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Operational Energy Demand & Consumption in Buildings & Construction Sector in India
-A study of Trends with Field Assessment & Case Study

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ABSTRACT

The Buildings & Construction sector is responsible for more than one third of the Energy Consumption in India, of which building operational energy is a large contributor. The Bureau ofEnergy Efficiency (BEE) in India, predicts that 40% of total building stock that will exist at the end of two decades from now, is yet to be built, which means India will witness an unprecedented construction boom leading to further increase in energy demand in this sector. To contain Greenhouse Gas (GHG) emissions and reduce carbon footprint of buildings, both new and existing, sustainable design strategies and technologies must be applied.

This paper highlights the performance and status of countries worldwide to fight climate change, where India stands - its path in achieving net zero targets. It also reviews key aspects of building sustainability in existing and new buildings, energy saving potential of old and new construction.Energy Conservation Measures are simulated using computer models for Building Performance Assessment - a case study of a LEED India Gold rated building in Chennai is presented.

Keywords: *Operational energy, carbon emissions, greenhouse gases, new construction, retrofits, energy simulation, building energy performance, ECMs, climate change and net zero*

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1. GLOBAL CARBON FOOTPRINT SCENARIO

The global race to remove carbon dioxide and other greenhouse gases from our atmosphere is on.Emissions released by human action are taking a catastrophic toll on our planet and propelling usfurther into an irreversible climate crisis and hence the situation is both grave and urgent. The world's major governments, scientists and heads of industry have all agreed that urgent action is necessary to avoid further global warming. General consensus is that the world must limit the global average temperature rise to 1.5°C, by roughly halving our carbon dioxide (CO2) emissions by 2030 and reaching net zero by 2050.

NET ZERO refers to the balance between the amount of greenhouse gas (GHG) that is produced and the amount that is removed from the atmosphere. It can be achieved through a combination of emission reduction and emission removal.

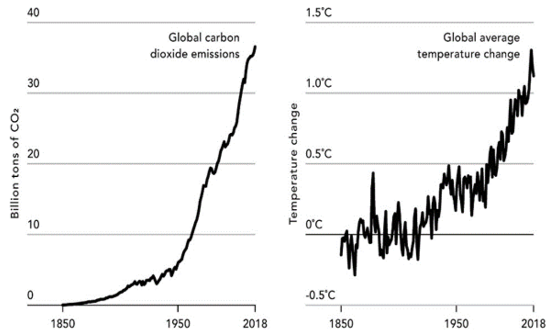

Figure-1: Graph showing rise in CO2 emissions and global temperatures (Global Carbon Budget 2019; Berkeley Earth)

Carbon dioxide is the most common GHG as compared to others such as nitrous oxide and methane. To quantify the amount of greenhouse gases released, absorbed or present in the atmosphere, it is commonly combined into a single measure known as carbon dioxide equivalents [CO2e]. The largest contributors to greenhouse gas emissions and climate change are developed countries like the US and members of the European Union. Although their emissions have slowed down, they have not shifted from a carbon-intensive economy and have merely replaced coal with natural gas

Country	Annual CO_2 emissions (tonnes)	Share of global emissions (in %)	Population	Share of world population (in %)
China	10064.69	27.52	1,392,730,000	18.34
United States of America	5416.28	14.81	326,687,501	4.30
India	2654.10	7.26	1,352,617,328	17.82
Russian Federation	1710.69	4.68	144,477,860	1.90
Japan	1161.98	3.18	126,529,100	1.67
Germany	759.00	2.08	82,905,782	1.09
Iran	720.41	1.97	81,800,269	1.08
South Korea	658.79	1.80	51,606,633	0.68
Saudi Arabia	621.30	1.70	33,699,947	0.44
Indonesia	614.92	1.68	267,663,435	3.53
Canada	568.41	1.55	37,057,765	0.49
Mexico	477.32	1.31	126,190,788	1.66
South Africa	467.56	1.28	57,779,622	0.76
Brazil	457.19	1.25	209,469,333	2.76
Turkey	428.18	1.17	82,319,724	1.08
Australia	420.22	1.15	24,982,688	0.33
United Kingdom	379.04	1.04	66,460,344	0.88
Poland	343.54	0.94	37,974,750	0.50
Italy	338.03	0.92	60,421,760	0.80
France	337.91	0.92	66,965,912	0.88

Figure 2: The world's top 20 emitters in 2018

China's coal power is expanding and the country has become the largest GHG emitterin the world, almost double the amount of emissions of the USA. India, with 17.8%share of world population, contributes only half of the GHG emissions of the US and is among the lowest per capita emitters in the world (only two tons). The world's biggest emitters (which are the richest countries)

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have to get to net-zero emissions by 2050 while middle-income countries andeventually the world, will need to followsuit. The countries that build great zero-carbon companies and industries willbe the ones to lead the global economy in the coming decades. Fossil fuels are the ultimate source of 85% of GHG emissions produced in the energy sector. A huge amount of work is needed to turn today's net zero goals into reality. A growing coalition of countries, cities, businesses and other institutions are pledging to get to net-zero emissions. More than 70 countries, including the biggest emitters/polluters – China, the United States, and the European Union – have set a net-zero target, covering about 76% of global emissions and hopefully will act to achieve it.

