Data Centre Energy Efficiency Benchmarking

Metrics, Results and Roadmap

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1. Introduction

The 21st century is driven by digital economy through vast use of "Information and Communication Technologies". This has created the "Data Centre Business and Industry" which will continue to grow with e-commerce, mobile users, social media, big data analytics, internet of things, smart cities and smart grid. This will drive the demand for data centre which eventually increases the consumption of energy. Energy cost makes up about 40% of the total operating cost of a data centre. According to US Environmental Protection Agency Report (EPA), US data centres energy consumption has grown at 15% annually from 2000 to 2006 as shown in Figure 1 and the trend may continue unless 'Energy Efficiency' efforts are in place to reduce carbon emissions from Data Centres [1].

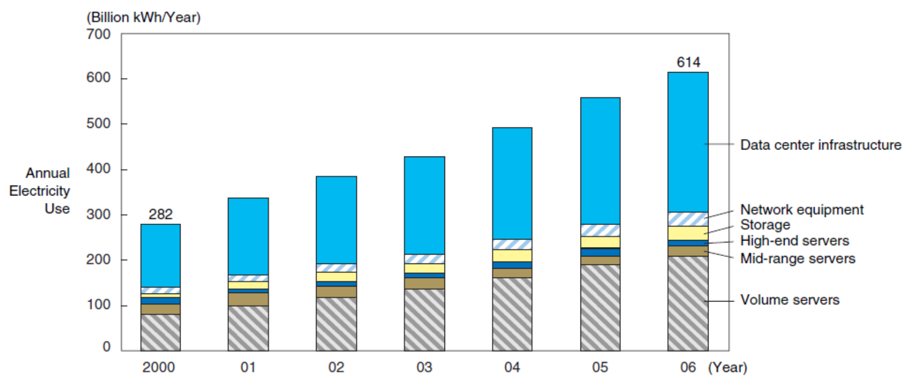


Figure 1 US Data Centre Electricity Use from 2000 to 2006 [1], [2]

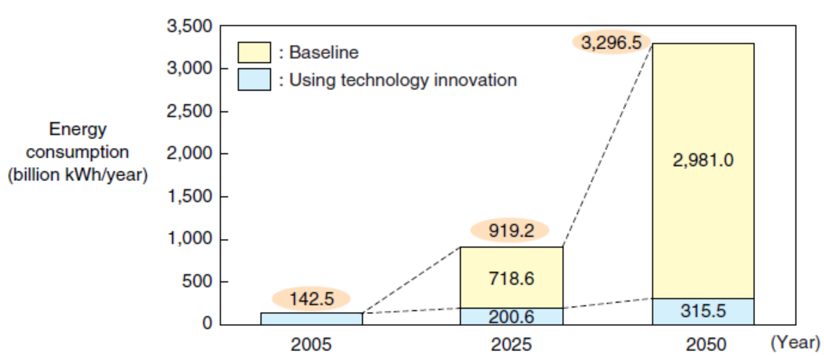


Figure 2 Worldwide Data Centres Energy Consumption Forecast [3]

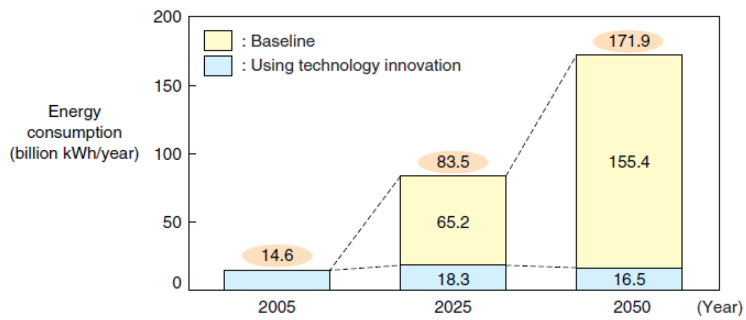


Figure 3 Forecast for Data Centre Energy Consumption in Japan [3]

In 2008, the Green IT Promotion Council of Japan used similar method used in EPA Report to forecast the amount of electricity consumed by data centres in 2005, 2025 and 2050 as shown in Figure 3. The report estimates that 6 times increase in annual energy consumption in Japan Data Centres from 14.5 billion kWh in 2005 to 83.5 billion kWh in 2025. It also highlights a similar increase in worldwide data centre energy consumption from 142.5 billion kWh in 2005 to 919.2 billion kWh in 2025 [3]. This prompted Japan to take lead in Global Competition of Data Centre business and propose new metric **Data Centre Performance per Energy [4]**. Recent publications by Nomura Research Institute highlight the significance of DPPE metric and the need for standardization of data centre energy efficiency metrics in preparation of global competition [3], [4].

2. Malaysian Green Initiatives

At COP 15 in Copenhagen, Malaysia announced that it would voluntarily reduce GHG emissions intensity of GDP by up to 40% by year 2020 based on 2005 levels. According to Low Carbon Society Scenarios Malaysia 2030 report Malaysia total GHG emission 271 MtCO_2 in 2005. The report analyses three different scenarios Business as Usual (BaU), Existing Low Carbon Measures (EXT) and Alternative Planning Scenario (APS). BaU scenario assumes development without introduction Low Carbon Measures while the EXT scenario involves the introduction of Low Carbon Measures mentioned in the Second National Communication (NC2) to United Nations Framework Convention on Climate Change (UNFCC) and other measures which are already planned by the Malaysian government. APS assumes more intensive implementation of the measures than currently planned, as well as other additional measures implemented in the future. In 2020BaU scenario GHG emissions increases up to 534 MtCO_2eq, which is a 97% increase from 2005 as shown in Figure 4. In 2020EXT and 2020APS scenarios, the total emissions are 419 MtCO_{2eq} and 360 MtCO_{2eq} which is 22% and 40% reduction from 2005 values. Thus, the official target of 40% reduction of GHG intensity in 2020 is only achieved in the APS scenario.

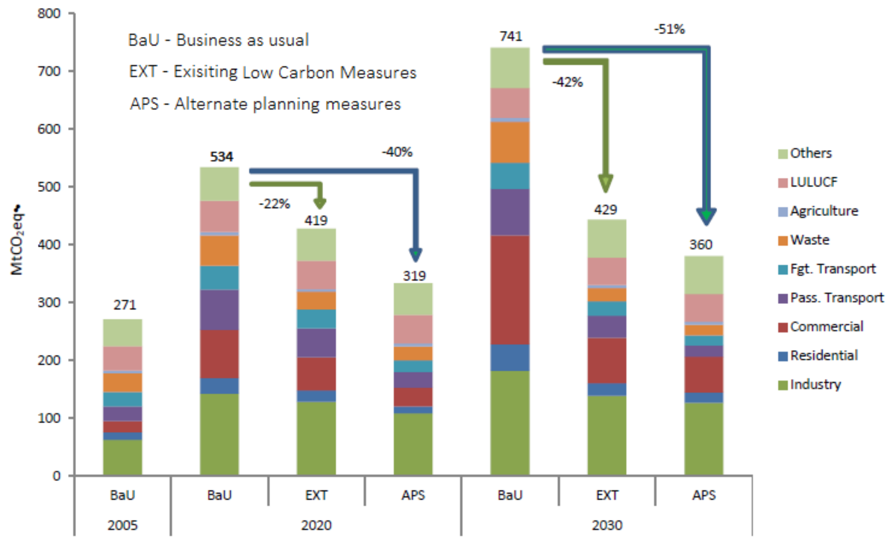


Figure 4 Green House Gas Emissions in Malaysia under various scenarios [5]

Since Malaysia economy is moving from manufacturing based to service based driven by ICT sector there is an opportunity for Data Centre industry growth due to IOT, Big Data Analytics, Cloud Computing, Smart Cities, Smart Grid and Digital Malaysia in the next 15 years. This will increase energy demand for ICT sector and create major challenges for reducing GHG emissions using Existing Low Carbon Measures (EE in Power Demand and Supply, RE in Transportation and Power Supply Sectors, Modal Shift, Avoiding Deforestation and Waste Recycling). Though many organizations and institutions are promoting Energy Efficiency, and Green Technologies (MGTC, GICT, SEDA, ST, KeTTHA) but there is no data available on GHG Emission and Mitigation efforts from ICT industry particularly Malaysian Data Centre industry.

