Data Center Facility Sustainability Metrics

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Executive Summary

Over the past 15 years, data center facilities have made significant improvements in energy efficiency. However, the narrow focus on energy efficiency is insufficient to meet new corporate sustainability goals and performance metrics. Greenhouse Gas (GHG) emissions, water use, and waste generation are some of the areas where further improvements must be made. It is imperative that data center operators put in place the right measurements and improvement action plans to ensure our industry's footprint on the plant is minimized.

This paper outlines a recommended set of sustainability metrics for data center facilities. These metrics focus on environmental sustainability and are not comprehensive to evaluate all performance aspects of a data center facility.

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1. Introduction

This paper outlines a framework of key performance metrics applicable to:

Internal performance evaluation:

- Metrics that are specific enough to allow data center operators to track and make improvements within each facility.
- Metrics that allow an organization to benchmark their facilities to drive improvements across their fleet.

External performance evaluation:

- Be a component of the OCP Ready™ Data Center Recognition Program.
- Give stakeholders such as municipalities and public utilities commissions a standard framework to guide regulation development.
- Allow potential customers and tenants a standardized framework to evaluate the sustainability performance of a facility.

To support the OCP Ready™ Data Center Recognition program metrics will carry one of 2 designations:

Required: Must be measured and published

Recommended: Voluntary to measure and report.

We recommend these designations be updated annually to keep pace with the maturity of the data center industry in measuring and reporting sustainability metrics.

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2. Compliance with Open Compute Project Tenets

2.1. Openness

The data center sustainability metrics presented in this paper can be used by any organization as a guide for improvement.

0.2. Efficiency

These metrics not only cover energy efficiency, but overall resource efficiency including energy, carbon, water, waste and the local ecosystem.

0.3. Impact

These metrics are intended to have a material positive impact on our environment and overall data center sustainability. They will allow designers and operators to take real action to improve their data center's overall sustainability. Additionally, these metrics will be incorporated into the OCP Ready™ Data Center Recognition program.

0.4. Scale

The metrics can be applied to any type of data center, in any region, allowing for benchmarking across within an organization, or between sites.

0.5. Sustainability

The metrics are specifically focused to help designers and operators improve their sustainability.

1. Stakeholders and users

We believe this paper will be useful to many stakeholders and users, for example:

Internal:

- Data Center Designers and Builders
- Developers and Operators
- Owners
- Executives

External / societal context

- Tenants / prospective tenants
- Investors
- OCP community

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- Public and Private Utilities
- Municipal leaders
- Local community and neighbors

2. Metrics

Environmental sustainability metrics are broken into five categories. Below are aspirational goals for data centers and the specific metrics that will help us measure our progress.

1. Energy - Reduce facility net energy overhead & participate in local grid and energy networks to promote more local carbon-free energy generation.
2. GHG - Continuously improve to net zero Scope 1, 2, and 3 GHG.
3. Water - Continuously reduce water use to have no impact on local water resources and power generation water use.
4. Waste - Reduce waste generation with a goal for zero waste to landfill.
5. Local Ecosystem - Build and Operate data centers which have little impact on the local environment and community.

Category	Metric	Unit	Use	Phase[1]
Energy	Total energy consumption	kWh	Required	O
Energy	Power usage effectiveness (PUE)	ratio	Required	D&B, O
Energy	Total renewable energy consumption	kWh	Required	D&B, O
Energy	Renewable energy factor (REF)	ratio	Required	D&B, O
Energy	Energy Reuse Factor (ERF)	ratio	Required	D&B, O
GHG	Scope 1 GHG	$mtCO_2e$	Required	D&B, O
GHG	Scope 2 location based	$mtCO_2e$	Required	D&B, O
GHG	Scope 2 market based	$mtCO_2e$	Required	O
GHG	Scope 3 GHG	$mtCO_2e$	Recommended	D&B, O
GHG	Carbon usage effectiveness (CUE)	$kgCO_2e/kWh$	Required	O
GHG	Total carbon offsets	$mtCO_2e$	Recommended	D&B, O
GHG	Hourly renewable supply & consumption matching	%	Recommended	D&B, O
Water	Total site water withdrawal	m^3	Required	D&B, O

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Water	Total site water consumption	m^3	Recommended	O
Water	Total source energy water usage	m^3	Recommended	O
Water	Water usage effectiveness (WUE)	m^3/MWh	Required	O
Water	Total water use in supply chain	L per product	Recommended	D&B, O
Waste	Total waste generated	metric ton	Recommended	O, EOL
Waste	e-waste generated	metric ton	Recommended	O, EOL
Waste	battery waste generated	metric ton	Recommended	O, EOL
Waste	total waste diversion rate	ratio	Recommended	O, EOL
Waste	e-waste diversion rate	ratio	Recommended	O, EOL
Waste	battery waste diversion rate	ratio	Recommended	O, EOL
Local ecosystem	Total land use	m^2	Recommended	D&B
Local ecosystem	Land use intensity	kW/m^2	Recommended	D&B
Local ecosystem	Outdoor noise	dB(A)	Recommended	D&B, O
Local ecosystem	Mean species abundance (MSA)	MSA/km^2	Recommended	D&B

[1]Lifecycle Phases: D&B = Design & Build; O = Operate; EOL = End of Life

2.2. Energy

2.2.1. Total energy consumption

Corresponding standard: none

Units: kWh (annual)
This is total energy consumption for all energy types serving the data center, measured in kWh. This is generally measured at the utility meter. It should also include energy produced onsite. For data centers that produce their own energy, or import energy in a form other than electricity, Annex B of the PUE standard, ISO/IEC 30134-2, should be referred to for consistent reporting.

