The Infosys campus in Bangalore is constantly monitored for performance metrics

Building Performance Metrics and Definitions – an Overview

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Introduction

The drive towards sustainable, low-energy buildings has increased the necessity for easy, yet accurate methods to gauge whether the building meets minimum standards for energy performance and human comfort. A key barrier to widespread adoption of sustainable design is the lack of availability of actual, measured performance information for sustainably designed and operated buildings.

Building energy performance assessment is crucial to ascertain the efficiency of energy use in buildings and is the basis for making decisions for enhancing energy efficiency. To assess the energy performance of existing buildings quantitatively, the energy use of the assessed buildings should be quantified first. The quantified energy use will be then used to compare with available assessment criteria, standards or benchmarks to determine the energy performance quantitatively.

This article aims to identify key performance indicators (KPIs) representing major and consistent variables affecting building energy use. The top-down approach to performance analysis begins with the whole-building annual benchmarks. This is drilled down to the system level and then to granular details around component performance that make up for the system. In a building, the 'system' refers to an aggregate total of all usage, electric or fuel, by a category of kit. Frequently used categories are HVAC, lighting and plug loads, with additional categories depending on the level of details of measurements. This article reviews building energy performance evaluation metrics at the whole-building, system, and individual equipment or component levels. The KPIs are not comprehensive and identify the necessity for more comprehensive system-level energy performance indicators, but nevertheless, function as good starting points.

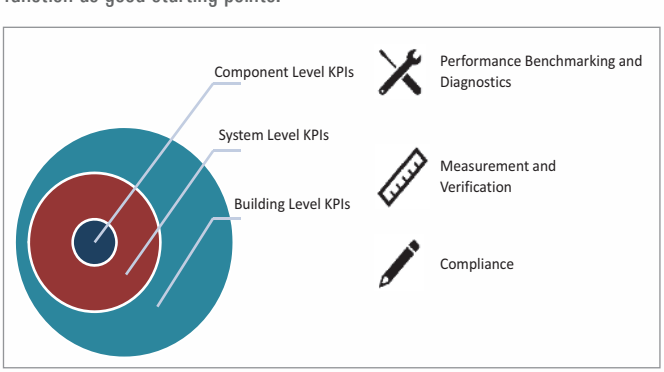

Figure 1: Building performance metrics

About the Author

Swapnil Joshi holds a master's degree in mechanical engineering and a post graduate diploma in business management, with over 17 years of experience in leadership roles. He is also a Fellow and an alumnus of the Chevening Gurukul program in Leadership and Excellence at the University of Oxford. He is a Principal Consultant at the Smart Spaces Centre of Excellence, ENCAS-IOT at Infosys and leads the Smart Buildings Practice. He specialises in automation, IOT for buildings and application engineering for HVAC and building controls. He leads various aspects of building sustainability, and has been the Program Manager for the LEED certification program at Infosys, to deliver the world's largest existing building LEED Platinum portfolio in the world. Prior to joining Infosys he was the DGM for Strategic Operations Sales and Technology at the Centre of Excellence, Johnson Controls India. He also played a role in the design of Bharati, the New Indian Research Station at Antarctica, where he designed smart building controls for the station.

