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DISCLAIMER

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We are grateful to the Indian Bureau of Energy Efficiency's (BEE) Director General, Dr. Ajay Mathur, and Energy Economist Mr. Sanjay Seth for providing extensive guidance and review throughout Phase I of this initiative.

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 stakeholders we would like to recognize are listed under survey and workshop participants in Appendix E. 2, E. 4, and F.1.

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Executive Summary

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 browsing, e-mail, social media, data storage, and processing. Growth in the data center industry is highly driven by sectors such as financial services, high-tech universities, media, telecommunication, government institutions, and retail (U.S. Environmental Protection Agency (EPA), 2007). According to reports, India will be the second largest market for data Centre infrastructure in Asia/Pacific in 2015. The Indian data center infrastructure market will total USD2.03 billion in 2015, a 5.4 percent increase from 2014 revenue (Gartner, 2014). Additionally, Indian spending on data center storage, server, and network equipment reached USD 2.2 billion in 2012 and this market is expected to grow at the compound annual growth rate of 8.5% to reach USD 3 billion by 2016 (NASSCOM, 2012).

Energy is one of the most important components of the operating expenses of a data center (Data Center Knowledge, 2012) but increasing energy costs and corresponding operational costs pose challenges to business competitiveness. Thus, it is necessary to reduce the energy consumption in data centers and enhanced energy efficiency has been recognized as an appropriate instrument for this purpose. Around the world, initiatives to enhance energy efficiency in data centers are underway. According to a report released in 2012, there were 28 types of energy standards applicable to data centers in 12 EMEA (Europe, the Middle East and Africa) countries (Data Center Knowledge, 2012). India has several policies that encourage energy-efficient buildings (e.g., office, hospitals, homes) and industries (e.g., cement, textile), but a policy does not exist to regulate the energy consumption and environmental impact of data centers.

This report documents Phase 1 of the “Accelerating Energy Efficiency in Indian Data Centers” initiative to support the development of an energy efficiency policy framework for Indian data centers. The initiative is being led by 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). 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 1 (November 2014 – September 2015) and Phase 2 (October 2015 – September 2016).

Phase 1 consisted of three main activities: a comprehensive review of existing energy efficiency policy in India and data center standards from around the world; analysis of these international standards for energy efficiency, including metrics, to the Indian context; and stakeholder engagement through an online survey and in-person workshop.

The results of these activities are presented in this report and directly support the development of a tailored policy framework to reduce the energy consumption of data centers in India.

Policy Review

International standards were categorized into approaches based on common characteristics (Whole Building, Best Practices, Comparative Scale, and Prescriptive or Performance Based). There are many similar characteristics between the international standards and existing energy efficiency policies in India. The categorization into approaches and insight into potential metrics were utilized during the stakeholder engagement activities and resulted in more specific and actionable feedback.

Approach	Examples
Whole Building (Point-based and Voluntary)	**Indian:** IGBC, GRIHA, LEED **International:** LEED, BREEAM, Green Mark, GBI
Best Practices (Guidelines)	**Indian**: No comparable policy framework **International**: European Code of Conduct, ISO 50001, and Blue Angel Eco-Label
Comparative Scale (Benchmark)	**Indian**: BEE Star Label **International:** ENERGY STAR rating and the National Australian Built Environment Rating System (NABERS)
Prescriptive or Performance Based (Mandatory Code)	**Indian:** ECBC **International:** ASHRAE 90.1, California Title 24
Energy Efficiency Obligations	**Indian:** Perform, Achieve and Trade (PAT) **International:** No Comparable example in Data Center

Stakeholder Engagement
Twenty-five key stakeholders, including data center owners and experts, responded to an online survey designed to capture industry's viewpoint on topics ranging from energy efficient technologies to different policy approaches to existing policy in India could be leveraged to cover data centers. Further stakeholder engagement was conducted through an in-person workshop with industry and the findings were presented to BEE. Each stage of engagement provided insight to guide the development of a standard for energy efficiency in data centers in India.

Conclusion and Next Steps (Phase II)
Enhancing energy efficiency through a standard has been recognized as an appropriate strategy to reduce energy consumption in Indian data centers. Though India has well-established energy efficiency standards in its commercial and industrial facilities, a dedicated standard for data centers does not exist. This initiative established that existing energy efficiency policies in India share certain similarities with some of the international standards reviewed in this study and these existing standards can be leveraged for data center energy efficiency.

Summary of Phase 1 Findings:

- An energy efficient data center in itself is an incentive or a reward for the data center industry. It not only improves the overall energy efficiency but also increases the business productivity of data centers.

- A "Composite Policy Framework" based on existing energy efficiency standards such as PAT, ECBC and S&L may be designed for Indian data centers to encompass all the components of a data center (e.g., IT, infrastructure), and should be applicable to both existing (brownfield) and new (greenfield) data centers.

- An Expert Stakeholder Group may be formulated to focus on the IT metric part and separately an Administrative Stakeholder Group will take care on the synchronization part with the existing ECBC, PAT, and S&L framework to make this standard easily adoptable by BEE.

- Formulation of the new standard must consider the following factors: variation in size of data centers; variation in type of data centers (e.g., captive, colocation) and their implication on energy use; reliability; and air and environmental quality.

Next Steps:

- Development of short-term and long-term strategies to implement an energy efficiency standard for Indian data centers in the context of existing policy (e.g., ECBC, PAT). This process will follow in-depth consultation with a broad DC Stakeholder Consultative group.

- Formulation of a Core IT Stakeholder Consultative Group to come to a consensus on an IT Energy Performance Metric, taking PUE into consideration.

- Development of technical and administrative procedures the standard.

- Stakeholder discussions to define a specific methodology to design the standard.

- Facilitation of the implementation and notification aspects of the standard.

- National and international-level dissemination.

Introduction

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, and retail (U.S. Environmental Protection Agency (EPA), 2007). The overall data center workloads are expected to double from 2013 to 2018 (Upsite Technologies, 2014) and the 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). 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, 2014). Some of the world's biggest technology organizations (e.g., Microsoft, Google, IBM, Cisco) have taken on the development of smart cities (Franks, 2014) and experts have stated that data centers located in the same region of the smart city will be the backbone (Consorci de Serveis Universitaris de Catalunya (CSUC)). For example, data centers will be storing and processing the data received through sensors to detect excessive air pollution, integrated traffic controls, and education systems. Overall, the number of data centers is expected to increase dramatically in the near future.

Considering the growth expected in data center industry, interest is growing to reduce the energy consumption and make data centers more energy efficient. The interest is also necessary as data centers operate 24/7 and are highly energy intensive. The energy intensity of a data center may be 10 to 100 times of a typical commercial building (USAID ECO-III Project, 2009). Rising energy prices are also increasing the operating cost of data centers and it has been reported that global data center carbon emissions will grow 7% year-on-year through 2020 (National Resources Defence Council, 2014). These factors and increasing business competitiveness is driving the data center industry to become energy efficient.

It is estimated that achieving just half of the technologically feasible savings through adopting best practices could cut electric use by 40% in data centers (Whitney & Delforge, 2014). These practices cover everything from facility lighting to cooling system design, and have proven useful in helping some companies curb the trend of rising data center energy consumption (Emerson Network Power). However, most organizations still lack a cohesive, holistic approach for reducing data center energy use. It is not considered sufficient to simply recognize the need to save energy and improve efficiency; one must quantify key benefits associated with energy-efficient practices and prioritize actions to achieve them. To assist organizations measure the savings from adopting best practices, associations such as The Green Grid have developed metrics such as Power Usage Effectiveness (PUE) and Data Center Infrastructure Efficiency (DCiE).

Best practices include energy-efficient technologies such as: (i) The use of variable frequency drives (VFDs), the installation of air- or water-side economizers, and improved air flow management in the cooling system; (ii) The use of energy-efficient uninterruptible power supplies (UPSs), premium efficiency distribution transformers, and direct current power systems in the electrical system; and (iii) Server virtualization and consolidation, and energy-efficient storage technologies in the IT systems. See Appendix B for a detailed list of potential technologies, inlcuding existing barriers.

Improvements in the energy efficiency of a data center provide data center managers with a greater understanding of, and control over, energy consumption. Enhanced control enables more effective execution of equipment refresh rates, updates, and maintenance. It also provides superior visibility over the performance and efficiency of the entire network, facilitating the ability to pinpoint areas of opportunity. Energy efficiency leads to increased reliability and availability of data centers, enhanced efficiency in design and operations, reduced operating costs, reduced greenhouse gas emissions, and enhanced grid support for the entire electric utility system (U.S. Environmental Protection Agency (EPA), 2013)

Many countries have developed standards to help design, rate, or certify data centers based on their environmental performance or energy consumption benchmarking to achieve the benefits of energy efficiency. Standards cover the whole range of energy efficiency-related issues in data centers rather than focusing on and solving a single issue and cover data centers of different sizes and characteristics. According to a report released in 2012, there were 28 types of standards applicable to data centers in 12 EMEA (Europe, the Middle East and Africa) countries (Data Center Knowledge, 2012). India has several policies that encourage energy-efficient buildings (e.g., office, hospitals, homes) and industries (e.g., cement, textile), but a policy does not exist to regulate the energy consumption and environmental impact of data centers in India.

This report documents Phase 1 of the "Accelerating Energy Efficiency in Indian Data Centers" initiative to support the development of an energy efficiency policy framework for Indian data centers. The initiative is being led by 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). 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 1 (November 2014 – September 2015) and Phase 2 (October 2015 – September 2016).

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Data Centers and Energy Efficiency in India

Over the last decade, India has experienced an increased demand for data due to the explosive growth in smartphones and widespread use of social media apps, banking and e-commerce transactions, and multimedia storage needs. This increased demand for data has provided the impetus for the large growth in Indian data center markets. It has been predicted that India will become the world's 5th largest data center market by 2050. The Indian government supports further growth in the data center industry through the inclusion of initiatives such as the provision of tax incentives for setting-up data centers and cloud services in its budget for 2015. Another project aims to provide 250,000 villages with broadband connectivity and enable Wi-Fi connectivity in schools by 2019 (Data Center Dynamics).

It has been estimated that the energy currently used by a 10 MW data center each year is equivalent to the energy consumed by 73,000 typical urban Indian houses or equivalent to energy consumed by 17,520 typical Indian cars (USAID ECO-III Project, 2009). In a country with a large and increasing energy demand, and an existing power-deficit, energy efficiency is key. With the introduction of the Energy Conservation Act 2001, the Government of India (GOI) began efforts to institutionalize and mainstream energy efficiency, which included the formation of the Bureau of Energy Efficiency (BEE) under the Ministry of Power.

Efforts to address energy efficiency in data centers officially began in 2009 when BEE launched an initiative to create a "Data Center Energy Efficiency Design Code" and a "Best practice

Manual" in partnership with Confederation of Indian Industry (CII) and industry members. In 2010, under the guidance of BEE, CII developed the "Energy Efficiency Guidelines and Best Practices in Indian Data Centers" report (Confederation of Indian Industry (CII) - Bureau of Energy Efficiency (BEE), 2010). Under this initiative, more than twenty data center-specific energy efficiency measures that offer high replication potential in the Indian data centers were identified. The early studies indicate that a focus on data center efficiency, reliability, and cost optimization has led to challenges in India such as: (i) lack of an integrated building design approach; (ii) lack of technical awareness, exposure to best practices, and energy-efficient solutions; (iii) the need for information technology (IT) infrastructure to keep up with evolving technologies; (iv) and lack of regulatory measures and an institutional framework to promote energy efficiency (USAID ECO-III Project, 2008).

Although a standard for data center energy efficiency does not exist in India, there are policies that cover the energy efficiency of buildings that could potentially be expanded to cover data centers. These policies include the Indian Green Building Council; Energy Conservation Building Code (ECBC); Star Rating for Buildings (Star Rating); Green Rating for Integrated Habitat Assessment (GRIHA); and the Standards and Labeling (S&L) program for appliances and equipment. See Appendix C for more information about the existing energy efficiency policies in India including assessment and award criteria.

Policy Review and Analysis

Data center standards from around the world

As part of the "Accelerating Energy Efficiency in Indian Data Centers" initiative, an extensive review of published journals, articles, white papers, and technical and strategic documents on existing energy efficiency standards for data centers was conducted. The review sought to unveil best practices and lessons learned from other data center standards already in place. National, regional, and international standards, both voluntary and mandatory, were reviewed.

The international energy efficiency standards reviewed include: Energy Star Rating (U.S.); Leadership in Energy and Environment Design, LEED (U.S); American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE 90.1 (U.S); California Title 24 standards (U.S); National Australian Built Environment Rating System, NABERS (Australia); Green Mark (Singapore); Green Building Index, GBI (Malaysia); Certified Energy Efficient Datacenter Audit, CEEDA (U.K); Building Research Establishment Environmental Assessment Method, BREEAM (U.K); European Code of Conduct; Blue Angel Eco-Label (Germany); and International Standards Organization (ISO) 50001: 2011 (Europe). The standards exhibit varied approaches for improving data center energy efficiency. See Appendix D for more information and analysis on each standard including assessment and certification criteria.

Based on common characteristics, the standards can be categorized under four broad approaches:

- Whole-Building (point-based and voluntary)
- Best Practices (Guidelines)
- Comparative Scale (Benchmark)
- Prescriptive or Performance-Based (mandatory code based)

Whole-Building (point-based and voluntary)
Whole-Building (point-based and voluntary) standards usually address other aspects of sustainable design and operation (e.g., water use, energy and water sources, materials, indoor environment) in an attempt to achieve a holistic rating. Points are assigned to different section/criteria and rating is based on an overall score determined by summing the points achieved for each section/criteria. These awards are usually time bound and need reassessment after fixed time tenures. Standards that follow this approach are Leadership in Energy and Environmental Design (LEED), Certified Energy Efficient Datacenter Audit (CEEDA), Building Research Establishment Environmental Assessment Method (BREEAM), Green Building Index (GBI), and Green Mark.

Best Practices (Guidelines)
Best Practices (Guidelines) standards allow data centers to voluntarily set energy efficiency targets based on the type of data centers and/or services provided. A policy document provides the guidance needed to develop an action plan to meet targets. The successful achievement of targets leads to the certification of the data center as an "Energy Efficient Data Center." Standards based on this approach are the European Code of Conduct, ISO 50001, and Blue Angel Eco-Label.

Comparative Scale (Benchmark)
Comparative Scale (Benchmark) standards evaluate an individual buildings' actual energy use through metrics such as the Energy Performance Index (EPI) or Energy Efficiency Ratio (EER). The building's performance is then compared to a peer group of buildings with similar characteristics and services. The rating is usually awarded based on a relative percentile. Standards based on approach rating are ENERGY STAR and the National Australian Built Environment Rating System (NABERS).

Prescriptive or Performance-Based (mandatory code based)
Prescriptive or Performance-Based standards focus on the energy efficiency of the building envelope, HVAC, service hot water and pumping, lighting, and electric power. Compliance is achieved through a Prescriptive, Trade-Off, or Whole-Building performance method that uses a simulation model to assess energy performance. Standards based on this approach include American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 and California Title 24 standards. ASHRAE 90.4: Energy Standard for Data Centers and Telecommunication Buildings is also based on this approach, but is still in the review process; it has not been formally adopted.

Approaches in the Indian Context

The existing energy efficiency standards/policies in India can also be categorized across each of the four approaches to data center standards. The categorization shows that although India does not have a standard specifically for energy efficiency in Indian data centers, it does have energy efficiency policies that exhibit similar characteristics as the international standards and could potentially be expanded to cover data centers.

Approach	Examples
Whole Building (Point-based and Voluntary)	**Indian:** IGBC, GRIHA, LEED **International:** LEED, BREEAM, Green Mark, GBI
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Energy Efficiency Obligations	**Indian:** Perform, Achieve and Trade (PAT) **International:** No Comparable example in Data Center

ECBC (Minimum Energy Performance Code)
ECBC by BEE takes a prescriptive or performance-based approach (Mandatory Code). It follows the same structure as ASHRAE 90.1 and California Title 24, covers similar building components, and offers the Prescriptive, Trade-Off, or Whole-Building compliance options. It is likely that an energy-efficiency standard for data centers in India will focus on improving energy efficiency through a system approach or through a whole facility approach. However, considering that GOI/BEE has not issued a segment-specific energy code or application guide, it is unlikely that government will adopt this approach.

