LOW-CARBON ICT REPORT

BASELINE STUDY OF TYPICAL GOVERNMENT DATA CENTRES

FOR

MALAYSIAN COMMUNICATIONS & MULTIMEDIA COMMISSION (MCMC),
MALAYSIAN TECHNICAL FORUM SDN BHD (MTFSB)

FINAL REPORT

BY

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY (SEDA MALAYSIA)

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CONTENT

1 GLOSSARY

PUE	Power Usage Effectiveness
DcIE	Data Centre Infrastructure Efficiency
DC	Data Centre
DEI	Data Centre Energy Index ($kWh/m^2/yr.$)
W	Watt
kW	Kilowatt
BI	Baseload Index (W/m^2)
DCI	Data Centre Carbon Index ($CO_2/m^2/yr.$)
CE	Carbon Emission
ICT	Information & Communications Technology
AC	Air-Conditioner
ACMV	Air-Conditioning Mechanical and Ventilation
T/RH	Temperature/Relative Humidity
ESM	Potential energy saving measures
UPS	Uninterruptable Power Supply
M&E	Mechanical & Electrical
IR	Infra-red
LED	Light-Emitting Diode
DB	Distribution Board
PAC	Precision Air Conditioning
UFAD	Under Floor Air Distribution

2 EXECUTIVE SUMMARY

The **Typical Data Centres in Malaysian Government Offices Baseline Study** covers the study conducted on carbon emissions from electrical energy usage in 10 selected data centres. This study is part of the Low Carbon ICT Project, conducted by **Sustainable Energy Development Authority (SEDA) Malaysia** in collaboration with **Malaysia Green ICT Committee, Malaysian Technical Forum Sdn Bhd (MTFSB)**, which is an agency under the **Malaysian Communications and Multimedia Commission (MCMC)**.

Low carbon ICT is part of the Green of ICT initiative. The baseline study includes;

a) Measure and evaluate current performance of the data centres,
b) Study the effectiveness of the current design, and;
c) Proposed general mitigation actions that able to make data centres operating more energy efficient and emits lower carbon emission.

The below are the ministries that participated in the study.

KPKT – Ministry of Urban Wellbeing, Housing and Local Government
KWP – Ministry of Federal Territories
KKM – Ministry of Health
KeTTHA – Ministry of Energy, Green Technology and Water
KPT – Ministry of Higher Education
SEDA – Sustainable Energy Development Authority
NRE – Ministry of Natural Resource and Environment
EPU – Economic Planning Unit
KLN – Ministry of Foreign Affairs
MOSTI – Ministry of Science, Technology and Innovation

The Low Carbon ICT project is part of the Green Technology Roadmap by the National Green Technology & Climate Change Council which focuses at the quantitative measures on electrical energy usage and carbon emissions through the use of the carbon conversion factor formula.

This report presents the findings of electrical energy used to operate the data centre and the equivalent carbon emissions from the amount of energy used. The electrical energy used is generated from mostly non-renewable energy sources in Malaysia. These petro-fuel energy sources will release carbon dioxide (CO_2) into the environment through its generation of electricity process. This is the primary greenhouse gas which has a negative effect on the environment, causing global climate warming.

From the analysis, all findings can be summarized as below:

SITES	AREA (m2)	1 YEAR ENERGY CONSUMPTION (kWh/year)	CO_2 EMISSION (kg/year)	PUE = TOTAL/ICT	DCIE = ICT/TOTALx100% (%)	DATA CENTRE ENERGY INDEX (kWh/m2/year)	DATA CENTRE CARBON INDEX (kg/m2/year)	RANKING PUE	Ranking DC Energy Index (BEI)
Site 1	30.0	41,698	31,148	2.17	46	1390	1038	4	2
Site 2	49.5	159,376	119,054	4.39	22.8	3220	2405	9	6
Site 3	40.0	354,166	264,562	1.25	79.9	8854	6614	1	11
Site 4	74.0	282,223	210,820	2.20	45.5	3812	2847	5	7
Site 5	103.1	282,663	211,149	2.04	49	2742	2048	3	4
Site 6	64.7	256,749	191,792	5.01	20	3971	2966	10	8
Site 7	79.4	235,831	176,166	2.63	38.3	2970	2219	8	5
Site 8	194.6	228,798	170,912	2.34	42.7	1176	878	7	1
Site 9	53.4	127,812	95,476	1.57	63.7	2393	1787	2	3
Site 10	104.1	432,983	323,438	2.3	43.8	4159	3107	6	9
				2.59	**45.2**	**3469**	**2591**		

Table 2 Summary of analysis for baseline study of typical Government Data Centre

From the above table average PUE obtained is 2.59 and DcIE is 45.2%. While carbon emission Data Centre Energy Index average is 3469 KWh/m^2/year and Data Centre Carbon Index is 2591 kg/m^2/year. It is found that the most efficient data center based on PUE and DcIE is site no. 3 with PUE value of 1.25 and DcIE value of 45.2%.

3 INTRODUCTION

This is a report of a baseline study, conducted into the subject of the **Typical Data Centres (DCs) in Malaysian Government Offices**, on carbon emissions from electrical energy usage in data centres. The baseline study is part of the Low Carbon ICT Project to study the effectiveness of design and implementation of energy efficient data centres or better known as Green of ICT.

The baseline study was conducted by the **Sustainable Energy Development Authority (SEDA Malaysia)** in collaboration with **Malaysia Green ICT Committee, Malaysian Technical Forum Sdn Bhd (MTFSB)**, which is an agency under the **Malaysian Communication and Multimedia Commission (MCMC)**.

The Low Carbon ICT project is part of the Green Technology Roadmap by the National Green Technology & Climate Change Council which focuses on the quantitative measures on energy usage and carbon emissions through the use of the carbon conversion factor formula.

In this baseline study project, 10 typical government data centres (DCs) have been involved. A team of engineers familiar with energy consumption studies and IT systems collect data by placing data measuring equipment on the electrical distribution board (DB) for recording the energy consumption of the ICT equipment and energy used for lighting, cooling and powering up the data centre. While at the same time, logging the temperature and humidity levels within the data centre environment.

The ICT equipment installed in the data centre consists of servers, monitors, hubs and routers that are interchangeable. The support equipment necessary for the ICT equipment includes the Uninterruptable Power Supply (UPS) and the Air-Conditioning (AC) system equipment. The baseline study provides an analysis of the efficiency of the energy used in the Data Centre (DC).

A common reference to determine the energy efficiency index of typical data centre is the ***Power Usage Effectiveness (PUE)***. This PUE is a measure of how efficient a data centre uses energy.

The PUE is derived from the ratio of the total electrical energy (kWh) used by the data centre facility (air conditioning, lighting and ICT equipment) to the electrical energy (kWh) used for operating the Information & Communication Technology (ICT) equipment alone. **An ideal PUE is 1.0 to 1.2. The lower the ratio, the more efficient the data centre.**

$$\mathrm{PUE} = \frac{\textit{Total Energy Consumption by Data Centre } (kWh)}{\textit{Total Energy Consumption by IT Devices } (kWh)}$$

The reference PUE itself was derived by a consortium called The Green Grid. The consortium is made up of a number of major IT providers, telcos and communication end-users as well as policy makers, facility architects and utility companies.The electrical equipment in the data centre usually consists of all ICT equipment including servers, server monitors, hubs/routers, uninterruptible power supplies (UPS) and communications devices. The total electrical energy for the data centre includes all ICT equipment as well as the air conditioning (both centralized and stand-alone) and lighting equipment.

The PUE is used by operators, facility managers and architects (data centre designer) to determine the energy efficiency of their data centres. To obtain the most accurate PUE, all electrical energy consuming equipment must be included in the main three segments, that is, ICT equipment, air conditioning equipment and lighting and any other electrical energy consuming equipment involved in the operations of the data centre.

Another industry parameter used is Data Centre Infrastructure Efficiency (DcIE). This is the reverse of the PUE and is valued as a percentage. **An ideal DcIE is 100%. The higher the percentage, the more efficient the data centre.**

$$\text{DcIE} = \frac{\textit{Percentage of total Energy Consumption by IT Devices}}{\textit{Percentage of total Energy Consumption by Data Centre}}$$

Naturally, climate plays a slight role in energy consumption of the data centre. For example, in a hotter climate, the air conditioning load will be substantially higher than in a cooler climate. So the data centre PUE should be compared with other data centres in the same region/climate.

In addition, the PUE should be calculated based on the full load capacity of the data centre as this will impact the results. For example, a data centre is built for a certain capacity but the ICT equipment is only partially used but the air conditioning system is designed for full capacity. The result will be affected by the high energy consumption of the air conditioning system and low energy usage of the ICT equipment giving a very high PUE. To determine the air conditioning system design, a closer look at the temperature setting and relative humidity level is required. ASHRAE recommends **a temperature range of between 18 and 27°C.** All ICT equipment are compliant to this ASHRAE recommendation. Most equipment are designed for temperatures up to 40°C while some others even higher. However, because of the build-up heat in the racks, the recommended operating temperatures are as stated. The recommended humidity level is 60% for the cold aisle.

Another factor contributing to the air conditioning loading is the amount of heat entering the data centre. This can be due to a number of reasons, including leaving the data centres doors open, insufficient ventilation for heat removal from ICT equipment and having a large external window area.

4 BACKGROUND

"I would like to announce here in Copenhagen that Malaysia is adopting an indicator of a voluntary reduction of up to 40% in terms of emissions intensity of GDP (gross domestic product) by the year 2020 compared to 2005 levels,"

Source: Prime Minister Datuk Seri Najib Tun Razak in his speech at the United Nations Climate Change Conference 2009.

The Low-carbon ICT project is expected to reduce energy consumption in buildings, in line with the National Green Technology Policy and carbon reduction intensity pledge of 40% per GDP by the Prime Minister at the Conference of Parties 15 (COP 15) in Copenhagen, Denmark.

Due to development in technology and communications, the yearly growth in ICT has been found to be between 7 and 10% contributing to higher energy consumption in building energy use. The **current world energy consumption** specifically only on ICT is **4%** and is expected to increase to **8%** by **2030**. In Malaysia, ICT contributes to 9.8% of the GDP and is targeted to increase to 17% by 2020.

The Low-carbon ICT project seeks to quantitatively assess the energy usage and carbon emissions of an ICT system, through the use of the carbon conversion factor formula. Having assessed the energy usage, the project also looks for measures and methods to reduce the energy usage, and consequently, the carbon emissions of the ICT system. The main purpose of the Low-carbon ICT project is to understand the current energy consumption pattern which is then converted to the amount of carbon emitted.

To start, SEDA Malaysia proposed the data centre energy efficiency baseline study of typical government data centres. The baseline study will provide the much-needed precise data required to resolve the two major issues affecting energy efficiency in the ICT sector, namely the absence of a baseline study of energy consumption and carbon emissions of typical data centres.

With this study, possibilities for carbon mitigation can be explored further. The aim is to reduce the carbon footprint of the ICT system while maintaining or increasing the performance of the system. With the information, facts and figures obtained through the baseline studies, possible solutions and measures for reducing energy usage and lowering carbon emissions can be formulated.

The findings or potential energy saving measures from this study can be used as a reference to guide industry players and data centre owners in future upgrades and modifications of their data centres. This would both involved design for data centre rooms as well as selection and operation of ICT equipment.

The study conducted by SEDA Malaysia was also assisted by the building ICT officers and facility management personnel.

The audit team members are listed below:

SEDA Malaysia

i. Energy Demand Management Division

   a. Steve Anthony Lojuntin
   b. Ishamuddin Mazlan
   c. Mohd Najmi Abdullah Sani
   d. Mohd Amirshaifulrazain
   e. Mohd Sharizal Sharif
   f. Mohd Faizal Nor Azmi
   g. Mohd Rozi Mohd Yaacob
   h. Andrea Jeanne D'Rozario
   i. Jeyakumar Singam

ii. Information Communication and Technology Division

   a. Leong Cheong Foo
   b. Hazril Izan Bahari

5 OBJECTIVE

The Low-Carbon ICT – Data Centre Baseline Study, undertaken by SEDA Malaysia seeks to determine the energy usage of existing data centres and therefore the energy efficiency and carbon emissions generated by typical government data centre operations.

As such, the objectives of the Low-Carbon ICT – Data Centre Baseline Study are:

1
- To determine the current baseline of typical data center, full description of audited data centers (kWh), the PUE, DciE, the carbon emission, the usage levels of data centers, and to collect demographic information of sample;

2
- To evaluate the progress/accomplishment of data center development in typical data center in office building and to provide base value for the chosen indicators; and

3
- To draw initial conclusion that can be applied generally to represent status of data center in typical data center in government office building.

6 SCOPE OF WORKS AND TIMELINE

Data Collection and Measurement

- Power, Energy, Temperature and Relative Humidity, ICT equipmentand facility energy consumption, etc.

Power Usage Effectiveness (PUE)

- Calculate the value of PUE in order to determine the current baseline.

Data centre infrastructure Effectiveness (DcIE)

- Calculate the efficiency of the data centre by percentage.

Data centre energy efficiency index (DEI)

- Calculate the enegry efficiency index based on yearly energy consumption of the facility size

Baseline Index (BI)

- Calcualte the data centre basline index based on energy consumption over unit floor area

Carbon Emission (DCI)

- Evaluate the amount of carbon emitted into the environment by the data centre operation.

General Potential Saving Measures

- Identify/recommend general possible saving measures

Figure 6.1 Scope of Works

The scope of works covers seven (7) main areas of study as shown in Figure 6.1 above. The timeline schedule of the project is seen in Figure 6.2 below.

Cadangan Pelan Kerja Projek ICT Rendah Karbon (Pembangunan Baseline Data Centre) 2014/2015

Bil.	Aktiviti	Status	2014									2015											
			Q2			Q3			Q4			Q1			Q2			Q3			Q4		
			4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1	Progress Report Submission & Invoice																						
1.1	- Penyediaan Deraf bajet & aktiviti termasuk penentuan lokasi dan parameter utama untuk Baseline.	100%																					
1.2	- Pembentangan kertas konsep kepada Jawatankuasa Kerja GICT (SKMM)	100%																					
1.3	- Pelantikan SEDA M'sia oleh SKMM (15% pembayaran)																						
2	Perancangan Awal																						
2.1	- Mesyuarat Kick -Off Program	100%																					
2.2	- Penubuhan & Mesyuarat Jawatankuasa Kerja LCICT (SEDA)	100%																					
3	Pelaksanaan Projek Perintis																						
3.1	a) Audit Tenaga (lokasi pertama) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.2	b) Audit Tenaga (lokasi ke-2) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.3	c) Audit Tenaga (lokasi ke-3) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.4	Progress Report Submission & Invoice (25% pembayaran)																						
3.5	d) Audit Tenaga (lokasi ke-4) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.6	e) Audit Tenaga (lokasi ke-5) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.7	f) Audit Tenaga (lokasi ke-6) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.8	Progress Report Submission & Invoice (25% pembayaran)																						
3.9	g) Audit Tenaga (lokasi ke-7) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.10	h) Audit Tenaga (lokasi ke-8) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.11	i) Audit Tenaga (lokasi ke-9) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.12	j) Audit Tenaga (lokasi ke-10) -Perbincangan, lawatan tapak, audit tenaga & analisa data	100%																					
3.13	Progress Report Submission & Invoice (25% pembayaran)																						
4	Penyediaan Laporan kajian projek perintis & Baseline																						
4.1	-Penyedian Laporan Keseluruhan	80%																					
4.2	-Penyediaan slide dan nota	80%																					
4.3	-Final Report Submission (10% pembayaran)																						
4.4	-Pembentangan kepada Jawatankuasa Kerja LCICT (SEDA)	0%																					
4.5	-Pembentangan kepada GICT WG (SKMM)	0%																					
4.6	-Taklimat kepada stakeholder	0%																					

Figure 6.2 Timeline of Study

7 ENERGY AUDIT METHODOLOGY

7.1 Study Approach

A methodical study was undertaken to review the electrical energy usage operations of the data centre. An emphasis was placed on considering the factors that affect the PUE, whether positively or otherwise. This is as the steps taken to reduce the PUE, and consequently the energy usage are tied to the carbon emissions.

7.2 Data Collection of Data Centre Operation & Determining Utilization Factor

As energy usage is influenced by the manner in which a facility is operated and utilized, it was necessary to collect energy usage data on a continuous basis, for a number of days, to have a comprehensive understanding of the energy usage of the DC, along with the working environment of the DC. In this study, the data was collected or logged for a continuous 7 day period. This allows for a thorough analysis of energy usage in the DC, both over working days and also the non-working days. Ordinarily, there should be a quantifiable difference between the energy usage readings for working and non-working days.

The energy usage was measured and analyzed in order to establish a baseline. Information on the layout of the cabinets and ICT equipment installed in the Data Centre was also collected. This, along with information gathering from the DC IT personnel, would help to have a better understanding of the day-to-day operations in the data centre and its effect on the DC energy usage.

To meet this data collection requirement, data loggers were used to establish the overall DC load profile and the major energy consuming elements in the DC.

7.3 Energy Audit Tools and Equipment

The energy audit team used a number of measuring and monitoring equipment for the data collection for use in the analysis. The list of the equipment is seen below in Table 7.1:

No.	Equipment	Brand	Model	Parameter
1	Temperature & Humidity Data Logger 	HOBO	UX100-003	Temperature

No.	Equipment	Brand	Model	Parameter
2	Power Meter Data Logger 	Kyoritsu	KEW 6305	I, V, kW, kWh, PF
3	Thermal Imaging 	Testo	875-1	Thermal Mapping
4	Lux Meter 	Testo	540	Illuminance

No.	Equipment	Brand	Model	Parameter
5	IR Thermometer 	IRtek	IR 40	Temperature
6	Anemometer 	Extech	AN100	Air flow rate

Table 7.1: List of equipment types used during the audit

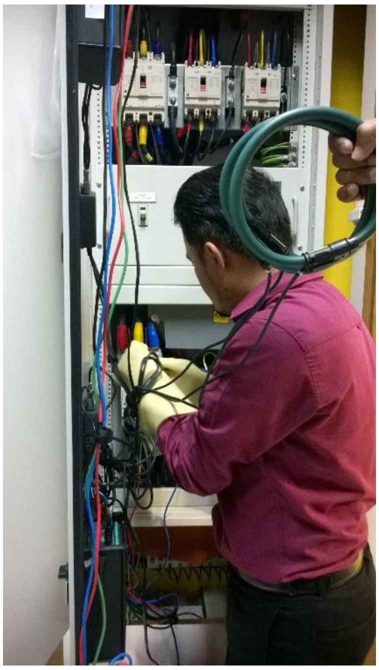


Figure 7.1 Data Logger installed at DB

Figure 7.1 shows the data logger being installed at the Distribution Board (DB) by a baseline team member.

Figure 7.2 HOBO Temp/RH Logger

Fig. 7.2 shows the HOBO Temp/RH Logger being mounted at the Data Centre air-conditioner by the team.

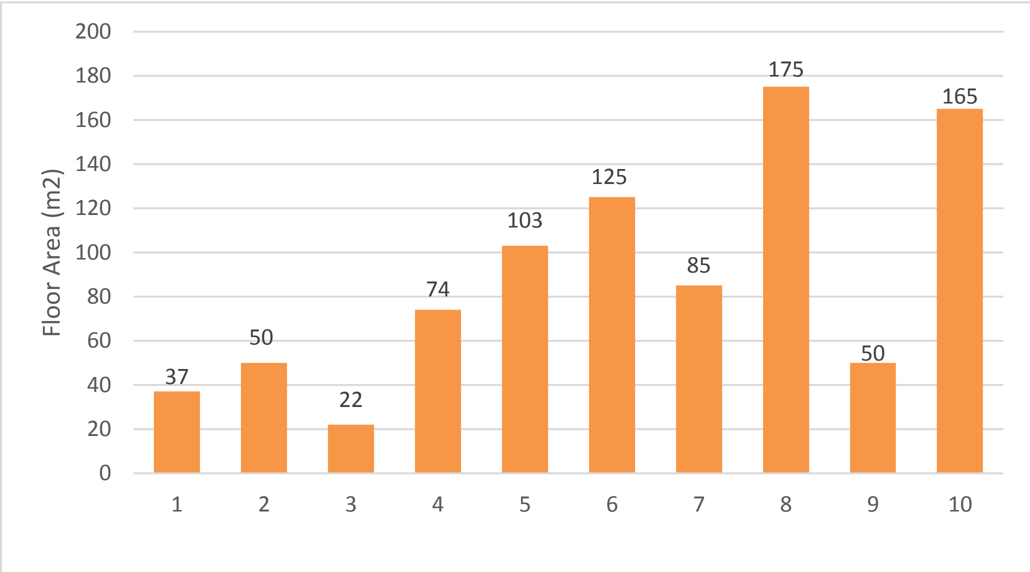
Note: Sample photos from previous study

8 DATA CENTRE INFORMATION AND DESCRIPTION

8.1 General Review

In the general review of the data centre, the team identified the layout of the room, locations of server racks and placement of the maintenance room where the battery racks, UPS and electrical distribution boards were located. This allowed the team to observe the functional effectiveness of the air conditioning system to remove heat and provide cooling.

