Accelerating Energy Efficiency in Indian Data Centers: Report for Phase II Activities

Confederation of Indian Industry and Lawrence Berkeley National Laboratory
Final Report
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On behalf of CII and LBNL, we extend our special thanks to all the stakeholders for their continued support and involvement during the survey and the workshop. The names of specific organizations we would like to recognize are listed under Appendix F.

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Executive Summary

The significant growth of the Indian IT Industry in recent years calls for a suitable policy that mandates Indian data centers to reduce their energy consumption. [1] Though India has well-established energy efficiency standards in its commercial and industrial facilities, a dedicated standard for data centers does not exist.

To support the development of an energy efficiency policy framework for Indian data centers, the Confederation of Indian Industry (CII), in collaboration with Lawrence Berkeley National Laboratory (LBNL)-U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and under the guidance of Bureau of Energy Efficiency (BEE), has taken the initiative on "Accelerating Energy Efficiency in Indian Data Centers." This initiative is also part of the larger Power and Energy Efficiency Working Group of the US-India Bilateral Energy Dialogue and consists of two phases: Phase-I (November 2014 – September 2015) and Phase-II (December 2015 – December 2016).

This report documents Phase II of the "Accelerating Energy Efficiency in Indian Data Centers" initiative, which built on Phase I findings related to international best practices and how existing energy efficiency standards in India could address data centers. The Indian standards central to Phase II were the Energy Conservation Building Code (ECBC), which is Prescriptive or Performance Based (Mandatory Code); and the Perform, Achieve & Trade (PAT) market-based scheme in which BEE sets sector-specific benchmarks and gives targets to Designated Consumers (DC).

Phase II consisted of two main activities: the development of recommendations for incorporating data center specific requirements into the 2016/2017 revision of ECBC and the evaluation of various Energy Performance Metrics for reporting data center energy efficiency under a PAT-type programme. Comprehensive policy review and stakeholder engagement were instrumental in both activities.

Energy Conservation Building Code (ECBC) for Data Centers

The Phase I study of over 20 international energy efficiency standards identified ASHRAE 90.1, 90.4 and California Title 24 as warranting further view to guide the integration of data centers into ECBC. The Phase II policy review related to ECBC focused on the standards' Electrical System and HVAC (Heating, Ventilation and Air-Conditioning) requirements to identify data center-specific technical specifications and test methods for incorporation into the new ECBC version. CII also formulated a Large Stakeholder Consultative Group consisting of 40 stakeholders and their involvement through periodic technical discussions and meetings helped CII and LBNL finalize data center specific recommendations, which are outlined below.

All commercial buildings that must comply with ECBC and have data center operations with an additional connected load of more than 100 kW of IT design load shall comply with the minimum energy efficiency requirements for HVAC and Electrical System:

ECBC Recommendations - HVAC

- Minimum equipment efficiency (Sensible Co-efficient of Performance) for CRAC units, which are specific to data centers shall be 2.5.
- Air and water economizer requirement to be waived off based on the stakeholder feedback.
- Data centers designed for air-cooled equipment shall include air barriers such that there is no significant air path for computer discharge air to recirculate back to the computer inlets without passing through a cooling system. Target IT inlet temperature shall be no more than 3 ˚C higher than the cooling system supply temperature.

- Temperature and Humidity Control requirements must be specified with the intent not to overcool data centers based on international best practices, to avoid simultaneous humidification and dehumidification (within -9˚C and 15˚C of dew point temperature and 60% RH), and to eliminate reheat with dehumidification.
- Fan Controls shall vary the airflow rate as a function of actual load.

ECBC Recommendations - Electrical System

- Diesel generators are identified as equipment that should have minimum specified efficiency and the provisions under this section may follow new ECBC 2016/2017 requirements.
- Sub metering at the data center shall be provided to allow the monitoring and calculation of Power Usage Effectiveness (PUE). Minimum metering includes IT equipment energy and total data center energy including cooling energy (e.g. compressors, fans and pumps), electrical distribution system losses (e.g., UPS), and lighting. PUE to be measured as per The Green Grid Level 1 guidelines. Minimum requirement for thermal (air) monitoring shall be at the IT equipment inlet at the top of every 5th rack (in the cold aisle).
- UPS modules to satisfy the minimum efficiency requirements of 94% at 100% load.

A PAT (Perform, Achieve & Trade)-Type Programme

To enable a PAT-like mechanism, 14 Energy Performance Metrics were reviewed and analyzed in regards to their applicability for benchmarking data center energy consumption in India. A Core IT Working Group comprising of 13 IT industry experts such as Dell, Intel, IBM, Oracle, and Cisco was also formulated by CII-LBNL in order to evaluate the identified 14 Energy Performance Metrics and arrive at a consensus on an appropriate metric to be considered for a PAT-type programme for data centers in India. Various periodic technical discussions were carried out with Core IT Working Group through a workshop and an online questionnaire referred to as the “PAT Pilot Study.”

The following are the major industry views on selecting an appropriate Energy Performance Metric for a PAT-type programme and have been presented to BEE. The two metrics that have been identified as the most important Energy Performance Metrics are PUE to measure and report infrastructure energy efficiency and CPU Utilization for measuring IT equipment energy efficiency, although the metric is not recommended for adoption at this time.

PUE

PUE is a well-established and matured Energy Performance Metric that is currently being used by many Indian data centers to report their infrastructure efficiency and operating efficiency to their management. This metric may be considered under a PAT- type programme for data centers, but it is recommended to take the following factors under consideration.

- PUE measurement and monitoring must be standardized. The Green Grid level 2 guidelines for PUE measurement and monitoring is recommended. Due to lack of instrumentation in existing data centers, this may be applicable to only new data centers (with IT load 100kW or more).
- Data centers may be categorized into: (a) New and Existing Data Centers; and (b) Data Center Size (e.g., Large and Small Data Centers) depending upon which PUE obligations may vary.
- One of the major issues with using only PUE as the Energy Performance Metric is that it does not take into consideration IT usage that includes server loads, underutilized servers/idle servers, utilization of storage and network devices etc.

CPU Utilization

CPU Utilization is a key Performance Metric as it tracks CPU performance regressions or improvements and is used to investigate performance problems. Also, CPU consumes approximately 50% of server power consumption. Even though the metric is considered important, there are various issues related to measuring and monitoring CPU Utilization:

- CPU Utilization values are highly variable and depend upon the nature of loads, application type, etc.

- Standardization of the metric is difficult for all data centers due to variation of categories of data centers, operation type etc.
- The metric is not suitable for colocation data center type as IT equipment in such data centers are controlled by the customers and not the data center owners.

Considering various challenges associated with collecting and reporting CPU utilization by the data centers, a mechanism may be introduced at this point to mandate data centers to at least monitor and document IT usage (i.e., number of underutilized/ idle servers).

Conclusion and Next Steps

Conclusion

Inclusion of Data Center Specific Requirements in ECBC 2016/2017 Draft

- Data centers previously excluded from the Indian ECBC standard have been included in the draft code for ECBC 2016/2017.
- Though HVAC requirements specified in the code may be applicable to data centers, CII and LBNL have strongly recommended minimum SCOP of 2.5 for CRAC units in data centers.
- Based on stakeholder discussions, Economizer requirement to be waived-off for Indian data centers which has not been included in the ECBC 2016/2017 draft code.
- Data center-specific requirements for Air Management, Fan-Control, Temperature and Humidity Control as mentioned above have strongly been recommended by CII and LBNL for inclusion in the current code.
- Under Metering and Monitoring section in draft ECBC 2016/2017, CII and LBNL have recommended PUE calculation and requirement for thermal monitoring, which is not currently captured in the draft version.
- UPS system efficiency values as mentioned in draft ECBC 2016/2017 are applicable to data centers in India.

Reporting Energy Performance of Data Centers under a PAT-type Programme in India

- PUE may be used as a metric under a PAT-type mechanism for Indian data centers.
- PUE measurement and monitoring must be standardized. Measurement as per the Green Grid Level 2 guidelines is recommended.
- Categorization of Data centers into:(a) New and Existing Data Centers; and (b) Data Center Size (e.g. Large and Small Data Centers) depending upon which PUE obligations may vary.
- For BEE to successfully implement the PAT programme for data centers, 'Data Center' definition including data center threshold and normalization factors must be clearly defined.

Recommended Next Steps

- Development of a detailed ECBC User-Guide for Indian data centers that documents data center best-practices and implementation guidelines for data center specific requirements included in ECBC new version.
- To successfully implement PAT programme for data centers under the next PAT cycle (2018), further data collection is required that includes identification of all data centers to be considered under the scheme, development of data collection format that includes total energy consumption and IT energy consumption used for measuring data center energy performance and identification of factors that may influence these parameters.
- In consultation with key stakeholders, organize workshops/awareness building sessions for data center owners/ large users.

Introduction

India has witnessed significant growth in the number of data centers in order to meet the growing needs for data. A detailed study on 'Data Center Market Growth and Projections' was conducted by CII and LBNL and is given in Appendix B. With technology shifting from premise-based to cloud-based technology, there is a race to set up data centers all over the world, particularly in India and Asia to keep up. In order to power this data-driven revolution, tremendous amounts of energy are required, but in India a policy does not currently exist to regulate the energy consumption of data centers or to sufficiently support the adoption of energy efficient technologies and best practices in Indian data centers.

The "Accelerating Energy Efficiency in Indian Data Centers" initiative supports the development of an energy efficiency policy framework for Indian data centers. The study is being conducted by the Confederation of Indian Industry (CII), in collaboration with Lawrence Berkeley National Laboratory (LBNL)-U.S. Department of Energy, and under the guidance of Bureau of Energy Efficiency (BEE). It is also part of the larger Power and Energy Efficiency Working Group of the US-India Bilateral Energy Dialogue. The initiative consists of two phases: Phase I (November 2014 – September 2015) and Phase II (December 2015 – December 2016).

This report documents Phase II of the "Accelerating Energy Efficiency in Indian Data Centers" initiative, which built on Phase I findings related to international best practices and how existing energy efficiency standards in India could address data centers. The Indian standards central to Phase II were the Energy Conservation Building Code (ECBC), which is Prescriptive or Performance Based (Mandatory Code); and the Perform, Achieve & Trade (PAT) market-based scheme in which BEE sets sector-specific benchmarks and gives targets to Designated Consumers (DC).

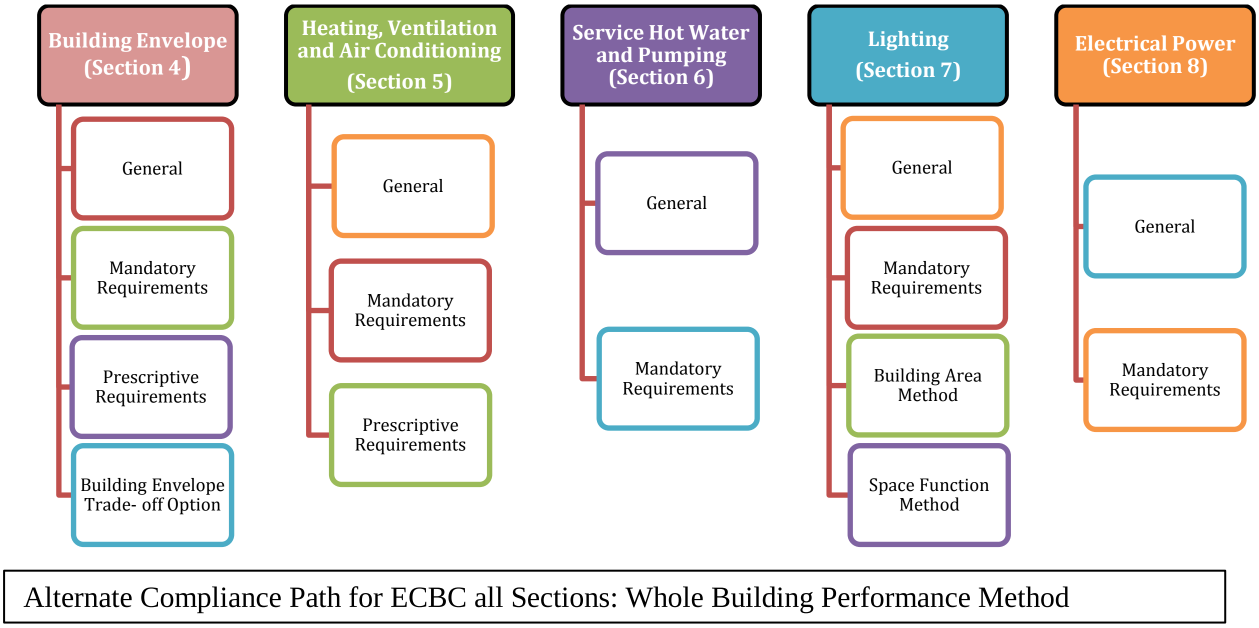
Phase II consisted of two main activities: the development of recommendations for incorporating data center specific requirements into the 2016/2017 revision of ECBC and the evaluation of various Energy Performance Metrics for reporting data center energy efficiency under a PAT-type programme. Comprehensive policy review and stakeholder engagement were instrumental in both activities.