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2.2.2. Power Usage Effectiveness (PUE)

Corresponding standard: ISO/IEC 30134-2:
Information technology - Data centres - Key performance indicators -- Part 2: Power usage effectiveness (PUE)[1]
Units: ratio of kWh/kWh (annual)

$PUE = E_{DC} / E_{IT}$

where
E_{DC} is the total data center energy consumption (annual), in kWh
E_{IT} is the IT equipment energy consumption (annual), in kWh.

By definition, the calculated PUE is always greater than 1.

PUE measures the facility energy overhead as compared to IT load and can provide opportunities to show the improvement of the operational efficiency of a data center and of the designs and processes of a data center over time. PUE only reflects energy use, not resource utilization, and varies widely due to location and design factors, making comparisons between data centers unreliable. Therefore, it is not intended to be used as a data center productivity or resource efficiency metric or to be used to compare different data centers.

There are three categories of PUE.

- Category 1 (PUE_1) — provides a basic level of resolution of energy performance data; e.g. IT load is measured at the output of the UPS.
- Category 2 (PUE_2) — provides an intermediate level of resolution of energy performance data, e.g. IT load is measured at the output of the PDUs or branch circuit.
  Category 3 (PUE_3) — provides an advanced level of resolution of energy performance data. e.g. IT load is measured at the input to the ITE; this means that energy consumption is tracked right where the power enters core computing hardware in a data center, including servers, storage devices, and networking equipment.

The higher categories of measurement provide more accurate reporting of energy usage and therefore enable greater opportunities for improved data center efficiency.

[1] https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-2:ed-1:v1:en

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PUE_1 is required and we recommend operators report on PUE at the highest category achievable.[3]
A helpful resource to reduce data center energy use comes from the EU, “2024 Best Practice Guidelines for the EU Code of Conduct on Data Centre Energy Efficiency”[2]

2.2.3. Total renewable energy consumption

Corresponding standard: ISO/IEC 30134-3
Information technology - Data centres - Key performance indicators Part 3[3]
Renewable energy factor (REF) or EN 50600-4-3 Information technology — Data center facilities and infrastructures — Part 4-3
Units: kWh (annual)

Total renewable energy that is owned, controlled, or purchased for use at a data center facility. This is the energy obtained from renewable energy sources such as solar energy, wind energy, geothermal energy, bioenergy, hydro, etc.

2.2.4. Renewable Energy Factor (REF)

Corresponding standard: ISO/IEC 30134-3
Information technology - Data centres - Key performance indicators Part 3[4]
Renewable energy factor (REF) or EN 50600-4-3 Information technology — Data center facilities and infrastructures — Part 4-3
Units: ratio of kWh/kWh (annual)

The Renewable Energy Factor (REF) is a metric used to quantify the percentage of a data center's total energy consumption that is derived from renewable energy sources.

$REF = E_{ren} / E_{DC}$

where

E_{ren}: Represents the total amount of renewable energy consumed by the data center in a given period.
E_{DC}: Refers to the data center's total energy consumption during the same period.

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[2] https://e3p.jrc.ec.europa.eu/sites/default/files/documents/publications/jrc136986_2024_best_practice_guidelines.pdf
[3] https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-3:ed-1:v1:en
[4] https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-3:ed-1:v1:en

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Higher REF scores implies that the data center's entire energy consumption comes from renewable sources.

2.2.5. Energy Reuse Factor (ERF)

Corresponding standard: ISO/IEC 30134-6
Information technology - Data centres - Key performance indicators Part 6[5] Energy Reuse Factor (ERF) or EN 50600-4-6 Information technology — Data center facilities and infrastructures — Part 4-6
Units: ratio of kWh/kWh (annual)

The Energy Reuse Factor (ERF) is a metric designed to measure how effectively a data center reuses the energy it consumes. It represents the percentage of a data center's total energy input that is beneficially reused outside the data center's boundaries. Examples of data center energy reuse include district heating, agricultural greenhouse heating, and thermoelectric power generation.

$ERF = E_{Reuse} / E_{DC}$

where

E_{Reuse}: energy from the data center (annual) that is used outside of the data center and which substitutes partly or totally energy needed outside the data center boundary.
E_{DC}: total data center energy consumption (annual).

As ERF ranges from 0 to 1 and a score which approaches 1 means more energy brought into the data center is being reused.

The corresponding standards for measuring ERF are in the EU and UK:

ISO/IEC 30134-6: This part of the ISO/IEC 30134 series specifies the procedures, conditions, and metrics for measuring the Energy Reuse Factor (ERF) in data centers. It focuses on the capability of data centers to reuse the energy they consume, providing a framework for improving energy sustainability and efficiency.

EN 50600-4-6: This European Standard, part of the EN 50600 series, outlines the requirements for data center facilities and infrastructures with a focus on energy efficiency. Part 4-6 specifically deals with the measurement and calculation of the Energy

[5] https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-6:ed-1:v1:en

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Reuse Factor (ERF), aligning with the ISO standard to provide a harmonized approach to assessing energy reuse in data centers across Europe.

