SUSTAINABLE SUBSEA NETWORKS

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REPORT ON BEST PRACTICES IN CABLE LANDING STATION SUSTAINABILITY

Sustainable Subsea Networks (SSN), a research initiative of the SubOptic Foundation, is an academic-industry collaboration to enhance the sustainability of subsea telecommunications cables. This report, prepared by Carbon3IT Limited in collaboration with the SSN's Cable Landing Station subgroup, is the culmination of one year of research conducted between 2024 and 2025 on the best practices in cable landing station sustainability.

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ASHRAE:
American Society of Heating, Refrigerating, and Air Conditioning Engineers.

BESS:
Battery Energy Storage System.

BMS:
Building Management Systems.

CLS:
Cable Landing Station, used as the CLS, CLSs, CLS facilities interchangeably.

CRAC:
Computer Room Air Conditioning.

CRAH:
Computer Room Air Handling.

CSRD:
Corporate Sustainability Reporting Directive.

DCIM:
Data Center Infrastructure Management.

DCMM:
Data Center Maturity Model: referring specifically in this document to the standard EN 50600-5-1: EN 50600-5-1: Information technology - Data Center facilities and infrastructures - Part 5-1: 'Maturity Model for Energy Management and Environmental Sustainability' (i.e. a Data Center Maturity Model: 'DCMM', which functions in similar ways to other technology maturity models).

EED:
Energy Efficiency Directive.

EF:
Emissions Factor, for electrical power (mass in: grams, kilograms or tonnes of CO_2e per kWh or MWh of electrical energy: gCO_2e/kWh, KgCO_2e/kWh, tCO_2e/kWh) or mass CO_2e per unit mass or volume: for example: EF diesel: 2.7KgCO_2e/l (i.e. per liter).

FP:
Fiber Pair.

GHG/GHG Protocol:
Green House Gas/Green House Gas Protocol.

ICT/ITE:
ICT, Information & Communication Technology; ITE, Information Technology Equipment: are used interchangeably and are defined as the any equipment used for telecommunications purposes (such as modems) and also IT equipment used for data processing (compute, memory, storage, network (internal)).

M&E/M&E+P:
Mechanical & Electrical infrastructure /Mechanical & Electrical infrastructure + Pump infrastructure.

tCO2e:
metric tonnes carbon dioxide emissions equivalent: i.e. the equivalent greenhouse warming potential for an emission expressed in metric tonnes carbon dioxide. Note that **metric tonnes** are used throughout.

PFE:
Power Feed Equipment.

PPA:
Power Purchase Agreement

PV:
Photovoltaic.

STLE:
Submarine Line Terminal Equipment.

TCDA:
Taxonomy Climate Delegated Act.

TTLE:
Terrestrial Line Terminal Equipment

UPS:
Uninterruptible Power Supply

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2: ORIGIN AND PURPOSE OF THIS DOCUMENT

Origin

This document is an output of Sustainable Subsea Networks, which has the aims of characterizing and quantifying the principal sustainability factors in the subsea cable ecosystem and is split into parts addressing the following elements: Cable; Cable Landing Station (CLS); Marine; and Recovery & Recycling: this document focuses solely on the CLS.

The CLS portion of the project aimed to identify and characterize the sustainability and energy efficiency areas which are most significant in impact and also amendable to performance improvement.

The selected approach was, first, in order to form a representative picture of the current population of CLS facilities, to develop and conduct a survey of the CLS facilities deployed by SubOptic Association members, detailing different functional areas (e.g. power; cooling; monitoring), best practices and standards.

Second, the survey responses were examined to understand whether they revealed any obvious patterns in functional areas where sustainability performance improvement could be applied. Third, these results were compared to the well developed sustainability and energy efficiency best practice frameworks, metrics and standards that are established for the data center sector, such as the EUCoC; EN 50600-5-1: essentially, CLS facilities and data centers have the same functional areas in infrastructure, operations and management.

The **Purpose** of this document is to provide:

- First, an overview of the findings of the survey, highlighting, in particular, areas which may be common points for improvement;
- Second, guidance to recommend frameworks and standards and the sustainability best practices and, in particular, metrics provided by them that may be applied to the CLS;
- Third, a proposed framework for practically using the best practices and metrics to assess, monitor and continuously improve CLS sustainability and energy efficiency performance.

Finally, the document provides extensive references to supporting resources and appendices that cover additional areas, such as materials use and circularity, GHG Protocol definitions and climate change mitigation.

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3: HOW TO USE THIS DOCUMENT

The section **Key Findings & Recommendations** details the most significant outputs of the project and the section **Overview and Background** outlines why the CLS is the most useful point at which to measure, act and implement improvement processes.

Part 1 presents the most important findings of the survey and **Part 2** introduces the sustainability and energy efficiency frameworks and standards that are used as the foundation for best practices and metrics.

The remainder of the document is divided into five appendixes each of which contains links to external references and resources:

Appendix 1 covers a basic description of the metrics, the relationships between them, how to use them in conjunction with their component absolute quantities, the principles of a continuous improvement process using the best practices in the standards and frameworks in tandem with the metrics, and also includes a simple hypothetical example.

Appendix 2 details considerations of material use and associated Scope 3 carbon emissions and links procurement policy with operational sustainability and energy efficiency in addition to total deployment life time impacts of equipment, infrastructure and non-powered items.

Appendix 3 overviews the definitions of Scope 1, 2 and 3 carbon emissions from the GHG Protocol.

Appendix 4 includes consideration of the development of a climate change risk mitigation plan for operations and business continuity and links this to the best practices, metrics, procurement policy and continuous improvement process detailed in the other appendices, with external references, and includes links to resources for active EU regulation: the TCDA and also the EED and CSRD.

Appendix 5 contains an example of best practices in the format used in the principal frameworks and standards used as the foundation of this document.

Appendix 6 contains a copy of the questions used in the CLS survey.

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4: EXECUTIVE SUMMARY

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The data center-oriented sustainability and energy efficiency resources selected were: the EUCoC and standard EN 50600-5-1: both cover all required functional areas within the CLS and also reference the performance metrics selected: PUE: EN 50600-4-2 (ISO/IEC 30134-2); CUE: EN 50600-4-8 (ISO/IEC 30134-8); WUE: EN 50600-4-9 (ISO/IEC 30134-9); REF: EN 50600-4-3 (ISO/IEC 30134-3). Additionally, these resources cover a fifth element that is not embodied in a single metric: material use and circularity, but which is covered in Appendix 2.

The responses from the survey showed recurring themes for action focus that mapped to specific sections of the selected sustainability and energy efficiency documents: the EUCoC and EN 50600-5-1. These areas were: Management & Reporting; Infrastructure, Environmental Control; Infrastructure, Power; Building, BMS: [Table 1]. Moreover, several cross-functional disciplines highlighted within these areas were:

- Metering/Monitoring, Data Management & Reporting.
- Energy Management.
- Materials Use & Circularity.
- Standards: Correct Application of Appropriate Standards in Sustainability, Energy Efficiency & Design.

Of these, metering, monitoring, data management and reporting are the keystone activities that are required to be correctly deployed in order for any program of performance improvement to be effected.

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Key findings:

Carbon emissions are neither generally comprehensively estimated nor split according to Scope 1, 2 or 3.

The CLS ownership model and its colocation status within a data center or stand-alone additionally determine the complexity in acquiring data necessary for monitoring sustainability performance.

Electricity was usually not monitored at all the points necessary to accurately evaluate three of the core metrics (PUE; CUE; WUE), although CLS facility-level values were monitored.

Standards: a holistic sustainability or energy efficiency standard was only used for a single reporting company.

Metrics: in only one case was an established performance metric (PUE) evaluated in compliance with the requirements of that standard.

Recommendations:

It is advised that:

One or both of the named sustainability resources (EUCoC; EN 50600-5-1) and also the metrics listed above should be acquired.

As a first step, a review of monitoring, data management and reporting be undertaken with regard to the metrics noted above, as the continuous improvement process and reporting of absolute quantities in tandem with the metrics both require that accurate measurements be taken at the correct points in the CLS.

A lead or leads be selected to understand their contents with regard to the CLS. and to devise and execute a program to: assess the current status of implementation of sustainability and energy efficiency best practices as detailed in the EUCoC/EN 50600-5-1; apply the metrics to gauge current performance; devise and implement an action plan based on gap analysis from the assessment; re-assess status: i.e. undertake a continuous improvement process, Appendix 1.

Metrics be reported in tandem with the absolute quantities used to evaluate them, as described in Appendix 1.

Dissemination of proposed actions for the sustainability performance improvement program occurs at various organizational levels and functions: corporate; operational management business unit/regional level; operational management, as detailed in Key Findings & Recommendations.

The procurement function be used a key enabler of long term sustainability performance, taking into consideration the long and short term impacts of equipment acquisition decisions, as detailed in Appendix 2.

The outputs of the metrics, perhaps in addition to the considerations outlined in Appendix 4 (Climate Change Mitigation & Adaptation Planning) be integrated into corporate reporting and operational management, as appropriate and include inclusion annually of updated practices, technologies and regulatory reporting requirements.

The section Key Findings & Recommendations contains further details of these considerations outlined above.

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5: THE CLS AS SUSTAINABILITY FOCAL POINT & SURVEY METHODOLOGY

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5.1 Why is the CLS a Key Focus for Sustainability Efforts in the Subsea Cable Communications System?

Cable Operational Performance: Energy Efficiency & Data Volume Transmitted: examination of the options for generating a simple metric, or metrics, that may be feasibly and unambiguously applied to cable data and energy performance to create standardized comparisons demonstrate that this is currently unfeasible due to the diversity in configuration across subsea networks and routes and the lack of key information: these are covered in depth in a paper under preparation (February 2025).

Discounting elements such as the submarine repeater, the CLS contains all of the powered equipment required for optical transmission plus supporting power and cooling infrastructure. Hence, improving sustainability performance of these CLS elements represents the principal impact point which may be acted upon. Since the power required to support data transmission for any completed configuration[1] of powered optical transmission equipment over any identified route is largely invariant with respect to data transmission volumes, the supporting infrastructure of the CLS is the clear focal point for investigation of sustainability and energy efficiency performance improvement.

5.2 Applicability of Data Center Best Practices & Metrics to the CLS

As noted in section 2, Origin and Purpose of this Document, and elsewhere[2], CLS facilities and data centers have largely the same best practice functional areas with respect to infrastructure and operations as data centers: i.e. essentially the same considerations and established practices and metrics related to sustainability and energy efficiency that apply to data centers may be usefully applied to CLS facilities.

However, although these fundamental factors are the same, there are specific characteristics of CLS facilities that may be required to be taken into consideration when applying the best practice frameworks described in this document.

Concerning location, in contrast to data centers CLSs are traditionally frequently located close to the shoreline of seas and oceans. Hence, certain environmental challenges arising from factors such as air with a high ambient salt and humidity values may have effects on how the best practices are applied and the resulting energy or other sustainability impacts. Hence, despite the generally simpler cooling requirements of CLSs compared to data centers, their environment often poses specific challenges for optimally executing best practices.

Likewise, there may be constraints on the resilience level for critical infrastructure that may be applied to the CLS that may not be the case for *all* data centers: i.e. as a CLS is a potential single points of failure in the global telecommunications network, where failure may have significant consequences across the network, CLSs may need to have high minimum resilience levels, 2N or 2N+1, thereby representing a ceiling for energy efficiency that may be attained from this component. However, the best practices described in the reference documents detail how to maximize the efficiency of whatever level of resilience is present: hence, operational practices may still be improved.

With respect to the evaluation of Scope 1, 2 and 3 emissions (Appendix 3), both the data center and the CLS may be viewed as nodes in energy, water and communications networks. Hence, the process of defining the system boundaries for emissions evaluation is identical in both cases: however, in the case of the CLS it is likely that some upstream and downstream Scope 3 categories may be more difficult to obtain and represent a higher proportion of the total emissions than for data centers. However, many important categories, such as capital goods, which represent embodied carbon in infrastructure or perhaps new buildings, represent the same challenges for both the CLS and the data center. For the case where the CLS is co-located within a data center, it is still useful to define the system boundary of the CLS for monitoring purposes in order to apply the assessment and improvement processes detailed in this in this document. Clearly the application of these processes, best practices and metrics to the data center housing the co-located CLS is required to maximize optimization.

[1] For example, upgrading the optical transmission equipment will result in an increase in the upper limit of data transmission rate for any given equipment power: once installed this is invariant. With regard to determining the energy use, for example, over a specific point to point or point to multi-point cable route, this is complicated by the requirement to access information on energy use across multiple branching routes. [2] Examples include: Section 6.2: Sustainability, Energy Efficiency & Metrics: Foundational Resources; Section 7.2: Key Best Practice Areas Highlighted for Potential Improvement; Section 7.3: Key Cross-Functional Disciplines; Section 8: Reference Documents: Sustainability and Energy Efficiency; Appendices 1, 2, 3 and 4.

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5.3: Representative CLS Layout, ICT Equipment & Infrastructure

The diagram below, Figure 1, shows a representative layout[3] and ICT equipment and infrastructure[4] for a CLS. Note that when an Open Cable Interface (OCI) is installed, the SLTE is connected to the subsea cable fiber pair via the cable's OCI equipment. OCI equipment models may allow optical spectrum sharing supporting multiple SLTEs on a designated fiber pair for the case of multiple owners of spectrum. The OCI includes wet plant supervisory and photonic equipment components.