Table 8.1 Floor area of each data centre / site



The table above shows the floor area (m^2) for each site. The smallest area being Site 3 and largest, Site 8. This information is crucial in determining the intensity of energy use of each site as in kWh/m^2. With this, each site can be compared against each other to show which layouts or designs or equipment selection is most energy efficient.

The following pictures show the layout of the data centres and the types of systems used for sites 4 to 10. For site 1, 2 and 3, pictures were not permitted to be taken.

a) Site 1 is a small room layout and uses split air conditioning units.

b) Sites 2 supply the cooled air from Precision Air Conditioning (PAC) directly to the data centre room. There are 3 ACSU units, in the data centre, which supply cooled air to the data centre room area.

c) Site 3 used In Row air-conditioner units which supply cooling air into the cubicle or enclosure directly. The cooling air is then ventilated out through the racks to the surrounding room area. The air is then sent back to the In Row air-conditioners PAC units through the return ducting in the ceiling. The heated air in the surrounding room is then drawn into the In Row air-conditioners.

d) In Site 4 seen below in Figure 8.1, the air conditioning is supplied to the surrounding room area through In Row units facing towards the outer side of the cubicles. The air is recirculated back through the ICT racks into the inner cubicle area and then ventilated out through ceiling ducts located above the cubicles.

Figure 8.1: Site No. 4

e) In Site 5 seen below in Figure 8.2, the air conditioning is supplied into the cubicles through the supply ducting and ventilated out through the racks to the surrounding room area. The air is then ventilated back to the PAC units through the return ducting in the ceiling.

Figure 8.2: Site No. 5

f) In Site No. 6 seen below in Figure 8.3, the air conditioning is supplied through PAC units located at different parts of the room. For site 6, the PAC supplies air through the UFAD system.

Figure 8.3 Site No.6

g) For site 7, the PAC units supply air directly into the room area.

Figure 8.4 Site No.7

h) In Site No. 8, the air conditioning is supplied through PAC units located at different parts of the room. The PAC units supply air through the UFAD system.

Figure 8.6 Site 8

i) Site No.9, differs slightly from site 4 where the In Row air conditioning system is located within the cubicle and the air is ventilated through the racks to the surrounding room area.

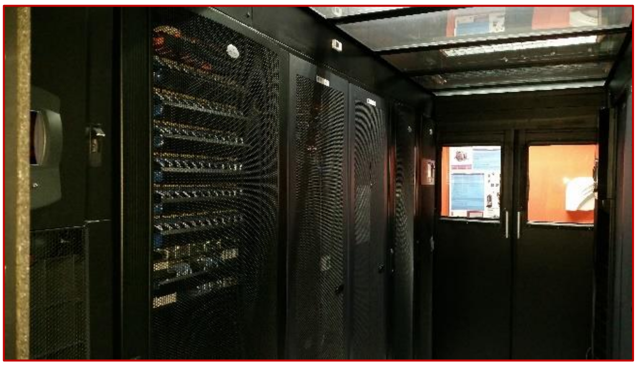


Figure 8.2 Site 9

j) In Site No.10, the air conditioning is supplied through PAC units located at different parts of the room. For site 10, the PAC units supply air through the UFAD system.

Figure 8.7 Site No.10

The detailed configurations of each site can be seen in Appendix 1.

8.1.1 Data Centre Passive System

The passive system of the data centre is the non-moving or non-electrical elements of the room which includes the wall and window construction, floor design and server rack configuration. A good passive design will provide good air movement and insulate the data centre room from outside heat.

8.1.2 Data Centre Active System

The active system of the data centre is the electrical elements that are used to supply power to the respective equipment such as the lights, air conditioning units, UPS, battery bank and ICT equipment. Proper selection and sizing of ICT equipment and cooling systems are crucial to optimize the energy consumed in the data centre.

8.1.3 Air Conditioning & Mechanical Ventilation System and Control System

The ICT room of the data centre has a dedicated air-conditioning system. As the cooling is used only to supply the data centre room, no outside air is drawn into the room. This eliminates the need for any mechanical ventilation in the form of an exhaust or inlet air fan.

Generally, three types of air conditioning equipment were used in the data centres participating in this study. Split Unit ACs are used in a few of the data centres. In Row ACs are units that can be slotted in between ICT racks that are usually placed in an enclosure. These In Row AC units are used in a few of the data centres here. The larger floor-sized data centres use PACs which provide a large amount of cooling for large areas.

8.1.4 Lighting System

The lights in the data centres are switched off at all times, unless required when maintenance work is carried for the ICT equipment. The lighting type uses 2 x 36W fluorescent lightbulbs with fully reflective louvres. The diffuser size is 2’ x 2’ and is fitted into the ceiling.

8.1.5 Uninterruptable Power Supply (UPS)

The incoming electrical supply is fed through the UPS unit to the ICT equipment. The UPS supplies a conditioned electrical supply to the ICT equipment. The UPS serves two purposes. The first is to provide an emergency or back-up power supply to the data centre, in the event of a failure of the power supply to the building. The second is to “condition” or “smoothen” the incoming power supply, by removing any “spikes” or “dips” in the incoming power supply voltage. Sharp spikes or dips tend to reduce the working lifetime of the ICT equipment and can also damage the ICT equipment.

It is important to note that the UPS consumes energy due to high frequency switching when conditioning the output power to the ICT equipment. The UPS usage amounts to approximately 5% of the total ICT load. It is important to consider this during measuring the energy consumption of the ICT equipment and data centre facility equipment.

The UPS supplies the emergency power supply only for a limited time, perhaps enough for 20 minutes time period. This time period is sufficient for the Data Centre staff to perform the proper shutdown procedure for the ICT equipment. Servers that have not been shut-down in the proper manner may suffer serious file system damage or data may be corrupted.

9 RESULT AND FINDINGS

9.1 Energy Breakdown and Carbon Analysis

To obtain the energy breakdown for each set of equipment, multiple energy data loggers were used. The data loggers connected to the electrical power supply to the major energy-consuming equipment groups including the overall data centre:

1. the total ICT equipment (before UPS)
2. the total ICT equipment (after UPS)
3. The total Air-Conditioning system for cooling ICT equipment.
4. The total data centre load.

Temperature loggers were also placed in various locations to obtain the temperature and humidity levels in the data centre. The data was collected over a 1-week (7-day) period. The summary report of each site is shown in Appendix 2.

The chart Table 9.1 below shows the percentage breakdown in energy consumption for the three major energy consuming groups. This is to show how much energy is needed for both ICT equipment and utilities (air conditioning and UPS).

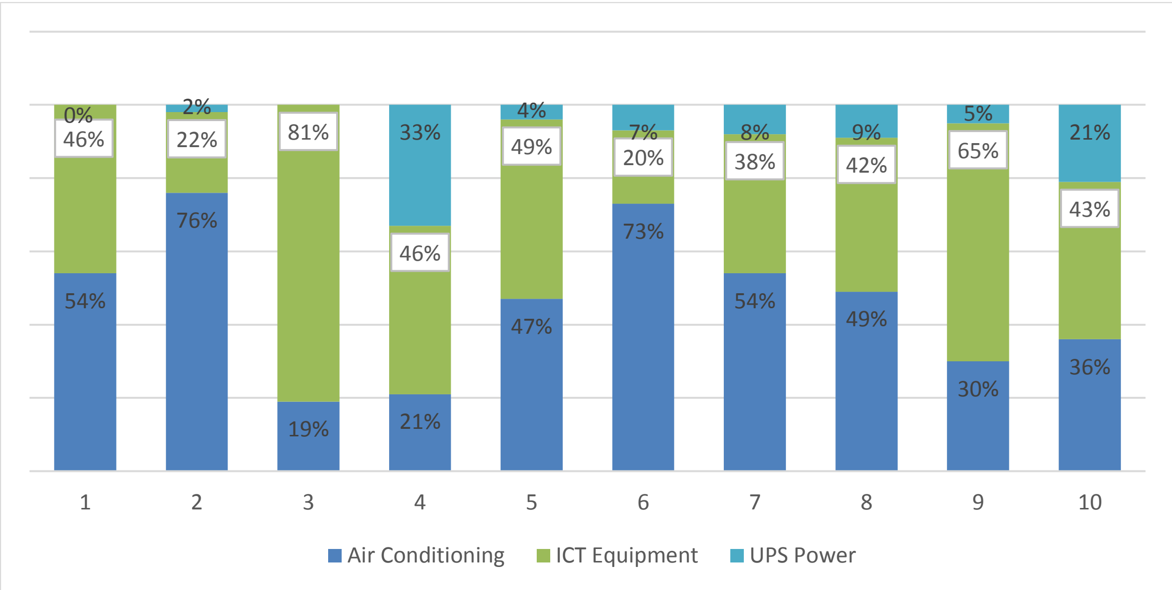


Table 9.1: Energy Consumption based on Percentage for each data centre (site)

From the graph above, it can be seen that Site No.2 consumes the most energy for the air conditioning system. This is not advisable as it is recommended that the same or less amount of energy should be consumed by the data centre utilities compared with the amount of energy used for the ICT equipment.

Similarly, Site No.4 may seem to use very little for the air conditioning but a lot of energy is used in the UPS. This is further explained when defining the Power Usage Effectiveness (PUE) of the data centre in *Chapter 9.4: Power Usage Effectiveness*

The estimated annual consumption calculated for each site is shown in Table 9.2. This was derived from the 1 week data logging conducted during the baseline study.

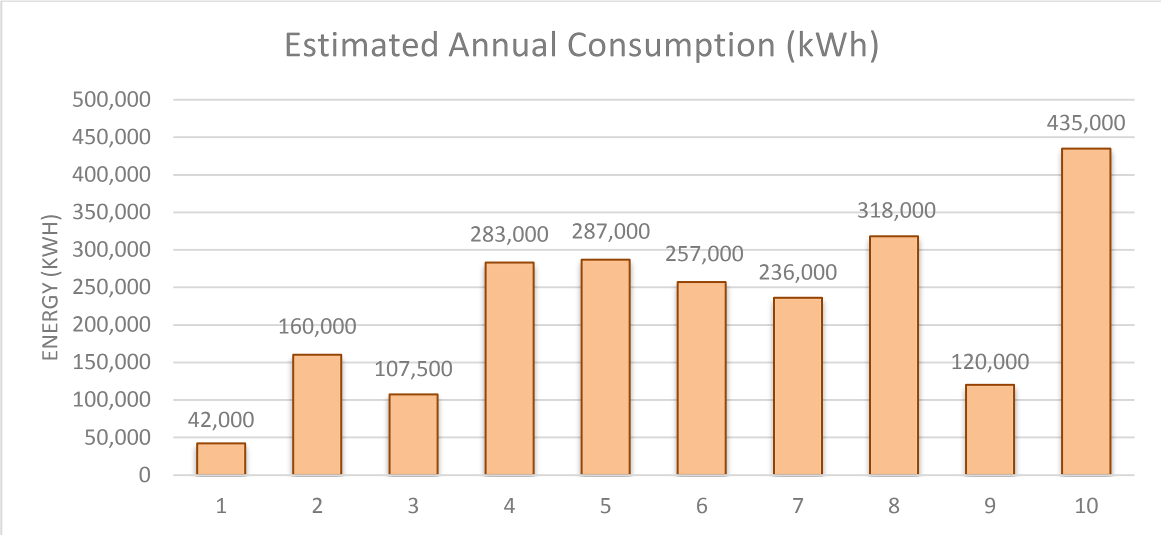


Table 9.2: Estimated Annual Consumption (kWh)

From the graph above, it can be seen that the largest consumer is Site No.10 and the smallest, Site No.1. To determine the power usage effectiveness of the data centre, these figures should be compared against the total energy consumption of ICT equipment for each data centres.

9.2 Data Centre Information

9.2.1 Lighting

The illuminance measurements, using the Lux Meter, shows that the illumination levels throughout the data centre is considered sufficient. The lighting levels, per *MS1525:2014 - Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (2014)* has not specifically provide the illuminating level for data centres. However, assuming for reading purpose at the general areas within the data centre, the illuminating level between 300 – 400 lux is sufficient.

The MS1525:2014 is a code of practice giving guidance on the effective use of energy including the application of renewable energy in new and existing non-residential buildings.

Average lux level readings were established where all main area (front and back of equipment racks have a range of 150 – 350 lux, while pathways at the side of equipment have a range of 130 – 250 lux. These readings show the lighting levels are adequate for workload-related activities and meet the MS1525:2014 Standards requirement. **The use of portable task lights are encouraged for dedicated works where possible.**

9.2.2 Temperature and Relative Humidity (RH)

The Hobo Temperature and Humidity Data Logger were used to measure and log the temperature and relative humidity levels in the data centre.

Relative humidity (RH) is defined as the amount of moisture in the air at a given temperature in relation to the maximum amount of moisture the air could hold at the same temperature. The *American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)* published standards and guidelines relating to ACMV systems and issues. In a data center or computer room, ASHRAE advises maintaining ambient relative humidity levels between 45% and 55%, is recommended for optimal performance and reliability.

9.3 Thermal Imaging

An important tool for performing data centre inspections is the thermal imager, also known as an infrared (IR) camera. It is used to inspect the respective data centre systems from the electrical source (a main power board, for example) to the server racks and everything in between, including the critical air-conditioning, mechanical and ventilation (ACMV) system.

Why thermal imaging?

A thermal imager can display and store two-dimensional images of an object's surface temperatures. Using an imager, inconsistencies or variances in the temperatures of electrical or mechanical components (items that are hotter or colder than similar objects in the same environment) can be easily detected. An overheating component usually indicates a potential problem that may require maintenance before failure occurs.

In a data centre, where cooling is important to keep servers from overheating, an uncharacteristically cool surface or component might also indicate a problem. This could perhaps be caused by an imbalance in air flow in the ACMV system, where there is mixing between the cooled incoming air and the hot equipment outgoing exhaust air, that requires correcting actions.

In addition to easily comparing temperatures of equipment surfaces, thermal cameras can also record the actual surface temperatures of the components, known in the industry as "hot spots". This helps in detecting situations such as an overheating power supply unit or perhaps a blower fan, allowing for repair or replacement before failure. Thermal imaging camera was used to identify hot spots in each of the panels. The hot ICT equipment exhaust air is released via the back of the cabinet, outside the enclosure.

The UPS devices do not require additional cooling. The ambient temperature of the room is sufficient to keep the devices cool and within their operating temperature parameters. Therefore, it is recommended that blanking panels are placed in the racks containing the UPS and battery pack to prevent the entry of cooled air from the "Cold-Aisle". This will reduce the cooling load. The server room ambient air temperature is sufficient to cool the UPS devices.

9.4 Power Usage Effectiveness (PUE)

A non-profit consortium of stakeholders in the data centre industry that focus on energy efficiency, the Green Grid has created an industry-standard measure for determining the energy efficiency of a data centre. The European Union in the *Code of Conduct for Data Centre Efficiency* recommends PUE as the ideal metric. This measure, the *Power Usage Effectiveness (PUE)* is a ratio of the total energy used by the Data Centre (DC) to the energy used by the IT equipment. The PUE for the data centre is seen below.

$$\boldsymbol{PUE} = \frac{\textbf{Total Energy Consumption by Data Centre (kWh)}}{\textbf{Total Energy Consumption by IT Devices (kWh)}}$$

We can see the various performance levels in Table 9.3 below. Table 9.3 is prepared by the Uptime Institute as part of the certification process of the data centres in industry.

Current PUE & DcIE		
PUE	**DcIE**	**Level of Efficiency**
3.0	33.3%	Very In-efficient
2.5	40%	In-efficient
2.0	50%	Average
1.5	67.6%	Efficient
1.2	83%	Very Efficient

Table 9.3 Uptime Institute Levels of Efficiency Ratings charts

According to *Uptime Institute's 2012 Data Centre Survey*, the global average PUE of the 1100 respondent's data centres is between 1.8 and 1.89. According to Uptime Institute, in 2011, the typical data centre has an average PUE of 2.5. Uptime estimates most facilities could achieve 1.6 PUE by using the most efficient equipment and best practices.

The PUE data compiled for each site from the baseline study is shown in Table 9.4. The table shows that Site No.3 and Site No.9 as having the lowest or best power usage effectiveness (PUE) ratio in the study. **Among the data centres involved in the study, these PUE figures lie in the range from being "very inefficient" to "efficient rating"**.

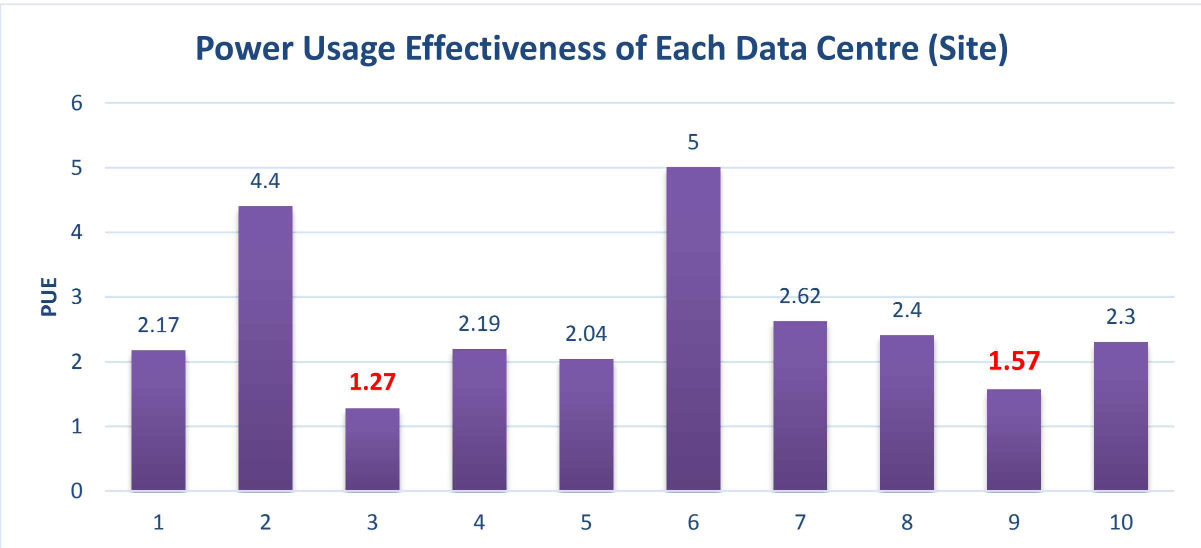


Table 9.4 Power Usage Effectiveness

9.5 Data Centre Infrastructure Efficiency (DcIE)

Data Centre Infrastructure Efficiency (DcIE)

Data Center Infrastructure Efficiency (DcIE) is an index developed by the Green Grid. It is an index that shows the energy efficiency of the data centre infrastructure, or the efficiency of the use of installed infrastructure to serve the ICT equipment in the data center. In most cases, the infrastructure is predominantly by the air conditioning system in terms of energy used.

DCiE expressed in percentages and the value does not exceed 100%. The larger the value, the higher the efficiency of the use of the available infrastructure to serve the ICT equipment in the data center.

With the energy usage for the 7-day week extended to a 52-week year, the DcIE for the DC is obtained below.

$$DcIE = \frac{Percentage\ of\ total\ Energy\ Consumption\ by\ IT\ Devices}{Percentage\ of\ total\ Energy\ Consumption\ by\ Data\ Centre}$$

The DcIE data compiled for each site is shown Table 9.5. It shows that both Sites No.3 & No.9 have the highest or best infrastructure effectiveness. For Site No.3 shows that 79% of the energy in data centre is used to serve the ICT equipment and only 21% (the balance of energy) wasted or used by non-energy efficient system or services.

