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Development of the EU Green Public Procurement (GPP) Criteria for Data Centres, Server Rooms and Cloud Services

FINAL TECHNICAL REPORT

Nicholas Dodd, Felice Alfieri, Miguel Gama Caldas (JRC)

Larisa Maya-Drysdale, Jan Viegand (Viegand Maagøe), Sophia Flucker, Robert Tozer, Beth Whitehead (Operational Intelligence), Anson Wu (Hansheng) Fiona Brocklehurst (Ballarat Consulting)

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Joint Research Centre

EUR 30251 EN

Contact information
Name: Product Bureau
Address: Joint Research Centre, Edificio Expo c/ Inca Garcilaso 3, E-41092 Seville, Spain
Email: JRC-B5-PRODUCT-BUREAU@ec.europa.eu
Tel.: +34 95 4488 284

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Abstract
The development of the Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services is aimed at helping public authorities to ensure that data centres' equipment and services are procured in such a way that they deliver environmental improvements that contribute to European policy objectives for energy, climate change and resource efficiency, as well as reducing life cycle costs.

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List of Abbreviations

AC	Award Criteria
AHWG1	First Ad-Hoc Working Group Meeting which took place in November 2017
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEMP	Best Environmental Management Practice
CAPEX	Capital Expenditure
CoP	Coefficient of Performance
CPC	Contract performance clause
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handler
EN	European Norm
ERF	Energy Reuse Factor
ETSI	European Telecommunications Standards Institute
EURECA	EU Resource Efficiency Coordination Action
GHG	Greenhouse gas
GO	Guarantee of Origin
GWP	Global Warming Potential
HDD	Hard Disk Drive
HFCs	Hydrofluorocarbons
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communications Technology
ISO	International Organisation for Standardisation
IT	Information Technology
ITE	Information Technology Equipment
LCA	Life Cycle Assessment
M&E	Mechanical and Electrical
MSP	Managed Service Providers
NTE	Network Telecommunications Equipment
OPEX	Operative Expenditure
PPA	Power Purchase Agreement
PSU	Power Supply Unit
PUE	Power Utilisation Effectiveness
RAM	Random Access Memory
REF	Renewable Energy Factor
SC	Selection Criteria
SERT	Server Efficiency Rating Tool
SNIA	Storage Networking Industry Association
SSD	Solid State Drive
TS	Technical Specification
UPS	Uninterruptible Power System
WEEE	Waste Electrical and Electronic Equipment

List of reference standards

Reference	Title
EN 50600-1:2012	Information technology - Data centre facilities and infrastructures - Part 1: General concepts
EN 50600-2-2:2014	Information technology - Data centre facilities and infrastructures - Part 2-2: Power distribution
EN 50600-2-3:	Information technology - Data centre facilities and infrastructures - Part 2-3: Environmental control
EN 50600-4-2:	Information technology - Data centre facilities and infrastructures - Part 4-2: Power Usage Effectiveness
EN 50600-4-3	Information technology - Data centre facilities and infrastructures - Part 4-3: Renewable Energy Factor
EN 50600-4-6	Information technology - Data centre facilities and infrastructures - Part 4-6: Energy Reuse Factor
EN50600 99-1	Information technology. Data centre facilities and infrastructures. Recommended practices for energy management
EN50600 99-2	Information technology. Data centre facilities and infrastructures. Recommended practices for environmental sustainability
ETSI/ES 205 200-1	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Global KPIs; Operational infrastructures; Part 1: General requirements
ETSI EN 300 019-1-3	Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weatherprotected locations
ETSI EN 303 470	Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for servers
ETSI EN 305 174-8	Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Management of end of life of ICT equipment (ICT waste/end of life)
ETSI EN 300 019-2-3	Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 2-3: Specification of environmental tests; Stationary use at weatherprotected locations
IEC 62474	Material Declaration for Products of and for the Electrotechnical Industry
IEC 62476	Guidance for evaluation of product with respect to substance-use restrictions in electrical and electronic products
ISO 21836	Information Technology -- Data Centres -- Server Energy Effectiveness Metric (under development)
ISO/IEC 30134-5	Information technology -- Data centres -- Key performance indicators -- Part 5: IT Equipment Utilization for servers (ITEUsv)
ISO/IEC 30134-2	Information technology -- Data centres -- Key performance indicators -- Part 2: Power usage effectiveness (PUE)
ISOIEC 30134-6	Information technology -- Data centres -- Key performance indicators -- Part 6: Energy Reuse Factor (ERF)

