A Framework for Data Center Efficiency: Power Usage Effectiveness (PUE)

Phatphong Phetkaewna
DC Consulting, Solution, PMO & Governance
East Asia Japan, India, Middle East Africa, South America

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Global Challenge on Data Center

6-12 months

Is the average time to deploy a **data center.**

Survey of Multiple Colocation Providers (2023)

Cybersecurity

Ranked **#1** business concern.

Allianz Risk Barometer

53%

of data center operators reported difficulty **finding qualified employees**.

Network World

80%

of data centers have experienced **some type of outage, preventable.**

Uptime Institute

40%+

By 2023, 1 in 2 companies will generate more than **40% of their revenue** from **digital products and services**, compared to 1 in 3 in 2020.

IDC

Up to 50%

Energy expenses.

IDC

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Global Concern on Data Center

New data centres in Singapore to meet higher standards when moratorium lifts in Q2 2022

THU, JAN 27, 2022 - 8:28 PM | UPDATED THU, JAN 27, 2022 - 9:09 PM

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Applicants will need to design more efficient data centres when the moratorium is lifted in the second quarter of this year. ST TELEMEDIA GLOBAL DATA CENTRES

Dublin and data centers: The end of the road?

Ireland was all set to be a major hub. Then data center power demands came up against the limitations of the grid

May 24, 2022 By: Dan Swinhoe Comment

Dutch government halts hyperscale data centers, pending new rules

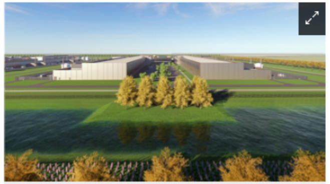
After a nine month moratorium, new facilities will need a license

February 17, 2022 By: Peter Judge Comment

The Dutch government has announced it will impose stricter rules for hyperscale data centers - and has banned new projects for nine months, while the new rules are worked out.

The ban will not affect Facebook's effort to build in Zeewolde, though this currently faces difficulties due to a government land sale. Other previously approved plans will go ahead, and projects such as Google's Groningen project, and others in Middenmeer will be allowed to go ahead because these areas are exempt from the ban.

"Our space is limited, so we have to make the right choices," said housing and planning minister Hugo De Jonge in a letter to the House of Representatives, according to a report on the Netherlands government website. "Hyperscale data centers take up a lot of space and consume a disproportionate amount of available renewable energy. That is why the cabinet wants to prevent hyperscale data centers being built throughout the Netherlands."



– Zeewolde Municipality

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• How respond to market trends

Improve efficiencies and reduce PUE

Accessible and simple, operation/maintenance tools

Unplanned downtime

Green power sourcing with time-of-day tracking

Electrical hazard reduction

Efficient asset management strategy

Automated and remote management

Resilient & Safe | **Efficient** | **Adaptive** | **Sustainability** | **Workforce Optimization**

Agnostic and interoperable systems

Supply chain decarbonization

System wide cyber resilience to protect data from threats

Requirements to remove GHG emissions (Scope 1,2,3)

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Key Area of Impact to Sustainability

Energy

Data Centers consume 1 - 2% of global energy

GHG emissions

Scope 1, 2 and 3 emissions have direct impact on climate change

Water

Data center cooling systems and power plants use significant amounts of water

Waste

Waste is generated during construction and operations

Land and biodiversity

Data center facilities and upstream value chain have impact on the ecosystem

Energy

The energy efficiency of data center facilities has dramatically improved over the last 10 years, but the growth of digital services requires continued effort to meet global sustainability goals. Improving energy efficiency reduces GHG emissions, air pollution, and even water used in electricity production.

Energy: **What to Measure**

Metric / KPI	Units	Definition or Rationale	Framework / Standard
Total energy consumption	kWh	The total energy consumed to operate the data center(s). This is typically the electrical energy drawn from the utility grid but would also include any energy production onsite from generators, solar, or wind. Energy imported in the form of natural gas, steam, or chilled water should also be counted.	SASB
Power usage effectiveness (PUE)	ratio	Total load of a data center divided by the IT load. It indicates data center facility efficiency and is a well-understood metric used by most data center operators.	ISO/IEC 30134-2
Total renewable energy consumption	kWh	Total renewable energy that is owned, controlled, or purchased for use at a data center facility. Data center operators can reduce their Scope 2 emissions by increasing the proportion of renewable energy they consume.	RE100
Renewable energy factor (REF)	ratio	Renewable energy owned and controlled by a data center organization divided by the total energy consumption of the data center.	ISO/IEC 30134-3
Energy reuse factor (ERF)	ratio	The ratio of reused energy to total data center energy consumption	ISO/IEC 30134-6

Energy: **Areas of Opportunity – Cooling System**

Design / Build	Operate and Maintain
Beginning • Specify VFD control for pumps and fans. • Design for expanded relative humidity range. • Use air containment. **Advanced** • Specify air-economizer systems or trim chiller solutions. • Design system for higher chilled water (CW) temperatures, > 20C. • Make accommodations for liquid cooling. • Leverage design tools like CFD to optimize layout and airflow. **Leading** • Export energy via district heating or other uses. • Locate data centers in climates that maximize free cooling.	**Beginning** • Digitally monitor cooling system to quickly detect performance degradation (e.g., filter changes, etc.). • Implement procedures to maintain tight air containment during white space changes. • Automate CRAH units to ensure no demand fighting. **Advanced** • Leverage predictive maintenance intelligence tools. **Leading** • Use digital twin of the system for off-line simulation, evolution and optimization. • Automate free cooling controls to maximize free cooling hours. • Orchestrate IT demand during periods of free cooling.

Energy: **Areas of Opportunity – Electrical System**

Design / Build	Operate and Maintain

Beginning
• Specify high-efficiency equipment, for example:
  • High efficiency UPSs with eco modes
  • High efficiency power supplies
  • High efficiency transformers
  • LED lighting.
• Specify a thorough monitoring system to identify inefficiencies early.
Advanced
• Use and develop a simulation tool for optimization.
• Adhere to good electrical design practices, including use of 415V distribution in NAM.
• Design electrical architectures around UPS efficiency curves.
• Move from 2N to distributed redundant designs.
Leading
• Bring MV as close as possible to the IT space.
• Leverage opportunities for MV or HV grid connection.
	Beginning
	• Use power monitoring software tools to maintain efficient operations
	  • Quickly identify underperforming equipment
	  • Maintain phase balancing
	  • Updated firmware to take advantage of new efficiency features
	  • Track setting changes
	  • Maintain documentations and guidelines
	• Use the green / eco mode in UPSs
	• Schedule appropriate preventative maintenance to identify problems, for example:
	  • Infrared scans / filter changes, etc/

Energy: **Areas of Opportunity - IT**

Design / Build	Operate and Maintain
Beginning • Specify high efficiency IT PSUs. **Advanced** • Leverage efficient rack architectures with centralize PSUs, such as Open Compute Project (OCP) and Open19. • Leverage liquid cooling architectures (reduces IT fan energy and leakage current)	**Beginning** • Decommission underutilized IT. • Leverage architectures such as virtualization and containers to fully load installed IT.

Metrics to measure energy

Metric Categories	Key metrics	Units	Recommendations		
			Beginning	Advanced	Leading
Energy	Total energy consumption	kWh	✓	✓	✓
	Power usage effectiveness (PUE)	Ratio	✓	✓	✓
	Total renewable energy consumption	kWh	✓	✓	✓
	Renewable energy factor (REF)	Ratio		✓	✓
	Energy reuse factor (ERF)	Ratio			✓

The PUE derby

Typical data center

Extreme PUE claims

Source …	***PUE reported …***
• Google	1.12
• Microsoft “data lab”	1.24
• Microsoft Generation 4 data centers (PUE target)	1.12
• A veteran designer of large-scale data centers	1.08 1.06 1.046

Great- Lets do it!

Five key PUE concepts

What are reasonable PUE expectations?

1

PUE is **based on math**

It is "knowable" using reasonable methods and standardized guidelines

2

PUE **comparisons are difficult**

Valid PUE comparisons are critically dependent on common terminology and assumptions

3

Shared building systems should be included for a real PUE

Often overlooked, these need to be fairly allocated to data center operations

4

Redundancy worsens PUE

Redundancy of power and cooling systems (an availability choice you make) reduces PUE because of lowered load across the redundant devices

5

Your **electric bill** and **efficiency (PUE)** are not the same thing

One can get better while the other gets worse, for legitimate design decisions you might make

Compare "apples to apples" and don't overlook hidden electrical losses

"The devil is in the details"

PUE = Total Facility Power / Total IT Power

The simple story

But to get The WHOLE story you need to ask questions …

- **What is included? (What's IN, what's OUT?)**
- **Annualized average or point-in-time snapshot?**
- **At what % load? (PUE degrades at lower loading)**
- **In what geographical location? (e.g., access to "free cooling")**

When comparing PUE, always make sure it's "apples to apples"

PUE less than 1.10? Unrealistic for ordinary data centers in ordinary places with ordinary budgets

Very large, purpose built examples may be closing in on impressive PUEs, but they have flexibility and resources you may not have:

- Choice of geographic location (for free-cooling opportunities)
- An extensive fault-tolerant system architecture (so equipment failure doesn't matter)
- Nonstandard servers (e.g., NEBS carrier grade) that are more tolerant of Spartan conditions

No UPS

Little or no power redundancy

"Free cooling" only

No air conditioning fans

AND …

- A very large budget to meet green initiatives !

These extreme strategies are rarely suitable or fundable for the typical enterprise data center

The big question: What's in, what's out?