Cutting down GHG emissions is urgent but challenging since it is unrealistic to abandon fossil fuels. A zero-carbon future will still involve emitting gases, but along with their removal in equal measure. Removing emissions that have been emitted is called net-negative emissions, which is the need of the hour. Fossil fuels, being prevalent and cheap, impact our daily lives but cause significant pollution and environmental degradation. Adopting new energy sources will take a long time, but transitioning from coal, oil, and natural gas to cleaner renewable energy is necessary.

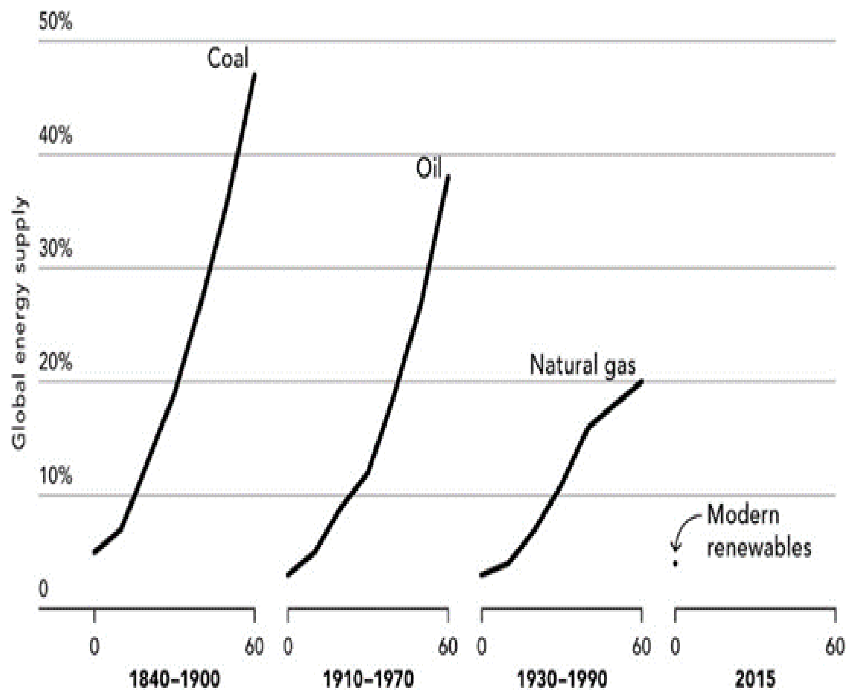

Figure 3: The time it took for the world to transition to new energy sources, 1800-2015 *(How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need)*

Innovation in clean and renewable energy is crucial to achieve net-zero. Per capita GHG emissions comprises use of automobiles, buildings, etc at individual level. With a growing population and urbanization, global energy demand is projected to increase by over 50% by 2050 and world building stock will double by 2060, resulting in increased carbon emissions.

Buildings are responsible for almost 40% of global energy-related carbon emissions, with operational and embodied emissions accounting for 27% and 13% of annual emissions, respectively. Integrating sustainability and risk management in the building and construction value chain is necessary to navigate challenges causedby climate change, urbanization,resource scarcity, and demographic shifts. Embodied carbon will become a bigger contributor to emissions in future since buildings are becoming more energy-efficient.

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The world is slowly advancing towards building energy efficiency with the annual rate of improvement dropping by half between 2016 and 2019. Existing building stock will become obsolete after introduction of new energy efficiency standards which will require operational energy be cut down to mandated thresholds.