Energy efficiency is not new to either Electrical or ICT industry. For the last one decade both industries played a major role in improving energy efficiency of both electrical and ICT devices (Green in ICT). This has led to ENERGY STAR ratings for Electrical Devices and Computer Server (Passive). However, there is a need to focus on energy efficiency improvement in operations through better energy management technologies which is an integration Electrical and ICT devices and known as Green by ICT (Active). This applies to enterprise Data Centres which consume large amount of energy compared to small and medium Data Centres. Most of this energy is for cooling the data centre using various technologies. Hence, better air-flow management through monitoring and control is required for optimizing the energy consumption. In addition, it is essential to reduce further energy waste by monitoring and turning off comatose servers. However, this is a not a standard practice and requires additional tools and resources to execute in large enterprise data centres. Finally, energy efficiency solutions need to be economical and viable to implement otherwise may require incentives and policy framework for adaptation. In addition, Corporate Social Responsibility (CSR), Green Building Index (GBI) and Leadership in Energy & Environmental Design (LEED) certifications may help in reducing passive energy but not active energy. This paper investigates energy efficiency opportunities and challenges in the Malaysian Data Centre industry with a summary on benchmarking study of Malaysian Data Centres. To overcome the existing barriers and enhance energy efficiency in the Malaysian Data Centres, the study proposes a Data Centre Energy Efficiency Roadmap and encourages knowledge sharing in this area by creating the 'Malaysian Data Centre Energy Efficiency Community' platform. This platform will be eventually serves as a reference and knowledge on the best practices and information for the DC industry stakeholders and policy makers.

3. Data Centre Energy Consumption

The diagram of a typical data centre with various electrical equipment and data centre loads is shown in Figure 5. It's important to study the data centre power system along with its loads for energy efficiency enhancement. Naturally, all electrical equipment such as Switchgear, UPS and Back-up Generator are selected based on the reliability and security of power supply necessary for data centre IT Load. The UPS rating depends on planned IT Load and HVAC Load which may increase over a period of time.

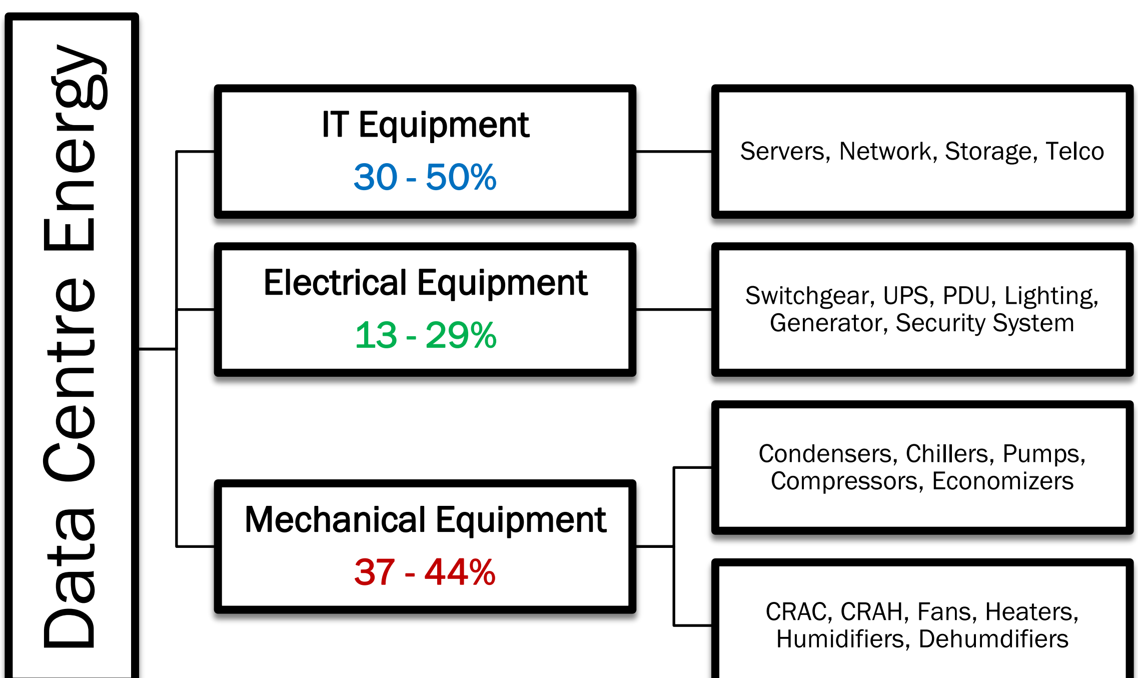


Figure 5 Typical Data Centre Energy Consumption

Most of the new data centres initially operate at lower capacity than designed limits due to smaller IT load in the first few years. However, IT load may increase as the Data Centre business grows allowing them to operate higher loads. The opportunity for energy efficiency in Data Centre increases with increase in IT Load. Also, higher the electricity bills the better reason for implementing energy saving measures.

4. Data Centre Energy Efficiency Metrics

Energy efficiency has two components (a) Passive (b) Active and passive efficiency is associated with saving energy through design and building of data centre while active efficiency is associated with saving energy during the operation of Data Centre. Thus passive energy efficiency is applicable for new data centre and active energy efficiency is applicable for all data centres especially for big & old. Also, the active energy efficiency primary objective is to reduce energy waste in HVAC loads through better air-conditioning through efficient cooling and air-flow management. However the secondary objective of active energy management is better usage of IT load through monitoring and control. This will reduce power loss in idle servers. It is important to note that 'Energy Saving Plan' need to be cost effective thus requires a detailed 'Energy Audit of Data Centre Facility' to identify potential saving opportunities. The Green Grid Association developed the Data Centre Energy Efficiency Metrics such as DCiE & PUE for benchmarking energy efficiency. Efficiency is defined as ratio of output over input. In the case of energy efficiency, it is the ratio of output energy over input energy.

Data Centre Infrastructure Efficiency (DCiE): Since the data centre infrastructure is powered by electrical energy from utilities, its efficiency is defined as ratio of electrical energy required by IT load over total energy required by data centre.

$$\text{DCiE} = \frac{\text{IT Equipment Energy}}{\text{Total Facility Energy}}$$

Power Usage Effectiveness (PUE): The inverse of data centre infrastructure efficiency is defined as 'Power Usage Effectiveness (PUE)', which is a commonly used metric for data centre energy efficiency worldwide.

$$\text{PUE} = \frac{1}{\text{DCiE}} = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

Thus, both PUE and DCiE highlight the efficiency of 'data centre facility' which is only one dimension of efficiency. The objective of measuring the data centre energy efficiency is to reduce the losses and optimize the energy usage of data centre facility there by improving the performance eventually reducing the carbon foot print. The power usage effectiveness (PUE) is a widely used metric for data centre energy efficiency worldwide but it does not provide complete picture, especially the efficiency of IT equipment or its operation. To improve the energy efficiency of data centre, it's important to improve both the efficiency of the facility as well as IT equipment.

Carbon Usage Effectiveness (CUE): It measures the carbon footprint of the data centre and is defined as the total CO_2 emissions from the data centre energy use divided by the IT equipment energy. CUE depends on the amount and source of energy a data centre is using. An ideal value of CUE is 0, where the power is totally derived from a source that has no carbon emissions such as Renewable Energy. Carbon Emission Factor (CF) for electrical energy (kWh) varies with location (country) and year as shown in Table 1.

$$\text{CUE} = \text{PUE} * \text{CEF} = \frac{\text{CEF} * \text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

Table 1: Carbon Emission Factors as per DEFRA 2012

Country	India	HK	China	Malaysia	US	Singapore	UK	Japan	EU
kgC0$_2$/kWh	1.42260	0.96825	0.92105	0.74159	0.65849	0.63575	0.58982	0.51416	0.43650

Source: https://www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting

Data Centre Performance per Energy (DPPE): Data Centre Performance per Energy (DPPE) metric was developed by Green IT Promotion Council (GIPC). The energy consumption of data centres can be measured in four phases: (a) Purchasing of Green Power (b) Efficient use of facility (c) Purchasing of efficient IT equipment (d) Efficient operation of IT equipment. DPPE has four sub metrics namely GEC, PUE, ITEE and ITEU for each phase to comprehensively assess the energy efficiency as highlighted in Figure 6.