Table 1: Whole building performance metrics

Performance Metric	Acronym	Definition	Units	Indicator
Total Energy Use	–	Total energy use of a building/s	kWh	Quantitative
Building Lifecycle Energy Use	–	Total energy use of a building/s for its lifecycle. (The value of this metric is incremental in nature).	kWh	Quantitative
Energy Use Intensity	EUI	Energy use intensity is the total energy use in a building divided by the total area. This is a normalised value.	kWh/m^2	Quantitative
Energy Performance Index / Building Efficiency Index	EPI/BEI	This is a building energy indicator and is defined as the number of electrical units consumed by 1 m^2 of space per year. The EPI considers energy used by building services for occupant comfort, and based on a prevalent climate condition.	kWh/(m^2*yr)	Quantitative
Electrical Load Factor	LF, ELF	The average electrical load divided by the peak load for a specified period.	Dimensionless	Quantitative
Energy Star Score	–	Score on a 1-100 scale that compares the building with similar buildings across a nation/ geography and grouped by similar nature of business.	Dimensionless	Rating Score
Zero Energy Performance Index	zEPI Index	A rating score indicating the likelihood of the building to be net zero. The smaller the score, the closer the building is to being net zero. The zero energy performance index (zEPI) is the ratio of energy performance of the rated building to the average energy consumption of a similar building at the turn of the millennium that is operated in a similar climate, for similar hours with and similar operating conditions.	Dimensionless	Rating Score
Smart Readiness Indicator	SRI	A score that indicates the readiness of a building to adapt to operations to suit the needs of occupants as well as optimize energy for energy efficiency and energy use flexibility. More specifically, it provides information on the technological readiness of buildings to interact with their occupants and the grid.	Dimensionless	Rating Score
Occupant Usage and Stability	–	Provides details and an assessment of how the occupant's usage impacts the building. Used as a check for other indicators and a way to assess the magnitude of occupant usage compared to benchmarks. Also indicates occupancy patterns over a period.	Dimensionless	Qualitative
Whole Building Performance Indicator	–	An aggregated performance indicator considering lighting, thermal comfort, maintenance, and indoor air quality.	Dimensionless	Rating Score
LEED/GRIHA/WELL/IGBC/GEM Certification	–	Rating systems for design, construction, operation and maintenance, wellness of buildings.	Dimensionless	Certification

Table 2: System level performance indicators

Performance Metric	Acronym	Definition	Units	Indicator	Scope
Lighting Power Density	LPD	Lighting power density (LPD) is defined as watts of lighting per square meter of floor area. It is a simple screening measure that indicates whether a space offers opportunities for energy savings.	W/m^2	Quantitative	Lighting
Daylight Effectiveness Indicator	DEI	A metric that reflects monthly lighting energy use density considering daylit hours. Determines if the daylight design or daylight controls are effective.	–	Quantitative	Lighting
Total System Performance Ratio	TSPR	A ratio of the sum of a building's annual heating and cooling load in thousands of kWh divided by the sum of the annual cost of energy consumed by the building HVAC systems.	kWh/$	Quantitative	HVAC
HVAC Operational Consistency Indicator	–	A metric reflecting the HVAC operation effectiveness under varying weather conditions.	–	Qualitative	HVAC
Load Energy Ratio	LER	The ratio of real total systems loads to the total system energy consumption to meet the loads. It is the ratio of total energy (kWh) used divided by the possible total energy used within a specified period, if used at the peak demand (kW) during the entire period.	kW/ton	Quantitative	HVAC
HVAC Energy Efficiency	η(HVAC)	The ratio of total HVAC demand (ideal case) to the total HVAC actual energy use.	–	Quantitative	HVAC
Plug-load Off-hours Ratio	–	The ratio of plug-load energy consumption during off-hours divided by the total plug-load consumption.	–	Quantitative	Plug- load

Table 3: Component level performance indicators

Performance Metric	Acronym	Definition	Units	Indicator	Scope
Coefficient of Performance	COP	Cooling: The ratio of the rate of heat removal to the rate of energy input of a complete refrigerating system. Heating: The ratio of the rate of heat delivered to the rate of energy input of a complete heat pump system.	–	Quantitative	HVAC
Energy Efficiency Ratio	EER	The ratio of the cooling capacity in BTU to the power input in watts, measured in a constant condition (EER is normally calculated with a 95°F outside temperature and an inside (return air) temperature of 80°F and 50% relative humidity) without considering seasonal temperature changes.	BTU/h/W	Quantitative	HVAC
Seasonal Energy Efficiency Ratio	SEER	The ratio of the cooling output (measured in BTU) during a typical cooling-season divided by the total electric energy input (in watt-hours) during the same period. The higher the unit's SEER rating, the more energy efficient it is.	BTU/Wh	Quantitative	HVAC
Heating Seasonal Performance Factor	HSPF	HSPF is defined as the ratio of heat output (measured in BTUs) over the heating season to total input electricity used (measured in watt-hours).	BTU/Wh	Quantitative	HVAC
Integrated Part Load Value	IPLV	A single-number expressing integrated part-load efficiency of air conditioning or heat pump equipment weighted on different part-load operation conditions (100%, 75%, 50%, and 25%-part load).	–	Quantitative	HVAC
Boiler Efficiency	η	The overall efficiency of the boiler considering the effectiveness of the heat exchanger and the radiation and convection losses.	–	Quantitative	HVAC
Luminous Efficacy	Lm/W	Luminous efficacy is a measure of how well a light source produces visible light. It is the ratio of luminous flux to power, measured in lumens per watt.	Lm/W	Quantitative	Lighting
Fan Energy Index	FEI	The ratio of the actual fan efficiency to a baseline fan efficiency, both calculated at a given airflow and pressure.	–	Quantitative	Fan
ACEEE Appliance Label	–	A label indicating annual operating cost and energy consumption for appliances.	–	Rating Score	Appliances
EnergyStar Label	–	A label indicating whether a product meets EPA's energy specification.	–	Qualitative	Appliances