Cooling subsystems are sometimes forgotten in the PUE calculation

Shared building-wide system power must be prorated for the data center's share of use

Items often omitted from the PUE calculation

Data center subsystem	*In the PUE formula, is it part of …* IT load?	Physical infrastructure?	Not included?
Cooling tower basin heaters		√	
Water treatment		√	
Pipe freeze protection		√	
Air compressors		√	
Condensate pumps		√	
Make-up air / fresh air system power		√	
Unit heaters		√	
Well pumps		√	

Excerpted from Table 1 in APC White Paper 158

Leaving these out will falsely improve PUE

APC White paper 118 efficiency effects of virtualization
APC White paper 138 efficiency effects of increased inlet temperature

PUE vs. the electric bill

Be careful of using PUE as your only metric

It may not tell the whole story !

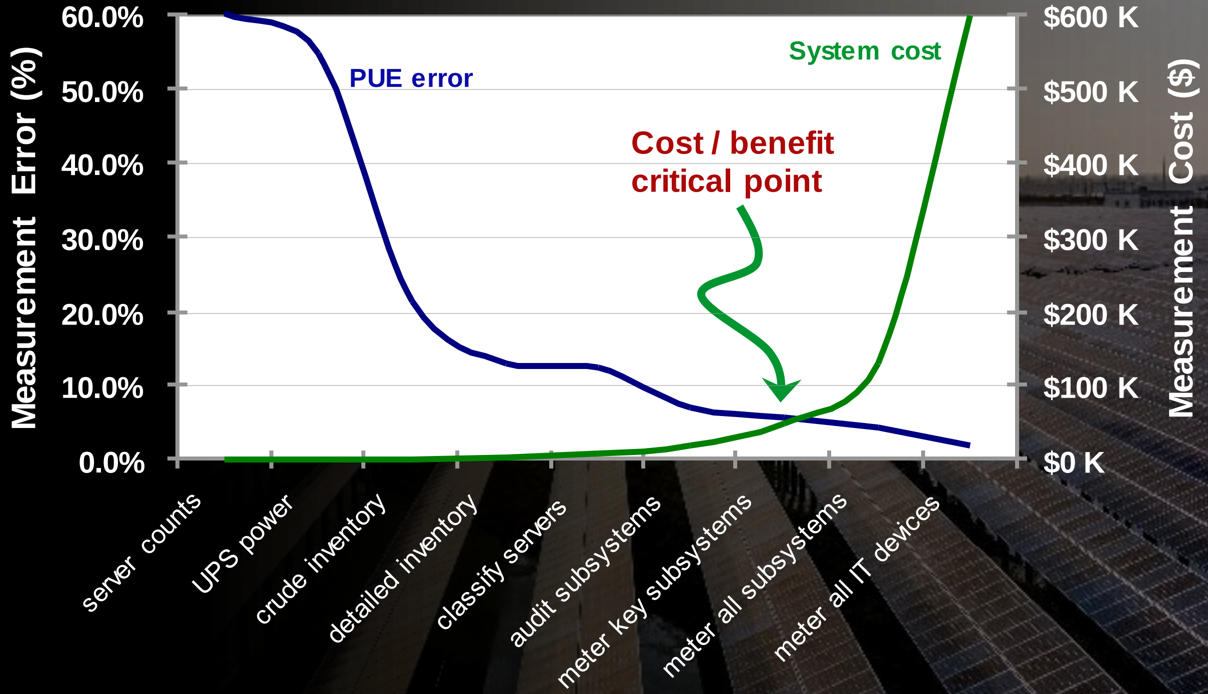
Data center design uprade	Electric bill	PUE
Virtualization / consolidation	BETTER (lower) *Because of optimized use of server capacity*	WORSE (higher) *Unless power and cooling are downsized to align with lower IT load **
Higher server inlet temperature	WORSE (higher) *If increased server fan power exceeds cooling system savings*	BETTER (lower) *Because of higher efficiency of cooling system*

Beware of "Cause and Effect "

How many meters?

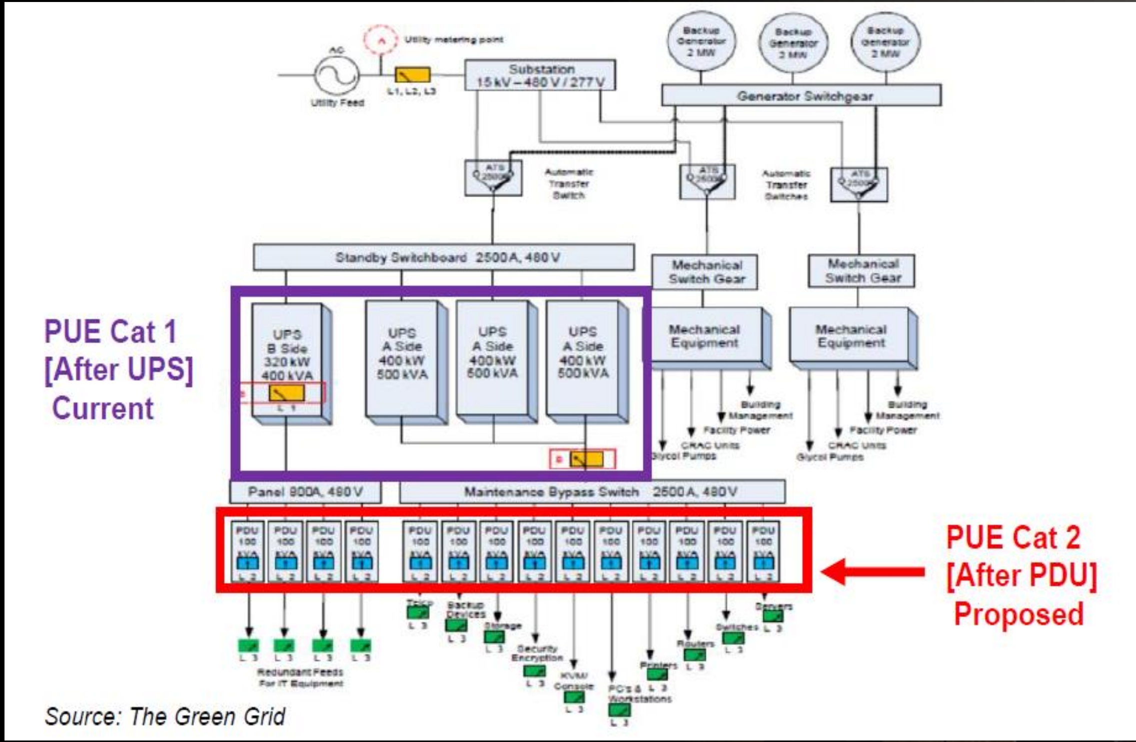
Cost/benefit tradeoff for data collection

APC White Paper #161 - Allocating data center energy costs and carbon to IT users



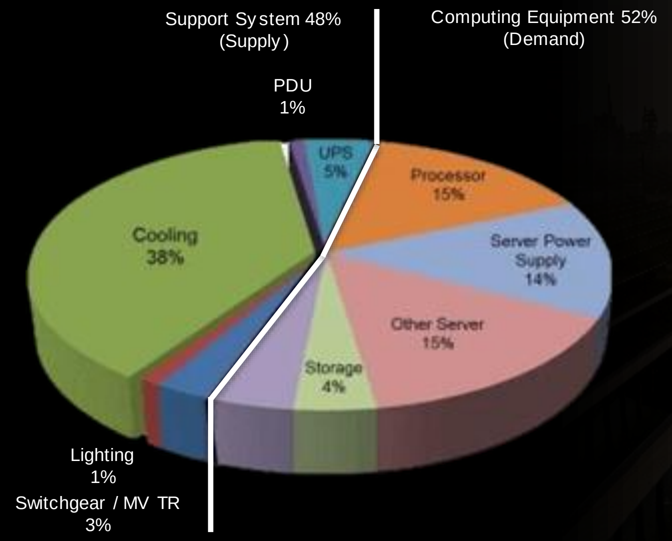
Metering for PUE has diminishing returns, but metering has other benefits

PUE Measurement Category



- Three types of PUE Measurement Categories depending on Accuracy requirement & cost budget
- **PUE Category 1**, ICT electrical energy usage measured at UPS Output
- **PUE Category 2**, ICT electrical energy usage measured at PDU Output
- **PUE Category 3**, ICT electrical energy usage measured at ICT equipment electrical system

