EXEMPLAR EDIFICES

BLUEPRINTS FOR A SUSTAINABLE FUTURE

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ISHRAE®

CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION

Danfoss ENGINEERING TOMORROW

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FOREWORDS

The world is heading for tougher times with urbanization picking up pace and its contribution towards energy footprint gaining with every passing day. With the growing urbanization and fast depleting resources come a growing demand for energy efficient and sustainable solutions, suitable for modern infrastructures.

The ACREX Hall of Fame is an effort to recognise iconic commercial buildings that not only meets the above needs, but also raises the bar on Energy Efficiency and Sustainability and sets global benchmarks. We hope that the recognition received by these projects will inspire others in the HVAC industry to adopt these benchmarks.

We are delighted to partner with CEPT Research and Development Foundation (CRDF) to bring together this compendium. In CEPT, we found a perfect partner from the realm of academia and research that shares the same focus on commercial buildings and brings in synergies as that of Danfoss. This collaboration between academia and industry aims to bring forward the best practices in the industry.

We believe that this compendium will be a source of inspiration, and provide guiding principles and valuable insights to stakeholders in the industry in making their future projects greener and more energy efficient.

Ravichandran Purushothaman
President, Danfoss Industries Private Limited

Buildings in India consume close to 40% of the nation's total energy today. We spend more than 80% of our life indoors in buildings – this number is about 90% for Europe and North America. Thus, energy conservation in buildings becomes a cornerstone of any sustainable development strategy and efforts. Further, more than 40% of the energy consumed in a building is by the building HVAC system.

Therefore, to provide a focus on this aspect of sustainable development efforts, ISHRAE in association with Danfoss India launched the ACREX Hall of Fame initiative in 2015. This initiative recognizes iconic buildings with highly efficient HVAC systems through a process of nomination and selection by an elite panel of jurists.

As part of an effort to provide learnings from the last 4 years of the program, Danfoss India in collaboration with the CEPT in Ahmedabad instituted a study to analyze the HVAC system data from the 26 buildings that were shortlisted for final consideration by the Jury. This report is a comprehensive presentation of this study through illustrative graphics, charts and visuals.

I congratulate Danfoss India for commissioning this study and the team at CEPT for undertaking this study. I am confident that the information presented in this report will be of immense benefit to builders, architects, HVAC system designers, contractors and facility managers, and contribute to the growing trend of energy efficient HVAC systems in buildings in the country.

Sushil K Choudhury
Presidential Member - ISHRAE and Chair - ACREX India 2020

Exemplar Edifices

Blueprints for a Sustainable Future

With great growth, comes a great need for power. And now, more than any other time in our planet's history, we need to act swiftly to save our future. As more and more people spend time inside commercial buildings worldwide, as well as in India, the buildings have to maximise their energy efficiency. The best starting point to increase the number of commercial buildings that are high on sustainability is to replicate the success that has already been achieved. Therefore, we've created a compendium of the most energy efficient and sustainable commercial buildings of India that can be used as a blueprint for the future. *Read on to follow in their footsteps.*

A Time **for Change**

With the dynamic proliferation of technology into our daily lives, our buildings are bound to change synchronously. The buildings of today are becoming increasingly complex organisms to design and operate, their varied functions call for the usage of non-congruous materials as well as construction and operation strategies. In the process of creating and living in these complex dwellings, our reliance on energy in the form of electricity is the utmost. Despite facilitating our daily lives by leaps and bounds, it is the same energy which is pushing our planet to the brink of a 'climate catastrophe'.

The energy supplied to our grids, largely by fossil fuel-based plants, comes at the cost of incessant greenhouse gas emission into the atmosphere. In the context of buildings, these direct and indirect emissions are not limited to energy usage alone but spread out to every resource utilized in the making of a building. This includes the emissions associated with extracting, manufacturing, procuring, installing, and disposal of any materials used in a building.

Therefore, in order to be truly 'sustainable,' the buildings must be well-designed using low-embodied energy materials and methods, and ultimately operated judiciously by the occupants.

Passive design strategies are one of the most effective and inherently affordable emission reduction methods. These strategies have been popularly romanticized to not require active methods of conditioning at all, which is incorrect. Instead, a passively-designed building judiciously uses the form and fabric of the structure to take the maximum possible advantage of the natural forces of the sun and wind. This includes spatial strategies like the stack effect, night ventilation, cross-ventilation, etc., along with construction strategies like appropriately placed thermal masses, cavity walls, exterior shading, etc. These strategies, coupled with efficient active conditioning devices, lead to reduced emissions, without compromising on the occupants' comfort.

It is important to categorize the buildings not just on their function or morphological typology, but also on their mode of operation. A building can be operated on – natural ventilation, mixed-mode ventilation, and active air-conditioned ventilation. Naturally ventilated buildings completely rely on the outdoor air to offer cooling to the indoors using passive design strategies, without using any mechanical cooling.

Air-conditioned buildings maintain the indoors separated from the outdoors and use active heating/cooling devices to maintain comfort conditions, irrespective of the outdoors. The balance lies within the mixed-mode buildings, which can be operated in the two aforementioned modes.