Both standards aim to encourage the design and operation of data centers in a way that enhances energy reuse, thereby reducing the environmental impact and improving the overall sustainability of these facilities.

2.3. Greenhouse Gasses (GHG)

2.3.1. Scope 1 GHG

Corresponding standard: GHG Protocol or ISO 14064
Units: mtCO2e

Scope 1 GHG emissions are the direct emissions that a company produces during the course of conducting business. These are the emissions from company's owned and controlled resources. Emissions could be from stationary combustion sources (fuel, heating, generators), mobile combustion sources (company owned and operated vehicles), fugitive emissions (leaks of gasses and vapors from equipment such as chillers and HVAC) and chemical processing emissions (waste etc.).

The TCFD recommends that all companies disclose their Scope 1 GHG emissions, regardless of the result of the independent materiality assessment. Scope 1 emissions are measured in carbon dioxide equivalent (CO2e), which is a measure that converts various GHGs emitted (such as CO2, CH4 N2O) into an equivalent amount of CO2 thus providing a standard unit for comparison.

2.3.2. Scope 2 location based

Corresponding standard: GHG Protocol or ISO 14064
Units: mtCO2e

Location-based Scope 2 emissions are the indirect greenhouse gas (GHG) emissions resulting from purchased electricity, steam, heating and cooling in a specific geographic location. These emissions are calculated based on the average emissions intensity of the network where the energy is consumed, without taking into account any specific measures taken by the company to purchase clean energy. More specifically:

- Scope 2 emissions: These are indirect emissions related to energy purchased by the company. They are part of the three scopes defined in the Greenhouse Gas (GHG) Protocol, with scope 1 being direct emissions from owned or controlled sources and scope 3 covering all other indirect emissions in the value chain.

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- Location-based: This approach uses the average emissions intensity of the energy network for the specific location where the energy is consumed. This takes into account the actual energy choices that a company may make, e.g. does not take into account the purchase of renewable energy.

2.3.3. Scope 2 market based

Corresponding standard: GHG Protocol or ISO 14064
Units: mtCO2e

Market-based Scope 2 emissions are indirect greenhouse gas (GHG) emissions resulting from purchased electricity, steam, heating and cooling consumption, calculated based on the specific energy sources a company chooses to purchase. This methodology takes into account actual contractual agreements and purchases a company makes to procure energy, such as: B. Purchasing Renewable Energy Certificates (RECs), entering into a renewable energy power purchase agreement (PPA) or purchasing electricity at a green tariff.

- Scope 2 Emissions: These are indirect emissions from the consumption of purchased energy. They fall under the Greenhouse Gas (GHG) Protocol's Scope 2 category, which is separate from Scope 1 (direct emissions from owned or controlled sources) and Scope 3 (other indirect emissions in the value chain).
- Market-Based Approach: This method focuses on the specific choices a company makes regarding its energy procurement. It reflects the emissions associated with the energy products or contracts a company selects, which can include:
    - Renewable Energy Certificates (RECs): Certificates representing proof that energy has been generated from renewable sources.
    - Power Purchase Agreements (PPAs): Contracts to purchase renewable energy directly from producers.
    - Green Tariffs: Special utility programs that allow customers to purchase renewable energy directly from their utility.

The market-based method is designed to incentivize companies to invest in cleaner energy sources by allowing them to reflect those efforts in their emissions reporting. It contrasts with the location-based method, which uses the average emissions factor of the grid where the energy is consumed, without considering the company's specific energy purchases.

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2.3.4. Scope 3 GHG

Corresponding standard: GHG Protocol or ISO 14064
Units: mtCO2e

Scope 3 emissions for data centers refer to the indirect greenhouse gas (GHG) emissions associated with the full lifecycle and operations of data centers that are not directly controlled by the company but are part of its value chain. These emissions can be significant due to the extensive supply chain and energy-intensive nature of data center operations.

The Main Categories of Scope 3 Emissions for Data Centers include:

1) Purchased Goods and Services:
    - Hardware Manufacturing: Emissions from the production of servers, storage devices, networking equipment, and other IT infrastructure. This includes raw material extraction, manufacturing, and transportation.
    - Software Services: Emissions associated with the development and deployment of software used in data centers, including cloud services.
2) Construction and Infrastructure: Emissions from the construction of data centers, including building materials, construction activities, and infrastructure development.
3) Upstream Energy Emissions: Emissions related to the extraction, production, and transportation of fuels used to generate electricity consumed by the data centers. This includes emissions from the energy supply chain before it reaches the data center (e.g., mining coal or extracting natural gas).
4) Transportation and Distribution:
    - Transportation of Equipment: Emissions from the transport of IT equipment, cooling systems, and other materials to and from data centers.
    - Distribution of Services: Emissions associated with the distribution of digital services, including the energy used by content delivery networks (CDNs) and other intermediary services that help deliver data to end users.
5) E-Waste Management: Emissions from the disposal, recycling, or repurposing of obsolete IT equipment, such as servers, storage devices, and networking hardware.
6) End-of-Life Treatment and Disposal of Equipment: Emissions related to the disposal and recycling of IT equipment once it reaches the end of its operational life.

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7) Energy Consumption by Users: If the data center services are part of a company's products (e.g., cloud computing services), emissions associated with the energy used by customers to operate these services can be considered Scope 3.