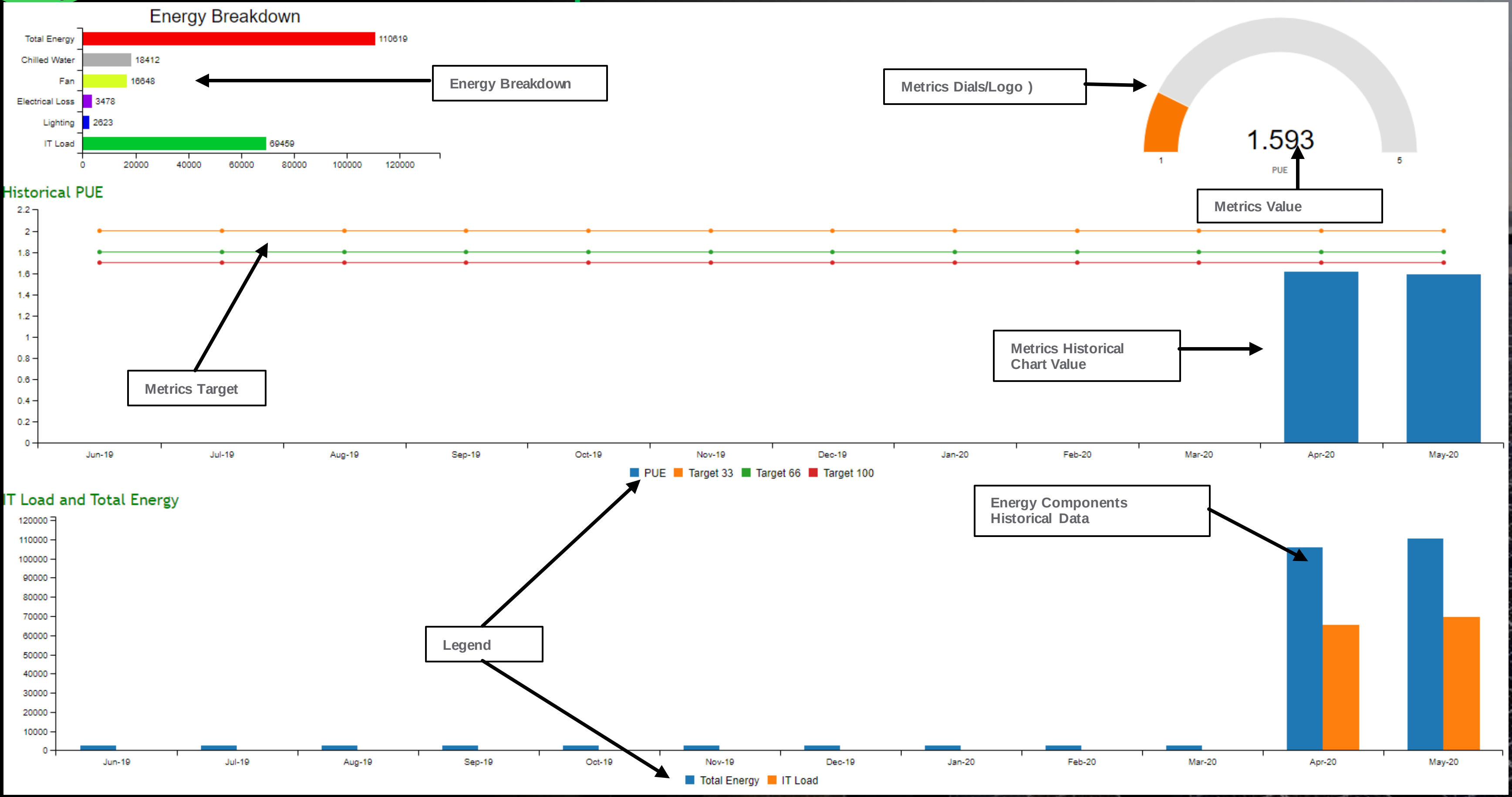
Key Efficiency Metric



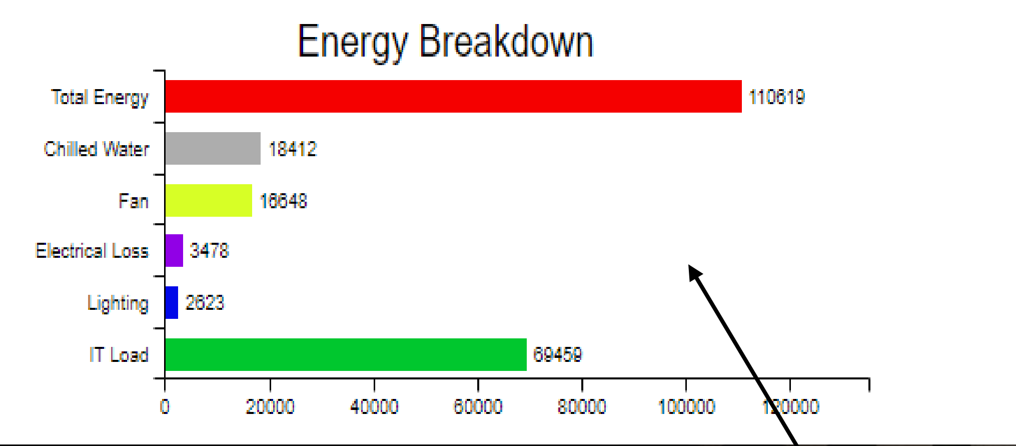
Electrical and Mechanical System

- Power utilization for cooling system is a major component in Data Center operation
- UPS efficiency losses contribute to increase PUE for Data Center
- Focus on high efficiency equipment to minimize losses for reducing Data Center PUE

Dashboard Components



PUE- Energy Breakdown



- Requirement from SS564:2013 of Energy Distribution Factors
- Important graph determine the Significant Energy Usage (SEU) i.e. areas that have high energy consumption
- The Sum of IT Load plus all energy consumption should be much less or nearly equal to Total Energy

These sets of metrics include metrics used to reflect the distribution of energy consumption of identified significant energy usages (other than ICT equipment usage). It typically consists of the following factors, although the organisation shall define the corresponding factors appropriately according to its operation condition and status, so as to effectively represent the contributions of its data centre's significant energy usages.

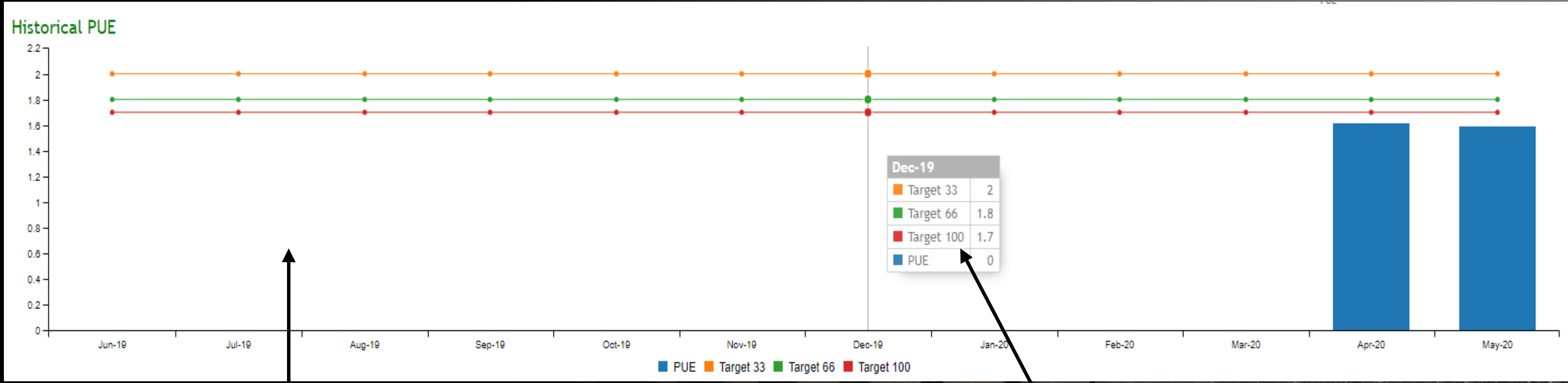
(a) Fan Energy Consumption Factor FEC

(b) Cooling System Energy Consumption Factor CEC

(c) Electrical System Dissipation Factor EEC

(d) Lighting Energy Consumption Factor LEC

Historical Chart & Target



This metric shall be measured at regular intervals (annually at a minimum). Annual data should be used if the organisation has built-in continuous measurement capabilities of the relevant parameters. However an organisation which engages professional energy audit/consultancy service for its regular metric measurement can consider defining a measurement period, during which the parameters are measured. Care shall be taken to ensure that the defined period is representative of the data centre operation (subject to any practical constraints in a specific data centre setup, e.g. the lack of historical data during initial measurement, limitation due to disruption to critical ICT systems and services, etc), and should be consistent across the year to ensure comparability.

In the case of a new data centre with no or low loading, some green data centre metrics (e.g. PUE) may not be very useful for future energy planning due to the extremely low utilisation of the data centre and its equipment/facilities. In such cases, besides measuring the metrics, the organisation should, if possible, also capture in the energy review the designed-in value of the metrics (e.g. through calculation of design parameters and equipment specifications) when the data centre is under the following loading conditions:

(a) 100% loading

(b) 66% loading, and

(c) 33% loading.

5.4.7 Objectives, targets and action plans

The organisation shall establish, implement and maintain its documented green data centre objectives and targets, inclusive of those for the green data centre metrics, at relevant functions and levels within the organisation.

The objectives and targets shall be measurable, where practicable, and consistent with the green data centre policy, while targets shall be consistent with the objectives. They shall include the commitments to improvement in energy performance of the data centre(s) by adopting the best practices in the following areas:

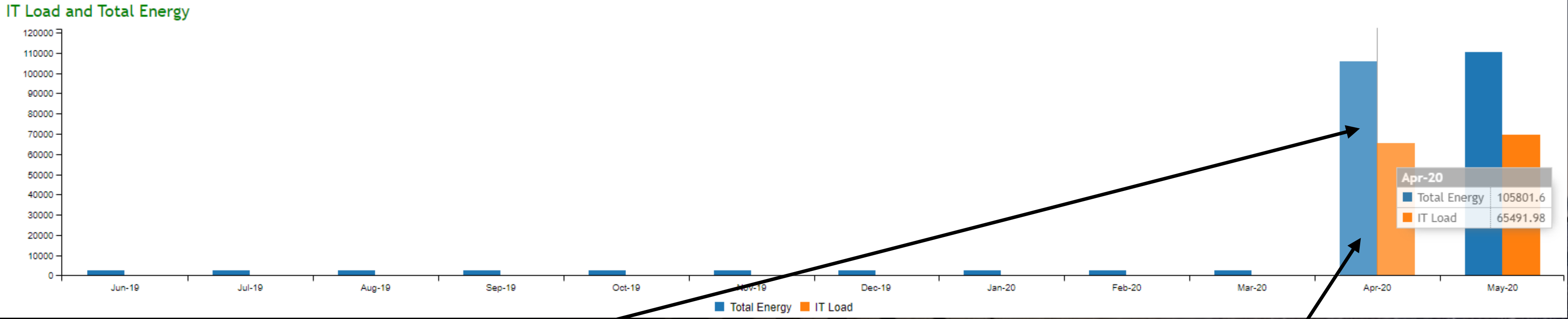
(a) Management of mechanical systems;

(b) Management of electrical systems;

(c) Management of ICT equipment; and

(d) Design of data centres.