Mixed-mode ventilation can be further classified as temporal mixed-mode, spatial mixed-mode, and concurrent-mixed mode. Temporal mixed-mode allows the variation between natural ventilation and air-conditioning with respect to time – the time of day which experiences excessively high outdoor temperature can be allocated to air-conditioned operation of the building, while during the time when the outdoor temperature remains moderated, the same space can be operated in a naturally ventilated mode.

Spatial mixed-mode allows specific zones of the building to be air-conditioned while keeping the other zones naturally ventilated, and concurrent mixed-mode keeps a zone conditioned using natural ventilation and air-conditioning simultaneously. This indicates that the path to devising an energy efficient ventilation strategy for a building is non-linear.

Energy efficient or high-performance buildings use less energy in comparison to conventionally designed buildings by the means of including sophisticated features from the envelope to the individual building systems.

Therefore, it is not one, but a multitude of subsystems, materials, operation strategies, and equipment, which might require a relatively higher initial investment, but ensure energy savings in the long run.

The variety of occupants' walks of life, economic backgrounds, and acclimatization patterns provides each of them a unique definition of what thermal comfort really is. In a case this diverse, providing a linear solution by drawing boxes around specific indoor climatic conditions is bound to cause user dissatisfaction. Building operation codes and models should not recommend the operation of an air-conditioner when the outdoor air temperature is within the comfortable band. The thermal comfort models devised for subjective respondents representing a specific region, should not be chosen for regions with a drastically different climatic context.

In order to help mitigate the effects of the climate catastrophe from the viewpoint of buildings, it is important for us, as a society, to evaluate, create the ideal thermal comfort models, and replicate the same so as to reduce energy footprint. This includes the evaluation of unconventional building design, construction, and operation practices, and bringing them to the mainstream as scientifically validated approaches to making energy efficient buildings.

The communication about such approaches should revolve around the environment and economics and specifically target three facets

- **Enhancing occupant behavior and well-being**
- **Reduction in load**
- **Reduction in consumption**

We must arm ourselves with the validated tools of science to tackle the climate crisis, for our buildings must respond to the changing times, and the times to come are indisputably sustainable.

Champions of Sustainability

Buildings from ACREX Hall of Fame

“

This compendium presents a brief analysis of the twenty-six (26) exemplary buildings shortlisted as finalists to the ACREX Hall of Fame between 2016 and 2019. **The objective of the compendium is to extract key findings from the selected buildings and develop a valuable resource on high performance buildings for designers, consultants, and facility managers.**