Energy Conservation Building Code (ECBC) for Data Centers

This section reviews the Energy Conservation Building Code (ECBC) structure and format in order to incorporate data center specific technical specifications for HVAC and Electrical Systems under relevant sections in the code. Since the Indian ECBC standard follows a structure which is similar to the shortlisted International standards (ASHRAE 90.1, 90.4, and California Title 24), these standards were reviewed in detail to identify specific requirements and test methods relevant to data centers that can be adopted in the Indian ECBC standard.

ECBC [5] provides minimum requirements for the energy-efficient design and construction of commercial buildings but does not contain data center-specific requirements. Support for the development of ECBC came from the United States Agency for International Development (USAID) as a part of the Energy Conservation and Commercialization (ECO) project. ECBC takes a Prescriptive or Performance-Based (Mandatory Code) approach. It follows the same structure and covers similar buildings components as ASHRAE 90.1, ASHRAE 90.4, and California Title 24. Similarly, ECBC also offers the Prescriptive or Whole Building compliance options and the option to make up for not meeting one of the requirements by going above and beyond for a different requirement. Figure 1 below describes the basic structure of ECBC, which was reviewed in order to incorporate data center specific technical specifications for HVAC and Electrical Systems under relevant sections in the code.

Figure 1: ECBC Sections and Compliance Paths



ASHRAE 90.1 and 90.4

ASHRAE 90.1 [6] and 90.4 [7] are consensus standards developed by the American Society of Heating, Refrigerating and Air -Conditioning Engineers (ASHRAE). ASHRAE is accredited by the American National Standards Institute (ANSI) and follows their requirements for due process and standards development. The purpose of ASHRAE 90.1 is to establish the minimum energy efficiency requirements of buildings (excluding low-rise residential buildings). It is also the reference standard for US Energy Policy Act and many building energy codes in the United States (e.g., California Title 24).

The purpose of the ASHRAE 90.4 standard is to establish minimum energy efficiency requirements of data centers. The standard applies to: (a) new data centers or portions thereof and their systems; (b) new additions to data centers or portions thereof and their systems; and (c) modifications to systems and equipment in existing data centers or portions thereof. The standard is based on ASHRAE 90.1, but caters to the data center-specific requirements for energy efficiency. Figure 2 and 3 below describes the basic structure of ASHRAE 90.1 and 90.4

Figure 2: ASHRAE 90.1 Sections and Compliance Paths

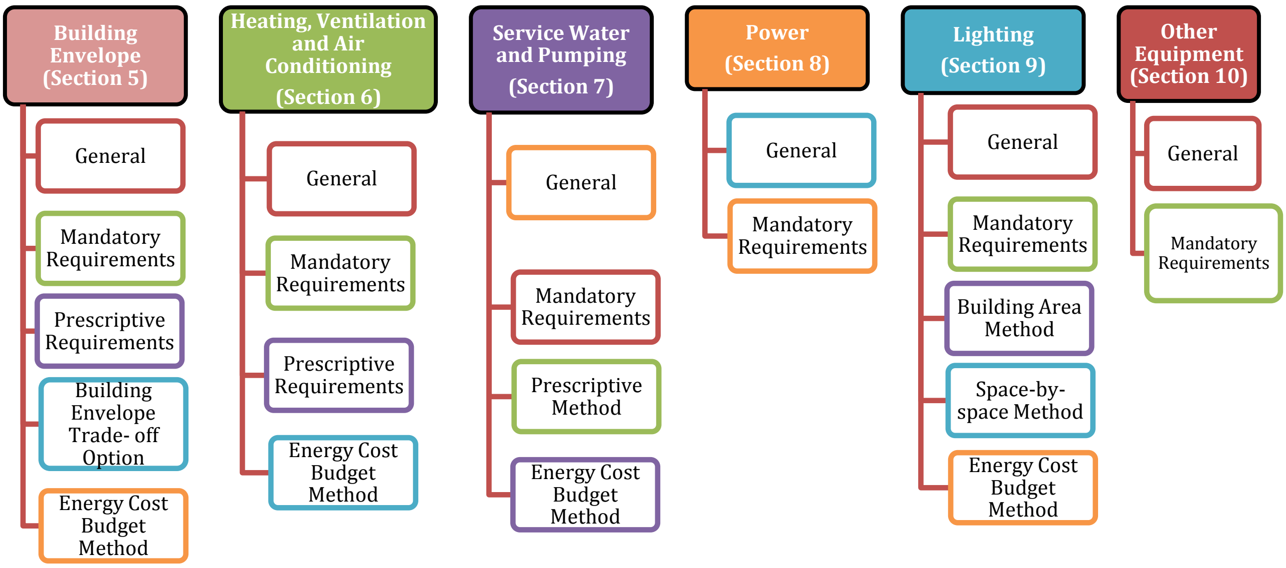
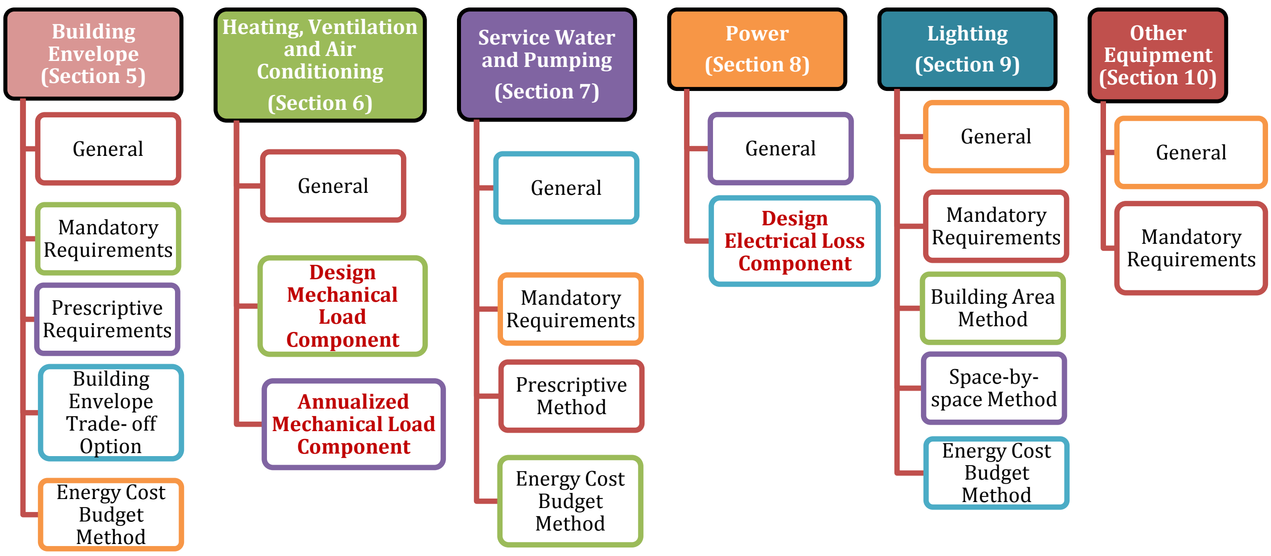


Figure 3: ASHRAE 90.4 Sections and Compliance Paths



California Title 24

The California Energy Code, part 6 of the California Building Standards Code, which is Title 24 of the California Code of Regulations [8], was created by the California Building Standards Commission in 1978 in response to a legislative mandate to reduce California's energy consumption. It is also titled The Energy Efficiency Standards for Residential and Nonresidential Buildings and is applicable to all buildings. It covers efficiency requirements for Building Envelope, HVAC, Service Water Heating, Lighting and Electrical System under different subchapters and sections. The 2013 Building Energy Efficiency Standards includes data center or computer room specifications under Section 140.9 – Prescriptive Requirements for Covered Processes.

ECBC Stakeholder Engagement

CII formulated a Large Stakeholder Consultative Group consisting of 40 stakeholders and their involvement through periodic technical discussions and meetings helped CII and LBNL finalize data center specific recommendations for incorporation into the new ECBC version.

Bangalore Workshop (April 1st, 2016)

A focused group discussion was conducted in Bangalore on April 1st, 2016 to share the findings of the work done so far under this initiative and gather valuable inputs from industry stakeholders to finalize data center-specific technical specifications and recommendations based on international standards (ASHRAE 90.1 and 90.4 and California Title 24). The programme agenda and the list of workshop participants are given in Appendix C and D respectively. Stakeholder views from the workshop are summarized below.

- It was agreed upon during the discussion that defining a threshold value for data centers to follow specific recommendations for accelerating energy efficiency would be of importance. Also, higher efficiencies may be considered in higher density data centers or data centers with larger air handlers.
- Since the use of economizers is not highly prevalent in India, they should not be mandatory for use in data centers in India.
- Temperature and humidity control would greatly affect the energy efficiency of a data center. Inlet air temperature may be in the range of 23˚ to 27˚c and suggested humidity control dead band is 30 % - 70%.
- Stakeholders agreed upon the fact that simultaneous humidification and dehumidification should not be allowed in a data center as well as reheat should not be permitted.
- Since Diesel Generators are a segment where energy efficiency can be achieved, it needs to be included for consideration into ECBC.
- It is necessary to monitor and calculate the Power Usage Effectiveness (PUE) of a data center for improving the energy efficiency in different segments. Sub-metering is an important aspect and PUE calculations may be as per The Green Grid Level-1 guidelines.
- One of the highest energy consuming segments in a data center is the UPS segment. Therefore, UPS efficiency is critical and a minimum efficiency of 94.0% at 100% load and 92.0% at 25% load was agreed upon.

Appendix E presents a detailed set of recommendations presented to the stakeholders with specific inputs received.

Meeting with the ECBC Working Groups for HVAC and Electrical System (April 29, 2016)

After extensive post-workshop discussions with our Advisory group members (Appendix F) regarding further technical inputs on specific issues, the recommendations were further revised. The data center-specific revised recommendations for incorporation into ECBC 2016/2017 version were presented to the working group (WG) meeting on April 29, 2016. Key Discussion Points from the WG meeting and CII-LBNL Response to specific issues are presented in Appendix G.

National Stakeholder Consultation on ECBC (May 27, 2016)

In order to make the ECBC update process transparent and inclusive, BEE and the PACE-D Team organized three stakeholder consultation workshops, one in each zone of the country – west, south, and east. The National Stakeholder Consultation on ECBC was organized on May 27, 2016 in New Delhi to present the ECBC update process and recommendations for the new ECBC that will include data centers.

Final Recommendations for ECBC New Version – Based on Stakeholder Inputs

All commercial buildings that must comply with ECBC and have data center operations with an additional connected load of more than 100 kW of IT design load shall comply with the minimum energy efficiency requirements for HVAC and Electrical System presented in Table 1a and 1b.

Table 1a: ECBC 2016/2017 Recommendations - HVAC

Sections	Suggested Additions by CII and LBNL based on Stakeholder Consultations	Inclusion in Draft ECBC 2016/2017
Minimum Equipment Efficiencies	As per ECBC 2016/2017 (draft version) requirements, with the addition of: Air conditioners and condensing units in data centers (CRAC units) shall have a minimum Sensible Coefficient of Performance (SCOP) value of 2.5.	DC specific performance requirements for CRAC units incorporated.
Air Economizers and Water Economizers	Since economizers are not common in Indian data centers, this requirement is waived off.	No specific waiver for data center economizers provided.
Data Center Air Management System	Data Centers designed for air-cooled equipment and with a design load exceeding 100 kW/room shall include air barriers such that there is no significant air path for computer discharge air to recirculate back to the computer inlets without passing through a cooling system. Target IT inlet temperature shall be no more than 3 ˚C higher than the cooling system supply temperature.	DC specific performance requirements not incorporated.