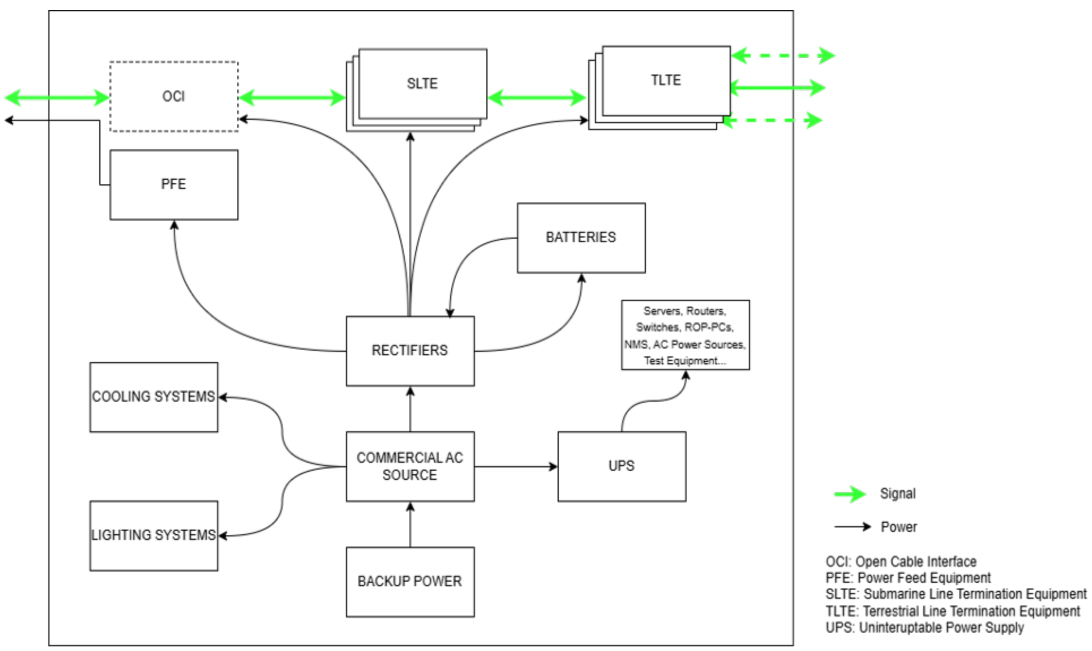

Figure 1: Representative CLS Layout, ICT Equipment & Infrastructure

5.4 CLS Survey

In order to help identify areas where specific attention in best practices may be required a survey of members was conducted covering the following areas:

- ICT Equipment: Optical Transmission & IT (servers).
- Power: Primary & Backup; AC/UPS & 48V DC.
- Cooling.
- Measuring, Metering/Monitoring & Reporting.
- Environmental Conditions.
- Standards Applied: Sustainability, Energy Efficiency & Related.
- Indicators Monitored & Logged: Carbon Emissions, Water Use.

The survey also included a request to estimate the kind of business model that was in place across the entire CLS estate used by the respondents: for example: shared; owned but managed by a third party; wholly owned and managed etc. The purpose of this was to try to gauge the limitations of approaches in, for example, monitoring and reporting, that may be recommended. Responses were obtained from companies representing around one hundred and fifty CLS facilities.

[3] Origin: Hesham Youssef, Senior Transmission Engineer, Telecom Egypt; Andrea Reschini, Head of Energy Efficiency & Sustainability, R&G Telecomm Group. [4] For the purposes of distinction, ICT equipment comprises modems and other optical transmission equipment in addition to any IT equipment per se, such as servers, which may be present, whereas infrastructure refers to supporting systems such as power, cooling, monitoring and so forth which supports this equipment.

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5.5 CLS Survey Methodology

The methodology for using the survey to generate information about potentially pertinent metrics, and best practice and functional discipline areas is shown below, Figure 2.

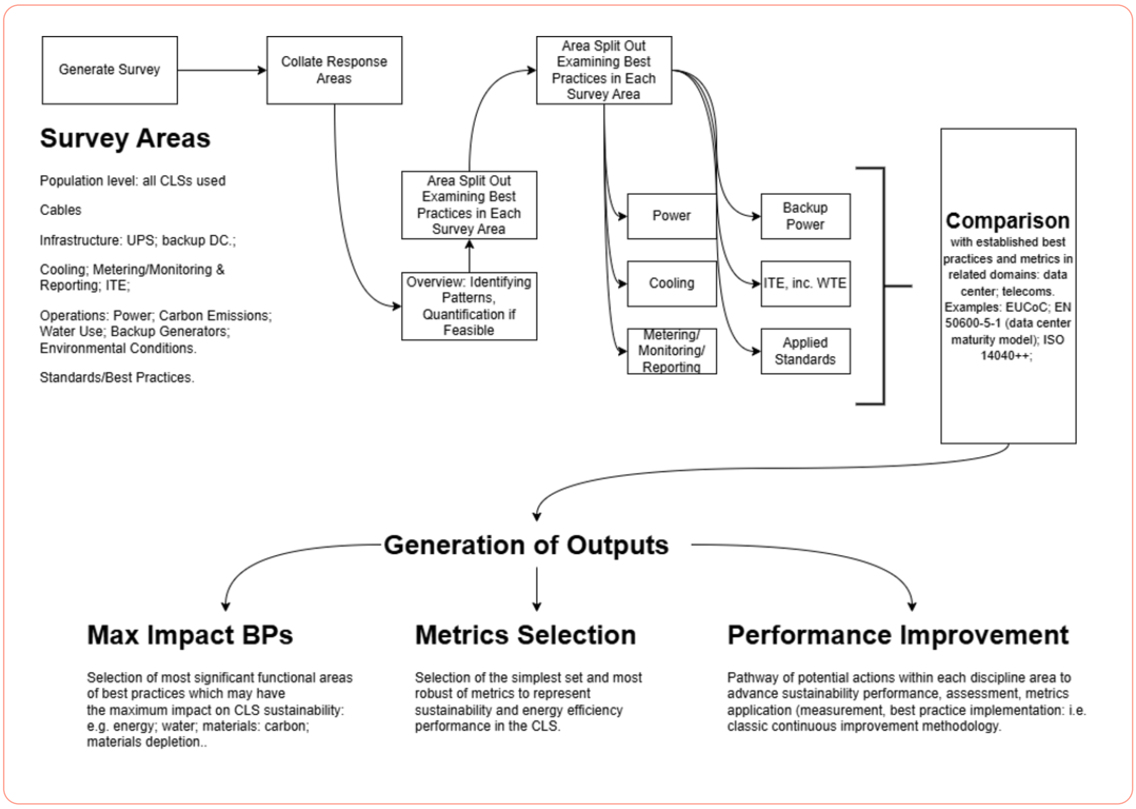

Figure 2: CLS Survey Methodology

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6: KEY FINDINGS & RECOMMENDATIONS

6.1 CLS Survey Findings

6.1.1 Best Practice Areas and Cross Functional Disciplines Highlighted

[See: Part 1: Overview of Survey Findings]

The survey highlighted recurring themes in best practice functional areas that broadly mapped very well to discrete sections within the two selected reference sustainability and energy efficiency documents: the EUCoC and EN 50600-5-1. These areas were: Management & Reporting; Infrastructure, Environmental Control; Infrastructure, Power; Building, BMS: [Table 1].

Additionally, the key cross-functional disciplines highlighted by the survey are:

- Metering/Monitoring, Data Management & Reporting.
- Energy Management.
- Materials Use & Circularity.
- Standards: Correct Application of Appropriate Standards in Sustainability, Energy Efficiency & Design.

Of these it is clear that Metering/Monitoring, Data Management & Reporting are absolute prerequisites for the others and for enabling the metrics to be accurately applied and key quantities to be measured and, therefore, are fundamental in the application of best practices and continuous improvement programs.

6.1.2 Headline Findings

Carbon emissions are not generally comprehensively estimated, and certainly not with respect to Scope 1, Scope 2 and Scope 3.

The specific ownership model of the CLS in question, in addition to whether it is co-located within a data center, partially determine the complexity in acquiring the data required for monitoring sustainability performance.

Electricity energy consumption was usually not monitored at all points within the CLS facility required to accurately evaluate some of the core metrics or to assign energy use and emissions to specific clients or sub-users of the CLS: in general, however, metering and monitoring of overall CLS energy use did occur and historic data was available for inspection and analysis.

The frequencies of equipment (ICT) and infrastructure (M&E, power and cooling) refresh rates were as expected, the former higher than the latter, with ICT refresh generally resulting in higher performance (data transmission; compute; storage) per unit of power or energy required. This demonstrates the importance of the impact of decisions made on acquisition and deployment with regard to long term sustainability performance. [See: Appendix 2: A Note on Materials Impact, Scope 3 Carbon Emissions and Procurement].

Standards: a holistic sustainability or energy efficiency standard was only installed via a single reporting company.

Metrics: in only one case was an established performance metric (PUE) evaluated in compliance with the requirements of that standard.

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6.2 Sustainability, Energy Efficiency & Metrics: Foundational Resources

6.2.1 EUCoC, EN 50600-5-1

[Part 2: Reference Documents: Sustainability and Energy Efficiency]

As noted, the selected EUCoC framework and the standard EN 50600-5-1 contain sections that correspond to the critical areas of potential action for sustainability and energy efficiency performance highlighted in the survey: [Table 1].

Moreover, they contain references to specific practices and standards in operational management, including life-cycle analysis, that are required to enhance sustainability: [Part 2 and Appendix 2].

In combination with the selected metrics and recommended program of continuous improvement [Appendix 1] and procurement policy [Appendix 2], performance improvement for all of the major sustainability impact may be measured, reported and effected.

6.2.2 Metrics

[Appendix 1: Selected Metrics, Best Practices & Continuous Improvement Cycles]

The selected metrics (PUE, CUE, WUE, REF), the absolute quantities used to evaluate them and their interactions provide comprehensive measures of the most immediate significant sustainability impacts.

In combination with material use considerations outlined in Appendix 2 these provide immediate and longer term measures for monitoring and improving performance.

6.3 Recommendations

The specific requirements for each organization will vary, however, the foundational recommendations are:

Acquire the recommended sustainability and energy efficiency resources: i.e. the EUCoC and/or EN 50600-5-1 and the standards corresponding to the selected metrics (Appendix 1: Metrics).

Assign a lead, or leads, within the organization to be tasked with understanding the content of these resources and how the key sections and best practices may be applied to CLS and, if appropriate other assets.

As a first step, a review of monitoring, data management and reporting should be undertaken with regard to the metrics noted above, as the continuous improvement process and reporting of absolute quantities in tandem with the metrics both require that accurate measurements be taken at the correct points in the CLS.

Metrics should be reported in tandem with the absolute quantities used to evaluate them, as described in Appendix 1.

Devise and execute a continuous improvement program based on the best practices and metrics, or incorporate them into existing programs.

Additionally, using the guidance and resources in Appendices 2 (Materials Impact, Scope 3 Carbon Emissions & Procurement) and 4 (Climate Change Mitigation & Adaptation Planning), consider how to A) devise and incorporate a scoring mechanism for sustainability impacts into procurement processes and, B) pull and aggregate key metrics/KPIs, to reporting flows at the operational management and corporate scales.

It is also advised that the sustainability function, in terms of quantitative and qualitative impacts[5], be rolled into corporate reporting and operational management at all scales, and include annual updating of practices, technologies and regulatory reporting requirements.

5. Including commercial and market positioning.

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6.3.1 Corporate

The application of the presented performance improvement resources in tandem with continuous improvement processes at both the single asset level and the business unit or regional scales will provides a cascade of information to enhance:

- Internal corporate reporting and governance.
- Multi-jurisdictional regulatory compliance.
- Investor relations.
- Client reporting requirements.
- Competitive advantage.

6.3.2 Operational Management – Business Unit/Regional Scale

The elements of this document may provide a supporting elements for initiatives which include:

- Overall sustainability and operational optimization across the asset estate, perhaps in combination with other assets, such as data centers, POPs (telecoms).
- Characterization of the of the maturity profile across the asset estate.
- Identification of outliers, high and low, with respect to sustainability performance of the implementation of the most suitable and advanced best practices.
- Quantification of the potential impacts of implementing improvement processes across the estate.
- Aiding decision-making on where the most sensitive point is to deploy financial, human and infrastructure resources in the context of reducing environmental impacts whilst enhancing resilience.
- Including quantitative impacts of sustainability measures in decision making tools such as Cost Benefit Analysis and Total Cost of Ownership.
- Enhancing and coordinating the knowledge and skill level throughout operations.

6.3.3 Operational Management – Practitioner

Many of the elements noted above at the Business Unit/Regional Scale apply to practitioners who are responsible for a specific asset or assets. Practitioners are likely to be the assigned leads for understanding the resources and will be responsible for applying the assessment of implementation of best practices and metrics.

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7.1 Headline Findings

Carbon Emissions: Scope 1, 2 and 3 are generally not evaluated, although Scope 2 (electrical power) is estimated on occasion. In particular there may be opportunities for reducing backup generator emissions (Scope 1) via examining whether the transition to a lower emissions regime is feasible. Additionally, the access of HVO or other low emissions fuels as substitutes for diesel may be investigated.

Ownership Model: CLS owner-operators (perhaps primarily telecoms companies) have more comprehensive inspection capabilities of power and equipment usage than all other possible ownership models. There are indications that the better data acquisition opportunities afforded by the owner-operator model are not always fully exploited. Where the CLS is collocated with a data center there may be additional difficulties in attributing energy use and, in particular, infrastructure energy use for share services such as cooling, especially in the case where discrete, separate environmental zones are not in place.

Electrical Energy Consumption & Monitoring: Monitoring via metering of power for the overall energy use of the CLS was deployed and as a minimum historical records were available in all cases for inspection. However, only one case included: separate power metering for M&E infrastructure (power, cooling and plumbing, if appropriate) or specific client rooms; remotely accessible monitoring with time vs energy use analysis for near real-time performance monitoring and correction. Note that electrical energy delivered to the data center by backup generators is also included in all metrics calculations and, as noted, associated environmental impacts are not always evaluated.