2.3.5. Carbon usage effectiveness (CUE)

Corresponding standard: ISO/IEC 30134-8
Information technology - Data centres - Key performance indicators Part 8, Carbon usage effectiveness (CUE)
Units: ratio of $kgCO_2e/kWh$

CUE is a metric used to measure the carbon efficiency of data centers. It indicates the amount of carbon dioxide (CO_2) emissions produced per unit of IT energy consumption in a data center. While PUE (Power Usage Effectiveness) focuses on the overall energy efficiency of a data center (measuring how much of the energy is used by IT equipment versus other infrastructure like cooling), CUE directly addresses the carbon impact, making it particularly relevant for sustainability goals.

The CUE metric is designed to help data centers assess their carbon footprint and identify opportunities to reduce their impact on the environment.

- Total CO_2 emissions: This includes all the carbon dioxide emissions resulting from the energy used to power the data center, including electricity, cooling, and any other energy needs.
- Total IT energy consumption: This is the amount of energy used by the IT equipment in the data center, such as servers, storage devices, and networking equipment.

CUE is a metric for understanding the environmental impact of a data center. It helps operators and companies:

- Assess their carbon footprint: By measuring the carbon emissions associated with energy use.
- Benchmark performance: Against industry standards or other data centers.
- Drive sustainability initiatives: By identifying areas where energy efficiency can be improved, or where renewable energy sources can be adopted to reduce CO_2 emissions.

2.3.6. Total carbon offsets

Corresponding standard: NA

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Units: mtCO2e

Data centers measure their total carbon offsets by determining the amount of carbon dioxide (CO_2) emissions they compensate for through various offset projects. The aim is to achieve a net reduction in the overall carbon footprint. These offsets are usually quantified in metric tons of CO_2 equivalent (tCO_2e) and signify the reduction or removal of greenhouse gases from the atmosphere via initiatives like reforestation, renewable energy projects, or carbon capture and storage.

1) Carbon Offsets: These are credits that a data center can purchase to compensate for its emissions. Each credit typically represents the reduction or removal of one metric ton of CO_2 or its equivalent in other greenhouse gases.
2) Net-Zero and Carbon Neutrality:
    - Net-Zero: A data center achieves net-zero emissions when it balances the amount of CO_2 it emits with an equivalent amount of CO_2 removal or offset.
    - Carbon Neutrality: A data center is carbon neutral when it offsets all of its emissions, effectively making its net carbon footprint zero.
3) Types of Carbon Offset Projects:
    - Renewable Energy Projects: Investing in wind, solar, or hydroelectric power projects that displace fossil fuel-based energy sources.
    - Reforestation and Afforestation: Planting trees that absorb CO_2 from the atmosphere as they grow.
    - Carbon Capture and Storage (CCS): Technologies that capture CO_2 emissions at their source and store them underground or use them in other industrial processes.
    - Energy Efficiency Projects: Funding projects that reduce energy consumption and associated emissions, such as retrofitting buildings or upgrading to more efficient equipment.

When reporting in this category, it is important to be transparent in the type and source of offsets.

2.3.7. Hourly renewable supply & consumption matching

Corresponding standard: None
Units: %

The concept of hourly renewable supply and consumption matching involves syncing a data center's power usage with the availability of renewable energy on an hourly basis. The objective is to ensure that the energy consumed by the data center originates from

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real-time renewable sources, rather than relying on yearly or monthly averages of renewable energy credits (RECs) or offsets. The main concepts include:

1) Real-Time Matching:
    - Unlike traditional methods where companies might purchase RECs on an annual basis to cover their electricity usage, hourly matching involves synchronizing energy consumption with renewable energy generation on an hourly basis.
    - This approach ensures that a data center is powered by renewable energy exactly when it is needed, rather than compensating for fossil fuel usage with RECs generated at another time.
2) 24/7 Carbon-Free Energy (CFE):
    - Some leading tech companies are striving for 24/7 Carbon-Free Energy, meaning they aim to match their electricity consumption with carbon-free sources (like wind, solar, hydro, or nuclear) for every hour of the day, every day of the year.
    - Achieving this requires sophisticated energy management systems, investments in a diverse mix of renewable energy sources, and sometimes the use of energy storage solutions to fill in gaps when renewable generation is low.
3) Grid Impact:
    - By matching consumption with real-time renewable generation, data centers can reduce their reliance on fossil fuel-based power during times when renewables are not available (e.g., at night when solar power is not generated).
    - This practice supports the stability and decarbonization of the electricity grid by increasing demand for renewable energy during peak generation times and encouraging the development of energy storage and other technologies to manage variability.

2.4. Water

2.4.1. Total site water withdrawal

Corresponding standard: GRI 303: Water and Effluents
Units: m^3

Water withdrawal is water removed from the ground or diverted from a surface water source for use. For a data center, this is the total quantity of water entering the data center facility, including potable and non-potable, and reclaimed water entering the facility. The quantity of water reported should be directly related to the IT operation.

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Water withdrawal for non-IT uses such as human consumption and irrigation of the grounds should not be included or reported separately.

In data centers, water withdrawals are mainly used for evaporative cooling systems, where water is added to compensate for evaporation losses. The amount of water needed depends on the heat that needs to be removed from the data center and the blowdown process, which removes some water to maintain proper water quality by controlling mineral buildup. Improving the quality of the water supplying cooling systems or using chemical additives can decrease the quantity of water withdrawal by decreasing the amount of blowdown water required. Decreasing water quality, either due to changes in the local water ecosystem or switching to a lower-quality recycled water source, will likely increase the Quantity of water withdrawals.

