Parameters Collected</td><td>Buildings Level:
Monthly Energy Consumption
Building covered area
System Level: DG Output, Gas Generator etc.
The questionnaires sought basic information of building, electricity consumption specific information like grid purchase, renewable, DG output, Gas generator etc. Specific area related information was sought such as gross</td></tr>
</table>

	floor area, enclosed service area, parking area, air conditioned area, and actual heated (carpet) area of a particular building. These sector specific questionnaires had been finalized in consultation with BEE. Survey questionnaire are not shared.
Analysis Methodology	No details provided

Results

Following EPIs were derived for different types of commercial building, across different climate zones

Office

Particulars	Less than 50% AC	More than 50% AC
	EPI (kWh/m²/year)	
Warm and Humid	101	182
Composite	86	179
Hot and Dry	90	173
Moderate	94	179

Shopping Mall

Particulars	EPI (kWh/m²/year)
Warm and Humid	428
Composite	327
Hot and Dry	273
Moderate	257

BPO

Particulars	EPI (kWh/m²/year)
Warm and Humid	452
Composite	437
Hot and Dry	-
Moderate	433

Hotel

Particulars	Upto 3 star	Above 3 star
	EPI (kWh/m²/year)	
Warm and Humid	215	333
Composite	201	290
Hot and Dry	167	250
Moderate	107	313

Hospital

Particulars	EPI (kWh/m²/year)
Warm and Humid	275
Composite	264
Hot and Dry	261
Moderate	247

Institute

Particulars	EPI (kWh/m²/year)
Warm and Humid	150
Composite	117
Hot and Dry	106
Moderate	129

- Office buildings with higher EPI were generally larger buildings with 24-hours, daily operations and large data centers
- Shopping malls with higher EPI were smaller-sized buildings with long operating hours and using split-unit air-conditioners or air cooled centralized chiller systems

	• Hotels with higher EPI are older, smaller-sized hotels using split air-conditioning systems
Challenges	Data Collection: • The operation of buildings in India are dynamic in nature • Lack of information provided by building owners to the surveyor • Building owners' unfamiliarity with the information required by the surveyor • Building owners' oversight leading to data entry error in the questionnaire submission • Inadequate knowledge of terminology used for technical fields in the submission form • Lack of up-to-date contact information of targeted building owners' • Building owners' reluctance in sharing information
Area of Improvement	Data Collection: The data collection task has to be detailed, informing various sources of data collection. Error checks in data collection should ensure that flawed entries are not in the final dataset.
Lessons	• Study focuses on the whole building energy use and does not differentiate between the impact of equipment, building operation and design on overall performance. It may be possible that the worst building gets best rating because it uses the most efficient equipment. • Study analyzes net electricity consumed (or site energy) as a metric for energy consumed. Many buildings use onsite diesel or gas generators to produce energy. By ignoring the fuel mix, it omits transmission and distribution losses, and thus underestimates total energy savings potential at a societal level. Use of source energy may be a better metric for future extensions.

Data collected under Green Building Rating Systems
Green building rating systems have been active in India for over a decade. These systems rate commercial and residential buildings. The noted rating systems prevalent in India include:
GRIHA (Green Rating for Integrated Habitat Assessment) – Initiative by TERI and MNRE
IGBC – Indian Green Building Council – Initiative by CII
LEED (Leadership in Energy and Environmental Design) – Initiative by USGBC

GRIHA
TERI developed GRIHA in 2005 which was adopted as the national rating system for green buildings by the Government of India in 2007. The system was developed to help 'design and evaluate' new buildings. A building is assessed based on its predicted performance over its entire life cycle – inception through operation. GRIHA rating V3 gives 33% weight to building energy consumption and V2015 gives approximately 20% weight to building energy consumption. GRIHA periodically examines the GRIHA rated building information and updates their benchmarks .