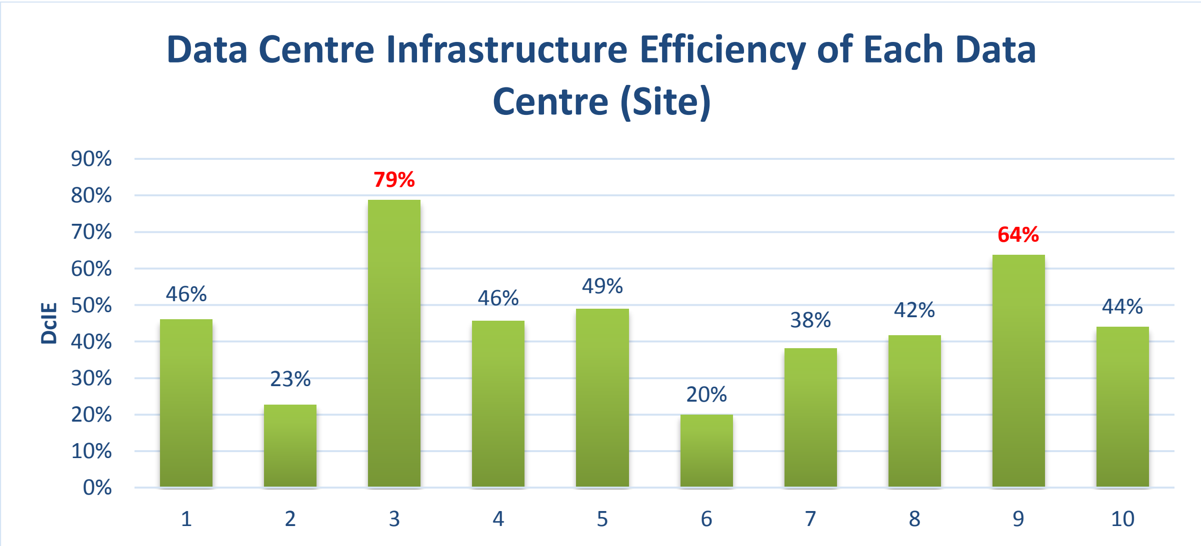


Table 9.5: Data Centre Infrastructure Efficiency (DcIE)

9.6 Data Centre Indices

9.6.1 Data Centre Energy Index (DEI)

The Data Centre Energy Index (DEI) is derived from the yearly energy consumption divided by the floor area of the data centre.

While PUE and DcIE is the industry reference points for a DC energy efficiency rating, perhaps a Data Centre Energy Index (DEI) where the yearly energy consumption per floor area of the DC **could also be a reference point for comparisons** of the DC's energy efficiency. **The lower the DEI the higher the energy efficiency level**.

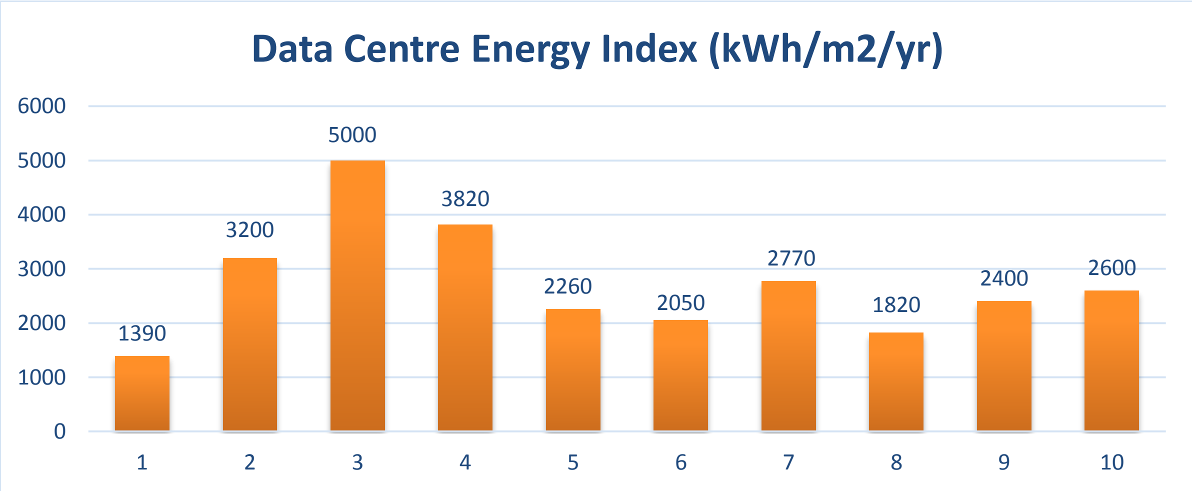


Table 9.6: Data Centre Energy Index

The data in the graph above shows the energy intensity of the data centre based on the overall energy consumption compared with the floor area. With reference to Table 8.1, it can be seen that Site No.3 has the smallest floor area, making it the most energy intensive although in Table 9.4 showing Site No.3 is the most energy efficient site. Site No.6 is the most inefficient site, however the data centre index show that it is among the lowest intensity.

In the analysis shows that Data Centre Energy Index (unit in kWh/m2/year) cannot be used as one of the indicator of efficiency. This is because floor area is not a good parameter to be used in the energy efficiency analysis of data centre especially data centres that practices high space utilization efficiency.

9.6.2 Baseload Index (BI)

Base load (also known as baseload) is the minimum level of demand on an electrical supply system over 24 hours. The Baseload Index (BI) is derived from the baseload consumption of the data centre divided by the floor area. **The lower the index, mean the more power efficient (lower power demand) of the data centre**.

The baseload index indicates the minimum energy consumed by the data centre compared to the floor area in W/m^2. Similarly to the Data Centre Energy Index (DEI), Baseload Index (BI) is also an additional new index that being introduced in the analysis. The purpose is to explore whether the proposed indexes are suitable and could be considered for data centres analysis in future, however care must be taken into determining the type of equipment used and energy patterns of the said equipment.

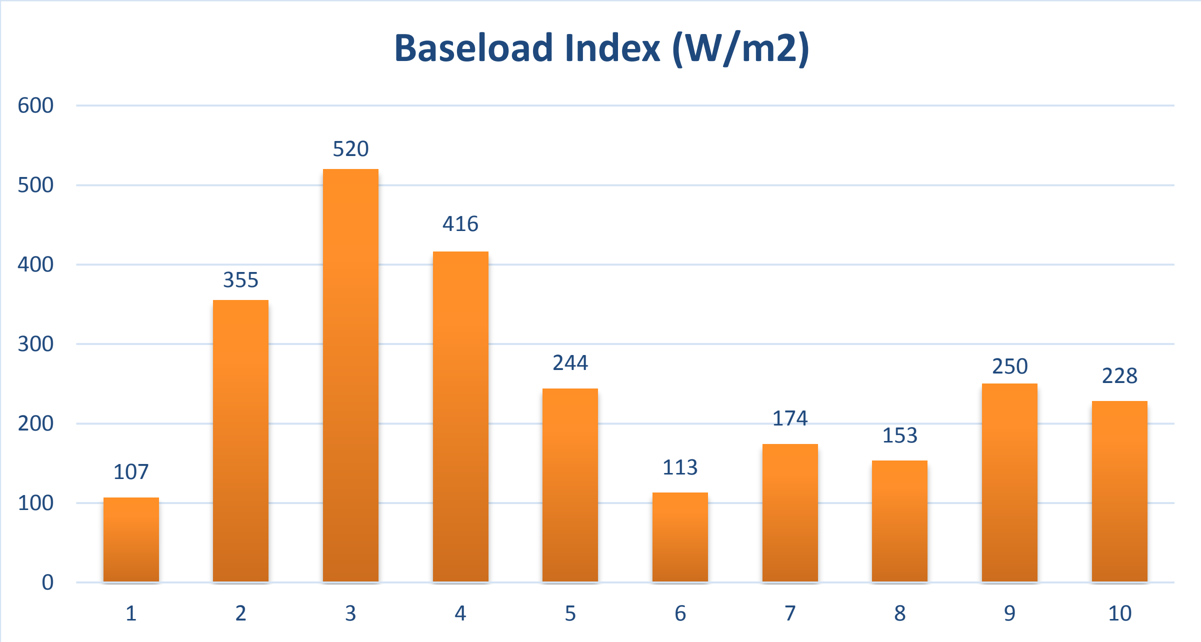


Table 9.7: Baseload Index

With reference to Table 8.1, it can be seen that Site No.3 has the smallest floor area, making it the highest baseload index although in Table 9.4 showing Site No.3 is the most energy efficient site. Site No.9 is the 2nd most efficient site, however the data centre baseload index show that it has average level of index. The Site No.6 is the most inefficient site, however its baseload index shows that it's achieved among the lowest index.

In the analysis shows that Data Baseload Index (unit in W/m2) cannot be used as one of the indicator of efficiency. This is because floor area is not a good parameter to be used in the energy efficiency analysis of data centre especially data centres that practices high space utilization efficiency.

9.6.3 Data Centre Carbon Index (DCI)

The Data Centre Carbon Index (DCI) is derived by multiplying the carbon emission factor of 0.747kgCO_2/kWh to the Data Centre Energy Index. This index can be evaluated to determine if it is a suitable reference point for any future data centre study.

Similarly to Data Centre Index (DEI), the analysis shows that Data Centre Carbon Index (unit in KgCO_2/m^2/year) cannot be used as one of the indicator of carbon emission efficiency. This is because floor area is not a good parameter to be used in the carbon emission analysis of data centre especially data centres that practices high space utilization efficiency.

9.7 Carbon Emissions

The electricity consumed to power the data centre is generated at the power plant. The large majority of power plants here in Malaysia use some form of non-renewable, usually fossil fuel, either natural gas, oil or coal. The combustion of these fossil fuels will cause the emission of carbon dioxide (CO_2) and as such is the primary greenhouse gas emitted through human activities.

As greenhouse gas emissions from human activities increase, these emissions build up in the atmosphere and warm the climate, leading to many other changes around the world - in the atmosphere, on land, and in the oceans. The carbon dioxide emissions from the generation of electricity in Peninsular Malaysia are quantified as 0.747kgCO_2/kWh. This is approximately the same amount of carbon dioxide emissions generated by the average family car travelling a distance of 5 kilometres.

Proton states that its Proton Gen-2 1.6L automatic car model will release 160g of carbon per kilometer or 160g/km. Honda states its City 1.5L automatic and Accord 2.4L automatic will release 135g/km and 192g/km respectively. Toyota states its Vios 1.5L automatic and Camry 2.5L automatic model will release carbon emissions of 147g/km and 184g/km respectively. Toyota's Prius C model is the most environmentally-conscious vehicle in Malaysia, with carbon emissions of 90g/km. This model produces 40% lower carbon than Proton's Gen-2 model.

 Electricity Generated **in kWh** **0.747kgCO_2/kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **in km** **160 gramCO_2/km**	 Equivalent number of tress to absorb amount of carbon emitted **305 – 350 kgCO_2/tree**

Figure 9.8 : Equivalent Carbon Emissions

The carbon emissions from the data centre will lead to Greenhouse gases increasing in the atmosphere and causing climate change. Carbon sequestration, a process where CO_2 is removed from the atmosphere and stored for a long period of time, may be one way to slow or reverse the accumulation of CO_2 in the earth's atmosphere.

The ability of trees to absorb and remove carbon from the atmosphere and store it long-term in wood and wood products is a common carbon sequestration or carbon sink measure. Forest carbon sequestration helps to maintain the ecosystem services forests provide and may also serve as a source of revenue for landowners through participation in various carbon trading programs.

Trees are a natural carbon sink, in that they will absorb the carbon dioxide emissions. This will reduce the carbon emissions that will lead to greenhouse gas buildup in the atmosphere. The Malaysian Palm Oil Council's Henson Report in 1999 states that the average hectare of 140 – 160 palm oil trees in a plantation, can assimilate CO_2 of 48.8 t CO_2 /ha/yr. The average healthy palm tree can store 305 – 350 kilograms of carbon dioxide (CO_2) per year.

Data Centre	Carbon emitted in tons by data centre	Kilometres driven by 1 car (Gen 2, 1600cc)	No. of palm oil trees to absorb amount of carbon emitted
1	31	195,000	100
2	120	745,000	390
3	80	500,000	260
4	210	1,300,000	690
5	214	1,340,000	700
6	190	1,200,000	630
7	176	1,100,000	580
8	238	1,500,000	780
9	90	560,000	290
10	325	2,030,000	1,065

Table 9.9 : Equivalent Carbon Emissions

The table above shows the number of kilometers driven by a car and number of trees required to absorb the carbon emitted from each car in relation to the energy consumed by each data centre in 1 year.

10 POTENTIAL ENERGY SAVINGS MEASURES (ESMs) AND RECOMMENDATION

During the study the team had also conducted brief energy audit exercise as part of the value added to the baseline study project. Each data centre has different energy saving potentials. However, after analyzing the potentials in the data centres, the team can generalized the potential saving measures into several parts.

Detail energy saving analysis and life cost cycle analysis are needed if the data centres owner want to implement the potential ESMs.

The following table shows the summary of all the energy saving measures identified for each site during the baseline study. In the following paragraphs, detailed explanations and recommendations are provided for the respective energy saving measures.

Site Name	Improve air flow and Increase AC Setpoint	Server Power Mgmt S/W	Inverter for ACSU	Portable Dehumidifier	Increase AC Setpoint in UPS Room	Insulate Window Area	Partition DC and Realign Cabinets	Partition under floor air plenum	Replace Glass/Plastic Doors with Grill	Relocate In Row AC
1	X	X	X	X	X		X			
2	X	X	X	X	X		X			
3	X	X		X						X
4	X	X		X						
5	X	X		X	X					
6	X	X		X	X	X	X	X	X	
7	X	X		X			X		X	
8	X	X		X		X	X	X	X	
9										X
10	X	X	X	X	X		X	X	X	

Table 10.1 Potential Energy Saving Measures

10.1 ESM 1 Improve Air Flow and Increase AC Set Point where applicable

This ESM would apply for the legacy data centres not employing either a "Hot – Cold" Aisle enclosure configuration, which are Sites No. 1, 2, 6, 7, 8 & 10.

In the legacy data centres, the floor plan layout of the cabinets/racks, where the IT equipment is placed, is generally not in a structured row manner. The air-conditioning units in these data centres employed either direct blower air-flow in the data centre common area or Under-Floor Air Distribution (UFADS). In these un-structured situations, the air-flow of the cooled air from the air-conditioner vent to the IT equipment in the cabinets/racks, where the cooled in required, mostly are poorly management.

It is advised that the cabinets/racks are oriented in an orderly row fashion for better management of the air-flow. The cabinets/racks should be arranged in rows with either the cabinet/rack fronts facing each other or the fronts facing away from each other. In this way, there will not be a situation where the front of the cabinets/racks in a particular row are facing the back of the cabinets/racks of the next row.

Also, the cabinet/rack layout in the data centre should be reviewed. The available space within each cabinet/rack should be utilized as much possible. The number of empty slots in the cabinets/racks should be the minimum number. With this, the area to be cooled should be reduced by partitioning of the data centre area which do not have any cabinets/racks containing ICT equipment to be cooled.

Partitioning the data centre to create the smaller cooled area will help with air-flow management to reduce the air-conditioner cooling load. This will help reduce the energy usage. The partitioning of the data centre may require some low cost investment.

Raising the air-conditioner set-point temperature, preferably to 24°C will also help reduce the energy usage and related carbon emissions. A detailed explanation is given in Chapter 12 Considerations for a Low Carbon Data Centre. ASHRAE recommends, for a Data Centre, that the air-conditioner is set to supply a chilled air environment of 20 to 25°C. This will give an estimated energy savings of 2-4% for every degree raised according to ASHRAE estimations.

ASHRAE stands for the American Society of Heating, Refrigerating and Air-Conditioning Engineers. A global society, it publishes commonly-accepted series of standards and guidelines relating to ACMV systems and issues.

Installing blanking panels within the rack, at the slots not utilized, will eliminate hot air backflow to the front of the rack, increasing the cooling load and also works in reducing the cooling load. This requires very minimal cost. These panels could perhaps be obtained from the rack and server equipment vendors at negligible cost.

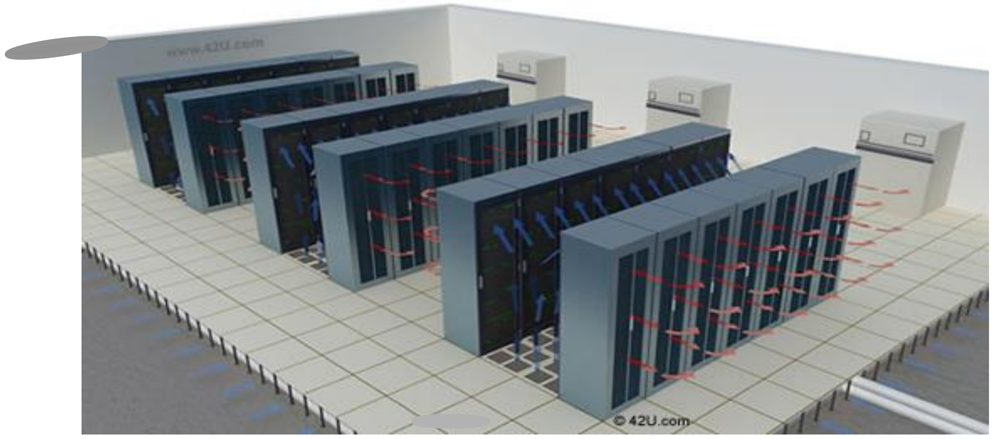


Figure 10.1 "Cold Aisle" configuration for Under Floor Air Delivery (UFAD)

Figure 10.2 "Cold Aisle" configuration for Under Floor Air Delivery (UFAD) using fixed plastic sheets

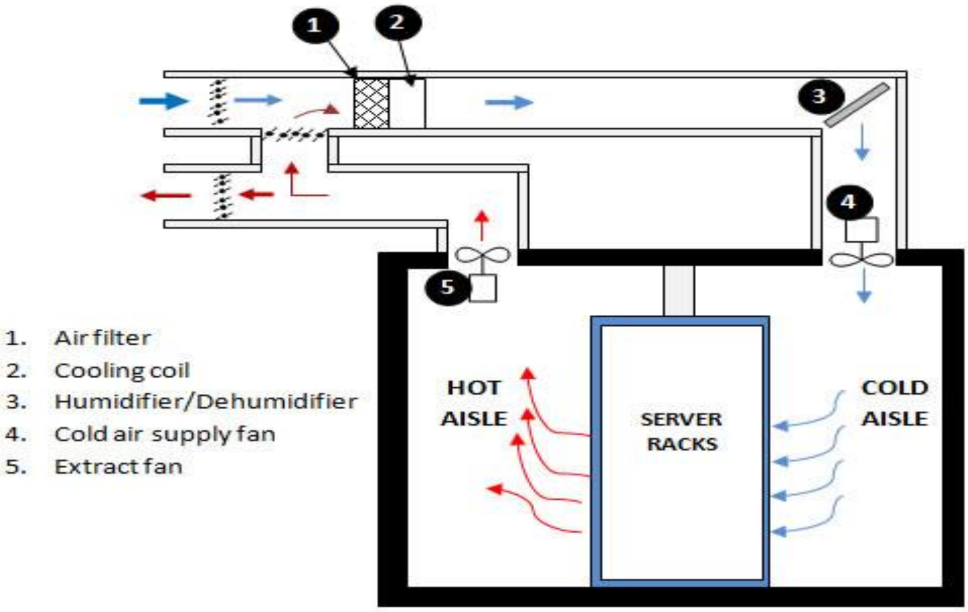


Figure 10.3 A hybrid "Hot & Cold Aisle" configuration for ceiling air dispersion

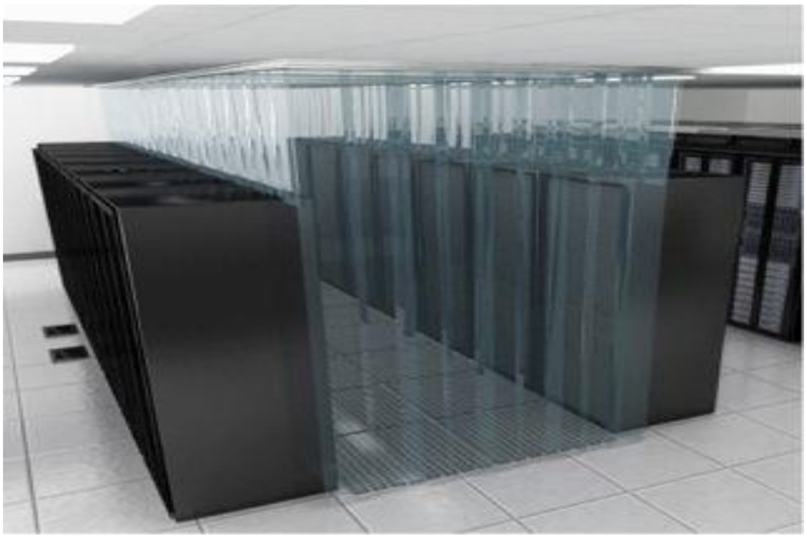
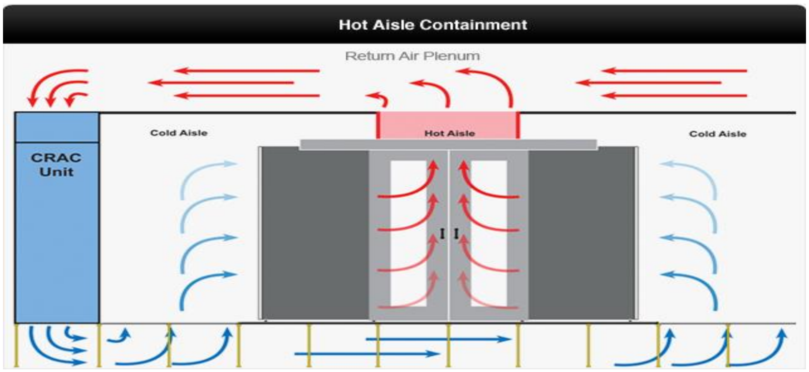


Figure 10.4 "Cold Aisle" configuration for Under Floor Air Delivery (UFAD) using flexible plastic sheets



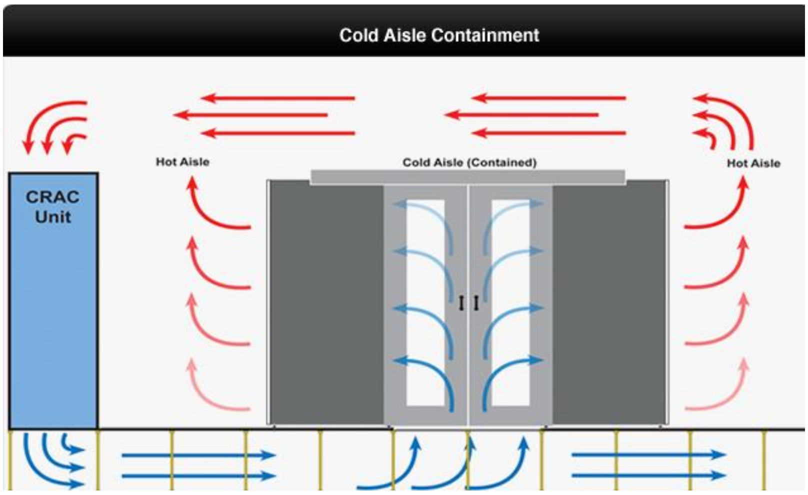


Figure 10.5 " Hot Aisle" (above) and "Cold Aisle" (bottom) configuration for Under Floor Air Delivery (UFAD)

10.2 ESM 2 Server power management software

It is recommended that power management settings are enabled in servers during weekends and after office-hours. The server will reduce energy usage by slowing or disabling some parts of the central processing unit during no- or low-usage network periods. The Data Centre System Administrator should monitor the network performance. If the server power management is viable, the settings can be enabled for all hours. Microsoft estimates energy savings of approximately 7-8% used when the power saving management tool in the servers are enabled.