Finalists **2016**

MANDI HOUSE METRO STATION
New Delhi

AVANI RIVERSIDE MALL
Howrah

INDIAN SCHOOL OF BUSINESS
Hyderabad

ADVANT NAVIS IT PARK
Noida

Inductee

Chhatrapati Shivaji International Airport
M U M B A I

Finalists 2017

PAHARPUR BUSINESS CENTRE
New Delhi

RAMANUJAN IT CITY
Chennai

JW MARRIOTT
Mumbai

ITO METRO STATION
New Delhi

CARBSE, CEPT UNIVERSITY
Ahmedabad

RBEI
Coimbatore

Finalists 2017

INDIRA PARYAVARAN BHAWAN
New Delhi

IGATE GLOBAL
Pune

IDC2 RELIANCE CORPORATE PARK
Navi Mumbai

Inductee

Infosys EC53 (M & C Building)
B E N G A L U R U

Finalists 2018

GAIL JUBILEE TOWER
Noida

DLF MALL OF INDIA
Noida

DEENANATH MANGESHKAR HOSPITAL AND RESEARCH CENTER
Pune

INFOSYS SDB-11
Pune

TSI WAVEROCK
Hyderabad

Inductee

Reliance Corporate IT Park
N A V I M U M B A I

Finalists **2019**

RADISSON BLU ATRIA
Bengaluru

ITC MAURYA
New Delhi

AVASA HOTELS
Hyderabad

SIR H N RELIANCE FOUNDATION HOSPITAL & RESEARCH CENTRE
Mumbai

Inductee

ITC Grand Chola
C H E N N A I

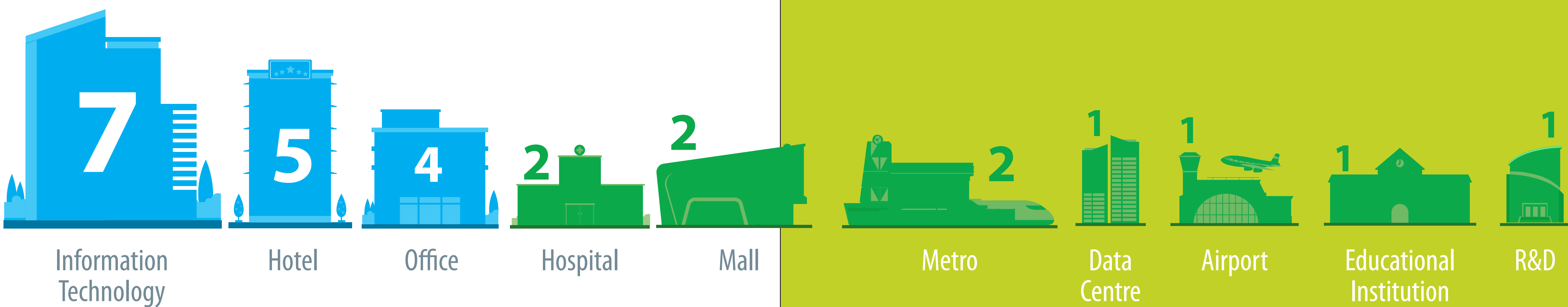
The Blueprint
Showing the Way Forward

The selection of nominees was based on the performance data from the buildings, as a mandatory requirement for the application process for all the years. Further, the jury of ACREX Hall of Fame, made up of a committee of esteemed members from the industry, implemented a rigorous evaluation process on all the submitted building applications.

Distribution of **Sectors**

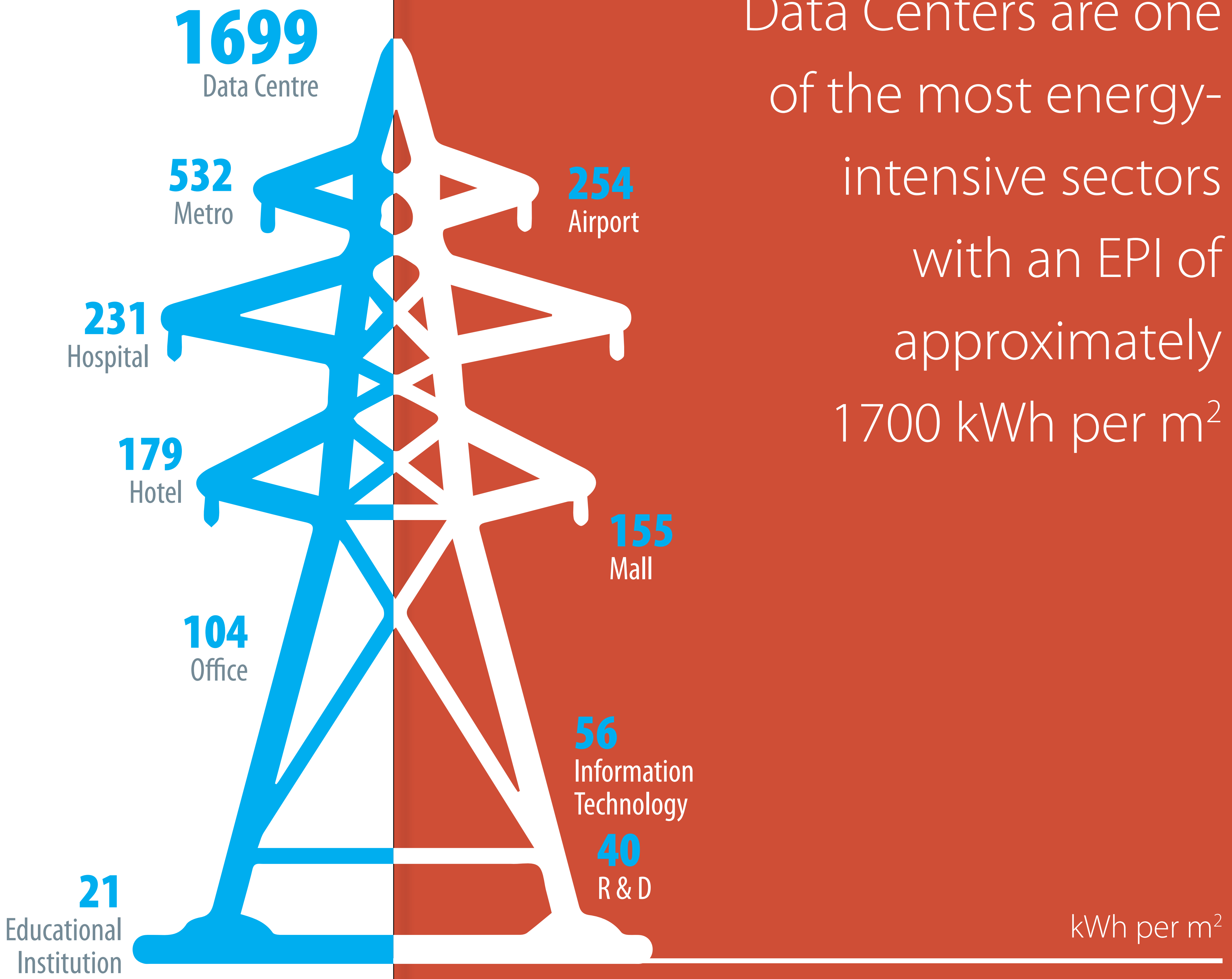
The visual shows the distribution of the sectors amongst the finalists nominated to the ACREX Hall of Fame between 2016 and 2019.