Complementary sub metrics:

- Breakdown of water withdrawals by source type such as surface water (includes harvested rainwater), groundwater, third party (ie municipal water supplier), non-potable.
- Breakdown by facility.
- Water withdrawals from areas with water stress.
- Any additional information that can provide context to how the data has been compiled or should be interpreted should be included.

2.4.2. Total site water consumption

Corresponding standard: GRI 303: Water and Effluents
Units: m^3

Water consumption is the part of water withdrawal that is evaporated, transpired, incorporated into products, or otherwise removed from the immediate water environment. For a data center, this is almost entirely the amount of water evaporated in evaporative cooling systems, including potable and non-potable, and reclaimed water. When calculating water discharge, all water, regardless of future use should be included. This quantity of water should be directly related to the IT operation.

$$Water\ Consumption\ =\ Total\ Water\ Withdrawal\ -\ Total\ Water\ Discharge$$

Generally, the amount of water consumption is directly related to the heat rejection of the facility and cannot be improved by increased cycles of concentration or improved water chemistry, though increased economization and improvements to facility heat transfer can decrease water consumption by limiting evaporation hours or the amount of heat rejection required. While water consumption requires additional monitoring, this metric

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provides additional information on the facility's operational impact on the immediate water environment.
Complementary sub metrics:

- Breakdown of water consumption by source type such as surface water (includes harvested rainwater), groundwater, third party (ie municipal water supplier), non-potable.
- Breakdown by facility.
- Water consumption from areas with water stress.
- Any additional information that can provide context to how the data has been compiled or should be interpreted should be included.

2.4.3. Total source energy water consumption

Corresponding standard: ISO/IEC 30134-9:
Data centres key performance indicators Part 9: Water usage effectiveness (WUE)
Units: m^3

Similar to how carbon emissions associated with offsite energy production can be calculated (Scope 2 emissions), the quantity of water required to produce energy can be determined. Understanding offsite water consumption is important as almost all local power grids use some amount of energy that consumes water during production. Consumption is defined in the same way as stated in section 4.3.2 above.

The most common method of determining water consumption from energy production is the use of an Energy Water Intensity Factor (EWIF) which is associated with the volume of water consumed (L) per kilowatt hour of energy (kWh). This factor is then multiplied by the IT power consumption of the facility.

Finding an accurate EWIF value is the most difficult aspect of reporting source energy water consumption. This value should be provided by the facility's power utility. While there are many estimated values available in literature these values may not account for the complex and changing mix of power generation sources within the grid. There is currently no standard for EWIF so any values used should have a note indicating how this value was determined. If values are estimated, then a description of how the estimation was performed should be communicated. Examples of information included: consumption based on cooling water at the generation source, excludes water consumption from transmission, excludes consumption due to extraction and processing of fuels. When calculating EWIF market-based RECs should not be used. The grid-averaged value for the specific facility should be used for calculations.

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Understanding this value can be used to make larger-scale decisions like system design and optimization of water-based economization systems onsite. This value can also help companies find ways to build facilities in locations with lower water-consuming power or purchase power from sources that use less water. Depending on the method of power production and the onsite cooling systems it is possible that more water is consumed offsite compared to onsite.

In addition, a quantitative description of water savings from RECs can also be reported.

Complementary sub metrics:

- Total source energy water consumption.
- Breakdown by facility.
- Water consumption from areas with water stress.
- Any additional information which can provide context to how the data has been compiled or should be interpreted should be included.
- Quantitative description of water savings from RECs can be reported.

2.4.4. Water usage effectiveness

Corresponding standard: ISO/IEC 30134-9:
Data centres key performance indicators Part 9: Water usage effectiveness (WUE)
Units: m^3/MWh

Water Usage Effectiveness (WUE) is a metric that provides the ratio of data center water consumed over the energy consumed by IT equipment. While the total quantity metrics, as described in sections 4.3.1 through 4.3.3, are useful to understand the absolute impact of a facility on the water environment, WUE helps understand how efficiently the facility is using that water. Given the large range of data center facility sizes, looking at both the absolute value and usage effectiveness is important to understand the holistic impact of a given facility.

WUE can be measured and reported in varying levels of complexity as indicated by the three metrics WUE_1, WUE_2, and WUE_3. In each of the three metrics the water usage (Input minus output) is adjusted based on various factors.

- WUE_1 is the most basic WUE metric and reports usage equal to the water withdrawal for the facility.
- WUE_2 reduces the withdrawal quantity by subtracting water used for non-industrial reuse.
- WUE_3 adjusts both the water input and output calculations. The water input to the facility is reduced by the amount of harvested rainwater used but the water

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consumed offsite for power production is added. Water use is further reduced by both industrial and non-industrial water reuse.

WUE can be used to compare water usage in relation to a given facility and environmental conditions. Caution must be taken when comparing WUE of various facilities or even across times of the year as factors such as ambient conditions will have a large effect on values.

Complementary sub metrics:

- WUE can be reported for specific subsets of time or conditions such as WUE for the month of July or WUE peak.
- Breakdown by facility.