Table 1a: ECBC 2016/2017 Recommendations – HVAC (Contd.)

Sections	Suggested Additions by CII and LBNL based on Stakeholder Consultations	Inclusion in Draft ECBC 2016/2017
Temperature and Humidity Control	Air temperature controls must be able to control the inlet air temperature to the IT equipment in the range of 23˚C to 27 ˚C (with preference to the upper end). Controls must prevent humidification or dehumidification when within the range of -9 ˚C to 15 ˚C dew point and 60% RH. Also, if multiple units serving the same space have humidity control, prevent simultaneously humidifying and dehumidifying in the same room. No reheat should be allowed with dehumidification.	(a) Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3°C within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum (b) Where separate heating and cooling equipment serve the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling (c)In warm and humid climates, thermostat controls shall also be programmed to maintain humidity at 60%
Fan Control	Each computer room air conditioner (CRAC) with mechanical cooling capacity exceeding 63,300kJ/hour (5 tons, 60,000 Btu/hour) and each air handler shall be designed to vary the airflow rate as a function of actual load and shall have controls and/or devices (such as variable speed control) that will result in fan motor demand of no more than 50 percent of design wattage at 66 percent of the design fan speed.	DC specific performance requirements not incorporated

Table 1b: ECBC 2016/2017 Recommendations – Electrical System

Sections	Suggested Additions by CII and LBNL based on Stakeholder Consultations	Inclusion in Draft ECBC 2016/2017
Diesel Generators	As per ECBC 2016/2017 (draft version) Requirements. Suggestion: Voluntary star labeling requirements shall be followed.	Provisions of this section shall comply with ECBC, 2016/2017.
Metering and Monitoring	For data center services exceeding 100 kW, sub metering at the data center shall be provided to allow the monitoring and calculation of Power Usage Effectiveness (PUE). Minimum metering includes IT equipment energy and total data center energy including cooling energy (e.g. compressors, fans and pumps), electrical distribution system losses (e.g. UPS), and lighting. PUE to be measured as per The Green Grid Level 1 guidelines. Minimum thermal (air) monitoring shall be at the IT equipment inlet at the top of every 5th rack (in the cold aisle).	DC specific electrical sub-metering requirements unclear. DC specific thermal monitoring not incorporated.
Uninterrupted Power Supply (UPS)	For data centers with an IT Design Load greater than 100kW, each UPS module shall have a minimum efficiency of 94.0% at 100% load and 92.0% at 25% load.	DC specific recommendation included in ECBC 2016/2017 as: UPS Size and Energy Efficiency Requirements at 100% Load kVA< 20 - 90.2% 20<=kVA <= 100 - 91.9% kVA > 100 - 93.8%

PAT (Perform, Achieve & Trade)-Type Programme

PAT is designed to accelerate energy efficiency in large, energy- intensive industries and facilities. It is a market-based mechanism to enhance cost effectiveness of improvements in energy efficiency through certification of energy savings that could be traded. PAT sets performance indicators for specific industry segments and assigns mandatory emission reduction targets for the industries (i.e., Designated Consumers). More specifically, energy saving targets and the grace period to achieve targets are based on actual energy consumption (i.e., Specific Energy Consumption or SEC) and validation is conducted by a third-party (authorized by BEE).

Energy Performance Metrics

To measure data center energy performance, organizations (e.g., The Green Grid, Uptime Institute) have introduced several metrics, which have evolved over the years to simplify the evaluation process and increase the efficiency of data capture for calculations.

In this context, the technical teams of LBNL and CII developed a Comparative Matrix on Various Energy Performance Metrics for Data Centers, which takes into account 14 different Energy Performance Metrics being used around the world.

Appendix H presents the 14 shortlisted metrics tabulated along with a brief description of each metric, the formula for calculating, and mandatory parameters for calculation. Appendix I identifies the organization(s) that introduced the selected metric, organization(s) that have implemented it, and the level of applicability to data centers. Based on their relevance, applicability, and adoptability to Indian data centers, a few metrics were selected for further analysis and review. These metrics as well as the benefits and drawbacks of each are outlined below.

Power Usage Effectiveness (PUE)
PUE is defined as the ratio of total facilities energy to IT equipment energy. Total facility energy is defined as the energy dedicated solely to the data center. The IT equipment energy is defined as the energy consumed by equipment that is used to manage, process, store, or route data within the compute space.

Benefits

- The most widely used metric to estimate the energy efficiency of the data centers. It provides a simple way to understand the energy consumed by the infrastructure for a given IT load. The energy consumption of a data center includes power consumed by infrastructure (cooling equipment, cooling systems, and other source of power consumption such as lighting and power losses) and IT equipment. The total amount of energy consumed by the whole facility (IT + Infrastructure) to per unit energy provided to IT equipment provides an easy and quick assessment of a data center.
- Enables comparison across various data centers and is scalable (considering climate conditions).
- Helps in identifying areas for energy improvement in a data center especially improvement in infrastructure when the efficiency of IT equipment improves. This ensures that the infrastructure should also scale up with improved IT equipment in the data center.

Drawbacks

- A dynamic number that can vary, owing to a variety of factors such as outside temperatures, equipment changes, and the load on the servers. Without monitoring and instrumentation, it is impossible to determine the cause and effect of PUE changes.
- No clear demarcation of IT equipment and Infrastructural equipment, which leads to a possibility of gaming the PUE value unless specified in clear and unambiguous way.
- Since Total Facility Energy or Total Energy Consumption is directly proportional to PUE and IT Equipment Energy is inversely proportional, PUE may reduce with improved IT Utilization. In turn, Total Energy Consumption of the Data Center may increase. This could serve as an incentive to keep the power consumption high in order to get a reduced PUE value for the data centers.

Data Center Infrastructure Efficiency (DCiE)
DCiE is defined as the fraction of the IT equipment energy divided by the total facility energy. It is the reciprocal of PUE. The total facility power is defined as the power measured at the incoming utility meter of data center. The IT equipment power is defined as the power consumed by the IT equipment supported by the data center as opposed to the power delivery and cooling components and other miscellaneous loads. Since DCiE is the inverse of PUE, the benefits and drawbacks are similar.

IT Power Usage Effectiveness (ITUE)
ITUE is the Total Power to IT in ratio to total power to compute components and is intended to be a "PUE-type" metric for IT equipment rather than for the data center. PUE is total energy divided by IT energy, analogously, ITUE is defined as total IT energy divided by computational energy.

Benefits

- Unlike PUE, this metric takes into consideration the IT support inefficiencies such as energy consumed by Computing Components, Internal Fans, Voltage Regulator, and Power Supplies that support the computing components. PUE takes into account the energy provided to IT Equipment but does not further bifurcate the energy used inside IT Equipment like ITUE does.
- ITUE used with PUE can be useful in comparing different data centers.

Drawbacks

- If PUE and ITUE are used in combination, the temperature at which the data center and the IT Equipment operate can significantly affect the energy values for both pushing one up and perhaps the other one down. For example, if the operating temperature is high due to an increase in workload, there would be an increase in HVAC energy as well to cool down the data center (seasonal variation also affects the energy consumption of HVAC). Measuring PUE at a given data center configuration with a certain temperature, then measuring ITUE at a different configuration and IT inlet temperature would render the Total Usage Effectiveness (TUE) value defined below invalid.
- Like PUE, if more efficient computing components are installed, ITUE will go up and thus it will skew the results.

Compute Power Efficiency (CPE)
CPE connects the efficiency of computer equipment in the data center with the efficiency of the entire data center.

Benefits

- Quantifies the overall efficiency of a data center while taking into account the fact that not all electrical power delivered to the IT equipment is transformed by that equipment into useful work product. CPU utilization is used as a proxy for the normalized amount of useful work a server produces.
- Allows comparison between various data centers.
- Since CPE is a unit-less metric and has a maximum value of 1.0 or 100%, it allows the CPE of two different data centers to be compared, as there is no need to convert the units of measurement.

Drawbacks

- There is no clear definition of utilization that works for all IT Equipment in all applications.

Space, Watts & Performance (SWaP)
SWaP is an objective, three-dimensional metric that characterizes a data center's energy efficiency by introducing the parameters of space, energy, and performance together.

Benefits

- It takes into consideration both power consumed and the space occupied by server racks.

Drawbacks

- There is no scalability of performance among different data centers. For example, if the user workload is Java based then a metric like SPECjbb would be used to measure performance per watt whereas for Compute related workload, metric like SPECcpu would be used.

Compute Units per Second (CUPS)

CUPS represent a universal measure of computing output. CUPS can be defined as the amount of work done by the IT equipment per second and can serve as the numerator in the equation that determines Compute Efficiency.

Benefits

- CUPS represent a proxy for a universal measure of computing output.

Drawbacks

- Challenges exist in identifying and calculating the IT productivity or the useful work done in data center.

Server Compute Efficiency (ScE)

ScE analyses each server's primary activities with respect to time and is a sub metric to DCcE. DCcE is basically an average of all servers taken into consideration.

Benefits

- Helps in finding the Useful Productivity assigned to the server irrespective of their utilization due to secondary and tertiary activities.

Drawbacks

- Not all servers have well-defined processes performing primary services.
- In large data centers, tracking and recording which processes on which servers are providing primary services, would require a great deal of administrative overhead.
- The method does not take into account the proportion of underlying operating system activity that contributes to the primary services.
- It is not scalable across various data centers.

Server Utilization Effectiveness (SUE)

With SUE, effectiveness of server performance is measured by looking at the number of servers present and factoring in server age. Higher SUE indicates the facility is using more servers to deliver same work-output (hence more energy consumption in using more server)

Benefits

- It can be defined as Total Efficiency as a function of PUE and SUE (Reduction in SUE gives more efficient figures in terms of energy saving and cost saving as compared to reduction in PUE).
- Easy to calculate.

Drawbacks

- It does not account for the differences in system architecture or absolute performance. This can be accounted but at the cost of increased complexity.

- It does not allow comparison between different data centers, as architectural differences and absolute performance of a server are not accounted for.

PAT-Type Programme Stakeholder Engagement

A Core IT Working Group comprising of 13 IT industry experts such as Dell, Intel, IBM, Oracle, and Cisco was formulated by CII-LBNL in order to evaluate the identified 14 Energy Performance Metrics and arrive at a consensus on an appropriate metric to be considered for a PAT-type programme for data centers in India. Various periodic technical discussions were carried out with Core IT Working Group through a workshop and an online questionnaire referred to as the “PAT Pilot Study.”

Bangalore Workshop (April 1, 2016)

As per the Core IT Working Group, the most important parameters for measuring the energy efficiency of data centers are listed in Table 2.

Table 2: Important parameters for measuring data center energy efficiency (in order of importance)

Parameter	Notes
1.IT Equipment Power	• Should include energy consumed by: (a) Server Boxes; (b) Storage Devices; and (c) Network Devices. • To be measured at Entry Level, either at Rack PDU, Main PDU or the UPS Output.
2.Utilization of IT Equipment	• Utilization is one of the ways to measure the performance level of the IT equipment. • To be measured for the following domains which include Server, Storage and Network devices. • Should be measured with respect to rated capacities.
3.Total Facility Power	• To be measured at utility inputs.
4.Time (measurement over a period of time)	• Frequency of measurement – Thrice a day (at the beginning of the shift) • Reporting time frame – Yearly

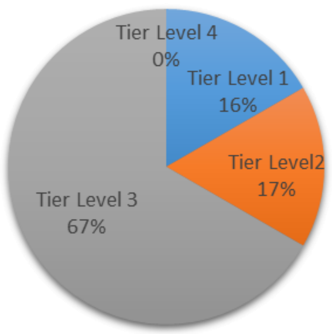
Pilot Study

Based on the discussion with the Core IT working Group in Bangalore, CII and LBNL piloted an online questionnaire to test the availability of data for the identified parameters (IT Energy, IT Utilization, Total Power, and Time Period for measurement). The structured questionnaire was comprised of 12 questions and can be found in Appendix J. Responses were collected from key stakeholders in the data center industry such as CISCO, Netmagic Solutions, IBM, Centre for Railway Information Systems, NextGen Data Center and Cloud Technologies, and Société Générale.