The maximum number of buildings that qualified as finalists, were from Information Technology, Hotels, and Office Spaces



Measured **Energy Performance Index**

Energy Performance Index (EPI) is an important metric to compare the energy performance between buildings. EPI is calculated by dividing the annual energy consumption of the building by total building area. Visual shows the measured Energy Performance Index of the finalists categorized by their respective sectors. Airports, metro stations, and malls show an average measured EPI of 254, 532, and 155 kWh per m^2 respectively. Hospitals, hotels, and offices show an average measured EPI of 144, 88, and 104 kWh per m^2 respectively.

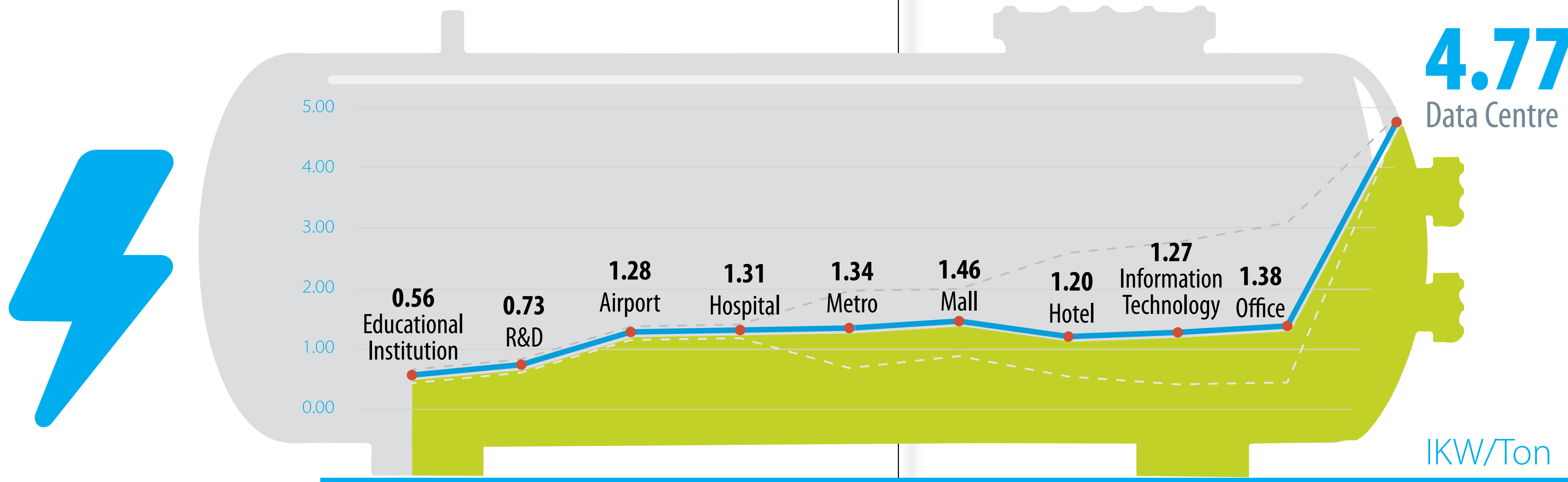


Data Centers are one of the most energy-intensive sectors with an EPI of approximately 1700 kWh per m^2

Measured
Chiller Efficiency

Another important performance metric in the air-conditioning industry is IKW per ton of refrigeration used. Visual shows the measured IKW/ton of refrigeration for each building sector.

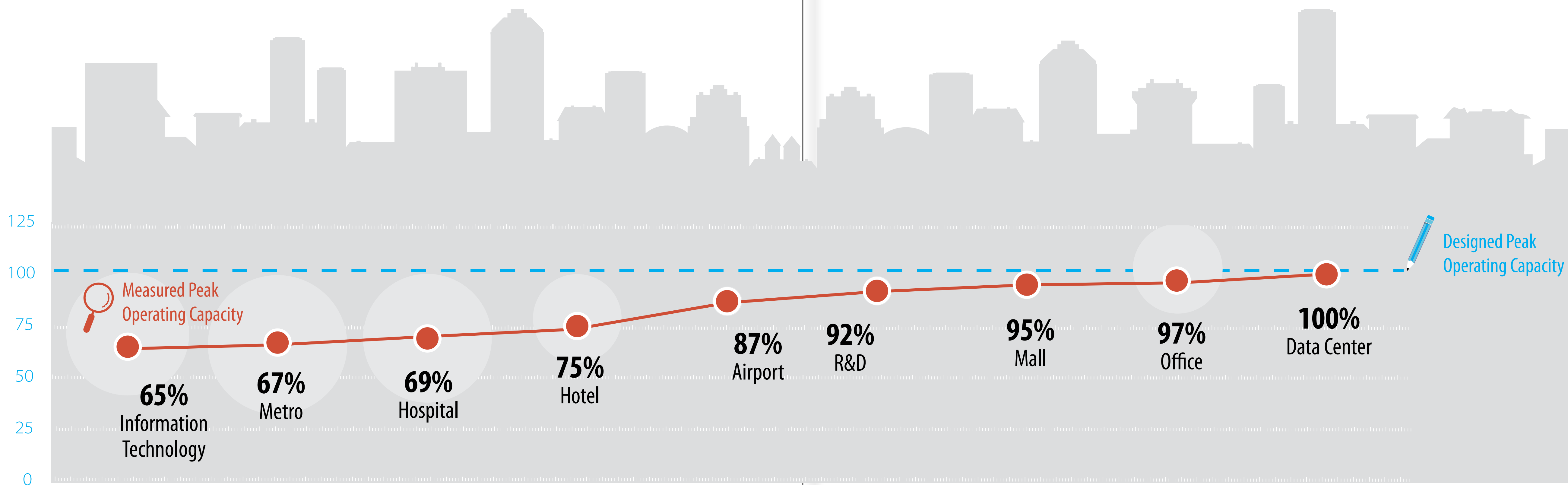
Chiller efficiency in the buildings, except for the Data Centers, varies from 0.56 to 1.38 IKW/ton