2.4.5. Total water use in supply chain

Corresponding standard: ISO 14046
Units: L per product

Similar to the way that carbon emissions associated with activities from assets not owned or controlled by the operating organization but indirectly through the value chain can be calculated (Scope 3 emissions), the quantity of water can be determined. Understanding water consumption throughout the supply chain can be assessed through a Life Cycle Analysis (LCA). The LCA is a structure that can be used to assess water withdrawal or consumption in every step of a product or service lifecycle, including but not limited to resource extractions, manufacturing, packing, and shipping.
When performing LCAs it is critical to clearly define the goal and scope of the LCA. This will ensure a transparent and consistent evaluation of the water withdrawal or consumption for a product or service. At this time there is no industry standard for the calculations so the goals and scope of the LCA should be reported with the results.

2.5. Waste

2.5.1. Total waste generated

Corresponding standard: GRI 300: Environmental - 306
Units: metric ton

This metric reports the weight of each kind of waste material (total / electronic equipment / battery) generated in a data center. Measurement should start from construction and continue through a data center's end of life. This metric only pertains to waste generated at the data center site and does not extend up into the supply chain. When reporting, it is important to put the data center's lifecycle in context to the metric, as

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construction might show very high levels of waste compared to the first few years of operation.

2.5.2. e-waste generated

Corresponding standard: GRI 300: Environmental - 306
Units: metric ton

Due to the relatively short life cycle of IT systems, e-waste will be the largest category of waste in a data center. Great effort should be made to send old IT systems to recycling centers.

2.5.3. battery waste generated

Corresponding standard: GRI 300: Environmental - 306
Units: metric ton

Batteries are one of the largest consumables within the data center facility. Lead acid batteries for UPS systems can have a life of about 5 years depending on use. Lithium-Ion backup system have a longer life of 10+ years. Fortunately, lead acid batteries have a very high recycling rate. As of 2024, recycling methods for Lithium-Ion battery systems are starting to emerge.

2.5.4. total waste diversion rate / e-waste diversion rate / battery diversion rate

Corresponding standard: GRI 300: Environmental - 306
Units: ratio of metric ton / metric ton

This is the total weight of waste recycled (total / electronic equipment / battery) divided by the total weight of waste generated (total / electronic equipment / battery) at a data center site. The waste can be diverted from landfills through circular methodologies including, but not limited to reuse, re-manufacturing, and recycling. Diversion rates allow for comparisons between data centers of different types and sizes.

2.6. Local Ecosystem

2.6.1. Total land use

Corresponding standard: none
Units: m^2

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Total direct land area consumed to operate a data center. Land use includes the land on which the physical data center building(s) is built, including any land area associated with data center operations such as outdoor power & cooling equipment / modules, parking lots, etc. Any land that has been cleared of vegetation to accommodate drainage, setback, or buffer requirements must also be included in total land use area. If the data center is located on a campus or industrial site with other activities, assign the appropriate proportion of land to the data center for this metric. The methodology for determining land use should be published.

Although data centers are not considered a high land use industry, high growth in hyperscale facilities has placed increased scrutiny in this area. This metric is an important consideration during the design phase. Considerations for multi-story data centers should be considered to reduce the impact. Designing the IT space ("white space") for high density racks also improves this metric, but this should be done with caution. If IT rack density comes in lower than the design point, the IT space will fill up before the power the cooling capacity is reached, poorly impacting other parts of sustainability like Scope 3 embodied carbon and site efficiency.

2.6.2. Land use intensity

Corresponding standard: none
Units: kW/m^2

The ratio of rated IT capacity to the total land footprint of a data center. Higher values mean better use of the land or less land use. This allows for benchmarking across different data centers.

2.6.3. Outdoor noise

Corresponding standard: none
Units: dB(A)

The sound level measured at the data center (emitter) property line. These values can be estimated during the data center design phase.

This metric can help data center operators and local jurisdictions identify if the sound level complies with local noise ordinances. In some data center locations, local jurisdictions are having ongoing discussions on how to prevent or mitigate sound related issues. Since noise can impact data center site approval and operation, data center operators can select silent HVAC and genset solutions to avoid these issues during the

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design phase. Designers may also leverage sound mitigating systems (e.g., acoustic shrouds, louvers, silencers).

2.6.4. Mean Species Abundance (MSA)

Corresponding standard: CDC Biodiversité[6]
Units: MSA/km^2
CDC Biodiversité[7] (France) developed this metric as a biodiversity footprint methodology with the objective of creating a global biodiversity score (GBS)13. This metric indicates the impact on local species by a data center in units of mean species abundance per square kilometer. This is not yet a global standard but can be used as a guide to the local ecosystem impact.
This metric makes a data center's impact on species more transparent during all phases of a data center. It can help data center operators assess the effectiveness of their plans to protect the species, through the whole lifecycle of the data center. Note - leveraging brownfield sites for data centers is an ideal way to optimize this metric, and many times gives opportunities to improve a site during reconfiguration to a data center.