Equipment and Infrastructure Refresh Rates: the approximate build and commissioning years of the CLS facilities reported comprised two sets: a set clustering on built/commissioning dates around 2000 and a set with built/commissioning dates around twenty years later, yet the most recent iteration of transmission equipment updates for the earlier commissioned CLSs occurred around the same year as the latter group were commissioned: i.e. note: **Appendix 2**: A Note on Materials Impact, Scope 3 Carbon Emissions and Procurement with regard to around refresh rates and deployment life extension with respect to material throughput, which, incidentally has implications for CAPEX phasing.

Standards and Frameworks: Although the standard ISO 14001 (Environmental Management Systems) was formally in place in one set of examples, there were no formal or informal structures for common standards or frameworks for energy efficiency or wider sustainability.

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7.2 Key Best Practice Areas Highlighted for Potential Improvement

Recurring themes occurred in the following broad operational best practice areas which can be grouped in approximate correspondence to the various sections of the reference sustainability and energy efficiency documents detailed in Part 2: Reference Documents: Sustainability & Energy Efficiency, these are summarized in Table 1, below.

Table 1: Summary of Highlighted Best Practice Area vs Reference Documents

Best Practice Functional Area	Section: EUCoC	Section: EN 50600-5-1
Management & Reporting	(3) Management, (9) Monitoring	(5) Management & Reporting
Infrastructure - Environmental Control	(5) Cooling	(8) Environmental Control
Infrastructure – Power	(6) Power Equipment	(7) Power
Building – BMS	(8) Building Management	(6) Building Management

Note that these highlighted broad areas do not exclude the very pertinent applicability of the other areas detailed in these reference documents, in particular in **Sections 9-12 (ICT) of EN 50600-5-1** and **Section 4 (IT)** of the EUCoC.

These best practices and standards referenced within these sections are applicable to CLS facilities, whether they are co-located within a data center or not because the focus in areas such as equipment audit, decommissioning of unused services and equipment and so forth, are universally applicable.

7.3 Key Cross-Functional Disciplines

Another way of classifying areas that were highlighted in the survey is to consider cross-functional disciplines. These disciplines are represented across multiple functional areas that is the organizational basis for the reference documents and the sets of questions within the survey.

Important cross-functional disciplines include:

- Metering/Monitoring, Data Management & Reporting.
- Energy Management.
- Materials Use & Circularity.
- Standards: identification and application of appropriate standards in sustainability, energy efficiency and design.

Of these it is clear that Metering/Monitoring, Data Management & Reporting are absolute prerequisites for the others and for enabling the metrics to be accurately applied and key quantities to be measured and, therefore, are fundamental in the application of best practices and continuous improvement programs.

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7.4 Summary: Survey Functional Areas

The survey (Appendix 6) is divided into two areas: Section A, which covers basic information about the CLS, such as its location, and aims to obtain information about the range of ownership and operation models across the range of CLS facilities within the organization; Section B, which focuses on a single CLS selected by the respondent as representative.

The survey provided, therefore, attempted to gather information about the overall profile of the CLS facilities used by an organization and focus on a set of functional areas within one of these CLS facilities, in sections and subsections as shown below:

Section A. Profile

A1. Organization Name

A2. CLS Population Profile – Ownership Model

Section B: Attributes of Selected Single Cable Landing Station (CLS)

B1. CLS Details: Location, Organization, Owned/Leased/Managed etc.

B2. CLS Building

B3. Cables

B4 Infrastructure

- B4.1 & B4.2 Power Infrastructure

B4.3 Cooling

B4.4 Metering, Monitoring, Reporting & Control

B4.5 Facility Owner - Client Metering [Questions specific to client metering]

B4.6 ITE

B5. Operations

- B5.1 Power
- B5.2 Carbon Emissions, Water Use
- B5.3 Power: Backup Generators
- B5.4 Environmental Conditions

B6 Standards/Best Practices

- B6.1 Overview
- B6.2 Cooling: See Environmental Conditions.
- B6.3 PUE
- B6.4 Design
- B6.5. Operations

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The overview below represents overall findings for each of these sections and subsections of the survey as denoted A(1..2) and B(1..6):

Section A. Profile

A2. CLS Population Profile – Ownership Model

Of the population of CLSs owned by the responding companies there was a clear division between those that were owner-operated and owned but operated by a third party. Notwithstanding the small sample size in terms of responding companies, there is a clear division between companies that are, or whose origins were, primarily telecommunication companies and those which operated primarily as tech companies or data center companies with significant data center real estate: the former being owner-operated and the latter being owned and operated by third parties.

It is likely that the pattern of ownership/operational management largely occurs in companies which are currently building out their own subsea networks.

Other potential ownership models (wholly or part leased; shared owner-operated) were not indicated, although they are likely to represent a portion of the global population.

Section B: Attributes of Selected Single Cable Landing Station (CLS)

B2. CLS Building

All CLSs were purpose built, ~40% of CLSs reported were collocated within a data center with the remainder being primarily dedicated to the CLS function. Aside from one of the data center collocated CLSs, which was housed within a three level building, all others were single level.

The total area of the CLS (or dedicated to CLS functions for data center collocated CLSs) ranged from 82m^2 to 2,940m^2 proportions of the area occupied by PFE and ITE (including optical transmission equipment) ranged from: ~25% to 69%, with all but one being over 50%.

All have had infrastructure or optical transmission equipment upgrades since commissioning.

B3. Cables

All cables had RFS dates from ~1999 though 2019 inclusive, with from 2 to 12 fiber pairs per cable and one CLS having multiple cables. Of these, where disclosed, from zero to ~two thirds were unlit and stated capacities ranged from 11Tbps to 90Tbps.

For the non-owner-operator CLSs, a combination of spectrum sharing only in the case of one CLS and, for another, all combinations of allocation were deployed: i.e. full fiber pair; partial fiber pair; spectrum; wavelength circuit capacity.

B4. Infrastructure

B4.1 & B4.2 Power Infrastructure

Power infrastructure: For AC, all but one were N+1 configuration, with power requirements appropriate to their equipment capacity: not all disclosed, but ranging from ~250kW to ~2000kW. In all but one case 2(N+1) configuration was used for UPS systems. For DC, the configuration was 2N or N(A+B), where disclosed, with appropriate power level , in the single case where it was disclosed.

The battery technology used was lead-acid in the cases where this was disclosed, likewise, power and energy capacity were only disclosed in a single case.

B4.3 Cooling

The primary cooling systems used were DX and direct over and under floor cooling, in configurations N+1 and, in one case, 2N. In cases where the CLS was collocated within a larger data center environment multiple cooling systems, including chillers, contribute to the cooling load.

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B4.4 Metering, Monitoring, Reporting & Control

Monitoring of the power at the level of the CLS was installed in all but one of the cases, which was where the CLS was collocated within a larger data center.

Metering at the following points was not available except in one case:

Individual M&E infrastructure.

Individual client rooms (or specific separate rooms in the case where there are it is owner-operated with no clients).

Remotely accessible monitoring: where available trend analysis is conducted: i.e. manual collection was used in all but one case.

In all cases gross records of the energy use are used to monitor energy efficiency performance with historical logs being maintained for three or more years.

B4.5 Facility Owner - Client Metering [Questions specific to client metering]

The responses concerning client metering only apply to non owner-operators.

In each case some form of monitoring was in place, ranging from self-monitoring of rack level power for clients or within a CLS shared services consortium model to simply metered current, power (AC and DC) and energy consumption.

Power and cooling were also shared across the individual clients and assignment of fees may include the use of PUE and contracted IT power. Hence, the commercial requirement of being able to evaluate PUE for attributing costs in this model. In principle this is not required if all infrastructure energy requirements are metered and logged separately in tandem with IT energy consumed over the billed period in combination with an overhead pricing function.

Note that it is entirely consistent that this is not present in owner operated CLSs. However, there could be use-cases where functions or departments internal to the owner-operator may wish to assign cost.

B4.6 ITE

Only owner-operated CLS facilities were able to respond re: the approximate year of equipment manufacture for both IT and transmission equipment elements of ITE, with refresh rates occurring within a two year window 2021-22 across all reported sites.

Note that refresh rate may be a significant factor and have counteracting impacts due to higher energy efficiency vs higher material throughput as rate increases: hence, the fate of used units may be critical in determining overall sustainability impact. Refer to **Appendix 2**: A Note on Materials Impact, Scope 3 Carbon Emissions and Procurement.

Separate environmental zones are not universally applied: see also B5.4 Environmental Conditions, below.

B5. Operations

B5.1 Power

Where available, all facilities used power from low carbon ('renewable') sources. This was in the form of PPAs or suppliers with a significant contribution of renewable sources in its supply mix: although overall emissions factors were not always reported, derived evaluations from reporting energy use give values of ~110 - ~135gKCO_2e/kWh.

B5.2 Carbon Emissions, Water Use

An estimate of total annual carbon emissions from primary electrical power was made for all of the owner-operated CLS facilities: 5.1.

In no case were emissions differentiation into Scope 1, 2 and 3, despite the fact that the annual volume of liquid fuel (diesel in all cases, below) consumed in backup generators was reported in most cases.

Water was either not used for cooling or the volume used was not reported.

B5.3 Power: Backup Generators

Generators that use liquid fuels were used in all cases as the means of backup power and diesel was the liquid fuel used in all cases.

Associated Scope 1 carbon emissions ranged from ~35tCO2e to ~ 0.5tCO2e. The volume of fuels used is dependent on the capacity of backup generation installed, the testing regime employed and the amount of time for outages and power required during those outages. Note also the complication in reporting and attribution of backup power in the cases of CLSs co-located within a data center with common primary power sources: i.e. a grid outage that impacted the data center would also impact the CLS: differential reporting or attribution was not available.

Environmental control measures, such as spill kits and fire suppression equipment, were in place in all cases and in compliance with the appropriate environmental and safety regulations for each jurisdiction.

B5.4 Environmental Conditions

Separate environmental zones were only used in a minority of cases (~17%), for separate environmental zones for power feed infrastructure and transmission equipment for example. All cases deployed cold/hot aisles and blanking panels where appropriate.

On occasion, separation of AC transmission equipment and DC equipment was in place, but for safety rather than environmental control reasons.

Note that the most of the energy from the PFE for optical transmission is dissipated at the repeaters on the cables.

Note that UPS and other M&E equipment were frequently in separate areas for environmental control reasons.

Where data halls are present (CLS co-located with a data center) typical operating conditions were compliant with ASHRAE environmental ranges (24C/50-60% RH), whereas the range recommended by ASHRAE is 18-27C.

For all of the CLS facilities of one organization, for the common ITE area the temperature was ~25C, RH ~50% and run in accordance with environmental management processes in ISO 14001-10.

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B6 Standards/Best Practices

B6.1 Overview

Aside from one reporting company, where ISO 14001 (environmental management processes) are applied, no other organization employed energy efficiency or operational sustainability practices or standards such as ISO 50001, the EUCoC or EN 50600-5-1.

However, selected specific best practices were implemented in areas such as variable fan speeds on CRACs. Note that air handling approaches may need to be adapted for coastal region location of CLS facilities due to the high salt content of the air.

B6.2 Cooling:

See Environmental Conditions.

B6.3 PUE

PUE was formally evaluated according to the standard (EN 50600-4-2/ISO 130134-X) in only one reporting company, using the PUE2 definition: i.e. rack level monitoring and the values attained were not shared. Where the ratio of total energy use versus ICT energy use was reported (i.e. not the actual annual energy values and monitoring in accordance with the standard). Where PUE was reported it was only in the case of colocation within a data center, with values ranging from ~2 to ~2.2, hence including shared power and for data center operations.

Note that the ownership model may make accurate measurement of PUE problematic in some instances and that it appears that PUE is not universally monitored and evaluated correctly.

B6.4 Design

Electrical layout design was optimized to minimize overall system losses or shortest connection distance from UPS output and therefore loses. No specific standard (e.g. Electrical Loss Component as defined in ASHRAE 90.4 or a similar measure) was used to gauge loss performance in electrical design.

Power factor correction equipment is used in all cases as are lighting control measures, ranging from timers to occupancy sensor activated lighting.

B6.5 Operations

Generators are tested monthly and within six month overall cycles in some cases.

Testing is performed for periods ranging from 1h/month to 4 or 5 hours/month and on partial, full or actual current site load, with logs being kept in most cases.

It is noted that compliance with local emissions' regulations concerning generator run time is not always required: i.e. implying that exemptions are permitted for intermittent use or perhaps standby power generation.

DCIM and/or BMS are implemented in all cases.

Regular planned testing or maintenance activities which were deemed to impact energy efficiency included: full load testing of the generators (biannually): i.e. reduces annualized energy efficiency versus performance; planned replacement rate of filters; cleaning of CRAC condenser coils: i.e. maintained efficiency.

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It is noted that numerous standards metrics and best practices addressing energy efficiency and sustainability have been developed for data center design and operation. Since many key functional areas within data centers and CLSs are the same, some of these standards, metrics and best practices represent a mature and tested set of resources that may be applied to CLS.

8.1 Principal Sustainability Impact Areas

Energy Use; Carbon Emissions (direct and indirect: i.e. all energy uses for operations have direct or indirect impacts on carbon emissions. Materials and water also have carbon emissions impact but mostly indirectly: see Annex 3: GHG Protocol & Carbon Emissions, Scope 1, Scope 2 and Scope 3); Water Use; Materials and Circularity.