Perform, Achieve, and Trade (PAT)
The PAT scheme by BEE demonstrates similarities with the Best Practices (Guidelines) approach. PAT sets performance indicators for specific industry segments and assigns mandatory emission reduction targets for the most energy intensive industries (i.e., Designated Consumers). More specifically, energy saving targets and the grace period to achieve targets are based on actual energy consumption and validation is conducted by a third-party (authorized by BEE). A data center energy efficiency standard that uses a widely acceptable performance indicator (e.g., PUE) and benchmarks against India-specific data may fit very well with the existing PAT framework. This approach will not have the granularity or flexibility of achieving compliance by targeting individual systems. An accompanying policy document will also be needed to provide guidance to organizations that will come under the purview of the PAT scheme.

Star Labeling of Buildings
Star Labeling by the BEE demonstrates similarities with the Comparative Scale (Benchmark) approach and specifically the ENERGY STAR standard. Star Labeling is based on actual performance (metered data), uses the Energy Performance Index (EPI) to evaluate energy performance, and also provides a peer group comparison. It is currently applicable to offices, hotels, retail malls, IT parks, and hospitals, and accounts for operational characteristics of the building such as climatic zone and hours of operation.

Data Center Performance Evaluation Metrics

Evaluation metrics gauge the level of energy efficiency and environmental impacts of a data center or its components. Evaluation metrics can also be used to capture unique requirements for Indian data centers such as backup generation due to unreliable electricity supply. Many metrics have evolved over the years to simplify the evaluation process and increase the efficiency of data capture for calculations. Most metrics focus on the efficient use of individual resources during operation and the single most important resource is energy. Most of the short-listed energy efficiency data center standards have adopted Power Usage Effectiveness (PUE) or Data Center Infrastructure Efficiency (DCiE), introduced by The Green Grid as an evaluation metric or criteria to rate data center energy efficiency. PUE is the ratio of a facility's total power drawn to the amount of power used solely by the data center's IT equipment and DCiE is its inverse. PUE and DCiE gauge the efficiency of a data center by focusing on the support infrastructure (e.g., cooling).

Evaluation can be grouped into two categories: Basic metrics define the level of "greenness" of a data center and Extended metrics are functions of basic metrics that provide an in-depth look at the data center.

Basic Metrics

- Cooling System Efficiency (CSE)
- Airflow Efficiency (AE)
- Cooling System Sizing (CSS)
- Air Economizer Utilization (AEU)
- Water Economizer Utilization (WEU)
- Data Center Infrastructure Efficiency (DCiE) (The Green Grid, 2009)
- Power Usage Effectiveness (PUE) (The Green Grid, 2007) (The Green Grid, 2009) (The Green Grid, 2010) (The Green Grid, 2010)
- HVAC Effectiveness
- Data Center Energy Productivity (DCeP) (The Green Grid, 2014) (The Green Grid, 2009)
- Space, Watts and Performance (SWaP)
- Server Compute Efficiency (ScE)
- Data Center Compute Efficiency (DCcE)

Extended Metrics

- Storage Utilization (Storage-U)
- Network Utilization (Network-U)
- Server Utilization (Server-U) (Wang, 2011)

There are many other metrics used around the world, typically to characterize sub-systems. For example, on the infrastructure side, cooling plant overall and component efficiencies, power distribution efficiency, and fan specific power are used. On the IT side, utilization, virtualization, and power management are used. Others include: Data Center Energy Efficiency and Productivity (DC-EEP) (Brill, 2007); Carbon (The Green Grid, 2014) (The Green Grid, 2010); Water Usage Effectiveness (WUE) (The Green Grid, 2011); Electronics Disposal Efficiency (EDE (The Green Grid). These evaluation metrics are Green Performance Indicators (GPIs), which assess overall environmental performance. GPIs are classified as Data Center Level GPIs, SI system Level GPIs, IT system Level GPIs, and IT Benchmarks (Schodwell, Zarnekow , & Erek , 2013).

Among the standards considered in this report, seven use PUE to provide scoring or rating. The Green Mark rating system has benchmarked PUE in the range of 2.2-1.5 for existing data centers and 2.0-1.4 for new construction. Malaysia's Green Building Index rating system (Green Building Index (GBI), 2012) has benchmarked PUE in the range of 1.3-1.9. The PUE metric drives the need to minimize power used by anything other than IT. However, there are concerns that the metric does not consider the actual productivity or efficiency of the IT equipment (The Green Grid, 2009). Server Compute Efficiency (ScE) and Data Center Compute Efficiency (DCcE) consider the efficiency of the data center compute infrastructure, and also focus on operational efficiency, much like PUE. Other metrics that evaluate energy use with consideration of the energy source are Energy Reuse Effectiveness (ERE) and Green Energy Coefficient (GEC). The ERE (The Green Grid, 2010) quantifies the amount of energy reused outside of the data center and GEC looks at the amount of renewable energy used. SI-EER is similar to PUE. The DCeP is the ratio of work produced in the data center to the energy used in in producing it (The Green Grid, 2009).

It has been reported that when assessing the energy demand of IT services all metrics fall short. For example PUE only measures the efficiency of whole infrastructure and IT equipment; inefficiencies are not addressed properly by PUE. The shortcomings are mainly due to the difficulty in modeling real life conditions of a data center. The development of such a metric is a proven challenge because of the different types of data centers and the services they provide. It should also be noted that an improvement in a specific metric might affect the outcome of another metric. A holistic approach can help to understand multiple metrics for energy efficiency of data center and reveal the effects of one metric on others.

Stakeholder Engagement: Online Survey

As part of the initiative, key data center stakeholders in India were grouped into two categories: data center owners (also includes large users) and data center experts (technology providers, academia, and R&D experts). CII developed and conducted an online survey with a different set of questions for the two groups. Thirty stakeholders were asked to participate in the survey and twenty-five participated. See Appendix E for survey questionnaires and list of participants for both stakeholder groups.

The survey was designed to capture industry's viewpoint on the following:

- Awareness of international data center standards.
- Metrics and international standards currently used by Indian data centers to determine their efficiency and benchmark energy consumption.
- Development of a standard for data centers in India including which existing energy efficiency policy in India is best suited to cover data centers.
- Importance and level of applicability of various energy efficient technologies in the electrical, mechanical, and IT sections of data centers.
- Characterization of data centers in India including type of services provided, size, sources of electricity, and respective annual average energy consumption.

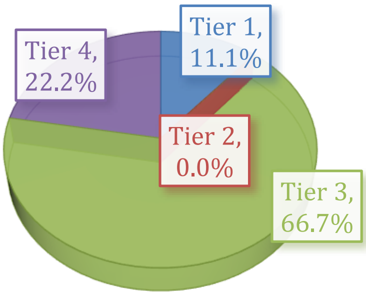
The three sections of the questionnaires are General Facility, Data Center Energy Efficient Technologies, and Energy Benchmarking. The inputs received from both stakeholder groups help define the appropriate approach to an energy efficiency standard for data centers in India and inform the various components such as categorization (e.g., size, services, energy consumption) and eligibility/compliance criteria.

Data Center General Facility Results

Tiers

Data center owners were asked at which tier their data operate. Tiers are based on the concept of redundancy in power distribution and components. Most data centers represented in this survey (66.7 %) operate at Tier 3. 22.2% operate at Tier 4, 11.1% operate at Tier 1, and 0% operate at Tier 2.

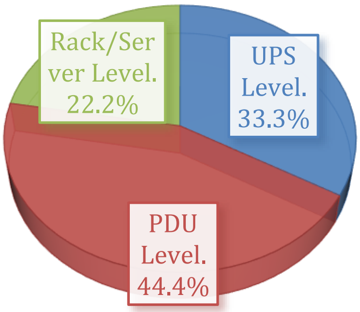
Tier Classification



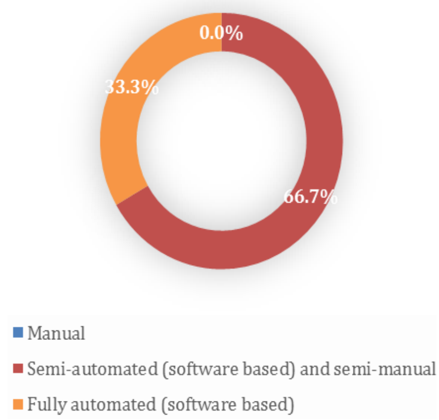
Level of IT Energy Metering

The highest existing level of IT energy metering in most data centers is at the PDU and UPS level. 44.4% of respondents selected PDU and 33.3% selected UPS. Most of the data center owners (66.7%) indicated that they use semi-automated (software based) and semi-manual method for record keeping and monitoring IT energy consumption.

Highest Level of IT Energy Metering



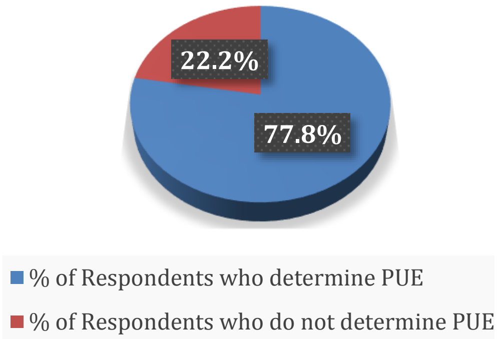
Monitoring IT Energy Consumption



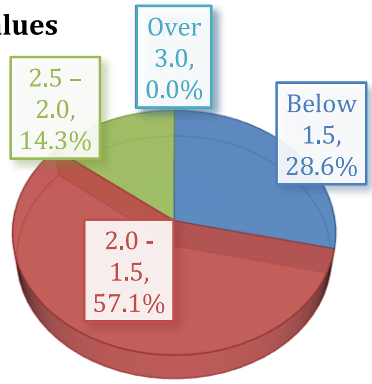
PUE

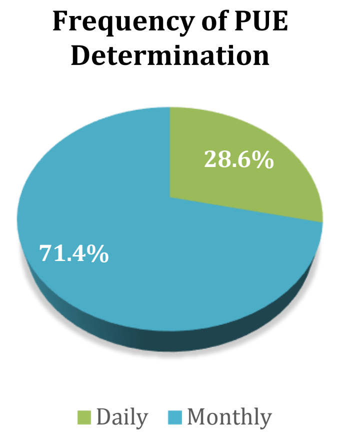
77.8% of respondents determine PUE for their data centers. The average PUE for the majority (57.1%) of the data centers lies within the range of 1.5 – 2.0. 28.6% of owners surveyed reported an average PUE better than 1.5. Furthermore, 100% of the participants have specified that they measure both "IT Power" and "Total Power" to determine the PUE of their facility. 71.4% of data center owners calculate their PUE on a monthly basis and 28.6% calculate their PUE on a daily basis.

PUE Determination

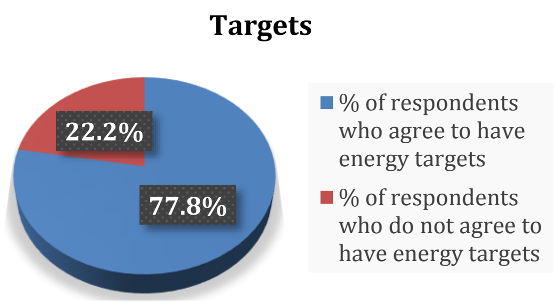


PUE Values





Energy Consumption Targets
77.8% of respondents have stated that they have set energy consumption reduction targets for their respective data center.

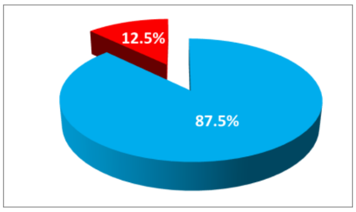
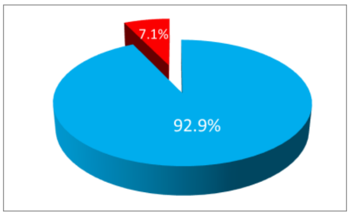
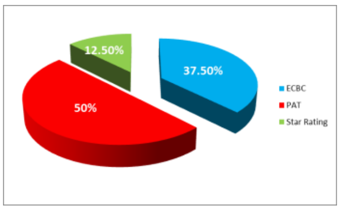


Energy Benchmarking (Rating/Certification/ Labeling) Results

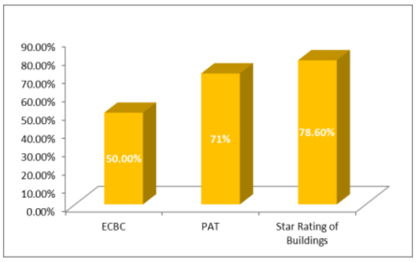
100% of both data center owners and data center experts agreed that a standard facilitating energy efficiency in data centers in India should be developed. Almost all (87.5% of data center owners and 92.9% of experts) agree that energy benchmarking (rating/certification/labeling) would help improve the overall efficiency and business productivity of their data centers.

Both owners and experts were asked which BEE energy efficiency policy (ECBC, PAT or Star Rating) could be extended to encompass all the components of a data center for the purpose of rating based on energy efficiency. Respondents were able to choose more than one policy. There were noteworthy differences between the responses for data center owners and experts. Over 50% of owners identified PAT as a policy that can be extended, 37.5% identified ECBC, and Star Rating was identified least frequently with only 12.5% of owners selecting this policy. Owners identified Star Rating the least, but experts identified this policy most frequently with 78.6% of data center experts selecting Star Rating.

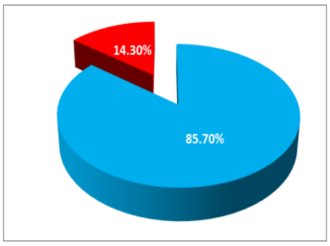
One overarching approach to data center standards in India did not reveal itself in the survey. The majority of data center owners (57.1%) selected Best Practices (Guidelines), Whole-Building (point-based and voluntary), and Comparative Scale (Benchmark) as a suitable approach for developing an energy efficiency policy for Indian data centers. Data center experts (64.3%) preferred the Prescriptive or Performance-Based (mandatory code based) and the Whole-Building (point-based and voluntary) approach. See figure below for more details on this section.

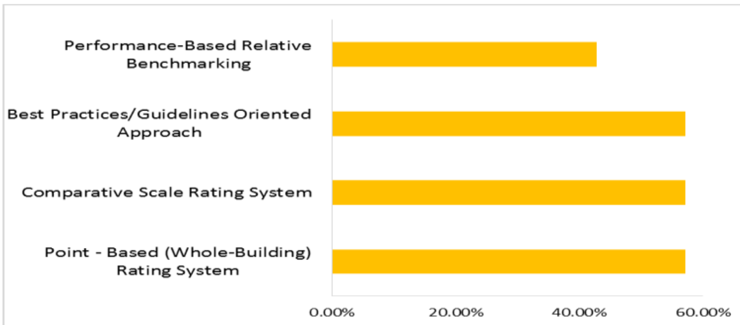
Respondents	Graphic and Inference
Question: Do you agree that Energy Benchmarking (Rating/Certification/ Labeling) would help to improve the overall "Energy Efficiency" and "Business Productivity" of your Data Centers, and a policy/standard facilitating Energy Efficiency in Data Centers in India should be developed?	
Data Center Owners	**87.5%** of the respondents agreed that Energy Benchmarking (Rating/Certification/Labeling) would help to improve the overall "Energy Efficiency" and "Business Productivity" of Data Centers  100% of respondents agreed and affirmed that a policy/standard facilitating energy efficiency in data centers in India should be developed.
Experts	**92.9%** of the respondents agreed that Energy Benchmarking (Rating/Certification/Labeling) would help to improve the overall "Energy Efficiency" and "Business Productivity" of Data Centers. 7.1% of respondents did not agree.  100% agreed and affirmed that a policy/standard facilitating energy efficiency in data centers in India should be developed.
Question: In Indian Scenario, Bureau of Energy Efficiency currently has three major programs to enhance the Energy Efficiency (ECBC, PAT and Star Rating of buildings). Which of these existing policies can be extended to encompass all the components of a Data Center for the purpose of rating based on Energy Efficiency? Do you agree that a "Composite Policy Framework" on Energy Efficiency in Data Centers may be designed focusing on ECBC, PAT and Star Rating of buildings?	
Data Center Owners	**50%** selected PAT to be extended to encompass all components of a data center for the purpose of rating. **37.5%** selected ECBC and the rest selected Star Rating.  100% affirmed that a "Composite Policy Framework" on Energy Efficiency in Data Centers might be designed focusing on ECBC, PAT and Star Rating of buildings.