Definitions

	Definition	Source
Enterprise Data Centre	A data centre which has the sole purpose of the delivery and management of services to its employees and customers and that is operated by an enterprise.	EN 50600-1:2012
CRAC/CRAH	Equipment that provides cooling airflow volumes into a computer room as a means of environmental control	CLC/TR 50600-99-1-2018
Co-location Data Centre	A data centre facility in which multiple customers locate their own network(s), servers and storage equipment	EN 50600-1:2012,
Managed Service	Data centre operated to provide a defined set of services to its clients either proactively or as the managed service provider (not the client) determines that services are needed	CLC/TR 50600-99-1-2018
Virtualisation	Creation of a virtual version of physical ICT equipment or resources to offer a more efficient use of ICT hardware	CLC/TR 50600-99-1-2018 CLC/TR 50600-99-2-2018
Network Telecommunications Equipment (NTE)	Equipment dedicated to providing a direct connection to core and/or access networks	ETSI/ES 205 200-1 V1.2.1 (2014-03)
Information Technology Equipment (ITE)	Equipment providing data storage, processing and transport services for subsequent distribution by network telecommunications equipment	ETSI/ES 205 200-1 V1.2.1 (2014-03)
White space	In data centres this refers to the area where ICT equipment is placed. Meanwhile, grey space in the data centres is the area where the back-end infrastructure is located.	

INTRODUCTION

This document is intended to provide the background information for the development of the EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services. The study has been carried out by the Joint Research (JRC) with technical support from a consulting consortium. The work is being developed for the European Commission's Directorate-General for Environment.

EU GPP criteria aim at facilitating public authorities' purchase of products, services and works with reduced environmental impacts. The use of the criteria is voluntary. The criteria are formulated in such a way that they can be, if deemed appropriate by the individual authority, integrated into its tender documents. This document provides the EU GPP criteria developed for the product group 'Data Centres and Server Rooms'.

There are four main types of GPP criteria:

a. **Selection Criteria (SC)** assess the suitability of an economic operator to carry out the activities/ services of a contract and may relate to:
   - (i) suitability to pursue the professional activity;
   - (ii) economic and financial standing;
   - (iii) technical and professional ability.
b. **Technical Specifications (TS)**, the required characteristics of a product or a service including requirements relevant to the product at any stage of the life cycle of the supply or service and conformity assessment procedures.
c. **Award Criteria (AC)**, qualitative criteria with a weighted scoring which are chosen to determine the most economically advantageous tender. The criteria are linked to the subject matter of the public contract in question and may comprise, for instance:
   - environmental performance characteristics, including technical merit, functional and other innovative characteristics;
   - organisation, qualification and experience of staff assigned to performing the activities required by the contract, where the quality of the staff assigned can have a significant impact on the level of performance of the contract; or
   - after-sales service and technical assistance, delivery conditions such as delivery date, delivery process and delivery period or period of completion.

   Award criteria shall be considered to be linked to the subject matter of the public contract. This may relate to the works, supplies or services to be provided under that contract at any stage of their life cycle, including factors involved in:
   - (a) the specific process of production, provision or trading of those works, supplies or services; or
   - (b) a specific process for another stage of their life cycleeven where such factors do not form part of their material substance.
d. **Contract Performance Clauses (CPC)**, special conditions laid down that relate to the performance under a contract and how it shall be carried out and monitored, provided that they are linked to the subject matter of the contract.

For each set of criteria there is a choice between two ambition levels:

- The core criteria are designed to allow for easy application of GPP, focusing on the key area(s) of environmental performance of a product and aimed at keeping administrative costs for companies to a minimum.
- The comprehensive criteria take into account more aspects or higher levels of environmental performance, for use by authorities that want to go further in supporting environmental and innovation goals.