8.2 Reference Documents

Reference documents are used for the selection of pre-existing established best practices that have been demonstrated to be useful improving the sustainability and energy efficiency performance of data centers:

- **EUCoC (v2024)**: [European Code of Conduct for Energy Efficiency in Data Centers]
- **EN 50600-5-1:2023**: [Information technology - Data Center facilities and infrastructures - Part 5-1: Maturity Model for Energy Management and Environmental Sustainability (i.e. a technology maturity model for data centers: 'DCMM').]
- The **EUCoC** is separated into a set of best practices in the areas of, parentheses indicates the section within the EUCoC:
- (3) Data Center Utilization, Management and Planning.
- (4) IT Equipment & Services.
- (5) Cooling.
- (6) Data Center Power Equipment.
- (7) Other Data Center Equipment.
- (8) Building Management.
- (9) Monitoring.
- (10) Practices to Become Minimum Expected.
- (11) Best practices Under Consideration.

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The European Norm (EN) **50600-5-1:2023** was developed by CEN/CENELEC[6], the electrotechnical committee for European standards.

It covers all of the areas detailed within the EUCoC but includes an additional further emphasis on sustainability areas. Further, it provides a ranking of the sophistication of sets of best practices within eight different functional areas, with the objective of performing a profile of any facility that is assessed: hence, the standard may be classed as a 'data center maturity model'[7] (DCMM).

The ranking occurs over five levels, 1 to 5[8] via demonstration of the implementation of the best practices at within each functional. The functional areas are:

- (5) Management & Reporting.
- (6) Building Management.
- (7) Power.
- (8) Environmental Control.
- (9) ICT – Compute.
- (10) ICT – Storage.
- (11) ICT – Network.
- (12) ICT – Software.

Note that the numbers in parentheses refer to the section numbers within the standard.

Appendix 5 shows the format of the best practices within the EUCoC and EN 50600-5-1 with actual examples.

8.3 Recommendations

For **EN 50600-5-1** the most pertinent areas are 5 through 8: 5: Management & Reporting; 6: Building Management; 7: Power; 8: Environmental Control.

For the **EUCoC**, best practices within all areas aide from number 4 (IT) may be applicable: 3: Management; 5: Cooling; 6: Equipment (principal); 7: Equipment (additional); 8: Building Management; 9: Monitoring; 10: Minimum Conditions.

Naturally, depending on the equipment within the CLS, best practices within EN 50600-5-1 (ICT: 9 though 12) and within the EUCoC (IT, 4) will also be applicable.

Specifically, the areas highlighted in the findings of the survey (Part 2, below) may require particular focus if they are broadly representative of operational best practices applied in CLSs.

[6] CEN/CENELEC: https://www.cencenelec.eu/ CEN: European Committee for Standardization, an association that aggregates the National Standardization Bodies of 34 European countries: https://www.cencenelec.eu/about-cen/ CENELEC: European Committee for Electrotechnical Standardization: https://www.cencenelec.eu/about-cenelec/ [7] Note that a data center maturity model for data centers was previously developed by The Green Grid in the 2010s: https://www.thegreengrid.org/ [8] For EN 50600-5-1 compliance assessment for each functional area of best practices (1 through 8) there are five levels of sophistication. Compliance of each level occurs if the following conditions for percentages of best practices implementation are met: Level 1: >0%, <50%: Level 2: ≥50%, <100%; Level 3: 100%; Level 4: 100%; Level 5: 100%. **Note** that for levels 4 and 5, implementation of 100% of best practices at all preceding levels must be demonstrated.

8.4 Resources

EUCoC: [European Code of Conduct for Energy Efficiency in Data Centers.]

Landing Page: https://e3p.jrc.ec.europa.eu/communities/data-centres-code-conduct

Full 2024 Edition, PDF download: https://e3p.jrc.ec.europa.eu/publications/2024-best-practice-guidelines-eu-code-conduct-data-centre-energy-efficiency

Assessment Framework for Data Centers in the Context of Activity 8.1 in the Taxonomy Climate Delegated Act. This is based on a subset of EUCoC 2023 best practices in tandem with climate risk planning and impact mitigation requirements of the TCDA and is described in detail in Appendix 4: https://e3p.jrc.ec.europa.eu/publications/assessment-framework-data-centres-context-activity-81-taxonomy-climate-delegated-act

EN 50600-5-1:2023[9]:

[Information technology - Data Center facilities and infrastructures - Part 5-1: Maturity Model for Energy Management and Environmental Sustainability (DCMM).]

https://knowledge.bsigroup.com/products/information-technology-data-centre-facilities-and-infrastructures-maturity-model-for-energy-management-and-environmental-sustainability-1?version=standard

Additionally, CENELEC has provided an overview of energy efficiency standards for data centers published in 2021 by CEN/CENELEC provides some background on the CENELEC Technical Reports (TR) CLC/TR 50600-99-1 and CLC/TR 50600-99-2 which ultimately provided the basis for the CENELEC Technical Specification CLC/TS 50600-5-1 (i.e the DCMM: Maturity Model for Energy Management and Environmental Sustainability), which now has the designation as a standard EN 50600-5-1. These technical reports were subsequently been withdrawn with the publishing of EN 50600-5-1, which incorporates their contents.

Further, the ISO and EN designations for the same data center energy efficiency and sustainability metrics standards (PUE; CUE etc.: EN 50600-4-X and ISO 130134-X) are also listed, in addition to specific electro-technical standards.

Review of Standardization Activities: Energy Management and Environmental Viability of Data Centers: https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN%20sectors/Digital%20Society/Green%20Data%20Centres/brochuredatacentrestandardizationedition8_2021.pdf

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[9] Note that, as of December 2024 the ISO group Sustainability, IT & Data Centers (ISO/IEC JTC 1/SC 39) are developing the ISO designated standard for EN 50600-5-1:2023, currently a technical specification ISO/IEC NP TS 22237-10.

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These metrics were selected because they measure the facets of sustainability: energy use; carbon emissions; water use. Of these three facets energy use is key because it impacts the other two. A fourth important aspect is materials use, is also considered at the foot of this appendix. Table 2, below, lists the metrics in combination with their standards, summary definitions and units, where applicable.

Name	Acronym	Units	Standards	Summary Definition
Power Usage Effectiveness	PUE	None	EN 50600-4-2 (ISO/IEC 30134-2)	($Energy_{ICT}$ + $Energy_{Infra}$) / $Energy_{ICT:}$ annual values.
Carbon Usage Effectiveness	CUE	$KgCO_2e$/ kWh (ICT)	EN 50600-4-8 (ISO/IEC 30134-8)	$Facility_{CO2e}$ / $Energy_{ICT:}$ annual values.
Water Usage Effectiveness	WUE	m^3H_2O/ MWh (ICT)	EN 50600-4-9 (ISO/IEC 30134-9)	V_{H2O} / $Energy_{ICT.:}$ annual values.
Renewable Energy Factor	REF	None	EN 50600-4-3 (ISO/IEC 30134-3)	$Electrical\_Energy_{Renewable}$/ $Electrical\_Energy_{Total}$/: annual values.

Table 2: Summary Attributes Table: Metrics: PUE, CUE, WUE, REF

Regarding the selection of the metrics: PUE; CUE; WUE; REF: as: A) all have established, well defined and practically applicable EN and ISO standards associated with them; B) collectively they pertain to the principal sustainability impact areas identified in this document; C) individually and collectively they enable the impact of measures in operational and procurement best practice areas in the frameworks and standards referenced to be gauged: i.e. they enable the process: assessment of the current status of best practices; obtaining a 'baseline' of performance by using the metrics to assess current performance; generation of an action plan for performance improvement (i.e. implementing best practices, as applicable); measuring or gauging the impact by using the metrics.

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9.1 Power Usage Effectiveness – PUE: EN 50600-4-2 (ISO/IEC 30134-2)

First, it is important to note that the energy used in ICT equipment defined in these metrics comprises: A) the optical transmission equipment plus, B) any ICT data processing equipment, such as servers, which may form part of the CLS powered equipment.

$$PUE = \frac{E_{ICT} + E_{Infrastructure}}{E_{ICT}} \text{ :Nounits...[1]}$$

Where: E_{ICT} is the total annual ICT[10] energy used, in the context of the CLS this is the annual energy used by all optical transmission equipment and IT equipment such as servers, should they be present; $E_{Infrastructure}$ is the annual energy used by all supporting infrastructure, principally power and cooling infrastructure. The points at which the energy use for evaluating PUE are measured are also defined in the standard, three points are defined, in increasing order of precision: Output from the UPS (PUE_1); Output from the PDU (PUE_2); Input to the ICT equipment (PUE_3). Note that any waste energy (heat) reuse that is factored into the evaluation will result in a depression of the PUE value due to the additional energy being applied for moving fluids and operating heat exchangers. Note that PUE requires the measurement of all electrical energy inputs to the facility. Hence, the electrical energy supplied by any use of backup generators during the annual measurement period is also included, with factors for the conversion of the energy in liquid fuel used to electrical energy input into the data center in kWh or the conversion of the logged fuel volume usage into carbon emissions based on emissions factors for the fuel used. Similarly, the value of non-electricity energy inputs obtained from outside of the facility system boundary, such as chilled water, heat, steam, hydrocarbon gas flows, are evaluated as part of the total annual facility energy use.

9.2 Carbon Usage Effectiveness – CUE: EN 50600-4-8 (ISO/IEC 30134-8)

Second, Carbon Usage Effectiveness (CUE) is defined as:

$$CUE = \frac{Facility_{CO_2e}}{E_{ICT}} \text{ : Units} = \frac{KgCO_2e}{kWh} \text{ ...[2]}$$

Where $Facility_{co\ e}$ is the annual mass of carbon emissions from the facility (data center or in this case, the CLS) in this case arising from its operation, in carbon dioxide equivalent and is defined as for PUE, above. The sources for $Facility_{CO_2e}$ are Scope 1 emissions arising from generating electricity onsite, or any other direct sources of GWP gases arising from onsite activities that provide power to the facility, plus Scope 2 emissions associated with the electricity supplied to power the CLS from the electrical grid: i.e. provided from a third party supplier. Additionally, emissions arising from the testing regime of any generators and the leakage of GWP gases used in any chillers is taken into account.

Although diesel generators are the current principal way of providing backup electrical power, some alternatives which are being deployed, such as electrochemical fuel cells will still produce Scope 1 carbon emissions if the energy source results in the oxidation of carbon with associated atmospheric release: e.g. methane or other hydrocarbon gases.

The principal component of $Facility_{CO_2e}$ are Scope 2 emissions arising from the electricity supplied to the facility by the electrical grid[11]. The electrical power supplier is able to provide an emissions factor for the electrical energy used over a period of time, which is presented in units of: gCO_2e/kWh, $KgCO_2e/kWh$, or perhaps tCO_2e/MWh[12]. As with PUE, services in addition to electricity which cross the facility system boundary, such as steam, heat and cooling are accounted for in the evaluation of annual carbon emissions, although this is less likely to arise in the case of a CLS than of a data center.

10. The standard defines this as IT energy, which is principally servers and which includes a small component of energy use by network communications equipment, in the context of a CLS ICT is used merely to note the significance of communications equipment energy use, other ICT energy use will vary depending on each specific CLS. 11. Note that the electrical grid is currently the prime method of energy supply, although the technical and commercial viability of using onsite primary electrical energy generation is improving. In the case of a facility with modest and defined power requirements such as certain CLS facilities, onsite renewable power (such as PV) may be used in combination with BESS or other energy storage solutions as the prime energy supply. 12. Note that the standard defines the reporting of CUE in the units: KgCO2e/kWh, equivalent to tCO2e/MWh.

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9.3 Water Usage Effectiveness – WUE: EN 50600-4-9 (ISO/IEC 30134-9)

The metric Water Usage Effectiveness (WUE) is defined as:

$$WUE = \frac{V_{H_2O}}{E_{ICT}} \text{ :Units : } \frac{m^3}{MWh} \quad ...[3]$$

Where V_{H2O} is the annual volume of water used by the facility measured in m³ and E_{ICT} is defined as in the case of PUE, above, but has the units of MWh rather than kWh.

9.4 Renewable Energy Factor – REF: EN 50600-4-3 (ISO/IEC 30134-3)

The fourth metric is Renewable Energy Factor (REF) and is simply the ratio of the total annual electrical energy to the total annual renewable energy used to power the facility, expressed as a decimal with a maximum value of 1.0 in the case where 100% of the electrical energy supplied to operate the facility is obtained from renewable sources, as shown in [4], below.

An overview of the quantities used to derive the metrics is shown below in Figure 3, below.

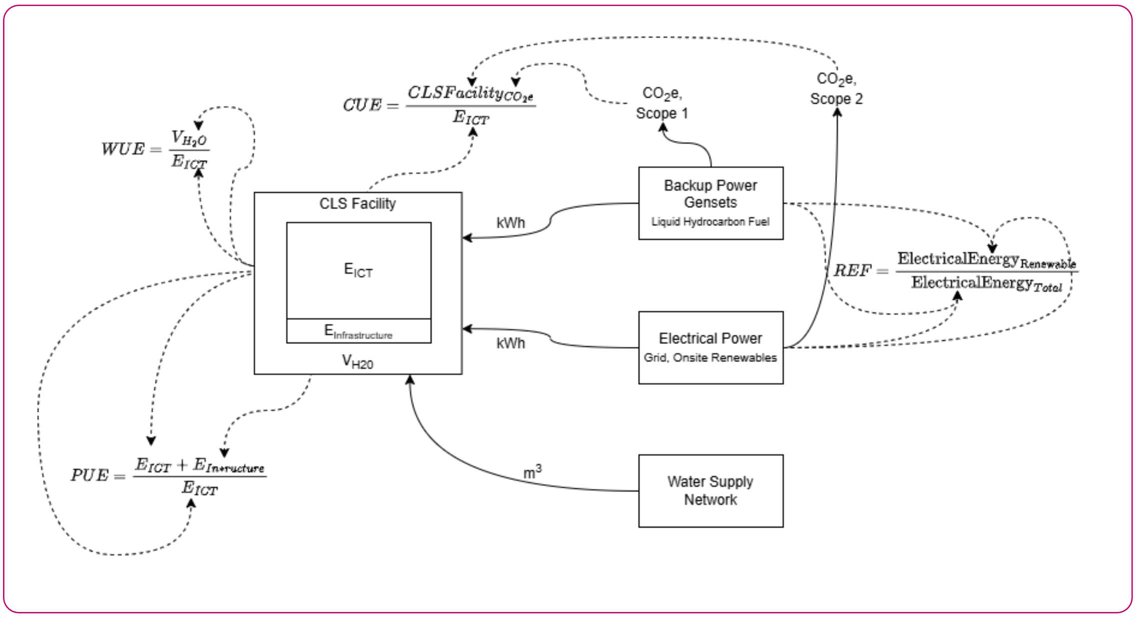

Figure 3: Metrics & Quantities. Note that electrical power may principally be supplied by the electrical transmission grid, contributions from any onsite renewable sources are also included in REF determination.