Designed Vs Measured
Peak Operating Capacity

The measured performance of buildings are often found to be different from the intended performance aimed during the design phase of the building. The section compares the designed performance of the ACREX Hall of Fame finalists with the measured performance. Visuals compare the designed peak operating capacity and EPI over the years with the measured performance.

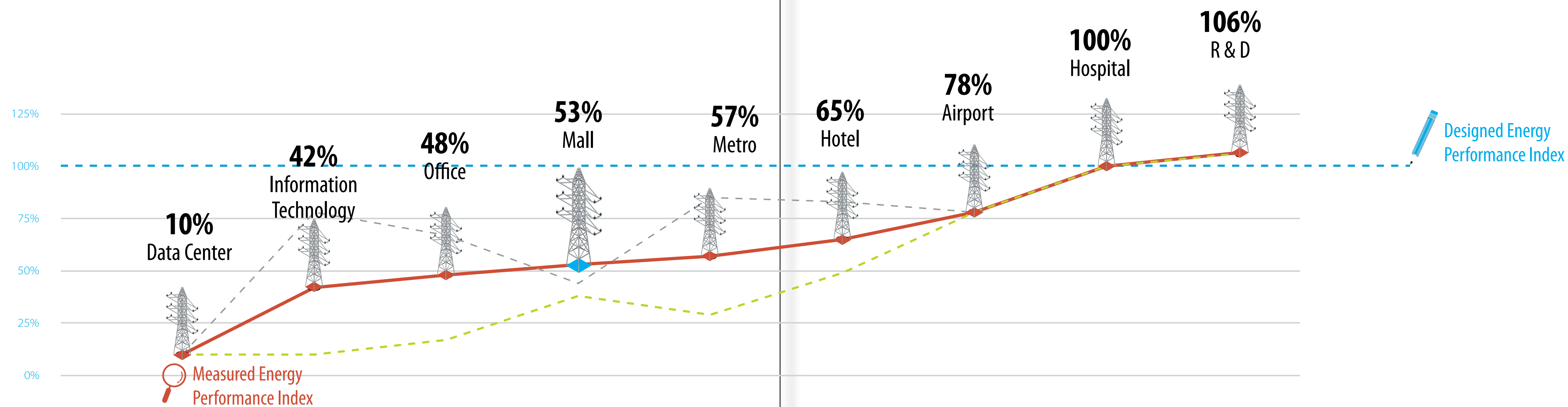
Measured data shows significantly lower actual Peak Operating Capacity compared to the design parameters



Designed Vs Measured
Energy Performance Index

The analysis indicates that there is an average 30-40% decrease in the actual peak operating capacity of the ACREX Hall of Fame finalists, compared to the designed peak operating capacity. The graphs also indicate significantly lower measured EPI compared to the designed EPI. Cursory analysis indicates potential to reduce installed capacity and overestimation of the energy use during operation. The analysis also highlights that the facility managers are conscious of operating the building more efficiently compared to the design estimates.