Historical Component Data



5.6 Checking performance

5.6.1 Monitoring, measurement and analysis

The organisation shall document, monitor and/or measure, at regular intervals, the key characteristics of its data centre operations that can affect the effectiveness of the energy and environmental management system. Measurement needs shall be defined and periodically reviewed. A measurement plan, including the plan for energy measurement, shall be maintained and implemented.

The key characteristics shall include, at a minimum:

(a) the results of the energy review;

(b) significant energy usage;

(c) energy performance metrics;

(d) the relevant factors or variables related to significant energy usage;

(e) evaluation of actual versus expected energy consumption; and

(f) effectiveness of the action plans in achieving objectives and targets.

5.4.3 Energy review

The organisation shall define and document the process, methodology and criteria for conducting energy review of its data centre. It shall conduct the energy review at regular intervals and when there are major changes to the data centres affecting its location, facilities, equipment, systems or processes. Records of the energy review shall be retained.

The energy review shall include:

(a) Energy usage and consumption analysis:

(i) identify existing energy sources;

(ii) evaluate the trend of energy usage and their consumption (based on measurement and other data); and

(iii) project future energy usage and their consumption;

(b) Identification of significant energy usages including the facilities, equipment, systems and processes that significantly affect energy usage and consumption of the data centre;

(c) Determination of current energy performances of the identified significant energy usages;

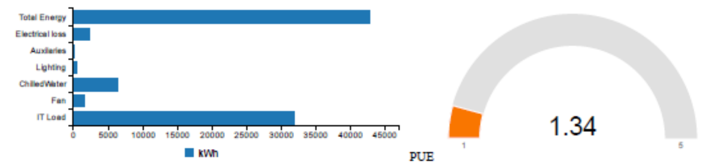
(d) Identification of personnel and other factors that may affect significant energy usages and

(e) Identification and prioritisation of any opportunities for energy performance improvement.

neider
Electric

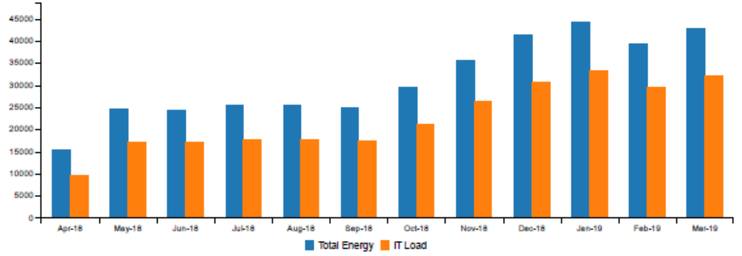
Power Usage Effectiveness –PUE

Metric	Formula	Explanation
PUE : Power Usage Effectiveness (category A)	PUE = Total_Energy / dE2	Total_Energy : Electrical Energy use (kWh) dE2 : ICT Electrical Energy use (kWh)



Historical PUE

IT Load and Total Energy



Category A Metrics

- Overall Measure of Data Center Efficiency
- Total Energy Consumption/ICT Energy Consumption
- Measured in regular Monthly Interval
- Lower the PUE value, Better Data Center Efficiency
- Lowest PUE value is 1.0 which means Total Energy Consumption = ICT Energy Consumption
- Important to maintain PUE < 2.0

Example of Efficiency Savings & Return On Investment

		PUE	Power Consumed (kW)	Energy Consumed (kWh)	Annual Energy Bill (ZAR)
	Current Situation	**2.16**	**1984.4**	**17,384,000**	**39,287,053**

In South Africa

STEP	Actions	PUE	Power Saved	Energy Saved	Energy Savings		Investment	ROI
			kW	kWh	ZAR	%	ZAR	
P1	Air management Improvement of Server & Network Room	2.07	84.4	739,355	1,670,942	4%	840,000	0.5
P2	Air management Improvement of Support Room (Energy Centre 1 & 2)	2.02	43.2	378,677	855,811	2%		0
P3	Power management and improvement	1.9	109.5	959,080	2,167,520	6%	6,739,200	3.1
	Combined impact (P1, P2, P3)	**1.9**	**237.1**	**2,077,112**	**4,694,273**	**12%**	**7,579,200**	**1.6**
P5	Cooling Optimization with AI & ML	1.45	413	3,618,176	8,177,078	21%	31,028,400	3.8
	Combined impact (P1, P2, P3, P5)	**1.45**	**650.1**	**5,695,288**	**12,871,351**	**33%**	**38,607,600**	**3**

Example of PUE & CO2 Reduction Roadmap Calculations

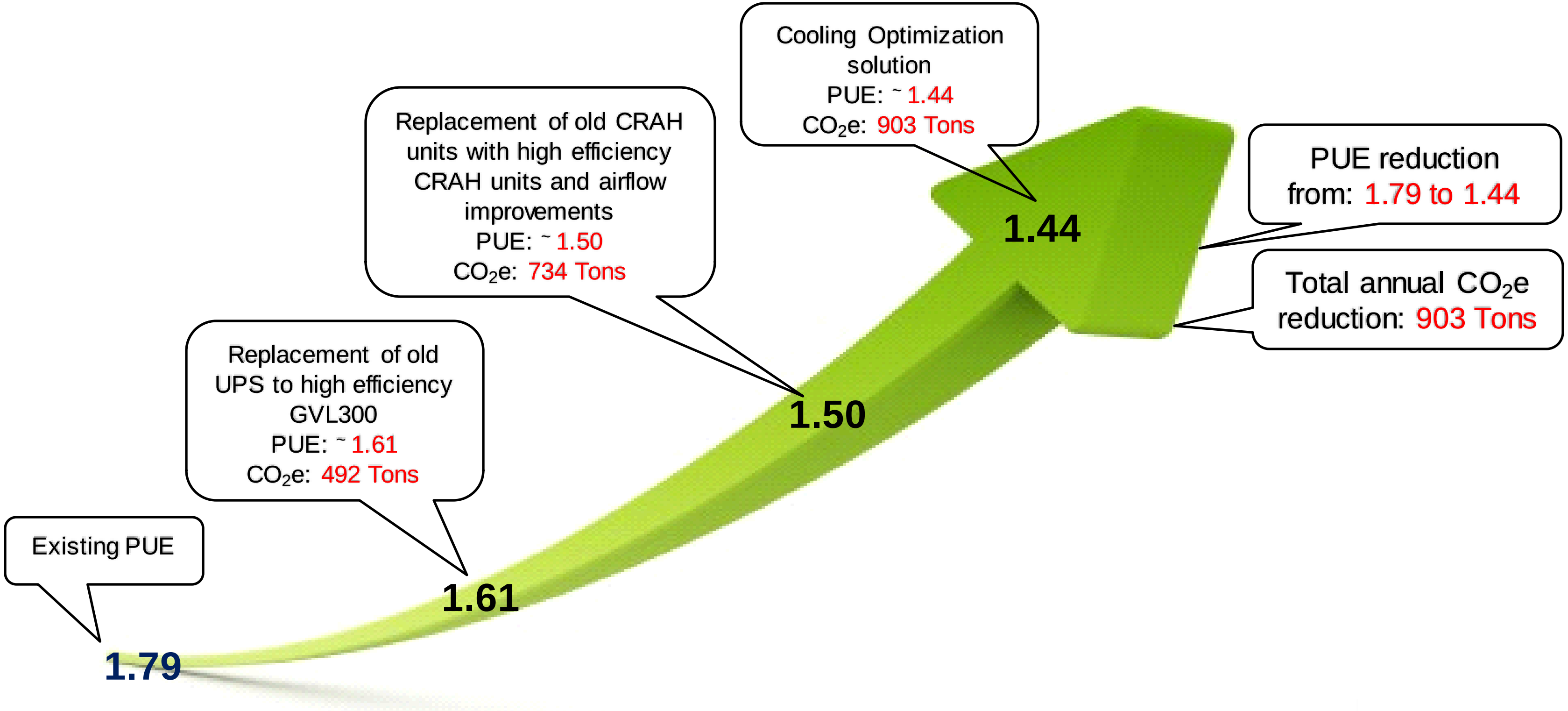
		PUE	Power Consumed (kW)	Annual Power Consumed (kWh)	Annual Energy Bill (MYR)
	Current Situation	**1.79**	**757**	**6,632,897**	**2,586,830**

In Malaysia

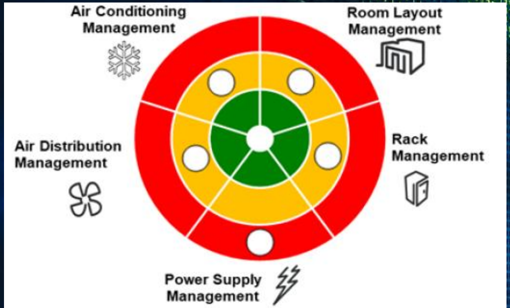
STEP	**Energy Conservation Measures** *Click on each measure for detailed calculations*	PUE	Power Saved (kW)	Annual Energy Saved (kWh)	Annual Cost Energy Saving (MYR)	Annual Energy Saving (%)	CO_2 Savings (Metric Tons)	Budgetary Investment (MYR)	ROI (%)	Payback Period (Years)
1	Replacement of **Old UPS** to New GVL 300 kW	1.61	85.87	752,221	293,366	11%	492	814,000	36%	2.8
2	Replacement of **Old CRAH** units with high efficiency CRAH units and airflow improvement*	1.51	42.3**	370,811	144,616	6%	242	2,129,000	7%	14.6
3	**Cooling Optimization** for new CRAH units for SW Car Room & Car Room1	1.44	29.6	259,296	101,125	4%	169	1,544,944	7%	15.3
	Combined Impact (1, 2 & 3)	**1.44**	**157.8**	**1,382,328**	**539,108**	**21%**	**903**	**4,158,944**	**12%**	**8.3**