An example of server power management software can be seen in the screen-shot from a high-end Dell PowerEdge R910 below in Fig. 10.6.

This ESM requires no cost.

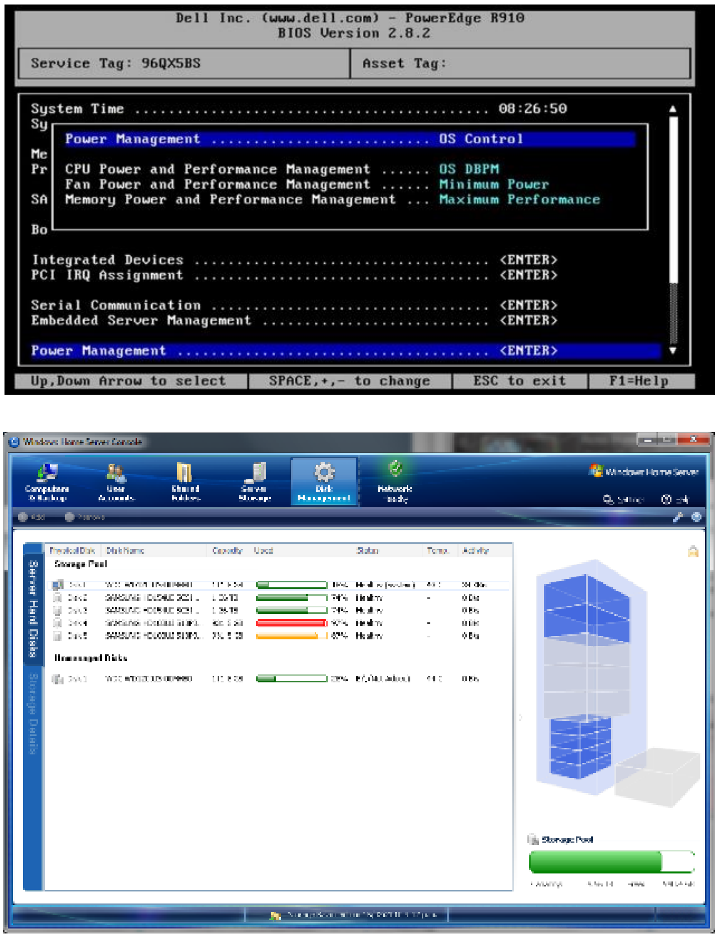


Figure 10.6 Screen capture of server management menu

10.3 ESM 3 Install Inverter or Energy Star-rated air-conditioners

Replace existing non-Energy Star rated air-conditioners which have failed, with Inverter air-conditioners which are energy efficient equipment. These can reduce energy usage by 15-20%. This applies for Sites 1 & 2.

This ESM requires medium cost.

ESM 4 Install Portable De-humidifiers

Portable de-humidifiers are about 30-40% more energy efficient than the air-conditioner built-in de-humidifier. This provides overall energy savings of about 3% from the air-conditioners yearly.

All Sites can implement this ESM.

This ESM requires low to medium cost.

Figure 10.8 Portable De-humidifier

10.4 ESM 5 Increase AC setpoint in UPS room

The UPS room AC temperature setpoint can be increased to 28°C as the UPS equipment can operate effectively at up to 30°C.

Sites 7 & 8 have placed the UPS in the data centre area. Partitioning the UPS equipment from the ICT cabinets/racks will reduce the floor area requiring cooling. This will reduce the cooling load on the air-conditioners, which reduces the energy usage.

Sites 1, 2, 4, 5, 6 & 10 have a separate UPS room.

This ESM does not require any cost.

Figure 10.9 increasing air-conditioner temperature set point

10.5 ESM 6 Insulate Window Area

External windows in the data centre are not advisable. Direct sunlight into the data centre will raise the air temperature. This is an additional load on the air-conditioners to cool the air. Placing insulation over windows or replacing the windows with insulating windows is recommended.

Sites 6 & 8 have external windows.

Figure 10.10 External windows

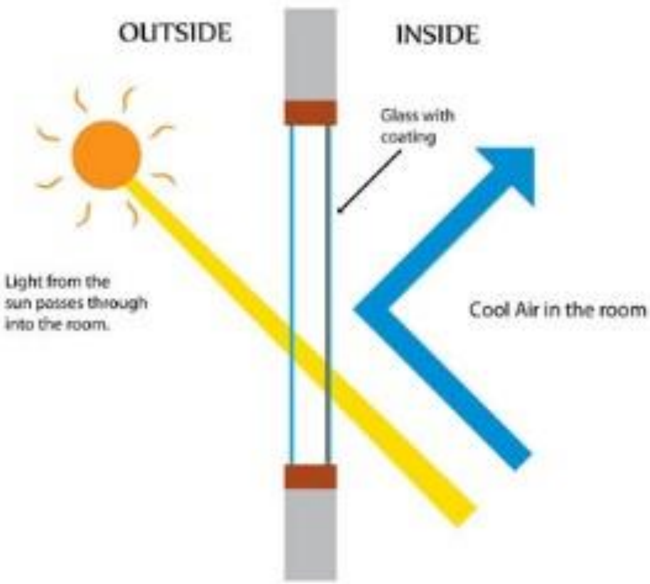


Figure 10.11 Direct sunlight heating the air in the data centre

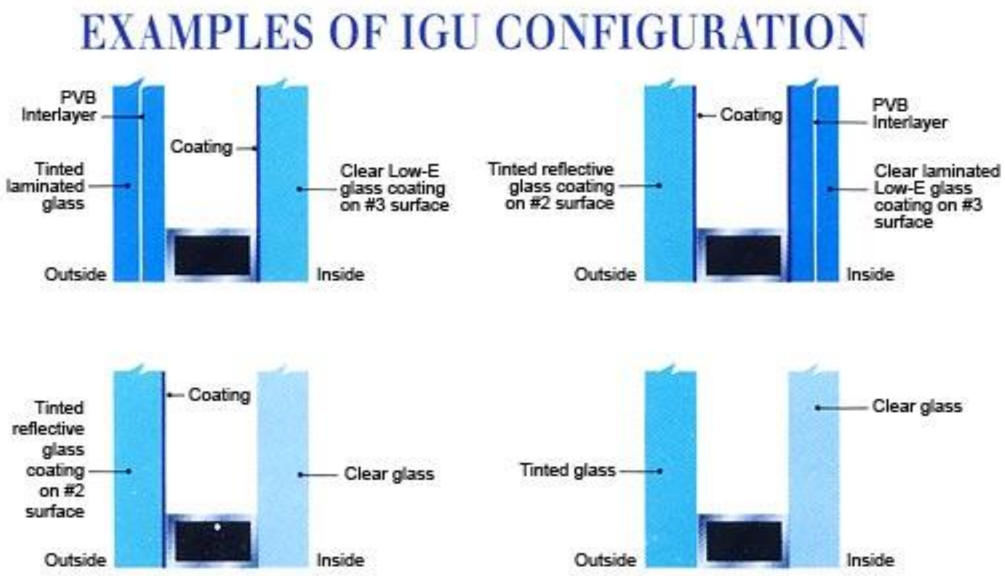


Figure 10.12 Different configurations of insulated glass windows

10.6 ESM 7 Partition racks and realign cabinets

As with ESM1, partitioning and realignment of the racks will help reduce the cooling load.

This ESM requires minimal to low cost and can come under data centre maintenance scope of works.

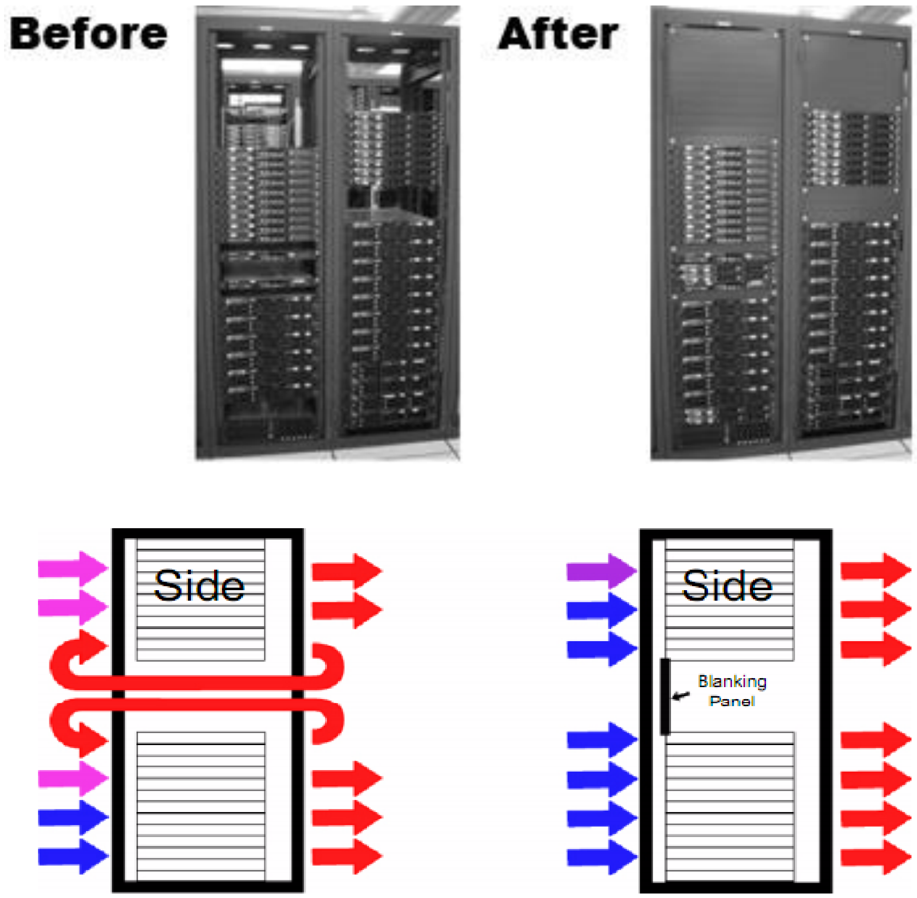


Figure 10.13 Air-flow management

10.7 ESM 8 Partition UFAD

Partition the UFAD by installing baffles. The baffles are placed with the UFAD units creating a direct pathway for air flow from the PAC to the racks. This ESM is applicable for data centres which use the raised-floor or false-floor configuration as the UFAD. The area under the false flooring, called the UFAD, is used to channel the cooled air from the PAC to the equipment. The volume of this UFAD can be partitioned, by placing baffles or panels, to channel the cooled air directly to the equipment.

Sites 6, 8 & 10 have implemented a UFAD system. This ESM requires low cost.

Energy Savings are not quantifiable at this time as further studies are required to determine actual savings achieved. This ESM also works in tandem with ESM1 in reducing the cooling load.

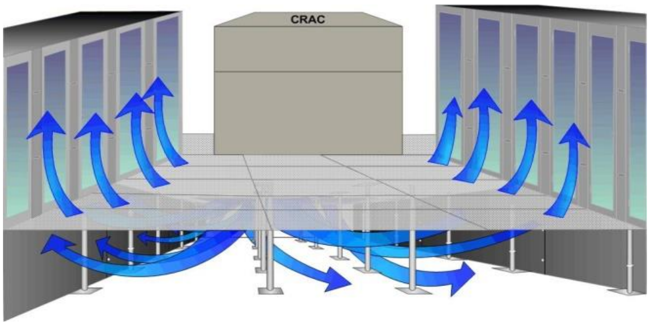


Figure 10.14 Air-flow management in UFAD using baffles

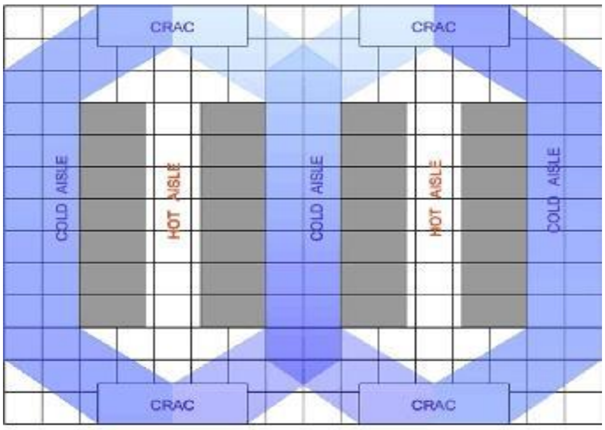


Figure 10.15 Overhead view of UFAD air-flow management

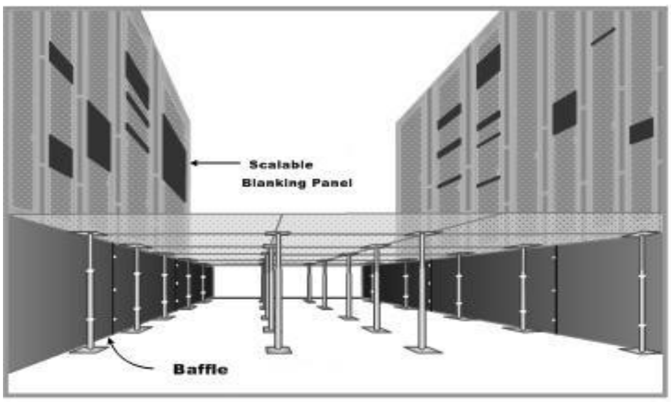


Figure 10.16 Under floor view of baffles in a UFAD

10.8 ESM 9 Replace Glass/Plastic doors with grills

Glass/Plastic doors are only useful if cooling is supplied from under the equipment racks. It does not work well if the cooling is supplied from the UFAD in front of the racks.

Sites 6, 7 & 8 have a few cabinets/racks fitted with glass/plastic doors.

This ESM requires low to medium cost.

Energy Savings are not quantifiable at this time as further studies are required to determine actual savings achieved. This ESM also works in tandem with ESM1 in reducing the cooling load.

Figure 10.17. Glass and grille door

10.9 ESM 10 Relocate In Row AC

In Row air conditioners supply cooled air equally in 3 directions, which is Left, Right and to the Front. Placing the air-conditioner units at the ends of the rows will cause the cooled air blown to the left or right (depending on orientation) to be directly cooling the cubicle/enclosure doors. This will reduce the cooling capacity available in the supplied cooled air to the ICT equipment.

It is advised the In Row units are re-located to the centre/middle of the row of cabinets/racks.

This can be applied in Sites No. 3 & 9.

Figure 10.18 Diagram of air-flow from an In Row air-conditioner

11 CONSIDERATIONS FOR A LOW CARBON DATA CENTRE – FURTHER STUDY & IMPLEMENTATION STRATEGIES (FSIS)

Further energy monitoring and measurement needs to be carried out in order to quantify the energy savings recommended. These may require re-configuration, physically, the equipment cabinets and the air-conditioners.

11.1 FSIS 1 Upgrade UPS

Replace UPSs that are older than 5years. Energy efficiencies of UPS are increasing with every new generation of UPS, due to more advanced electronics and circuitry. The newer-generation UPSs also do not require to be placed in an air-conditioned room to function well.

Also, the size of the UPS can be reduced. The UPS serves to supply an emergency electrical supply in cases when the main supply is interrupted or unavailable.

If the Data Centre does not serve a critically important application, where the DC must be kept operating at all times, then the UPS may be sized appropriately (usually smaller) to supply a back-up electrical supply for a sufficient time duration to allow the System Administrator to initiate a controlled shutdown of the servers and other ICT equipment.

11.2 FSIS 2 Consolidate servers

Consolidate application onto fewer servers. Fewer servers units in operation will reduce the energy usage. The energy savings due to “server consolidation” to be calculated with field results.

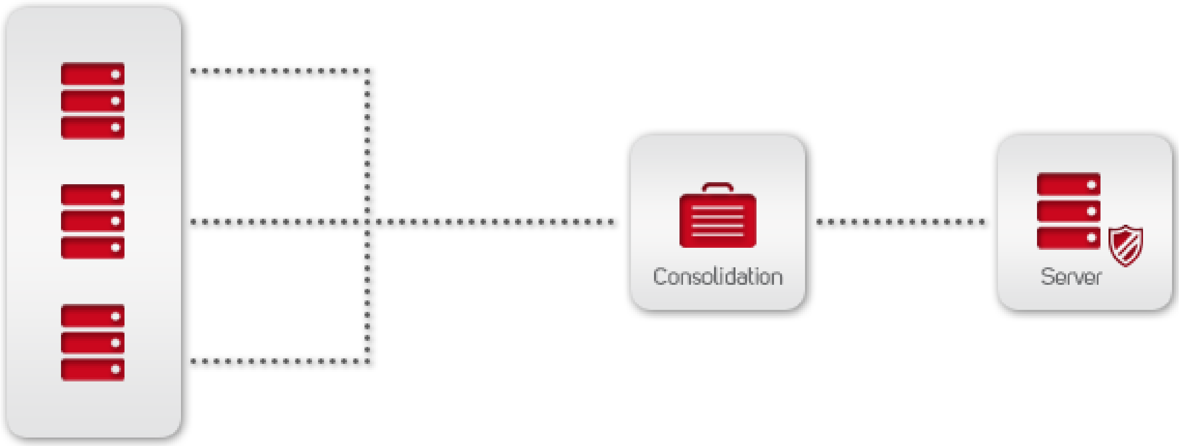


Figure 11.1 Diagram of server consolidation to reduce the number of servers required

Figure 11.1 above shows that the number of servers being used should be reduced, to cut down on the carbon emissions previously released by operating far more servers than are required. The present-generation servers can easily perform 2 or more applications within the same server.

11.3 FSIS 3 Consolidate storage

Consolidate storage drives into a network attached storage or storage area network. The energy savings due to “storage consolidation” to be calculated with field results.