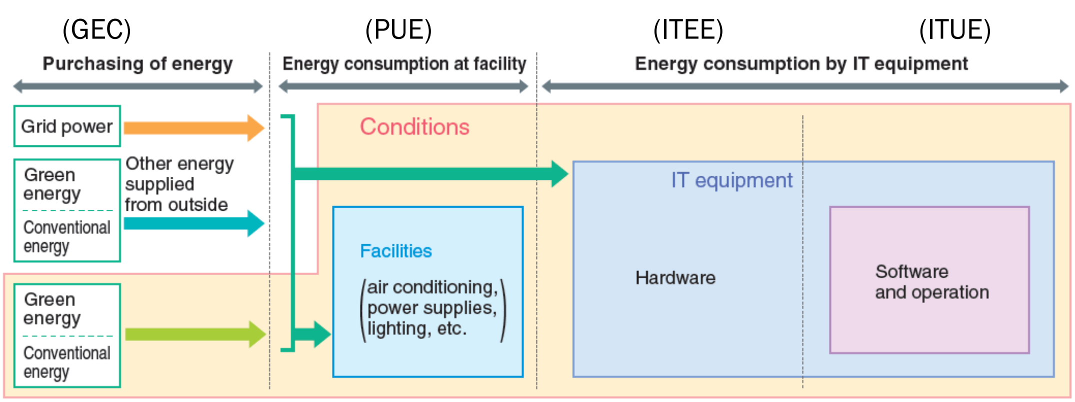


Figure 6 DPPE Metric model proposed by GIPC, Japan [8]

The use of these four metrics helps in identifying the scope of energy efficiency improvement areas in the data centre in a holistic approach. This also reduces the carbon footprint of the data centre while enhancing its performance very similar to Intel processor whose computation speed increased over the years while power consumption reduced. DPPE can be computed as per following equation:

$$\text{DPPE} = \text{ITEU} \times \text{ITEE} \times \text{DCiE} \times \left\{\frac{1}{1 - \text{GEC}}\right\}$$

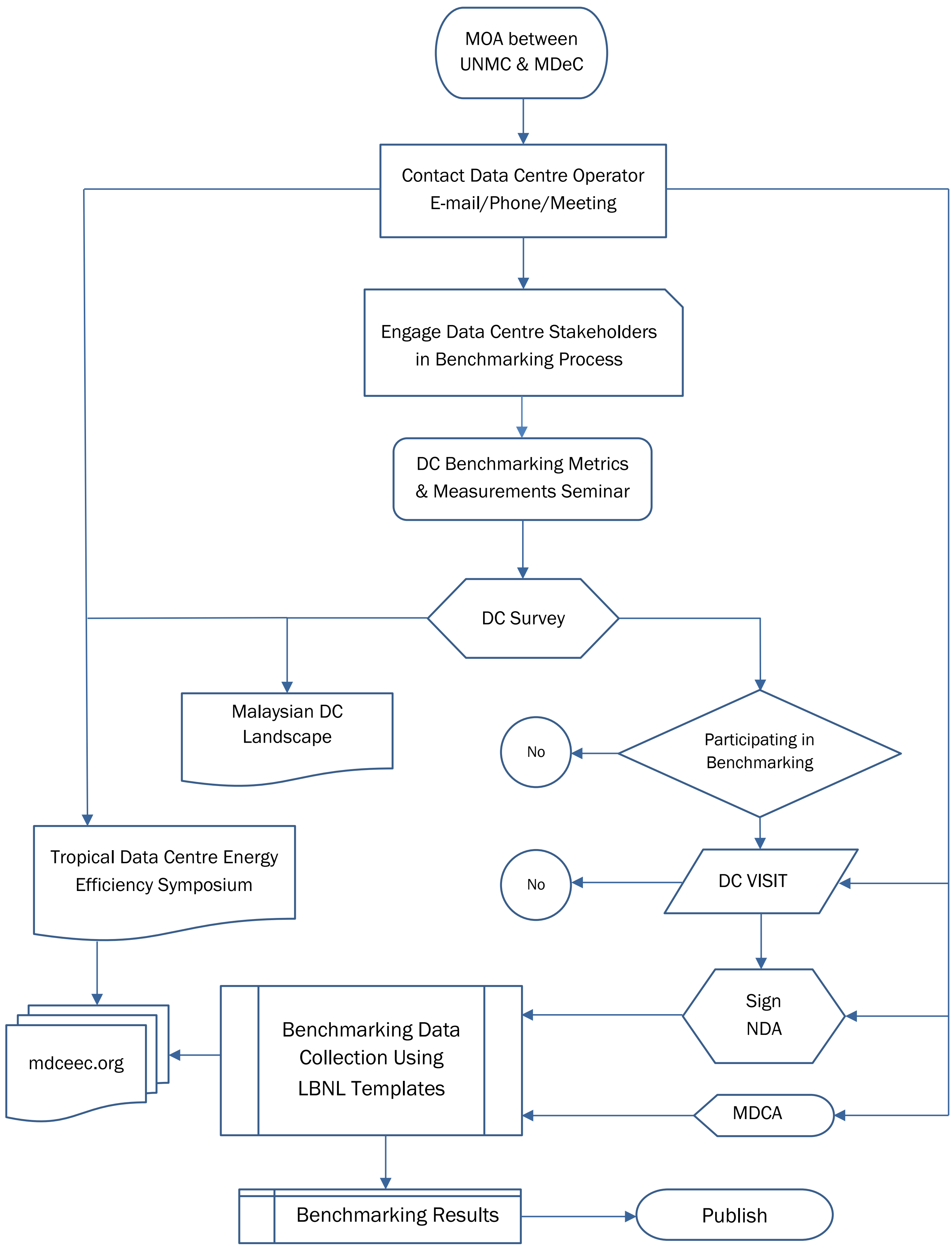
GEC	ITEE	ITEU
$\left\{\frac{\textbf{Green Energy}}{\textbf{Total Energy Consumption of the DC}}\right\}$	$\left\{\frac{\text{Total rated capacity of IT equipment}}{\text{Total rated power of IT equipment}}\right\}$	$\left\{\frac{\text{Actual energy consumption of IT equipment}}{\text{Total rated power of IT equipment}}\right\}$

The higher the value of DPPE indicates better performance of the data centre and more efficiency. For large data centres, it's essential to measure DPPE. There are two ways to assess data centre energy efficiency using the DPPE metric. The four sub-metrics are plotted on a spider chart. The larger the area enclosed by four metrics higher the efficiency. A comprehensive assessment of data centre over a period of time can provide better assessment to demonstrate higher productivity by computing DPPE. Currently, DPPE metric is under consideration by The Green GRID for adaptation. PUE is a basic DC energy efficiency metric which is widely used and it allows computation of DCiE and CUE. It is also used in the Data Centre Energy Efficiency Benchmarking studies by US(2007), EU(2010), Singapore(2011) and India (2012) thus useful for comparison benchmarking results. However, measurement of DPPE is complex and requires additional tools and resources. Thus, PUE is considered for the Malaysian Energy Efficiency Benchmarking study.