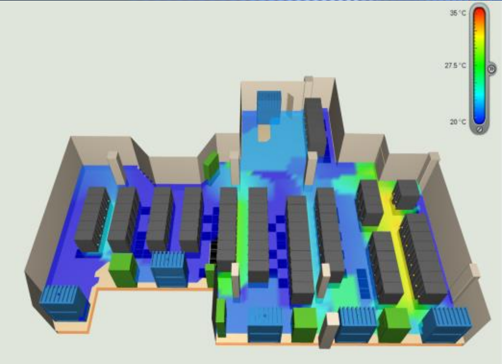
Final Emissions Factor = 0.65352 kgCO2e/kWh

Example of PUE & CO2 Reduction Roadmap



Major Co-Location DC Provider





Customer Background & Challenges

- Co-location DC with 700 racks, 2MW IT load
- 14-year-old data center
- Single Point of Failure (downstream)
- Equipment aging issues
- High PUE and energy bill

Schneider executed Data Center Audit to

- Analyze gaps with respect to Tier standards
- Single Point of Failures (SPoF) mitigation
- PUE & efficiency of UPS systems & Cooling
- 3D thermal analysis of data halls
- Analysis with respect to ASHRAE standards
- Data hall space optimization
- Data Center Operations Maturity

Audit Outcome

✓ PUE 2.16, potential to bring down to 1.45
✓ UPS energy efficiency improvement opportunity
✓ Air management improvement opportunity
✓ Power Factor improvement opportunity
✓ SPoF mitigation measures implementation
✓ Dynamic cooling optimization

Summary of recommendations

1. **UPS** efficiency improvement from 78% to 97% - **energy savings of 6%**
2. **Air management optimization** – Aisle containment, auto-sequencing, plug leakages & recirculation, increase set-points **– energy savings of 6%**
3. **PF correction panels** to be added for improved power factor saving **4% in total energy bill**
4. Re-evaluate and consolidate the IT equipment, potential to approximately **free more than 150 racks**
5. **Rack ATS** for racks having single source devices
6. **Dynamic cooling optimization** giving further **savings of 20% in HVAC**

Major Bank Primary Data Center, Dubai

Customer Challenge

- 13-year-old data center
- Aging equipment with low energy efficiency
- Not compliant with Uptime Institutes Tier III
- Ineffective monitoring systems

Multi-Domain Consultancy - Walkthrough

- Measurement, Performance & Safety (MPS)
  - identified vulnerabilities in the Electrical System
  - no predictive analytics
- Data Center Audit identified:
  - Gaps with respect to Tier III
  - Single Point of Failures (SPoF)
  - Lack of digitization
  - Low Efficiency of UPS systems (88%)
  - PUE – 2.06

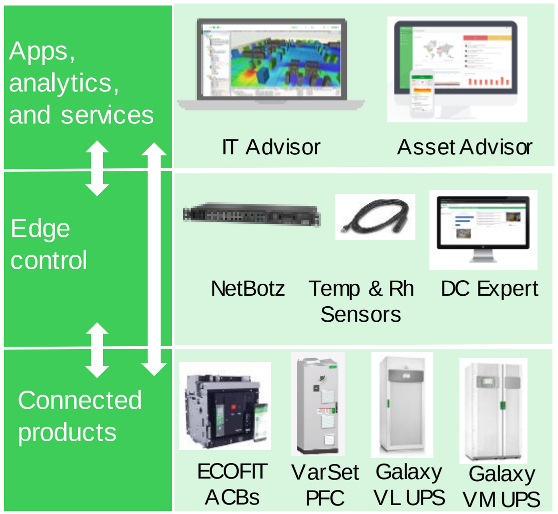
Customer Benefits

✓Comply with Tier III requirements
✓Eliminated risk with high reliability ACBs
✓Improved Power Factor correction
✓High reliability & efficient UPS system
✓PUE improvement from 2.06 to 1.8
✓Full visibility of utility performance
✓Digital Twin data hall environment with power, cooling, space management

Equipment Upgrade & Digitization

ACB, PFC Panels, UPS Systems with Lithium Ion, Predictive analytics, data hall digital twin for full visualization & simulation

EcoStruxure Innovation At Every Level for Data Center



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Base Strategy to DC Sustainability

Improve IT Efficiency, Utilization & Operation

Reduce Electrical Distribution Losses

High Efficiency Cooling

Reduce GreenHouse Gas (GHG)

IT System Efficiency

ENERGY STAR® is a joint program of the Environmental Protection Agency (EPA) and the Department of Energy (DOE). Its goal is to help consumers, businesses, and industry save money and protect the environment through the adoption of energy-efficient products and practices.

Data Center Equipment

- Enterprise Servers
- Uninterruptible Power Supplies
- Data Center Storage
- Large Network Equipment

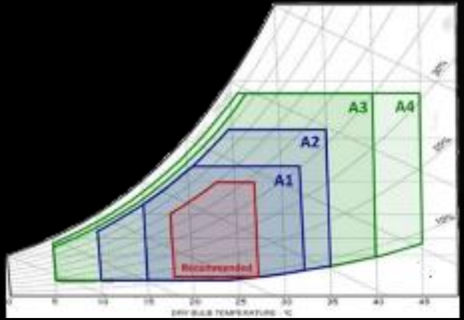
Enterprise Servers

Schneider Electric Galaxy UPS

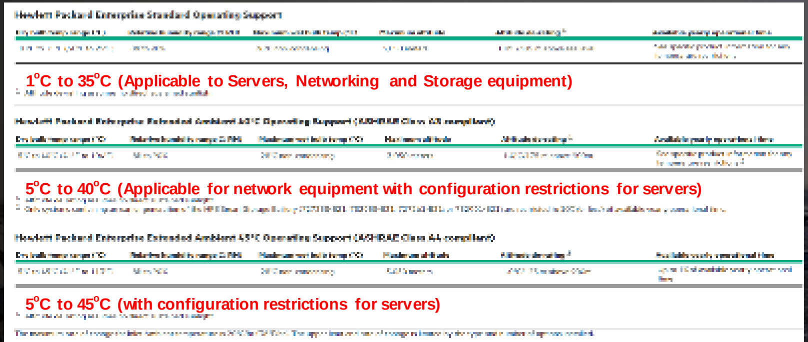
Network Equipment

Data Center Storage

Industry Wide Drive for Sustainability



ASHRAE Recommended Temperature range



Server with broader operating temperature

Liquid Cooling IT Server System

Investing in Technology for Sustainability

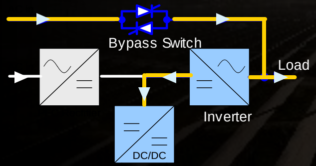
High Efficiency Iso TX

98.5% Efficiency

High Efficiency UPS

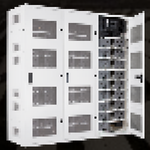
97% Efficiency

E-Conversion



99% Efficiency

Li-Ion Battery



Small Footprint
Long Lifespan
Less Heat

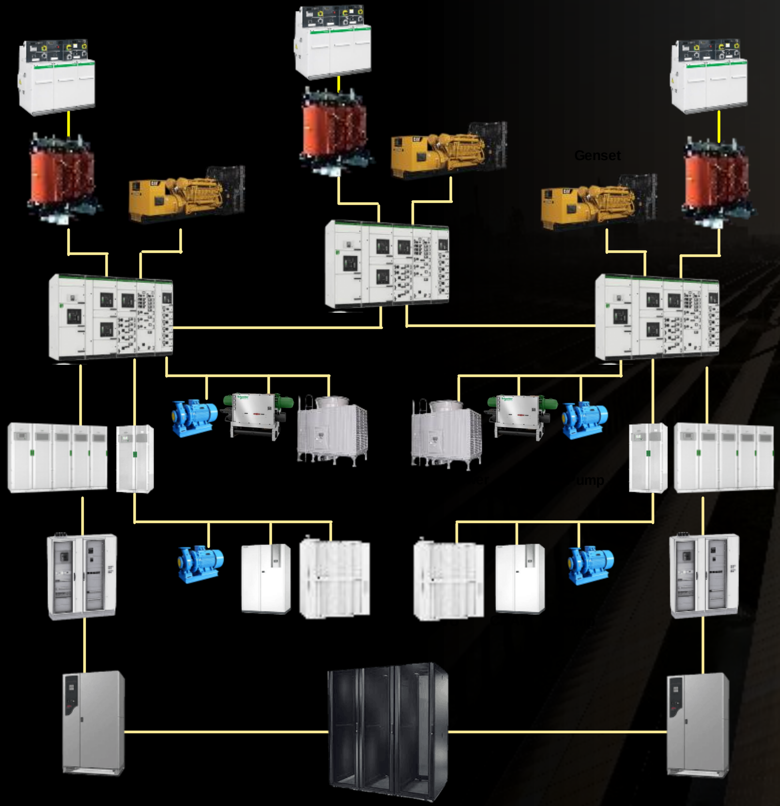
High Efficiency MV TX

99% Efficiency

SF6 Free MV SWG

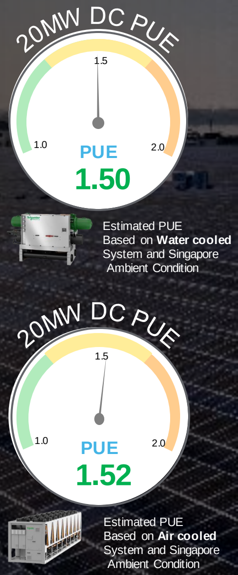
No Sulfur Hexaflouride

Investing in Technology for Sustainability



Typical System Losses

Ring Main Unit	0.02%
MV Cabling	0.01%
MV Transformer	2%
LV Cabling/Busway	0.15%
LV Main Switchboard	0.25%
LV Cabling	0.15%
UPS	6%
LV Cabling	0.08%
UPS Output Switchboard	0.25%
LV Cabling	0.25%
PDU + Iso Transformer	2.5%
LV Cabling	0.25%
	11.91%