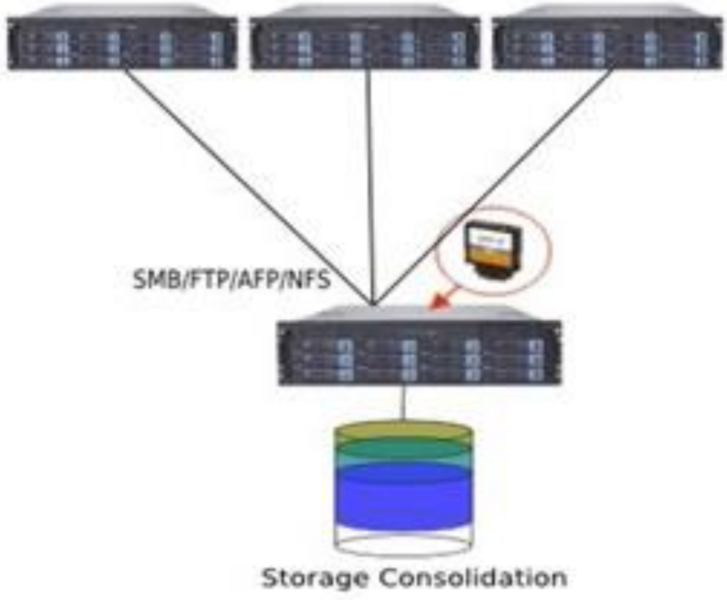


Figure 11.2 Diagram of storage consolidation to reduce the number of hard disks required

Figure 11.2 above shows that the number of hard disks for storage being used should be reduced, to cut down on the carbon emissions previously released by operating far more storage systems than are required.

11.4 FSIS 4 Replace IT equipment older than 7 years

Dell & Cisco reveal that, every 5-7 years, the next generation servers are twice as powerful while reducing power consumption by half.

11.5 FSIS 5 Virtualisation of hardware

This measure improves operational efficiency, as well as supporting consolidation, decommissioning, and cost management programs. For most users, virtualization should reduce hardware, which translates into lower operating depreciation costs and less-expensive maintenance and support. Virtualisation also helps control energy costs and lower carbon emissions with server energy consumption reduced by as much as 82% and floor space by as much as 86%. The energy savings due to “equipment virtualisation” to be calculated with field results.

12 CONCLUSION

This report presents the findings of electrical energy used to operate the data centre and the equivalent carbon emissions from the amount of energy used.

From the analysis, all findings can be summarized as below:

SITES	AREA (m2)	1 YEAR ENERGY CONSUMPTION (kWh/year)	CO_2 EMISSION (kg/year)	PUE = TOTAL/ICT	DCIE = ICT/TOTALx100% (%)	DATA CENTRE ENERGY INDEX (kWh/m2/year)	DATA CENTRE CARBON INDEX (kg/m2/year)	RANKING PUE	Ranking DC Energy Index (BEI)
Site 1	30.0	41,698	31,148	2.17	46	1390	1038	4	2
Site 2	49.5	159,376	119,054	4.39	22.8	3220	2405	9	6
Site 3	40.0	354,166	264,562	1.25	79.9	8854	6614	1	11
Site 4	74.0	282,223	210,820	2.20	45.5	3812	2847	5	7
Site 5	103.1	282,663	211,149	2.04	49	2742	2048	3	4
Site 6	64.7	256,749	191,792	5.01	20	3971	2966	10	8
Site 7	79.4	235,831	176,166	2.63	38.3	2970	2219	8	5
Site 8	194.6	228,798	170,912	2.34	42.7	1176	878	7	1
Site 9	53.4	127,812	95,476	1.57	63.7	2393	1787	2	3
Site 10	104.1	432,983	323,438	2.3	43.8	4159	3107	6	9
				2.59	**45.2**	**3469**	**2591**		

Table 12 Summary of analysis for baseline study of typical Government Data Centre

From the above table average PUE obtained is 2.59 and DcIE is 45.2%. While carbon emission Data Centre Energy Index average is 3469 $KWh/m^2/year$ and Data Centre Carbon Index is 2591 $kg/m^2/year$. It is found that the most efficient data center based on PUE and DcIE is site no. 3 with PUE value of 1.25 and DcIE value of 45.2%.

From the Potential energy saving measures (ESMs) in Chapter 10, many of the measures can be easily implemented, with little or no investment necessary. The ESMs that do require capital outlay provide a simple payback period of less than 2 years.

If the ESMs are implemented during the design stage of the data centre, the energy savings achieved can be substantial. The operating costs and carbon emissions can then be significantly reduced using the recommendations in Chapter 10.

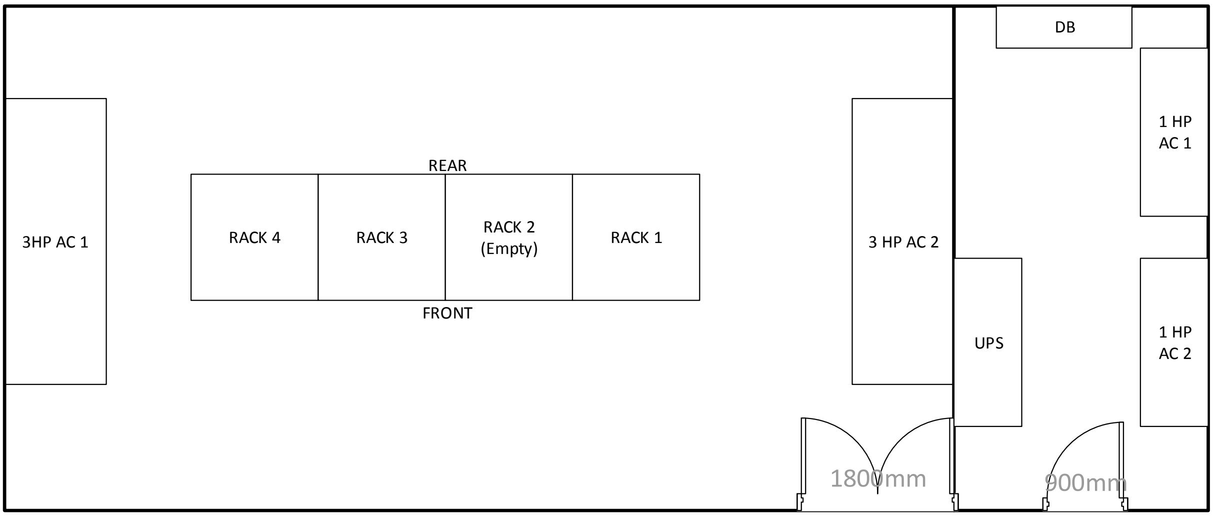
These ESMs, implemented in a refurbishment of an existing DC, will provide almost immediate returns on investment, with the reductions in energy usage and carbon emissions.

Most of the ESMs stated above would be applicable or necessary in a DC that is over 5 years old. There are great advances in equipment design and performance of new equipment today compared to equipment from as little as 5 years ago.

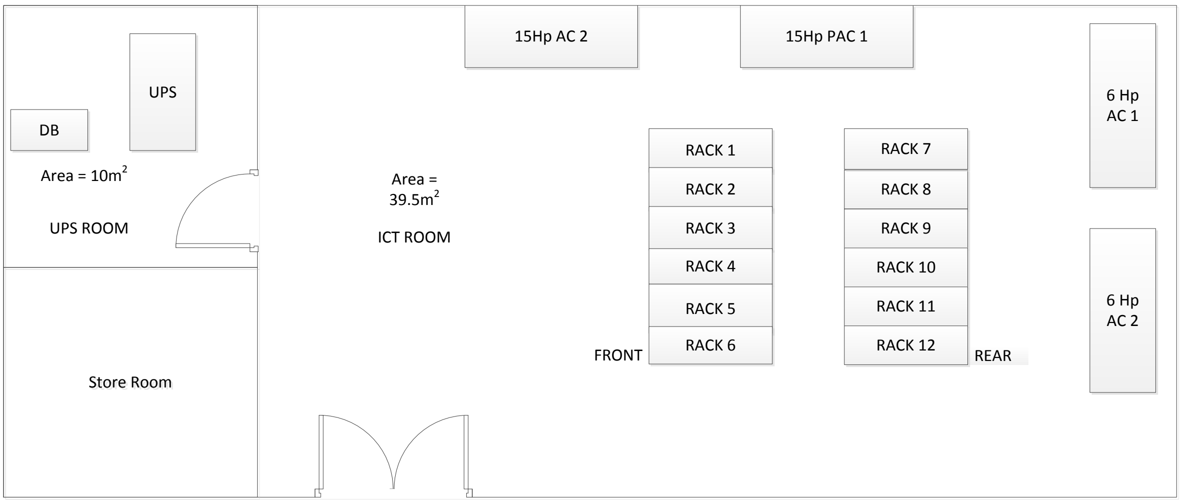
In a completely new DC designed today, the energy savings will be higher. This is as the DC support equipment systems, such as air-conditioning and lighting, will be matched to the ICT requirements. This will then allow greater energy savings, with further carbon emissions reductions than would be achievable from a refurbishment exercise on an existing DC.

13 APPENDICES

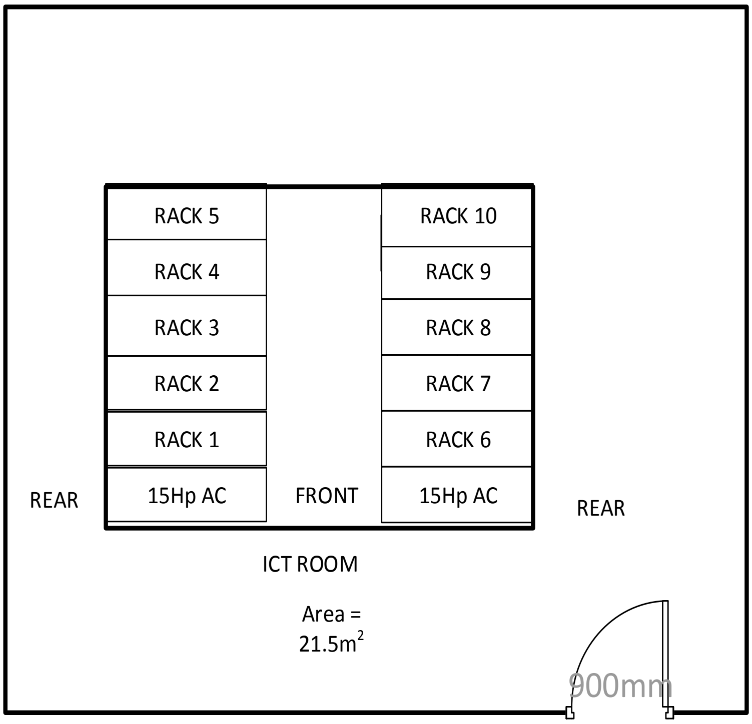
Appendix 1 - Floor Layout



Floor Layout Data Centre (Site) No.1



Floor Layout Data Centre (Site) No.2



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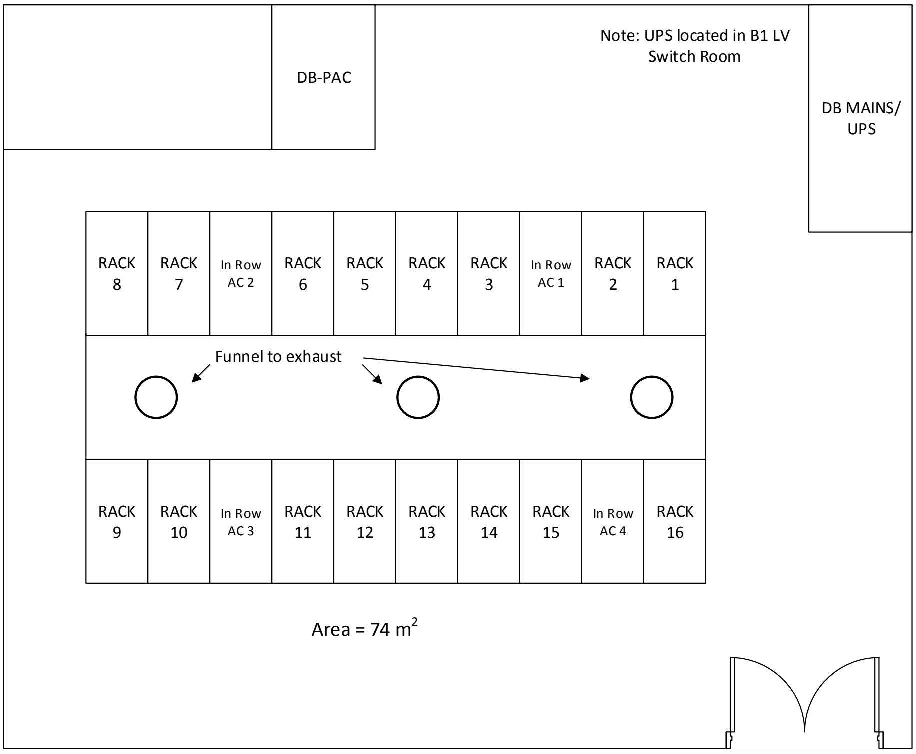

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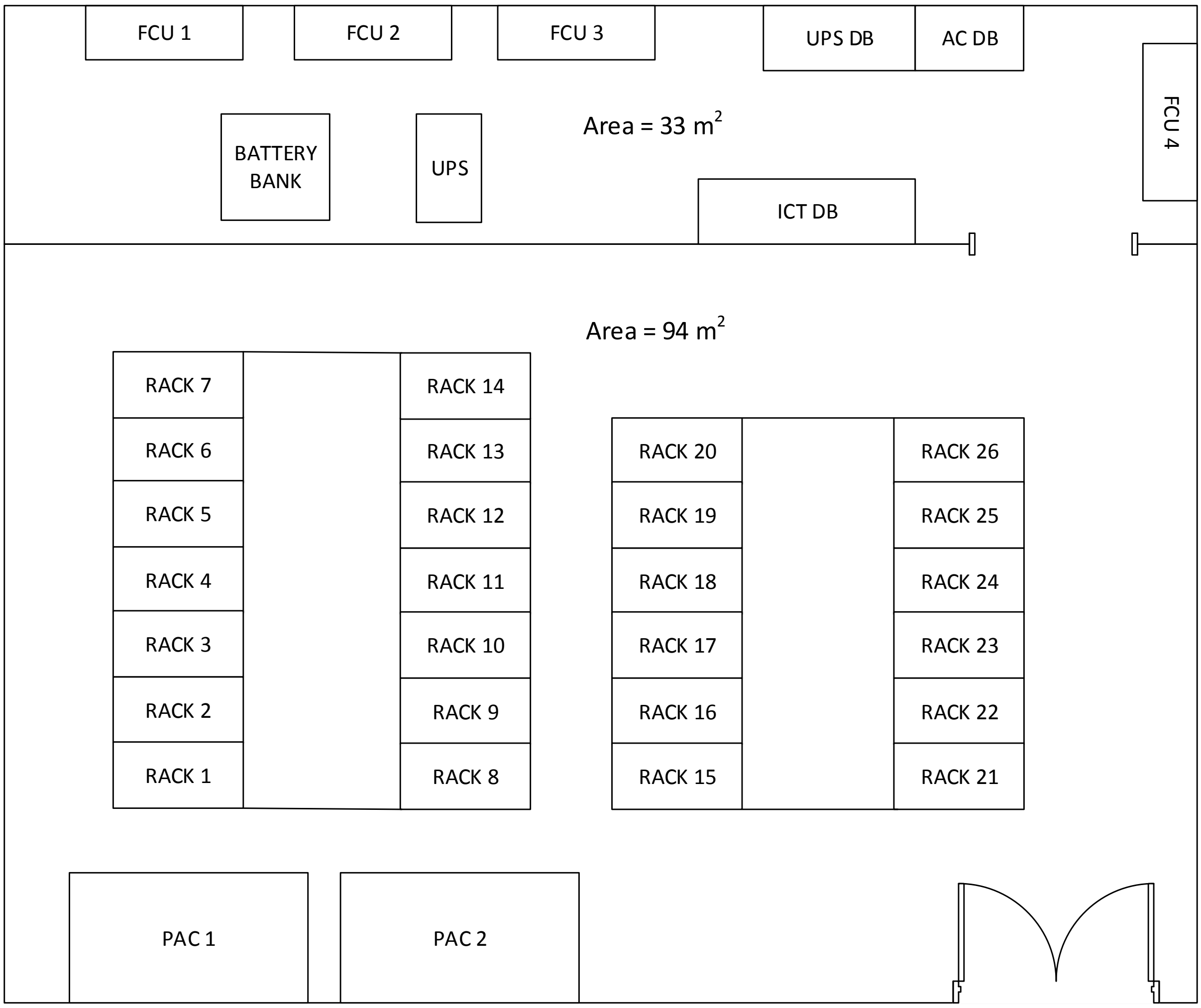

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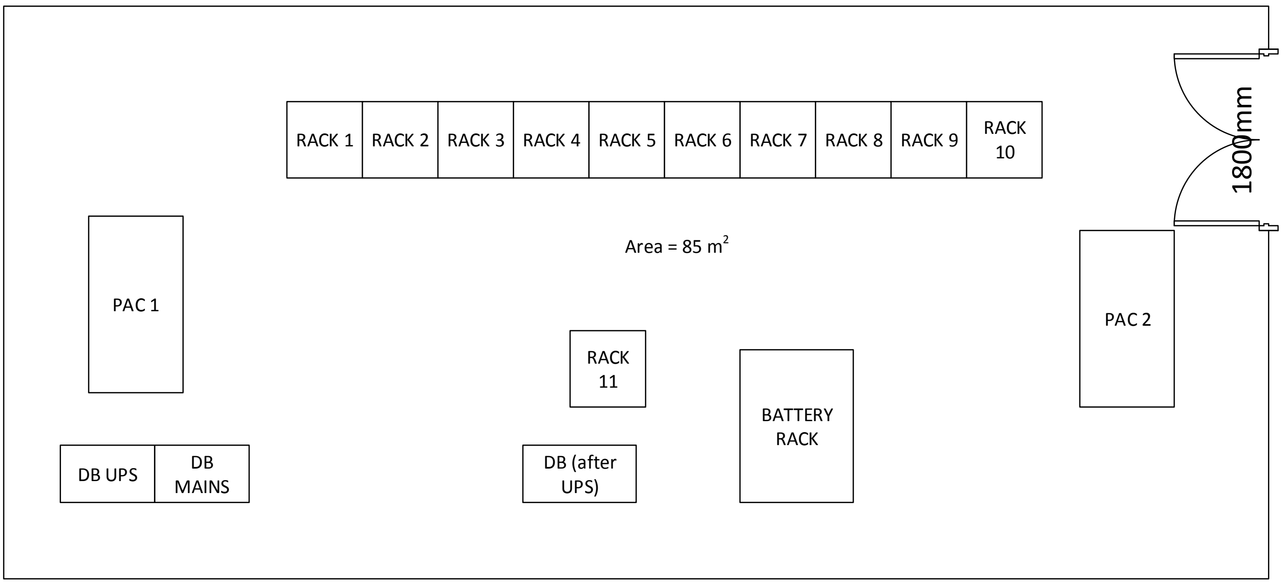
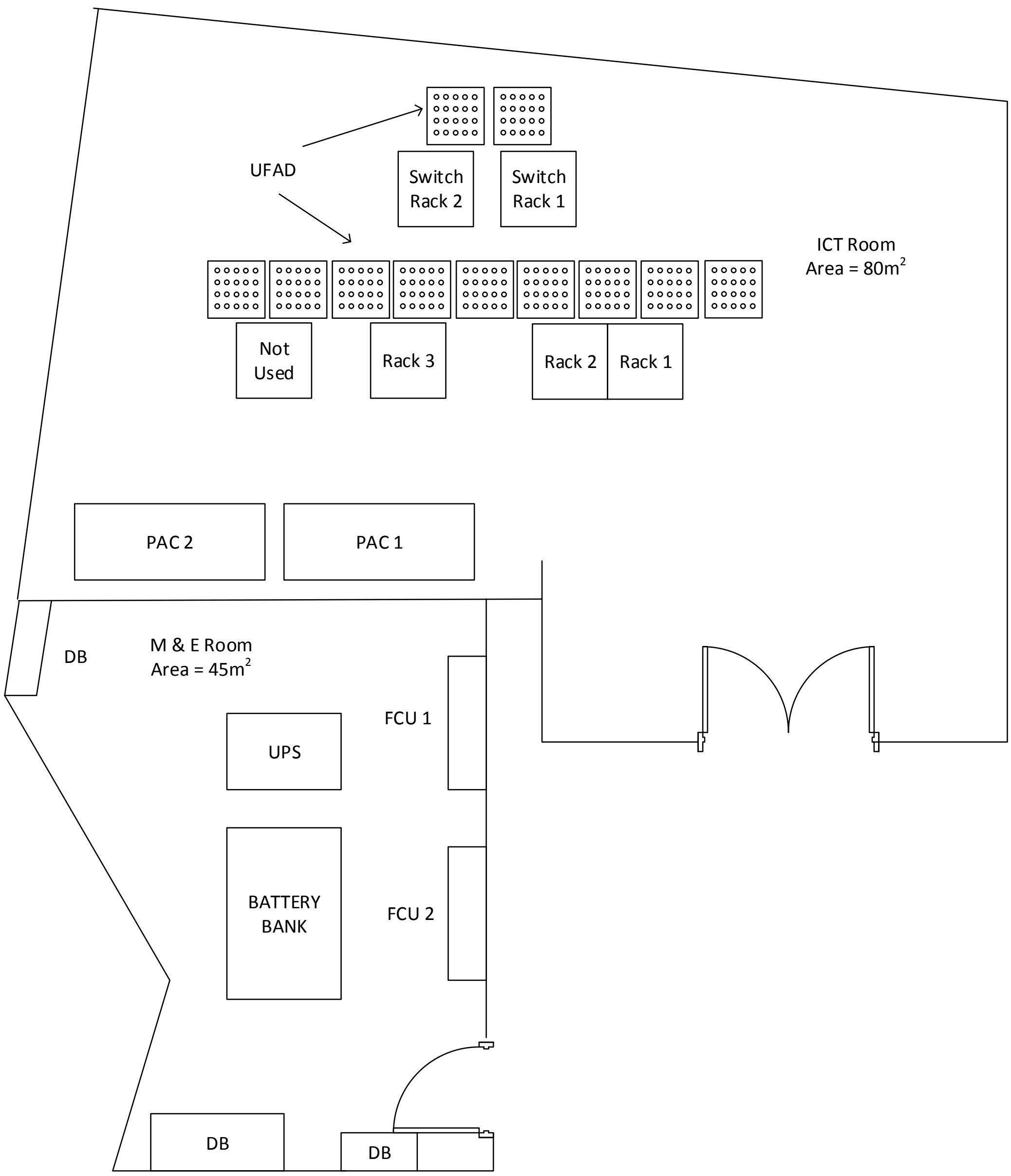