5. Benchmarking Process

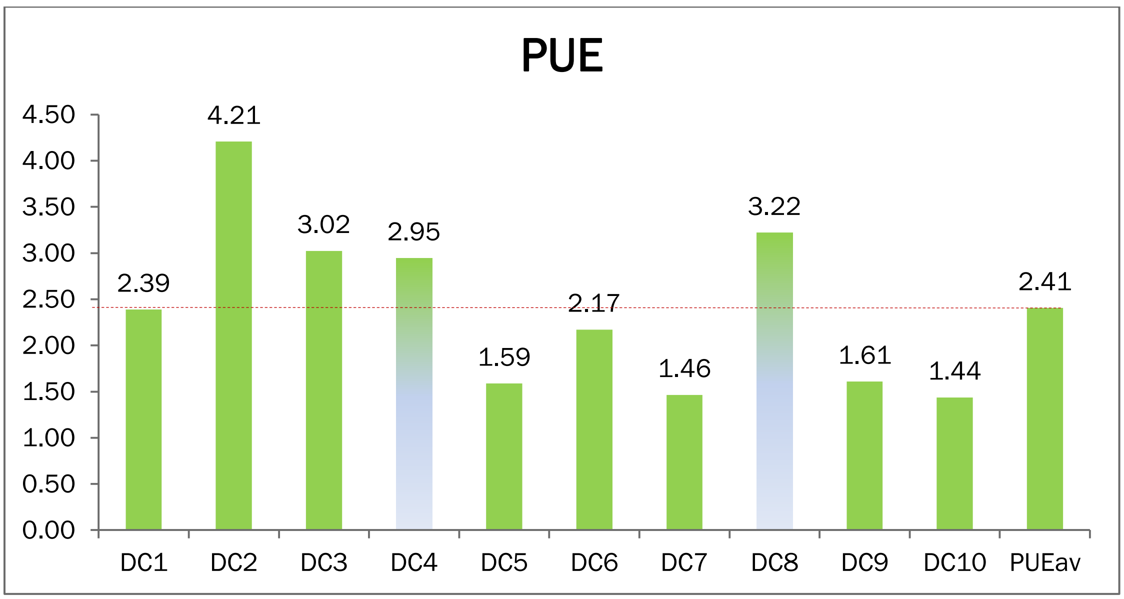
The Malaysian Data Centre (DC) Energy Efficiency benchmarking project by Nottingham University Malaysia Campus (UNMC) in collaboration with Multimedia Development Corporation (MDeC) was initiated with a seminar on Data Centre Energy Efficiency Metrics and Measurements. The seminar was mainly organized to engage DC industry stakeholders in the energy efficiency benchmarking study. It highlighted the importance of data centre energy efficiency metrics and measurement for sustainable development and for Malaysia to become a regional hub for the data centre industry. The seminar also conducted a short survey to capture Malaysian Data Centre industry awareness on Energy Efficiency and their interest in participating in benchmarking studies. Malaysia has 28 collocation data centres as per Figure 9(b) with several of them operating more than one site with majority (46%) of them located in Cyberjaya. However, only 10 data centres participated in the Benchmarking study and the detail benchmarking process flowchart is shown in Figure 7 and the results are discussed in the following section.

Figure 7 Benchmarking Process Flow Chart



6. DC Energy Efficiency Benchmarking Results

Figure 8 shows the PUE of various Malaysian Data Centres participated in the benchmarking assessment. Currently, the average PUE_{av} of Malaysian data centres is 2.41 based on the assessments of 10 Data Centres. In this study, **PUE Category 1** is used for assessment of all data centres except for DC4 & DC8. However, both DC4 & DC8 are assessed based on **PUE Category 0**. Also, the PUE of Malaysian Data Centres ranges from 1.44 to 4.21. The data centres assessed in this study come from variety of industries spanning across Banks, Telecommunications, Disaster Recovery, Manufacturing and Government. The study was conducted from November 2014 to June 2015 and the data collection and analysis is referenced to the LBNL Benchmarking Templates and site visits.



Note: DC4 & DC8 - PUE Category 0

Figure 8 Power Usage Effectiveness of Malaysian Data Centres

In the recent energy efficiency benchmarking study conducted by the National Environmental Agency (NEA) and the Infocomm Development Authority (IDA) of Singapore on 23 data centres gave an average PUE of 2.07[3]. Similarly, the average PUE of US and European Union is 2.2 and 2.02 respectively [3]. Indian data centre average PUE is 1.9 based on benchmarking of 16 data centres [7] while Japan average PUE is 1.8 based on 20 data centres [5] as shown in Table 3. The average PUE of Malaysian data centres is 2.41 as shown in Table 3 which is mainly due to the small Data Centres with relatively light load. Further analysis shows that average PUE of small data centres (PUE_{sav}) is 3.35 while average PUE of large data centres (PUE_{Lav}) is 1.78 from the Figure 10 and Figure 11 respectively. It is mainly new and small data centres contributing to a high PUE_{av} whereas old and large data centres have low PUE_{av}.

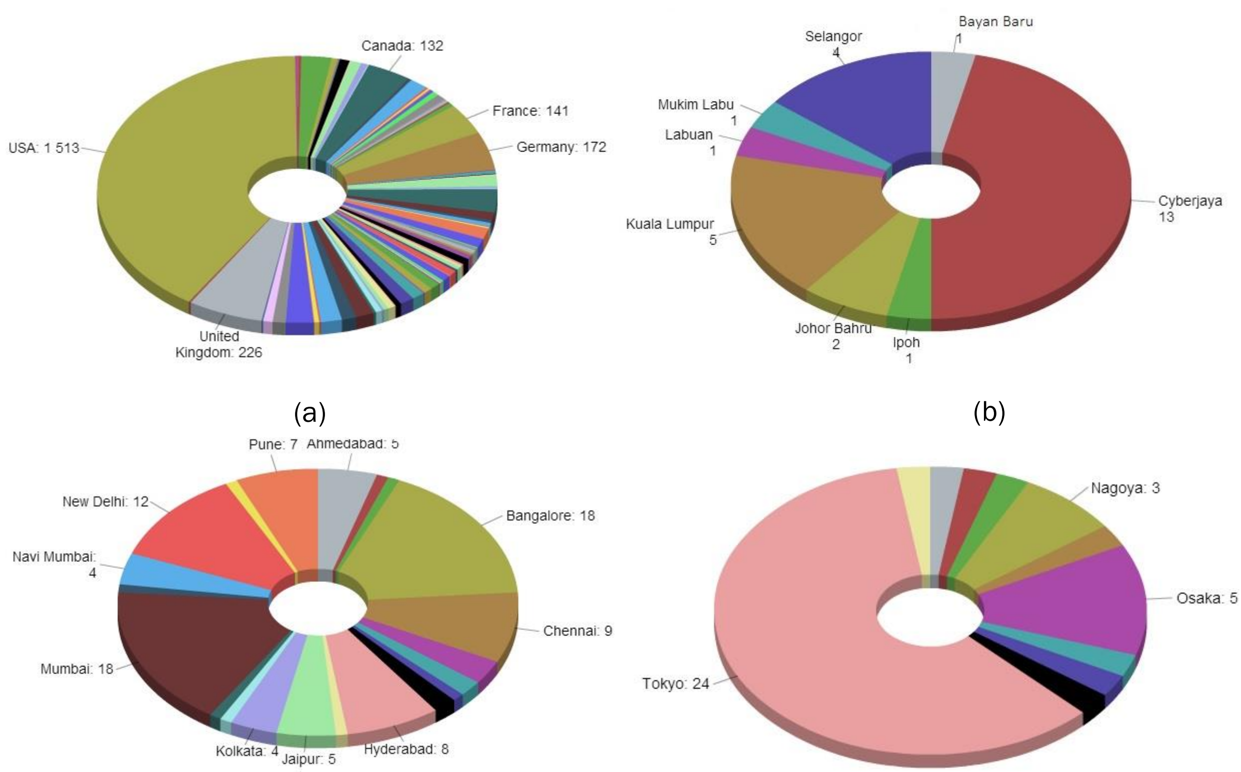


Figure 9 Collocation Data Centres in (a) Worldwide (b) Malaysia (c) India (d) Japan [7]

Table 3: Data Centre Energy Efficiency Benchmarking Study [6], [8], [10]