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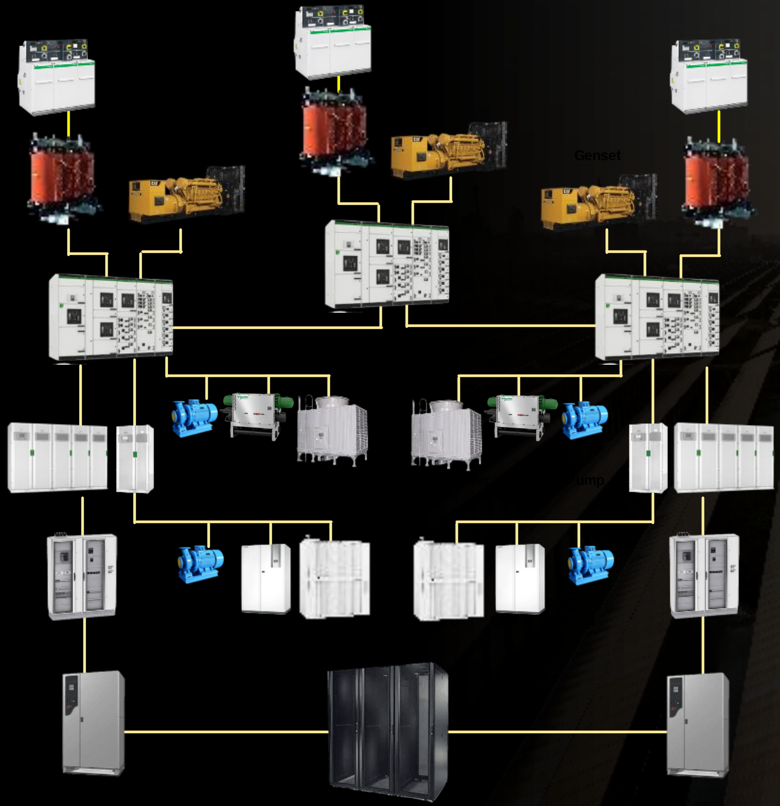
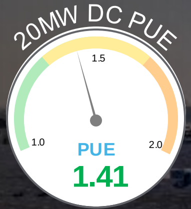
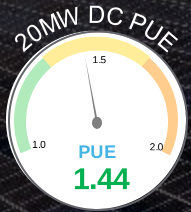


	Typical System Losses		Optimized System Losses
Ring Main Unit	0.02%		0.02%
MV Cabling	0.01%		0.01%
MV Transformer	2%	High Efficiency MV TX	1%
LV Cabling/Busway	0.15%		0.15%
LV Main Switchboard	0.25%		0.25%
LV Cabling	0.15%		0.15%
UPS	6%	EConversion Mode	1%
LV Cabling	0.08%		0.08%
UPS Output Switchboard	0.25%		0.25%
LV Cabling	0.25%		0.25%
PDU + Iso Transformer	2.5%	High Efficiency Iso Tx	1.5%
LV Cabling	0.25%		0.25%
	11.91%	7% Reduction	4.91%



Estimated PUE Based on **Water cooled** System and Singapore Ambient Condition



Estimated PUE Based on **Air cooled** System and Singapore Ambient Condition

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SS 530:2014 Distribution Transformers Efficiency

Minimum energy requirements set out for distribution transformers manufactured imported into developed country must comply with SS 530:2014 requirements which are set out in SS 530-2014 & tested to IEC 60076-11.

Table 8 – Minimal Efficiency Requirements for Distributions Transformers

Table 8 – Minimal efficiency requirement for distribution transformers

Transformer type	Rating (kVA)	Liquid-immersed	Dry-type		
		Efficiency (%) at 50 % load	Efficiency (%) at 50% load Um = 12 kV	Efficiency (%) at 50% load Um = 24 kV	Efficiency (%) at 50% load Um =36 kV
Single phase (and SWER*)	10	98.42	97.53	97.32	96.87
	16	98.64	97.83	97.55	97.11
	25	98.80	98.11	97.78	97.37
	50	99.00	98.50	98.10	97.74
Three phase	25	98.50	97.42	97.42	96.92
	63	98.82	98.01	98.01	97.30
	100	99.00	98.28	98.28	97.58
	200	99.11	98.64	98.60	98.26
	315	99.19	98.82	98.74	98.44
	500	99.26	98.97	98.87	98.62
	750	99.32	99.08	98.98	98.77
	1000	99.37	99.14	99.04	98.87
	1500	99.40	99.21	99.12	98.99
	2000	99.40	99.24	99.17	99.00
	2500	99.40	99.27	99.20	99.00
	3150	99.40	99.27	99.20	99.00

≥ 98% Efficient ≤ 2%

≥ 99% Efficient 1%

Distribution Transformers Efficiency Levels

Ref: Section 8: Distribution Transformers; Table 8; pages 28/32

Trihal Cast Resin Distribution Transformers 500-3150kVA

A high efficiency transformer corresponds to equipment designed for low level of losses to ensure reduced cost of ownership for end user.

The losses can be divided into two categories: load losses, which are proportional to the transformer load (square of current); and no-load losses, which are caused by the magnetization of the core as long as the transformer is energized, and are constant - independent of the transformer load.

The energy efficiency of a transformer is linked with the following influencing factors:

- the losses (load and no-load);
- transformer lifespan;
- mission profile (application).

Description	Transformer Electrical Data				
Rated kVA	1000	1600	2000	2500	3150
No Load Losses (NLL) - w	1395	1980	2340	2790	3420
Load Losses (LL) –w	9000	13000	16000	19000	22000
Pow er Factor 1.0	1.0	1.0	1.0	1.0	1.0
Eff % @Full Load	98.97	99.07	99.09	99.14	99.20

1%

≥ 99% Efficient

Based on PFC: 0.85

Description	Transformer Electrical Data				
Rated kVA	1000	1600	2000	2500	3150
No Load Losses (NLL) - w	1395	1980	2340	2790	3420
Load Losses (LL) –w	9000	13000	16000	19000	22000
Pow er Factor 0.85	0.85	0.85	0.85	0.85	0.85
Eff % @Full Load	98.79	98.91	98.93	98.98	99.06

1%

≥ 99% Efficient

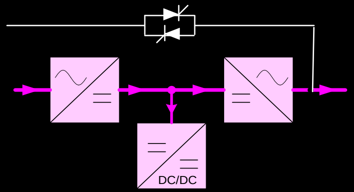
Ref: Distribution Transformers-ECO Design Tier 2: Main Electrical Characteristics: pages 31/71

The Econversion Technology

- A patented high-efficiency protection mode developed by Schneider Electric for Galaxy V Series 3-Phase UPSs
- Takes the best of Double Conversion and ECO mode to provide highest efficiency and no-break transfer

Double Conversion

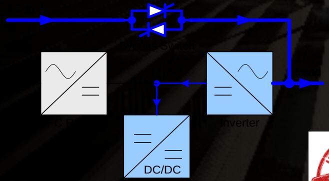
Load is supplied through the double conversion path requiring high electricity use



Regulate Voltage	***
Regulate frequency	***
Recharge batteries	***
No transfer time	***
R1 Pf Corr.	***
Efficiency	**96-97%**

eConversion

Load is supplied through the static switch but inverter is kept operating in parallel providing batteries recharge, power factor correction, and harmonics compensation



Regulate Voltage	**
Regulate frequency	**
Recharge batteries	***
No transfer time	***
R1 Pf Corr.	***
Efficiency	**99%**

Highest Power Efficiency

- **eConversion is IEC62040-3 Class 1**
- **99% efficiency = 3x electricity savings**

99%

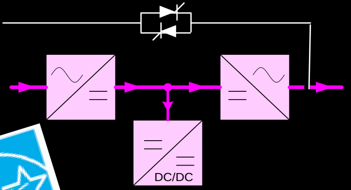
eConversion Benefits

- **Ultra-high efficiency** up to **99%**
- **No break transfer**: Compliant with IEC 62040-3 Class 1 output voltage of UPS standard, **third-party certified**: the highest protection category
- Input **power factor correction** and no harmonics
- Continuously **charged batteries**

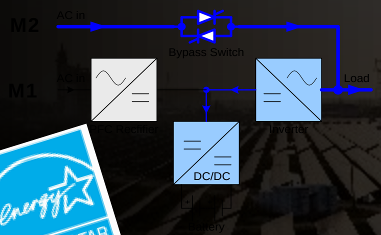
The Econversion Technology

	Double Conversion	eConversion	ECO mode
Voltage fluctuation	***	**	**
Frequency fluctuation	***	**	**
Recharge batteries	***	***	No
No transfer time	***	***	No
PF Correction	***	***	***
Protection class	1	1	3
Efficiency :	96-97%	99%	99%