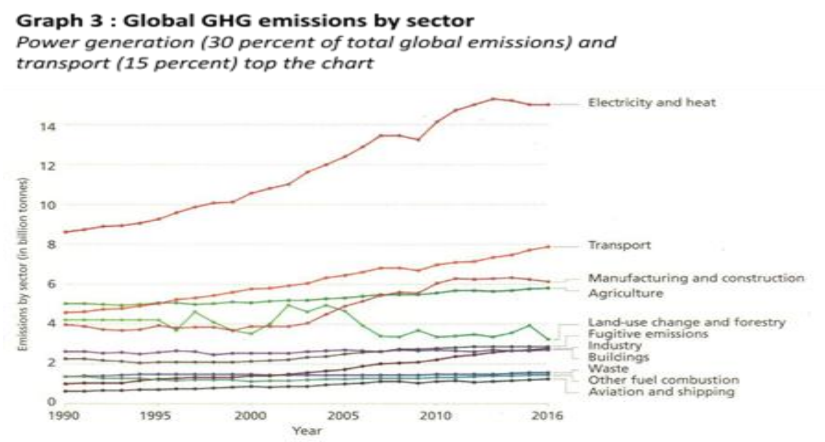

Figure 4: Global GHG emissions by sector

2. INDIA’S UNIQUE POSITION

Being a developing economy, India faces a unique set of challenges regarding climate change, including a growing population, rising energy demand, increased fossil fuel imports, urbanization and a deficit in meeting electricity demand. India is the world's third-largest emitter of greenhouse gases, with a high share of emissions coming from the energy sector. Due to India's diverse climate zones, ecosystems, and topography the climate risks are unevenly distributed and climate-related risks and high air pollution rates threaten both the population and economy. Increased temperatures and intense frequent droughts have affected agriculture harvests. Water availability for agricultural, domestic, and industrial use is impacted due to warming temperatures.

Net zero targets - At the 26th Conference of Parties (CoP26) held in Glasgow in 2021, India declared a five-fold strategy termed as the ‘**Panchamrita**’— to achieve Net Zero emissions by 2070 which are:

1. India will get its non-fossil energy capacity to 500 gigawatt (GW) by 2030
2. India will meet 50 per cent of its energy requirements from renewable energy by 2030
3. India will reduce the total projected carbon emissions by one billion tonnes from now onwards till 2030
4. By 2030, India will reduce the carbon intensity of its economy to less than 45 per cent
5. By the year 2070, India will achieve the target of Net Zero

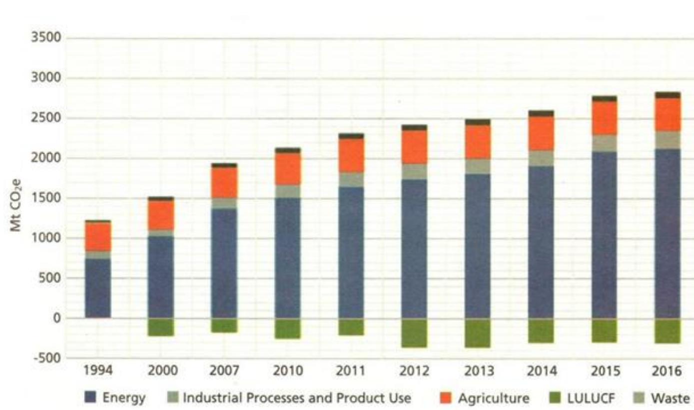

Figure 5: India’s GHG emissions by sector

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2.1 Current scenario and challenges

India's CO_2 emissions are on the rise, due to coal still being dominant in the energy mix. Phasing out unabated coal power by 2040 and increasing renewable capacity targets well beyond 500 GW by 2030 can help transitionIndia to a low-carbon economy.

India has made progress in its climate performance and is now ranked 8th in the Climate Change Performance Index (CCPI, 2023). The India Energy Conservation (Amendment) Bill 2022 includes provisions to promote non-fossil energy, improve energy efficiency, and establish carbon markets. Phasing out coal, switching to electric vehicles, creating forests to absorb carbon dioxide, and installing more solar power plants are all in the agenda. Access to finance is crucial for India's success in achieving its net zero targets. Strategic planning, scientifically designed policies, and strict implementation are necessary, and climate actions need to be fast-tracked and supported at the sub-national level.

Despite India's rapidly growing economy and emerging status as an economic and industrial power, socio-economic challenges remain. Most developed countries have relied on an economic development model where growth was coupled with the consumption of fossil fuels. But India has the opportunity to adopt a different development model, "decarbonise as it develops," where low cost clean technology and immense renewable energy potential can be made use of to achieve its stated net-zero ambition by 207

2.2 Sector-wise Energy Performance

The power, industry, and transport sectors hold immense potential to cut down emissions. In India, the construction sector will need to make significant strides to reach net-zero emissions, especially given the population growth and increasing demand for built space that are fuelling construction. Other aspects to consider include the demand for oil, political instability, and economic volatility caused by fossil fuels. It is not surprising that the price of oil has increased over 30% in a six-month period 62 times since 1970. Driving adaptation at scale across critical systems like agriculture, water, and coastal infrastructure can build resilience and strengthen communities in the face of climate change. A sectoral representation of Energy Demand in India is shown below :-