I. The criteria development process and evidence base

The main purpose of this document is to present the final draft of the developed criteria, taking into account the background technical analysis presented in the preliminary report and addressing key environmental impacts of the product group. This document is complemented and supported by a preliminary report addressing the following[1]:

- Review of relevant initiatives and definition of scope (Task 1)
- Technical state of play and market analysis (Task 2)
- Environmental analysis (Task 3)

A general questionnaire about the scope was sent out to a wide range of stakeholders. The target groups were government, industry, NGOs, academics and public procurers. The input provided was incorporated into the preliminary report, and, together with the proposed criteria presented in the first draft of the report, was the basis for continuing the consultation with the stakeholders.

Stakeholders contributed to the shaping of the final criteria during the two following Ad-Hoc Working Group meetings organised (the first one in Seville, in November 2017 and the second as a webinar in May 2018) and through the submission of written comments on three draft versions of the Technical Report. The main changes made by the JRC in response to these inputs during the development of the criteria are summarised below:

- Scope and definitions: expansion of the title and definition of the product group as 'data centres and server rooms'. Server rooms are common in the public sector and in most cases have a poor performance in terms of energy efficiency. The inclusion of server rooms in the title of this product group aims to promote the improvement opportunities related to this subgroup.
- Server energy efficiency: alignment of the proposed criteria with the new regulation (Regulation (EC) 2019/424) for servers and data storage in particular related to the following aspects included in the criteria:
    - active efficiency of servers;
    - idle power of servers;
    - Operating Range Classes of servers and data storage;
    - provision of instructions to enable a non-destructive repair or replacement.

  The prioritisation of criteria on 'active efficiency' versus 'idle power' criteria was discussed, and it was agreed that improvements in idle power should be subservient to active efficiency. Deployment power is also encouraged as it best reflects the performance of a data centre's fleet of servers and their configurations.
- Optimisation of performance: Inclusion of two selection criteria based on the competencies of bidders on relevant aspects of the data centre's management: the utilisation level of the servers and the cooling energy management. These selection criteria try to reflect the different perspectives on optimisation – professional experience versus smart monitoring
- Reference to the European Code of Conduct: Inclusion of two Technical Specifications based on the Code of Conduct for Data Centres and CLC/TR 50600-99/1 'Recommended practices for energy management' which is considered to be the main reference for the implementation of energy efficiency best practices in data centres.
- Power Utilisation Effectiveness (PUE): Specific PUE targets have been removed from criteria due to the limitation of the PUE metric as recognised during the consultation with the stakeholders. The applicability is now limited to the cases where IT loads and environmental conditions are defined in the tender documentation and within Award Criteria.

[1] The previous Task 1-4 reports and further information can be downloaded at http://susproc.jrc.ec.europa.eu/computers/stakeholders.html

- High-GWP refrigerants: A more specific criterion on the GWP of refrigerants used in cooling plants replaces the initial proposal of a criterion based on the GHG inventory of the data centre. Overall, a criterion on the GHG inventory was not considered to be suitable as this type of data collection and reporting is not yet commonplace in the market and there would be issues related to the consistency of calculation for comparative purposes.
- Durability of servers: The initial proposal aiming to increase durability was rejected as it was considered by many stakeholders that the use of old legacy equipment is one of the reasons for the low efficiency of data centres in the public sector. The final proposal instead encourages the replacement of servers managed by data centre – referred also as the refresh, or which will be managed on their behalf, according to the optimal server lifetime from a life cycle point of view. However it was also decided in the end not to introduce a specific refresh rate metric because the proposed metrics are not considered to be sufficiently mature yet.
- Hazardous substances: The initial proposal on product performance was considered to be too detailed for the data centres' scope and was changed to focus more generally on product manufacturers' substance control systems and to prioritise Substances of Very High Concern. End-of-life hazardous emissions are now addressed by the control of end-of-life routes for WEEE arisings.
- Water use: Although this was initially proposed it was rejected early on in the process as there was limited evidence of potential for improvement.
- Renewable Energy Factor (REF): The initial proposal was retained in a general form, but load matching was introduced as an objective and, following checks, found to be more readily verifiable than earlier proposals, allowing greater additionality within the legal framework of EU procurement.