Floor Layout Data Centre (Site) No.7



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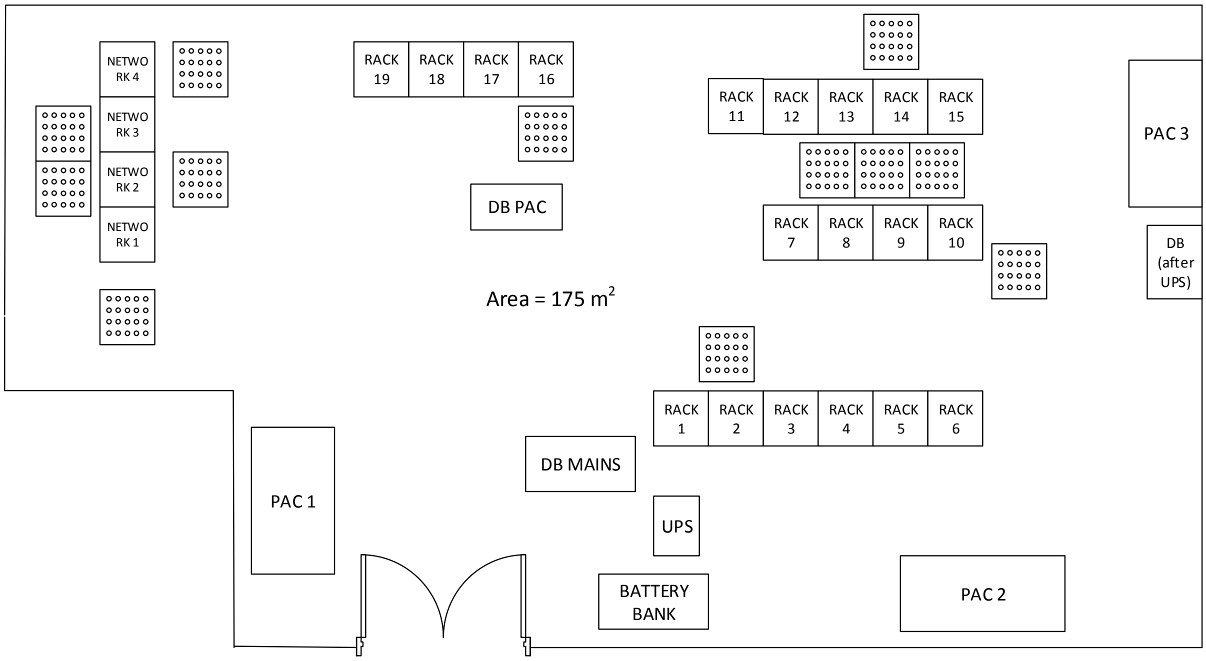
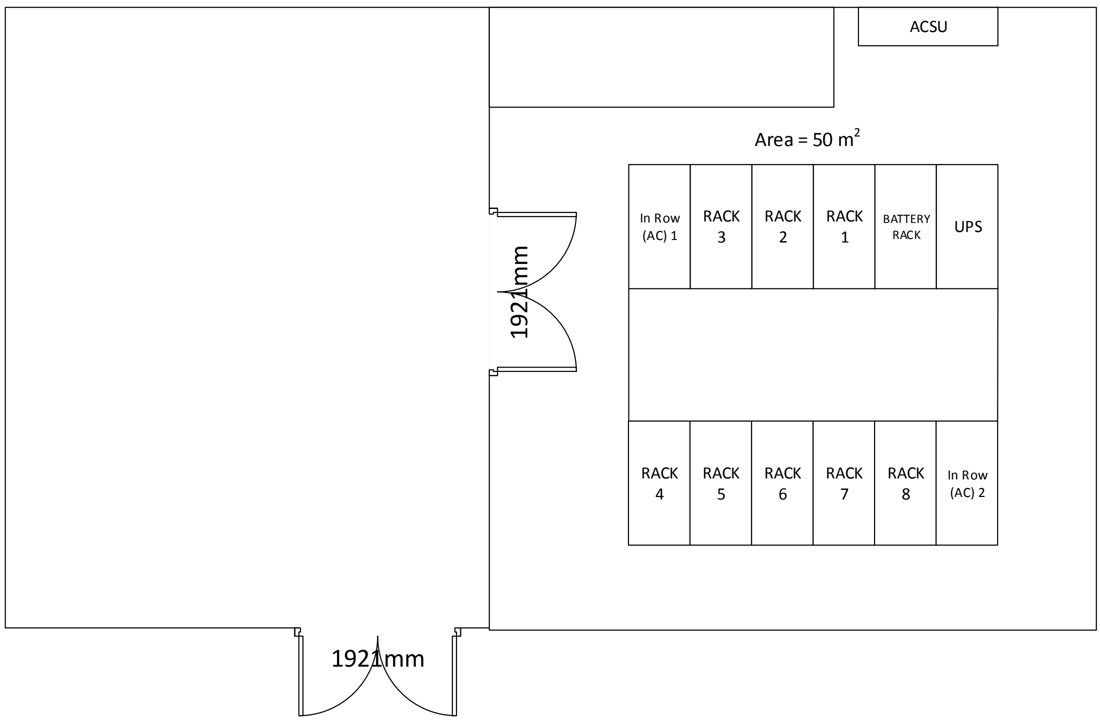
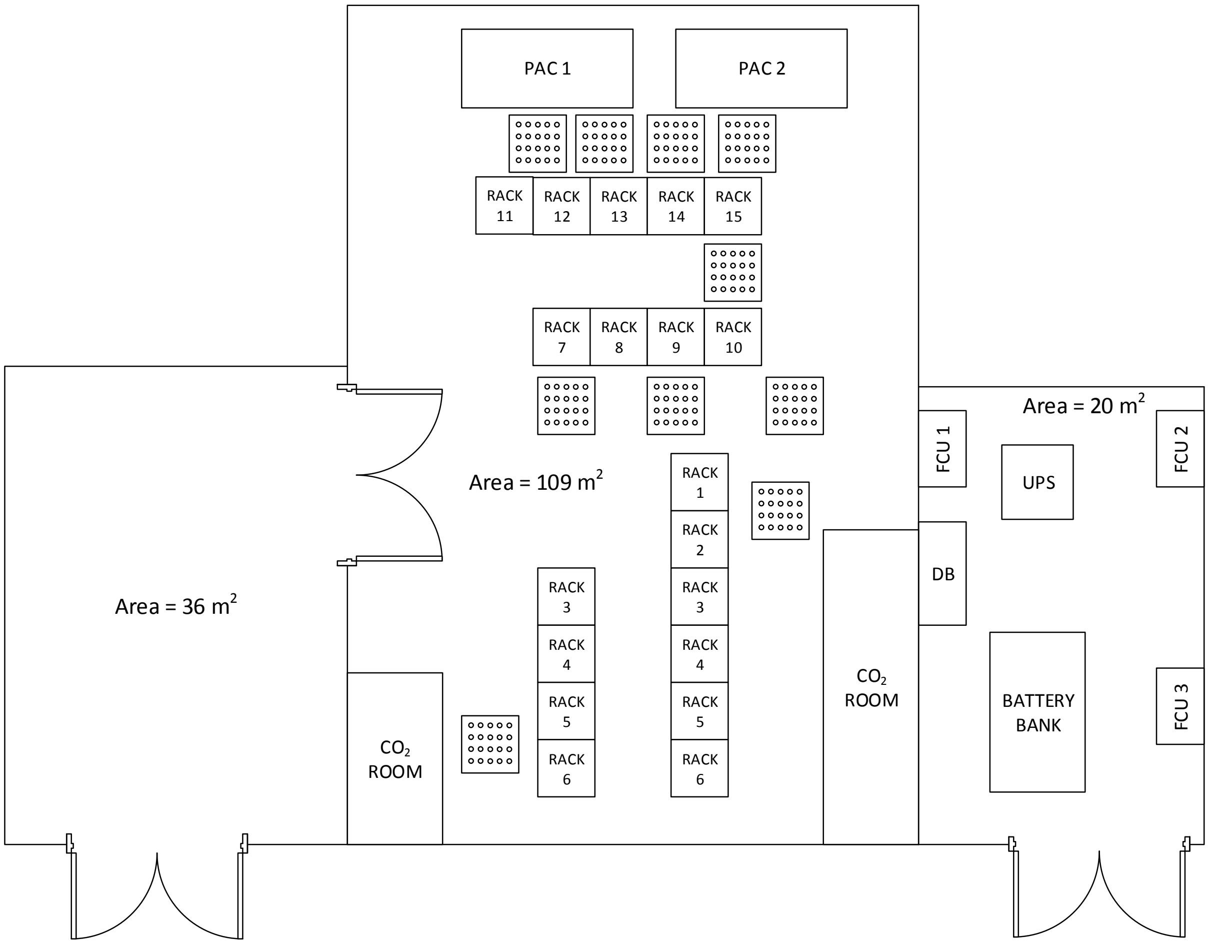


Floor Layout Data Centre (Site) No.8



Floor Layout Data Centre (Site) No.9



Floor Layout Data Centre (Site) No.10

Appendix 2 - Summary Reports

a) Study Report of Data Centre (Site) No.1

Results from the baseline study conducted from **12 to 17 September 2013** for **Site 1** found that the estimated annual electrical load is **41,700kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM15,400**. The estimated annual carbon emissions is **31.1** tonnes.

 Electricity Generated **41,700kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **194,700 km**	 Equivalent number of tress to absorb amount of carbon emitted **102 trees**

Figure Appendix 1a : Carbon Emissions Equivalent

The data centre comprises 3 major energy-consuming equipment groups which are Information & Communications Technology (ICT) equipment, 3Hp Air-Conditioning equipment, 1Hp Split-Unit Air-Conditioner. The ICT load comprises of about 46% of the total load and the 3HP and 1HP split unit air conditioners, 42% and 12% respectively, as seen in **Fig. Appendix 1b** below.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.17 and DcIE of 46% obtained from the baseline study, give a performance rating of between "Average" and "In-efficient".

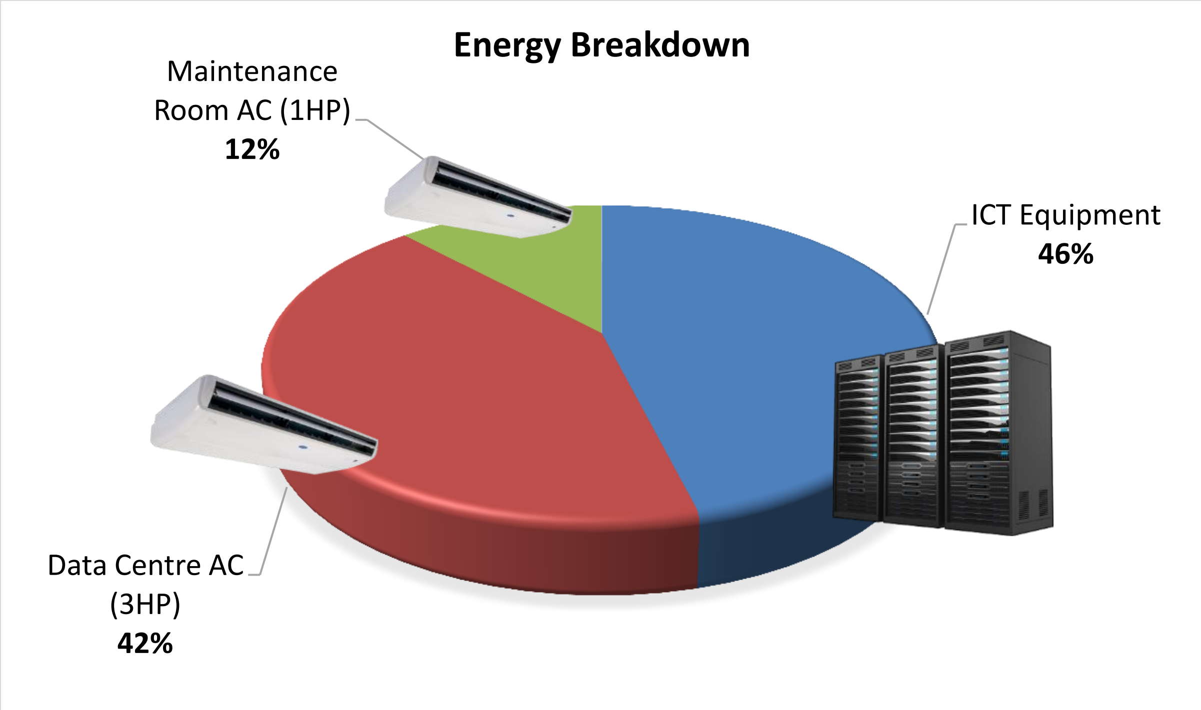


Figure Appendix 1b : Energy Breakdown

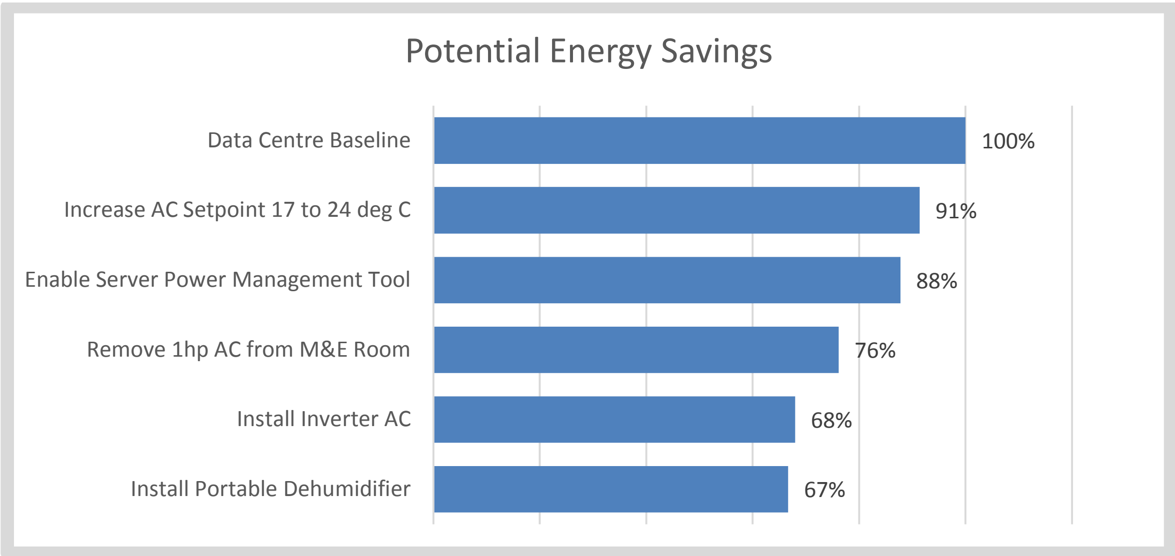


Figure Appendix 1b : Estimated Energy Savings (kWh) from implementing the ESMs

By implementing the potential energy saving measures in Fig 2.3, the energy consumption can be reduced from 41,700kWh by 13,900kWh **to 27,800kWh**, saving approximately **RM5,100** annually.

The carbon emission from **31.1 tons CO_2** can be reduced to **20.7 metric tons CO_2**, a reduction of 33%. The lowered electrical energy usage will reduce the carbon footprint of the Data Centre by **10,400 kg** or 10.4 **tonnes** yearly

With the implementation of all ESMs, the PUE can be reduced from **2.17** to **1.60** and the DcIE can be increased from **46%** to **62%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 2.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	1,390kWh/m^2/yr
Baseload Index	BI	355kW/m^2
Data Centre Carbon Index	DCI	1,040kgCO_2/m^2/yr

Table 1.1: Data Centre Indices

b) Study Report of Data Centre (Site) No.2

Results from the baseline study conducted from **17 to 24 October 2013** for **Site 2** found that the estimated annual electrical load is **159,400kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM59,000**. This is equivalent to 119.1 tonnes of carbon emissions per year.

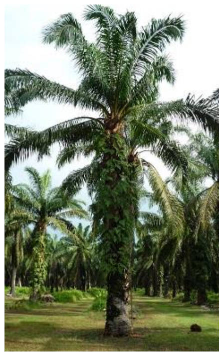
 Electricity Generated **159,400kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **744,200 km**	 Equivalent number of trees to absorb amount of carbon emitted **390 trees**

Figure Appendix 2a : Carbon Emissions Equivalent

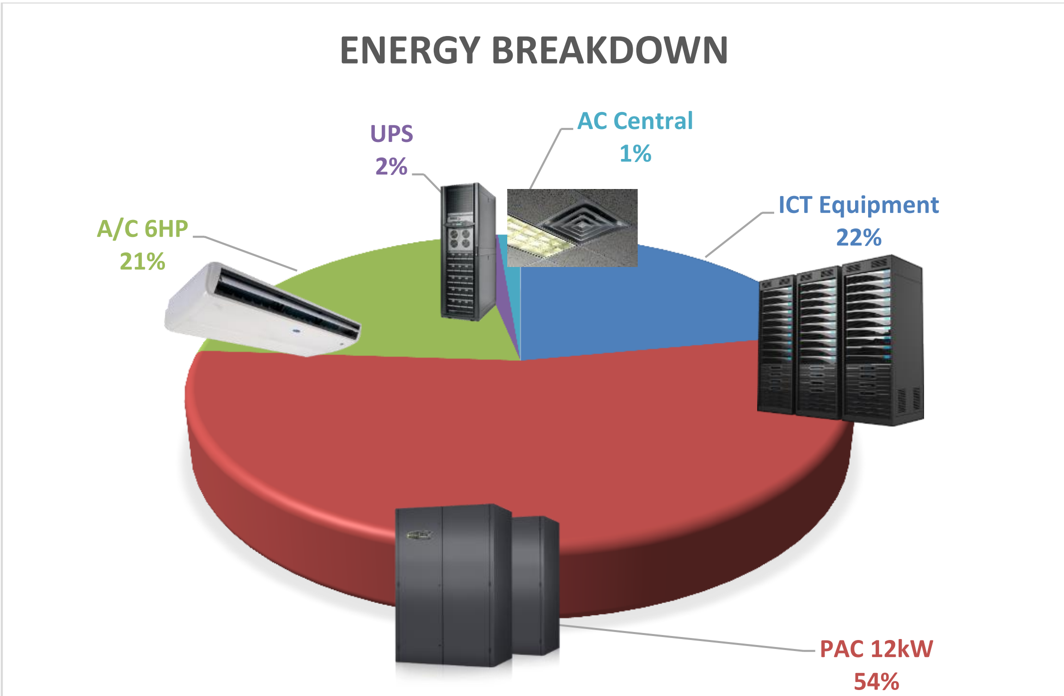


Figure Appendix 2b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 2b** above, the ICT load (ICT) 22%, the 15Hp Precision Air-Conditioner (PAC) 55%, the 6Hp split unit air conditioners (AC) 21% and the UPS consumes the remainder 2% of the electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 4.4 and DcIE of 23% obtained from the baseline study, give a performance rating of beyond "Very In-efficient".