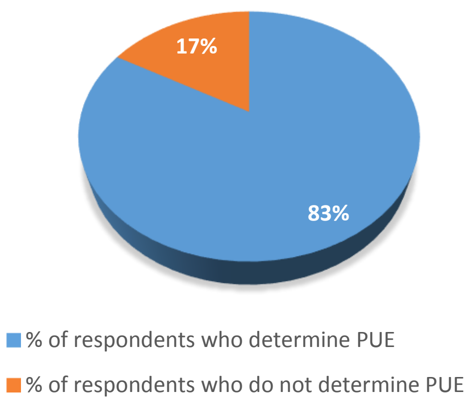
Type and Size of Data Centers
The data centers that participated in this pilot study primarily fall under the following categories of data center types: Hosting Services, Managed Services/Managed Hosting, Cloud Services, Colocation Services and Enterprise. The size of the data centers varies from 350 – 30,000 Square Meter.

Major Source of Power/Electricity
Majority of the respondents procure electricity from the grid (about 99-100%).

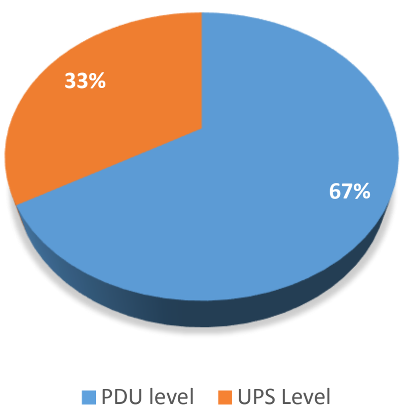
Tier-level
67% of respondents have specified that they operate at Tier 3, 17 % operate at Tier 2 and 16% at Tier 1 level.



PUE Measurement
It was found that majority of the participants determine PUE for their data centers and the average PUE lies in the range of 2.0 - 1.5.

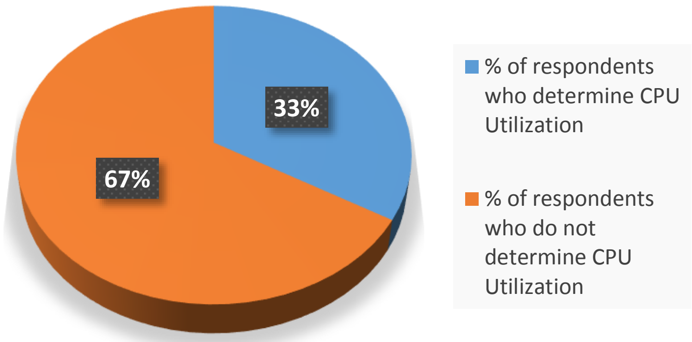


Level of IT Energy Metering
Highest existing Level of IT Energy Metering in most data centers is at the PDU and UPS level. 67% of respondents selected PDU level and 33 % selected UPS level.



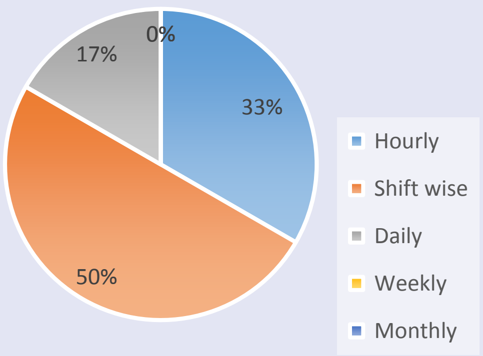
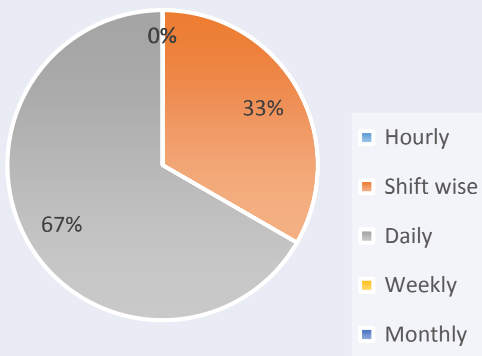
Average Annual CPU Utilization Measurement

Majority of the respondents (67%) do not collect CPU Utilization data. Only 33% measure the Average Annual CPU Utilization, which lies in the range of 30 – 50 %.



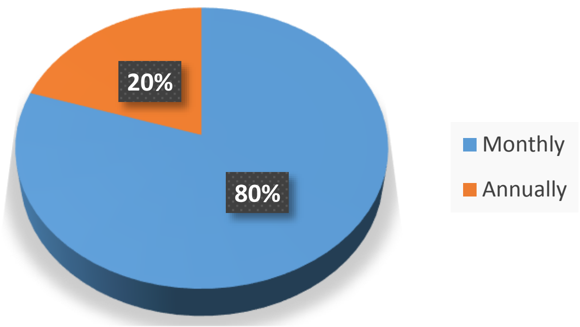
Frequency of Measurement

50% of the respondents measure IT and Total Energy on a shift-wise basis whereas 33% report it at an hourly basis and 17% report on a daily basis. Out of the 33% of respondents who collect CPU utilization data, majority (67%) measure Average Annual CPU Utilization on a daily basis and the remaining (33%) measure it on a shift-wise basis.

Frequency of Measurement of IT and Total Energy	Frequency of Measurement of Average Annual CPU Utilization
	

Reporting Frequency
80% of the respondents report IT and Total Energy on a monthly basis whereas 20% report it annually. 100% of the respondents who collect Average Annual CPU Utilization report it on a monthly basis.

Reporting Time- IT and Total Energy



Results from the survey indicated the following:

- PUE is the metric measured by all the data centers which had participated in the study. Majority of the data centers measure their IT Energy at the PDU level on a shift-wise basis and reporting for the same is done on a monthly basis.
- Importance of measuring CPU Utilization is recognized by most of the data center owners/large users but measuring utilization at the data center level is not currently practiced in many data centers in India.

PAT-Type Programme Recommendations

Based on the discussions during the Pilot Study and after sharing the results of the study with our Core-IT Working Group members, the two (02) metrics that have been identified as the most important Energy Performance Metrics are:

PUE

PUE is a well-established and matured Energy Performance Metric that is currently being used by many Indian data centers to report their infrastructure efficiency and operating efficiency to their management. This metric may be considered under a PAT-type programme for data centers, but it is recommended to take the following factors under consideration:

- The metric must be standardized. It may be measured as per the Green Grid Level 2 guidelines where;
  - (i) Measurement of IT Energy Equipment is at PDU Outputs,
  - (ii) Measurement of Total Facility Energy is at Utility Inputs
  - (iii) Measurement Interval is 15 minutes or less.

- Data centers may be categorized into:
  - (i) New and Existing Data Centers; and;
  - (ii) Data Center Size (e.g., Large and Small Data Centers)
  - (iii) Based on data center categorization PUE obligations may vary for example, existing DCs may not have measuring facility at PDU output and therefore measuring at the UPS output would be appropriate.

Considering the lack of instrumentation in existing data centers, only new data centers with the IT design load exceeding 100 KW may be mandated to follow The Green Grid level 2 guidelines for PUE measurement and monitoring.

- One of the major issues with using only PUE as the Energy Performance Metric is that it does not take into consideration IT usage that includes server loads, underutilized servers/idle servers, utilization of storage and network devices etc.

CPU Utilization

CPU Utilization is a key Performance Metric as it tracks CPU performance regressions or improvements and is used to investigate performance problems. Also, CPU consumes approximately 50% of server power consumption. Even though the metric is considered important, there are various issues related to measuring and monitoring CPU Utilization:

- CPU Utilization values are highly variable and depend upon the nature of loads, application type, etc.
- Standardization of the metric is difficult for all data centers due to variation of categories of data centers, operation type etc.
- The metric is not suitable for colocation data center type as IT equipment in such data centers are controlled by the customers and not the data center owners.

Considering various challenges associated with collecting and reporting CPU utilization by the data centers, a mechanism may be introduced at this point to mandate data centers to at least monitor and document IT usage (i.e., number of underutilized/ idle servers).

New Delhi Workshop (December 06, 2016)

CII in collaboration with LBNL-US DoE, under the guidance of BEE, Ministry of Power, organized a workshop at India Habitat Center – Juniper Hall, Lodhi Road, New Delhi.

The objective of this workshop was to share the findings of the study and provide participants with an opportunity to discuss the following topics important to the data center industry:

- A “Composite Policy Framework” for Indian data centers, based on existing energy efficiency standards in India (i.e., PAT and ECBC).
- Role of energy efficiency standards and technology interventions in accelerating the adoption of best practices in Indian data centers.

Participants of the workshop included experts from the data center industry that included data center owners/large users, technology providers, energy managers and consultants and policy makers who may help in accelerating the adoption of energy efficient technologies in Indian data centers. The Programme Agenda of the workshop is presented in Appendix K, the List of Participants is available in Appendix L and Workshop Group Photo is attached in Appendix M.

Some of the key discussion points include:

- Energy efficiency in most of the states in India takes lower priority. Energy efficiency standards in most of the countries are mandatory whereas in India, they are mostly voluntary.
- For many data centers in India, high availability is more important than energy efficiency. Standards and technology Interventions are necessary to maintain balance between availability and energy efficienc
- There are several advanced energy efficient technologies available in the market such as Immersive Cooling and Chip Cooling, but there is time-lag in availability of these technologies in Indian markets. Also many of the advanced technologies do not get commercialized.

- Renewable energy technologies must be explored for creating green data centers. Currently in many data centers across the world renewable energy is used to support non-critical equipment and not servers which are highly energy intensive.

- To achieve energy efficiency in data centers, we need an appropriate management framework that is implementable.

Meeting with Bureau of Energy Efficiency (December 07, 2016)

CII and LBNL had an in-depth discussion with BEE, Ministry of Power on the findings of the CII-LBNL study, incorporation of our data center specific recommendations in ECBC 2016/2017 and inclusion of data centers under PAT-programme.

Inclusion of Data Centers under PAT-programme – Recommendations by BEE

In order to include data centers under Indian PAT scheme, it is important to come up with an "appropriate Energy Performance Metric."

- If PUE is the metric to be considered under the PAT scheme, further data collection is required that includes:
    - List of all data centers that may be considered under the programme with details such as Name, Address, Energy Consumption data, etc.
    - Clearly defining the term 'Data Center' under the PAT programme including data center threshold (may be applicable to large data centers with IT load 500kW or higher and 1MW or higher).
    - Factors that influences the parameter(s) for measuring data center energy performance (i.e., Total Energy Consumption and IT Energy Consumption) must be identified.

- PAT Process: Two Notifications will be issued by BEE.
    - 1st Notification: Identification of all the buildings that will be considered under the Scheme.
    - Format of data collection to be developed in order to capture all relevant information that has to be reported under the programme such as Total Energy Consumption, IT Energy Consumption, and Measurement Period etc. for Data Centers.
    - 2nd Notification: PUE targets would be given to all the data centers under the scheme.
    - Data centers are likely to be considered under PAT in the next cycle (2018).

Inclusion of Data Center Specific Recommendations in ECBC 2016/2017– Recommendations by BEE

- Schedule for ECBC 2016/ 2017
    - Draft 2016/2017 version already circulated for comments/suggestions.
    - A meeting with Director General, BEE is scheduled in January for discussion on the code.
    - A smaller committee meeting on HVAC and a bigger committee meeting for finalization of the code is also scheduled in January.
    - ECBC 2016/2017 is scheduled to be launched by January 2017 and may be followed by the launch of a "User-Guide".

Conclusion and Next Steps

Conclusion

Inclusion of Data Center Specific Requirements in ECBC 2016/2017

- Data Centers previously excluded from the Indian ECBC Standard has now been included in the draft code.
- Though HVAC requirements specified in the code may be applicable to data centers, but CII and LBNL have strongly recommended minimum SCOP of 2.5 for CRAC units in data centers.
- Based on stakeholder discussions, Economizer requirement to be waived-off for Indian data centers which has not been incorporated in ECBC 2016/2017 draft code.
- Data Center specific requirements for Air Management, Fan-Control, Temperature and Humidity Control as mentioned above have strongly been recommended by CII and LBNL for inclusion in the current code.
- Under Metering & Monitoring section in draft ECBC 2016/2017, CII and LBNL have recommended PUE calculation and requirement for thermal monitoring which is not currently captured in the draft version.
- UPS system efficiency values as mentioned in draft ECBC 2016/2017 are applicable to data centers in India.