The consultation process was done primarily with further input from industry, Member States, NGOs, academics and collaborative projects such as EURECA[2].

A Commission Staff Working Document is available at https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm to describe in a more concise way the main output of this study and the criteria developed.

A Procurement Practice Guidance Document is also planned to be provided to complement the final Technical Report and the Commission Staff Working Document. The aim is to provide procurers and project teams with simplified guidance on how to procure an environmentally improved data centre, with a focus on the potential for consolidation of existing distributed server rooms into new data centres.

II. Structure of this report

Based on the findings from the preliminary report, the report is divided into six sections:

- The definition of the proposed scope.
- The identified procurement routes followed when public organisations purchase data centre products and/or services.
- The estimated market volumes in the EU within the proposed scope.
- The key environmental impacts of data centres, and the potential improvement areas which led to the areas of focus and draft proposed criteria.
- The key life cycle costs associated with investment in data centres.
- The draft proposed criteria divided by area of focus.

[2] EURECA is an EU funded project with the aim of assisting the public sector with the update of innovative energy efficient and environmentally sound data centre products and services - see https://www.dceureca.eu/

The areas of focus identified refer to the level at which the procurers can apply the criteria and engage the tenderers to reduce their life cycle environmental impacts, focusing on those presenting the most improvement opportunities from cost and market perspectives and which can be verified.

For each area of focus, one or more criteria are proposed, accompanied by a discussion summarising the rationale for supporting the proposal(s):

- Background for the proposed criteria in terms of environmental impacts and existing criteria and/or metrics.
- Life cycle environmental hotspots and potential improvements.
- Life cycle cost implications and trade-offs with potential environmental improvements.
- Possibilities for verification.
- Market implications and functionality.
- Applicability to public procurement.

SCOPE AND DEFINITION

I. Definition of a data centre

As explained in the preliminary report, a large variety of data centre definitions and categorisations exist based on size, ownership of equipment and infrastructure and IT load. According to results from EURECA[3], 80% of the data centres found in 360 public institutions in Ireland, the UK and the Netherlands are actually small enough to be classified as server rooms and server closets (with up to 25 racks)[4]. This indicates that this product group should encompass smaller spaces which is why the scope for this product group was extended to include server rooms as a separate product type.

Definitions of data centres and server rooms are proposed in Table 1, which combine the definitions from the EU Code of Conduct[5] and NACE[6] on data centres and those from ASHRAE[7], BEMP[4] and US DOE[8] on server rooms, which form this product group. Although overprovisioning is an important issue, as highlighted by some stakeholders, a link to the Uptime Institute's Tier Classification system[9] has not been included in the definition. According to stakeholders, the different tiers do not represent actual reliability but different levels of maintenance opportunities without interrupting service availability. Furthermore, focus was placed on using non-commercial references to develop the data centre definition and categories.

Data centres are typically formed of three groups of systems: ICT equipment, electrical and mechanical equipment, and a building infrastructure (see Figure 1). A server room may share power and cooling capabilities with the rest of the building.

[3] Presentation at Data Centre World, Frankfurt 29th November 2017: "Making the business case for Energy Efficiency in Data Centres – Lessons learned evaluating near 300 public sector data centres in Europe". Dr Rabih Bashroush. See https://www.dceureca.eu/?page_id=3007

[4] Based on classifications found in BEMP document for telecommunications and ICT (2016) – see http://susproc.jrc.ec.europa.eu/activities/emas/documents/TelecomICT_BEMP_BackgroundReport.pdf, and the US Data centre Energy Usage Report by Ernest Orlando Lawrence Berkeley National Laboratory (2016) – see https://eta.lbl.gov/sites/all/files/publications/lbnl-1005775_v2.pdf.

[5] https://ec.europa.eu/jrc/en/energy-efficiency/code-conduct/datacentres

[6] Nomenclature Générale des Activités Économiques dans les Communautés Européennes.