Country	No of Data Centres Assessed in Benchmarking	Average PUE	Year of Assessment	Total Collocation Data Centres[1]
US	75	2.20	2007	1513
India	16	1.90	2012	105
Japan	20	1.80	2011	40
Singapore	23	2.07	2012	22
European Union	25	2.02	2010	1200
Malaysia	10	2.41	2015	28

Source [1]: www.datacentermap.com

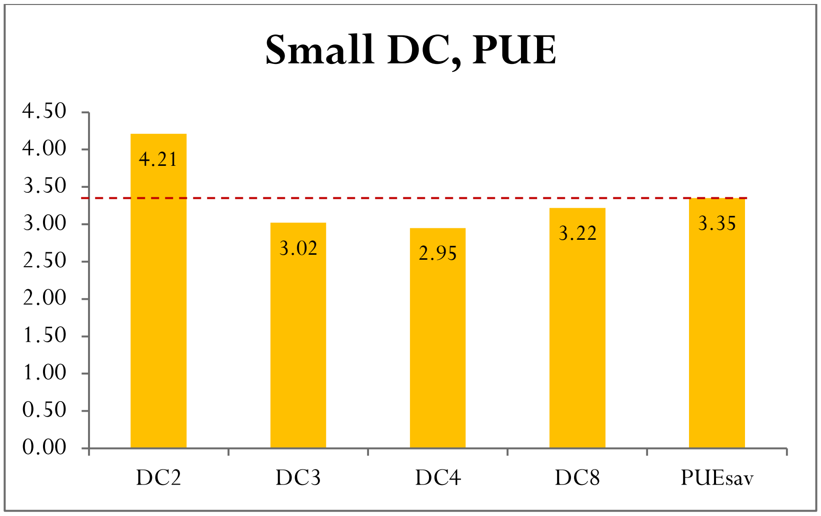


Figure 10 Power Usage Effectiveness of Small Data Centres

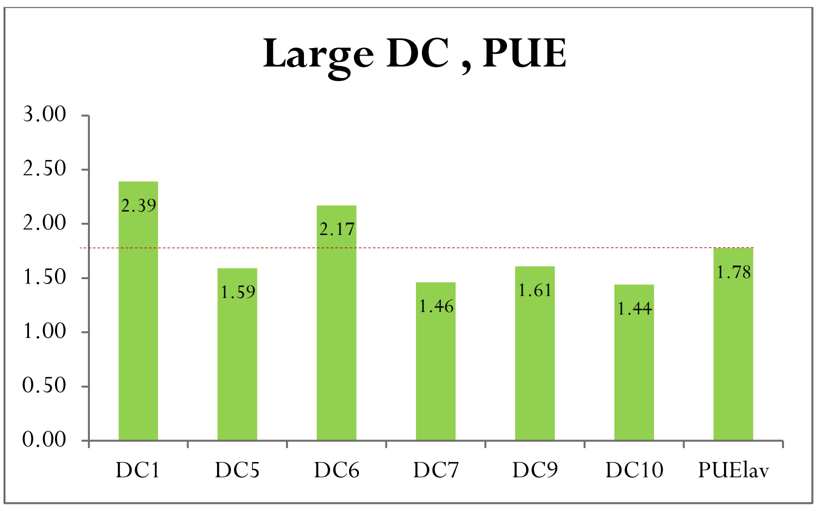


Figure 11 Power Usage Effectiveness of Large Data Centres

Table 4 compares the PUE_{Lav} and DCiE of Malaysian and Singapore data centres for the 6 sites highlighting the better energy efficiency of Malaysian data centres. Further improvement in average PUE of large data centre will enhance Malaysian Data Centre industry competitive and enhance business growth.

Table 4: Classification of Data Centre [8]

Data Area	m^2	ft^2	PUE_{av}		DCiE	
			Singapore (2011)	Malaysia (2015)	Singapore (2011)	Malaysia (2015)
Small	< 300	< 3,500	2.18(6)	3.35(4)	45.87	29.85
Medium	301 - 1000	3,501 -10,000	2.06(11)	-	48.54	-
Large	> 1000	> 10,000	**1.96(6)**	**1.78(6)**	**51.02**	**56.18**

Figure 7 shows the average data centre infrastructure efficiency of Malaysian data centres is 47% which is slightly below the standard value recommended by [10] as shown in Table 5. Similarly, PUE_{av} of Malaysia data centres is 2.41 which is below recommended value highlights the need for improvement of energy efficiencies, especially for medium and small data centres.

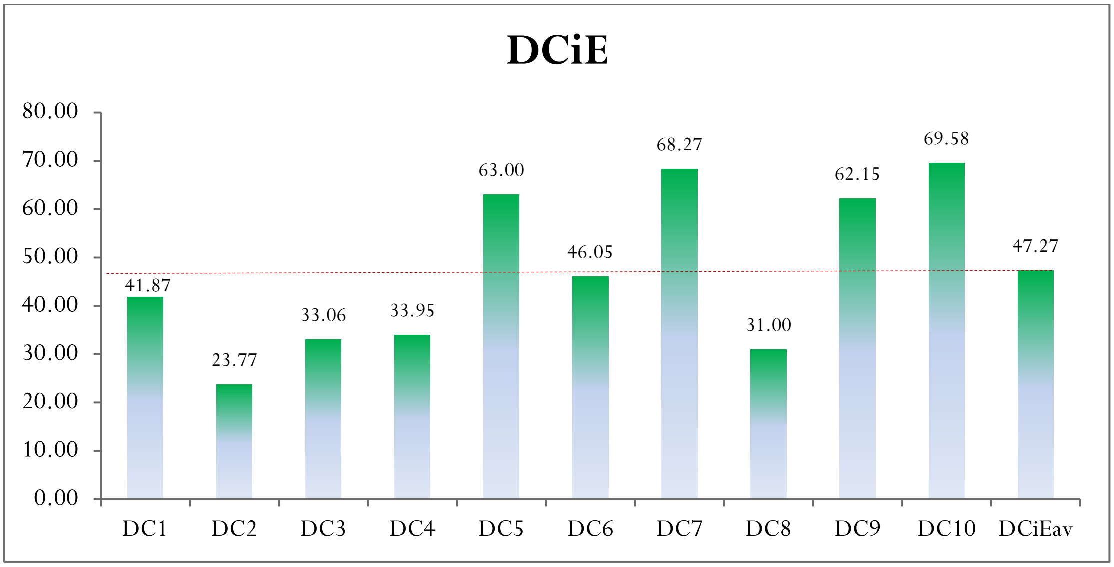


Figure 12 Data Centre Infrastructure Efficiency of Malaysian Data Centre

Table 5 Recommended DC Benchmarking Metric Values [12]

Metric	Standard	Good	Better	Malaysian DC
PUE	2.0	1.4	1.1	2.41
DCiE	0.5	0.7	0.9	0.47
$HVAC_e$	0.7	1.4	2.5	1.10
Air-Flow Efficiency, W/cfm	1.25	0.75	0.5	-
Cooling System Efficiency, kW/ton	1.1	0.8	0.6	-

Note: HVAC Load ≅ Non-IT Load

Carbon Usage Effectiveness (CUE) measures the carbon footprint of the data centre and is defined as the total CO_2 emissions from the data centre energy use divided by the IT equipment energy. CUE depends on the amount and source of energy a data centre is using. An ideal value of CUE is zero, where the power is totally derived from a source that has no carbon emissions such as RE.

