"Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative"
MARK THROWER MANAGING EDITOR

Energy-efficient data centres

By Adetunji Lawal, Associate at BSSEC

In 2019, over 57 per cent of the world's population had internet access. With 4.3bn active internet users an enormous volume of internet activity occurs daily. In a second, 63,000 searches are conducted by internet users on Google, accounting for 90 per cent of the search engine market worldwide. Our internet activity is made possible by millions of servers worldwide, much of which are housed in data centres, best described as warehouses of racks containing servers and computer systems through which our online activity flows.

Data centres are one of the most energy-intensive building types, consuming 10 to 50 times the energy per floor area of a typical commercial office building[1].

Global data centre electricity demand in 2018 was an estimated 200TWh of electricity, or almost 1 per cent of global final electricity demand[2]. As the world becomes increasingly digitalised, data centres and data transmission networks are emerging as an important source of energy demand. Maintaining uptime is a core deliverable for data centre operators, sometimes leading to a desire for reliability over energy efficiency.

To meet the carbon reduction target of governments, energy efficiency in data centres must become a core objective. This presents considerable difficulties in ensuring that energy-efficient operation is considered and maintained.

In an ideal world, all data centres would be new with the most up-to-date equipment. They would be designed to maximise free cooling, be fully monitored and controlled and have integrated renewable energy installations. Unfortunately, this is not always the case.

Establishing a data centre's energy efficiency is a key first step towards reducing power consumption and related energy costs. PUE (power usage effectiveness) is a widely used metric that provides a basic guide to the energy efficiency of a data centre. PUE was published in 2016 as a global standard under ISO/IEC 30134-2:2016.

Power usage effectiveness is the ratio of total energy used by a data centre facility (IT load, cooling, lighting, security, electrical systems), to the energy delivered to computing equipment (IT load). An ideal PUE is 1.0.

$$\text{PUE} = \frac{\text{Total Facility Energy (kWh)}}{\text{IT Equipment Energy (kWh)}}$$

New data centres with the latest high-efficiency power and cooling plant can achieve a PUE as low as 1.2, while the UK average is approximately 1.8. However, older data centres should be able to attain a PUE of 1.4 by adopting best practice measures.

The key to energy efficient operation is to understand what type of equipment you have, how and when it operates, the operating parameters and how you manage environmental conditions to maintain the equipment's performance.

Implementing a robust energy audit can identify where energy is being used, how the environment is being managed and how energy can be saved. An energy audit survey methodology should include:

• a review of IT and HVAC installations including emergency back-up;
• failed assets replacement policy;

Table 1:

Efficiency	PUE	Definition
Inefficient	3	Old plant or poorly managed
Average	1.8	Mix of old and new plant with some best practice
Efficient	1.4	Well managed using best practice
Very Efficient	1.2	Newly built with high efficiency plant

Some PUE figures have been suggested as indicative of performance levels[3]

Produced in Association with energy institute

• equipment arrangement, rack location, size, obstructions such as columns;
• the existing cooling and ventilation arrangement. Is there an existing hot/cold aisle arrangement?
• investigate conflicting hot/cold separation such as wrongly positioned floor grilles, cold-on-cold or hot-on-hot installations;
• configuration of Computer Room Air Conditioning (CRAC);
• aisle width, ceiling heights, obstructions, floor plenum depths;
• lighting types (LED preferred), positions and switching;
• fire detection and suppressions systems;
• review energy use data, policies, procedures and guidance;
• check control operating setpoints; and
• review electrical distribution infrastructure such as utility feeds, transformers, to PDUs, to racks, with a view to reducing loses.

A basic package of metering, monitoring and control should include:
• total facility power;
• facility environmental controls setting;
• security; and
• IT rooms, racks and specific equipment.