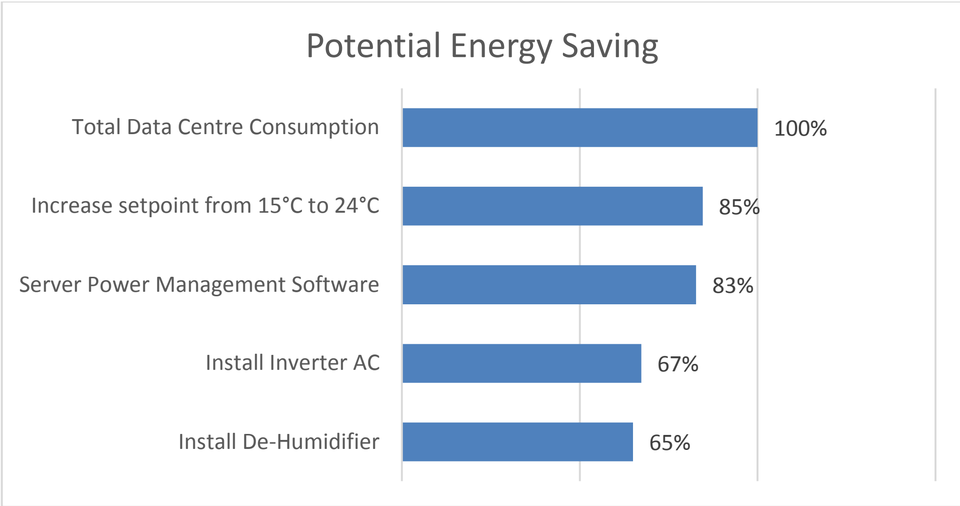


Figure Appendix 2b : Estimated Energy Savings (kWh) from implementing the ESMs

By implementing the potential energy saving measures in Fig 2.3, the energy consumption can be reduced from 159,400kWh by **55,800 kWh to 103,600kWh**, saving approximately **RM20,700** annually.

The carbon emission from **119.1 tons CO_2** can be reduced to **77.4 metric tons CO_2**, a reduction of 35%. The lowered electrical energy usage will reduce the carbon footprint of the Data Centre by **41,700 kg** or **41.7 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **4.4** to **3.10** and the DcIE can be increased from **23%** to **32%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 2.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	3,320kWh/m^2/yr
Baseload Index	BI	355W/m^2
Data Centre Carbon Index	DCI	2,400 kgCO_2/m^2/yr

Table 2.1 Data Centre Indices

c) Study Report of Data Centre (Site) No.3

Results from the baseline study conducted from 11 to 24 December 2013 for **Site 3** found that the estimated annual electrical load is **107,400kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM39,700**. This is equivalent to 80.2 tonnes of carbon emissions per year.

 Electricity Generated **107,400kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **501,400 km**	 Equivalent number of trees to absorb amount of carbon emitted **263 trees**

Figure Appendix 3a : Carbon Emissions Equivalent

The Energy Breakdown of the main equipment usage in the data centre are the ICT load of 81% and the 15Hp In-row Air-Conditioning equipment load is 19% of the remainder annual electrical load. This can be seen in the 52-week Energy Breakdown pie chart below in **Figure Appendix 3b**.

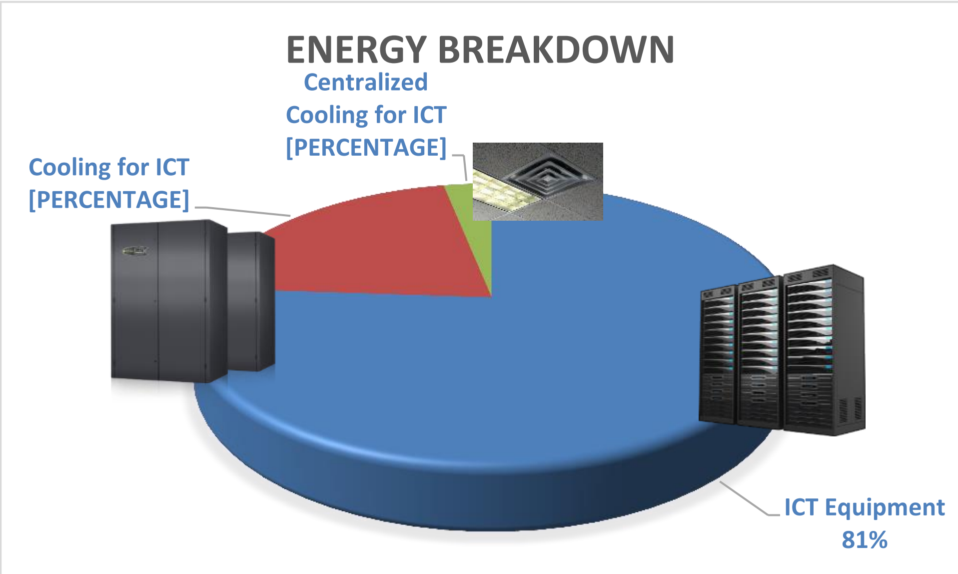


Figure Appendix 3b : Energy Breakdown

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 1.27 and DcIE of 79% give a performance of between Efficient and Very Efficient

Using the estimated energy consumption of **107,400kWh** and implementing all recommended Energy Saving Measures, the energy consumption can be reduced by 8,400kWh, saving approximately RM3,100 annually. Figure 2.3 show the estimated energy savings that can be achieved by implementing the measures.

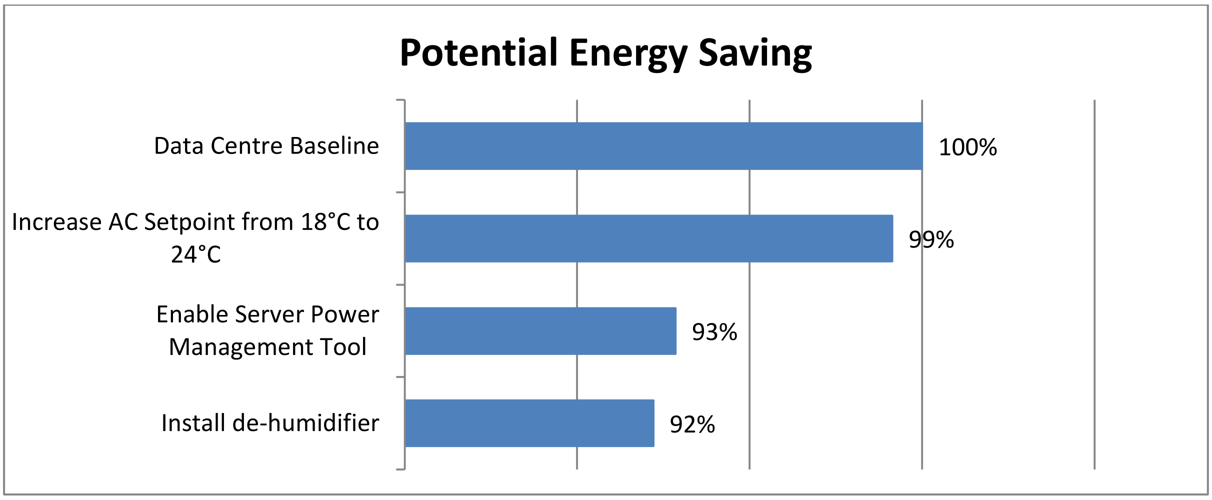


Figure Appendix 3b : Estimated Energy Savings (kWh) from implementing the ESM's

The carbon emission from **80.2 tons CO_2** can be reduced to **74.0 metric tons CO_2**, a reduction of 8.3%. The lowered electrical energy usage will reduce the carbon footprint of the Data Centre by **6,200 kg** or **6.2 tonnes** yearly

With the implementation of all ESMs, the PUE changes from **1.27** to **1.28** and the DcIE changes from **79%** to **78%**. These values are more or less the same, however the overall energy consumption of the data centre has reduced. The ultimate aim of reducing the carbon emissions has been achieved as the DC operations is now releasing 8.3% lower carbon emissions.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 3.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	5,160kWh/m^2/yr
Baseload Index	BI	520W/m^2
Data Centre Carbon Index	DCI	3,735kgCO_2/m^2/yr

Table 3.1 Data Centre Indices

d) Study Report of Data Centre (Site) No.4

Results from the baseline study conducted from **25 April to 1 May 2015** for **Site 4** found that the estimated annual electrical load is **283,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM105,000**. The estimated annual carbon emissions are 211 tonnes.

 Electricity Generated **283,000kWh**	 Equivalent carbon emission based on kilometers driven by 1 car (Gen 2, 1600cc) **1,300,000 km**	 Equivalent number of tress to absorb amount of carbon emitted **693 trees**

Figure Appendix 4a : Carbon Emissions Equivalent

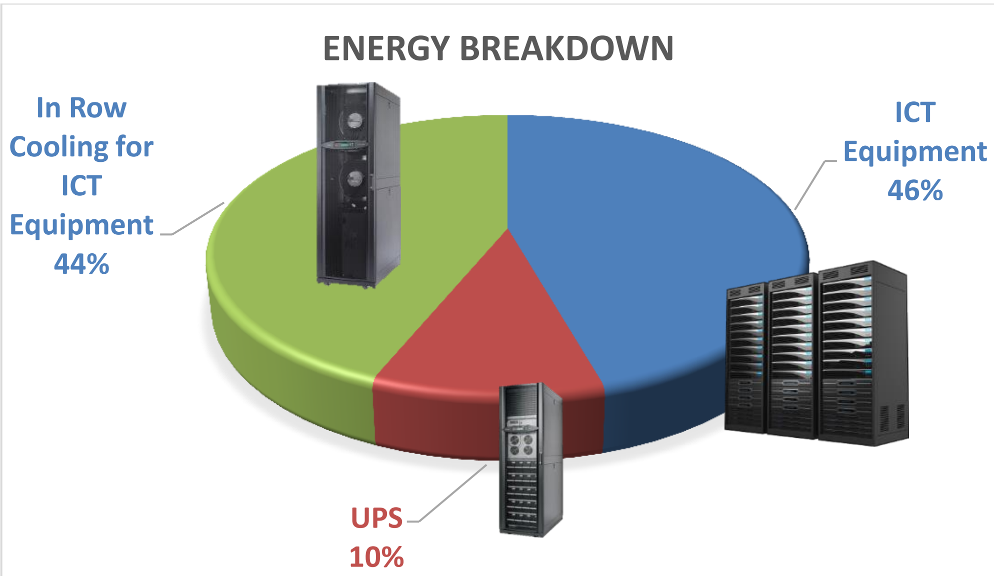


Figure Appendix 4b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 4b** above, the ICT load labeled "ICT" consumes about 46% of the total electrical load. The UPS installed before the ICT equipment consumes 10% of the electrical load. The 10kW In Row Air-Conditioner which is used for cooling the ICT equipment in the Data Centre consumes 44% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.19 and DcIE of 46% obtained from the baseline study, give a performance rating of between "Average" and "In-efficient".

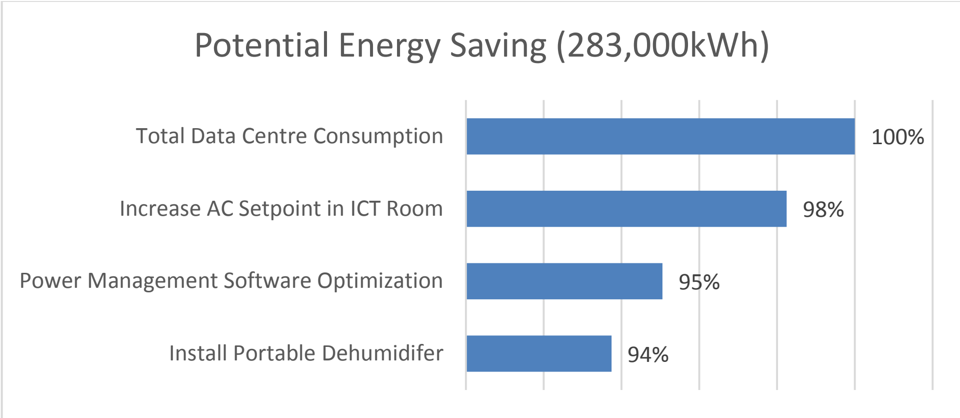


Fig. Appendix 4b : Estimated Energy Savings (kWh) from implementing the ESMs

Figure 2.4 show the estimated energy savings that can be achieved by implementing the measures.

By implementing the potential energy saving measures in fig 2.3, the energy consumption can be reduced from 283,000kWh by **19,000 kWh to 264,000kWh**, saving approximately **RM7,000** annually.

The carbon emission from **211 tons CO_2** can be reduced to **197 metric tons CO_2**, a reduction of approximately 6%. The reduced electrical energy usage will reduce the carbon footprint of the Data Centre by approximately **14,200 kg** or **14.2 tonnes** yearly.

It was noted that the humidity in the data centre is high, from 60% - 80%. This is above the recommended range. The source and cause of this higher than recommended humidity will require further research.

With the implementation of all ESMs, the PUE can be reduced from **2.19** to **2.11** and the DcIE can be increased from **46%** to **47%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 4.1**.**

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	3,820kWh/m^2/yr
Baseload Index	BI	416W/m^2
Data Centre Carbon Index	DCI	2,850 $kgCO_2/m^2$/yr

Table 4.1 Data Centre Indices

e) Study Report of Data Centre (Site) No.5

Results from the baseline study conducted from **9 April to 15 April 2015** for **Site 5**, found that the estimated annual electrical load is **287,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM106,000**. The estimated annual carbon emissions is 214 tonnes.

 Electricity Generated **287,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **1,340,000 km**	 Equivalent number of tress to absorb amount of carbon emitted **703 trees**

Figure Appendix 5a : Carbon Emissions Equivalent

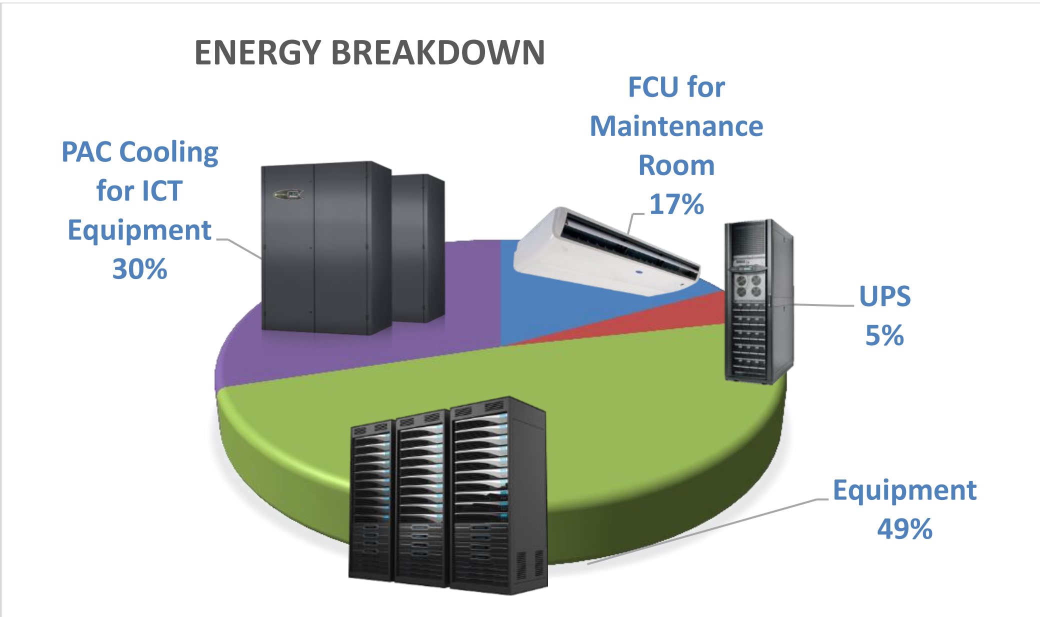


Figure Appendix 5b : Energy Breakdown

The Energy Breakdown in Figure 2.2 above, the ICT load labeled “ICT” consumes about 49% of the total electrical load. The UPS installed before the ICT equipment consumes 5% of the electrical load. The 20Hp Precision Air-Conditioner labeled “PAC” which is used for cooling the ICT equipment in the Data Centre consumes 30% of the total electrical load and the FCU uses 17% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.04 and DcIE of 49% obtained from the baseline study, give a performance rating of “Average”.

Using the estimated energy consumption of **287,000kWh** and implementing all recommended Potential energy saving measures, the energy consumption can be reduced by **35,000kWh to 252,000kWh**, saving approximately **RM12,900** annually.

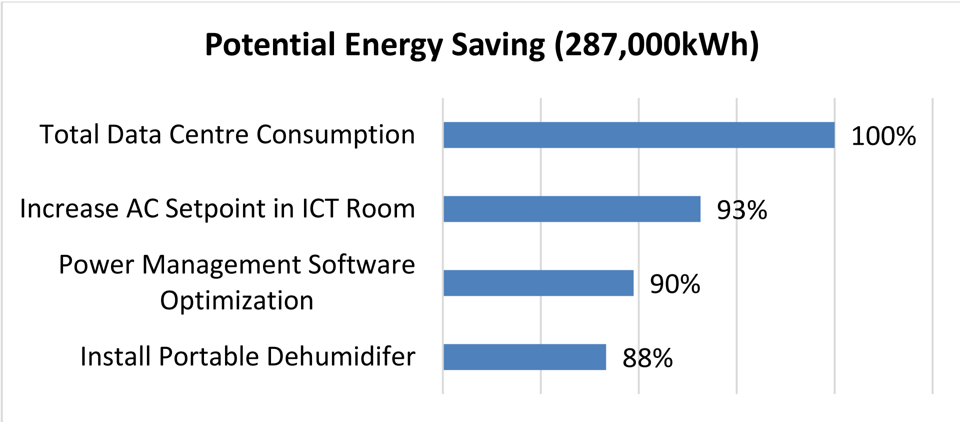


Fig. Appendix 5b : Estimated Energy Savings (kWh) from implementing the ESMs

The carbon emission from **214 tons CO_2** can be reduced to **188 metric tons CO_2**, a reduction of 12%. The reduced electrical energy usage will reduce the carbon footprint of the Data Centre by26,000 **kg** or **26 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **2.04** to **1.96** and the DcIE can be increased from **49%** to **51%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 5.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	2,260kWh/m^2/yr
Baseload Index	BI	244W/m^2
Data Centre Carbon Index	DCI	1,688 $kgCO_2/m^2$/yr

Table 2.1 Data Centre Indices

f) **Study Report of Data Centre (Site) No.6**

Results from the baseline study conducted from **17 April to 23 April 2015** for **Site 6** found that the estimated annual electrical load is **257,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM95,000**. The estimated annual carbon emissions are 192 tonnes.

 Electricity Generated **257,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **1,200,000 km**	 Equivalent number of tress to absorb amount of carbon emitted **630 trees**

Figure Appendix 6a : Carbon Emissions Equivalent

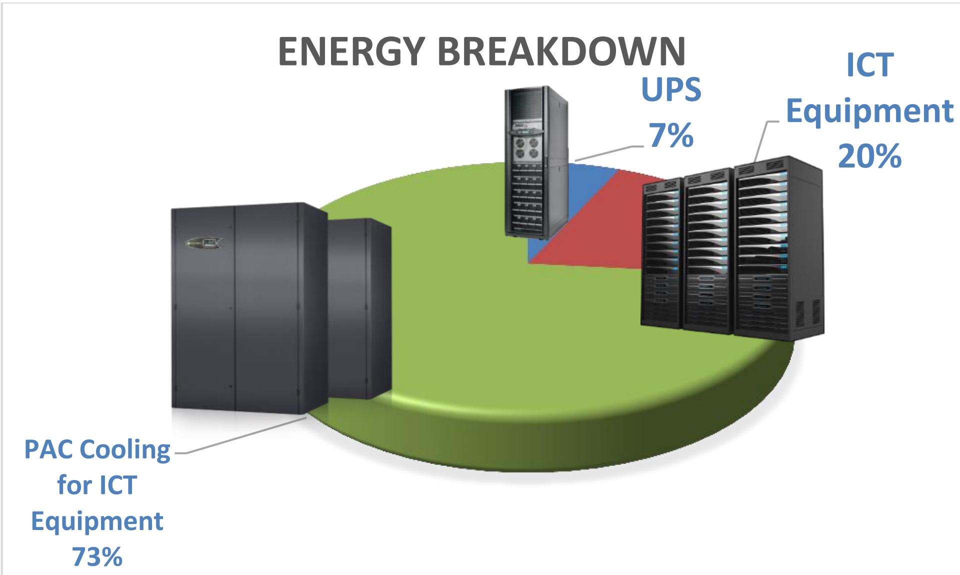


Figure Appendix 6b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 5b** above, the ICT load labeled "ICT" consumes about 20% of the total electrical load. The UPS installed before the ICT equipment consumes 7% of the electrical load. The 15HP PAC Air-Conditioner which is used for cooling the ICT equipment in the Data Centre consumes 73% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 5 and DcIE of 20% obtained from the baseline study, give a performance rating of beyond "Very In-efficient".