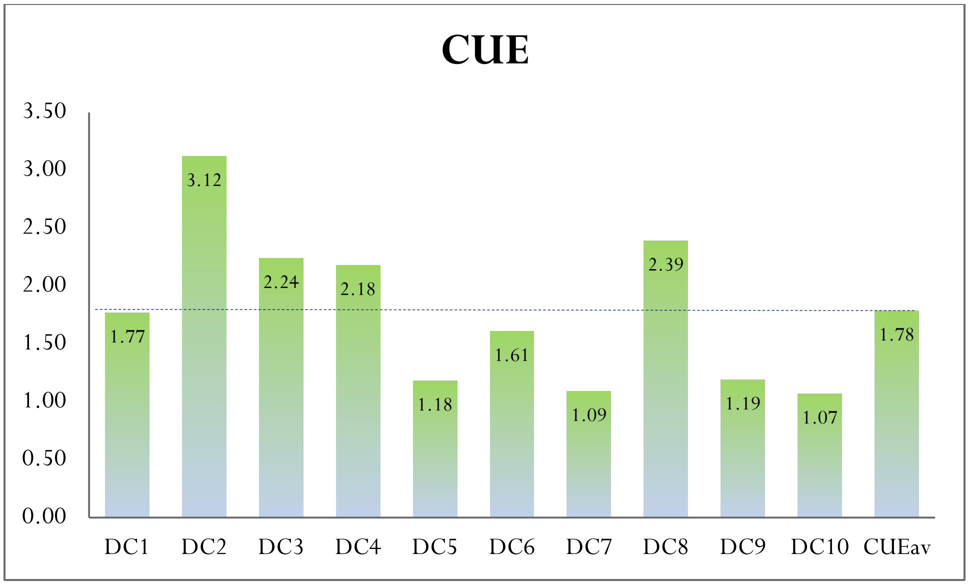


Figure 13 Average Annual Carbon Usage Effectiveness of Malaysian Data Centres

The average annual CUE of Malaysian Data Centre is 1.78 as shown in Figure 13 with the lowest value at 1.07 and highest at 3.12. The electricity grid carbon emission factor used in this report is based on year 2012 value, at 0.741 kg/kWh as shown in Table 6.

Table 6 Carbon Emission Factors for Malaysia [11]

Region	Grid Emission Factors (tCO_2/MWh)				
	2008	2009	2010	2011	2012
Malaysia	0.672	0.683	0.760	0.747	**0.741**
Sarawak	0.825	0.805	0.847	0.840	0.872
Sabah	0.651	0.612	0.574	0.531	0.546

Source: Study on Grid Connected Electricity Baseline in Malaysia

Figure 14 shows the average of Mechanical PUE of Malaysian Data Centres which is around 1.1 which is slightly higher than US (0.88), EU (0.74), Singapore (0.80). This benchmarking study could not measure electrical PUE as it requires measurement of losses in power distribution. It requires DC site access and more time to collect the data through Power Quality Monitoring Equipment such as FLUKE 435/437. Figure 10 shows an overall comparison of Malaysian Data Centre Benchmarking results with similar studies conducted by US, EU, India and Singapore. The number of data centres assessed and local climate condition contribute significantly to the evaluated metrics as well as recommended solutions to improve energy efficiency and data centre performance.

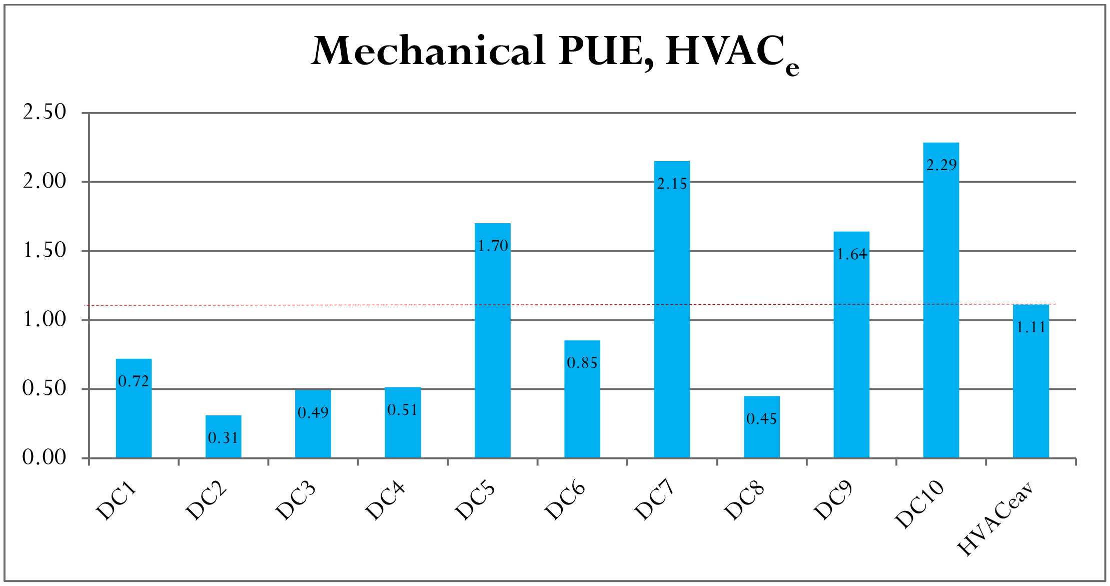


Figure 14 HVAC Effectiveness (PUE_{mech}) of Malaysian Data Centres

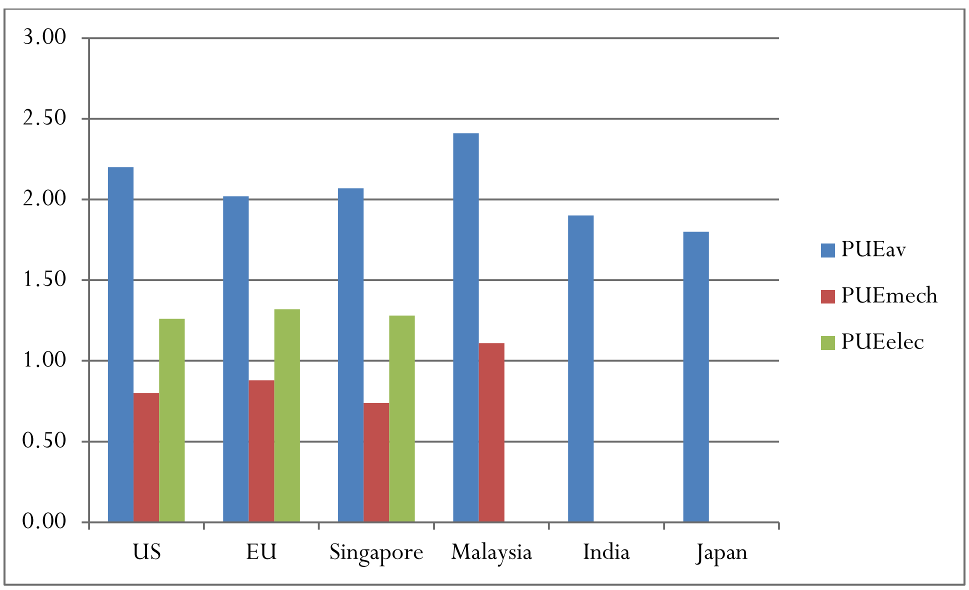


Figure 15 Overall Benchmarking Metrics Comparison [8]

Figure 16 shows the Malaysian Data Centre Landscape highlighting the small and data centre classification mapping. Similarly, Figure 17 shows Energy Footprint of the Malaysian Data Centres which participated in the benchmarking study. Perhaps, more Data Centres assessment will lead to the development of Energy Intensity of Malaysian DC industry in the near future. It will also help in developing Carbon Footprint Map of Malaysian DC Industry.