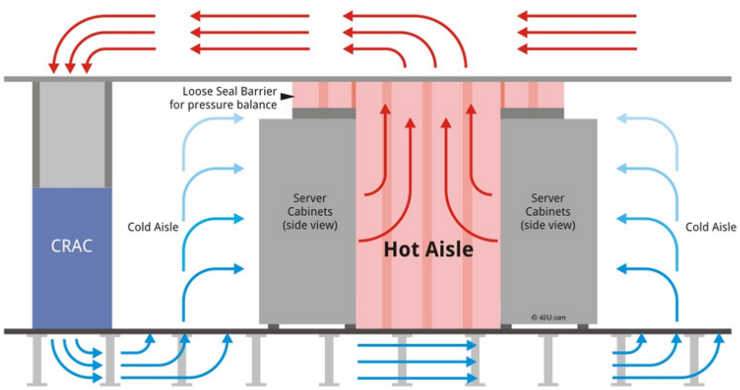
Monitoring and metering should be carried out by submetering or on-board measurement of energy use, power monitoring, power alarming and analytics. These functions support critical activities such as notification of and response to electrical network problems, maintenance (planned and unplanned), facility expansion/retrofit projects, and power reliability analysis.

Providing hot and cold aisle containment greatly improves the efficiency of the cooling system and should be the starting point when designing installations and when replacing IT equipment.

A ducted hot aisle containment system (Ducted HACS) (see Fig. 1) can be used with a hard floor or raised floor installation. This method isolates the hot aisle with end-of-row doors and a ceiling structure that encloses the top of the entire row. The rest of the room acts as a large cold air plenum.

Ducted HACS are suitable for rooms where:

Fig 1: Ducted hot aisle containment system. Image courtesy of Dnipro[4]



• the rooms are frequently occupied with staff;
• there is a uniform distribution of racks; and
• there are stand-alone equipment installations at the perimeter.

The cold aisle containment system (CACS) is perhaps the most widely used method. It utilises the raised floor and isolates the cold aisle with end-of-row doors and an aisle ceiling that covers the entire cold row. The rest of the room acts as a hot-air return plenum. CACS are suitable for rooms where:
• there is an existing hot/cold aisle configuration; and
• there is a raised floor with cold air in floor plenum in place and uniform distribution of racks.

A ducted rack is suitable for installations with distributed racks or high-density racks where the hot aisle is ducted into a dropped ceiling arrangement.

Ducted rack is suitable for rooms where:
• there is front to back airflow;
• an existing drop ceiling air return plenum or where additional ducting runs at ceiling level can be installed;
• retrofitting existing rooms;
• different types of racks exist;
• variation of ventilation is required throughout the room, and
• obstructions prevent other methods of containment.

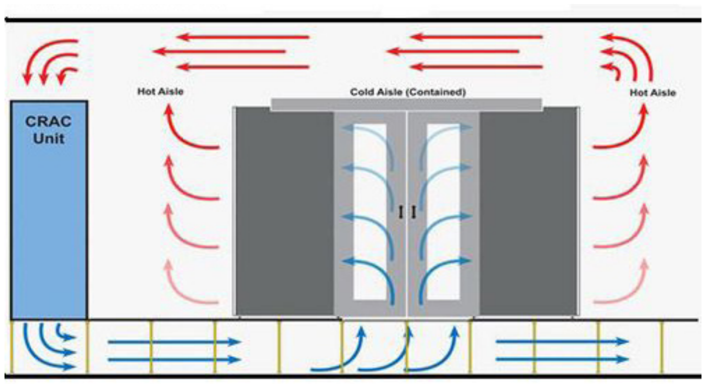
Rack air containment systems (RACS) integrate rack-based cooling units within the racks to circulate air in the containment area.

RACS are suitable for rooms where;
• there is high-density, stand-alone equipment;
• space for additional ductwork is not available;
• complete isolation is required, and
• where security is required such as multi-client rooms.

Reductions in PUE

Aisle systems have delivered significant reductions in PUE, as well as cost savings to data centres. In one example, it reduced the facilities PUE from 1.85 to 1.55, with a financial pay back less than six months. A data centre with segregated hot and cold aisles can expect energy savings of around 25 per cent compared to systems which do not segregate hot and cold air flows.