Measured EPI is 30-40% lower than the design in most building sectors

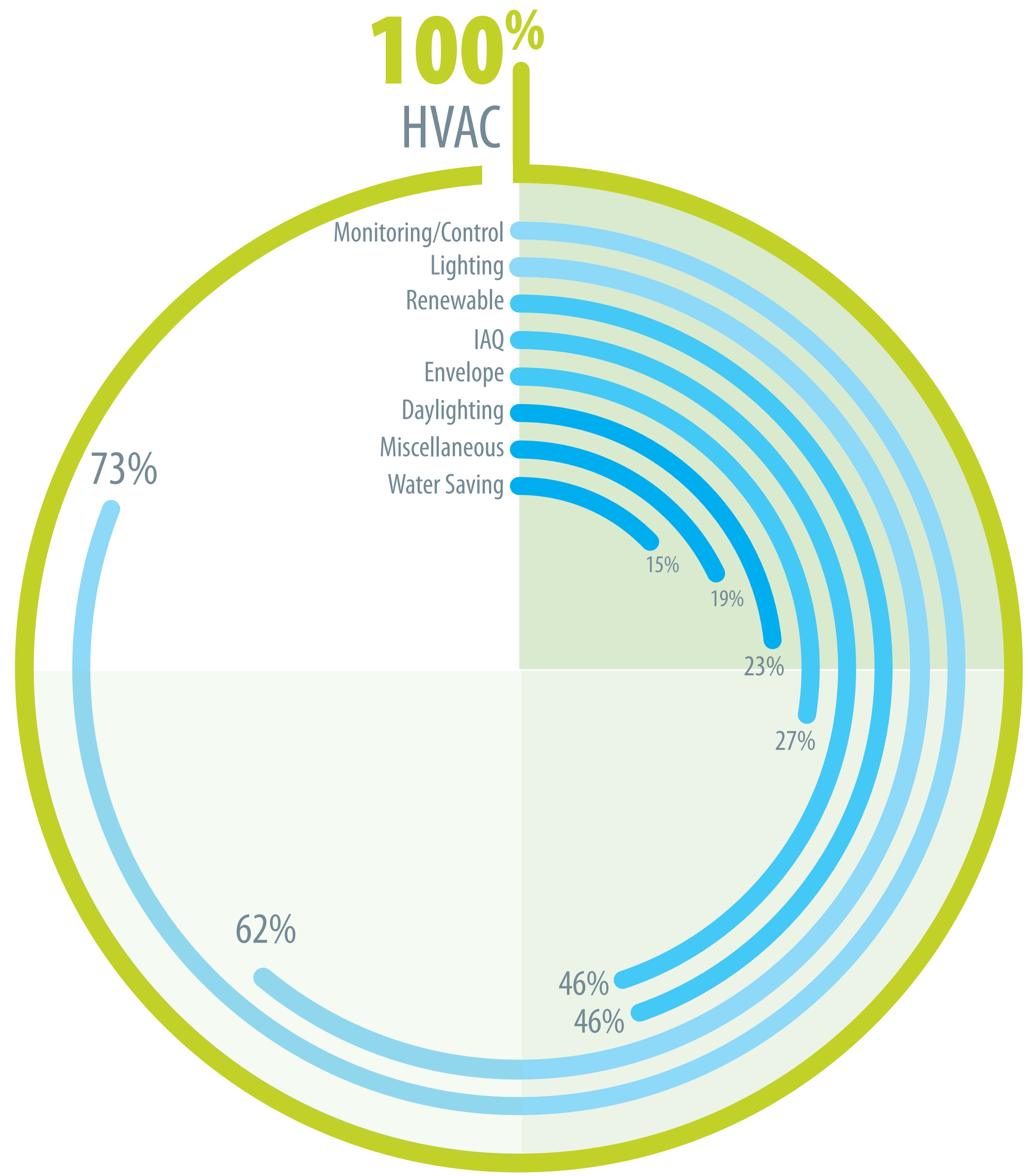


Key Strategies
used in Buildings

This section analyzes key strategies used by ACREX Hall of Fame finalists to achieve high building performance. The key strategies used by the buildings have been divided into nine categories – HVAC system, monitoring & control, lighting, renewable systems, Indoor Air Quality (IAQ), envelope, daylighting, water saving, and miscellaneous.

Visual shows strategies implemented in the building. As seen in the figure, one or more HVAC strategies have been used by all the ACREX Hall of Fame finalists to achieve high performance. Furthermore, 72% of the nominees have reported one or more monitoring and control strategies in their applications. The implementation of envelope, daylighting, and water saving strategies have been found to be at 27%, 23%, and 17% respectively. Some of the strategies, such as HVAC system strategies, have direct impact on the buildings' energy-consumption while a few other strategies, such as water saving strategies, focus more towards providing sustainable building design.