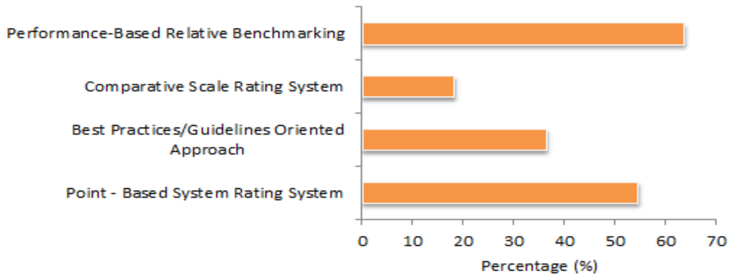
<table>
<tr><td>Experts</td><td>78.6% of respondents selected Star Rating to be extended to encompass all components of a data center for the purpose of rating. 71.4% selected PAT and 50% of respondents selected ECBC.



85.7% respondents affirmed that a “Composite Policy Framework” may be designed focusing on ECBC, PAT and Star Rating of buildings.


</td></tr>
<tr><td colspan="2">Question: This ongoing study of CII-LBNL on Accelerating Energy Efficiency in Indian Data Centers, has categorized the worldwide existing standards for Energy Benchmarking (Rating/Certification/ Labeling) methods in the area of Efficient & Sustainable operations into four categories. With this analytical context, according to you which one of the following methodologies (please refer table) would be more suitable for developing a policy on Energy Efficiency for Indian Data Centers?</td></tr>
<tr><td>Data Center Owners</td><td>57.1% of respondents selected Best Practices, Whole-Building, and Comparative Scale as a suitable methodology for developing a policy on energy efficiency for Indian Data Centers. 42.9% selected the Prescriptive or Performance-Based approach.

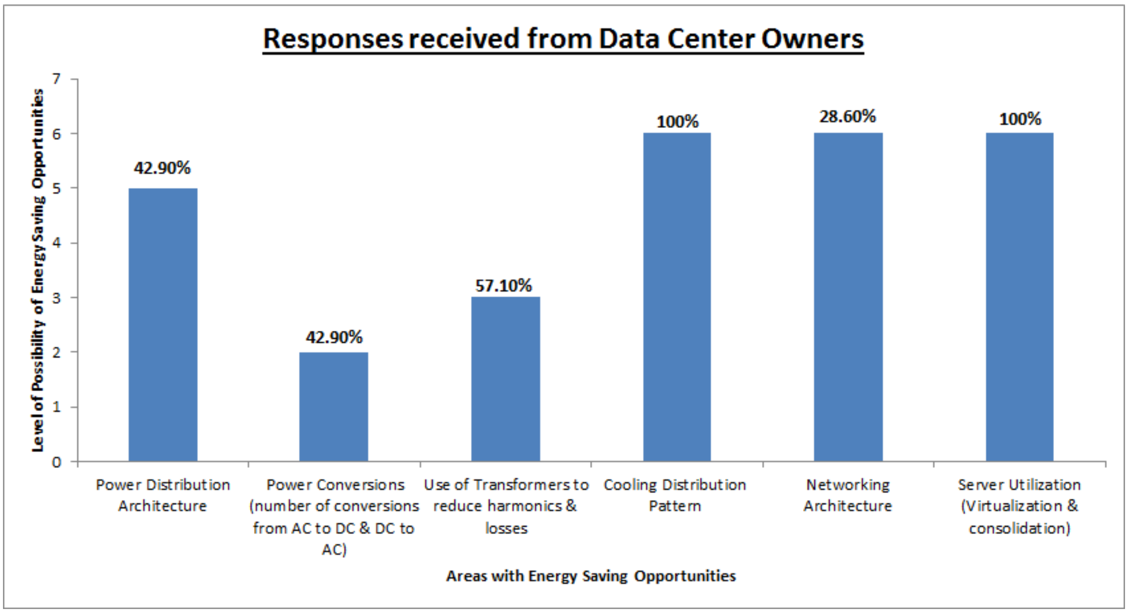

</td></tr>
<tr><td>Experts</td><td>64.3% selected Prescriptive or Performance-Based and the Whole-Building approach. 42.9% of respondents selected Best Practices and 28.6% selected Comparative Scale.


</td></tr>
</table>

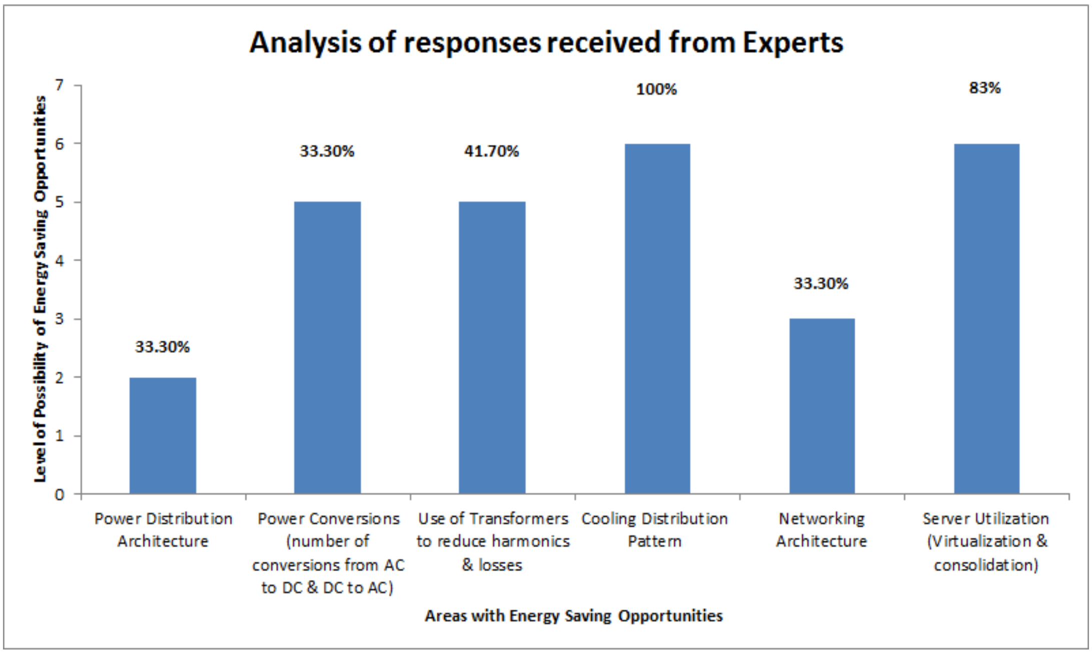
Energy Saving Opportunities

Both stakeholder groups were asked to identify and prioritize specific sections within a data center in regards to their potential for energy savings opportunities. On a scale of 1 to 6, 1 signifies the least possibility of energy efficiency and Level 6 signifies the maximum possibility of energy efficiency.

Data Center Owners on Energy Saving Opportunities
The responses received from data center owners are diverse and informative in nature. 100% of respondents prioritized cooling distribution pattern and server utilization (Level 6), which signify the areas with the most energy saving opportunities. Power distribution architecture was the second highest priority area for energy saving opportunities as 42.9% of respondents selected Level 5. Only 28.6% of respondents selected Level 6 for networking architecture as an energy saving opportunity, most of the participants gave it a rating of 1, 2 and 3. A majority of stakeholders (57.1%) selected Level 3 for use of transformers and 42.9% selected Level 2 for power conversions (number of conversions from AC to DC).



Data Center Experts on Energy Saving Opportunities
Data center experts also prioritized cooling distribution pattern and server utilization. However, experts identified power distribution architecture as the section with the least opportunity to save energy whereas data center owners prioritized this section much higher (Level 5). Additionally, experts prioritized power conversions and the use of transformers much higher than data center owners.

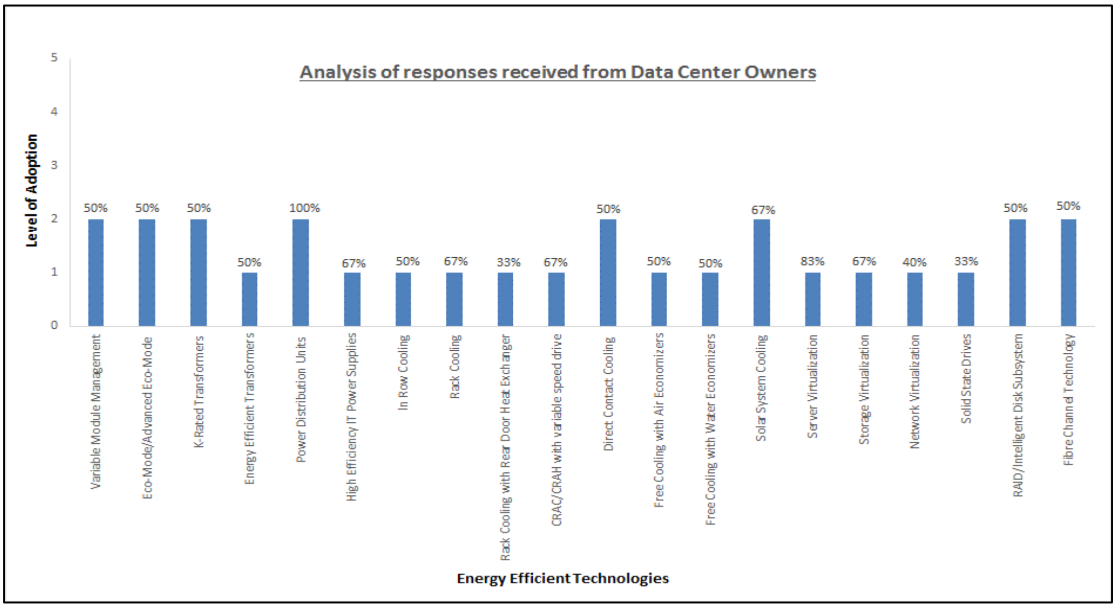


Adoption of Energy Efficient Technologies

Both stakeholder groups were asked questions regarding energy efficient technologies. Data center owners were asked about the potential of these technologies and experts were asked about the current level of adoption in data centers.

Data Center Owners on Energy Efficient Technologies

Data center owners were asked to prioritize technologies according to their applicability and suitability in a data center. On a scale of 1-4, Level 1 signifies the most suitable technology and Level 4 signifies that the technology is not required at all. The figure below shows the responses of data center owners.

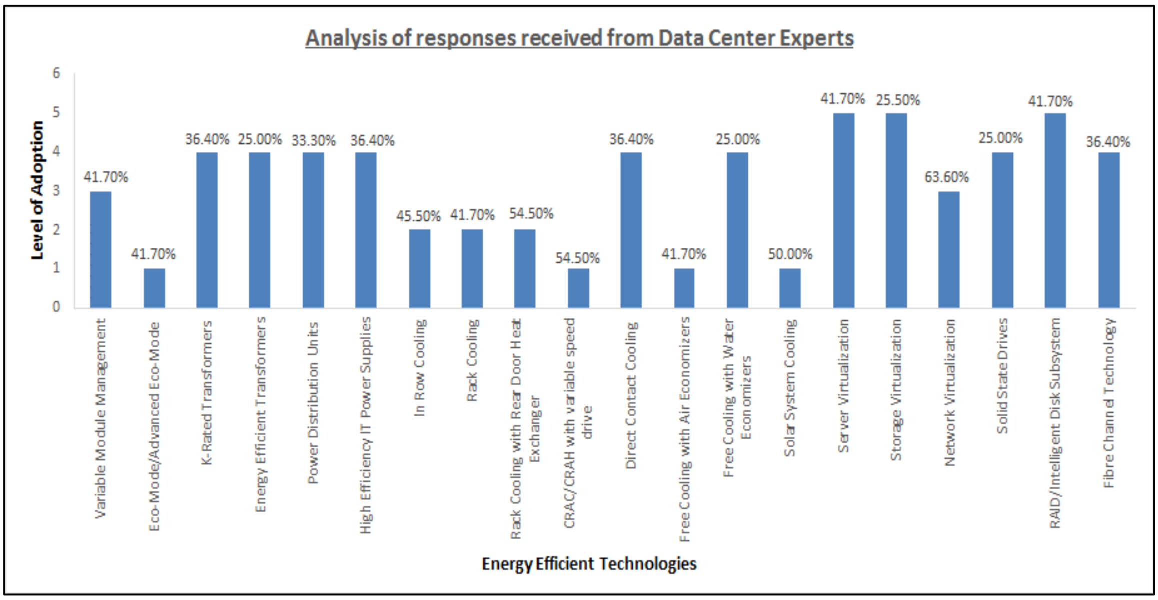


In the electrical system, prioritization has been given to high efficiency IT power supplies followed by energy efficient transformers. 66.7% participants selected Level 1 for IT power supplies and 50% of participants selected Level 1 for transformers. For other technologies including variable module management system (VMMS) and K-rated transformers, Level 2 was selected by 50% of the participants. For power distribution unit (PDU), 100% of participants selected Level 2.

In the Cooling section, prioritization is given to CRAC/CRAH units with variable speed drives and rack cooling; 66.7% of participants selected Level 1 for both the technologies. 50% of participants selected Level 1 for in row cooling and free cooling with air and water economizers. Rack cooling with rear door heat exchanger was also selected as level 1 technology by 33.30% of participants. Solar cooling system and direct contact Cooling were selected as level 2 technologies by 66.70% and 50% of participants respectively.

In the IT Peripheral section, prioritization is given to server, storage and network virtualization followed by solid state drives. Level 1 was selected for the server virtualization by 83.30% participants, storage virtualization by 66.7% participants, and network virtualization by 40% participants. Solid state drives were designated at Level 1 by 33.3% of participants. 50% of participants selected Level 2 for fiber technology and RAID/Intelligent Disk Subsystem.

Data Center Experts on Energy Efficient Technologies
Data center experts were asked to identify and prioritize energy efficient technologies in regards to their level of adoption in data centers. On a scale of 1 to 5, Level 1 signifies low adoption and Level 5 very high adoption. The figure below represents the consolidated responses of the experts.



In the electrical Section, prioritization is given to K-rated transformers and high efficiency IT power supplies followed by PDU and energy efficient transformers, signifying a high level of adoption in data centers Level 4 was selected for K-rated Transformers and high efficiency IT power supplies by 36.40% of participants. 33% selected level 4 for PDU and 25% selected Level 4 for energy efficient transformers, still indicating a high level of adoption.

In the cooling section, high prioritization was given to direct contact cooling followed by free cooling with water side economizers, signifying a high level of adoption in data centers Level 4 was selected for both the technologies by 36.40% participants and 25% participants respectively.

In the IT peripheral section, prioritization was given to server virtualization and storage virtualization followed by RAID/Disk intelligent subsystem. Level 5 was selected by 41.7% participants for server virtualization and RAID/Disk intelligent subsystem and by 25.50% participants. Network virtualization received Level 3 by 63.30% participants. Further Fibre Channel Technology and solid state drives received Level 4 by 36.40% and 25% participants respectively.

Key Policy Findings from Stakeholder Surveys

- Energy benchmarking (Rating/Certification/Labeling) is the key to improve overall "Energy Efficiency" and "Business Productivity" of data centers. The Indian government may systematically formulate a standard facilitating energy efficiency in data centers in India.

- A data center is essentially a building with high-energy intensity. The large variation and associated refresh rate of IT technologies and infrastructure impacts its energy consumption as well. Thus, any single existing energy efficiency policy in India (e.g., PAT, ECBC, Star Rating) may not encompass all components of a data center.