Reporting Energy Performance of Data Centers under a PAT-type Programme in India

- Based on our findings from stakeholder discussions and primary survey, it may be concluded that Power Usage Effectiveness (PUE) may be recommended to Bureau of Energy Efficiency (BEE) as the Energy Performance Metric under a PAT type mechanism for data centers in India.
- PUE measurement and monitoring must be standardized. The Green Grid level 2 guidelines for PUE measurement and monitoring is recommended.
- Data Centers to be categorized into:(a) New and Existing Data Centers; and (b) Data Center Size (e.g., Large amd Small Data Centers) depending upon which PUE obligations may vary.
- For BEE to successfully implement the PAT programme for data centers, 'Data Center' definition including data center threshold and normalization factors must be clearly defined based on which BEE will set targets for data centers under the PAT programme.

Recommended Next Steps

- Development of a detailed ECBC User-Guide for Indian data centers that documents data center best-practices and implementation guidelines for data center specific requirements included in new version.
- To successfully implement PAT programme for data centers under the next PAT cycle (2018), further data collection is required that includes identification of all data centers to be considered under the scheme, development of data collection format that includes total energy consumption and IT energy consumption used for measuring data center energy performance and identification of factors that may influence these parameters.
- In consultation with key stakeholders, organize workshops/awareness building sessions for data center owners/ large users.

Appendix A: References

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Appendix B: Data Center Size and Growth- Market Projections

INTRODUCTION

Data centers are energy-intensive facilities that house computer systems, a dedicated cluster of computers and associated components and support a diverse set of services such as Web, e-mail, data storage, and processing. Data centers are essential to the functioning of modern economy and are found nearly in every sector of the economy: financial services, high-tech universities, media, telecommunication, government institutions, businesses, communication systems etc. The overall data center workloads are expected to double from 2013 to 2018 (Upsite Technologies, 2015) and approximately five exabytes (EB) of data online in 2002 rose to 750 EB in 2009, by 2021 it is expected to cross the 35 zettabytes (ZB) level (Cognizant, 2012). In addition, the growth of data centers is also driven by the evolution of Cloud based services and Smart Cities. By 2018, more than 78% of workloads will be processed by cloud data centers and almost 22% will be processed by traditional data centers (Upsite Technologies, 2015). Considering the evolution of smart cities, some of the world's biggest technology organizations, such as Microsoft, Google, IBM, Cisco etc. have taken up the initiative to develop smart cities and experts have stated that data centers will be the backbone of these smart cities with their data centers located in the same region. Data centers will be storing and processing the data received through sensors to detect excessive air pollution, integrated traffic controls and education systems which indicates that number of data centers are expected to tremendously increase in the near future.

Based on the inputs received from various industry experts, there are about 100 – 150 total number of data centers with total electrical load of 500kW to 1000kW (consisting of IT and facility load) and 50-75 data centers with total electrical load of 1MW and higher. There may be about 10-20 data centers that are bigger than 2 MW and 3-5 data centers that are 5MW or higher. About 60-75% of data centers in India are cloud and colocation providers and about 25-40% are Enterprise data centers. Primary colocation and cloud services providers in India - Tata Communications, Bharti Airtel, BSNL, Reliance comm, Reliance JIO, Control-S, SIFY, Nextra, NetMagic and NextGen. In the 1 MW or higher category, approx. 1 out of 4 are standalone data center buildings and the remaining data centers are part of large commercial buildings.

DYNAMICS OF INDIAN DATA CENTER INDUSTRY

Data center operators in India are classified into two categories**- Hosted Data Centers** and **Captive Data Centers**. Hosted data centers are owned by third-party service providers that provide infrastructure and maintenance services to clients through their own data centers. Captive data centers, on the other hand, are only for captive usage. The majority of the data centers in India are captive but a few of them also provide third-party services. The key driving factors for captive data centers are- increased employee intake to company due to expansion in their activities and increase in service offering. In the coming years, Third Party data centers are expected to grow at much faster rate than captives as enterprises are showing much interest towards these in order to help them focus on their core business areas.

MARKET SIZE AND GROWTH OF IT INFRASTRUCTURE

Data center IT infrastructure includes network equipment, storage, servers/ rack etc. Data center racks are used to support servers, switches, routers, and other network equipment. Market as a whole has been growing at a reasonable rate; it has been the storage segment which has grown most impressively compared to servers and network equipment segments. The data center storage segment is estimated to grow at a CAGR of 5.16% during the period 2015-2020 (Infoholic Research 2014).

According to Alchemy Research, data center infrastructure market, in terms of revenue, is estimated at USD 2.03 billion for the year 2015–enterprise networking contributes the maximum share (47%) to this, followed by servers (33%). However, Gartner's estimation for IT infrastructure has shown that network equipment segment will be leading among other segments in terms of revenue as well as growth, as given in the table below:

Table 1**-** Indian IT Infrastructure Revenue by Technology (Million USD

Indian IT Infrastructure Revenue by Technology(Million USD)					
IT Infrastructure	2015	2016	2017	2018	2019
Network	910	963	1019	1042	1040
Storage	298	307	317	321	323
Servers	663	698	732	760	756
Total	1871	1969	2068	2123	2120

TechNavio's analysts forecast that the data center rack market in India will grow at a CAGR of 13.76 % over the period of 2013-2018 and analysis by Frost and Sullivan, "India Rack and Rack Options Market", suggest that the market has earned revenues of INR 6.59 billion in 2014(fiscal year) and is estimated to reach INR 10.31billion in FY 2019.

KEY MARKET TRENDS

Increase in Server Demand across the Country

The Server Market in India is largely driven by IT and IT enabled services and the Banking, Financial services and Insurance (BFSI) sector, with growing demand for rack and blade servers. Growing popularity of cloud computing, big data, and virtualization is boosting the Server market in India, wherein micro servers and blade servers are the major drivers.

Adoption of Co-location and Cloud Services

Organizations are focusing on spending on technology that can scale according to business requirements and they do not have to go through the tiresome process of IT infrastructure procurement, while adoption of cloud services helps them to significantly reduce time. Most vendors are looking at providing- managed, colocation, or cloud services that will eventually contribute to the growth of the IT Infrastructure market in India.

Increase in Number of Specific Service Providers

With the presence of several players in the market with similar offerings, there is an increasing need for differentiation, resulting in the emergence of firms specializing in specific services. This has led to strategic solutions like on-demand cloud storage, backup services and Desktop Virtualization Solution (DVS) over cloud.

Growing Usage of Data Centers in Data Center

The concept of Data Center In Data Center is one of the emerging trends in the IT Infrastructure market in India. Data Center In Data Center is likely to host service providers such as IBM, Dell, and HP who in turn host the infrastructure for their own customers. This technology helps service providers to focus on their core expertise, such as application and SaaS (Software as a Service) hosted services, without making extensive investments in power and cooling.

Energy Efficiency in Data Centers

Energy Consumption in data centers is increasing day by day due to heavy infrastructure, high end cooling equipment, increasing storage capacity and computational requirements. This has led to increasing concern for monitoring energy consumption by data center solution providers.

Thus energy efficiency has become a key trend owing to the dynamism in data centers. It has been estimated that energy, accounts for over 12 % of Data Center expenses (Netmagic 2015). According to the Datacenter Dynamics Intelligence Industry census data, Power of 1.04 GW was consumed by data centers in India in 2012.

MARKET SIZE AND GROWTH OF DATA CENTERS

Data center market size and growth can be categorized on the basis of different parameters such as storage, space and revenue as follows:

Growth by Storage

In the past decade, India has witnessed an exponential increase in the demand for digital storage. Data center service providers are expected to invest significantly to multiply their capacities, so as to fulfill the demand arising from small and midsize users. This growth is mainly driven by increasing requirements from the sectors such as financial institutions, telecom operators, manufacturing and services. Large financial institutions and telecom companies are likely to build captive data centers for hosting their growing data storage needs. According to a study by International Data Corporation (IDC), the data storage requirement is expected to reach 40,000 Exabyte or 40 trillion Gigabyte by 2020.

Growth by Space

It has been expected that “space requirement” by data centers would increase by 2.38 million sq. ft by 2017 based on the projects under construction (Alchemy 2015). According to Netmagic and BICSI, there will be an increase in space requirement of data centers up to 3 million sq. ft approximately by 2017.

Growth by Revenue

The data center market in India is expected to reach USD 2.45 billion by the end of 2020, (Infoholic Research 2014). Growth of Indian data centers market is forecast to reach 20% year over year, against the 11% globally for the period 2013-2018 (Alchemy 2015).

Key Technological Trends in Data Center Industry

Two key technologies impacting the future of data centers are Virtualization and Cloud Computing. Virtualization is an innovation that impacts optimization and efficiency - both capacity utilization and power consumption of a data center. Advent of Cloud is changing the definition of how data centers are being looked at. The adoption of these technologies is the key driver to growth of data center business in India, with organizations trying to reduce their data centers footprint and depend on third party providers.

Virtualization

- Virtualization across servers, desktop or storage helps reduce the hardware cost and enables greater flexibility and efficiency in data centers.
- As per IDC, server virtualization market in India will reach USD 3.89 billion by 2020.

Cloud Computing

- Advent of cloud-computing has increasingly led to a service-based model of data center.
- The exponential growth in cloud services market is shaping data center demand.

CONCLUSION

With the increasing demand from various sectors and the big players globalizing their operations, the future of the data center market in India seems to be on the rise. According to various industry analysts, data center industry shows a huge potential for growth in the near future.

Increasing numbers of users online and the Government's 'Make in India' initiative, is driving data center operators to respond to change with innovative solutions at nominal costs. Network equipment will always be the working horse and storage segment is on the growth path amongst IT infrastructure. The growth drivers for data center industry are the Telecom sector, BFSI Sector (Banking, Financial Services and Insurance), IT, Media and Entertainment, Manufacturing and Digitalization initiatives taken by Indian government. The increasing demand for data center services has led to adopt two key trends *Virtualization* and *Cloud Computing* which are shaping the data center industry's future.

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Appendix C: Bangalore Workshop – Agenda (April 1, 2016)

1000 – 1030 Hrs.	**Registration**

1030 - 1115 Hrs.	**Overview of Phase II Initiative on “Accelerating Data Center Energy Efficiency In India”**	
1030 - 1045 Hrs.	Welcome Address	Mr. Dale Sartor P.E Staff Engineer, Applications Team Lead Lawrence Berkeley National Laboratory (LBNL)
1045– 1115 Hrs.	Presentation on “Accelerating Data Center Energy Efficiency In India-Phase II”	Dr. Suprotim Ganguly Confederation of Indian Industry (CII)

1115 – 1300 Hrs.	**Large Stakeholder Consultative Group Discussion**	
1115 - 1245 Hrs.	**Interactive session with the Large Stakeholder Consultative Group on “Data Center Specific Recommendations in ECBC Version 2 based on International Standards ASHRAE (90.1 and 90.4) and California Title 24”.**	
1245 -1300 Hrs.	Capturing the Inputs	CII and LBNL

1300 – 1400 Hrs.	**Networking Lunch**

1400 – 1615 Hrs.	**Smaller Group Discussion**	
1400 - 1545 Hrs.	**Interactive session with the Core-IT Consultative Group on “Developing Core IT Metric to Report Energy Performance of Data Centers in India through a PAT Type Mechanism”.** ”	
1545 -1600 Hrs.	Capturing the Inputs	CII and LBNL
1600-1615 Hrs.	Vote of Thanks	Dr. Suprotim Ganguly Confederation of Indian Industry (CII)

Appendix D: Bangalore Workshop - List of Participants

S.No	Name	Designation	Organization
1	**Mr. K Jeyabalan**	Head - South Region, Infra and projects	Nxtra Data Ltd.
2	**Mr. John Bennet**	Data Center Operation Manager-Bangalore	
3	**Ms. Shalini Singh**	LEED AP BD+C Real Estate and Workplace India	VMware
4	**Mr. Pushpendra Pandey**	Manager - IT Infrastructure and Green-IT	IBM India Pvt. Ltd
5	**Mr. Vaidyanathan Srinivasan**	Server Platform Architect	
6	**Mr. Veerendra Para**	Data Center Specialist	
7	**Mr. Vidhya Shankar**	Senior Data Center Specialist	
8	**Mr. Nagarajan**	Data Center Expert	Cisco Systems
9	**Mr. Ravi A Giri**	Enterprise Solutions Architect	Intel Technology India Pvt. Ltd.
10	**Mr. Rajkumar Y Kambar**	Data Center Manager	
11	**Mr. Amod Ranade**	General Manager- Data Center Business Development	Schneider Electric
12	**Mr. Malikarjun Patil**	Project Manager	SCHNABEL DC Consultants India
13	**Ms. Shaheen Meeran**	Managing Director	
14	**Mr. Nakul O C**	General Manager - Projects	NxtGen Data Center and Cloud Technologies Pvt. Ltd
15	**Mr. L.P. Lakshmi Ranganath**	Asst. VP - Non IT Operations	
16	**Mr. Shankar KM**	Senior Manager - Data Center Operations	Tata Communications Ltd.
17	**Mr. Sampath R**		
18	**Mr. Adagouda M**	Facility Manager	
19	**Mr. Baiju. B**	Director, Data Center Design	Emerson Network Power
20	**Mr. Shrirang Deshpande**	Country Head – Data Center Business	
21	**Mr. Nitheen C Nataraja**	Product Manager - INLPLS	ABB India Ltd.
22	**Mr. Punit Desai**	Regional Manager - Infrastructure and Green Initiatives	Infosys