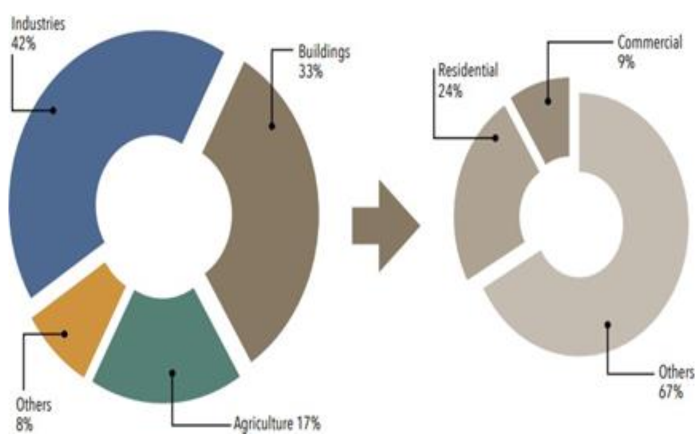

Figure 6: Sector wise Breakup of energy demand (right) and by building type (left) in India 2015-2016

Sectors such as electricity generation, transportation, manufacturing and construction will have a significant impact on achieving these targets. The Indian government is focusing on the economic and technical potential of renewable energies such as solar and wind, which the country has been blessed with, contributing to a climate-neutral energy supply

3. SUSTAINABILITY IN THE BUILDING & CONSTRUCTION SECTOR

Electricity demand in India was estimated to increase by 37.5% by 2021-22 over a baseline of 2016-17. Electricity in both residential and commercial sectors is primarily consumed by HVAC, lighting, appliances and entertainment systems.

In the commercial sector, HVAC accounts for 55% of the total electricity consumption, lighting contributes to 23%, another 23% is linked with internal plug loads and the rest 4% is consumed by other processes.

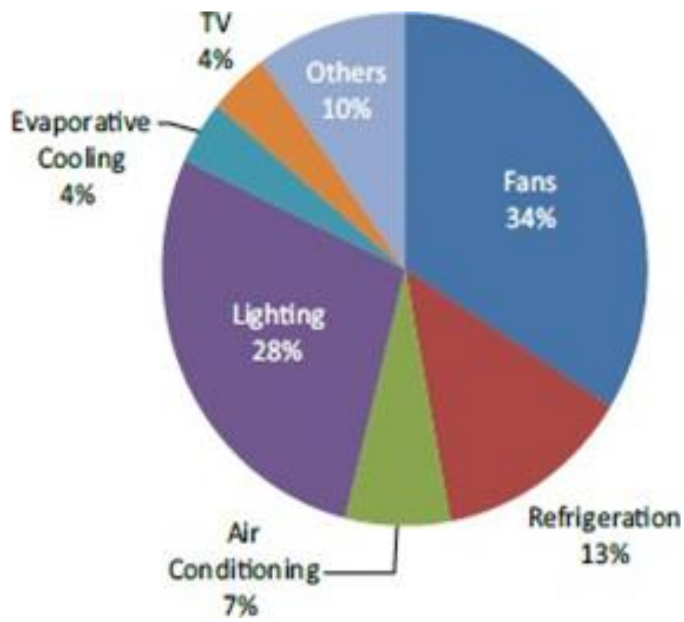

Figure 7: Residential energy consumption breakup

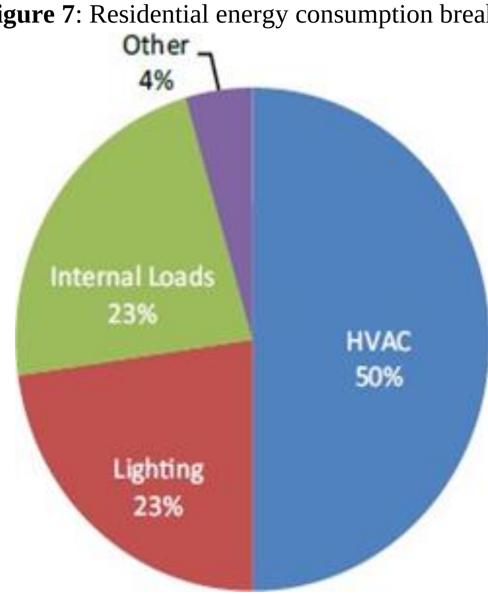

Figure 8: Commercial energy consumption breakup

3.1 Old Buildings Stock: Retrofits

In India, a major stock of commercial buildings was built before the implementation and access to modern energy saving technologies. Most of the buildings operating as commercial office spaces, hospitals and hotels were inefficiently planned without

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any attention to passive design strategies, choice of systems and climate responsive building materials which paves way for optimization of energy consumption.