9.5 Assessment of Maturity Level, Plan Generation, Implementation and Measuring

First, as highlighted in the responses to the survey, monitoring is a vital area for improvement in sustainability and energy efficiency and accurate, repeatable monitoring, measurement and reporting is required in order to be able to gauge baseline performance and the impact of any subsequent improvement program. The application of frameworks and standards detailed in this document is based on: A) the best practices (BPs) and, B) the metrics described: these may be applied in a continuous improvement methodology as illustrated in Figure 4, below.

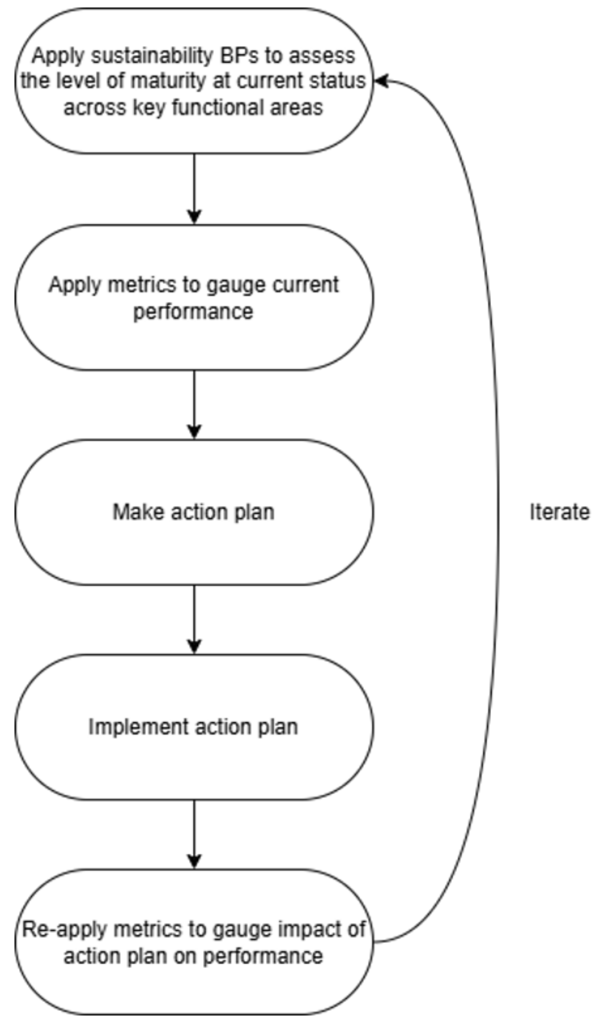

Figure 4: Continuous Improvement Cycle: Best Practices & Metrics

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9.6 Using Non-Annual Data

All of the metrics require that the measured inputs be monitored and measured over a full year to comply with the standard definition. However, it is useful and reasonable to be able to use the ratios that define the standards over representative time periods and comparative periods of the year in order to gauge performance. Concerning time periods, the ratio total facility electrical energy use versus ICT energy use is routinely used as an 'instantaneous' indication of the current value of 'PUE' at a given time, here the time periods may be minutely or simply total power versus ICT power requirements are used as an approximation: this is not the PUE value as it is not annual energy use and does not take into account other energy sources, however, it is useful to give an indication of performance. For the ratios detailed in PUE, CUE and WUE quarterly or monthly evaluations may useful to gauge comparisons with values obtained in the same quarter or month in previous years, hence providing an indication of

Note that the impact of season is a function of the variation in temperature and humidity conditions at the location of the data center: for example, as location deviates from the equator the seasonal impact on cooling energy required, for example, increases. However, measures such as passive or free cooling methodologies are able to reduce the impact of seasonal temperature and humidity variation.

9.7 Relationships Between the Metrics & Absolute Quantities

As the metrics PUE, CUE and WUE are the expressions of ratios of quantities, there are conditions where the value of the metric may appear to indicate an improvement or degradation in sustainability performance, which may not be the case. Examples conditions include:

The total quantity of energy used to deliver the same volume of services decreases:

- PUE may increase if the reduction in energy is due to more energy efficient ICT equipment or better management of the services supported by that equipment, whether there have or have not been adjustments in the management of the supporting power and cooling infrastructure: i.e. infrastructure energy use does not change significantly, hence PUE increases. Similarly, the value of PUE may also increase if optimization or changes in cooling results in higher energy use by internal server fans and an associated increase in the value of total ICT energy increases. Although Best practices in server thermal and fan settings may obviate some of these effects, this highlights the importance of logging and reporting the absolute quantities of energy used in conjunction with the PUE value.

There have been no changes in the equipment, infrastructure, services or management, yet total energy use, PUE, CUE and WUE are elevated compared to the previous year:

- Increasing energy use due to cooling and losses arises with increasing temperature and humidity, if there are significantly higher external temperature and humidity over the course of the current year this may result in higher absolute energy use and increased values for PUE, CUE and WUE, the latter dependent on on water-use in cooling. This scenario may also occur if the facility is located in a region with known regular temperature oscillations, e.g. a CLS located on the west coast of LATAM is subject to El Niño and La Niña periods, where temperatures are significantly elevated or depressed over the course of a year or more.

A new electrical power supplier has been acquired which has a REF value of 0.80, consequently the emissions factor of the electricity supply has fallen from 350gCO_2e/kWh to 70gCO_2e/kWh, 20%[13] of the value. Further, a new generator testing regime has been put in place, reducing the annual planned generator operating hours by 60%.

- Due to a significant outage requiring operation of diesel fueled generators the carbon emissions and therefore the CUE have not decreased as much as anticipated.

There are clearly multiple other scenarios where the metric value alone is not indicative of performance. Hence, it is recommended that the use of a metric in order to gauge the impact of improvement measures be accompanied by consideration of the absolute values of the quantities comprising the metric in question. In the three examples above the quantities or external data that needs to be used in association with the metrics are: change in power (...and therefore energy use) of the ICT equipment and the total energy used; record of temperatures and deviation from records; logs of outages and diesel fuel volume usage.

13. Note that renewable power may be classed as zero emissions at point of generation, however, the estimation of embodied carbon in the power generation infrastructure in combination with estimates of project lifetime energy generation do enable estimates of emissions factors.

9.8 Composite Metrics

It may be considered that a composite metric or metrics, composed of the quantities or ratios of established metrics detailed here could be a useful approach in order to generate a simple absolute value or ratio that is indicative of sustainability performance.

However, this potential approach has a number of weaknesses:

- Information is 'lost' or obscured when combining the outputs of metrics which themselves may be dimensionless ratios or contain quantities that may themselves become dimensionless when combined.
- The actual absolute quantities composing any composite metric is hidden.
- Consequently, comparison between sustainability performance across time for a single facility or between sets of facilities is not transparent.

Moreover, the metrics selected already have the weakness of obscured information when viewed in isolation without consideration of the absolute quantities that they are composed. Hence, it is recommended that the metrics are used in combination with absolute quantities: the significance for single metrics, the inter-dependency between metrics and the impact of operational best practices is illustrated in the hypothetical example below.

9.9 Simplified Example: Metrics & Absolute Quantities

Take the example of a facility with a mean annual power for ICT and infrastructure elements of 500kW and 200kW respectively (a total load 700kW), yielding annual ICT energy use of 4380MWh and infrastructure energy use of 1752MWh and a PUE of 1.4. Considering a scenario where applications of energy efficiency best practices in operations for infrastructure result in reductions of power requirements of 10% and 20% compared to the original case. Figure 5, below, shows the impact on CUE of these measures in combination with REF of between zero and 1 for a grid emissions factor of 0.35KgCO_2e/kWh at an REF of zero.

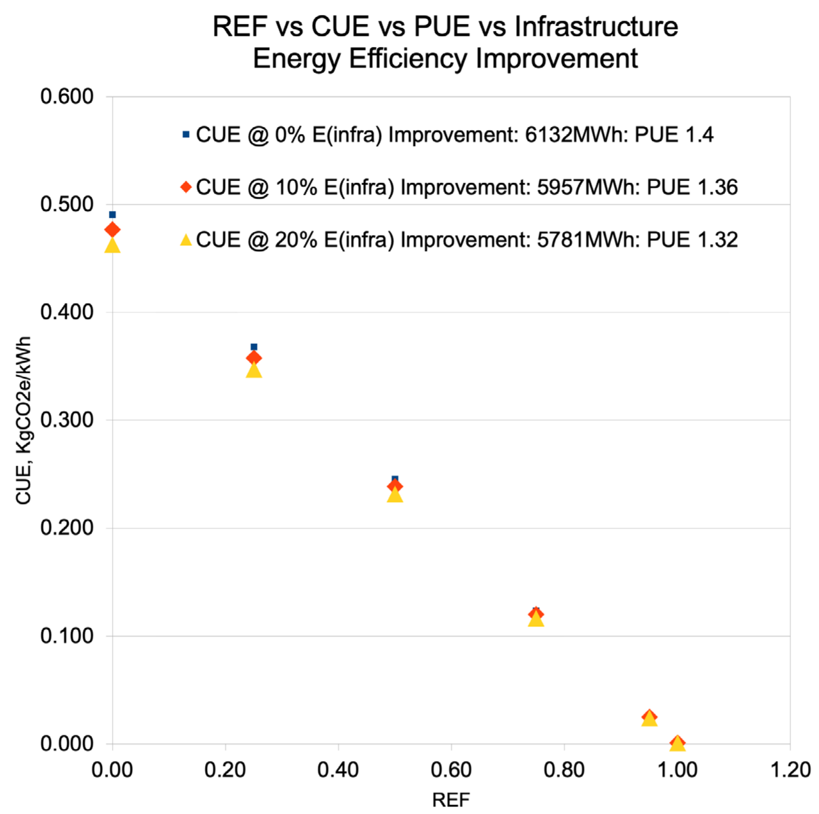

Figure 5: REF vs CUE vs PUE vs Progressive Infrastructure Energy Efficiency Improvement

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Figure 5, above, represents the impact of REF and energy efficiency improvement in infrastructure on CUE. The key and obvious point to note here it is possible to report very low CUE values[14] at high REF values, yet still run the facility sub-optimally with respect to energy efficiency: hence, the importance of considering and reporting internally absolute quantities in combination with the metrics. Moreover, the acquisition of low carbon power and sub-optimal energy efficiency both have significant cost implications.

Further, in this simplified hypothetical example backup power is provided by generators fueled by diesel. As noted the electrical power provided by the generators and associated carbon emissions are also part of the input quantities to the metrics PUE, CUE and WUE.

REF	EF_Grid, KgCO2e/kWh	KgCO2e/y, Grid	KgCO2e/y, Generators (outages)	Carbon Emissions, Gensets (outages) as % of Total	CUE, KgCO2e/kWh ICT
E_{ICT} = 4380MWh, E_{infra} = 1752MWh, PUE = 1.40: Baseline, Zero Measures Implemented					
0.00	0.350	2,144,054	4,780	0.22%	0.496
0.25	0.263	1,608,040	4,780	0.30%	0.375
0.50	0.175	1,072,027	4,780	0.44%	0.253
0.75	0.088	536,013	4,780	0.88%	0.132
0.95	0.018	107,203	4,780	4.27%	0.035
1.00	0.000	0	4,780	100.00%	0.011
E_{ICT} = 4380MWh, E_{infra} = 1577MWh, PUE = 1.36: ~10% Reduction in infrastructure power requirement and $E_{Infra/y}$					
0.00	0.350	2,082,795	4,780	0.23%	0.482
0.25	0.263	1,562,096	4,780	0.31%	0.364
0.50	0.175	1,041,398	4,780	0.46%	0.247
0.75	0.088	520,699	4,780	0.91%	0.129
0.95	0.018	104,140	4,780	4.39%	0.034
1.00	0.000	0	4,780	100.00%	0.011
E_{ICT} = 4380MWh, E_{infra} = 1402MWh, PUE = 1.32: ~20% Reduction in infrastructure power requirement and $E_{Infra/y}$					
0.00	0.350	2,021,536	4,780	0.24%	0.468
0.25	0.263	1,516,152	4,780	0.31%	0.354
0.50	0.175	1,010,768	4,780	0.47%	0.240
0.75	0.088	505,384	4,780	0.94%	0.125
0.95	0.018	101,077	4,780	4.52%	0.034
1.00	0.000	0	4,780	100.00%	0.011

Table 3: Table of Values: REF & Energy Efficiency Improvement vs CUE & PUE

Table 3, above, represents of the impact of REF and energy efficiency improvement in infrastructure on CUE, with CUE, PUE and associated annual energy use shown in Figure 3, above.