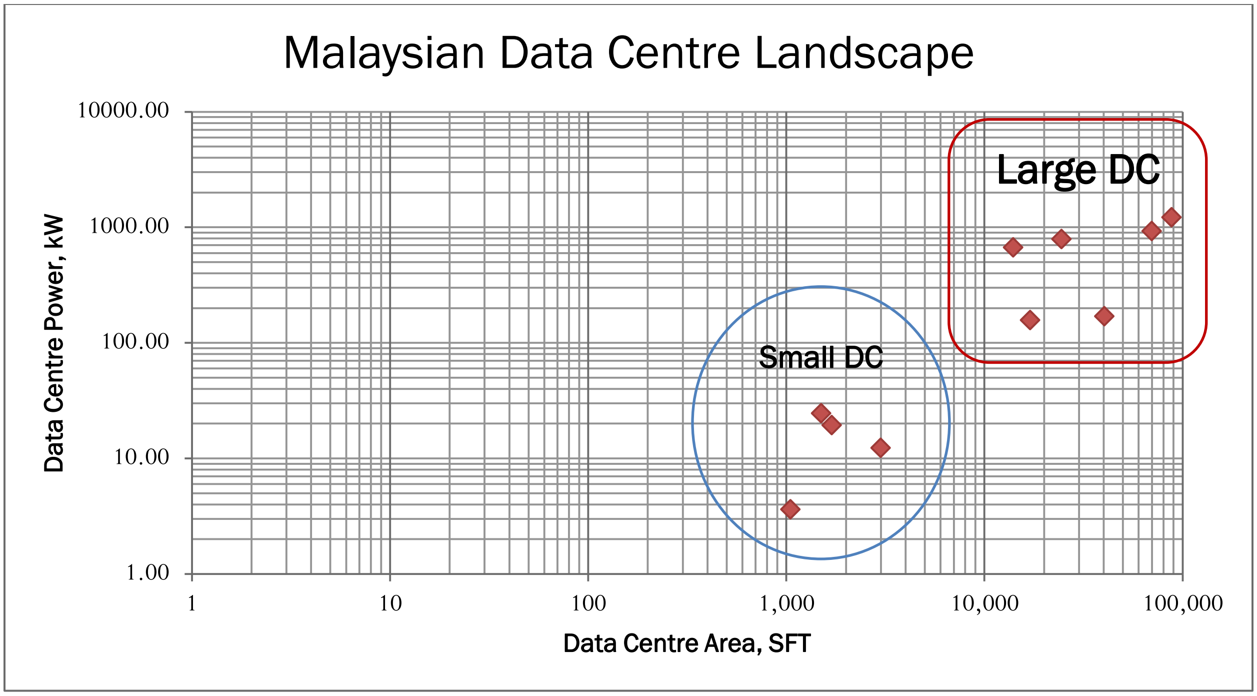


Figure 16 Energy Density Mapping of Malaysian Data Centres

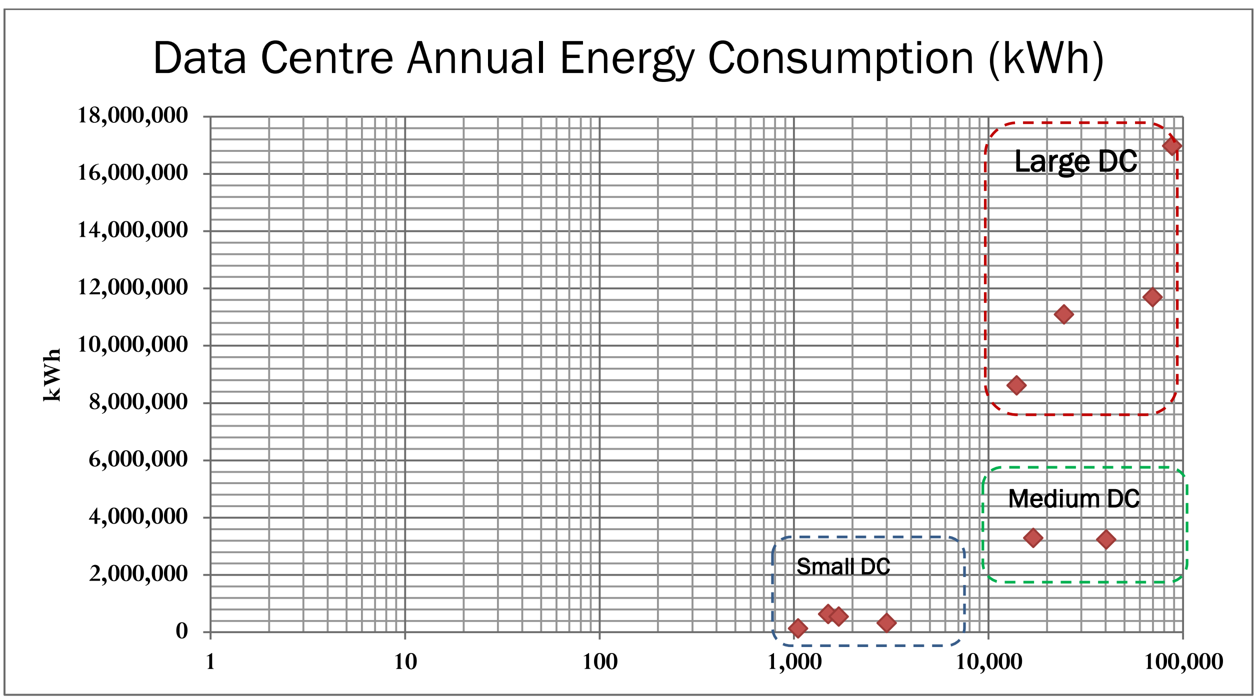


Figure 17 Energy Footprint Mapping of Malaysian Data Centres

Based on the benchmarking study the average PUE of Malaysian Data Centre is 2.41 and many data centres are running at low efficiency. The following general recommendations were provided to improve DCiE to 70% and also holistic ways to reduce CO_2 emissions is shown in Table 7.

- Measuring and reporting annual energy consumption of IT load and DC facility.
- Real-time monitoring of PUE/DCiE of Data Centre.
- Conduct Energy Audit through certified Energy Manager/Consultant/ESCO.
- Use Data Centre Best Practices Checklist to identify energy efficiency opportunities.
- Use the Energy Efficiency tools to estimate and set PUE/DCiE targets and prepare action plan based on desired cost savings and reduce carbon footprint as CSR initiative.
- Use Data Centre Best Practices Guidelines to implement energy efficiency solutions and report improvements.

Table 7 Strategies to Reduce CO_2 Emissions of Data Centres [2]

Area	Concept	Specific examples
(1) Reducing electricity consumed by IT equipment	Reducing CPU power consumption	• Using energy-saving servers equipped with quad core CPUs • Using energy-saving servers equipped with CPU power control software
	Reducing power consumption by integrating servers	• Reducing the number of servers and improving the rate of operation through virtualization
	Reducing power consumption of storage (external memory) devices	• Using smaller hard disks • Reducing the number and improving the operating rate of storage devices by virtualization
	Improving server cooling system	• Improving rack cooling efficiency by using a rear-door heat exchanger or enclosed rack systems
(2) Reducing electricity consumed by data centers (facilities) housing IT equipment	Improving airflow efficiency (cool air supply and waste heat recovery)	• Optimizing the flow of cool air by preventing heat accumulation and air leakage • Removing objects blocking airflow on and under the floor • Separating hot (heat exhaustion) and cold (cooling air) aisles
	Improving efficiency of air conditioners	• Using inverter-controlled energy-efficient air conditioners • Using a nighttime cold heat storage system
	DC power supply	• Using DC power supplies for routers and servers to reduce power loss during AC-DC power conversion
	Reducing power consumption of cooling devices	• Using free cooling (outdoor air cooling)
(3) Changing to green energy	Using photovoltaic power generation	(• Usage depends on the available space surrounding a data center)
	Using hydropower generation	(• Usage depends on the location of a data center)
	Using cogeneration (combined heat and power)	(• Usage depends on the surrounding environment)

Note: Quad-core CPU = a microprocessor that contains four central processing units in one package.