Retrofitting of existing buildings offers significant opportunities for reducing global energy consumption and GHG emissions. A building once operational, continues to consume energy and increase its carbon footprint throughout its life. Standard life-span of Buildings in India is considered to be 50 to 60 years and its energy efficiency measures could potentially bring about a 20% savings in existing buildings through application of suitable retrofit measures. Building components such as walls, roofs and floors, fittings such as windows and entrance doors and building services like lighting, heating, and cooling, equipment, etc are the main components that can be refurbished to cut down operational costs in a building.

3.2 New Buildings Stock: Design, Simulation, ECMs, Construction & Performance Measurements

More than half of all buildings that will exist 30 years from now have not yet been built. Energy Conservation in Design can be achieved in 2 ways:

- **Passive** design strategies are integrated into the design of a building to work with natural elements on a site (including sun and wind patterns). The selection of the material (recycled/refurbished), insulation, the orientation, and the form of the building, site-orientation and form, daylighting, solar shading and natural ventilation are some examples. They optimize and conserve the potential use of energy.
- **Active** design strategies include use of energy efficient sub-system interventions such as Electrical & Mechanical that consume power. Daylight & Occupancy sensors, Heat harvesting systems and other high efficiency Heating, Ventilation and Air conditioning (HVAC) systems are adopted. Clean Energy sources could offset the demand on Power of buildings that predominantly currently use fossil fuels.

Energy Conservation Measures (ECMs), defined as any kind of technological resource employed to improve the energy performance of a building, can be simulated in advanced computer models to assess outcomes before executing on site. The objective of their application is to reduce the amount of energy used by a particular technology or installation. For some buildings, the envelope (i.e., walls, roofs, floors, windows, and doors) can have an important impact on the energy used to air-condition the facility. Some of the commonly recommended ECMs to improve the thermal performance of the building envelope are:

- **Addition of thermal insulation**. For building surfaces without any thermal insulation, this measure can be cost-effective.
- **Replacement of windows** When windows represent a significant portion of the exposed building surfaces, using more energy-efficient windows can be beneficial in both reducing the energy use and improving the indoor comfort level.
- **Reduction of air leakage** When the infiltration load is significant, leakage area of the building envelope can be reduced by simple and inexpensive weather-stripping techniques.

3.2.1 Building Energy Simulation: Tools and Benefits

Energy Simulation is a computer-based analytical process that helps building owners and designers to evaluate the energy performance of a building and make it more energy efficient by making necessary modifications in the design before the building is constructed (Bureau of Energy Efficiency).

The stage of building performance simulation is instrumental in analyzing and comparing the selected ECMs, based on the analysis, the effectiveness and outcome of ECMs can be estimated.

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Category	Purpose	Source
Geographical location (climate)	Accurate load calculation based on external environment	Weather file
Geometry • Plan • Section • Elevation	Model geometrical attributes of buildings and any site specific features (shading, reflection by tree or building)	Architectural drawings
Construction • Wall • Roof • Window • Overhangs	Model building envelope attributes for thermal load and daylighting calculations	• ECBC • ISHRAE • CBRI • Software library • Vendors • ASHRAE
Daylighting and lighting • Layout • Technology and controls	• Visual comfort • Reducing LPD • Integration with daylight	• Lighting consultant • Vendors • ISLE/IES
Internal Load • Usage (e.g. number of hours) • Schedule • People, equipment, lighting	Accurately capture sources of internal heat gain within building	• Client • Energy modeler • Benchmarking data • Nameplate data
HVAC (type and controls) • Component specification • Control strategy • Layout and distribution	• Sizing the system • Design optimization • Comfort satisfaction	• HVAC consultant • ASHRAE/ISHRAE • ARI • ECBC

Figure 9: Data required for energy modelling

Technological advancements in computer software have provided several tools that can help the designers to predict and analyze the energy performance of a building with good accuracy and with minimal efforts. Such programs allow for sensitivity analysis of various design options and decisions - from the conceptual and schematic phases to the detailed specification of building components and systems. A simulation program takes into account the building geometry and orientation, building materials being used, building façade design and characteristics, climatic parameters, indoor environmental conditions, occupant activities and schedules, HVAC and lighting systems and other parameters to analyze and predict the energy performance of a building.