- A "Composite Policy Framework" may be designed for existing (brownfield) and new (greenfield) data centers based on existing energy efficiency policies in India (e.g., PAT, ECBC, Star Rating). These policies can be extended to encompass all the components of a data center for the purpose of energy efficiency rating.

- While designing the composite policy framework for Indian data centers, appropriate inputs may be considered from the Best Practices (Guidelines) approach, Whole-Building (point-based and voluntary) approach, and Prescriptive or Performance-Based (mandatory code based) approach.

Stakeholder Engagement: Workshop

To gain further insight into the viewpoint of relevant stakeholders, an in-person stakeholder workshop took place in Bangalore on July 13th, 2015. See Appendix F for participants list and agenda.

Summary of Viewpoints from the Stakeholder Workshop:

- The Indian Government may initially come up with a voluntary standard that can later be made mandatory. Incentives may not be required in the new policy framework; comparative framework and public recognition leads to peer pressure, which is sufficient motivation.

- Considering the poor power infrastructure in India, the recognition through this new standard or rating by BEE may help in providing better quality and reliable electricity from distribution companies. This in itself will act as an incentive for the data center industry.

- Diversity in the types of data centers and related technologies, especially IT technologies may act as a barrier to policy formulation. The standard should be able to address the real time challenges and variations in technologies and operational parameters for different types of data centers (e.g., captive and colocation data centers).

- It is necessary to have the proper ecosystem to support the new standard or policy framework for data centers. For example, qualified energy auditors with requisite level of understanding of data center technologies and operations should be made easily available to provide the certification/rating/ expert advisory.

- Considering that PAT may be considered for this sector, an appropriate and feasible "Energy versus Output" reporting format should be developed for this standard. A standard where a metric such as Energy Performance Index (EPI) with a variant of PUE can be considered with IGBC/US GBC rating used for certification should also be considered.

- The new standard must set a benchmark and should encourage the reporting of information in form of the "Energy Vs. Output" reporting format. If PUE is the metric used then it must clearly define what PUE is considered good, average, and bad based on the size and type of data centers.

- A hybrid approach is appropriate where data center infrastructure related aspects of ECBC can be extended to new data center design, PAT may be applicable to large and existing data centers standards with S&L applied to IT equipment. This arrangement will allow continuous improvement in operation where targets can be changed over the time.

Presentation to BEE: Bangalore Consultative Meeting

The findings of the policy review and stakeholder engagement activities (online survey and workshop in Bangalore) were presented to BEE on July 21st 2015.

Key commentary from BEE:

- For ECBC integration into the new data center energy efficiency standard in India it is important to define a compliance path for data centers which is not currently addressed. International energy efficiency standards having similar characteristics as ECBC (e.g., Title 24, ASHRAE 90.1) that may be studied in detail.

- In regards to PAT for data centers, data centers being an energy intensive niche building market, PAT for commercial buildings may be initiated at this stage starting with voluntary notification. It is important to identify an appropriate performance metric for core IT Load and also define thresholds (e.g., 500 kW) for data centers.

- Standards & Labeling (S&L) may be applied to specific IT products (e.g., server, UPS) in data centers. Currently nineteen products are covered under S&L out of which three are mandatory and nine are in the process to become mandatory. S&L for data center equipment would be a major effort and may not fit within the BEE S&L.

Conclusion and Next Steps (Phase II)

Enhancing energy efficiency through a standard has been recognized as an appropriate strategy to reduce energy consumption in Indian data centers. Though India has well-established energy efficiency standards in its commercial and industrial facilities, a dedicated standard for data centers does not exist. The deeper understanding of existing energy efficiency policy in India and the review of standards and specific metrics used around the world provided a strong base for the development of a standard for data centers in India. The alignment of these standards to Indian data centers, the results from stakeholder engagement, and feedback from BEE have also provided valuable insight for the development of an effective policy framework for data center energy efficiency. Phase 1 of the "Accelerating Energy Efficiency in Indian Data Centers" initiative established that existing energy efficiency policies in India share certain similarities with some of the international standards reviewed in this study and these existing standards can be leveraged for data center energy efficiency.

Summary of Phase 1 Findings:

- An energy efficient data center in itself is an incentive or a reward for the data center industry. It not only improves the overall energy efficiency but also increases the business productivity of data centers.

- A "Composite Policy Framework" based on existing energy efficiency standards such as PAT, ECBC and S&L may be designed for Indian data centers to encompass all the components of a data center (e.g., IT and Infrastructure), and should be applicable to both existing (brownfield) and new (greenfield) data centers.

- An Expert Stakeholder Group may be formulated to focus on the IT metric part and separately an Administrative Stakeholder Group will take care on the synchronization part with the existing ECBC, PAT, and S&L framework to make this standard easily adoptable by BEE.

- Formulation of the new standard must consider the following factors: variation in size of data centers; variation in type of data centers (e.g., captive, colocation) and their implication on energy use; reliability; and air and environmental quality.

Next Steps:

- Development of short-term and long-term strategies to implement an energy efficiency standard for Indian data centers in the context of existing policy (e.g., ECBC, PAT). This process will follow in-depth consultation with a broad DC Stakeholder Consultative group.

- Formulation of a Core IT Stakeholder Consultative Group to come to a consensus on an IT Energy Performance Metric, taking PUE into consideration.

- Development of technical and administrative procedures the standard.

- Stakeholder discussions to define a specific methodology to design the standard.

- Facilitation of the implementation and notification aspects of the standard.

- National and international-level dissemination.

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Appendix B: Efficient Technologies Matrix

SYSTEM COMPONENT	TECHNOLOGY	Technological Barriers	DESCRIPTION OF TECHNOLOGY
Uninterrupted Power Supply(UPS) & Batteries	Topologies	Topologies depend on the amount of **Reliability, Availability and Power Quality Requirements** of load, which are data center specific.	There are **9 electrical problems** which can harm a Data Center and **UPS Topologies**, along with power system architecture, impacts Data Center **Availability** and **Efficiency**. Depending on the level and requirement of power problem resolvement Topologies are selected on basis of **3-5-9 concept**. 3 resembling Off Line, 5 Line Interactive and 9 Online Double Conversion.
	Eco-Mode	Long transition times to inverter	An **Economy Mode** of operation (Eco-Mode) changes the way a **Double-Conversion** UPS is employed to increase **Energy Efficiency** and reduce the **Operating Expenses** experienced in the data center. Eco-Mode allows Double-Conversion UPS topology to switch the UPS between Double Conversion and static bypass depending on the operation conditions.
	Variable Module Management System (VMMS)	1. It is limited to **Multi-UPS Parallel Systems**, and 2. Flexibility to adapt to the load can only be done in the large steps of full UPS capacity.	VMMS optimally employs **Uninterruptible Power Modules (UPMs)** in the UPS to achieve higher efficiencies in **Double Conversion Mode** in order to maximise the percentage load level of the remaining active UPMs by switching UPMs that are not needed to ready state. VMMS **thresholds the system configuration (redundancy requirements) and load level of UPS system to 80%** (calculated).
	Energy Saver System	Maximizes efficiency when the input is within the **Acceptable Voltage and Frequency Window**	Energy Saver System is a technology which enables a seamless switchover to DC link, that is kept active, in less than two milliseconds if mains power is lost or exceeds preset output limits. **Advanced DSP (Digital Signal Processing) Controls** are used to control the power conversion in the system.
	Capacity on Demand: Software Enabled and Hardware Enabled	It is important to look for power cores that incorporate distributed intelligence and scalable power in a common assembly and allow configuration of a completely redundant power and control system, sized to match the capacity of the protected equipment.	**1. Software Enabled Scalability:** helps a UPS system to be sized to current requirements and then easily scaled up to a larger capacity as power needs change, with a simple software key. These types of modules are scalable in increments, such as **scalable from 40 to 80 kVA, from 80 to 120 kVA, or from 160 to 200 kVA.** **2. Hardware Enabled Scalability:** allows quick power capacity increases with the addition of internal power core hardware assemblies. These core assemblies allow the system to expand for capacity or redundancy in 15 kW increments up to 45 or 90kW within a single cabinet.
Transformers	Energy Efficient Transformers/ K Rated Transformers/ Harmonic Mitigating Transformers	**Space Constraints:** Large capacity transformers are larger in size	Since transformers are energized continually, even a small improvement in efficiency can provide significant energy savings. **Energy Efficient Transformers** are designed not to exceed 115°C temperature rise above a 40°C ambient under full linear load and not to exceed 150°C rise under a non-linear load level of K13 (K20 for HMT units). **K-rated Transformers** handle the heat generated by harmonic currents. The higher the K-factor, the more heat from harmonic currents the transformer is able to withstand.
Filter Circuits	Active Filters	High cost	These provide the **Most Comprehensive Cancellation of Harmonic Distortion** available. Active filters inject an additional current into the line that's identical to but 180 degrees opposite of the harmonic current coming from the load. Active filters cancel the **entire spectrum of harmonics, usually up to the 50th order**.
Power Distribution Systems	Floor and Rack level PDUs	Need to **check suitability** of PDU in present Data Center Architecture/ layout	**Power Distribution Units (PDUs)** in a data center deliver power to remote power panels (RPPs), which in turn deliver power to racks. Different architectures and types of units provides opportunities in improvements in efficiency, power density, power monitoring, and reconfigurability in data center power distribution.
Cabinet Cooling	In-Row Cooling	Not ideal for very small, low-density server spaces or the very largest deployments.	A row cooler is a device that **collects warmed server exhaust air from the "rear" of the rack** and is placed directly adjacent to computer racks, either within the row between two server racks or above the racks. The collected warm air is then drawn into this device and is **cooled using an air-to-water or air-to-refrigerant heat exchanger.**
	Rack Cooling	Not efficient in **large-scale deployments** when compared with other strategies.	Rack Cooling technology includes an **enclosure system for a small number of racks**, typically one or two. Rack coolers contain heat exchangers that cool the heated server exhaust air and return the cooled air to the server air inlet. The device contains **fans or blowers** that provide the flow needed to **overcome the pressure drop** through the enclosure and across the heat exchanger.
	Rack Cooling with Rear-Door Heat Exchanger	Requires **additional piping** which creates additional potential **leakage points.**	During operation of a **passive style Rear Door Heat Exchanger (RDHx)**, hot server-rack airflow is forced through the RDHx device by the server fans. Heat is exchanged from the hot air to circulating water from a chiller or cooling tower. Thus, server-rack outlet air temperature is reduced before it is discharged into the data center.
Economization	Free Cooling	1. **Geographic limitations**, depending upon average year-round outside air temperature ranges. 2. There is a potential of increased risk from airborne contaminants in air-side economizer deployments.	There are two types of free cooling- **Air-Side and Water-Side Economizers**. The operation and arrangement of economizer with mechanical cooling system depends on the outdoor conditions and cooling load requirements. **Air Side Economizers uses the outdoor air** and **Water Side Economizers uses water** and reduces or eliminates the need for mechanical cooling.
Direct Contact Cooling	Direct-to-Chip Cooling	1. Used only with **Customized Servers** without servers fans. 2. **Additional piping** is required.	The device is called a **Direct-Touch Cooler**. Hot electronic components located inside IT equipment are cooled directly by **conduction of heat to refrigerant** for heat removal. This design is unique because it uses **custom modified servers with server chassis level fans removed** thereby providing reduced power consumption for a given amount of computing.
	Liquid Immersion Cooling	1. **Space constraints** as this technology requires big containers with di-electric fluid to accommodate servers. 2. Current hard disks leak, and the oil crashes the heads.	Servers are placed side-by-side in a lidded bath of **Dielectric Fluid**. The devices cause fluid to boil and rising vapor condenses on a condenser cooled by facility water.Servers plug into an **immersed backplane & power** and IO enter/exit through a conduit that terminates below the liquid level. Servers can be hot-swapped and leave the bath dry.It is **1200X more effective** at removing heat than air. Increased packaging density can increase communication bandwidth. It causes silent elimination of air cooling infrastructure and greatly reduces **Capital and Operating Expense** vs. conventional data centers.
Rooftop/Building Exterior	Solar Cooling Systems	1. **Higher Initial Investment** costs compared with conventional cooling systems 2. To date, not cost efficient from a business point of view 3. There is **Lack of Awareness** about the technology among consumers.	The sun collectors are equipped with **Vacuum Tubes** and the heat gets collected to a H**ot Water Buffer Tank**. The hot water is pumped to the **Absorber Cooling Machine** where through a chemical reaction the warmness would be changed to cooling (without mechanical power, only a pump.) The cold water can be used for air cooling systems (closed control unit or direct rack cooling systems). A solar cooling installation consists of a typical solar thermal system made up of **Solar Collectors, Storage Tank, Control Unit, Pipes and Pumps** and a **Thermally Driven Cooling Machine.**
SERVERS	Blade Server	1. Greater strain on the powering and cooling of the datacenter. 2. A blade server chassis utilized to its full potential **generates a substantial amount of heat.**	**Blade Servers** are composed of a standardized chassis in which server blades are inserted. Each server blade is a separate system that runs its own **Operating System** and **Application Software** independently of the rest of the system, relying on its local processor(s), memory and I/O resources to handle its applications. The server chassis contains the **Shared Power**, **Cooling** and **Network Connections** to the rest of the data center.
	Server Virtualization	1. Virtualizing a server implies big changes to the whole system and **adds complexity**. 2. Not suitable for application which requires high processing power 3. Limits the amount of storage space.	**Server Virtualization** is an **Abstraction** technology that enables the division of the hardware resources of a given server into multiple execution environments and enables the **Consolidation** of multiple servers and hardware resources into a single computing resource. **Virtualization Software** is a layer of software that runs between the hardware of the server and the OSs and applications that run on the server. There are two parts to the virtualization software: The **Hypervisor or Virtual Machine Monitor** which creates and manages the second part, the **Virtual Machines** that mimic the operation of a real physical system. There are two types of Server Virtualization: Hosted Virtualization
STORAGE	Solid State Drives(SSDs)	1. Though SSDs offer exceptionally high performance but have much **Less Capacity per Drive**. 2. They are also relatively **Expensive** when compared to HDDs.	**Solid state drives (SSDs)** use **Flash Memory** to store data, they read and write faster than **Hard Disk Drives(HDDs)** and often use **Less Power** when active and outperform HDDs by 500x for random access I/O benchmarks. SSDs are utilized at the front-end of the transactional system to deliver **Ultra High Input/Output Operations Per Second (IOPS)** and **Mission-Critical Storage and Retrieval** functionality are performed by high-capacity HDDs. The result is a data center environment capable of delivering the highest levels of **Performance, Capacity and Reliability.**
	Storage Virtualization	1. If one system is breached, the entire network is compromised. 2. Transition from a non-virtualized environment to a virtualized environment is not smooth. 3. Adds complexity to the whole system.	It is the process of presenting a logical view of the physical storage directly connected to the host. **Logical Storage** appears and behaves as physical storage directly connected to the host. Two major types of Storage Virtualization are: **Host-/Server-Based Virtualization & Network-Based Virtualization.**
	RAID/Intelligent Disk Subsystems	**Installation is complicated**- Requires installation of drivers, updating firmware and running consistency checks	**RAID controllers** bring together several physical hard disks to form **Virtual Hard Disks** that are **Faster** and more **Fault-Tolerant** than individual physical hard disks. It increases performance by striping and increases fault-tolerance by redundancy. The controllers of **Intelligent Disk Subsystems** offer additional functions over and above those offered by RAID such as **Instant Copies & Remote Mirroring.**
	Software Optimized Flash	Flash storage has **capacity issues** that prevent it from reaching the same size as higher end hard disk drives	Flash software accelerates system performance, helps accommodate data growth, and lowers total overall cost. It features **Outstanding Performance, Low Power Consumption, Non-Volatile Data Persistence,** and **Highly Durable, Solid-State Reliability**. Flash technology can be integrated in the system to increase the DRAM capacity while circumventing the limited capabilities of HDDs.
	Storage Area Network(SAN)	If a SAN or its fabric experience major problems then no servers may be able to boot.	A SAN can be defined as a **Specialized, High-Speed Network** whose primary purpose is the transfer of data between computer systems and storage elements while increasing **Flexibility of Networking** to enable one server or many heterogeneous servers to share a common storage utility, which may comprise of many storage devices, including disk, tape, and optical storage. Additionally, the storage utility may be located far from the servers that use it.
NETWORKS	Fiber Channel Technology	1. Fibre Channel requires special **Host Bus Adapters (HBAs)** and switches that are more expensive than comparable Ethernet components. 2. FC environments are more **complex to implement and manage**	**Fibre Channel Technology** is a networking technology which facilitates **High Speed Data Transfer** between computer systems and storage devices. It maintains the speed and low overhead of a channel while adding the flexibility (through connectivity) and the longer distances that are characteristic of a network.
	10 Gigabit Ethernet	Scaling up from the conventional Network Interface Card (NIC) to 10GbE will effect the CPU's Processing Power and Throughput would be severely limited.	**10 Gigabit Ethernet (10 GbE)** supports **10 Gigabits per second transmission** over distances up to **80 km**, and is fully compatible with previous versions of Ethernet. In a data center environment, by using 10GbE connections to the LAN, blade servers can scale to larger numbers of processors without the network connection becoming a major bottleneck. It also **Simplifies Data Center Infrastructure** (reducing number of switch ports, cables etc.) while **Reducing Power & Cooling** requirements.
	Network Virtualization	1. Virtualization of network appliances adds complexity to the whole system and may result in **Reduced Performance** as all high-speed routing and packet forwarding tasks are performed by a general purpose CPU.	**Network Service virtualization** simplifies the network operations and **Consolidate Multiple Services** into a single physical device. Eliminating the need for additional physical devices, it effectively removes the need for additional power supplies, cooling, and rack space which would otherwise have been required.