Fig 2: Cold Aisle Containment System (CACS) Image courtesy of Dnipro[5]



Best practice for aisle containment includes:
• a raised floor 'plenum' of at least 500mm so that air being pushed by air conditioning equipment can pass through;
• use of cabinets rather than open racks which cannot easily be sealed to prevent cool air escaping from the aisle.
• installing self-closing doors at the ends of the cold aisle;
• ensuring isolation partitions are installed to prevent hot air recirculation and ensure appropriate ventilation rates/air pressure.
• deploying high cubic feet per minute (CFM) rack grills that have outputs in the range of 600 CFM.
• considering ceiling heights, rack size, access, security and fire suppression provisions. This may require airflow and pressure modelling.

IT equipment is designed to operate efficiently within temperature and humidity ranges. Understanding these and how the cooling and ventilation installation maintains these is critical in an energy-efficient operation.

Temperature sensing either on board equipment or remote sensing should be installed and monitored.

Since 2015, ASHRAE has recommended rack intake temperature range of 18 to 27°C, and humidity of 8 to 60 per cent. For most new devices, recommended operating temperature ranges are as wide as 15 to 32°C, although some data centre operators run at higher temperatures. This saves energy and opens new possibilities for data centre operators, allowing for higher densities in server rooms without expensive air-conditioning upgrades. It also increases the duration of year when free cooling is possible, further improving the PUE[6].

In reality, most are set too low, wasting energy by over cooling. There are multiple case studies and strategies available, indicating that for each 1°C increase in inlet temperature an energy saving of up to 4 per cent can be achieved. However, it is important to fully understand airflow and where hot spots may occur through temperature sensing and modelling.

IT equipment drawing more than 10kW per rack enclosure is considered high density. Populated racks of servers can draw from 6kW to 35kW per rack. Yet the majority of data centres today are designed for a power density of less than 6kW per rack. Installations that exceed the design density of the facility is one of the greatest risks to efficient operation, causing stresses on the power and cooling systems, downtime from overloads, overheating, and loss of redundancy. A process should be in place to assess density implications during equipment replacement.

Redundant racks of servers

Legacy data centres can have racks of servers which have become redundant yet still consuming energy. In some cases, servers are standing as triplicates or quadruplets of old data sets, but actively contributing to the energy demand of the data centre every minute, alongside the electrical distribution serving them. Ensuring that redundant equipment is periodically removed will realise a reduction in energy consumption.

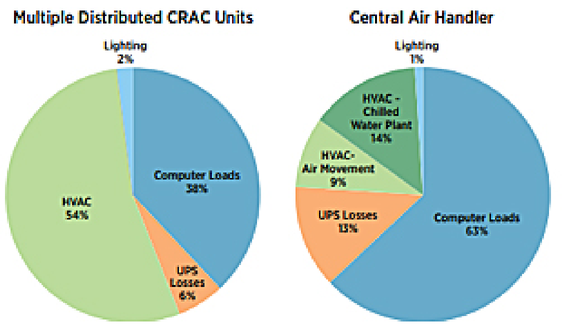
Other technology options include:

- **renewable energy:** technology companies have sought to reduce their carbon impact. Google, for example, has said it has been a carbon-neutral company since 2007. In reality, the neutrality is via carbon offsets by purchasing credits and plugging into renewable tariffs. The key though would be for a data centre's claim of carbon neutrality to be viewed at location i.e. onsite power generation accounting for 100 per cent of its energy consumption. This is possible via a mix of renewable energy technologies such as solar PV on the roof, wind turbines, and renewable hydrogen fuel cells.

If renewable technologies are maximised on-site, some data centres could be 100 per cent renewable energy powered, thus being zero carbon.