Table 6.6 Green Building Rating System – GRIHA

Year of launch	2007
Founder	TERI with support from MNRE
GRIHA Rating variants	• GRIHA: Built up area ≥ 2500 sqm • SVA GRIHA: Built up area between 100 – 2499 sqm • GRIHA LD: Site area ≥ 50 hectares • GRIHA Pre-certification
Weightage to resources	**GRIHA V3** Site Planning – 11% Energy – 33% Renewable Energy – 11% Water and wastewater – 15% Solid waste management – 4% Materials – 14% Health and Wellbeing – 12% **GRIHA V2015** Site Planning – 8% Energy – 20% Occupant comfort and wellbeing – 12% Water – 17% Sustainable Building Materials – 14% Construction Management – 9% Solid Waste Management – 6% Socio-Economic Strategies – 6% Performance Monitoring – 8%
Buildings registered	650 projects totaling to over 230 million sq.ft

<table>
<tr><td>Buildings Rated</td><td>30 projects, these have led to a cumulative annual energy consumption reduction of 74,000 MWh and installation of 14.5 MWp of renewable energy.
The potential impact of the current 650 projects is expected to lead to a cumulative annual energy consumption reduction of 1600GWh/annum and installation of 315 MWp of renewable energy.</td></tr>
<tr><td>Parameters collected</td><td>Building Level and System Level:
Site Area, Built-up area, Heat gain through building envelope, outdoor lighting luminous efficacy and connected load, Interior lamps and luminaires connected load, EPI (lighting and space cooling), ECBC mandatory requirements (type of chiller, COP and capacity, Controls for cooling tower and closed circuit fluid coolers, time clock control, piping insulation, ductwork, system balancing, condenser location, treated water for condensers, space control, control in day lighted areas, exit signs, transformer losses, motor details, power factor correction etc.) Renewable energy capacity, hot water systems, thermal comfort conditions, building materials details (building insulation, glazing SHGC, window shading etc.), daylight penetration (Daylight Autonomy(DA)) etc.</td></tr>
<tr><td>GRIHA EPI benchmarks</td><td>GRIHA V3
GRIHA V3 EPI benchmarks were derived from building energy simulation. Benchmarks are:
<table>
<tr><th colspan="3">Energy Performance Index (EPI) – (kWh/ m^2/year)</th></tr>
<tr><td rowspan="2">Climate Classification</td><td>Day time occupancy</td><td>24 hours Occupancy</td></tr>
<tr><td>5 Days a week</td><td>7 Days a week</td></tr>
<tr><td colspan="3">Commercial/Institutional buildings</td></tr>
<tr><td>Moderate</td><td>120</td><td>350</td></tr>
<tr><td>Composite / Warm and humid / hot and dry</td><td>140</td><td>450</td></tr>
<tr><td colspan="3">Residential buildings</td></tr>
<tr><td>Composite / Warm and humid / hot and dry</td><td colspan="2">100</td></tr>
<tr><td>Moderate</td><td colspan="2">85</td></tr>
</table>
GRIHA V2015
V2015 EPI benchmarks revisions were based on the 30 GRIHA rated buildings performance data. Benchmarks are:
<table>
<tr><th colspan="3">Energy Performance Index (EPI) – (kWh/ m^2/year)</th></tr>
<tr><td rowspan="2">Climate Classification</td><td>Day time occupancy</td><td>24 hours Occupancy</td></tr>
<tr><td>5 Days a week</td><td>7 Days a week</td></tr>
<tr><td colspan="3">Commercial/Institutional buildings</td></tr>
<tr><td>Moderate</td><td>75</td><td>225</td></tr>
<tr><td>Composite / Warm and</td><td>90</td><td>300</td></tr>
</table></td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>humid / hot and dry</td><td></td><td></td></tr>
<tr><td colspan="3">Residential buildings</td></tr>
<tr><td>Composite / Warm and humid / hot and dry</td><td colspan="2">50</td></tr>
<tr><td>Moderate</td><td colspan="2">70</td></tr>
</table>
</td></tr>
<tr><td>Analysis methodology</td><td>Building energy simulation to obtain building EPI.
Buildings are rated after completion based on the simulation and GRIHA team’s due diligence. The final GRIHA rating is provided after building is 80% occupied and is functioning with 80% occupancy for one year. The rating has to be renewed after five years from date of final rating. There are five GRIHA final rated projects.
GRIHA rated projects case study cards are published on GRIHA website.</td></tr>
<tr><td>Limitations</td><td>The dataset is limited to green buildings, or buildings that are high-performing and have applied for the GRIHA rating, and is therefore representative of a particular sub-population.</td></tr>
</table>

High Performance Commercial Buildings in India: Adopting Low-Cost Alternatives for Energy Savings by TERI with support from APP

The project discusses EPIs for conventional, solar passive design and ECBC buildings for all five climate zones in India. A Total of 15 buildings were studied under this project to estimate the EPI.