In the case of outages the generators supply the power that would have been provided by the primary grid power supply. Additionally, quantities from the generator maintenance testing regime are included. The carbon emissions per kWh of electricity delivered by diesel-fueled generators are significantly higher than most grid supplies, worldwide.

[14] Note that water use and therefore WUE may also be reduced by these measures impacting the cooling system. Typical values of WUE for existing data centers are ~2 to less than 1m3/MWh energy and may be significantly less for low water use cooling approaches.

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For example, as illustrated in Table X, above, consider an annual outages[15] rate of 0.1%[16], amounting to ~8.76h/y of generator activity required to cover the total load of 700kW for this period of time, typical generators may consume ~200-220l/h of diesel at this power output and depending on level of maintenance, hence the annual carbon emissions from annual outages may be estimated[17] as ~4800KgCO_2e, supplying ~6132kWh of energy.

In contrast, at the supplied grid emissions factor of 0.35KgCO_2e/kWh the annual emissions at 99.9% of the electrical energy delivered, the emissions are ~2144tCO_2e (~2,144,050KgCO_2e), from ~6126MWh.

In the cases where no highly significant outages occur and the REF for grid supplied power remain low, the contribution of the generators to the annual operational carbon emissions and CUE value remain low.

However, in the case where REF forms is higher than ~0.80 the contribution to carbon emissions due to the defined outages frequency becomes increasingly significant.

PUE, CUE and WUE and their respective absolute quantities (energy; carbon emissions; water volume) are therefore partially a function of the operational best practices that have been put into practice.

Often, a set of best practice measures will have an effect on all of these three metrics and their quantities: for example, raising the set points for temperature and humidity will reduce the amount of mechanical energy required for cooling infrastructure and also the amount of water required in the case where evaporative cooling is deployed, likewise grid-fed carbon emissions will be reduced.

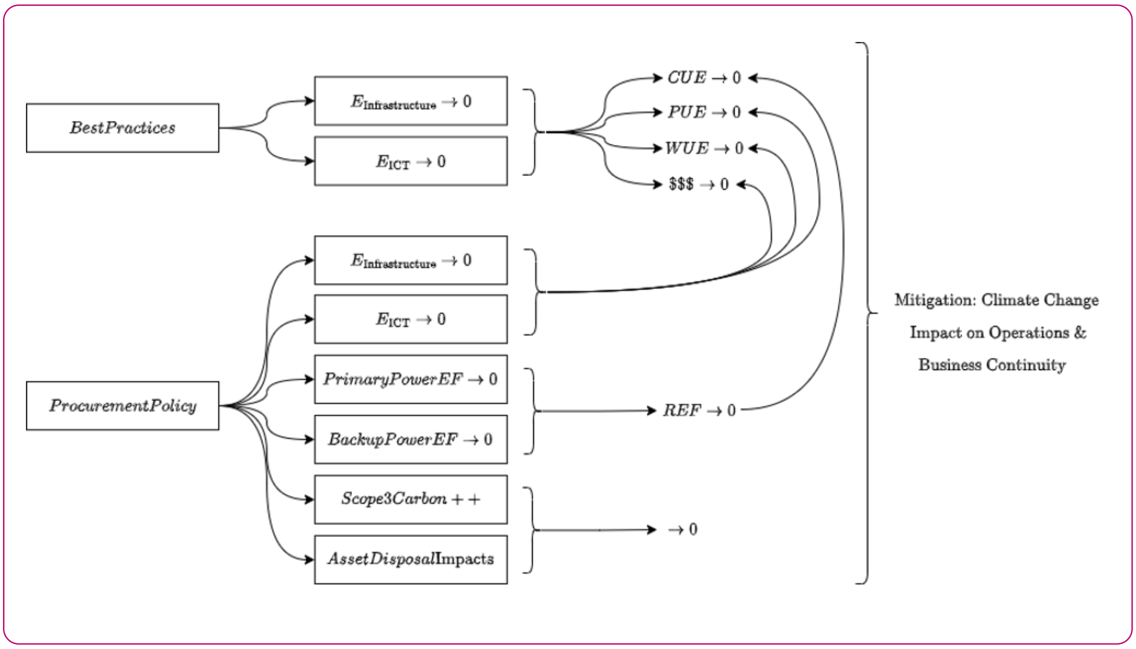

Figure 6: Inter-dependencies: Best Practices, Metrics, Procurement Policy, Climate Change Impact Mitigation

Figure 6, above, represents the principal relationships between the metrics detailed in this appendix. The Best Practices illustrate operational impact on energy efficiency for, especially, infrastructure as noted in the example above, but also potentially for ICT. Additionally, the longer term impacts of procurement policy for products and services, such as the acquisition of low carbon power providers, on REF, the operational energy efficiency of infrastructure and ICT equipment and in turn the further depression of CUE, PUE, WUE and operating costs for any given service profile. The applied procurement policy also impacts Scope 3 carbon emissions [Appendix 3] and end of deployment lifetime sustainability. Collectively, these actions mitigate against potential climate change impacts on operations and therefore business continuity [Appendix 4].

[15] Note that the generator maintenance testing regime may make a significant contribution to carbon emissions and CUE: in the example above, if these gensets (i.e. generators = engine + alternator) were run at the total load power output for 24h/y, this would result in ~13tCO2e/y of additional emissions. Maintenance testing regimes of currently produced gensets enable significantly lower testing times and power outputs. Additionally, the leakage of GWP gases such as refrigerants used in cooling systems such as chillers is also accounted for in evaluating CUE. [16] Depending on location, this may be considered excessively high or excessively low. [17] i.e. 202 l/h over 8.76h ~1770l, giving ~4800KgCO2e using ~2.7KgCO2e/l for diesel.

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9.10 Resources

Note that the most up to date version or amendment to a standard should be used. Generally, a search on the stem of the designation (e.g. 50600-4.2) of the standard will provide a list of versions and amendments on sites such as:

- ISO: https://www.iso.org/home.html
- EN: https://knowledge.bsigroup.com/

The EN standards may be acquired from the sources referenced below (GBP), alternative currencies are available from sites such as:

- https://www.en-standard.eu
- https://www.nbn.be/en

PUE: EN 50600-4-2 (ISO/IEC 30134-2):

ISO/IEC 30134-2:2016-2018:

- 2016: https://www.iso.org/standard/63451.html
- Amendment 2018: https://www.iso.org/standard/72702.html
- Under development: https://www.iso.org/standard/85172.html

EN 50600-4-2:2016+A1:2019 – TC:

https://knowledge.bsigroup.com/products/information-technology-data-centre-facilities-and-infrastructures-power-usage-effectiveness?version=tracked

CUE: EN 50600-4-8 (ISO/IEC 30134-8):

- ISO/IEC 30134-8:2022: https://www.iso.org/standard/77691.html
- EN 50600-4-8:2022: https://knowledge.bsigroup.com/products/information-technology-data-centre-facilities-and-infrastructures-carbon-usage-effectiveness?version=standard&sv1=affiliate&sv_campaign_id=720533&awc=3911_1736864979_5f0272291bd9c8725297cd51010a1749

WUE: EN 50600-4-9 (ISO/IEC 30134-9):

- ISO/IEC 30134-9:2022: https://www.iso.org/standard/77692.html

EN 50600-4-9:2022:

- EN 50600-4-9:2022: https://knowledge.bsigroup.com/products/information-technology-data-centre-facilities-and-infrastructures-water-usage-effectiveness?version=standard&sv1=affiliate&sv_campaign_id=720533&awc=3911_1736865057_33c7d7d2d96d3bd9dbe31b5ed39b0942

REF: EN 50600-4-3 (ISO/IEC 30134-3):

- ISO/IEC 30134-3-2016: https://www.iso.org/standard/66127.html
- ISO/IEC 30134-3-2016, Amendment 2018: https://www.iso.org/standard/72703.html
- EN 50600-4-3:2016+A1:2019: https://knowledge.bsigroup.com/products/information-technology-data-centre-facilities-and-infrastructures-renewable-energy-factor?version=tracked

Data Center Knowledge & Training Courses & Providers

- Course: Certified Data Centre Energy Professional (CDCEP)
- Provider: Uptime Institute/C-Net:
- URL: https://cnet-training.com/programs/certified-data-centre-energy-professional-cdcep/

Course: Energy & Sustainability Professional

- Provider: DCD Academy[18]
  URL: https://www.datacenterdynamics.com/en/dcd-academy/

Course: Data Centre/Server Room/CLS Energy Efficiency

- Provider: National Data Centre Academy[19]
  URL: https://www.nationaldatacentre.academy/course-catalogue/

Course: Certified Data Centre Environmental Sustainability Specialist (CDESS)

- Provider: EPI
- URL: https://www.epi-ap.com/services/1/3/154/_Certified_Data_Centre_Environmental_Sustainability_Specialist_(CDESS)

Course: Various

- Provider: IDCA
- URL: https://www.idc-a.org/data-center-training

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18. Note that DCD has collaborated with Professor Nicole Starosielski (UC Berkeley, Film & Media) to develop the course Certificate in Global Digital Infrastructure: https://bcnm.berkeley.edu/digital-infrastructures/. Nicole Starosielski is Principal Investigator of the project responsible for this report: the Sustainable Subsea Networks project (https://www.sustainablesubseanetworks.com/) by the SubOptic Foundation: https://www.suboptic.org/ 19. Note that the owners and company directors of Carbon3IT Limited are also owners and company directors of the National Data Centre Academy and operational directors of both companies.

10: APPENDIX 2: A NOTE ON MATERIALS IMPACT, SCOPE 3 CARBON EMISSIONS AND PROCUREMENT

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10: APPENDIX 2: A NOTE ON MATERIALS IMPACT, SCOPE 3 CARBON EMISSIONS AND PROCUREMENT

The supporting frameworks and standards containing the best practices and referencing the metrics used in this document also references materials use and Life Cycle Analysis (i.e. pertaining to the notion of the 'Circular Economy') but linked to standards (for example: the ISO 14000-series) rather than a specific metric: i.e. there is currently no standardized metric regarding materials use versus 'work performed' (e.g. ICT energy use; quantity of compute/time etc) that could be expressed in terms of, for example: embodied energy per unit of ICT energy[20] used over a defined time period ($MJ_{ICT\_equipment}/kWh_{ICT\_energy\_used}$ or $kWh_{ICT\_equipment}/kWh_{ICT\_energy\_used}$) or the equivalents for embodied (Scope 3, Category 2 if classed as a Capital Good): i.e. $KgCO_2e_{ICT\_equipment}/kWh_{ICT\_energy\_used}$).

In the absence of a standardized metric or metrics, a set of preferences for the acquisition of materials, products, services and capital goods that quantify and rank proposed items for acquisition may be applied within procurement processes.

10.1 Procurement Policy: A Foundation for Long Term Sustainability Performance

Although the metrics selected are indicative of operational performance of a facility: the foundations and potential scope of the operational 'sustainability performance' are laid in decisions concerning design and selection of services[21], equipment and infrastructure[22]. Hence, decisions on which equipment to acquire impact sustainability performance of the facility for many years after purchase and deployment. Therefore, it is recommended that sustainability criteria be incorporated in the tender process at both the PQQ and RFP levels.

The tender process should ideally state that environmental sustainability is part of the selection process and request Environmental Product Declarations (EPDs) at both the PQQ and RFP stages.

Note that for the life-cycle considerations below represent an outline of the kind of considerations to include in scoring for the procurement process: specific scoring schemes, in tandem with other specifications including price, are required for specific projects or organizations.

With respect to product life-cycle[23]:

1. Production (A1-A3)[24]: embodied carbon, energy, abiotic materials use and other environmental impacts are estimated at the point of completed production and dispatch from the manufacturer of the item, sometimes referred to as 'to-gate', i.e. the outbound gate of the manufacturer. The manufacturer or supplier is able to provide varying levels of detail, depending on the sector: generally, common materials used in construction are well characterized, whereas information for large complex infrastructure items are currently (2024/25) only sparsely available.

- Request, in order of preference:
  - Type III (i.e. externally independently verified) EPD in compliance with ISO 14025 (equipment, products, engineering infrastructure items); EN 15804-A2 or ISO 21930 for construction products which are also specifically non-powered items.
  - Internally generated Life Cycle Analysis (LCA), in compliance with ISO 14040.
  - Carbon Footprint estimation in compliance with ISO 14067.
  - An estimate of the embodied carbon in the materials used in product fabrication and an estimate of carbon emissions associated with energy use in fabrication.

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[21] As illustrated by low carbon power supply example within Appendix 1. [22] Similar considerations apply to materials used in construction of new building structures: EPDs are widely available for the components such as concrete and steel that comprise the bulk of the mass of materials used in conventional building structures. [23] These points focus on products and services, additionally due diligence on the procurement and suppliers policy of potential suppliers themselves is required and, in the case of ISO 20400 (sustainable procurement) this is also a useful additional filtering point. [24] The stages denoted here (A1...D) are standard designations in EPDs and LCAs. A1: Raw Materials Supply; A2: Transport; A3: Manufacturing; A4: Transport; A5: Installation. B1: Use; B2: Maintenance; B3: Repair; B4: Replacement; B5: Refurbishment; B6: Operational Energy Use; B7: Operational Water Use. C1: Deconstruction, Disassembly, Demolition; C2: Transport; C3: Processing, Reuse, Recovery, Recycling; C4: Waste Disposal. D: Beyond System Boundary Benefits and Impacts: i.e. estimates of the net benefits and loads resulting from the reuse of products, materials recycling, energy recovery and any other circularity input.

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2. Transport & Installation (A4-A5):

- Consider/estimate transport and installation impacts, for examples carbon emissions.