Appendix C: Existing Energy Efficiency Standards in India

The following energy efficiency policy/standards currently exist in India: Indian Green Building Council; Energy Conservation Building Code (ECBC); Star Rating for Buildings; Green Rating for Integrated Habitat Assessment; and Standards and Labeling program for appliances and equipment.

Indian Energy-Efficiency Policy Consolidation Matrix (Descriptive)			
S.No	COUNTRY	EXISTING ENERGY EFFICIENCY POLICY STANDARDS	ASSESSMENT & CERTIFICATION CRITERIA
1	INDIA	Indian Green Building Council (IGBC) Green SEZ Rating System	This tool enables the designer to apply green concepts and criteria, so as to reduce the environmental impacts, which are measurable **Assessment Criteria:** The assessment is carried out through certain credit points using a prescriptive approach and other credits on a performance based approach. The credit points are awarded for the following parameters: Site Preservation & Restoration (16 Points), Site Planning & design (25 Points), Water Efficiency (15 Points), Energy Efficiency (30 Points), Materials & Resources (10 Points), Innovation & Design (4 Points). **Award Criteria:** The certification received are Certified (51-60), Silver (61-70), Gold (71-80), Platinum (81-100).
		Energy Conservation Building Code (ECBC) by Bureau of Energy Efficiency (BEE)	The **ECBC** by Bureau of Energy Efficiency aims to provide **minimum requirements** for energy efficient design and construction of buildings and their systems. ECBC encourage energy efficient design or retrofit of buildings so that it does not constrain the building function, comfort, health, or the productivity of the occupants and has appropriate regard for economic considerations. **Assessment Criteria:** ECBC follows the same structure as ASHRAE 90.1 standard and covers the following areas: Building Envelope, HVAC, Service Hot Water and Pumping, Lighting, Electric Power etc. The code allows a Prescriptive path or Simulated (baseline building) Calculation to show compliance. **Compliance Criteria:** Energy performance is regulated through prescriptive requirements for the thermal envelope and performance requirements for HVAC, hot water & pumping, lighting and auxiliary systems.
		GRIHA – Green Rating for Integrated Habitat Assessment National Green Building Rating System	GRIHA is a guiding and performance-oriented system where points are earned for meeting the design and performance intent of the criteria. Each criterion has a number of points assigned to it and **maximum 100 points** can be achieved regarding the building's environmental performance in each category. **Assessment Criteria:** Rating is given on the basis of total score achieved by the building across 34 criteria categorized under various sections such as Site Selection and Site Planning, Conservation and Efficient Utilization of Resources, Building Operation and Maintenance, and Innovation points. 2. Eight of these 34 criteria are mandatory, four are partly mandatory, while the rest are optional. **Award Criteria:** 1 star: 50-60 points; 2 star: 61-70 points; 3 star: 71-80 points; 4 star: 81-90 points; 5 star: 91-100 points.
		Perform, Achieve & Trade (PAT) by Bureau of Energy Efficiency (BEE)	**PAT** is a **Market Based Mechanism** to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. **Assessment Criteria:** The scheme imposes mandatory Specific Energy Consumption (SEC) targets on the covered facilities with less energy efficient facilities having a greater reduction target than the more energy efficient ones. A facility's baseline is determined by its historic specific energy consumption between 2007-2010. **Compliance Criteria:** Facilities making greater reductions than their targets receive "EsCerts" or "energy saving certificates" which can be traded with facilities that are having trouble meeting their targets, or banked for future use.
		Standards & Labeling Program by Bureau of Energy Efficiency (BEE)	The Objectives of **Standards & Labeling Program** is to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed energy consuming equipment. **Assessment Criteria:** The amount of electricity consumed per unit amount of appropriate service delivered by the equipment over a period of time. **Award Criteria:** The energy performance of the equipment is rated on a 1 to 5 star scale. Higher star rating means better energy efficiency.
		Star Rating for Buildings by Bureau of Energy Efficiency	This standard is based on the actual performance of a building in terms of its specific energy usage in kwh/sq m/year. Buildings have been categorized into two categories, having air-conditioned area greater than 50% and less than 50% of built up area. **Assessment Criteria:** Rating is given on the basis of Energy Performance Index (EPI) in kWh/sqm/year. Only those buildings having a connected load of 100kW and above are considered for assessment. **Award Criteria:** This programme rates office buildings on a 1-5 Star scale, with 5 Star labelled buildings being the most efficient.

Indian Green Building Council (IGBC) Green SEZ Rating System
The IGBC rating system enables the designer to apply green concepts and criteria, so as to reduce the environmental impacts, which are measurable. The certifications available are Certified (51-60), Silver (61-70), Gold (71-80), and Platinum (81-100). The assessment is carried out through certain credit points using a prescriptive approach and other credits on a performance-based approach. The credit points are awarded for the following parameters: (i) Site Preservation and Restoration (16 Points); (ii) Site Planning and Design (25 Points); (iii) Water Efficiency (15 Points); (iv) Energy Efficiency (30 Points); (v) Materials and Resources (10 Points); and (vi) Innovation and Design (4 Points).

Energy Conservation Building Code (ECBC) by Bureau of Energy Efficiency (BEE)
The ECBC by Bureau of Energy Efficiency aims to provide minimum requirements for energy efficient design and construction of buildings and their systems. ECBC encourages energy efficient design or retrofit of buildings so that it does not constrain the building function, comfort, health, or the productivity of the occupants and has appropriate regard for economic considerations. ECBC follows the same structure as ASHRAE 90.1 standard and covers the following areas: Building Envelope, HVAC, Service Hot Water and Pumping, Lighting, and Electric Power. It also provides both prescriptive and performance-based compliance framework for buildings with connected load of more than 100 kW or 120 kVA to achieve compliance either at the component level or at the whole building level.

Green Rating for Integrated Habitat Assessment National Green Building Rating System (GRIHA)
GRIHA is a performance-oriented rating system where points are earned for meeting the design and performance intent of the criteria. GRIHA rating system consists of 34 criteria categorized under various sections such as Site Selection and Site Planning,

Conservation and Efficient Utilization of Resources, Building Operation and Maintenance, and Innovation points. All buildings (e.g., offices, retail spaces, institutional buildings, hotels, hospital buildings, healthcare facilities, residences, multi-family high-rise buildings) more than 2,500 square meters are eligible for certification under GRIHA. Industrial complexes are only eligible in the design stage. GRIHA measures and rates the building's environmental performance in the context of India's varied climate and building practices. Different levels of certification, on a scale from one star to five stars, are awarded based on the number of points earned. 1 star: 50-60 points; 2 star: 61-70 points; 3 star: 71-80 points; 4 star: 81-90 points; 5 star: 91-100 points.

Perform, Achieve & Trade (PAT) by Bureau of Energy Efficiency (BEE)

PAT is a market-based scheme launched in 2011 under The National Mission for Enhanced Energy Efficiency (NMEEE). NMEE is one of the eight missions under the National Action Plan on Climate Change (NAPCC). PAT aims to improve the energy efficiency in energy-intensive large industries and facilities by setting sector-specific benchmarks and giving targets to Designated Consumers (DC). The implementation of Phase 1 of the PAT scheme has laid a strong foundation that can now be extended to other energy intensive sectors such as the sugar industry, commercial buildings, and chemicals.

The Ministry of Power (MoP) notified 478 Designated Consumers in eight energy-intensive sectors: Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron & Steel, and Aluminum. The scheme imposes mandatory Specific Energy Consumption (SEC) targets on the covered facilities with less energy efficient facilities having a greater reduction target than the more energy efficient ones. Facilities making greater reductions than their targets receive "E-certs" or "energy saving certificates" which can be traded with facilities that are having trouble meeting their targets, or banked for future use. The PAT scheme establishes plant-specific targets rather than a sectoral target, with the average reduction target being 4.8% and a cumulative target of 6.68 Mtoe that was to be achieved by the end of the first phase in March 2015.

Star Rating for Buildings by Bureau of Energy Efficiency

Star Rating is based on the actual performance of a building in terms of its specific energy usage in kwh/m^2/year. The standard rates office buildings on a 1-5 Star scale, with 5 Star labeled buildings being the most efficient. Only buildings with a connected load of 100kW and above are considered for assessment under this voluntary programme. This scheme provides public recognition to energy efficient buildings, to create a demand for such buildings. The major assessment criteria are as follows: Energy Performance Index (EPI) in kWh/m^2/year. Buildings have been categorized into two categories, having air-conditioned area greater than 50% and less than 50% of built up area.

Appendix D: Approaches to Energy Efficiency Standards

1. Review

International energy efficiency standards for data centers reviewed in this study are: Energy Star Rating (U.S. Environmental Protection Agency (EPA), 2013) (U.S.); Leadership in Energy and Environment Design (U.S) (U.S. Green Building Council, 2014); American Society of Heating, Refrigerating and Air-Conditioning Engineers (U.S) (American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2010); California Title 24 Standards (U.S) (California Energy Commission (CEC), 2013); National Australian Built Environment Rating System (Australia) (State of NSW and Office of Environment and Heritage, 2012); Green Mark (Singapore) (Building and Construction Authority (BCA) and Infocomm Development Authority (IDA)); Green Building Index (Malaysia) (Green Building Index (GBI), 2012); Certified Energy Efficient Data Center Audit (U.K) (British Computing Society -The Chartered Institute for IT, 2011); Building Research Establishment Environmental Assessment Method (U.K) (Building Research Establishment (BRE) Global, 2010); European Code of Conduct (European Commission, 2008); Blue Angel Eco-Label (Germany) (The Blue Angel, 2012); and International Standards Organization (ISO) 50001: 2011 (Europe) (International Standard Organization (ISO), 2011). The following section describes these standards.

Country- Wise Data Center Energy-Efficiency Policy Consolidation Matrix

S.No	COUNTRY	STANDARD	ASSESSMENT & CERTIFICATION CRITERIA
1	USA	Energy Star Rating for Data Centers by Environment Protection Agency (EPA)	The ENERGY STAR score, expressed as a number on a 1 - 100 scale, such that one point represents one percent of the population, rates performance on a percentile basis. **Assessment Criterion:** It scores a given facility based on the **Energy Efficiency Ratio (EER) [EER=Actual PUE/ Predicted PUE].** **Award Criteria:** Data centers with a score (EER) of 50 perform better than 50% of their peers; data centers earning a score of 75 or higher are in the top quartile of energy performance.
		LEED (Leadership in Energy and Environmental Design) for Data Centers	LEED certification recognizes best-in-class data center based on the score achieved by a data center on a scale of 110 points, spread across: **Assessment Criteria: Sustainable Sites (10 points), Water Efficiency (9 points), Energy and Atmosphere (29 points), Materials and Resources (9 points),Indoor Environmental Quality (17 points), Innovation (6), Integrative Process (3 points), Location & Transportation (14 points), Performance (9 points), Regional Priority (4 points).** **Award Criteria: 40 points** provide the **'Certified'** rating, **50 points 'Silver', 60 points 'Gold',** and **80 points** and above leads to **'Platinum' rating.**
		ASHRAE 90.1 for Data Centers	The purpose of this standard is to establish the minimum energy efficiency requirements of Data Centers and Telecommunications Buildings, for: a. design, construction, and a plan for operation and maintenance, and b. utilization of on-site, or off-site renewable energy resources. **Assessment Criteria** used is spread across: Building Envelope, HVAC, Service Water Heating, Electrical, Lighting, Other Equipment. **Compliance Criteria**: There are mandatory provisions (pre-requisites) under each area of assessment for all compliance options which include: Prescriptive, Trade-Off & Performance Based compliance methods.
		California Title 24 for Data Centers	The California T-24 standard focuses on several key areas to improve the energy efficiency of newly constructed Data Centers and additions & alterations to existing Data Centers as well. **Assessment Criteria:** include HVAC, Power, Lighting etc. which vary according to building type (Residential/Non-residential). **Compliance Criteria:** There are mandatory provisions (pre-requisites) under each area of assessment for all compliance options which include: Prescriptive & Energy Budget method (performance based).
2	AUSTRALIA	National Australian Built Environment Rating System (NABERS) for Data Centers	This tool measures environmental performance on a scale of 1 to 6 stars. Rating is done across 03 major categories as enlisted below: **Assessment Criteria:**1. **IT Equipment Rating - Processing capacity & storage capacity** 2. **Infrastructure Rating - Power Usage Effectiveness (PUE) ratio** . 3. **Whole Facility Rating -** Includes both IT & Infrastructure rating. **Award Criteria:** Three stars represent market median performance and a 6-star rating demonstrates market-leading performance. A 1-star rating represents below median market practice and indicates that there is considerable scope for improvement.
3	MALAYSIA	Green Building Index (GBI) for Data Centers	GBI is fundamentally derived from existing rating tools, including the Singapore Green Mark but extensively modified for relevance to the Malaysian tropical weather, environmental context, cultural and social needs. **Assessment Criteria** used for the purpose of rating in this scale is spread across **Energy Efficiency (35 points), Indoor Environmental Quality (21 points), Sustainable Site Planning & Management (16 points), Material & Resources (11 points), Water Efficiency (10 points), Innovation (7 points)** **Award Criteria:** Projects are scored on a 100-point scale, with four Green Mark ranking levels: **certified (50-65 points), silver (66-75 points), gold (76-85 points)**, and **platinum (86 points & above)**.
4	SINGAPORE	Green Mark for Data Centres	The Green Mark System is a performance-based rating system which awards points for green features, energy efficiency and best practices adopted by the data centres. **Assessment Criteria** includes **Energy Efficiency (88 points), Water Efficiency (12 points), Sustainable Operation (7 points), Indoor Environmental Quality (8 points), Other Green Innovations (10 points).** **Award Criteria**: Based on the total number of points scored, a final rating is awarded as follows: **Platinum (>=90), GoldPLUS (85 to <90), Gold (75 to <85) or Certified (50 to <75) is given.**
5	EUROPE	European Code of Conduct by The European Commission for Data Centers	Data Center Code of Conduct aims to promote Data Center energy efficiency by setting energy efficiency targets, improving the understanding of energy demand within the data centre, raising awareness, and recommending energy efficient best practices. **Assessment Criteria:** All Participants have the obligation to continuously monitor energy consumption and adopt energy management in order to look for continuous improvement in energy efficiency. The energy saving focus of the Code of Conduct covers two main areas: 1. **IT Load** and 2. **Facilities Load.** **Measurement metric: Data centre infrastructure efficiency (DCiE)**
		Certified Energy Efficient Datacenter Audit (CEEDA) - UK	CEEDA award is given to a data center after assessing the implementation of energy efficiency best practices within a datacentre. **Assessment Criteria** is based on the following key areas within the data centre facility: **Data Centre Utilisation,IT equipment and services, Cooling, Power equipment,Data centre building & Monitoring.** **Award Criteria** is based on a set of up to 90 best practices and metrics from ASHRAE, Energy Star, European Telecommunications Standards Institute (ETSI), EUCoC and The Green Grid. It involves a **3 Tiered Certification award - Bronze, Silver and Gold.**
		BREAM (Building Research Establishment Environmental Assessment) for Data Centers - UK (also followed by Hong Kong)	Rating is based on the total score achieved by a data center across ten categories. **Assessment Criteria:** The points are spread across: **Management (10), Health & Wellbeing (15), Energy (28), Transport (10), Water (8), Materials (15), Waste (7), Land Use & Ecology (10), Pollution (11)** All categories are given a section weightage respectively, which multiplied with the percentage of points scored in a category gives the final score in that category. An additional 1% can be added to the final BREAM score for each 'innovation credit' achieved (up to a max. of 10%). **Award Criteria:** The credits added together produce a single overall score on a scale of: **Unclassified (<30), Pass (≥30), Good (≥45), Very Good (≥55), Excellent (≥70), Outstanding (≥85)**
		Blue Angel Eco-Label for Data Centers - Germany	The Blue Angel eco-label may be awarded to resource-conscious companies committed to the implementation of a long-term strategy aiming at improving the energy and resource efficiency of their data center with respect to the IT services to be delivered and conducting regular monitoring to optimize the data center operations. **Assessment Criteria**: There are two set of requirements (a) Binding Criteria and (b) Recommendations for Energy Saving Under the binding criteria, the applicant must provide the respective compliance verifications whereas the recommendations for energy saving represent a set of key measures that may help improve the energy efficiency of a data center. **Measurement metric:** Energy Usage Effectiveness (EUE) which is the average PUE over a certain reference period.
6	GLOBAL STANDARD (Implemented in 44 ISO member countries)	IS/ISO 50001 Standard: Energy Management Systems	This International Standard specifies energy management system (EnMS) requirements for a data center, upon which a data center can develop and implement an energy policy, and establish objectives, targets, and action plans which take into account legal requirements and information related to significant energy use. **Assessment Criteria: Plan - Do - Check - Act (PDCA)** continual improvement framework, which incorporates energy management into everyday organizational practices. **Measurement Metric: Energy Performance Indicators(EnPIs)** [e.g. energy consumption per unit time, energy consumption per unit of production, and multi-variable models]. The organization can choose EnPIs that inform the energy performance of their operation and can update the EnPIs when business activities or baselines change.