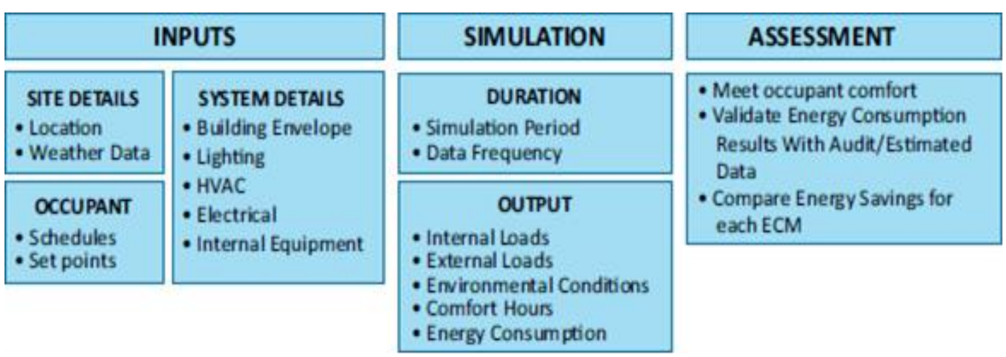

Table 3 : Assessing Energy Savings Potential through Building Simulations

Figure 10: Stages of building energy modelling

Energy performance simulation tools allow designers to:

- Predict thermal behavior of buildings in relation to its outdoor environment
- Predict the impact of daylight and artificial light inside the building
- Model the impact of wind pattern and ventilation and assess its effect on energy use
- Estimate the size/capacity of equipment required for thermal and visual comfort

- Assess the changes in energy consumption with respect to design changes affecting building geometry and materials, components, systems, etc.

Figure 11: Simulation outputs and its load breakdown

Whole Building Simulation Programs : EnergyPlus is a building energy simulationprogram for modeling building heating, cooling, lighting,ventilating, and other energy flows. It builds on the mostpopular features and capabilities of BLAST and DOE-2 but also includes many innovativesimulation capabilities.

DesignBuilder provides a user-friendly interface to model the geometric spaces and can export data for further analysis that can be done in EnergyPlus. Other programs like eQUEST and Visual DOE are also used to run the DOE2 simulation engine to perform energy calculations. ECOTECT can calculate heating and cooling loads for models with any number of zones or any type of geometry. ECOTECT's ability to predict energy performance of complex buildings may not be on par with EnergyPlus and DOE2 but it is a great concept design tool to determine solar exposure and penetration studies, façade optimization and visualization.

Once inefficient aspects of the building are identified, possible ECMs which could provide the highest savings in energy consumption to meet the facility's requirement. This is while keepingin mind the physical and economic viability of the Conservation Measure.

The accuracy in the estimation of saving potentials for each viable ECM is integral to the success of the project. To make an informed decision, the nuances ofa project such as site conditions, building typology, system details,occupant behaviour and schedules need to be considered. Estimation can be done throughboth manual calculations and software simulations. The process of identifying and recommending ECMs after a detailed performance evaluation of thebuilding and is called a **building energy audit**

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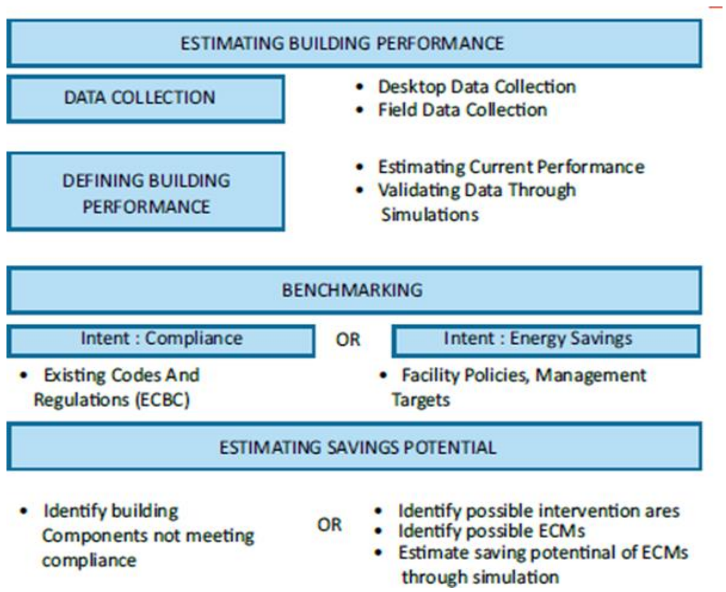

Figure 12: Steps of a building energy audit

In order to assess the energy saving potential of a facility, it is essential to understand and record its current performance through an investigation of operations and building energy use patterns. Aspects like building envelope, Lighting systems, HVAC and electrical systems need to be assessed in detail during the energy audit. While there are multiple approaches to perform energyaudits in the building, the widely accepted approach is defined by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). ASHRAE has created a set of audit standards – Levels I, II and III – that allow for a common understanding of service levels in the marketplace.