3. Operations: Use Phase (B1-B7): here for powered equipment and infrastructure the most significant points are likely to be: B2: maintenance; B4: replacement (implying the importance operational deployment period); B6 and B7: operational energy and water use, respectively. Hence, ranking considerations should favor high efficiency items which fulfill the required performance specifications and, in terms of the overall scoring or ranking allocated to different items, this should be performed in tandem with the output of #1 (A1-A3) and the post-deployment phases (#4, #5) in order to estimate the total lifetime impact.
4. End of Deployment Life Phase (C1-C4): the immediate fate of the components post-deployment and their impacts: footnotes, below[25].
5. Beyond System Boundary Benefits and Impacts: (D): estimation of benefits or loads post-phases C1-C4: footnotes, below.

10.2 Resources

Guides, LCA, EPD:

- LCA Guide (Ecochain): https://ecochain.com/blog/life-cycle-assessment-lca-guide/
- EPD Guide (Ecochain) https://ecochain.com/blog/environmental-product-declaration-epd-basics/

Standards:

- ISO 14025: 2006: https://www.iso.org/standard/38131.html
- ISO 21930: 2017: https://www.iso.org/standard/61694.html
- EN 15804:2012+A2:2019: https://knowledge.bsigroup.com/products/sustainability-of-construction-works-environmental-product-declarations-core-rules-for-the-product-category-of-construction-products-2?version=standard
- ISO 14040:2006: https://www.iso.org/standard/37456.html
- ISO 14040:2006:Amd 1:2020: https://www.iso.org/standard/76121.html
- ISO 14067:2018: https://www.iso.org/standard/71206.html

[25] Total lifetime impact: this is similar to Total Cost of Ownership (TCO) and in fact has the same component structures and may be considered for specific impacts, such as carbon emissions, or Whole Life Carbon (WLC) emissions used in the built environment.

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11: APPENDIX 3: GHG PROTOCOL & CARBON EMISSIONS: SCOPE 1, SCOPE 2 AND SCOPE 3

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The reporting structure of the Green House Gas (GHG) Protocol has been designed to classify and capture GHG emissions associated with a specific organization (a company or other entity) to enable standardized reporting of these emissions by that organization. Applying the same reporting structure to a specific asset or other defined part of the organization provides the same standardization of reporting for that asset. Emissions are classified into three groups:

Scope 1: Direct emissions from sources owned of controlled by the organization. Examples include: combustion of hydrocarbons, for generation of electrical power in stationary or mobile use-cases; leakage of refrigerant gases used in cooling systems.

Scope 2: Emissions associated with energy services generated outside of the reporting organization, i.e generated by third parties outside of the system boundary of the entity or asset owned by the entity. The energy services comprise: electrical energy; steam; heat; cooling.

Scope 3: Emissions comprise all other emissions, upstream and downstream of the reporting organization. There are eight categories of upstream emissions and seven categories of downstream emissions: for example, the purchase of ICT equipment or engineering infrastructure are classed as Scope 3 Category 2[26] emissions:

Upstream Emissions

Category 1: Purchased Goods and Services

Category 2: Capital Goods

Category 3: Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2

Category 4: Upstream Transportation and Distribution

Category 5: Waste Generated in Operations

Category 6: Business Travel

Category 7: Employee Commuting

Category 8: Upstream Leased Assets

Downstream Emissions

Category 9: Downstream Transportation and Distribution

Category 10: Processing of Sold Products

Category 11: Use of Sold Products

Category 12: End-of-Life Treatment of Sold Products

Category 13: Downstream Leased Assets

Category 14: Franchises

Category 15: Investments

[26] Generally the classification of an item as a Capital Good (Category 2)rather than a Product (Category 1) follows the classification of the item for financial reporting purposes.

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11.1 Resources

General: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

Scope 1 and 2 https://ghgprotocol.org/sites/default/files/Guidance_Handbook_2019_FINAL.pdf

Scope 2 https://ghgprotocol.org/scope-2-guidance

Scope 3 Guidance, calculation: https://ghgprotocol.org/scope-3-calculation-guidance-2

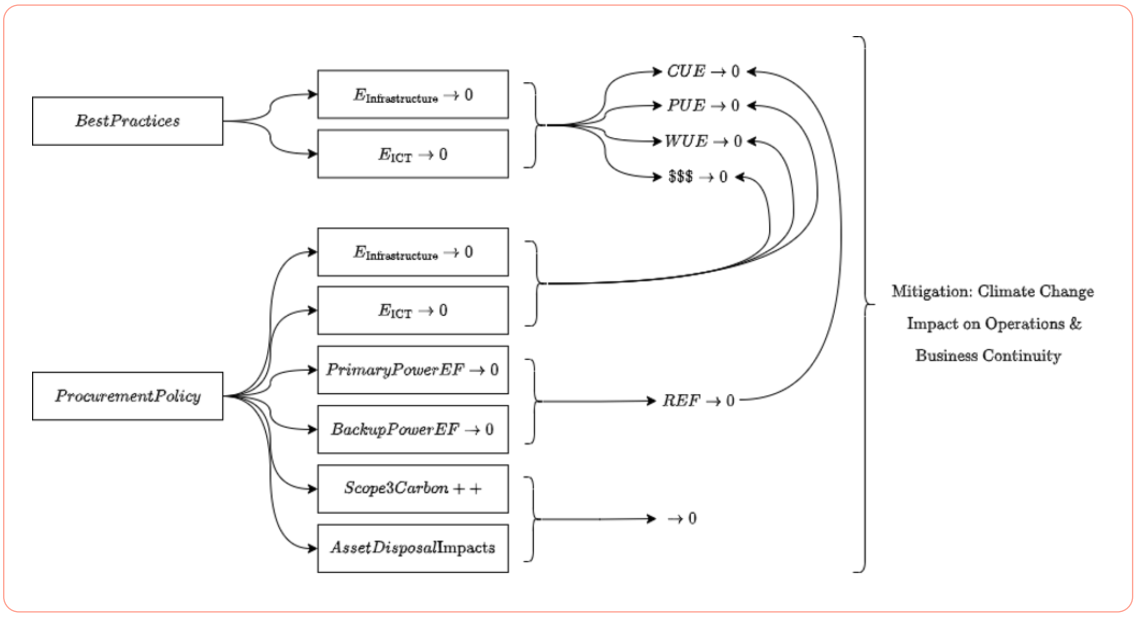

Figure 7: Copy, Figure 6: Inter-dependencies: Best Practices, Metrics, Procurement Policy, Climate Impact Mitigation

[27] Figure 7 is a copy of Figure 6, placed here for convenience. [28] Currently the framework of best practices is based on a subset of the EUCoC, in future this may be EN 50600-5-1. [28] Currently the framework of best practices is based on a subset of the EUCoC, in future this may be EN 50600-5-1.

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12: APPENDIX 4: CLIMATE CHANGE MITIGATION & ADAPTATION PLANNING

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12: APPENDIX 4: CLIMATE CHANGE MITIGATION & ADAPTATION PLANNING

As shown in Figure 4, copied below as Figure 6 for the convenience of reference, the aggregate influence on energy and material use, operational sustainability performance and asset disposal legacy arising from applying the best practices and modified procurement function result in enhanced business resilience and lower potential climate change impact.

Figure 7[27], above, is a representation of the principal relationships between the metrics detailed in this appendix. The Best Practices illustrate the operational impact on energy efficiency for, especially, infrastructure as noted in the example above, but also potentially for ICT. Additionally, the longer term impacts of procurement policy for products and services, such as the acquisition of low carbon power providers, on REF, the operational energy efficiency of infrastructure and ICT equipment and in turn the further depression of CUE, PUE, WUE and operating costs for any given service profile. The applied procurement policy also impacts Scope 3 carbon emissions [Appendix 3] and end of deployment lifetime sustainability. Collectively, these actions mitigate against potential climate change impacts on operations and therefore business continuity.

This figure includes some of the inter-dependencies between best practices, metrics and critical sustainability indicators which also illustrate how they may collectively mitigate against the impact of climate change risk on operations and, therefore, business continuity.

The EU has developed a framework and regulation for classifying and reducing potential impacts of climate change on critical sectors of the economy, with each sector being assigned appropriate frameworks: the Taxonomy Climate Delegated Act (TCDA).

Within the TCDA as it applies to the data center sector a set of reporting actions is required to detail the measures planned to be taken in order to reduce the potential impact of climate change on this sector.

Currently[28] (Q4 2024/Q1 2025) the reference document for the data center sector comprises a subset of the 2023 EUCoC best practices combined with these climate change risk mitigation measures.

Although clearly it is only data center companies operating within EU states are required to comply with the TCDA, consideration of these requirements may be universally useful for companies wishing to predict operational and business risk due to climate change and to develop appropriate action plans which mitigate negative impacts.

12.1 Resources: TCDA

Assessment Framework for Data Centers in the Context of Activity 8.1 in the Taxonomy Climate Delegated Act:

https://e3p.jrc.ec.europa.eu/publications/assessment-framework-data-centres-context-activity-81-taxonomy-climate-delegated-act

This document contains two annexes:

- Annex A: Taxonomy Criteria for Data Centers
- Annex B: Relevant Definitions[29] Related to the European Code of Conduct for Energy Efficiency in Data Centers

The relevant annexes to the TCDA related to climate mitigation risk are referenced with links to the source annexes of the regulation are shown below, in tandem with a brief description of their purpose. It is recommended that the document referenced immediately above is accessed for a full description, perhaps in tandem with the appropriate TCDA pages if desired.

[29] Note that this document also references the technical report from CEN/CENELEC CLC TR 50600-99-1 as matching criteria alternative to the selected EUCoC best practices in this document. Note that CLC TR 50600-99-1 is one of the two technical reports that were used to generate EN 50600-5-1:2023.

Annex A

Within the TCDA-Annex I covers filtering of economic activities which may contribute to climate change mitigation and includes data transmission and associated switching and other processes, in addition to core data center areas of data storage and compute, and therefore CLS activity even in isolation from the data center fulfills the criteria for substantial contribution. The 'do no significant harm criteria' comprise the following areas, with references to the TCDA Appendices:

- Climate Adaptation: TCDA Appendix A: https://ec.europa.eu/sustainable-finance-taxonomy/assets/documents/CCM%20Appendix%20A.pdf
- Water Use: TCDA Appendix B: https://ec.europa.eu/sustainable-finance-taxonomy/assets/documents/CCM%20Appendix%20B.pdf
- Circular Economy: References to compliance with Directive 2009/125/EC (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0125) for servers and data storage equipment; restricted substances in compliance with Annex II to Directive 2011/65/EU (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011L0065); requirement for a waste management plan to be implemented; reuse, recycle, recovery requirements as detailed in Annex VII to Directive 2012/19/EU (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32012L0019).

Annex II within the TCDA focuses on climate change adaptation and, as with TCDA-Annex I, CLS activities in isolation to any data center components of the operation also fulfill the criteria to be subject to the TCDA. The same areas highlighted above (Climate Adaptation; Water Use; Circular Economy) are used as reference criteria for the assessment of the sensitivity, vulnerability and criticality of the operations to potential climate change impacts and the risk of those impacts. After assessing the scope and risk for impact, the final requirement is the generation of climate adaptation and mitigation plans as detailed in the source document at the head of this section: Assessment Framework for Data Centers in the Context of Activity 8.1 in the Taxonomy Climate Delegated Act.

Annex B

The EUCoC selected best practices (...or CLC TR 50600-1-99) used in the document 'Assessment Framework for Data Centers in the Context of Activity 8.1 in the Taxonomy Climate Delegated Act' are fully covered by the key reference documents: the EUCoC and EN 50600-5-1.

Further, Annex B lists the standards referenced within the EUCoC (...which are also present, or their homologues, in EN 50600-50-1) for asset management for infrastructure (M&E+P) and ICT equipment: maintaining accurate asset records is a requirement for optimizing energy management of these assets. Examples referenced within the EUCoC: Asset Management (ISO 55001); Energy Management Systems (EN ISO 50001); Environmental Management (EN ISO 14001); Life Cycle Assessment (EN ISO 14040, EN ISO 14044: referenced previously. Finally, the full set of EN 50600-4-X (or: ISO/IEC 30134-X) metrics are referenced in addition to PUE, CUE, WUE and REF detailed in Appendix 1.

12.2 Further Resources: TCDA, EED, CSRD

Further additional resources for the TCDA are shown immediately below, in addition to overview pages to the EED and CSRD with links to the directives themselves.

TCDA (Taxonomy Climate Delegated Act)

- Taxonomy Navigator: a guide for taxonomy users: https://ec.europa.eu/sustainable-finance-taxonomy/
- Taxonomy Compass: provides a list of activity areas and links to specific measures: https://ec.europa.eu/sustainable-finance-taxonomy/taxonomy-compass
- Taxonomy Compass: Data processing, hosting, data transmission and related activities: https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/357/view

CSRD (Corporate Sustainability Reporting Directive)

- Overview: https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en
- CSRD Directive: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

EED (Energy Efficiency Directive)

- Overview: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en
- The Energy Efficiency Directive: https://eur-lex.europa.eu/eli/reg_del/2024/1364/oj

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13: APPENDIX 5: BEST PRACTICES, EXAMPLE FORMAT

13: APPENDIX 5: BEST PRACTICES, EXAMPLE FORMAT

The best practices related to metering and environmental control, below, illustrate the format of the best practices as presented in the reference documents: the EUCoC and EN 50600-5-1. The title of the best practices in addition to their references in each of the documents is shown in bold. The guidance for areas of applicability is shown at the foot of each item.