- **underwater data centres:** some far reaching measures have been taken by the industry to reduce energy consumption and cooling, one of which is an underwater data centre in the ocean, where the environment is cooler. Water and electricity are not natural friends so the long-term integrity of such installations in the face of tides and other marine activities is a consideration. The concept will no doubt save energy, but the heat dissipated by such centres ultimately ends up warming the oceans. So, overall, this could have a less favourable environmental impact.
- **free air cooling:** this is where colder external air is drawn in as a cooling source. It reduces or eliminates the need for refrigerant air conditioning. This has been used by some technology giants who have set up data centres in Scandinavian countries, benefitting from the lower ambient temperatures.
- **chilled storage:** this is a method of storing energy in a reservoir for later use and is particularly useful in facilities with high cooling loads including data centres. In climates with cool, dry night-time conditions, cooling towers can directly charge a chilled water storage tank into ice; then release that in the day, using a small fraction of the energy otherwise required by chillers. It can result in peak electrical demand savings and improve chilled water system reliability. An ice storage tank can also be an economical alternative to additional mechanical cooling capacity.
- **central versus modular air handling systems:** a centralised system offers many advantages over the multiple distributed unit system, some of which evolved as easy, drop-in cooling systems. Centralised systems use larger motors and fans that tend to be more efficient. They are also well suited for variable volume operation through the use of VSDs and maximise efficiency at part-loads. A US study[7] compared two similarly sized and loaded data centres in adjacent buildings, but with different air handling systems. The pie charts in Fig 3 show the performance of both, with the central air handling system using more energy for revenue generating computing work.
- **lower energy servers:** blade servers are an easy-to-use, power-efficient modular solution which provides performance, equal to or greater than, standard rack-mounted servers. It is essentially a modular server design to allow multiple servers to be housed in a small area, minimising physical space and energy. While standard rack-mounted servers run on a power cord and a network cable, a blade chassis houses multiple blade servers, supplies power, networking, cooling, etc. together, blade servers and blade chassis form the blade system.
- **implement cable management:** under-floor and over-head obstructions often interfere with the distribution of cooling air, impacting free airflow as well as air distribution. Cable congestion in raised-floor plenums can sharply reduce the total airflow as well as degrade the airflow distribution through the perforated floor tiles; promoting the development of hot spots. A data centre should have a cable management strategy to minimise air flow obstructions caused by cables and wiring. This strategy should target the entire cooling air flow path, including the rack-level IT equipment air intake and discharge areas as well as under-floor areas. Instituting an ongoing cable mining programme (i.e. a programme to remove abandoned or inoperable cables) will help optimise the air delivery performance of cooling systems.

Fig. 3 Central versus modular air handling system



Energy managers should consider following the 2016 Best Practice Guidelines for the EU Code of Conduct on Data Centres, setting objectives for replacement of legacy equipment including:

- the inclusion of energy efficiency as a specified requirement for new or replacement installations. This may be through the use of Energy Star, SERT, SPECPower or a bespoke performance specification, considering the full system efficiency including power supply;
- the calculation of data centre inventory and aim for PUE of 1.0; and
- the setting of specific operating temperature and humidity ranges for existing and new installations.

Design features should include renewables such as roof top solar photovoltaics, energy storage systems, high efficiency UPS systems, low energy LED lighting with automatic controls (reducing heat gains), free cooling, high CoP (coefficient of performance) chillers with heat recovery (to provide heating and hot water to administrative areas or neighbouring buildings), low energy air handling units with low specific fan powers using heat recovery technology, and premium efficiency motors.

There are opportunities for improving the energy efficiency of data centres that form the backbone of an increasingly digital world, via technology, making use of nature and careful design. Embedding a programme of monitoring enables a clearer view of energy use and leads to an insight into where energy is being wasted and where over cooling is occurring.

References

1) https://www.energy.gov/eere/buildings/data-centers-and-servers
2) https://www.iea.org/reports/tracking-buildings/data-centres-and-data-transmission-networks
3)https://www.ait-pg.co.uk/library-and-resources/cost-saving-calculators/data-centre-pue-calculator/
4) https://www.dcimpro360.com/air-flow-containment/
5) https://www.dcimpro360.com/air-flow-containment/
6) tps://www.apl-datacenter.com/en/increasing-server-room-temperature-to-improve-data-center-energy-performance/
7) https://www.energy.gov/sites/prod/files/2013/10/f3/eedatacenterbestpractices.pdf