Appendix E: Data Center Specific Technical Recommendations Presented at the Workshop

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
1	**Heating, Ventilation and Air-conditioning**	**Minimum Equipment Efficiencies**	Heating and Cooling Equipment Efficiencies	**As per ASHRAE 90.1**, Air conditioners and condensing units primarily serving computer rooms shall meet the requirements in **Table 6.8.1K (Page 67).** **As per California Title 24 Section 140.9 (Page 199):** The **total fan power** at design conditions of each fan system shall not exceed **27 W/k Btuh** of net sensible cooling capacity.	General Remarks: 1. Need to set threshold for data center size (e.g 100-200 kW IT load). 2. Need to clarify what a data center is (overall standard) Specific to Minimum Equipment Efficiencies:- 1. Consider higher efficiencies in higher density data centers or data centers with larger air handlers. 2. Consider two levels of compliance – "standard" and "high efficiency". 3. Clarify that 27W/kBTU applies to both CRACs and CRAHs. Confirm availability in India. 4. Check requirements for later ASHRAE version (e.g. 2013).
		System Balancing	Air-system balancing	As per ECBC Requirements.	
			Hydronic System balancing	As per ECBC Requirements.	

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
		Economizers	Air Economizers And Water Economizers	**As per California Title 24 Section 140.9 (Page 199):** Each individual cooling system primarily serving computer room(s) shall include either: **A.** An integrated air economizer capable of **providing 100 percent of the expected system cooling load** as calculated in accordance with a method approved by the Commission, at **outside air temperatures of 55°F dry-bulb/50°F wet-bulb and below**; or **B.** An integrated water economizer capable of providing **100 percent of the expected system cooling load** as calculated in accordance with a method approved by the Commission, at **outside air temperatures of 40°F dry-bulb/35°F wet-bulb and below.** **Note:** **1)** Economizers must be Mandatory for Data Centers. **2)** Air-Economizers may be Direct or Indirect (with air to air heat exchanger to accommodate poor outdoor air quality). **3)** Considering different climatic zones in India, Wet Bulb/Dry Bulb temperatures may be revised.	1. Consider requirements for specific climate zones where it makes most sense. 2. Economizers may not be mandatory. 3. Size, Location, Cost (RoI) building variants to be considered.
		Data Center		**As per California Title 24 Section 140.9 (Page 199)**	1. Clarify data center vs. computer room, IT racks vs computer racks (may need

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
		Air Management System		Computer rooms with air-cooled computers in racks and with a **design load exceeding 175 kW/room** shall **include air barriers** such that there is no significant air path for computer discharge air to recirculate back to computer inlets without passing through a cooling system.	to be done throughout) 2. Consider a common threshold for the various requirements (as mentioned in General Recommendations in First Section) 3. Target maximum inlet temperature 3 deg C inlet higher than supply.
		Controls	Temperature and Humidity Control	**Recommendations as per LBNL:** **1.** For **air-cooled IT equipment**, **set point** must be such to keep the inlet air temperature to the IT equipment in the range of **18 to 27 ˚C (64.4 to 80.6 ˚F) with preference to the upper end.** **2.** Suggested use of **supply air temperature** from the cooling equipment for control rather than return air temperature **(since supply is more closely related to the IT inlet temperature).** **3. Humidity Control - 40% (e.g 30 to 70%)** or more - dead band to be followed. Simultaneous humidification and dehumidification must not be allowed by the control system. **4. No reheat should be allowed.** **5. Control set points** must be **set to prevent humidification or dehumidification** when within the limits **of -9 ˚C to 15 ˚C dew point and 60% RH** .Also, if multiple units serving the same space have humidity control, prevent simultaneously humidifying and dehumidifying. **Note:** The temperature and humidity ranges are the recommended ranges as per ASHRAE Thermal Guidelines for Data Processing	1. Inlet air temperature should be as per the AHRAE Standard or should increase the temperature range from 23˚ to 27˚. 2. Confirm with manufacturers for the temperature range offered. 3. Dead band range to be confirmed with manufacturers. 4. Humidity Control should be increased from 30% to 70% (selected 40%). 5. Reheat should not be permitted. 6. Simultaneous humidification and dehumidification should not be allowed (important).

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
				Environments, 4th Edition, 2015.	
			Fan Control	**As per California Title 24 Section 140.9 (Page 199):** Each **unitary air conditioner** with mechanical cooling capacity exceeding **60,000 Btu/hr** and each chilled water fan system shall be designed to vary the airflow rate as a function of actual load and shall have controls and/or devices (such as variable speed control) that will result in fan motor demand	As noted and revised in the recommendations column itself- **1.** Could be VFD and electronically controlled as well. **2.** Should not be limited to two speed (variable speed).

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
				of no more **than** 50 percent of design wattage at 66 percent of design fan speed.	
		Variable Flow Air Systems		**As per California Title 24 Section 140.4 page 169**, VAV requirements are as follow: **A.** The **total fan power index** at design conditions of each fan system with total horsepower over **25 hp** shall not exceed **1.25 watts per cfm** of supply air; and **B. Static Pressure Sensor Location**: Static pressure sensors used **to control variable air volume fans** shall be placed in a position such that the controller **set point is no greater than one-third the total design fan static pressure,** except for systems with zone reset control complying point C below. **C. Set point Reset-** For systems with direct digital control of individual zone boxes reporting to the central control panel, **static pressure set points shall be reset based on the zone requiring the most pressure**; i.e., the set point is reset lower until one zone damper is nearly wide open.	**1.** Preference to cfm vs K BTU. **2.** Reduce W/cfm to ~ 0.25W/ cfm (check with manufacturers). **3.** Remove Static pressure sensor location and set point reset. **4.** Combine this section with the Air Management System section.
		Variable Flow Hydronic Systems		As per ECBC Requirements	

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
		Performance - Based Calculation	Whole Building Performance Method	As per ECBC Requirements.	
2	**Electrical System**	**Transformers**		As per ECBC Requirements.	1. Add efficiency requirements for Diesel Generators. 2. Consider energy mix (e.g. use of renewable).
		Motors	Energy Efficient Motors	As per ECBC Requirements.	
		Power Factor Correction		As per ECBC Requirements.	
		Metering and Monitoring		**As per LBNL recommendation:** For data center **services exceeding 65KVA**, Sub metering at the data center shall be provided to allow the **monitoring and calculation of PUE - IT equipment** energy and total data center energy including cooling energy (including compressors, fans and pumps), losses in UPS, and lighting.	1. Use common threshold. 2. Reference The Green Grid standard (PUE level 1). Clarify/confirm that The Green Grid standard specs cover monitoring of thermal load. 3. Add minimum thermal (air) monitoring per ASHRAE - top of every 5th rack in the cold aisle.
		Power Distribution Systems	Power Distribution Losses	As per ECBC Requirements.	

S.NO.	Broad Sections	Sub-Sections	Key Parameters	Recommended to be included in ECBC Version 02- From ASHRAE 90.1 (2010), ASHRAE 90.4 (2016) and California Title 24 (2013).	Remarks
		Performance - Based Calculation	Whole Building Performance Method	As per ECBC Requirements.	
		Uninterrupted Power Supply (UPS)		**As per ASHRAE 90.4(Third Draft) Section 8- Table 8.2.1.1 and 8.2.1.2** **<u>IT Design Load Less than 100kW:</u>** **Single Feed UPS (N, N+1 or No UPS)-** **at 100% :** Loss/Efficiency= 12.0%/88.0% **at 50% :** Loss/Efficiency= 14.0%/86.0% **Dual Feed UPS (2N, 2N+1 etc)-** **at 50% :** Loss/Efficiency= 14.0%/86.0% **at 25% :** Loss/Efficiency= 20.0%/80.0% **<u>IT Design Load Greater than 100kW:</u>** **Single Feed UPS (N, N+1 or No UPS)-** **at 100% :** Loss/Efficiency= 9.0%/91.0% **at 50% :** Loss/Efficiency= 10.0%/90.0% **Dual Feed UPS (2N, 2N+1 etc)-** **at 50% :** Loss/Efficiency= 10.0%/90.0% **at 25% :** Loss/Efficiency=15.0%/85.0%	**1.** Recommended efficiencies are too low- need to increase to at least 94% across the board at 50-100% load; 92% at 25% load. **2.** Need to clarify whether efficiencies to be considered should be component level or system level. **3.** Check with vendors that these are reasonable and available in India. **4.** UPS Product specifications; actual efficiency will vary with configuration. **5.** First option goes away anyway since defined scope may be above 100 kW.

Appendix F: Advisory Group Members

S.No	Organization/Institution's Name	Category
1	Nxtra Data Ltd	Data Center Owner/Hosting Provider
2	Vmware	Technology Provider
3	IBM India Private Limited	Data Center Owner and Technology Provider
4	Cisco Systems	Data Center Owner and Technology Provider
5	INTEL	Data Center Owner and Technology Provider
6	Schneider Electric	Data Center Owner and Technology Provider
7	Schnabel DC Consultants	Consultants
8	NxtGen Data Center and Cloud Technologies Pvt. Ltd	Data Center Owner/Hosting Provider
9	Tata Communications	Data Center Owner/Hosting Provider
10	Emerson Network Power	Technology Provider
11	ABB India Limited	Technology Provider
12	Infosys Technologies	Data Center Owner and Technology Provider
13	NetDataVault	Data Center Owner/Hosting Provider
14	Dell	Data Center Owner and Technology Provider
15	Oracle	Data Center Owner and Technology Provider
16	EMC 2	Data Center Owner and Technology Provider
17	NetMagic Solutions	Data Center Owner/Hosting Provider
18	Aeon Consultants	Consultants
19	Indian Institute of Technology, Madras	Academic Expert
20	Center for Railways Information Systems	Data Center Owner /Large users

S.No	Organization/Institution's Name	Category
21	Ctrl S	Data Center Owner/Hosting Provider
22	Reliance Communications	Data Center Owner/Hosting Provider
23	Airport Authority of India	Data Center Owner /Large users
24	National Informatics Center	Data Center Owner /Large users
25	NetApp	Data Center Owner and Technology Provider

Appendix G: Key Discussion Points from the WG meeting and CII-LBNL Response to Specific Issues

General Comments

- The scope needs to be modified to address Data centers in the current ECBC draft 2016/2017 version. The present classification of commercial buildings excludes data centers.

- There was considerable amount of discussion on defining the threshold of 100 kW for data centers in the document – whether there should be a separate threshold for connected load for DCs and if that is just for the IT load or for both IT and facility loads. *CII-LBL team will consult with the DC Stakeholder group and provide its response.*

CII-LBNL Response (In consultation with stakeholders): We would like to clarify that our data center specific recommendations apply to all commercial buildings that comply with ECBC and have data center operations with an additional IT load of more than 100 kW as IT load is easier to check at design conditions than the connected load. As per stakeholder discussions, it becomes too onerous for small office buildings with lesser IT loads to comply with data center specific requirements in ECBC.

- There was discussion on the inclusiveness of the DC Stakeholder group. The comment made was the stakeholder group included all individual companies, institutions and did not include the relevant industry associations. Details of names of the companies, organizations was shared with the working groups.