ICT equipment intake air temperature | EUCOC 5.3.1, EN 50600-5-1 8.1.1.8 |

Data Centres should be designed and operated at their highest efficiency to deliver intake air to the IT equipment within the ASHRAE Class A2 allowable range for Data Centres. Operations in this range enable energy savings by reducing or eliminating overcooling. Note: Some data centres may contain equipment with legacy environmental ranges as defined in 4.1.2, the maximum temperature for these facilities will be restricted by this equipment until segregation can be achieved as described in Practices 5.1.11, 5.34 and 5.3.5. Note: Additional Best Practices for airflow management as defined in section 5.1 may need to be implemented at the same time to ensure successful operations. Note: Some, particularly older, IT equipment may exhibit significant increases in fan power consumption as intake temperature is increased. Validate that your IT equipment will not consume more energy than is saved in the cooling system. A summary of ASHRAE environmental guidelines can be found at:

https:/www.ashrae.org/file%20library/technical%20resources/bookstore/supplemental%20files/referencecard_2021thermalguidelines.pdf

| Areas: Throughout entire data center |

Automated daily readings | EUCOC 9.2.2, EN 50600-5-1 8.1.1.11 |

Automated daily readings enable more effective management of energy use. Note: Supersedes Periodic manual readings.

| Areas: Retrofit, New Build |

Monitoring and management of air quality | EUCOC 3.2.12, EN 50600-5-1 8.1.1.11 |

Ensure that air quality is monitored and managed to ensure that critical equipment is not damaged by particulates or corrosive elements which might impact both IT equipment and cooling equipment in terms of performance, energy efficiency and reliability. This should inform the choice of filters used and the planned replacement schedule as well as the frequency of routine technical cleaning program (including underfloor and ceiling void areas if applicable). Filter choices should be informed by ISO 16890-1.

The AHSRAE white paper '2011 Gaseous and Particulate Contamination Guidelines for Data Centers' recommends that data center air quality is monitored and cleaned according to ISO 14644-8 Class 8. This can be achieved by routine technical cleaning and simple filtration. Note: Airborne Contaminants including gaseous contaminants should be managed according to ANSI/ISA 71.04-2013.

| Areas: Throughout entire data center |

Aisle (row/cabinet) level metering of temperature | EUCOC 9.1.7, EN 50600-5-1 8.1.1.11|

Improve visibility of air supply temperature in existing hot / cold aisle environments to assist in recognizing and dealing with air flow management issues and both over-cooling and under-cooling of IT equipment.

Note: This would be applicable in both contained and non-contained aisles.

| Areas: Recommended where applicable|

Dynamic control of cooling | EUCOC 5.2.6, EN 50600-5-1 8.2.2.3 |

Consider implementing control systems that take multiple factors including cooling load, data floor air temperature and external air temperature into account to optimize the cooling system, (e.g. chilled water loop temperature) in real time. Control should be according to an agreed strategy.

| Areas: Recommended advanced practice|

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14: APPENDIX 6: LIST OF SURVEY QUESTIONS

A copy of the survey as structured when disseminated is shown below, containing the following sections:

Section A. Profile

- A1. Organization Name
- A2. CLS Population Profile – Ownership Model

Section B: Attributes of Selected Single Cable Landing Station (CLS)

- B1. CLS Details: Location, Organization, Owned/Leased/Managed etc.
- B2. CLS Building
- B3. Cables
- B4 Infrastructure
  - B4.1 & B4.2 Power Infrastructure
  - B4.3 Cooling
  - B4.4 Metering, Monitoring, Reporting & Control
  - B4.5 Facility Owner - Client Metering [Questions specific to client metering]
  - B4.6 ITE
- B5. Operations
  - B5.1 Power
  - B5.2 Carbon Emissions, Water Use
  - B5.3 Power: Backup Generators
  - B5.4 Environmental Conditions
- B6 Standards/Best Practices
  - B6.1 Overview
  - B6.2 Cooling: See Environmental Conditions.
  - B6.3 PUE
  - B6.4 Design
  - B6.5 Operations

Questions CLS Survey

Purpose

The purpose of the survey is to gather baseline information about the key attributes of CLSs owned by, or leased by, members of the group.

Clearly, there are multiple CLSs that individual companies in the group use and these may be classed as: owner-operated; leased (wholly, 100%); part-/shared-lease. Additionally, models exist such as where the data center connects with the CLS via backhaul and an OLO.

Therefore, given the multitude of ownership models and size/capacity (power; connectivity), we would like to ask you to select a CLS which you believe is representative both in terms of ownership model and size. If responding as a colo tenant of a CLS, you will most likely need to reach out to the CLS facility operator team to answer some of the below questions.

In order to gauge what is representative in terms of ownership/use model, it would also be useful to know the raw numbers of CLSs in each category, as shown in Attributes of the CLS, below.

A. Profile

A.1 Your Details

- Your Name.
- Position.
- Company/Organization.

A.2 Overall Usage Profile: End-Users

In the case that you are an end-user client, in terms of the total population of CLSs that your organization uses, what are the numbers in the following categories? [The objective of this question it to attempt to gauge the proportions of these categories across the sample group of companies.]

- Total number.
- Owner-operated (wholly owned and operated by your company).
- Part-owner-operated.
- Wholly leased.
- Part-leased.
- Any other ownership model/s (please state how many and the model), e.g. wholly owned, operated by a third party.

B. Attributes of Selected Single Cable Landing Station (CLS)

B1. CLS Details

- Name of the CLS/ DC/ PoP (SLTE location).
- Company/companies owning the CLS.
- Location of the CLS.
- State whether your company owns or is leasing the CLS detailed in this survey.

B2. CLS Building

- Is the CLS a purpose-built facility? (Y/N) What was the year of construction?
- Is the CLS a repurposed facility? (Y/N) What was the year of construction?
- What year was the CLS commissioned?
- Is the CLS housed within a data center?
- Have there been major retrofits since commissioning? If so, in which year/s and what was the detail of the retrofit? (short description, detailing the equipment substituted/upgraded in: A) power; B) Cooling; C) ITE (including optical transmission equipment).)
- What is the total area of the CLS facility building (m2)?
- Is the CLS a single or multi-level building?
- What is the total area of the CLS dedicated for PFE and ITE (m2)?

B3. Cable(s) Associated with Facility and Owner

- Cable(s) RFS date.
- What is the total design capacity, assuming that all fiber pairs are lit, of the cable(s), (Gbps to Tbps, as
- appropriate)?
- What is the total number of fiber pairs in the cable or cables?
- Of the total number of fiber pairs, how many are unlit?
- How many clients use each fiber pair, for the cable or each of the cables (in the case of multiple cables)?
- Capacity allocation: please state whether the capacity is allocated/sold at: A) full fiber pair; B) partial fiber pair; C) spectrum; D) wavelength circuit capacity; E) a combination of A) thought D), please state the combination and any additional allocation approach...
- Please add any additional detail concerning the CLS, its ownership and operations model, cables, capacity allocation or other points that may be useful in helping characterize the CLS.

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B4. Infrastructure

B4.1 Power Distribution Switchgear

- What is the configuration / fault tolerance of the primary electrical power distribution for the CLS facility? (e.g. 1N single switchboard? or 2N switchgear? or distributed redundant 3N2?
- What is the total rated load power capacity, kW of the CLS facility?

B4.2 Primary Battery Backup Power System

All of the types below, as appropriate:

AC Power: UPSs

- Power, kW?
- Battery type (e.g. LiON, NiZn) and capacity (kWh)?
- Configuration (e.g. N, 2N, N+1, 2(N+1))?

DC Power: 48V DC Backup

- Power, kW?
- Battery type (e.g. LiON, NiZn) and capacity (kWh)?
- Configuration (e.g. N, 2N, N+1, 2(N+1))?

B4.3 Cooling

- What type of cooling equipment / heat rejection is used? (e.g. DX Direct Expansion? Chillers? Cooling towers? Indirect evaporative Cooling units? other?)
- What is the total rated load capacity, kW?
- What is the configuration (e.g. N, 2N, N+1, 2(N+1))?

B4.4 Metering Practices

- Are power meters installed at the CLS facility?
- If power meters are installed - how many power meters are there, what type, and what are the primary locations?
- Are sub-meters installed across the facility enabling more granular sub-metering of individual Mechanical & Electrical Plant (e.g. Chillers, UPS/DC plant, CRAC units etc.)
- Are sub-meters installed across the facility enabling more granular sub-metering of individual large dedicated Customer cages or rooms)?
- Is there any Branch circuit power metering (BCPM) installed at the CLS site, enabling sub-metering of individual Customer circuits from colo/common shared-use power distribution boards?
- Are installed power meters accessible remotely over a Network (e.g. IP), or via a protocol converter gateway (e.g. Modbus TCP/IP)?
- Is data regularly collected from the power meters and recorded? If so, how is that data collected (e.g. manual readings, or automatic polling)?
- If data from power meters is collected electronically (e.g. over a network), is that data graphed anywhere, for trend analysis?
- How long is power meter data recorded for / retained (either physical paper records, or database systems)?
- Do you use recorded power and energy data to help guide measures to improve energy efficiency?

B4.5 CLS Facility Owner – Client Metering

- Please describe the method of individual client metering:
- There is no individual client metering.
- Current only, A?
- Power, kW, for both AC and DC?
- Energy consumption, kWh?
- How is any common CLS power and cooling energy use that is shared amongst different clients allocated between those clients?

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B4.6 ITE

- Annual collective energy consumption of data transmission equipment, kWh (by preference), or the collective rated operational power of this equipment, kW, if known.
  - ...and when was this equipment manufactured? (approximate years).
- Annual collective energy consumption of any IT-equipment present, e.g. servers, storage, kWh, (by preference), or the collective rated operational power of this equipment, kW, if known.
  - ...and when was this equipment manufactured? (approximate years).

Note: If annual values for energy consumption (kWh) are not available, please provide annualized values from a known and stated base period: example, 3 months, Q1 2023.

B5. Operations

B5.1 Power

- Is the power for the CLS derived from renewable energy sources?
- Do you know the emissions factor for the power supplied to the CLS? (e.g. 300g CO2e/kWh)

B5.2 Carbon Emissions, Water Use

- Are overall carbon emissions for the CLS evaluated and, if so, what is the annual value, $KgCO_2e$?
- Are Scope 1, 2, 3 carbon emissions evaluated and if so, what is the annual value for each, $KgCO_2e$?
- Is water use for the CLS evaluated, if so, what is the annual value, liters or m^3?
- If the CLS in question is part-owned, leased, part-leased, please give indicate whether portioned values for carbon emissions and water use are available and their magnitude.

B5.3 Power: Backup Generators

- What fuel is used for any backup generators, e.g. diesel or HVO?
- What is the annual consumption of liquid fuel, liters?
- If non-diesel/HVO generators backups are used, please describe the system used?
- Does the Facility have an approved environmental control, spill prevention and countermeasures plan? (e.g. are spill kits in close proximity to tanks, or other mechanisms for controlling spills; does the facility meet or exceed all local, state, and Federal environmental standards?)

B5.4 Environmental Conditions

- Does the CLS include separate environmental zones for sets of equipment requiring different temperature and humidity ranges for operation? For example: telecoms equipment versus servers in the case where the CLS is collocated with a data center; separation of 48VDC equipment (e.g. PFE (Power Feed Equipment) or OCI) from non 48VDC equipment.
- Is 48VDC equipment (e.g. PFE (Power Feed Equipment) or OCI) located in separate environmental zones from non 48VDC telecoms equipment?
  - (Yes/No/Not Applicable: if yes, please include the detail of these zones as requested below).
  - If so, please list these zones, noting equipment within them, temperature and humidity set-points/ranges and any equipment environmental standards (ASHRAE, ITU, ETSI or similar) which are applied: (e.g.: 48VDC; non-48VDC; servers/racks etc.)
  - If there are **not** any separate environmental zones, please detail the temperature and humidity set-points/ranges and any equipment environmental standards (ASHRAE, ITU, ETSI or similar) which are applied.
  - Does the CLS facility use airflow management best practices, separating wherever possible hot/cold airflow, use of blanking panels, hot/cold aisles?
  - If not in use, please briefly detail reasons why?

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B6. Standards/Best Practices

B6.1 General

- Which energy efficiency or sustainability Standards are applied at the CLS? (e.g. ISO 50001)
- Are any energy efficiency guidelines or best practices applied at the CLS? (e.g. EU Code of Conduct for Data Centers).
- If so, provide a brief summary of energy efficient best practices implemented?

B6.2 Cooling

- See: 'B5.4 Environmental Conditions', above.

B6.3 PUE

- Is PUE evaluated for the CLS and if so, is this in accordance with EN 50600-4-2/ISO/IEC 30134-2?
- If PUE is evaluated to these standards, which class of PUE measurement is taken? i.e. PUE1, at the UPS output; PUE2, at the PDU output; PUE3, at the ITE equipment input.
- If evaluated, what is the PUE value?
- If PUE is evaluated, in addition to the prescribed annualized value required for standard compliance, is it also recorded at shorter time intervals, e.g. monthly, daily, 'instantaneous' values?

B6.4 Design

- How was the design optimized to minimize the electrical losses for: A) overall system losses; B) AC (UPS); C) 48VDC and non-48VDC? [For example, electrical loss component as described in ASHRAE 90.4 or similar, estimations of loss components under anticipated operating power loads.
- Does the CLS facility utilize any Power factor correction equipment across the site
- Does the CLS facility utilize any efficient lighting control measures, such as automatically turning off lights in areas of the building that are unoccupied (manual timers, motion detectors etc.)

B6.5 Operations

- How frequently are any generators tested?
- Are Generators tested under partial/full load? Or under no load?
- How long are Generators run for when tested, and is a log kept of runtime hours?
- Does the CLS facility owner have to comply with Generator emissions reporting / run-time limits?
- Are the UPSs operated in 'eco' mode?
- Maintenance: what planned maintenance practices are in place that impact energy efficiency?
- Does the Facility have a fully implemented DCIM/BMS, and is that standardized across all sites?

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