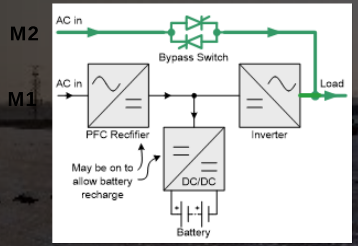
Double Conversion



eConversion



ECO mode

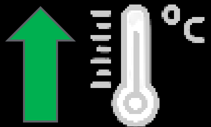


Investing in Technology for Sustainability

Fan Wall Cooling

High Capacity
High Efficiency
Consistent Rack Temp

Increase CW Temperature



Improve efficiency

TurboCor Compressor

Low kW/RT
Low Start Current

Green Refrigerant

No HFC & HCFC

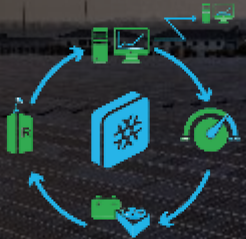
Free Cooling

Utilize Ambient Cooling

Adiabatic System

Improve Chiller Efficiency

AI & Machine Learning



Improve CRAC & FWU operation

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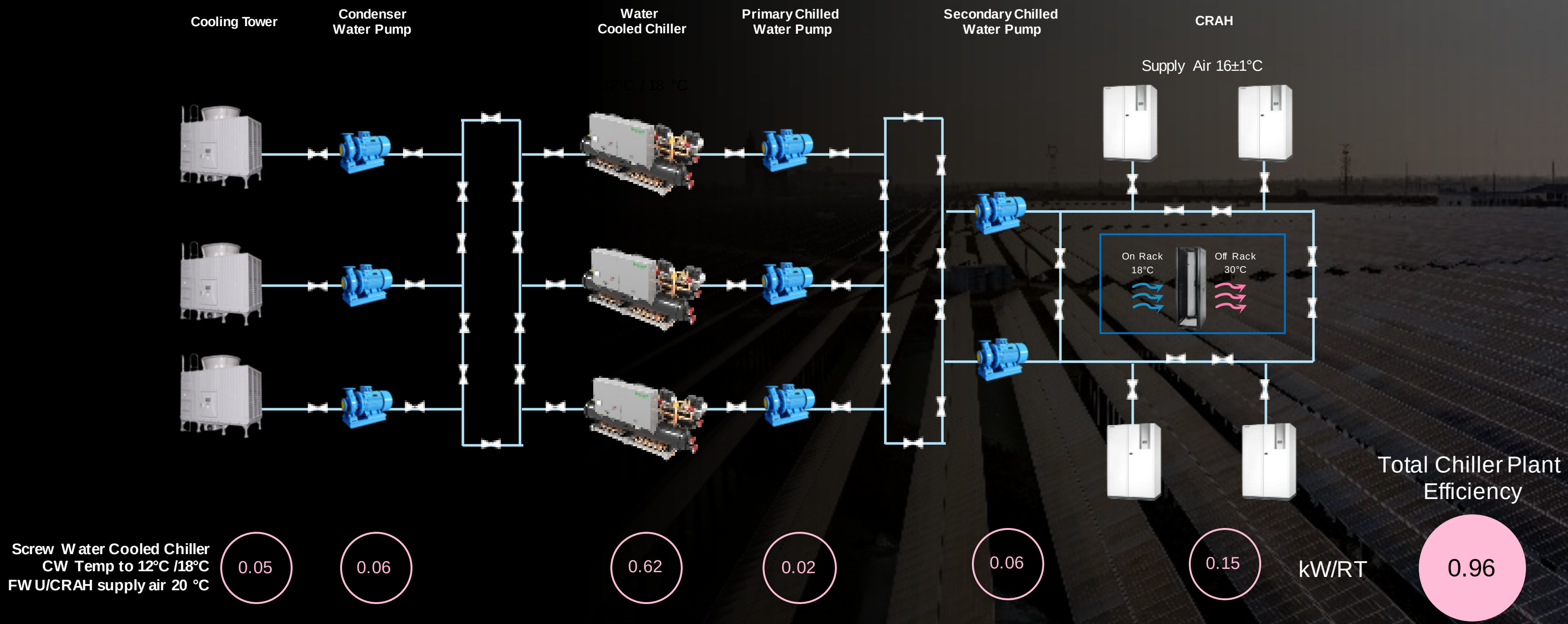
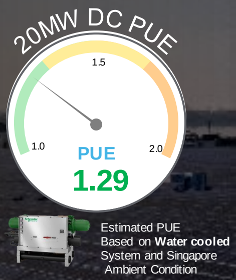
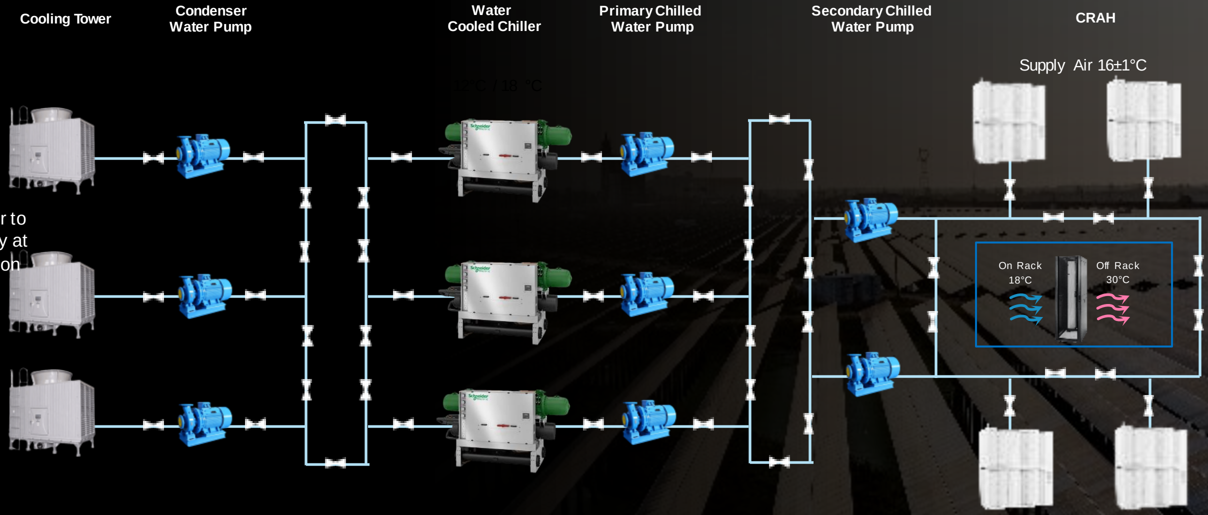




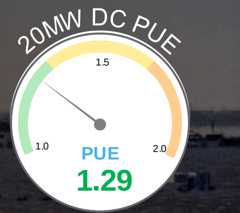
Investing in Technology for Sustainability

Utilize TurboCor Technology Chiller to improve efficiency at all loading condition



Optimize by supply air control at **25°C** and return air **37°C / 30%RH**. Improve CRAH Sensible heat ratio & overall refrigeration cycle

Increase FWU/CRAH operating setpoint allow higher chiller operation temp and Cooling Tower operation



Estimated PUE Based on **Water cooled** System and Singapore Ambient Condition

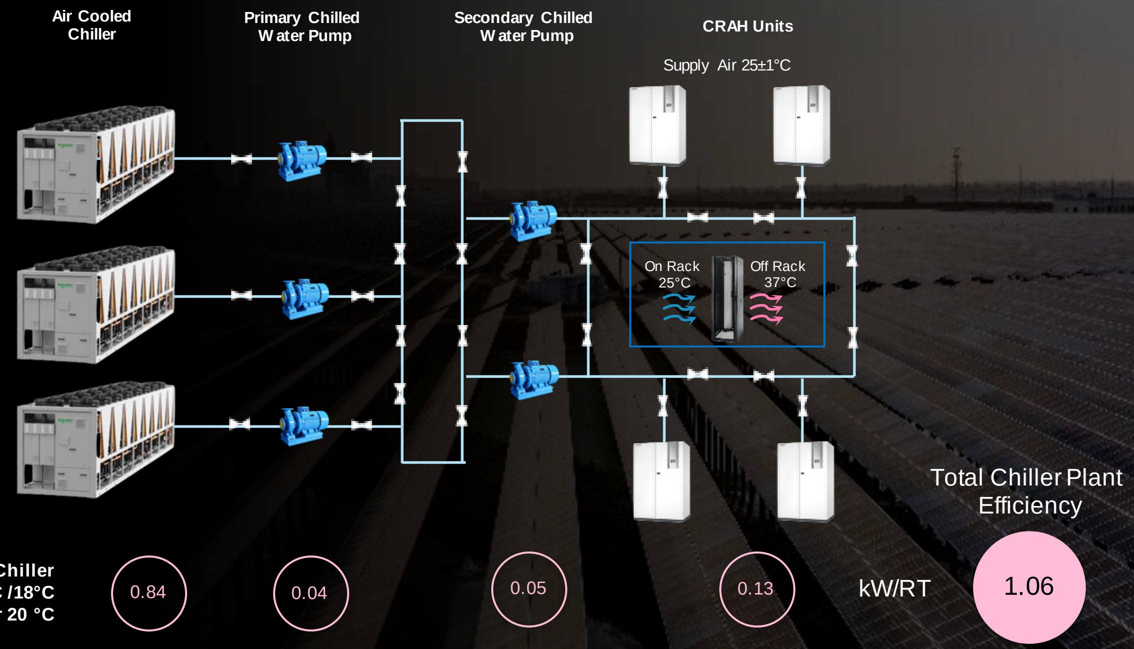
Total Chiller Plant Efficiency

	Cooling Tower	Condenser Water Pump	Water Cooled Chiller	Primary Chilled Water Pump	Secondary Chilled Water Pump	CRAH		Total
Screw Water Cooled Chiller CW Temp to 12°C /18°C FWU/CRAH supply air 20 °C	0.05	0.06	0.62	0.02	0.06	0.15	kW/RT	0.96
Use TurboCor Chiller Raise CW Temp to 22°C/32°C FWU/CRAH supply air 25 °C	**0.03**	**0.04**	**0.39**	**0.018**	**0.03**	**0.12**	kW/RT	0.63