3.3 A Case Study : Anna Centenary Library Building, Chennai, India

Anna Centenary Library is a state-of-the-art public LEED India Gold Rated Library located in Kotturpuram, Chennai amidst Educational/Institutional surroundings. The plot area is 8 acres and approximate built-up areais 0.38 mn sft. The library's vision demonstrates the commitments of the Tamil Nadu State Government towardsprotecting the environment for future generations. The project consisting of (G+8) building that houses the library and an auditorium (G+1) has many green features incorporated towards Energy Efficiency.

Figure 13: Anna Centenary Library building, Chennai

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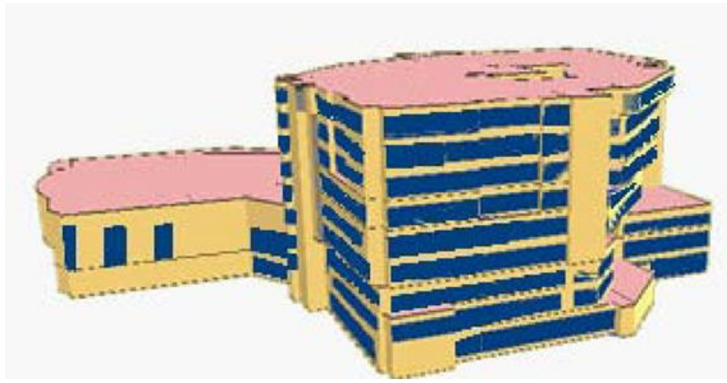


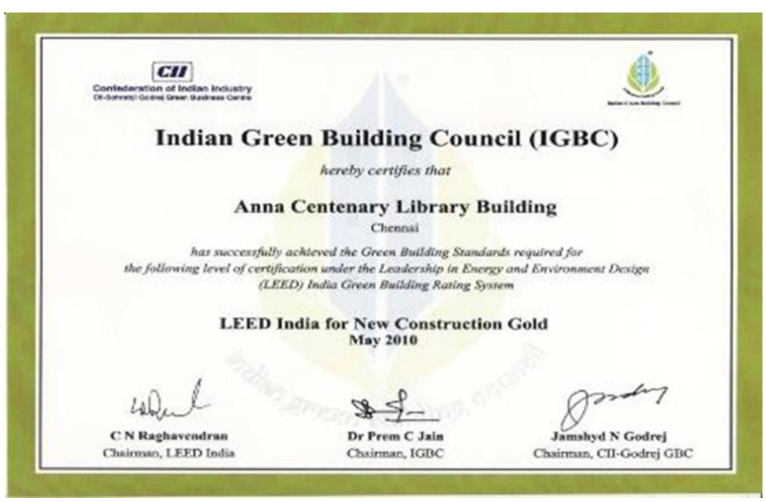
Figure 14: Energy model of Anna Centenary Library building, Chennai

- To reduce the heat ingress into the building, the library block's terrace area is painted with high albedo (that which allows heat to be reflected back into the atmosphere) paint while theAuditorium's green roof and mid-terraces of the library at 1st, 2nd and 3rd floors, keep the heat due to insolation to a minimum.
- Daylight reaches all parts of the floor plate and is only augmented under ambient cloudy/overcast sky conditions with efficient artificial lighting systems coupled with daylight and occupancy sensors
- The project has installed energy saving Heat Recovery Wheels and Demand Control Ventilation Systems that work on motors, pumps and air cooled chillers with highCoefficient of Performance (CoP) / efficiency, to save energy.
- The roof is insulated with a 75mm thick layer of over-deck (above the roof slab) extruded polystyrene to prevent heat from entering the building.
- Energy and water meters are provided at strategic locations to quantify the energy and water usage.
- The building has a very low lighting power density of 0.71 W/sq.ft with daylight controls for perimeter areas.
- Double Glazing with low Solar Heat Gain Coefficient of 0.2 prevents unwanted heat gain through windows.

The project achieved 17.5 % of energy use reduction compared to a standard building.

In conclusion, the building showed 17.5% savings in energy, the payback period for which was just under 2.5 years through operational energy efficiency.

The Certificate awarded by Indian Green Building Council (IGBC) to the Building project is shown below.


CII
Confederation of Indian Industry

Indian Green Building Council (IGBC)

hereby certifies that

Anna Centenary Library Building

Chennai

has successfully achieved the Green Building Standards required for the following level of certification under the Leadership in Energy and Environment Design (LEED) India Green Building Rating System

LEED India for New Construction Gold

May 2010

C N Raghavendran, Chairman, LEED India | Dr Prem C Jain, Chairman, IGBC | Jamshyd N Godrej, Chairman, CII-Godrej GBC

Figure 15: LEED Gold certificate of Anna Centenary Library

4. CODES, GREEN BUILDING RATINGS AND ENFORCEMENT

The Energy Conservation Act, 2001 was enacted to promote energy efficiency and conservation in India. The government has launched several initiatives towards sustainable and inclusive development such as Smart Cities, Clean India, and Skill India.