Table 4: Lighting system KPIs

System	Sub-system	KPI Definition	KPI Unit	Impact Category
Lighting System	Interior, Exterior and Emergency Lighting System (three categories)	Lighting energy use per m^2 floor area per year.	kWh/(m^2*yr)	Energy
		Lighting power per m^2 floor area.	W/m^2	Demand
		Lighting energy usage normalized per day.	kWh/day	Energy
		Energy use intensity based on people count over a year.	kWh/(person*yr)	Energy
		Lighting energy consumption per occupied hour.	kWh /(FTE_Occupied Hours)	Energy

Table 5: Miscellaneous system KPIs

System	Sub-system	KPI Definition	KPI Unit	Impact Category
Plug Loads or Miscellaneous Loads	Occupants and Non-occupants (two categories)	Energy demand of the system per m^2 floor area, per person.	W/m^2	Demand
		Annual energy consumption per m^2 floor area, per person.	kWh/(m^2*yr)	Energy
		The percentages of four statuses – active, idle, sleep, and off.	Usage Profile	Energy

Table 6: HVAC system KPIs

System	Sub-system	KPI Unit	KPI Definition	Impact Category
HVAC System	–	kWh/m^2	Overall HVAC system energy use intensity, including subsystems of cooling, heating, air distribution, and ventilation.	Energy
	–	W/m^2	Overall HVAC system peak power demand intensity, including subsystems of cooling, heating, air distribution, and ventilation.	Demand
	Cooling System	W/m^2	Cooling system demand per floor area.	Demand
		kWh/kWh	Cooling system consumption per delivered cooling energy.	Energy
		kW/ton	Cooling system power demand per delivered cooling tonnage.	Demand
		kWh/m^2	Cooling system energy use intensity.	Energy
		kWh/(m^2*C DD)	Cooling system energy use intensity normalized by cooling degree days.	Energy
		Ton-hour/kWh	Energy efficiency of a central cooling plant, including energy use of chillers, chilled water pumps, cooling towers, and condenser water pumps (for water-cooled chillers). The KPI is calculated as the ratio of ton-hour of delivered cooling energy to kWh of consumed electricity of all central plant equipment.	Energy
	Air Distribution System	cfm/m^2	Airflow rate per m^2 floor area.	Energy
		W/cfm	Airflow rate per unit of consumed electricity	Demand
		FEI (Fan Energy Index)	The ratio of the actual fan efficiency to a baseline fan efficiency, both calculated at a given airflow and pressure.	Energy
	Ventilation	Δppm(CO_2)	The difference between indoor and outdoor air CO_2 concentration.	Air quality
		cfm/m^2	The average outdoor airflow rate per m^2 floor area for a given time interval.	Air quality
		cfm/person	The average outdoor airflow rate for a given time interval per person.	Air quality
	Air Economizer	Actual Working Ratio	The ratio of actual working hours to the theoretical working hours of economizer.	Energy
		Mechanical Cooling Ratio	The ratio of mechanical cooling hours to free-cooling hours.	Energy
	Hydro-transportation	W/gpm	Ratio of hydro-system (water, refrigerant) power to the flow rate transported.	Demand
		PEI (Pump Energy Index)	Ratio of the electrical input power of a reference pump to the electrical input power of the actual pump.	Energy

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