- The working group requested that a "whole building performance metric" (e.g. PUE) for DCs with efficiency ranges be looked into for inclusion in the ECBC by the DC stakeholder group. *CII-LBL team will consult with the DC Stakeholder group and provide its response.*

CII-LBNL Response (In consultation with stakeholders): As per our technical discussions with the industry stakeholders including data center experts, there is insufficient Indian data center performance (e.g. PUE) data to establish a performance threshold. The proposed standards will address that by requiring PUE metering so that a PUE standard may be adopted in the future as more data becomes available. Defining a range or maximum value for PUE would require developing a data center PUE model run for different climatic zones in India and for all configurations that meet the prescriptive standard. ASHRAE (American Society of Heating Refrigeration and Air-conditioning Engineers), the professional body for cooling engineers, recently abandoned its effort to establish maximum values for PUE. Considering the issues and challenges related to defining maximum PUE, at this point we would only like to mandate measurement of PUE as per the Green Grid guidelines (Level 1) to meet the minimum energy efficiency requirements for metering and monitoring. Buildings with data centers will still have a performance path using the ECBC whole building performance approach. The IT design load would be the same under both the prescriptive and compliance models and users would be free to trade-off prescriptive requirements while meeting a performance target based on a hypothetical building meeting the prescriptive requirements.

Suggestions/Comments on HVAC System Recommendations

- There was a suggestion that just like specifications for CRAC Units were recommended, there should also be recommended specifications for Precision Air Handlers (CRAH units). ***CII-LBL team will consult with the DC Stakeholder group and provide its response***

CII-LBNL Response (In consultation with Stakeholders): Assuming that there are requirements for air handlers in ECBC, the same specs should apply to CRAHs.

- The ECBC Joint Working Group felt that some form of Economizers should be considered to attain higher efficiencies in data centers and should not be waived off. It should be noted that there was considerable resistance to including Economizer option in the DC Stakeholder group as was shown to the WG members in the sheet capturing compiled comments. ***CII-LBL team will consult with the DC Stakeholder group and provide its response.***

CII-LBNL Response (In consultation with Stakeholders): Based on the inputs received from our industry stakeholders during the workshop and post workshop, the requirement for economizers was waived-off as the majority of data centers owners/ users have raised concerns over considering economizer requirements for different climatic zones, air quality, maintenance issues, cost etc. We would like to clarify that the CII-LBNL team does not recommend economizers as per suggestions received from our advisory group, it may be included in the new ECBC version if the ECBC working group really feels the need for it in data centers. It is our opinion that it is preferable to have meaningful data center standards in place that do not have the requirement for economizers than to exclude data centers from all requirements (hence also not requiring economizers). Economizer requirements can be added as the Indian data center industry gains experience in their use, but at this point requiring economizers would not have industry support. Should the working group decide to include economizers, we recommend noting that tower side and pumped refrigerant economizers would meet the requirement.

- There was a suggestion to define the range for Relative Humidity (RH) as it was not clear if there is a lower limit to go with the 60% RH higher limit. ***The lower limit is already provided in the current recommendations - the -9°C and 15°C of dew point temperature and will change based on the outdoor conditions.***

Suggestions/Comments on Electrical System Recommendations

- As per the discussion, Diesel Generators for higher capacities to be addressed in "Standards and Labeling" group. Higher capacity generators pose challenges in terms of test conditions - both specifications and ease of conducting them.

- PUE values to be defined to buttress the "Metering and Monitoring" requirements in data centers. ***CII-LBL team will consult with the DC Stakeholder group and provide its response.***

CII-LBNL Response (In consultation with stakeholders): Please see point (d) under general comments for explanation.

Appendix H: 14 Shortlisted Metrics

S.NO.	Energy Performance Metrics	Brief Description	Metric Calculation	Parameter 1	Parameter 2	Parameter 3
1	Power Usage Effectiveness (PUE)	PUE is defined as the ratio of total facilities energy to IT equipment energy. Total facility energy is defined as the energy dedicated solely to the data center. The IT equipment energy is defined as the energy consumed by equipment that is used to manage, process, store, or route data within the compute space.	**PUE** = Total Facility Energy/ IT Equipment Energy	Total Facility Energy (Infrastructure + IT Energy)	IT Equipment Energy	
2	Data Center Infrastructure Efficiency (DCiE)	DCiE is defined as the fraction of the IT equipment energy divided by the total facility energy. **It is the reciprocal of PUE.** The total facility power is defined as the power measured at the incoming utility meter of data center. The IT equipment power is defined as the power consumed by the IT equipment supported by the data center as opposed to the power delivery and cooling components and other miscellaneous loads.	**DCIE =** IT Equipment Energy/ Total Facility Energy	IT Equipment Energy	Total Facility Energy (Infrastructure + IT Energy)	
3	IT Power Usage Effectiveness (ITUE)	ITUE is intended to be a "PUE-type" metric for IT equipment rather than for the data center. PUE is total energy divided by IT energy, analogously, ITUE is defined as total IT energy divided by computational energy.	**ITUE = IT** Equipment Energy/ **Total** Energy into the Compute Components	Total Energy into IT Equipment (Including internal fans, power supplies, and voltage regulators (VRs), etc.)	Total Energy into the compute Components (The Compute components can be defined as the CPU, memory, and storage.	
4	Total Power Usage Effectiveness (TUE)	TUE is the total energy into the data center divided by the total energy to the computational components inside the IT equipment	**TUE** = ITUE * PUE OR Total Facility Energy/ Total Energy into the Compute Components	Total Energy into Data Center	Total Energy into the Compute Components	
5	Compute Power Efficiency (CPE)	CPE connects the efficiency of computer equipment in the data center with the efficiency of the entire data center.	**CPE** = Computer Equipment utilization rate / PUE OR Computer Equipment Utilization Rate * IT Equipment Energy/ Total Facility Energy	Computer Equipment Utilization Rate is determined by the average CPU utilization percentage of all servers in the data center	Total Facility Energy (Infrastructure + IT Energy)	IT Equipment Energy
6	Power to Performance Effectiveness (PPE)	PPE can be defined as actual power performance to optimal power performance. PPE is used to analyze the effective use of power by existing IT equipment, relative to the performance of that equipment	Performance of IT Equipment (Actual)/ Watt Consumed ____________________ Performance of IT Equipment (Optimal) / Watt Consumed	Performance of IT Equipment is synonym to IT Productivity	Watt Consumed (same as IT Equipment Energy)	
7	Space, Watts & Performance (SWaP)	SWaP is an objective, three-dimensional metric characterizes a data center's energy efficiency by introducing three parameters of space, energy and performance together.	**SWaP** = Performance/ (Space * Power Consumption)	*Performance*: Information about the level of performance or throughput a server maintains can come from any industry-standard.	*Space*: The space a server occupies can be measured by the rack unit height of the system.	*Power*: watts consumed by the system
8	Compute Units Per Second (CUPS)	CUPS represent a universal measure of computing output. CUPS can be defined as the amount of work done by the IT equipment per second. CUPS can serve as the numerator in the equation that determines Compute Efficiency.	**CUPS = IT** Productivity / Second	IT Productivity is the IT service output of the datacenter (includes network transactions, storage or computing cycle)	Second (Unit of Time)	

S.NO.	Energy Performance Metrics	Brief Description	Metric Calculation	Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
9	Data Center Compute Efficiency (DCcE)	DCcE is calculated by simply averaging the ScE values from all servers during the same time period.	**DCcE = Summation** (Σ) of all values of ScE taken from all server in a given time period/ Total Number of server (m)	All values of SCE taken from all server in a given time period	Total Number of server (m)			
10	Server Compute Efficiency (ScE)	ScE is a time-based metric; it measures the proportion of time the server spent providing primary services and is expressed as a percentage value. Primary service include: -Average amount of CPU utilization attributable to primary services. - The amount of I/O attributable to primary services. -A primary services process (not a secondary or tertiary service) has received an incoming session based connection request. - There has been an interactive logon to the server.	**ScE = Summation** (Σ) of number of samples where the server is found to be providing primary services i.e **(Parameter 1 + Parameter 2 + Parameter 3 + Parameter 4)**/ The total number of samples taken over that time period. **(Parameter 5)** X 100	Total average CPU utilization minus average CPU utilization from secondary and tertiary services	Total I/O minus I/O from secondary and tertiary services	A primary services process has received an incoming session based connection request	Interactive Logon to servers	The total number of samples taken over that time period (i.e. the measurement of primary service taken at given time period)
11	Data Center Energy Efficiency & Productivity (DC-EEP)	The DC-EEP Index can be defined as the delivered IT Productivity “out” to information users per watt of site infrastructure energy “in.”	**DC-EEP** = IT Productivity / Total Facility Energy	IT Productivity is the IT service output of the datacenter (includes network transactions, storage or computing cycle)	Total Facility Energy (Infrastructure + IT Energy)			
12	IT Productivity per Embedded Watt (IT-PEW)	IT- PEW measures the operating/ power efficiency (bytes processed/ W) of IT equipment or captures the power efficiency of the IT equipment	**IT-PEW** = IT Productivity / Embedded Watt	IT Productivity is the IT service output of the datacenter (includes network transactions, storage or computing cycle)	Embedded Watt is a synonym of IT Equipment Power			
13	Site Infrastructure Energy Efficiency Ratio (SI-EER)	The SI-EER ratio can be defined as power “in” to the data center as measured at the utility electric meter divided by the conditioned power “out” to run the IT equipment for computing.	**SI-EER** = Total Facility Energy / IT Equipment Energy	Total Facility Energy (Infrastructure + IT Energy)	IT Equipment Energy			
14	Server Utilisation Effectiveness (SUE)	Effectiveness of servers performance is measured. The efficiency of the number of servers present considering its age factor is measured. Higher SUE indicates, facility is using more server to deliver same work-output (hence more energy consumption in using more server)	SUE = No of Servers / Summation (Σ) of Servers *0.707^age	Total No of Servers in Facility	Total no of server age wise multiplied by 0.707 raise to the power of age of the server			

Appendix I: Implementatation of Metrics

S.No.	Energy Performance Metrics	Institution(s)/Organization(s) which Introduced the Metric	Organization(s) where Metric is Implemented	Level of Applicability *
1	Power Usage Effectiveness (PUE)	The Green Grid	Facebook, Federal Datacenter, Microsoft, Fujitsu, IDC, Google, Ebay, Ambient IT, Turk Telekom, Tata Communication, Amazon, Schneider Electric, NetApp, IHU, Internet Initiative Japan INC.	High
2	Data Center Infrastructure Efficiency (DCiE)	The Green Gird	IHU	High
3	IT Power Usage Effectiveness (ITUE)	Energy Efficient HPC Working Group, Intel Corporation, Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories	Jaguar System (ORNL)	Moderate
4	Total Power Usage Effectiveness (TUE):	Energy Efficient HPC Working Group, Intel Corporation, Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories	Jaguar System (ORNL)	Moderate
5	Compute Power Efficiency (CPE)	Green Grid		Moderate
6	Power to Performance Effectiveness (PPE)	Gartner Inc.	Power Assure, Inc. (Provides Data center power optimization software)	Moderate
7	Space, Watts & Performance (SWaP)	Sun Microsystems	IBM, Sun Microsystems	Moderate
8	Compute Units Per Second (CUPS)	Emerson	Intel Corporation	Low
13	Data Center Compute Efficiency (DCcE)	The Green Grid		Moderate
9	Server Compute Efficiency (ScE)	The Green Grid		Moderate
10	Data Center Energy Efficiency & Productivity (DC-EEP)	The Uptime Institute		Moderate
11	IT Productivity per Embedded Watt (IT-PEW)	The Uptime Institute		Moderate
12	Site Infrastructure Energy Efficiency Ratio (SI-EER)	The Uptime Institute		Moderate
14	Server Utilization Effectiveness (SUE)	Intel Corporation	Intel Corporation	Moderate

Note: Level of Applicability: * High (On the basis of High usage & Popularity), Moderate (on the basis of moderate usage & Ease of Measurement), Low (Less Applicability & Acceptability)

Appendix J: PAT Pilot Study Questionnaire

Accelerating Energy Efficiency in Indian Data Centers – Phase II

Confederation of Indian Industry

Developing Core-IT Metric for a PAT like scheme for Data Centers in India - Data Collection Form

General Guidelines:

This form has been specially formulated as a part of the study on "Accelerating Energy Efficiency in Indian Data Centers - Phase II" consisting of 12 questions.

This is a pilot study conducted by CII & LBNL to test the availability of data on the basis of which Bureau of Energy Efficiency (BEE) may consider implementing an appropriate reporting framework to measure energy performance of Indian data centers.

The information provided by you would be completely confidential.

Please Note:
(a) You may provide data for a part of your data center without disclosing your data center's location.
(b) For organizations having more than one data center, you may provide data for the largest data center or data center for which information is easily available.