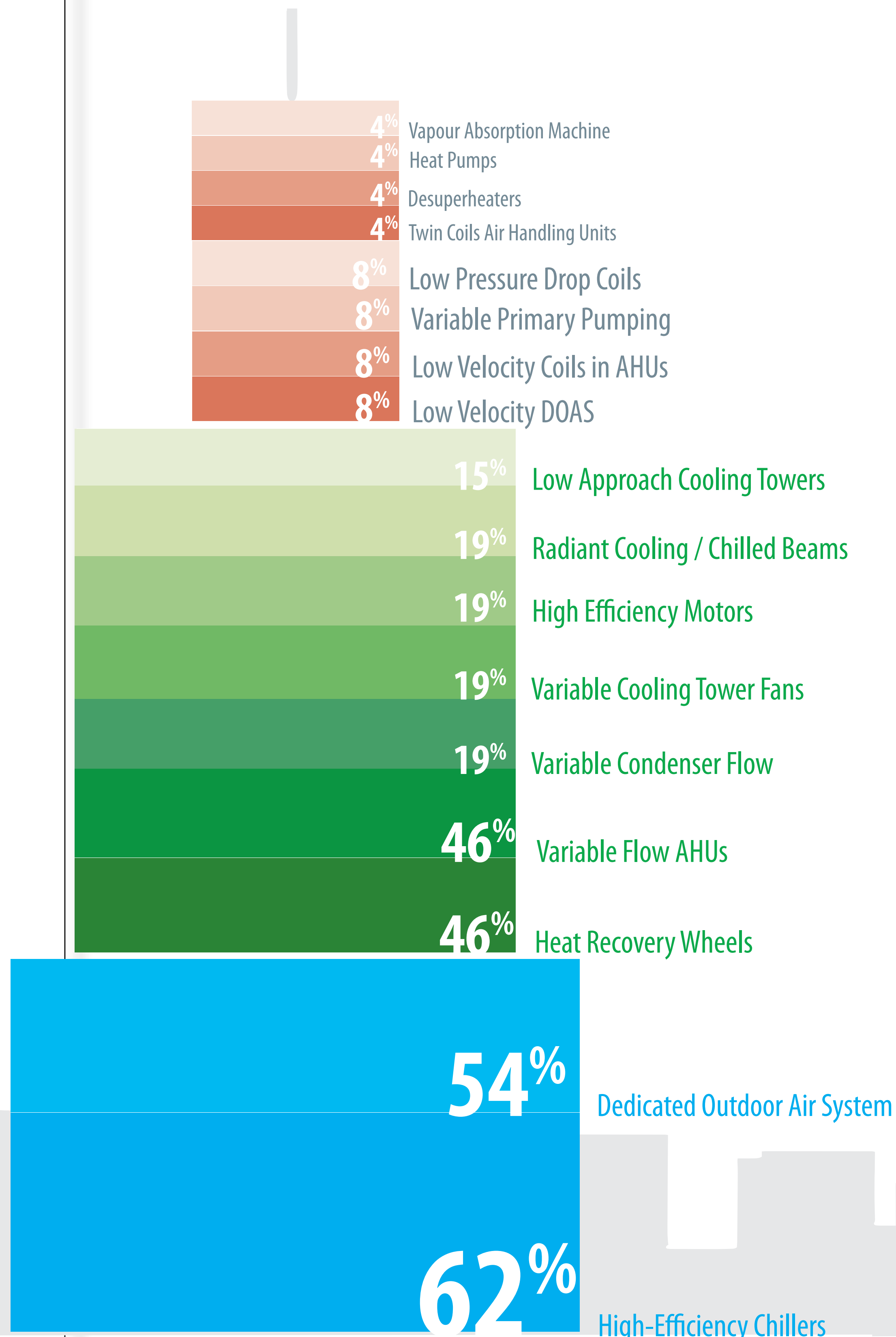
All the finalist buildings have implemented one or more HVAC strategies



HVAC Strategies
used in Buildings

Visual shows the most common strategies used by the nominees to reduce energy consumption by the HVAC systems. High-Efficiency chiller is one of the most common measures used by the finalists to achieve energy-efficiency. The participation of Dedicated Outdoor Air System (DOAS), heat recovery, and variable flow air handling unit have been found to be at 54%, 46%, and 46% respectively.

High-efficiency chiller is the most common HVAC strategy used by the finalists



Recommendations for **High-Performance Buildings of the Future**

It is recommended to follow a three-stage approach in designing energy-efficient buildings.

Stage 1
Minimize Cooling Needs

In the first stage, envelope, daylighting, and lighting strategies should be used to minimize heat load of the building. A few finalists have demonstrated that good thermal insulation in walls and roofs, high-efficiency glazing system such as double-glazed system with low emissivity coating, external shading systems, and high-reflectivity external coatings can significantly reduce envelope heat gains of the building. A few buildings have also used daylighting strategies, such as design of separate daylight and vision windows, to increase visual comfort and reduce energy consumption of the building. LED lights have been used in several buildings to reduce energy consumption. One of the buildings has effectively used task lights to reduce the requirement of ambient lighting in the space. While natural ventilation has seldom been used by the buildings nominated to the ACREX Hall of Fame, it could be an effective approach to maintain comfort during favorable outdoor conditions.

Stage 2
Efficient Cooling Delivery

In the second stage, efficient ventilation and air-conditioning system designs and technologies should be used to deliver cooling to the building with minimum energy use. High-efficiency water-cooled chillers with good part-load performance have been used by many of the buildings to reduce cooling energy consumption. Variable speed systems have been extensively used in the air handling units and chilled water plants to significantly reduce energy consumption of the air-conditioning system especially during the period of low cooling needs.

Many of the buildings have also used Dedicated Outdoor Air Systems (DOAS) to provide necessary outdoor air, as well as to effectively use heat recovery systems to reduce energy cooling systems. A few buildings have also used radiant cooling systems to reduce energy consumption while improving comfort inside the building. Segregation of sensible and latent load delivery can be an effective approach to reduce energy consumption of the building.