The Energy Conservation Building Code (ECBC) has been introduced in India by the Bureau of Energy Efficiency (BEE) for new commercial buildings, with a connected load of 100kW or above, setting minimal energy criteria of the buildings in operation. The ECBC provides minimum standards for energy-efficient building design, construction, and system installation, without compromising comfort levels.

The Bureau of Energy Efficiency has taken up various policy and regulatory initiatives to enhance energy efficiency of the building sector namely ECBC, ENS, voluntary star rating program for commercial buildings, star rating for energy efficient homes, net zero energy buildings. This program focuses on conducting feasibility studies of 100 existing buildings to understand the energy consumption scenario & provide solutions to the building representatives for achieving nZEB (net Zero Energy Building) status.

BEE has also developed the Energy Performance Index (EPI) benchmark, which is based on the actual energy performance of a building in terms of power consumed in commercial units(kWh)/unit area(sqm) per year. The benchmarks vary based on the 5 different climatic zones that India is divided into in the building. This Program rates buildings on a 1-5 star scale, with 5-Star labelled buildings being the most energy efficient. Energy benchmarks for commercial buildings in India have also been established by BEE.

Climate Zone	Less than 50% AC	More than 50% AC
EPI (kWh/m^2/yr)		
Warm & Humid	101	182
Composite	86	179
Hot & Dry	90	173
Moderate	94	179

Figure 16: EPI benchmarks for office buildings (BEE)

Eco Niwas Samhita 2018, Part – I Building Envelope **(Energy Conservation Building Code for Residential Sector)** was developed and launched in 2018 to set minimum building envelope performance standards to limit heat gains/heat loss while ensuring adequate natural ventilation and daylighting. The code is applicable to all residential use building projects built on plot area ≥500sqm.
Some of the prominent green rating systems for buildings in India are –

- **Green Rating for Integrated Habitat Assessment (GRIHA) by TERI, The Energy Research Institute**
- **Leadership in Energy and Environment Design (LEED) by US Green BuildingCouncil**
- **India Green Building Council (IGBC) Rating System**

These Green Rating Systems aim to quantify the environmental, economic and socio-economic benefits of green building design with an emphasis on sustainable site planning, optimized energy performance, efficient materials, and construction practices, water, and waste management strategies and indoor environmental quality.
These Codes and Rating Programs, if enforced and made mandatory, will keep the Operational Energy demand and consumption low as related to Carbon Emissions and its impact on Climate Change.

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5. CONCLUSION

Climate change is a global problem that requires immediate attention from each individual. A few degrees of temperature rise will have significant climatological impacts, causing rising sea levels, heat waves, intense precipitation, droughts and tropical storms.

Building Climate Consensus as Bill Gates puts it – Global Cooperation is notoriously difficult. It is hard to get every country in the world to agree on anything - more so, when it is asked of them to incur new costs, say - the expense of curbing carbon emissions.

In context of India's and the world's efforts to transition to cleaner power production to achieve net zero targets, the construction boom presents an opportunity to integrate energy efficient systems in future buildings. Operational energy which is driven by mechanical cooling/heating of buildings, appliances like fans, chillers, etc. needs to be better regulated by Building Energy Efficiency policies and codes. Although many energy policies and initiatives are in place and ECBC is being made mandatory in the country and the amendment in 2022 has changed the code to "Energy Conservation and Sustainable building code", there is still a lack of holistic execution of energy efficiency in buildings.

Efficient technology does not necessarily improve occupant comfort in the buildings or reduce the need for cooling. It is not sufficient to rate the individual performance of the building without the context/surroundings of the site. Strategies to minimize cooling demand and provide thermal comfort through better layout, design and choice of materials is important too.

Heating, Ventilation, Air Conditioning System (HVAC) is the prominent system which accounts for most of the building energy demand in commercial buildings like offices. Building sector space cooling has a dominant share of the entire cooling energy demand at around 57%. By 2050, space cooling could drive almost 30% of India's electricity demand growth and 45% of its peak electricity load. The International Energy Agency (IEA) predicts that by increasing the efficiency of space cooling equipment, India can reduce 46% of its projected annual electricity demand. The building sector also shows potential improvement in 2027, at roughly 17% reduction in energy consumption and total emissions. Role of building energy code is increasingly important to reinforce the need to build in strategies and interventions to reduce the cooling demand. Implementation of ECBC and ECBC-R must be made mandatory in all states and ensuring compliance through strict governance. Potential energy savings from refrigerant-based space cooling in buildings will come from proper implementation of envelope and HVAC related guidelines and minimum performance thresholds driven by code.

6. ACKNOWLEDGEMENT

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