3. Regional considerations

3.2. Europe and UK

3.2.1. EU Regulations and Aspirations:

- FD Energy:
  - European Green Deal: Aims for a climate-neutral continent by 2050.
  - Fit for 55 Package: Includes legislative proposals to reduce net greenhouse gas emissions by at least 55% by 2030.
- GHG Emissions:
  - European Climate Law: Codifies the 2050 climate-neutrality target.
  - EU Emissions Trading System (ETS): Cap-and-trade system for reducing industrial GHG emissions.
- Water:
  - Water Framework Directive: Aims for good status of all water bodies.
  - Drinking Water Directive: Ensures clean and safe drinking water.
- Waste:

[6] https://www.cdc-biodiversite.fr/
[7] https://www.cdc-biodiversite.fr/

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- Circular Economy Action Plan: Part of the European Green Deal, focuses on reducing waste and promoting sustainability in products' lifecycle.
- Single-Use Plastics Directive: Reduces the impact of certain plastic products in the environment.

- Local Ecosystem:
  - Biodiversity Strategy for 2030: Aims to protect and restore biodiversity.
  - EU Nature Restoration Law: Proposed law to set binding restoration targets for specific habitats and species.
- Data Centres in Europe – Reporting Scheme
  - This delegated regulation act sets out a reporting scheme to rate the sustainability of data centers in the EU[8].
  - Metrics to be reported on an annual basis:
    - PUE, WUE, ERF, REF

3.2.2. UK Regulations and Aspirations:

- Energy:
  - Climate Change Act: Commitment for net-zero carbon emissions by 2050.
  - Energy Savings Opportunity Scheme (ESOS): Encourages large enterprises to improve energy efficiency.
  - Renewable Heat Incentive (RHI): Promotes the use of renewable heat.
- GHG Emissions:
  - Net-Zero by 2050: Legally bound commitment.
  - Carbon Pricing: Implements carbon tax to reduce GHG emissions.
- Water:
  - Environment Act 2021: Enhances protection of water resources and management.
  - Water Use (Reduction) Bill: Proposed legislation focusing on reducing water consumption.
- Waste:
  - Resources and Waste Strategy: Aims for zero avoidable waste by 2050.
  - Plastic Packaging Tax: Encourages the use of recycled plastic.

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8 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13818-Data-centres-in-Europe-reporting-scheme_en

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- Local Ecosystem:
  - Environment Act 2021: Includes measures for biodiversity net gain for developments.
  - Wildlife and Countryside Act: Protects native species and natural habitats.

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4. Future views

4.2. Measuring the impact of liquid cooling

The increasing use of liquid-cooled IT equipment has raised questions about the continued relevance of PUE as the primary energy efficiency metric for data centers. Liquid cooling reduces the energy consumption of IT components like fans, power supplies, and voltage regulator modules (VRMs), but these savings are not reflected in PUE. PUE specifically measures reductions in facility cooling energy and does not account for efficiency improvements within the IT equipment itself. However, liquid cooling can still lead to lower facility cooling energy, which would result in a PUE improvement. In 2011, Lawrence Berkeley National Lab (LBNL) and the HPC community created a new metric, called Total Usage Effectiveness (TUE)[9]. This metric captures efficiency savings within the IT equipment (e.g. fans, power supplies, and VRMs).

When deploying liquid cooling, in most cases this will result in reduced energy and reduced water usage, especially when the facility design is optimized for the warmer water temperatures. Care should be taken to pay attention to water use. In many climates, liquid cooled IT can be cooled by compressor-less adiabatic coolers. This will have very good energy savings but could have higher than desired water use.

Recommendation: As measurement capabilities for energy use within servers improve, developing server efficiency metrics or expanding frameworks to include IT overhead energy is recommended. Currently, this document focuses solely on facility sustainability.

4.3. The sustainability of AI data centers

As of 2024, the expansion of generative AI training clusters is significantly driving the growth of data center deployments, leading to increased power requirements and energy consumption. It's important to note that evaluating the sustainability of an AI data center is no different from assessing a traditional data center. In fact, AI data centers have the potential to be among the most sustainable due to their high density and the use of liquid cooling systems. Additionally, depending on an operator's business model, AI training clusters may have lower availability requirements, which can enable optimized designs and flexible operating models. For instance, model training could be paused or time-shifted to better align with the needs of the local electrical grid.

Recommendation: Future work should focus on identifying metrics that capture the sustainability advantages of time-shifting IT workloads in AI data centers.

[9] https://datacenters.lbl.gov/sites/default/files/isc13_tuepaper.pdf

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4.4. Leveraging AI to make data center facilities more sustainable

Artificial Intelligence can significantly enhance the design and operational sustainability of data centers, far beyond current capabilities. Applications of AI span both the design and operational phases:

Design Phase

- Analyze environmental impact on the local ecosystem.
- Assess impacts on local grid infrastructure and network resilience.
- Optimize data center layout and design to reduce embodied carbon.
- Use digital twin modeling to accurately predict operational efficiency.

Operational Phase

- Utilize real-time digital twin visualizations to optimize energy and water use.
- Collaborate with grid operators to maximize renewable energy use.
- Use generative AI chatbots for enhanced workforce and personnel training, customer support, and facilities maintenance.
- Employ predictive analytics and recommender systems to prevent failures, reduce downtime, and extend equipment life, minimizing unnecessary maintenance.

Recommendation: Future efforts should identify how AI can optimize data center sustainability. Examples can include:

- **Dynamic Power Management:** Implement AI-driven power management to adjust GPU power consumption based on real-time workload demands. Use digital twins to simulate and optimize power usage, freeing up stranded capacity and reducing overall energy consumption.
- **AI Optimized Power Usage Effectiveness (PUE):** Continuously enhance PUE through AI-driven analytics and resource optimization, striving for advanced levels like PUE3. Leverage AI to simulate and improve advanced cooling technologies, including liquid and immersion cooling.
- **Renewable Energy Integration**: Maximize renewable energy use through AI-automated energy generation, distribution, and integration with the grid. Deploy AI models to manage on-site renewable sources (e.g., fuel cells, solar, wind) and dynamically balance supply and demand with long-duration energy storage.