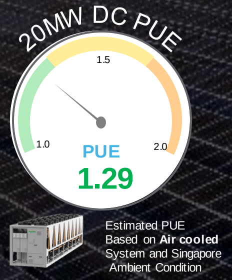
>35% More Efficient

Schneider Electric

Investing in Technology for Sustainability



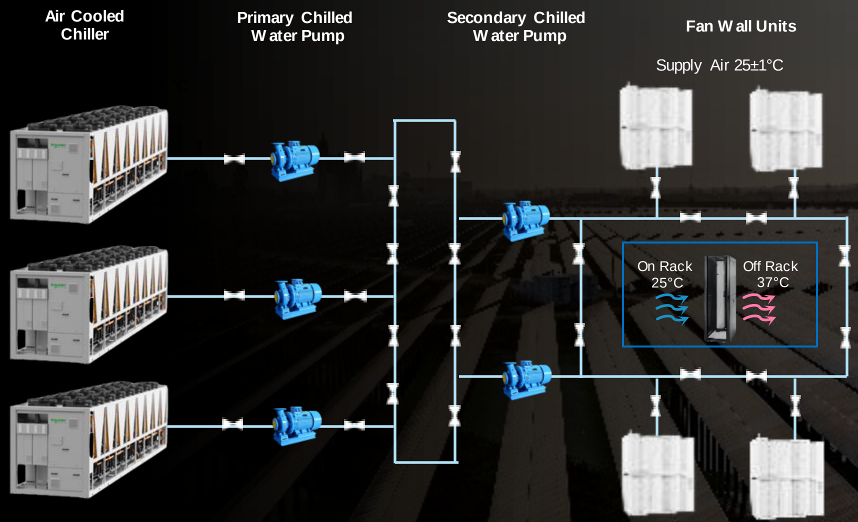
Air Cooled Screw Chiller
CW Temp to 12°C /18°C
FWU/CRAH supply air 20 °C



Investing in Technology for Sustainability

Increase FWU/CRAH operating setpoint allow higher chiller CW Temp to utilize Free-Cooling + Adiabatic

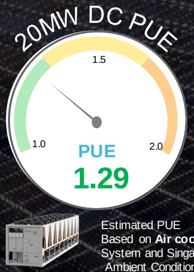
Utilize TurboCor Technology Chiller to improve efficiency at all loading condition



Optimize by supply air control at **25°C** and return air **37°C / 30%RH**. Improve CRAH Sensible heat ratio & overall refrigeration cycle

	Air Cooled Chiller	Primary Chilled Water Pump	Secondary Chilled Water Pump	Fan Wall Units		Total Chiller Plant Efficiency
Air Cooled Screw Chiller CW Temp to 12°C /18°C FWU/CRAH supply air 20 °C	0.84	0.04	0.05	0.13	kW/RT	1.06
TurboCor Chiller Raise CW Temp to 22°C/34°C FWU/CRAH supply air 25 °C	**0.46**	**0.016**	**0.03**	**0.116**	kW/RT	0.62

>40% More Efficient



Estimated PUE Based on Air cooled System and Singapore Ambient Condition

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Investing in Technology for Sustainability

Typical DC System

20MW DC PUE

PUE **1.50**

System Description
- N+1 / 2N / Distributed Redundant Electrical
- N+1 Water Cooled Screw Chiller
- Typical MV Tx and Iso Tx

Operation Parameter
- UPS on Double Conversion
- IT On-Rack 20°C
- FWU/CRAH Off-Coil 16°C
- CW Temp 12°C / 18°C

Electrical Optimization

20MW DC PUE

PUE **1.41**

System Description
- N+1 / 2N / Distributed Redundant Electrical
- N+1 Water Cooled Screw Chiller
- **High Efficient** MV Tx and Iso Tx

Operation Parameter
- UPS on **eConversion Mode**
- IT On-Rack 20°C
- FWU/CRAH Off-Coil 16°C
- CW Temp 12°C / 18°C

Cooling Optimization

20MW DC PUE

PUE **1.29**

Estimated PUE based on air cooled System and Singapore Ambient Condition

System Description
- N+1 / 2N / Distributed Redundant Electrical
- N+1 **Water Cooled TurboCor Chiller**
- **High Efficient** MV Tx and Iso Tx

Operation Parameter
- UPS on **eConversion Mode**
- IT On-Rack **25°C**
- FWU/CRAH Off-Coil **25°C**
- CW Temp **22°C / 34°C**

20MW DC PUE

PUE **1.29**

System Description
- N+1 / 2N / Distributed Redundant Electrical
- N+1 **Air-Cooled TurboCor Chiller**
- **Adiabatic & Free-Cooling**
- **High Efficient** MV Tx and Iso Tx

Operation Parameter
- UPS on **eConversion Mode**
- IT On-Rack **25°C**
- FWU/CRAH Off-Coil **25°C**
- CW Temp **22°C / 34°C**

Investing in Technology for Sustainability

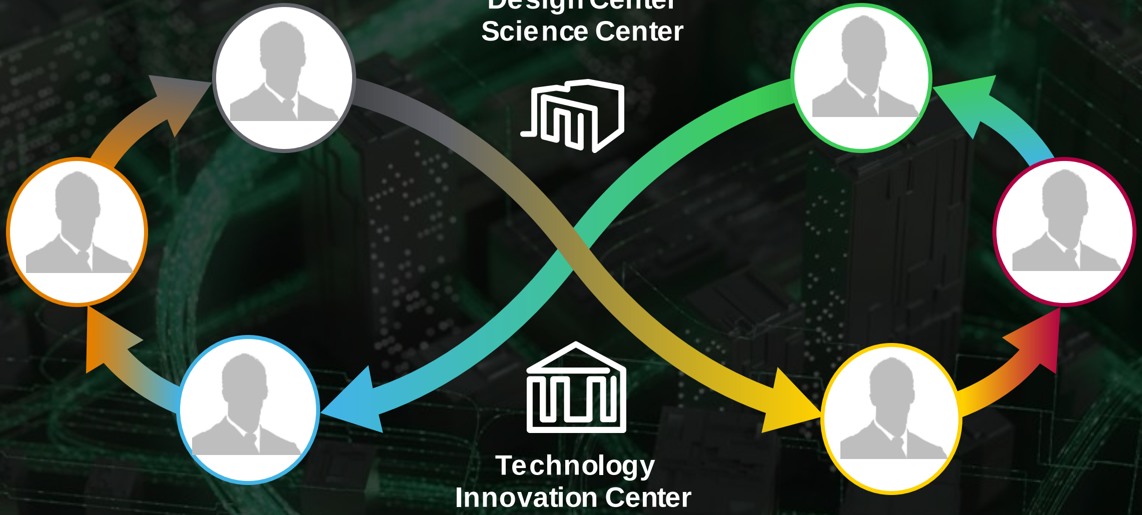
	Air-Cooled CW Plant	Water-Cooled CW Plant	Notes
Estimated PUE	1.29	1.29	
Estimated WUE	0.2	2.0	
Water Usage	35,211 m^3/yr	351,261 m^3/yr	
Annual Water Cost	$ 55,634	$ 554,993	Based on industrial water price $1.58/$m^3$ from 1 Jul 2018
Refrigerant	R1234ze	R1234ze	R1234ze with GWP<15 compliant to Singapore (NEA & SCDF) regulatory requirement
Technology	TurboCor Oil Free Centrifugal Adiabatic Spray Free-Cooling	TurboCor Oil Free Centrifugal	Adiabatic & Free-cooling may earn GM points under Green features and innovation
Capex Cost	Lower or equivalent	Higher	Additional consideration for WC chiller condensing water equipment & piping works
Opex Cost	Lower	Higher	Maintenance for WC chiller Cooling tower, makeup water, condensing pump may add opex

How Schneider Electric can help

Resilient & Safe	Efficient	Adaptive	Sustainable	Workforce Optimization
Reduce vulnerability to unplanned downtime	Improve operational efficiency and reduce energy and water consumption	Future-proof designs to accommodate new technologies	Sustainable supply chain, consulting services, and procurement services to support your corporate goals	Standardized, digitized solutions that help enable efficient operations.

Addressing service provider challenges with infrastructure digitalization

The Schneider Electric EcoSystem



System Expert

Multi-Disciplinary Engineering in Data Center Mechanical and Electrical Domain

Design Expert

provide engineering advice and technical solutions on different projects to be trusted advisor

Product Expert

A Complete breadth of knowledge of Product to component level. Translate client requirement to manufacturing

Operation Expert

responsibility to achieve and improve the high availability and manageability of data center operations

Sustainability Expert

Responsible for designing and executing programs on energy and resource conservation to reduce impact of an organization on the environment

Project Manager

planning, organizing, and directing the completion of specific projects for an organization while ensuring these projects are on time, on budget, and within scope

The Schneider Electric Value

Sustainability
We are the most Sustainable Corporation

Value to Client
SE holistic coverage lead to customer value

World Class Product
Lifecycle Support

Full Domain Knowledge
Competent in all System

Practical Experiences
Live Project in all geography

Project Management
Experienced Project Organization

Critical Facility Ops
Insights from Data Center we operate

Certified Resources
Global Expertise

Certified Uptime Project
Global Project References

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