[7] BSR/ASHRAE Standard 90.4P. 3rd ISC Public Review Draft Energy Standard for Data centres. Third ISC Public Review (January 2016).

[8] US Data centre Energy Usage Report by Ernest Orlando Lawrence Berkeley National Laboratory (2016).

[9] Tier Classification System by Uptime Institute https://journal.uptimeinstitute.com/explaining-uptime-institutes-tier-classification-system/

Table 1: Proposed definition for the product group (data centres and server rooms)

Definition of data centres and server rooms
Data centres means structures, or group of structures, dedicated to the centralised accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control, together with the necessary levels of resilience and security required to provide the desired service availability.
Server rooms, also referred to as computer rooms or server closets, are rooms or parts of a building serving a specific IT load, determined by the power density of the equipment in the room. Server rooms have usually IT control and may have some dedicated power and cooling capabilities. Server rooms are enterprise data centres but on a smaller scale, usually housed in an area of less than $46 m^2$ and consisting of approximately 25 racks[10].
Data centres providing digital services in the cloud refers to where the customer pays for a service and the vendor provides and manages the ICT hardware/software and data centre equipment required to deliver the service. This includes the co-hosting of multiple customers, which may take the form of a cloud application environment. Different business models are associated with cloud services but it is important to note that the scope only extends to the data centre component. The most common cloud services identified are as follows: • Infrastructure as a service (IaaS): a service provider offers clients pay-as-you-go access to storage, networking, servers and other computing resources in the cloud. • Platform as a service (PaaS): a service provider offers access to a cloud-based environment in which users can build and deliver applications. The provider supplies underlying infrastructure. • Software as a service (SaaS): a service provider delivers software and applications through the internet. Users subscribe to the software and access it via the web or vendor Application Programme Interfaces.

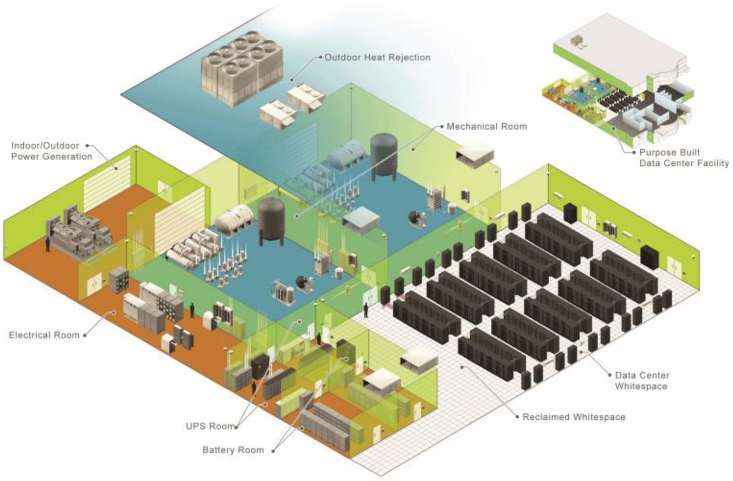


Figure 1: Typical data centre layout[11]

[10] Floor size defined in BEMP document for telecommunications and ICT (2016), available at http://susproc.jrc.ec.europa.eu/activities/emas/documents/TelecomICT_BEMP_BackgroundReport.pdf

[11] Reproduced with permission of Schneider Electric.

II. Product group classification

Data centres can be classified as different types, and these are proposed to be included within the scope of the criteria (see Table 2).

Table 2: Data centre classification and definitions

Product group type	Definition
Enterprise data centre	A data centre which has the sole purpose of the delivery and management of services to its employees and customers and that is operated by an enterprise[12].
Co-location data centre	A data centre facility in which multiple customers locate their own network(s), servers and storage equipment[13].
Managed Service Providers (MSP) data centre	A data centre offering server and data storage services where the customer pays for a service and the vendor provides and manages the required ICT hardware/software and data centre equipment. This management service includes the co-hosting of multiple customers, which may take the form of a cloud application environment.