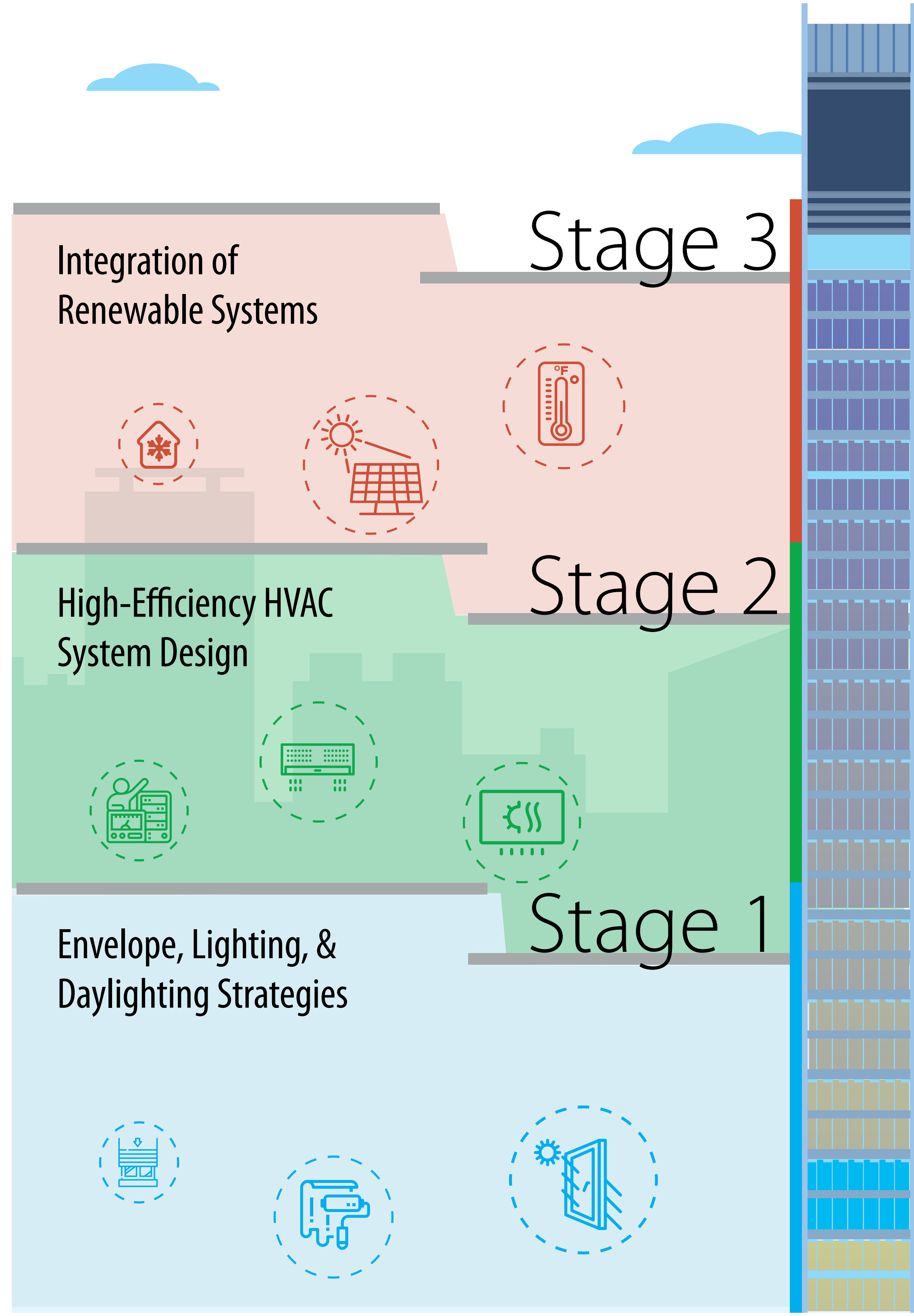
Stage 3

Energy Generation

In the final stage, strategies should be used to generate additional energy through renewable sources. Several finalists have used online photovoltaic systems on the roof to generate energy. Well-designed monitoring systems supported by active management strategies can provide a very cost-effective approach to reduce energy consumption of the buildings. Many buildings have installed monitoring systems in the building to continuously monitor energy consumption and system performance in the building.

Most of the finalist buildings use constant temperature setpoints to maintain comfort inside the buildings. Past studies have indicated that tropically acclimatized occupants can be comfortable in elevated temperatures with the use of increased air velocity. Use of alternate comfort models, such as adaptive thermal comfort model, or maintaining a slightly higher setpoint could provide significant energy savings in the buildings.

It is extremely important to maintain indoor environmental quality inside the building for better productivity and the well-being of occupants. Indoor environmental quality parameters should be considered as an integral part of the design and operation of exemplary buildings of the future. Similarly, water saving strategies, acoustic considerations, as well as fire safety strategies should also be incorporated in future buildings.



With these recommendations as a replicable blueprint, and the Hall of Fame buildings as inspiration, the stage is set for upcoming commercial buildings to become an Exemplar Edifice themselves and take us into a much more sustainable, healthy, and bright future for everyone to work in and conduct business.

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