For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 20** energy institute

SERIES **17** | MODULE **10** | APRIL **2020**

CPD ENTRY FORM

DATA CENTRE MANAGEMENT

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. What PUE should a modern data centre aim for?
- ☐ 3.0
- ☐ 2.0
- ☐ 1.0
- ☐ 3.8

2. What would be considered as a high-density rack?
- ☐ 2kW
- ☐ 4kW
- ☐ 6kW
- ☐ 10 kW

3. What does HACS mean in terms of containment?
- ☐ Heating Arrangement Containment System
- ☐ Heated Access Containment System
- ☐ Hot Air Containment System
- ☐ Hot Aisle Containment System

4. What percentage of global electricity is consumption is used in data centres?
- ☐ 15 per cent
- ☐ 10 per cent
- ☐ 0.02 per cent
- ☐ 1.0 per cent

5. How much energy can be saved for each 1°C uplift in inlet temperature?
- ☐ Up to 6 per cent
- ☐ Up to 4 per cent
- ☐ Up to 2 per cent
- ☐ All the above

6. What is the meaning of PUE?
- ☐ Pass utility enterprise
- ☐ Power unit effectiveness
- ☐ Power usage effectiveness
- ☐ Potential urban ecolie

7. What containment system is most suitable for complete isolation of a rack?
- ☐ HACS
- ☐ CACS
- ☐ RACS
- ☐ Row-cooled HACS

8. What equipment should be specified that does not require cooling in itself during normal operation
- ☐ IT Equipment
- ☐ M&E Equipment
- ☐ Blade server
- ☐ Cable trays

9. The use of LED lighting with automatic controls in data centres can help achieve which of the following?
- ☐ Lower heat gains
- ☐ High wind velocity
- ☐ X-ray pollution
- ☐ Liquid damage

10. What is considered to be the optimum rack inlet air temperature?
- ☐ 12°C
- ☐ 20°C
- ☐ 38°C
- ☐ 27°C

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms)..............................

Business ....

Business Address ....

....

....

.... Post Code ....

email address ....

Tel No. ....

Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry, P.O. Box 825, GUILDFORD, GU4 8WQ. Or scan and e-mail to editor@eibi.co.uk. All modules will then be supplied to the Energy Institute for marking

Produced in Association with energy institute

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

How to obtain a CPD accreditation from the Energy Institute

Energy in Buildings and Industry and the **Energy Institute** are delighted to have teamed up to bring you this **Continuing Professional Development** initiative.

This is the tenth module in the seventeenth series and focuses on **Data Centre Management**. It is accompanied by a set of multiple-choice questions.

To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to EiBI for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, **free of charge** for both Energy Institute members and non-members.

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject.

Modules from the past 16 series can be obtained free of charge. Send your request to editor@eibi.co.uk. Alternatively, they can be downloaded from the EiBI website: www.eibi.co.uk

SERIES 16

MAY 2018 - APR 2019

1. BEMS
2. Refrigeration
3. LED Technology
4. District Heating
5. Air Conditioning
6. Behaviour Change
7. Thermal Imaging
8. Solar Thermal
9. Smart Buildings
10. Biomass Boilers

SERIES 17

MAY 2019 - APR 2020

1. Batteries & Storage
2. Energy as a Service
3. Water Management
4. Demand Side Response
5. Drives & Motors
6. Blockchain Technology
7. Compressed Air
8. Energy Purchasing
9. Space Heating
10. Data Centre Management

** ONLY available to download from the website after publication date*

Terms: in submitting your completed answers you are indicating consent to *EiBI*'s holding and processing the personal data you have provided to us, in accordance with legal bases set out under data protection law. Further to this, *EiBI* will share your details with the Energy Institute (EI) with whom this CPD series is run in contractual partnership. The EI will process your details for the purposes of marking your answers and issuing your CPD certificate. Your details will be kept securely at all times and in a manner complaint with all relevant data protection laws. For full details on the EI's privacy policy please visit www.energyinst.org/privacy.

• To hear more from the EI subscribe to our mailing list: visit https://myprofile.energyinst.org/EmailPreferences/Subscribe