7. Barriers for Energy Efficiency

There are many barriers for energy efficiency benchmarking study and some of them are highlighted here. These are mainly due to lack of awareness and necessary resources. This could be due to lack of regulatory framework as Malaysian DC industry is still in developing stage. In fact, several Data Centres are new and some are relatively small with little scope for energy efficiency improvements. Also, for many Data Centres energy efficiency is not a top priority and thus not keen on participating in benchmarking study. To promote the energy efficiency in Malaysian Data Centres, a workshop is organized followed by symposium highlighting the importance of benchmarking data centre performance in tropical conditions. However, to promote energy efficiency in Data Centres it also requires R & D collaboration between DC industry and research institutes similar to 'Green Data Centre Innovation Program' launched by IDA, Singapore.

a) **Lack of regulatory framework**

Current energy efficiency initiatives in data centres are on voluntary basis thus relatively small number of DCs are measuring PUE for certain clients as per their customer needs. In addition, there is no information available on PUE measurement to stakeholders. This is due to lack of regulatory framework for Data Centres to share PUE to all its stakeholders.

b) **Lack of energy efficiency initiative and support**

Majority of the data centres lack resources and budget for energy efficiency initiatives from the management. This is particularly evident in small and new data centres which are on early stages of business and focused on revenue growth. However, many data centres need training for skills development to assess energy efficiency accurately and make necessary improvements, especially for large enterprise data centres.

c) **Low awareness on energy efficiency opportunities**

Lack of awareness on benefits of energy efficiency is the main reason for low participation in energy efficiency benchmarking study. Even, large enterprise data centres do not have regular energy audit and continuous PUE assessment. In addition, a couple of large enterprise data centres consume lot of energy and fall under "Efficient Management of Electrical Energy Regulations" by Energy Commission Malaysia and supposed to conduct energy audit through certified Energy Manager but no details are available in public domain.

d) **Short of expertise and resources to collect data**

This is a major concern among Malaysian data centres as many of them do not have skilled staff to assess the data centre energy efficiency and identify potential opportunities. It was noticed during the benchmarking study that data supplied by DC managers was not accurate and required site visit for verification.

e) **Not monitoring consumptions of IT/HVAC loads**

Lack of separate energy monitoring system for IT & HVAC loads at the site made collection and verification of data difficult.

f) **Shared data centre facility**

Some DCs are shared facilities thus measuring HVAC consumption for individual DCs impossible. The PUE assessment in this case is possible for entire facility alone.

g) **New data centres with light load**

Some of the data centres are relatively new and the current IT load is smaller than designed capacity. Average PUE of new and small data centres is high due to light load.

h) **Lower electricity tariff than Singapore**

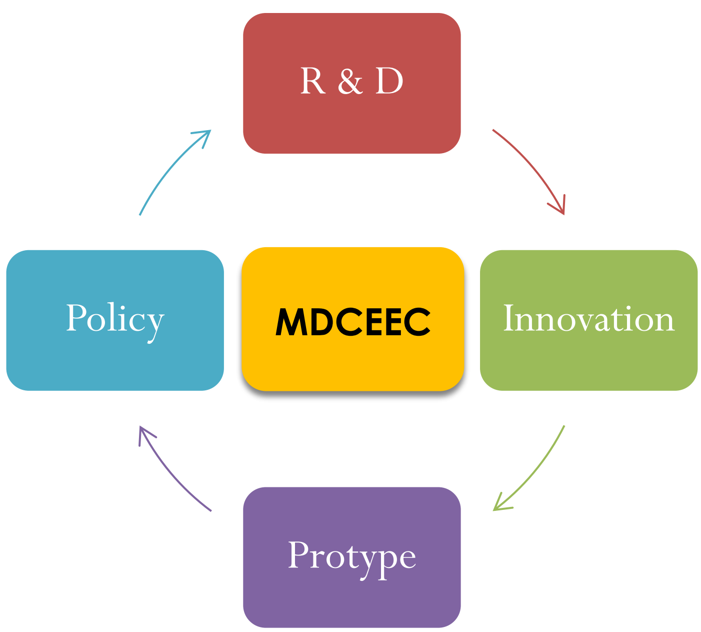
Malaysian electricity tariff is comparatively lower than Singapore and other neighboring counties thus in many data centres reducing energy cost is not a top priority unless the energy consumption is huge and improving PUE gives tangible benefits.

i) **Low energy consumption and electricity costs especially for small DCs**

Energy efficiency is not cost effective for small data centres due to low energy consumption and lower electricity bills.

8. Malaysian DC Energy Efficiency Roadmap

Malaysia is a strategic location for Data Centre business with reliable, secure and quality power supply in the ASEAN. However, Energy Efficiency is the key driver for global competitiveness in Data Centre industry. To stay competitive it is essential to enhance overall performance of Date Centres. This requires technology and solutions for not only designing and building energy efficient data centres but also operate efficiently at higher power density, operating temperatures and humid conditions. To overcome these challenges ahead it is essential to establish an R & D Program on Energy Efficient Data Centre Innovation with the collaboration of industry and university partnership in the following four key areas:



- **Research and Development:** Provide funding to innovation in energy efficient technologies for tropical data centres, modular data centres, mission critical data centres.

- **Promote Innovation**: Development and adoption of innovative technologies and solutions for energy efficient data centre through collaboration and cooperation.
- **Develop Prototypes**: Develop Energy Efficient Data Centre Innovation Centre to show case proof of concept for future technologies.
- **Develop Policy and Framework**: Develop policies and framework resources for Malaysian Data Centre Energy Efficiency Community.

9. Conclusion

The paper highlighted the energy consumption growth in the data centre industry and discussed challenges faced by ICT industry for GHG emission reduction. It explained the significance of energy efficiency in Malaysian Data Centres due to potential opportunity to reduce CO_2 emission as well as to enhance business opportunities. The paper reviewed various Energy Efficiency metrics suitable for benchmarking Data Centres and presented the Malaysian Data Centre Energy Efficiency Benchmarking project results.

The Data Centre Energy Efficiency Benchmarking project assessed 10 DCs participated in the assessment successfully. The results obtained through the assessment are comparable with similar benchmarking studies conducted by the US, EU, Japan, Singapore and India. However, further research is essential to find complete information on energy intensity of Malaysian Data Center industry through effective collaboration between various stake holders. Also, the study found that Data Centre Uninterrupted Power Supply (UPS) manufacturer can provide useful information to the energy efficiency benchmarking study as UPS can monitor IT load energy consumption.

The average PUE of Malaysian Data Centres is found to be 2.41 which is slightly higher than other countries. Also, the average data centre efficiency is found to be 47% which is slightly lower than recommended standard value. However, the large enterprise data centres in Malaysia are operating at higher efficiencies than Singapore. In future, perhaps with increase in Data Centre energy consumption and hike in electricity tariff may lead to more aggressive efforts to apply energy efficiency measures and benchmarking overall data centre performance. Figure 18 shows the snap shot of Malaysian Data Centre Energy Efficiency Benchmarking Findings.

Finally, it highlighted the current barriers for energy efficiency benchmarking in Malaysian Data Centres and recommended Data Centre Energy Efficiency Roadmap for implementing data centre energy efficiency innovation centre to enhance competitiveness of Malaysian Data Centre industry and make regional hub in ASIA.

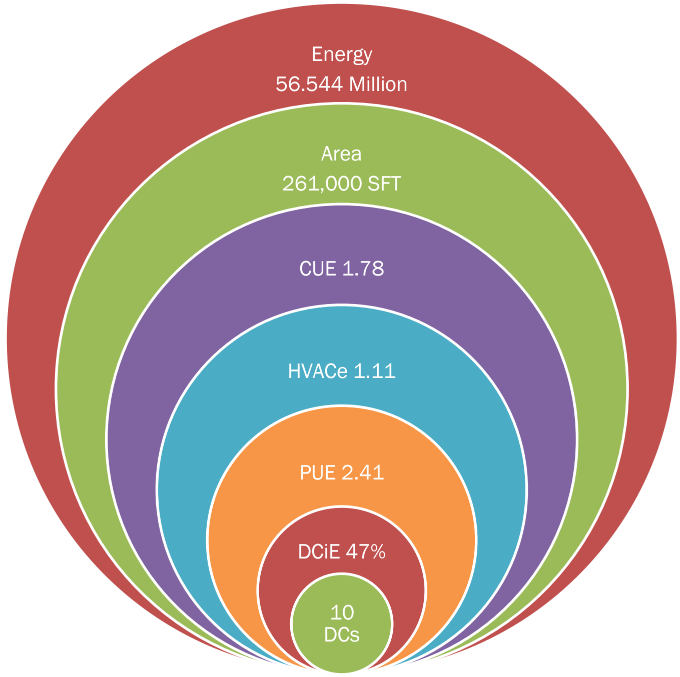


Figure 18 Malaysian Data Centres Energy Efficiency Benchmarking Study Findings

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