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5. Reporting

Increased improvement in sustainability comes with increased transparency both internally and externally. This section covers specific aspects of reporting metrics.

5.2. Facility Identification and Scope

It is important the boundary of the data center is specified, especially in mixed use buildings and campuses.

5.3. Periodicity

Annual: Metrics are generally measured over the period of a year and reported as such. E.g, Annualized PUE vs snapshot. Each metric should include the period of time it covers.

5.4. Reporting frequency

Required: External - Annual
Recommended: External - Quarterly, using the trailing 12 months.
Internal Tracking: We recommend continuous or monthly internal tracking to be able to make faster improvements.

OCP Ready™ Data Center Recognition Program
The requirements for reporting frequency differ between the two versions of the data center site assessments and depending on the parameter selected will result in an 'Optimum' or 'Acceptable' assessment result.

OCP Ready™ v2 for Hyperscale data center site assessment
PUE
- Required (Optimum): Continuously monitored
- Required (Acceptable): Other (notes required)

WUE
- Required (Optimum): Continuously monitored
- Required (Optimum): Not applicable (e.g. zero water requirement)
- Required (Acceptable): Other (notes required)

CUE
- Required (Optimum): Continuously monitored
- Required (Acceptable): Other (notes required)

OCP Ready™ v1 data center site assessment
PUE

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Recommended (Optimum): Continuously monitored
Recommended (Acceptable): Periodically measured
Recommended (Acceptable): Other (Notes required)

WUE

Recommended (Optimum): Continuously monitored
Recommended (Acceptable): Periodically measured
Recommended (Acceptable): Other (Notes required)

CUE

Recommended (Optimum): Continuously monitored
Recommended (Acceptable): Periodically measured
Recommended (Acceptable): Other (Notes required)

5.5. Methodology & assumptions

Operators must be able to detail how the metrics are measured or the assumptions used when estimates are made. The assumptions for any estimates should be recorded and easy to find.

OCP Ready™ Data Center Recognition Program
Data center operators that are part of the program are encouraged to be transparent, but it is not mandatory that details on how the metrics are measured and calculated, or the assumptions used when estimates are made, are reported upon in the site assessment.

Climate Zones
It is important to take into account the climate zone that a data center is located in when considering if a data center meets the OCP Ready™ requirements for 'Site Design PUE' (v1) or 'Site Design PUE at Full Load' (v2) and 'Site Annualized PUE Current Achievement' (v1 &v2). For example, data centers based in climate zones OA (Ashrae 169) e.g. Mumbai India and Singapore, if they are unable to achieve a score of <1.3 (v2) PUE using air for heat transfer, an 'Acceptable' result could be considered, as the preferred score may not be achievable due to their specific environmental conditions.

5.6. Where to report

Data center operators should publish key metrics on their own website in a format to meet their countries and customers specific requirements as there is an increasing demand for greater transparency e.g. providing detailed information on energy sources and 24x7 real-time usage patterns.

OCP Ready™ Data Center Recognition Program

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Reporting requirements differ between the two versions of the data center site assessments and depending on the parameter selected will result in an ‘Optimum’ or ‘Acceptable’ assessment result.

OCP Ready™ v2 for Hyperscale Data Center Site Assessment
PUE
Required (Optimum): Real-time available online
Required (Acceptable): Other (Notes required)

OCP Ready™ v1 Data Center Site Assessment
PUE
Recommended (Optimum): Real-time available online
Recommended (Acceptable): Other (Notes required)

Sustainability metrics are reported by colocation data center operators as part of the self-certification process in the OCP Ready™ Data Center Recognition Program and included in the data center site assessment, with specific metrics that are required and others designated to be reported on a considerations and for information only (recommended) basis. OCP provides a contribution platform that enables the capture, recording and open-source publishing of sustainability metrics alongside other metrics for data center efficiency.

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6. Conclusion

The adage “you can’t improve what you don’t’ measure” applies to data center sustainability now more than ever. Implementing these metrics will help data center operators to make meaningful improvement and be able to apply resources to the most impactful areas. Additionally, transparency in reporting shows our seriousness in making improvements in our industry.

7. References and Resources

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9. About Open Compute Foundation

The Open Compute Project (OCP) is a collaborative Community of hyperscale data center operators, telecom, colocation providers and enterprise IT users, working with the product and solution vendor ecosystem to develop open innovations deployable from the cloud to the edge. The OCP Foundation is responsible for fostering and serving the OCP Community to meet the market and shape the future, taking hyperscale-led innovations to everyone. Meeting the market is accomplished through addressing challenging market obstacles with open specifications, designs and emerging market programs that showcase OCP-recognized IT equipment and data center facility best practices. Shaping the future includes investing in strategic initiatives and programs that prepare the IT ecosystem for major technology changes, such as AI & ML, optics, advanced cooling techniques, composable memory and silicon. OCP Community-developed open innovations strive to benefit all, optimized through the lens of impact, efficiency, scale and sustainability. Learn more at www.opencompute.org.

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