III. Proposed scope of the criteria

The proposed scope encompasses the main functional components of a data centre, including the mechanical and electrical (M&E) equipment and the ICT equipment, the two being important sources of impacts on the life cycle environmental hotspots of the data centre. The proposed scope applies to server rooms too, but in some cases the applicability of the criteria may only fall within data centres' boundaries and not within server rooms'. Server rooms may share cooling infrastructure with the rest of a building and in some cases, depending on the size, may have their own additional cooling capacity. The proposed scope encompasses the three systems to cover the whole product group (see Table 3).

For the purposes of these GPP criteria, it is proposed to exclude the building infrastructure because evidence shows that it is of little relevance to the overall environmental impacts of a data centre. Only 1 out of the 10 studies reviewed in the preliminary report[14] indicates that the facility contributes to 33% of the life cycle environmental impacts. However, this stems from both the M&E systems and the building's construction and operation. No breakdown is shown on the separate contribution of each of these subsystems. However, the other LCA studies reviewed show evidence that the building's contribution is minor. Therefore, the evidence from this one study is insufficient to provide evidence with a different conclusion, and thus building has been excluded.

As well as its components, the scope also covers the product group performance characteristics at system level. Finally, the applicability of the criteria can be determined for the physical system and/or components, and for data centre services which are supplied by the physical system and/or components. The applicability of each criterion is specified in the following section.

[12] From EN 50174-2:2009/A1:2011, 3.1.8.

[13] From EN 50600.

[14] Environmental performance of data centres - A case study of the Swedish National Insurance Administration (2012). Caspar Honée, Daniel Hedin, Jasmin St-Laurent & Morgan Fröling. Published in: 2012 Electronics Goes Green 2012+. Available at: https://ieeexplore.ieee.org/document/6360435

Table 3: Proposed scope of the data centre GPP criteria

Proposed data centre and server room criteria scope
For the purposes of this GPP criteria set, the scope shall encompass performance aspects of: • the ICT equipment and associated network connections that carry out the primary function of the data centre, including the servers, storage and network equipment; • the mechanical and electrical equipment used to regulate and condition the power supply (transformers, UPS) and the mechanical systems to be used to regulate the environmental conditions (CRAC/CRAH) in the white space[15]; • data centre systems as a whole or a managed data centre service. The building itself (i.e. physical structure of the building and its respective building materials) is not included in the proposed scope.

IV. Summary of stakeholders' comments following AHWG1

During the first Ad Hoc Working Group Meeting (AHWG1), most of the stakeholders already noted that the scope needed further improvement to reflect the smaller scale of systems installed in public authorities' buildings.

When following up with stakeholders, EURECA[3] shared more detailed data on the data centres used by public authorities in Ireland, the Netherlands and the UK showing that the majority of data centres in the public sector in these countries (80%) are up to 25 racks. Considering an average of 2 m^2 per rack and 215 W/m^2, the 25-rack threshold is more or less comparable with the server room definition. This data is used as an indicator of the presence of server rooms in the EU, but it does not correspond to white space inventory or number of servers in server rooms. This inventory data does not exist at this level of detail for the whole EU. At the same time, this source states that these data centres run an aging IT infrastructure, with 40% of servers being older than 5 years old, and accounting for 66% of the energy consumption while only producing 7% of the computing capacity.

EURECA provided a breakdown of the annual energy consumption from 2016, showing a large potential for improvement by replacing old servers with new ones and secondly by virtualisation of on-premises data centres (which could be achieved through consolidation of distributed IT and small server rooms in a more efficient data centre).

The inclusion of server rooms in the scope of this product group aims to highlight these improvement opportunities. Several GPP criteria developed and presented in this technical report are then applicable to consolidation processes of small server rooms.

V. Summary of stakeholders' comments following AHWG2

Several stakeholders asked for better definition and distinction of server rooms and data centres. The JRC proposed to classify server rooms and data centres based on the size and number of racks, omitting the reference to the IT loads (kW). In addition, some stakeholders considered that clearer recommendations should be provided on which criteria are relevant for use for servers and data centres, as well as for different procurement routes.