*Required

Name *

Designation

Organization *

Data Center Location & Contact Details

Address/Phone/Email

Please provide the following information:

1. Please specify the following for your Data Center *

a) Type of Service(s):

- [ ] Hosting Services
- [ ] Managed Services/Managed Hosting
- [ ] Cloud Services
- [ ] Outsourcing
- [ ] Colocation Services
- [ ] Enterprise
- [ ] Other

Please specify, if any other

b) Tier level

c) Total covered area of your Data Center

If your Data Center is a part of a big building then mention the areas of both the buildings separately.

2. Percentage wise contribution from various sources of power/electricity procured.

Grid %

Diesel Generator %

Renewable Energy %

3. Annual IT Energy Consumption (kWh)

4. Component-wise IT Energy Consumption (kWh)

Servers

Storage Devices

Network Devices

For additional comments

5. Total Facility Energy Consumption (kWh)

6. Do you determine Power Usage Effectiveness (PUE) for your data center ?

- Yes
- No

If yes, what is the average PUE of your Data Center?

7. Please specify the Average Annual CPU Utilization (%) for your data center

8. Do you collect utilization data for storage & network devices?

- Yes
- No

If yes, please specify the method of data collection for the following:

Storage Devices

Network Devices

9. Please specify the "Frequency of Measurement" for the following:

a) IT & Total Energy Consumption

- Hourly

- Shift wise
- Daily
- Weekly
- Monthly

For additional comments

b) CPU Utilization for your data center

- Hourly
- Shift wise
- Daily
- Weekly
- Monthly

For additional comments

10. Reporting Time Frame

a) IT & Total Energy Consumption

- Monthly
- Annually

For additional comments

b) CPU Utilization for your data center

- Monthly
- Annually

For additional comments

11. Would you consider Average Annual CPU Utilization as the best measure for data center IT energy efficiency under a PAT type program?

- Yes
- No

Please comment in support of your answer

12. We request you to provide us with your feedback on this questionnaire or any additional comments/suggestions to further improve this questionnaire in terms of ease of data collection under a PAT like scheme for data centers in India.

We sincerely thank you for providing us the data for all the above parameters. With your support, we will be able to recommend an appropriate IT-specific energy performance metric (which may the combination of parameters mentioned above) to the Government to enable a PAT-type program for data centers in India.

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Appendix K: Agenda for Workshop at New Delhi (December 06, 2016)

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CII Confederation of Indian Industry

Workshop on

"Accelerating Data Center Energy Efficiency in India"

6th December 2016, Juniper Hall, India Habitat Centre, Delhi

Programme Agenda

0900 – 0930 Hrs.	**Registration**

0930 – 1005 Hrs.	**Inaugural Session**		
0930 – 0935 Hrs.	Welcome Note	**Dr. Satish Kumar** Senior Advisor and Guest Scientist Lawrence Berkeley National Laboratory (LBNL)	
0935 - 0940 Hrs.	Special Address	**Ms. Sheila Moynihan** Deputy Director - International Team, U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)	
0940 – 0950 Hrs.	Special Address	**Dr. Ajay Kumar** Special Secretary, Ministry of Electronics & Information Technology	
0950 - 1005 Hrs.	Keynote Address	**Mr. B.P Pandey** Director General, Bureau of Energy Efficiency (BEE) Special Secretary, Ministry of Power, GoI	
1005 – 1045 Hrs.	Inaugural Presentation on CII- LBNL initiative on "Accelerating Data Center Energy Efficiency In India" – Findings from the Study	**Mr. Dale Sartor** P.E, Staff Engineer, Applications Team Lead, Lawrence Berkeley National Laboratory (LBNL)	**Dr. Suprotim Ganguly** Chief Executive Officer, Global Innovation & Technology Alliance (GITA)
1045 – 1100 Hrs.	**Interactive Q&A Session**		

1100 – 1120 Hrs.	**Tea Break**

1120 – 1230 Hrs.	Session on **"Development of a Composite Policy Framework for Indian Data Centers based on existing Energy Efficiency standards in India i.e. PAT & ECBC".**	
1120 – 1140 Hrs.	Presentation on ECBC Update Process	**Mr. Tanmay Tathagat** Director, Environmental Design Solutions (EDS)
1140 – 1200 Hrs.	Presentation on CII-GBC Initiative for Indian Data Centers	**Mr. S Karthikeyan** Senior Counsellor – Green Business Centre, Confederation of Indian Industry (CII)
1200 – 1230 Hrs.	**Interactive Q&A Session**	

1230 – 1330 Hrs.	**Networking Lunch**

1330 - 1440Hrs.	Session on **“Energy Efficiency Technologies & Best Practices in Indian Data Centers”.**	
1330 -1335 Hrs.	Opening Remarks by Session Moderator	**Ms. Shaheen Meeran** Managing Director, Schnabel DC Consultants
1335 – 1350 Hrs.	Presentation	**Mr. Mani Kiran Kumar T** Senior Manager – Data Center Solution and Services Schneider Electric – IT Business
1350– 1405 Hrs.	Presentation	**Mr. Vivek Kumar Rajendran** Director - Software Engineering, Dell India
1405 – 1420 Hrs.	Presentation	**Mr. Nagarajan** Data Center Expert, Cisco Systems
1420 – 1440 Hrs.	**Interactive Q&A Session**	

1440 – 1450 Hrs.	**Tea Break**

<table>
<tr><td>1450 – 1615 Hrs.</td><td colspan="2">Panel Discussion on “Role of Energy Efficiency Standards and Technology Interventions in Accelerating the Adoption of Best Practices in Indian Data Centers ”</td></tr>
<tr><td>1450 – 1455 Hrs.</td><td>Opening Remarks by Session Moderator</td><td>Mr. S.S Mathur
General Manager – Data Center Infrastructure,
Centre for Railways Information System (CRIS)</td></tr>
<tr><td>1455 -1545 Hrs.</td><td colspan="2">Panelists:
• Mr. Dale Sartor
P.E, Staff Engineer, Applications Team Lead,
Lawrence Berkeley National Laboratory (LBNL)
• Mr. Malikarjun Patil
Technical Director,
Schnabel DC Consultants
• Mr. B. Rajput
Senior Technical Director, National
Informatics Center (NIC)
• Mr. Shrirang Deshpande
Head - Datacenter Business,
Emerson Network Power
• Mr. Siddharth Jain
Managing Director,
EPI - India
• Mr. Pushpendra Pandey
Senior Manager – IT Infrastructure,
IBM India Private Limited</td></tr>
<tr><td>1545 – 1615 Hrs.</td><td colspan="2">Interactive Q&A Session</td></tr>
</table>

1615 – 1700 Hrs.	**Valedictory Session**		
1615 – 1625 Hrs.	Special Address	**Dr. Murali Krishna Kumar** Senior Adviser, NITI Aayog	
1625 – 1640 Hrs.	Concluding Remarks	**Mr. Dale Sartor** P.E, Staff Engineer, Applications Team Lead	**Ms. Sheila Moynihan** Deputy Director - International Team, U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)
1640– 1655 Hrs.	Way Forward	**Mr. Saurabh Diddi** Acting Secretary, Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India	
1655– 1700 Hrs.	Vote of Thanks	**Ms. Soma Banerjee** Principal – Energy& Infrastructure Confederation of Indian Industry (CII)	

Appendix L: Participants at Workshop in Delhi

Workshop on "Accelerating the Energy Efficiency in Indian Data Centers"- December 06, 2016			
S.No.	**Name**	**Designation**	**Organization**
1	Mr. Ashish Rakheja	Managing Director	Aeon Consultants
2	Mr. Anil Kumar	Director	Bhagwat Technologies & Energy Conservation Pvt. Ltd.
3	Mr. Saurabh Singh	Sr. Business Analyst	CtrlS Datacenters Ltd.
4	Ms. Archana Walia	Director of India Programs	CLASP
5	Mr. Gurvinder Singh	Dy. Director General (W)	Central Public Works Department, CPWD
6	Mr. Vipul Kumar	System Administrator Data Centers	Computer Sciences Corporation (CSC)
7	Mr. Raj Kumar Khilnani	Managing Director	Energy Tech Consultants Pvt Ltd
8	Mr.Kanishk Khanna	Manager	Elion
9	Mr. Narender Khanna	Director	Elion
10	Mr. Chandan Sudip	Sr. Business Developer	Felidae Systems
11	Mr. Vaibhav Goel	Manager Northern Region	Godrej Green Building Consultancy
12	Dr. Sushma Goel	Resource management and design application department	Lady Irwin College
13	Mr. K Jeyabalan	Associate Vice President DC Facilities Projects	Netmagic Solutions
14	Mr. LPL Ranganath	AVP Non IT Operations	NxtGen Data Center & Cloud Technologies Pvt. Ltd
15	Mr. Sunny Sapra		NxtGen Data Center & Cloud Technologies Pvt. Ltd
16	Mr. Mohan Kumar Subramaniyan	Sr. Manger-DC Infrastructure	Nxtra
17	Mr. Sanjay Suman	SME	Nxtra
18	Mr. Yogesh Bhardwaj	Sr. Engineer HVAC & Energy Analyst	PSI (Partnership for Sustainable India)
19	Mr. Shankar Sadarangani	Associate	PSI (Partnership for Sustainable India)
20	Mr. U.P.Singh	Associate G.M	Schneider Electric Conzerv India Pvt
21	Mr. SK Nayak	Head, Projects	IL&FS Environmental Infrastructure & Services Ltd.
22	Mr. Manoj Kapil	Head-Data Center	Wipro Technologies
23	Mr. Himadri Nayak	Technical Specialist	Wipro Technologies
24	Mr. C.P.Srivastava	Independent Management Consultant & Founder and CEO(Former CEO Alstom)	DCS Group
25	Ms. Rekha Misra	Executive Director	Industrial Development Services (IDS)

Workshop on “Accelerating the Energy Efficiency in Indian Data Centers”- December 06, 2016			
S.No.	**Name**	**Designation**	**Organization**
26	Mr. Prashant Bandhu	Sr. Research Officer	Industrial Development Services (IDS)
27	Mr. Arpit Sharma	Sr. Research Officer	Industrial Development Services (IDS)
28	Mr. Prashant Tewari	Engineer	Energy Efficiency Services Ltd.
29	Mr. Harish Singh Karki		Industrial Development Services (IDS)
30	Ms. Sonia	Sr. Research Officer	Industrial Development Services (IDS)
31	Mr. G.P Rao	Chief Technical Officer	Nanosoftechinc.com
32	Dr. Shivraj Dhaka	Counsellor	CII- GBC
33	Mr. V. Sundeep	Counsellor	CII- GBC
34	Mr. Sanjay Kumar	Manager	Emerson
35	Mr. Vishal Goyal	Senior Executive	SGS
36	Mr. Deepak Tewari	Senior Consultant Advisory- GRID	PricewaterhouseCoopers
37	Mr. Tushar Saxena	Asst. Manager	Global Energy
38	Mr. Tarun Garg	Manager- GRID- Energy, Utilities & Mining	PricewaterhouseCoopers
39	Mr. Siddharth Singla	Advocate	MNRE
40	Mr. M. Thaslim	Energy Auditor	Global Energy
41	Mr. Faraz Alam	Asst. Engineer Projects	Global Energy
42	Mr. R. P Sirohi	Scientist "C"	National Informatic Center
43	Mr. Tanmay Tathagat	Director	Environmental Design Solutions (EDS)
44	Mr. Nagarajan	Data Center Expert	Cisco Systems
45	Mr. Mani Kiran kumar T.	Senior Manager - Data center services & solution Schneider Electric	Schneider Electric
46	Ms. Shaheen Meeran	Managing Director	SCHNABEL DC Consultants India
47	Mr. B. Rajput	Senior Technical Director	National Information Center
48	Mr. Vivek Kumar Rajendran	Director - Software Engineering	Dell
49	Mr Malikarjun Patil	Project Manager	Schnabel DC Consultants
50	Mr. S. S Mathur	General Manager – Data Center Infrastructure(CRIS)	Indian Railways
51	Mr. Shrirang Deshpande	Head - Datacenter Business	Emerson Network
52	Mr. Siddharth Jain	Managing Director	NetDataVault
53	Mr. Pushpendra Pandey	Manager - IT Infrastructure & Green IT	IBM India Private Limited

Appendix M: Workshop – Group Photo(December 06, 2016)