By implementing the potential energy saving measures in Fig 2.3, using the estimated energy consumption of **257,000kWh** and implementing all recommended Potential energy saving measures, the energy consumption can be reduced by **84,400kWh to 172,000kWh**, saving approximately **RM31,200** annually.

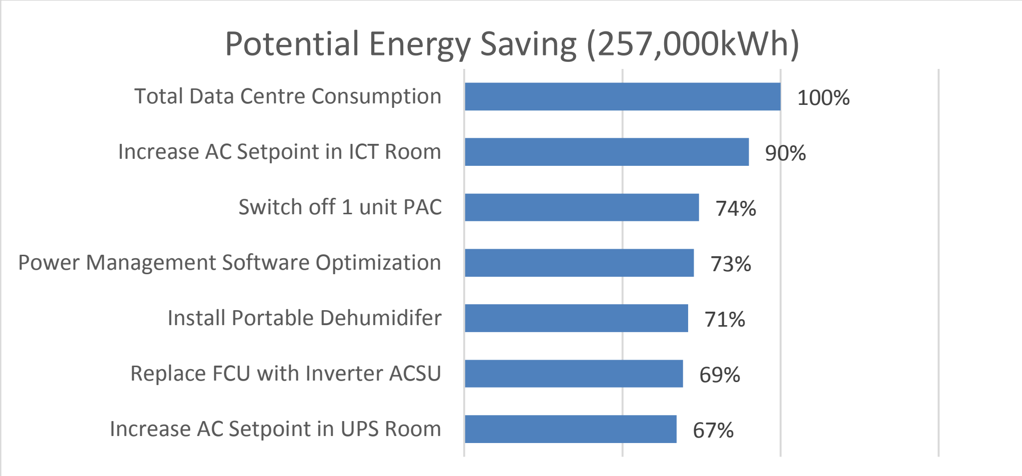


Fig. Appendix 6b : Estimated Energy Savings (kWh) from implementing the ESMs

The carbon emission from **192 tons CO_2** can be reduced to **128 metric tons CO_2**, a reduction of 33%. The reduced electrical energy usage will reduce the carbon footprint of the Data Centre by **63,000 kg** or **63 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **5** to **3.64** and the DcIE can be increased from **20%** to **27%**. Although, this is still very high due to an oversized cooling system to the amount of ICT equipment.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 6.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	2,050kWh/m^2/yr
Baseload Index	BI	113W/m^2
Data Centre Carbon Index	DCI	1,530 $kgCO_2/m^2$/yr

Table 6.1 Data Centre Indices

g) Study Report of Data Centre (Site) No.7

Results from the baseline study conducted from **14 May to 25 May 2015** for **Site 7** that the estimated annual electrical load is **236,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM87,000**. The estimated annual carbon emissions are 176 tonnes.

 Electricity Generated **236,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **1,100,000 km**	 Equivalent number of tress to absorb amount of carbon emitted **578 trees**

Figure Appendix 7a : Carbon Emissions Equivalent

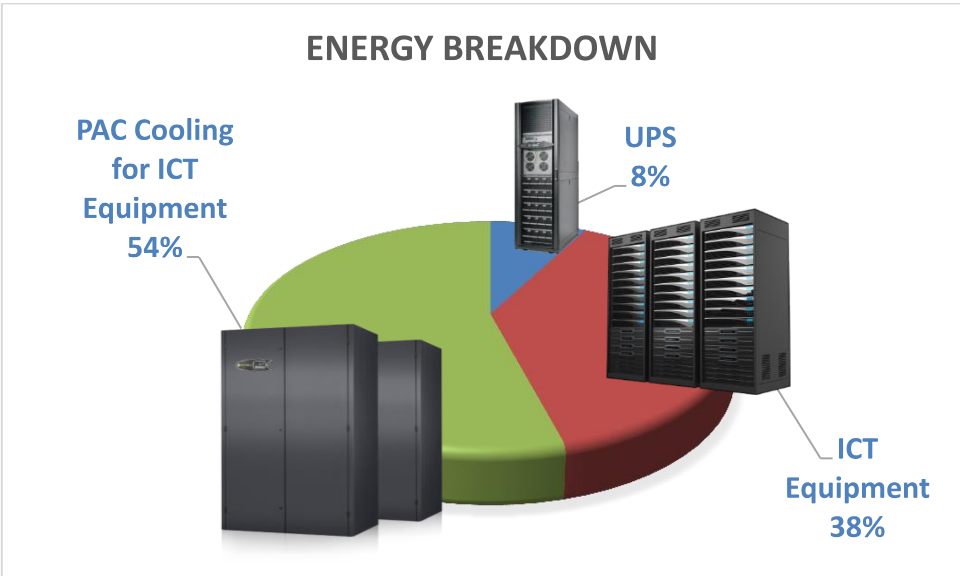


Figure Appendix 7b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 7b** above, the ICT load labeled "ICT" consumes about 38% of the total electrical load. The UPS installed before the ICT equipment consumes 8% of the electrical load. The 20HP PAC Air-Conditioner which is used for cooling the ICT equipment in the Data Centre consumes 54% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.62 and DcIE of 38% obtained from the baseline study, give a performance rating of between "In-efficient" and "Very In-efficient".

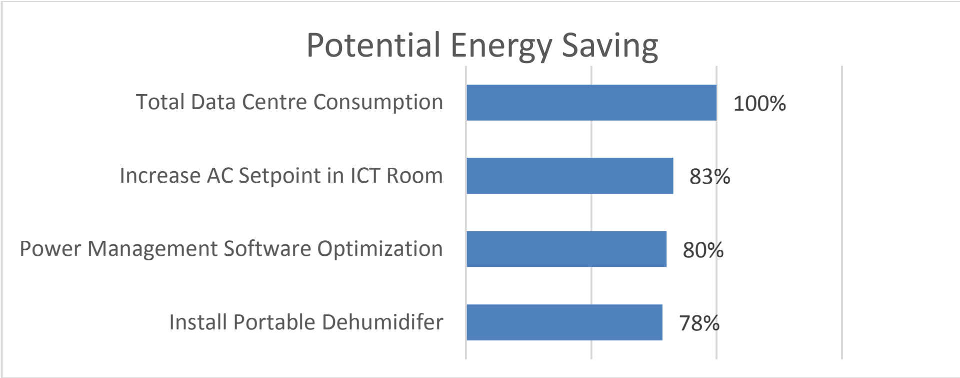


Fig. Appendix 7b : Estimated Energy Savings (kWh) from implementing the ESMs

Using the estimated energy consumption of **236,000kWh** and implementing all recommended potential energy saving measures, the energy consumption can be reduced by **31,400 kWh to 184,000kWh**, saving approximately **RM11,600** annually.

The carbon emission from **176 tons CO_2** can be reduced to **153 metric tons CO_2**, a reduction of 13%. The reduced electrical energy usage will reduce the carbon footprint of the Data Centre by **23,500 kg** or **23.5 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **2.62** to **2.10** and the DcIE can be increased from **38%** to **48%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 7.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	2,770kWh/m^2/yr
Baseload Index	BI	174W/m^2
Data Centre Carbon Index	DCI	2,070 $kgCO_2/m^2$/yr

Table 7.1 : Data Centre Indices

h) Study Report of Data Centre (Site) No.8

Results from the baseline study conducted from **5 June to 11 June 2015** for **Site 8** found that the estimated annual electrical load is **318,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM117,600**. The estimated annual carbon emissions is 238 tonnes.

 Electricity Generated **318,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **1,490,000 km**	 Equivalent number of trees to absorb amount of carbon emitted **779 trees**

Figure Appendix 8a : Carbon Emissions Equivalent

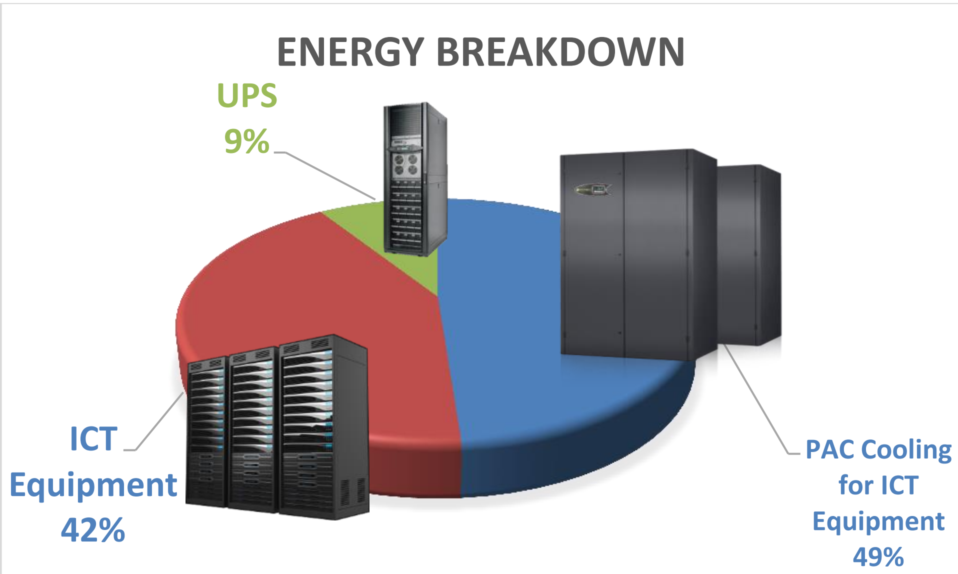


Figure Appendix 8b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 8b** above, the ICT load labeled "ICT" consumes about 42% of the total electrical load. The UPS installed before the ICT equipment consumes 9% of the electrical load. The 12HP Precision Air-Conditioner labeled "PAC" which is used for cooling the ICT equipment in the Data Centre consumes 49% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.38 and DcIE of 42% obtained from the baseline study, give a performance rating of between "Average" and "In-efficient".

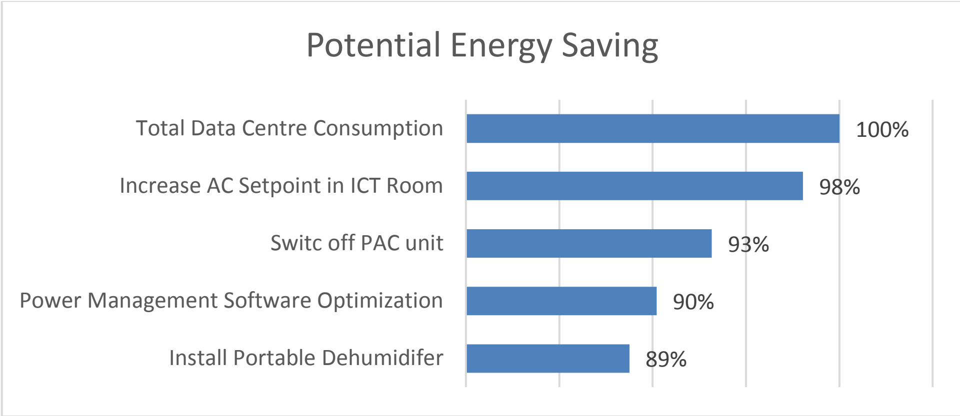


Fig. Appendix 8b : Estimated Energy Savings (kWh) from implementing the ESMs

Figure Appendix 8b show the estimated energy savings that can be achieved by implementing the measures.

Using the estimated energy consumption of **318,000kWh** and implementing all recommended Potential energy saving measures, the energy consumption can be reduced by **37,000kWh to 281,000kWh**, saving approximately **RM13,700** annually.

The carbon emission from **238 tons CO_2** can be reduced to **210 metric tons CO_2**, a reduction of 12%. The lowered electrical energy usage will reduce the carbon footprint of the Data Centre by **27,700 kg** or **27.7 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **2.38** to **2.16** and the DcIE can be increased from **42%** to **46%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 8.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	1,820kWh/m^2/yr
Baseload Index	BI	153W/m^2
Data Centre Carbon Index	DCI	1,360 kgCO_2/m^2/yr

Table 8.1 : Data Centre Indices

i) Study Report of Data Centre (Site) No.9

Results from the baseline study conducted from **6 May to 12 May 2015** for **Site 9** found that the estimated annual electrical load is **118,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM44,000**. The estimated annual carbon emissions is 88 tonnes.

 Electricity Generated **118,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **550,000 km**	 Equivalent number of tress to absorb amount of carbon emitted **380 trees**

Figure Appendix 9a : Carbon Emissions Equivalent

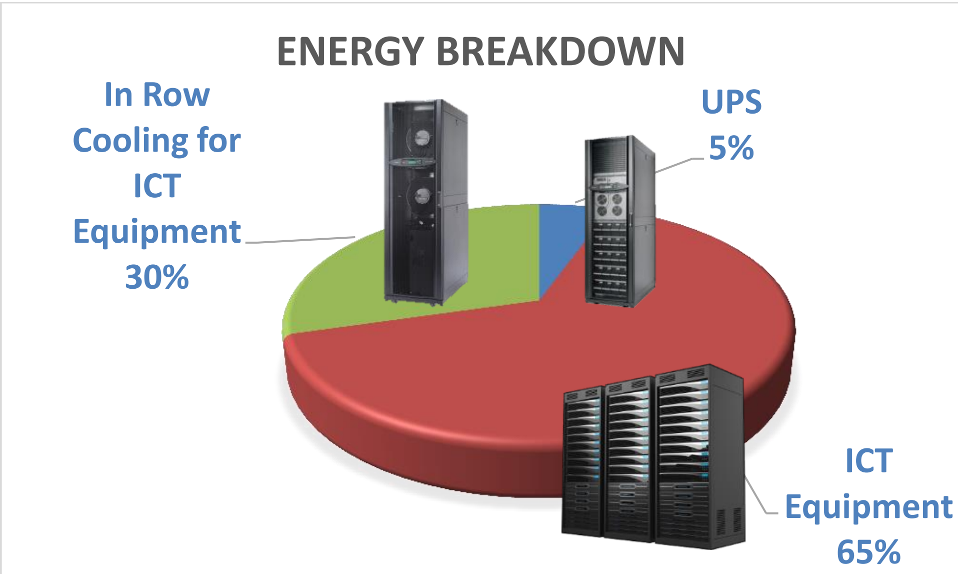


Figure Appendix 9b : Energy Breakdown

The Energy Breakdown in **Figure Appendix 9b** above, the ICT load labeled "ICT" consumes about 65% of the total electrical load. The UPS installed before the ICT equipment consumes 5% of the electrical load. The 10kW In Row Air-Conditioner which is used for cooling the ICT equipment in the Data Centre consumes 30% of the total electrical load.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 1.54 and DcIE of 65% obtained from the baseline study, give a performance rating of "Efficient".

From The study, it can be said that the data centre has fully utilized its design strategy to be labeled a **GREEN Data Centre**. Further savings can be achieved with other technologies and improved design of data centre as discussed in Chapter 12.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 9.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	2,360kWh/m^2/yr
Baseload Index	BI	250W/m^2
Data Centre Carbon Index	DCI	1,760 kgCO_2/m^2/yr

Table 9.1 : Data Centre Indices

j) Study Report of Data Centre (Site) No.10

Results from the baseline study conducted from **30 June to 6 July 2015** for **Site 10** found that the estimated annual electrical load is **435,000kWh.** At the current tariff rate of RM0.37/kWh, this costs **RM160,800**. This is equivalent to 325 tonnes of carbon emissions per year.

 Electricity Generated **435,000kWh**	 Equivalent carbon emission based on kilometres driven by 1 car (Gen 2, 1600cc) **2,031,000 km**	 Equivalent number of trees to absorb amount of carbon emitted **1,065 trees**

Figure Appendix 10a : Carbon Emissions Equivalent

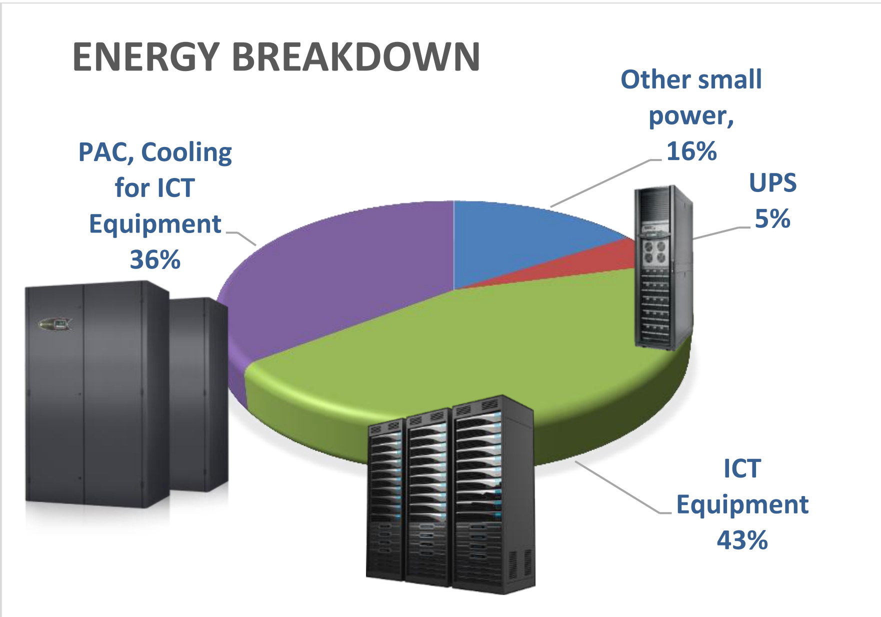


Figure Appendix 10b : Energy Breakdown

The Energy Breakdown of the main equipment usage in the data centre are ICT equipment 43%, UPS 5% and 15Hp Precision Air-Conditioner (PAC) 36% of the total electrical load. Other small power loads comprise the remaining 16%.

The **Power Usage Effectiveness (PUE)** measures how efficiently a data centre uses energy. The PUE of 2.3 and DcIE of 44% obtained from the baseline study, give a performance rating of between "Average" and "In-efficient".

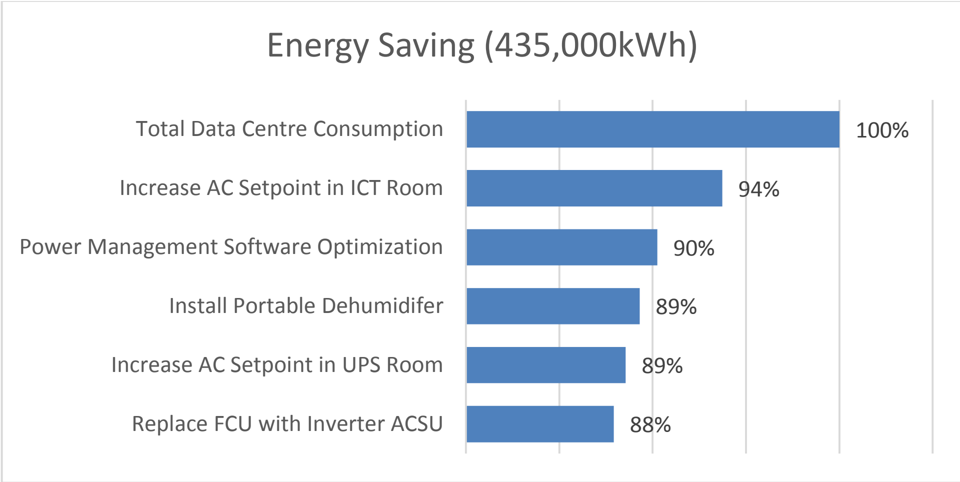


Fig. Appendix 10b : Estimated Energy Savings (kWh) from implementing the ESMs

Figure Appendix 10b show the estimated energy savings that can be achieved by implementing the measures.

By implementing the potential energy saving measures in Fig 2.3, the energy consumption can be reduced from 435,000kWh by **52,000 kWh to 383,000kWh**, saving approximately **RM19,500** annually.

The carbon emission from **325 tons CO_2** can be reduced to **285 metric tons CO_2**, a reduction of 12%. The lowered electrical energy usage will reduce the carbon footprint of the Data Centre by **39,200 kg** or **39.2 tonnes** yearly.

With the implementation of all ESMs, the PUE can be reduced from **2.3** to **2.19** and the DcIE can be increased from **44%** to **46%**.

In addition to the PUE and DcIE, three other indices were calculated as shown in Table 10.1

Description	Abbreviation	Index Amount
Data Centre Energy Index	DEI	2,600kWh/m^2/yr
Baseload Index	BI	228W/m^2
Data Centre Carbon Index	DCI	1,950 kgCO_2/m^2/yr

Table 10.1 : Data Centre Indices