Table 6.7 High Performance Commercial Buildings in India: Adopting Low-Cost Alternatives for Energy Savings

<table>
<tr><td>Year</td><td>2010</td></tr>
<tr><td>Conducted by</td><td>The project on 'High Performance Commercial Buildings in India', which was undertaken under the Asia-Pacific Partnership on Clean Development and Climate, aimed to establish relevance and impacts of low-energy passive strategies and ECBC-recommended measures on improving energy performance of commercial buildings in five climatic zones of India. The project was supported and funded by the US Department of State and the Bureau of Energy Efficiency, Government of India. It was implemented by TERI, India, and White Box Technologies, USA.</td></tr>
<tr><td>Data Collection Methodology</td><td>Primary data collection</td></tr>
<tr><td>Data set</td><td>The project selected fifteen buildings from various climate zones of India and studied their performance. These comprised five buildings (one from each climate zone) each of conventional & solar passive type, constructed in the pre-ECBC era and the ECBC Compliant buildings from the post-ECBC era.</td></tr>
<tr><td>Parameters collected</td><td>Building level and system level
Conventional Building:
Operation schedule, area of building, function of building, Building envelope details (walls, roof, glazing), building lighting – lighting system, lighting controls, HVAC system design, building design (orientation, landscape and water bodies), Day light integration</td></tr>
<tr><td>Analysis methodology</td><td>Not discussed</td></tr>
<tr><td>Result</td><td>EPI of the buildings analyzed were presented
<table>
<tr><td rowspan="2">Climate</td><td colspan="3">Building type – EPI (KWh/sqm/yr)</td></tr>
<tr><td>Conventional</td><td>Solar passive design</td><td>ECBC Compliant</td></tr>
<tr><td>Hot & Dry</td><td>199</td><td>131</td><td>121</td></tr>
<tr><td>Warm & Humid</td><td>237</td><td>70</td><td>-</td></tr>
<tr><td>Temperature</td><td>309</td><td>76</td><td>107</td></tr>
<tr><td>Composite</td><td>231</td><td>147</td><td>55</td></tr>
<tr><td>Cold</td><td>335</td><td>219</td><td>-</td></tr>
</table></td></tr>
</table>

Challenges	Not Discussed
Areas for Improvement	Various building energy consumption parameters are analyzed in the project, however detailed list of the parameters affecting each building energy demand are not provided. The data set is limited and is not representative of the larger building stock of either ECBC-compliant or pre-ECBC units.

7. SUMMARY AND CONCLUSIONS

The foregoing review of building data framework across different countries provides a range of approaches to collecting relevant energy data. The value of different types of information and collection methodology or approach will naturally vary depending on the use cases they address, as well as the granularity they seek. The cross-country comparison provides a detailed account of the process and value of the existing methods and formats for data collection, validation and reporting. The comparison highlights the strengths and weaknesses of the different data collection approaches.

The summary of efforts in India specifically illuminates the need as well as the utility of a comprehensive building energy data set. The review also points to the serious lack of representativeness in the past data collection efforts, while all the individual activities on India enumerated in this report have filled a significant gap and have provided some understanding of the size, range, and diversity of the building stock and the nature of end-use consumption. There is not a single comprehensive data collection activity that has been able to provide a reasonable representation of the commercial building stock in India with adequate coverage to climate zone, building type, size and age, envelope and end-use detail, and demographics. Given the existing gaps and the unquestionable need for reliable data to effectively track building energy consumption and effectiveness of policies, a comprehensive commercial building data framework for India is certainly an imperative.

The cross-country review in this study has led to a reasonable understanding of the commercial building use cases. Review of other countries data framework allows for a whole range of uses for the building energy data. The documented past efforts in India highlight the uses that drove specific data collection. While there can be many potential uses of building energy data, the most relevant for India might constitute those uses that address data-driven and evidence-based policy making at the national level. For instance, energy conservation building code impact and updates require building performance tracking. Other uses could include those efforts that transform the market for energy efficiency in the building sector by enabling adoption of energy-efficient building design and operation and maintenance practices, and allow for better specification and procurement of end-use equipment and systems. As part of the CWF funded project, the study team will next focus on use cases for developing a data framework.

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