ENERGY STAR Rating by Environment Protection Agency (EPA)

ENERGY STAR selected Power Usage Effectiveness (PUE) as the metric to evaluate data center energy performance. To develop the rating, EPA extensively collected data on energy use and operating characteristics from a large number of existing data centers. Regression analysis was used to identify the operating characteristics (e.g., Heating Degree Days (HDD), Cooling Degree Day (CDD), Building Square Footage, Data Center

Square Footage, Number of Racks, UPS Utilization, Annual IT Energy) that explain the variation in PUE among data centers. Out of the numerous variables analyzed, only the Annual IT energy consumption was found to be statistically significant in explaining the variation in energy use; data showed that facilities with higher IT energy consumption have lower PUE values, on average. For a given facility the actual measured PUE can be compared with this prediction. A facility whose actual PUE is lower than the predicted PUE is doing better than average. The Energy Efficiency Ratio (EER = Actual PUE/Predicted PUE) is mapped to a 1-100 scale such that one point represents one percent of the population.

Leadership in Energy and Environmental Design (LEED)
LEED certification recognizes a best-in-class data center based on the score achieved on a scale of 110 points. Areas of assessment & credits assigned pertaining to data centers are: (i) Sustainable Sites (10 Points): Site selection, building reuse, alternative transportation measures etc; (ii) Water Efficiency (9 Points): Water use reduction, landscaping, and wastewater technologies; (iii) Energy and Atmosphere (29 Points): Energy efficiency, renewable energy commissioning, refrigerant management, measurement and verification, and green power; (iv) Materials and Resources (9 Points): Building reuse, construction waste management, materials reuse, recycled content etc; (v) Indoor Environmental Quality (17 Points): Outdoor air delivery monitoring, ventilation, and indoor air quality management; (vi) Innovation (6 Points): Exceptional or innovative performance. Other categories include: Integrative Process (3 Points); Location & Transportation (14 Points); Performance (9 Points); and Regional Priority (4 Points). The section points are then added together to give the overall LEED score. The overall score is then compared to the threshold levels to determine the LEED rating, provided all pre-requisites have been met. There are four levels of certification - the number of points a project earns determines the level of LEED certification that the project will receive. Typical certification thresholds are: (i) CERTIFIED: 40-49 Points; (ii) SILVER: 50-59 Points; (iii) GOLD: 60-79 Points; and (iv) PLATINUM: 80+ Points.

California Title 24 Standards
California Title 24 focuses on key areas to improve the energy efficiency of new data centers, additions, and major alterations to existing data centers. Areas of assessment include HVAC, Power, Lighting systems etc. There are two methods for achieving Title 24 compliance in California: (i) Prescriptive Method: The simplest approach to Title 24 compliance where each individual component of the proposed building must meet a prescribed level for energy efficiency. An applicant need only show that a building meets each minimum or maximum level prescribed in the set of requirements contained in a package. The prescriptive method is not recommended for new constructions or larger additions, and can result in higher construction costs. (ii) Performance Method: The use of computer models provide the most flexibility and accuracy when seeking Title 24 compliance. Detailed accounting of energy trade-offs between measures is possible with this compliance approach. The computer program automatically calculates the energy budget for space conditioning. The budget is determined from the standard design, a version of the building, which is upgraded or downgraded to achieve minimum compliance with the prescriptive package conservation features. To comply with the Standards, the predicted combined "Energy Use" of the Proposed Design cannot exceed the combined "Energy Budget" of the Standard Design. There are mandatory provisions (pre-requisites) under each area of assessment, which are required to demonstrate code compliance.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1
ASHRAE 90.1 establishes the minimum energy efficiency requirements of buildings, including Data Centers and Telecommunications Buildings, for design, construction, and a plan for operation and maintenance, as well as utilization of on- or off-site renewable energy resources. It is the reference standard for US Energy Policy Act and many state building energy codes in the United States; it has been adopted in many countries as a model for energy efficiency guidelines and codes. In terms of structure and compliance options, it is very similar to California Title 24.

National Australian Built Environment Rating System (NABERS)
The National Australian Built Environment Rating System (NABERS) is the industry standard for measuring and benchmarking the environmental performance and efficiency of existing Australian buildings. NABERS rating tools measure environmental performance on a scale of 1 to 6 stars. Three stars represent market median performance and a 6-star rating demonstrates market-leading performance. A 1-star rating represents below median market practice and indicates that there is considerable scope for improvement.

There are three types of rating:

- IT Equipment rating: benchmarks the greenhouse gas emissions associated with the energy consumed by the IT equipment within a data center over a one-month period (approximately). NABERS has developed two metrics: Processing capacity – measures the sum of the number of server cores multiplied by clock speed in gigahertz (GHz), and Storage capacity – measures the total unformatted storage capacity in terabytes (TB).
- Infrastructure rating: benchmarks the greenhouse gas emissions associated with the energy consumed in supplying infrastructure services to IT equipment within a data center over a 12-month period. The NABERS benchmark for an Infrastructure Rating measures the energy efficiency in delivering support services to IT equipment, using the widely accepted industry Power Usage Effectiveness (PUE) ratio.
- Whole facility rating: benchmarks the greenhouse gas emissions associated with the energy used by the IT equipment and infrastructure services within a data center over a 12 month period.

Green Mark
Green Mark is a Singaporean performance-based rating system that awards points for green features, energy efficiency, and best practices. Points are awarded across the following categories: (i) Energy Efficiency (88 points): Overall energy efficiency, systems energy efficiency (cooling, IT equipment), energy assessment and monitoring, energy policy/management, energy efficiency innovations; (ii) Water Efficiency (12 points): Water-use efficiency, alternate water use, water consumption of cooling tower; (iii) Sustainable Operation (7 points): Refrigerants and fire suppressors, sustainable policies; (iv) Indoor environmental quality (8 points): Thermal comfort, noise level, indoor air quality and ventilation, lighting quality and management; (v) Other Green Innovations (10 points): Green features and innovations. The assessment system is a performance-based rating system that awards points for green features, energy efficiency, and best practices adopted by the data centers. Based on the total number of points scored a final rating, from Certified to Platinum is given. Platinum (>=90); GoldPLUS (85 to <90); Gold (75 to <85); or Certified (50 to <75).

Green Building Index (GBI)

GBI is derived from existing rating tools, including Green Mark, but has been extensively modified for relevance to the Malaysian tropical weather, environmental context, and cultural and social needs. Points are awarded across 6 main categories: (i) Energy Efficiency (35 points): Design, commissioning, verification and maintenance; (ii) Indoor Environmental Quality (21 points): includes air quality, thermal comfort, lighting, visual, acoustic comfort, and verification; (iii) Sustainable Site Planning and Management (16 points): Site planning, construction management, transportation, design; (iv) Material and Resources (11 points): Reused and recycled materials, sustainable resources, waste management, and green products; (v) Water Efficiency (10 points): Water harvesting and recycling, and energy efficiency; and (vi) Innovation (7 points). Projects are scored on a 100-point scale, with four Green Mark ranking levels: certified (50-65 points); silver (66-75 points); gold (76-85 points); and platinum (86 points & above).

Certified Energy Efficient Datacenter Audit (CEEDA)

CEEDA is an U.K-based award that assesses the implementation of energy efficiency best practices within a data center. The CEEDA framework involves certifies data centers at three different levels: Bronze, Silver and Gold. The certification is received through the British Computing Society – The Chartered Institute for IT and is valid for 2 years. The assessment process is two years. In year one, the initial assessment provides a detailed analysis of the implementation of a set of energy efficiency best practices in M&E, IT, and operational management. In year two, a second assessment evaluates the energy efficiency impacts of the roadmap, new infrastructure deployment, and new services delivered. The assessment is based on a set of up to ninety best practices and metrics from ASHRAE, Energy Star, ETSI, EUCoC, and The Green Grid. The assessment covers the following key areas within the data center facility: Data center utilization, IT equipment and services, cooling, power equipment and data center building monitoring.

Building Research Establishment Environmental Assessment for Data Centers (BREEAM)

BREEAM sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance. This U.K-based rating, also practiced in Hong Kong, is based on the total score achieved by a data center across ten categories: (i) Management (10 Points): Site commissioning, contractor issues, overall policy management; (ii) Health and Wellbeing (15 Points): Elements that impact building user comfort and health, such as fresh air ventilation and controls for lighting and temperature; (iii) Energy (28 Points): Power consumption and carbon emissions, heating and cooling efficiencies, metering; (iv) Transport (10 Points): Elements to reduce carbon emissions associated with transportation from the use of local building materials to the proximity to public transit to encourage employee usage; (v) Water (8 Points): Water consumption, efficiencies; (vi) Materials (15 Points): Building material; (vii) Waste (7 Points): Construction site waste management, recycled aggregates , recyclable waste storage; (viii) Land Use & Ecology (10 Points): Use of existing facilities rather than undeveloped land, or cleanup of previously contaminated property; (ix) Pollution (11 Points): air and water pollution; and (x) Innovation (additional 1%). The percentage of 'credits' achieved in each section is then multiplied by the corresponding section weighting. Section weightings for data centers depend on the type of data center, which are categorized into: Large Associated Function Area, Small Associated Function Area & No Associated Function Area. Credits are awarded in ten categories according to performance. These credits are then added together to produce a single overall score of Unclassified, Pass, Good, Very Good, Excellent and Outstanding.

European Code of Conduct by the European Commission

The European Code of Conduct promotes data center energy efficiency by setting targets, understanding energy demand, raising awareness, and recommending energy-efficient best practices. The energy saving focus of the European Code of Conduct covers two main areas: (i) IT Load: relates to the consumption of the IT equipment in the data center; (ii) Facilities Load: relates the mechanical and electrical systems that support the IT electrical load. The Code of Conduct uses the ratio of IT Load to Facilities Load (DCiE), known as 'facility efficiency', as the key metric in assessing infrastructure efficiency. The Code of Conduct has both, an equipment and system-level scope: (i) Equipment Level: All energy using equipment within the data center, such as: IT equipment (e.g., rack optimized and non-rack optimized enterprise servers, blade servers, storage and networking equipment), cooling equipment (e.g., Computer room air-conditioner units) and power equipment (e.g., uninterruptible power supplies and power distributions units), and miscellaneous equipment (e.g., lighting). (ii) System Level: At system level, the Code of Conduct proposes actions which optimize equipment interaction and the system design (e.g., improved cooling design, correct sizing of cooling, correct air management and temperature settings, correct selection of power distribution), to minimize overall energy consumption. All Participants have the obligation to continuously monitor energy consumption and adopt energy management in order to look for continuous improvement in energy efficiency.

Blue Angel Eco-Label

Blue Angel Eco-Label in Germany may be awarded to any resource-conscious company committed to the implementation of a long-term strategy to improve the energy and resource efficiency of its data center. Label requires regular monitoring to optimize its data center operations. The Blue Angel eco-label is awarded to the entire data center building defined by a specific location and company name. If an organization runs several data centers located at different locations and/or independent data centers, each one shall be considered as an independent data center for which a separate application needs to be filled. This environmental label requires the implementation of an energy management system according to EN 16001. This includes a transparent energy efficiency strategy, a plan for concrete energy saving measures, a monitoring system, and clear definition of responsibilities in the data center. Applicants must provide a basic analysis of the data center according to specified guidelines. Analysis is required to include information on the Energy Usage Effectiveness (EUE) measured over a period of 12 months. Data provided must not be more than 3 months old. The applicant also needs to fulfill a number of requirements regarding procurement and management of the IT and infrastructure.

International Organization for Standardization (ISO) 50001 Standard for Energy Management Systems (EMS)

ISO 50001 is an international standard that specifies EMS requirements upon which data centers can develop and implement an energy policy, and establish objectives, targets, and action plans which take into account legal requirements and information related to significant energy use. ISO 50001 can be implemented individually or integrated with other management system standards. This international standard is based on the Plan-Do-Check-Act continual improvement framework and incorporates energy management into everyday organizational practices. (i) Plan: Conduct the energy review and establish the baseline, energy performance indicators (EnPIs), objectives, targets and action plans necessary to deliver results in accordance with opportunities to improve energy performance and the data center's energy policy; (ii) Do: Implement the energy management action plans; (iii) Check: Monitor and measure processes and the key characteristics of its operations that determine energy performance against the energy policy and objectives and report the results; and (iv) Act: Take actions to continually improve energy performance and the EnMS.

Additional energy efficiency standards reviewed were the Building Energy Rating (Ireland) (Sustainable Energy Authority of Ireland (SEAI)); Green Star Rating System (Australia) (Green Building Council of Australia); and German Sustainable Building Certificate (German Sustainable Building Council, 2008). Two other important mechanisms to determine resource availability are Uptime Institute (U.S) (Uptime Institute Professional Services, 2012) and Data Center Star Audit (Germany) (European Business Reliance Centre (EBRC), 2013). The Green Grid has also developed the Data Center Maturity Model (Singh.H, 2011).

2. International and Indian standards, categorized by approach

		WHOLE-BUILDING (point-based and voluntary)		
S.No	**COUNTRY**	**STANDARD/POLICY**	**BROAD KEY CHARACTERISTICS**	**IMPERATIVES IN INDIAN CONTEXT**
1	USA	**LEED (Leadership in Energy and Environmental Design) for Data Centers**	1. Point based rating process usually considers Energy & Environmental Performance Criteria. It gives high emphasis on Energy Efficiency but also consider other factors such as Environment, Reliability, Water Efficiency etc. 2.Each section includes credit points for a set of Minimum Requirements which are mandatory. 3. This type of rating is mostly applicable to both existing and newly constructed Data Centers. 4. The assessment identifies the specific energy efficient and environment-friendly features and practices which have been incorporated in the projects. 5. Additional Innovation Points are awarded for incorporating environment-friendly features which are better than normal practices. 6. Rating achieved for a facility in its design phase may not be reflected in its actual performance. 7. In a point based rating system an applicant seeking a certification is more concerned about scoring higher points than actually improving the performance of the building. 8. Though it gives more weightage to energy efficiency, it does not focus on specific technologies which may impact overall efficiency. 9. It focuses only on reducing the environmental effects of the building and does not consider criticality of operation/performance of data centers.	1. **BEE Star Rating** for Office Building determines **the Energy Performance Index (EPI) but it only focuses on kWh/Sqm/ Year**. A new approach may focus on addition of more attributes other than a single one in existing system. 2. **Indian Green Building Council (IGBC) Green SEZ Rating System** by CII Green Business Center is based on a framework similar to other point-based rating systems which **evaluates building performance against set criteria** and points are assigned accordingly. It promotes a whole-building approach to sustainability by addressing various environmental factors such as **Sustainable Sites, Water Efficiency, Energy Efficiency, Materials Resources, Innovation & Design.**
3	UK	**BREAM (Building Research Establishment Environmental Assessment) for Data Centers**		
4	MALAYSIA	**Green Building Index (GBI) for Data Centers**		
5	SINGAPORE	**Green Mark for Data Centres**		
		BEST PRACTICES (guidelines)		
S.No	**COUNTRY**	**STANDARD/POLICY**	**BROAD KEY CHARACTERISTICS**	**IMPERATIVES IN INDIAN CONTEXT**
1	GLOBAL STANDARD (Across 44 ISO member countries)	**IS/ ISO 50001 Standard: Energy Management Systems**	1.Key performance parameters such as DCIE, IT Productivity, Total Data Center Energy Consumption are the basis on which energy efficiency is measured for any data center. 2.Percentage Targets for yearly Energy Efficiency Improvements (voluntary in nature) are set depending on type & services of the data centers. 3.It involves a Continual Improvement process through an Energy Management Program. 4.It Includes assessment and implementation of best practices and new technologies. 5.In most cases it involves Third Party Validation and Certification. 6.This type of approach offers too much of flexibility to data center owners/operators in terms of setting their own targets for improving energy efficiency. 7. Being a purely voluntary programme, there are no penalties incurred if compliance with these standards are not achieved, and resignation from the programme is permitted at any time.	**Perform, Achieve & Trade (PAT) Mechanism**, an initiave by BEE to improve energy efficiency of energy intensive industries in India demonstrates some similarities with this approach. Energy saving targets and compliance period to achieve the targets are set on the basis of specific energy consumption. Validation is conducted by third party authorized by BEE. **Considering the Diversity in Productivity, Typical Output and Various Types of Technologies being adopted across Data Centers, a new Standard may be proposed where a part of the mechanism may focus "In Line" with this approach which may further be tagged with existing PAT scheme of BEE with a provision for data centers to participate in the trading mechanism similar to the PAT scheme**. Along with this approach we can pitch for the **State-of-the Art Technologies** which will facilitate the participants in achieving their given Targets.
2	EUROPE	**European Code of Conduct by The European Commission for Data Centers**		
		Blue Angel Eco-Label for Data Centers - Germany		
		COMPARATIVE SCALE (Benchmark)		
S.No	**COUNTRY**	**STANDARD/POLICY**	**KEY CHARACTERISTICS**	**IMPERATIVES IN INDIAN CONTEXT**
1	USA	**Energy Star Rating for Data Centers by Environment Protection Agency (EPA)**	1. EPA star rating allow users to Compare the Energy Performance of one data center with others and also enable to compare with the national average (peer group used for comparison is identified through nationally representative survey data). 2. It is based on "Actual as-billed" energy data. 3.It involves Tracking, Measurement, and Improving energy consumption on a regular basis. 4. Unit of Analysis is being carried out in terms of (Total Energy / IT Energy). It measures infrastructure efficiency i.e it captures impact of cooling and support systems but does not capture IT equipment efficiency. 5. This certification process requires data for 11 months of continuous operation of the facility before rating can be evaluated. 6. The rating determines the Rank of a data center in its peer group of data centers which essentially does not reflect the implementation of best practices and new energy efficient technologies in that data center.	**Star Labelling of Buildings by BEE** in India demonstrates certain similarities with the EPA Energy Star Rating scheme which include: 1. Evaluation of energy performance of a building is based on **Actual Performance** in terms of specific energy use. 2. Provides **Peer Group Based Comparison Mechanism** (applicable to Offices, Hotels, Retail Malls, IT Parks and Hospitals). 3.Accounts for **Operational Characteristics** of the building (e.g climatic zone, hours of operation etc.). 4. Provides a simple metric to evaluate energy performance of the building i.e. **Energy Performance Index (EPI).** **Based on the above mentioned standard, datacenters can also be classified in two groups such as: Stand alone Data Center and Data Center as part of a Building.**
2	AUSTRALIA	**National Australian Built Environment Rating System (NABERS) for Data Centers**	1. It offers the ability to separately rate the Building Infrastructure, Whole Building and Tenancy of a data center and gives flexibility to the applicants to choose rating for any one of the three in form of Infrastructure Rating, IT Equipment Rating and Whole Facility Rating. 2. It measures actual performance of the data center as it uses metered data of actual energy consumption. 3.The number of stars is calculated by benchmarking the energy consumption and comparing it against a tailored benchmark derived from a list of data centres with similar attributes. 4.Requires 12 months of building operation before rating can be evaluated.	A typical Rating framework in Indian context focusing on **Infrastructure Rating, IT Equipment Rating & Whole Facility Rating** may be suitable to bring to the fore the importance of the adoption of various State of Art Technologies in all areas/aspects
		PRESCRIPTIVE OR PERFORMANCE-BASED (mandatory code based)		
S.NO	**COUNTRY**	**STANDARD/POLICY**	**KEY CHARACTERISTICS**	**IMPERATIVES IN INDIAN CONTEXT**
1	USA	**California T-24: Building Energy Efficiency Standards for Data Centers**	1. Provides flexibility in choosing a compliance method - Prescriptive, Trade-Off, Energy Cost Budgeting Method. 2. After fulfillment of the minimum requirements, in some sections (e.g. HVAC, Infrastructure Designing, etc.), excess credit points may be extended to the other sections to achieve a trade off to achieve overall rating/ compliance. 3. These standards focus on energy efficiency related to Building HVAC, Lighting, water etc. and does not consider energy efficiency of Equipment in the facility e.g. energy efficient IT technologies in data centers.	**Energy Conservation Building Codes by BEE** follows the same structure as ASHRAE 90.1 standard and covers the following areas: **Building Envelope, HVAC, Service Hot Water and Pumping, Lighting, Electric Power etc. Similar to ASHRAE 90.1 & California T-2** 4 there are 3 compliance options - **Prescriptive, Trade-Off & Whole-Building Performance Method.**
		ASHRAE-90.1 for Data Centers		

Appendix E: Survey Questionnaires and Participants

1. Questionnaire for Data Center Owners/Large Users

Online Questionnaire on

Developing Energy Efficiency Policy/Code for Data Centers in India

Confederation of Indian Industry

Questionnaire for Data Center Owners/ Hosting Providers

General Guidelines:
This Questionnaire have been specially formulated as a part of the study on "Accelerating Energy Efficiency in Indian Data Centers" consisting of 16 questions which are divided in following two sections:

a) Section 1: General Facility Related Questions
b) Section 2: Energy Benchmarking Related Questions
c) Section 3: Data Center Energy Efficient Technologies Questions

The information provided by you through this questionnaire may lead to the formulation of a conducive policy defining Energy Efficiency Standards for Indian Data Centers.

* Required

Name of the Person *

Designation *

Name of the Data Center and Contact Details *
Address/Phone no/Email

General Facility Related Questions

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 building 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

d) Percentage wise contribution from various sources of power/electricity procured

Grid %

On-site %

e) Sanctioned Load (kW) by Distribution Companies (DISCOMs) (Optional)

(Note: "Sanctioned Load" means the load which the Licensee has agreed to supply from time to time subject to the governing terms and conditions)

Operational Load (kW) (Optional)

f) Average Annual Energy Consumption (kWh) (Optional)

- ○ Estimated
- ○ Measured

g) Highest existing Level of "IT Energy Metering" and frequency of measurement & monitoring of the data in your Data Center

Level of metering

Frequency of Monitoring

Method/Tool for monitoring and record keeping

Energy Benchmarking (Rating/Certification/ Labeling) Related Questions

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

- Yes
- No

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

Please specify the basis of values for both "IT Power" and "Total Power" to determine PUE.

- Both values Measured
- Both values Estimated
- Measured IT Power value and Estimated Total Power
- Measured Total Power and Estimated IT Power

What is the frequency of calculating PUE in you data center?

Please specify any other Energy Efficiency related "Performance Measuring Attribute".

3. Are there any energy consumption reduction targets for your Data Center (set by your Management)?

- Yes
- No

4. Do you agree that Energy Benchmarking (Rating/Certification/ Labeling) would help to improve the overall "Energy Efficiency" and "Business Productivity" of your Data Centers?

- Yes
- No

Please comment in support of your answer

5. Has your Data Center (Overall Building) achieved any Environmental Compliance/ Sustainability Certification?

- ◯ Yes
- ◯ No

If yes, please specify the certification program and Level of Certification

For example: LEED Gold Certificate, Star Labelling - 3 Star

If No, are you planning or are in the process to get any certification?

6. a) In Indian Scenario, Bureau of Energy Efficiency currently has three major programs to enhance the Energy Efficiency (refer the table for description). Which of these existing policies can be extended to encompass all the components of a Data Center for the purpose of rating it based on Energy Efficiency?

(Note: PAT is a Mandatory Standard, BEE Star Rating & ECBC are Voluntary Standards)

- ◯ Energy Conservation Building Code (ECBC)
- ◯ Perform Achieve and Trade (PAT)
- ◯ Star Rating for Building

Programme	Description
Energy Conservation Building Code (ECBC) by Bureau of Energy Efficiency (BEE)	The **ECBC** by Bureau of Energy Efficiency aims to provide **minimum requirements** for energy efficient design and construction of buildings and their systems. ECBC encourage energy efficient design or retrofit of buildings so that it does not constrain the building function, comfort, health, or the productivity of the occupants and has appropriate regard for economic considerations.
Perform, Achieve & Trade (PAT) by Bureau of Energy Efficiency (BEE)	**PAT** is a **Market Based Mechanism** to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. Facilities making greater reductions than their targets receive "EsCerts" or "energy saving certificates" which can be traded with facilities that are having trouble meeting their targets, or banked for future use.
Star Rating for Buildings by Bureau of Energy Efficiency (BEE)	This standard is based on the actual performance of a building in terms of its **specific energy usage in kwh/sqm/year**. Buildings have been categorized into two categories, having air-conditioned area greater than 50% and less than 50% of built up area. This programme rates office buildings on a 1-5 Star scale, with 5 Star labelled buildings being the most efficient.

b) Standard & Labelling program evaluates the Energy Efficiency Performance of any equipment (eg. Refrigerator, AC etc.), on a scale of 1 star to 5 stars based on the annual energy consumption. This Energy Efficiency policy/tool extends an overall recognition to any set of equipment. Are you aware of the above stated mechanism?

- ○ Yes
- ○ No

c) Sustainable energy efficiency policy for Indian Data Centers may consider both the concepts of 'Specific Energy Consumption' improvement and the 'Building Energy Efficiency'. In this context, do you agree that a 'Composite Policy Framework' on Energy Efficiency in Data Centers may be designed on focusing both ECBC, PAT and Star Rating of buildings?

- ○ Yes
- ○ No

Please comment in support of your answer

7. This ongoing study of CII-LBNL on Accelerating Energy Efficiency in Indian Data Centers, has categorized the worldwide existing standards for Energy Benchmarking (Rating/Certification/ Labeling) methods in the area of Efficient & Sustainable operations into four categories. With this analytical context, according to you which one of the following methodologies (please refer table) would be more suitable for developing a policy on Energy

Efficiency for Indian Data Centers?

You may select combination more than one

- ☐ Point - Based (Whole-Building) Rating System
- ☐ Comparative Scale Rating System
- ☐ Best Practices/Guidelines Oriented Approach
- ☐ Performance-Based Relative Benchmarking

S.No	Rating/Certification Method	Description	Example
1	Point - Based (Whole Building) Rating System	This process usually considers Energy & Environmental Performance Criteria of a facility. Points are assigned to each of the sections/criteria and rating is based on an overall score which is determined by adding the points achieved for different sections/criteria.	LEED (USA), BREEAM (UK), GRIHA , IGBC (India)
2	Comparative Scale Rating System	Evaluation of energy performance of a building is based on 'Actual Performance' in terms of specific energy use. It provides Peer Group Based Comparison Mechanism. It provides a simple metric to evaluate energy performance of the building such as Energy Performance Index (EPI), Energy efficiency Ratio etc.	EPA Energy Star Rating (USA)
3	Best Practices/Guidelines	Annual targets for Energy Efficiency improvements (voluntary in nature) are set by data centers depending on data center type, services etc. It involves a continual improvement process via an Energy Management Program. Includes assessment and implementation of best practices and new technology.	ISO 50 001 (Global Standard), European Code of Conduct for DC, PAT (India)
4	Performance-Based Relative Benchmarking	These standards focus on energy efficiency related to Building HVAC, Lighting, water etc. Compliance via prescriptive, trade-off or whole building performance method which uses simulation model to assess energy performance of the building.	ASHRAE 90.1 for DC , California Title 24 for DC (USA), ECBC (India)

Please comment in support of your answer

Data Center Energy Efficient Technologies Related Questions

9. Please prioritize the following areas on basis of possibility of energy efficiency in a data center on a scale of 1 to 6.

1- Least possibility of energy efficiency, 6- Maximum possibility of energy efficiency

	1	2	3	4	5	6
Power Distribution Architecture (AC/DC based & topology from source to load)	○	○	○	○	○	○
Power Conversions (number of						

conversions from AC to DC & DC to AC)	○	○	○	○	○	○
Use of Transformers to reduce harmonics & losses	○	○	○	○	○	○
Cooling Distribution Pattern (air management, the efficiency and control of the cooling equipment in the IT room, and the efficiency and control of the chiller plant)	○	○	○	○	○	○
Networking Architecture	○	○	○	○	○	○
Server Utilization (Virtualization & consolidation)	○	○	○	○	○	○

Any other area of inefficiency, specific to your data center

10. Please specify the area of highest energy savings in your data center

- ○ Power Distribution Architecture (AC/DC based & topology from source to load)
- ○ Power Conversions (number of conversions from AC to DC & DC to AC)
- ○ Use of Transformers to reduce harmonics & losses
- ○ Cooling Distribution Pattern (air management, the efficiency and control of the cooling equipment in the IT room, and the efficiency and control of the chiller plant)
- ○ Networking Architecture
- ○ Server Utilization (Virtualization & consolidation)

11.The global IT industry's drive towards Energy Efficiency has led to the commercialization of a variety of Energy Efficient technologies for Data Centers. Please prioritize the following technologies on the basis of suitability and applicability in a data center on a scale of 1 to 4.
1- Most likely/ Suitable, 2- Suitable, 3- May be adopted, 4- Not required

	1	2	3	4
Variable Module Management System for UPS load management	○	○	○	○
Eco-Mode/Advanced Eco-Mode for switching	○	○	○	○

between different UPS topologies				
K-Rated Transformers for reducing Harmonics level				
Energy Efficient Transformers with low rise operating temperatures				
Power Distribution Units for distribution of power to IT equipment and Infrastructure				
High Efficiency IT Power Supplies				
In Row Cooling to draw server warm air and cool it				
Rack Cooling				
Rack Cooling with Rear Door Heat Exchanger				
CRAC/CRAH with variable speed drive				
Direct Contact Cooling – heat is removed by conduction, i.e. by direct contact with hot IT equipment.				
Free Cooling with Air Economizers				
Free Cooling with Water Economizers				
Solar System Cooling				
Server Virtualization				
Storage Virtualization				
Network Virtualization				
Solid State Drives				
RAID/Intelligent Disk Subsystem				
Fibre Channel Technology				

12. What are the different types of "Air Distribution" technology/arrangement(s) are being followed/adopted /operational at your Data Center?

- ◯ Hot Aisle Containment
- ◯ Cold Aisle Containment
- ◯ Under-floor Air Cooling Plenum
- ◯ Blanking Panels
- ◯ Air Supply through CRAC Unit
- ◯ Hot & Cold Air Seperation

Please specify, if any other

13. What are the types of servers have you deployed in your Data Center?

- ☐ Blade Server
- ☐ Rack Optimized Server
- ☐ Universal or Tower Server

Please specify, if any other

14. What is the annual average level of server utilization your Data Center?

- ◯ 90 % to 100 %
- ◯ 70% to 90%
- ◯ 50% to 70%
- ◯ Below 50%
- ◯ Don't Know

15. Virtualization may increase the effective utilization of any Server, Network or Storage equipment by manifolds and may significantly improve the PUE with rationalization of the infrastructure facilities. Have you implemented Virtualization technology in your Data Center?

- ◯ Yes
- ◯ No

If Yes, Please select which area (s) in the IT environment the virtualization/consolidation has been applied to?

- ◯ Server
- ◯ Storage
- ◯ Network
- ◯ All of the above

16. Do you agree that a policy/standard facilitating Energy Efficiency in Data Centers in India should be developed?

- ◯ Yes
- ◯ No

We appreciate your patience to complete the above questionnaire. We are also sincerely thankful for your valuable inputs and this will enable the appropriate authority of Government of India to formulate a conducive policy (design a Code) on Energy Efficiency for Data Centers in India.

Submit

2. Survey Participants: Data Center Owners

Organization/Institution's Name	Designation	Sector (Govt. or Private)
NetDataVault	Managing Director	Private Sector
Centre for Railway Information Systems (CRIS)	General Manager – Data Center Infrastructure	Government Sector
Airport Authority of India	Executive Director	Government Sector
National Informatics Center	Senior Technical Director	Government Sector
Nxtra Data Ltd	GM-Infrastructure	Private Sector
Reliance Communication	Plant Engineering Head	Private Sector
CtrlS Datacenters Ltd	Vice President	Private Sector
Dell Inc	Director - Software Engineering	Private Sector
Oracle Corporation	Project Manager- Real Estate & projects	Private Sector
NetMagic Solutions	Senior Vice President and Head DC Facilities	Private Sector

3. Questionnaire for Data Center Experts

Online Questionnaire on

Developing Energy Efficiency Policy/Code for Data Centers in India

BERKELEY LAB

CII Confederation of Indian Industry

Questionnaire for Academicians, Industry Experts and Technology Providers

General Guidelines:
This Questionnaire have been specially formulated as a part of the study on "Accelerating Energy Efficiency in Indian Data Centers" consisting of 9 questions which are divided in following two sections:

a) Section 1: Data Center Operation Related Questions
b) Section 2: Energy Benchmarking Related Questions

The information provided by you through this questionnaire may lead to the formulation of a conducive policy defining Energy Efficiency Standards for Indian Data Centers.

* Required

Name of the Person *

Designation *

Institution's Name *

Data Center Operation Related Questions

1. Based on the concept of redundancy in power distribution and components, data centers can be classified as: Tier1/2/3/4. Please suggest any other criteria (eg. services) for classification of Data Centers.

2. Please prioritize the following areas of inefficiency in a Data Center on a scale of 1 to 6.

1- Least inefficient, 6- Most inefficient

	1	2	3	4	5	6
Power Distribution Architecture (AC/DC based & topology from source to load)	○	○	○	○	○	○
Power Conversions (number of conversions from AC to DC & DC to AC)	○	○	○	○	○	○
Use of Transformers to reduce harmonics & losses	○	○	○	○	○	○
Cooling Distribution Pattern (air management, the efficiency and control of the cooling equipment in the IT room, and the efficiency and control of the chiller plant)	○	○	○	○	○	○
Networking Architecture	○	○	○	○	○	○
Server Utilization (Virtualization & consolidation)	○	○	○	○	○	○

Any other area of inefficiency:

3. The global IT industry's drive towards Energy Efficiency has led to the commercialization of a variety of Energy Efficient technologies for Data Centers. Please prioritize the following Energy Efficient technologies on the basis of their Level of Adoption in Indian Data Centers:

1 - Very Low, 2 - Low, 3 - Medium, 4 - High, 5 - Very High

	1	2	3	4	5
Variable Module Management System for UPS load management	○	○	○	○	○
Eco-Mode/Advanced Eco-Mode for switching between	○	○	○	○	○

different UPS topologies					
K-Rated Transformers for reducing Harmonics level	○	○	○	○	○
Energy Efficient Transformers with low rise operating temperatures	○	○	○	○	○
Power Distribution Units for distribution of power to IT equipment and Infrastructure	○	○	○	○	○
High Efficiency It Power Supplies	○	○	○	○	○
In Row Cooling to draw server warm air and cool it	○	○	○	○	○
Rack Cooling	○	○	○	○	○
Rack Cooling with Rear Door Heat Exchanger	○	○	○	○	○
Direct Contact Cooling – heat is removed by conduction, i.e. by direct contact with hot IT equipment.	○	○	○	○	○
CRAC/CRAH with variable speed drive	○	○	○	○	○
Free Cooling with Air Economizers	○	○	○	○	○
Free Cooling with Water Economizers	○	○	○	○	○
Solar System Cooling	○	○	○	○	○
Server Virtualization	○	○	○	○	○
Storage Virtualization	○	○	○	○	○
Network Virtualization	○	○	○	○	○
Solid State Drives	○	○	○	○	○
RAID/Intelligent Disk Subsystem	○	○	○	○	○
Fibre Channel Technology	○	○	○	○	○

4. Servers are commissioned to provide one or more specific services in a data center. Knowing whether servers are being well used for productive work and turning off those that are not (comatose servers), may help reduce redundant infrastructure and avoid unnecessary

spending and environmental impact. Do you agree?

- Yes
- No

What should be the frequency to check for in-activeness or percentage usage of the Comatose" servers?

- Annually
- Semi-Annually
- Quarterly
- Monthly

5. According to you, what should be the level of "IT Energy Metering" and frequency of measurement & monitoring in a Data Center?

Level of metering

Frequency of Monitoring

Energy Benchmarking (Rating/Certification/ Labeling) Related Questions

6. Data Centers consume as much as 100 times the energy of a typical office building on a square-meter basis and Gartner predicts a 5.4 percent increase in Indian Data Center Infrastructure market.

a. Considering this, do you think Energy Efficiency standards for Indian Data Center should be developed and implemented ?

- Yes
- No

b. Do you agree that Energy Benchmarking (Rating/Certification/Labelling) would help to improve the overall "Energy Efficiency" and "Business productivity" in Data Centers?

- Yes
- No

Please comment in support of your answer

7. This ongoing study of CII-LBNL on Accelerating Energy Efficiency in Indian Data Centers, has categorized the worldwide existing standards for Energy Benchmarking (Rating/Certification/ Labeling) methods in the area of Efficient & Sustainable operations into four categories. With this analytical context, according to you which one of the following methodologies (please refer table) would be more suitable for developing a policy on Energy Efficiency for Indian Data Centers?

You may select combination more than one

- ☐ Point - Based System Rating System
- ☐ Comparative Scale Rating System
- ☐ Best Practices/Guidelines Oriented Approach
- ☐ Performance-Based Relative Benchmarking

S.No	Rating/Certification Method	Description	Example
1	Point - Based (Whole Building) Ratings	In this approach appropriate parameters are defined against all the crucial components and processes of a data center. Points are awarded against each of these parameters and the cumulative sum of these points is categorized to define the level of energy efficiency achieved.	LEED (USA), BREEAM (UK), GRIHA , IGBC (India)
2	Comparative Scale Ratings	This approach emphasizes a relative rating system, wherein a peer group of buildings with similar characteristics and services are defined and the rating is awarded based on relative percentile.	EPA Energy Star Rating (USA)
3	Best Practices/Guidelines	This approach is based on defining energy efficiency targets, which must be achieved through a defined action plan, based on the guidelines defined in the standards. The successful achievements of these targets leads to the certification of the data center as an "Energy Efficient Data Center."	ISO 50 001 (Global Standard), European Code of Conduct for DC, PAT (India)
4	Performance-Based Relative Benchmarking	This approach focuses on energy efficiency related to building envelope, heating, ventilation, and air-conditioning (HVAC), lighting, water, gas, etc. It offers compliance through Prescriptive, Trade-off or whole building performance method, which uses simulation model to assess energy performance of the building.	ASHRAE 90.1 for DC , California Title 24 for DC (USA), ECBC (India)

A brief comment in support of your answer

8. a) In Indian Scenario, Bureau of Energy Efficiency currently has three major programs to enhance the Energy Efficiency (refer the table for description). Which of these existing policies can be extended to encompass all the components of a Data Center for the purpose of rating it based on Energy Efficiency? You may select more than one.

(Note: PAT is a Mandatory Standard, BEE Star Rating & ECBC are Voluntary Standards)

- ☐ Energy Conservation Building Code
- ☐ Perform, Achieve & Trade
- ☐ Star Rating for Building

Programme	Description
Energy Conservation Building Code (ECBC) by Bureau of Energy Efficiency (BEE)	The **ECBC** by Bureau of Energy Efficiency aims to provide **minimum requirements** for energy efficient design and construction of buildings and their systems. ECBC encourage energy efficient design or retrofit of buildings so that it does not constrain the building function, comfort, health, or the productivity of the occupants and has appropriate regard for economic considerations.
Perform, Achieve & Trade (PAT) by Bureau of Energy Efficiency (BEE)	**PAT** is a **Market Based Mechanism** to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. Facilities making greater reductions than their targets receive "EsCerts" or "energy saving certificates" which can be traded with facilities that are having trouble meeting their targets, or banked for future use.
Star Rating for Buildings by Bureau of Energy Efficiency (BEE)	This standard is based on the actual performance of a building in terms of its **specific energy usage in kwh/sqm/year**. Buildings have been categorized into two categories, having air-conditioned area greater than 50% and less than 50% of built up area. This programme rates office buildings on a 1-5 Star scale, with 5 Star labelled buildings being the most efficient.

b) Standard & Labelling program evaluates the Energy Efficiency Performance of any equipment (eg. Refrigerator, AC etc.), on a scale of 1 star to 5 stars based on the annual energy consumption. This Energy Efficiency policy/tool extends an overall recognition to any set of equipment. Are you aware of the above stated mechanism?

- Yes
- No

c) Sustainable energy efficiency policy for Indian Data Centers may consider the concepts of 'Specific Energy Consumption' improvement and the 'Building Energy Efficiency'. In this context, do you agree that a 'Composite Policy Framework' on Energy Efficiency in Data Centers may be designed focusing on ECBC, PAT & Star Rating of buildings?

- Yes
- No

Please comment in support of your answer

9. Do you agree that a policy/standard facilitating Energy Efficiency in Data Centers in India should be developed?

- Yes
- No

We appreciate your patience to complete the above questionnaire. We are also sincerely thankful for your valuable inputs and this will enable the appropriate authority of Government of India to formulate a conducive policy (design a Code) on Energy Efficiency for Data Centers in India.

Submit

4. Survey Participants: Data Center Industry Experts, Academia, and Technology Providers

Organization/Institution's Name	Designation	Sector (Govt. or Private)
Cisco Systems, Inc	Distinguished IT Engineer	Private Sector
Nxtra Data Limited	Head - South Region; Infra & projects	Private Sector
National Informatics Center	Senior Technical Director	Government Sector
Centre for Railway Information Systems (CRIS)	General Manager – Data Center Infrastructure	Government Sector
Airport Authority of India	Executive Director	Government Sector
Indian Institute of Technology, Madras	Professor	Government Sector
Indian Institute of Technology, Bombay	Professor	Government Sector
National Association of Software and Services Companies (NASSCOM)	Vice President	Private Sector
CtrlS Datacenters Ltd	Vice President	Private Sector
Tata Communications Limited	Vice President	Private Sector
AEON Consultants	Managing Director	Private Sector
SCHNABEL DC Consultants India	Managing Director	Private Sector
Emerson Network Power	Head - Datacenter Business	Private Sector
ABB India Limited	Product Manager - INLPLS	Private Sector
Schneider Electric India Pvt. Ltd.	GM- Data Center Business Development	Private Sector
CtrlS Datacenters Ltd	Vice President	Private Sector
Tata Communications Limited	Vice President	Private Sector
AEON Consultants	Managing Director	Private Sector
SCHNABEL DC Consultants India	Managing Director	Private Sector

Appendix F Stakeholder Workshop Participants and Agenda

1. Workshop Participants

S.NO.	Organization/Institution's Name	Name of the Person	Designation
1	National Information Center	Mr. S.M Shankar Raju	Senior Technical Director
2	Oracle India Private Limited	Mr. Krishna Rao	Senior Facilities Specialist
3	Intel Technology	Mr. Rajkumar Y Kambar	Data Center Manager
4	NetMagic Solutions	Mr. Mahesh Trivedi	Senior Vice President and Head DC Facilities
5	SCHNABEL DC Consultants India	Mr. Mallikarjun Patil	Project Manager
6	Intel Technology	Mr. M.D Ravindranath	Resource & Capacity Manager
7	NxtGen Data Center & Cloud Technologies Pvt. Ltd	Mr. Nakul O C	General Manager Projects
8	Tata Communications	Mr. Arun Kher	Vice President
9	Emerson Network Power	Mr. Baiju. B	Director, Data Center Design
10	SCHNABEL DC Consultants India	Ms. Shaheen Meeran	Managing Director
11	Emerson Network Power	Mr. Shrirang Deshpande	Head - Datacenter Business
12	IBM India Private Limited	Mr. Shankar KM	Manager- IT Infrastructure
13	Schneider Electric India	Mr. Amod Ranade	General Manager- Data Center Business Development
14	IBM India Private Limited	Mr Veerandra	Data Center Specialist
15	EMC 2	Mr. Pradeep KS	Lab Systems Engineer
16	NxtGen Data Center & Cloud Technologies Pvt. Ltd	Mr. V Kannan	Director Operations
17	IBM Systems Lab Services	Mr Vaidyanathan Srinivasan	Server Design Architect

18	Nxtra Data Ltd	Mr.John Bennet	Data Center Operation Manager-Bangalore
19	Dell India R&D	Mr. Vivek Kumar Rajendran	Director - Software Engineering
20	EMC 2	Mr. Venkatesh Kuncham	Manager India Environment, Health & Safety
21	IBM Systems Lab Services	Ms Vidhya Shankar	Senior Data Center Specialist
22	Nxtra Data Ltd	Mr. K Jeyabalan	Head - South Region; Infra & projects
23	Emerson Network Power (India) Private Limited	Mr Arun Prasad	Senior Director
24	NetApp	Mr Mario Dias	Facilities, Operations Manager
25	IBM India Private Limited	Dr Rahul Rao	Senior Technical Staff Member

2. Bangalore Consultative Meeting Agenda

Programme		
1030 – 1100 Hrs.	**Registration**	
1100 - 1150 Hrs.	**Overview of the Initiative on "Accelerating Data Center Energy Efficiency In India"**	
1100 - 1110 Hrs.	Introductory Short Video on "Energy Efficiency Guidelines & Best Practices in Indian Data Centers"	
1110 - 1135 Hrs.	Welcome Address	**Mr. Dale Sartor P.E** Staff Engineer, Applications Team Lead Lawrence Berkeley National Laboratory (LBNL)
1135 – 1205 Hrs.	Presentation on "Accelerating Data Center Energy Efficiency In India"	**Dr. Suprotim Ganguly** Head- Energy (Technology) Confederation of Indian Industry (CII)
1205 - 1245 Hrs.	**Interactive/Q&A session with the stakeholders on "Energy Efficiency Policy Framework" for Data Centers in India.**	
1245 -1300 Hrs.	**Capturing the Inputs & Conclusion**	**CII & LBNL**
1300 – 1400 Hrs.	**Lunch**	