There were various views on the need to group or prioritise the list of criteria according to the different procurement routes and environmental significance; moreover, it was suggested to introduce a third category in the form of outsourced cloud.

[15] White space in data centres refers to the area where IT equipment are placed. Meanwhile, grey space in the data centres is the area where the back-end infrastructure is located.

Summary rationale for the final proposal

- Data centre and server room definitions are now based on size and an indicative number of racks. As a result, any reference to kW load has been removed because it is difficult to calibrate this against the higher power densities achievable with new server equipment.
- A description of different types of cloud services is now also included, in particular Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS). This is considered to reflect the most common cloud services on the market. These service types have been added to the procurement routes described in Figure 2, Figure 3, Figure 4 and Figure 5 .
- A new section on the application of the criteria to different procurement routes has been added. In an attempt to make the applicability clearer, the previous tabular format has been replaced by a series of diagrams which illustrate packages of recommended criteria for different situations and procurement routes.

PUBLIC PROCUREMENT ROUTES FOR DATA CENTRES AND SERVER ROOMS

The identified routes for the public procurement of data centres, including server rooms, have been established from information collected from the EURECA[16] project team and other identified examples of procurement practices in the EU.

When public organisations procure data centre products and/or services, these typically fit within one of the following routes:

1. Building a new data centre or equipping a server room.
2. Expansion and consolidation of the infrastructure or a new IT project, e.g.:
    a. retrofitting such as upgrading electrical equipment or cooling system optimisation;
    b. expansion and/or consolidation[17] of existing server rooms and/or data centres into new or existing data centres;
    c. virtualisation[18] of existing server capacity;
    d. services to expand existing buildings with new data centre and server room infrastructure.
3. Outsourcing to a hosted and/or cloud application environment, which means procuring a service and not a physical product. For cloud services, it includes the following:
    a. Infrastructure as a Service (IaaS): a MSP provides clients pay-as-you-go access to storage, networking, servers and other computing resources in the cloud.
    b. Platform as a Service (PaaS): a MSP provider offers access to a cloud-based environment in which users can build and deliver applications. The provider supplies underlying infrastructure.
    c. Software as a Service (SaaS): a MSP delivers software and applications through the internet. Users subscribe to the software and access it via the web or vendor Application Programme Interfaces.
4. Operation and/or maintenance of the facility, e.g.:
    a. specification of data centre and server room operational requirements; or
    b. arrangements to locate and/or operate your ICT equipment from within a co-location data centre

Based on public organisations' procurement needs, typical procurement routes have been defined. They start with the definition of the procurer's need, some through market dialogue while preparing the tender (in some Member States this is common practice such as in Denmark), which in turn influences the type of product (server room or data centre) and/or service they will purchase (Figure 2, Figure 3, Figure 4 and Figure 5). During this step there is the potential to audit server rooms to identify inefficiencies and opportunities for consolidation. This could be done internally or externally, through a procured auditing service which could be included in the scenario described in Figure 3, but in a step before consolidation.

The type of contract and the procurement procedure for selecting and/or excluding tenderers depend on the needs of the procurer and the type of product and/or service. By identifying separate procurement routes and matching them with data centre types, it is easier to establish

[16] https://www.dceureca.eu/

[17] Data centre consolidation (also called 'IT consolidation') is an organisation's strategy to reduce IT assets by using more efficient technologies. Some of the consolidation technologies used in data centres today include server virtualisation, storage virtualisation, replacing mainframes with smaller blade server systems, cloud computing, better capacity planning and using tools for process automation.

[18] Virtualisation refers to the act of creating a virtual (rather than actual) version of computer hardware platforms, storage devices, and computer network resources.

and provide guidance on the applicability of the GPP criteria. They are the assumed routes based on current knowledge of the market, and have been corroborated with stakeholders during the consultation process. In the specific case of procuring server rooms, the route will be similar to when procuring enterprise data centres as they are owned by the public organisation.

The boxes in green are those activities controlled by the procurer, and those in orange are those specifically related to the type of product and/or service that the data centre provides.

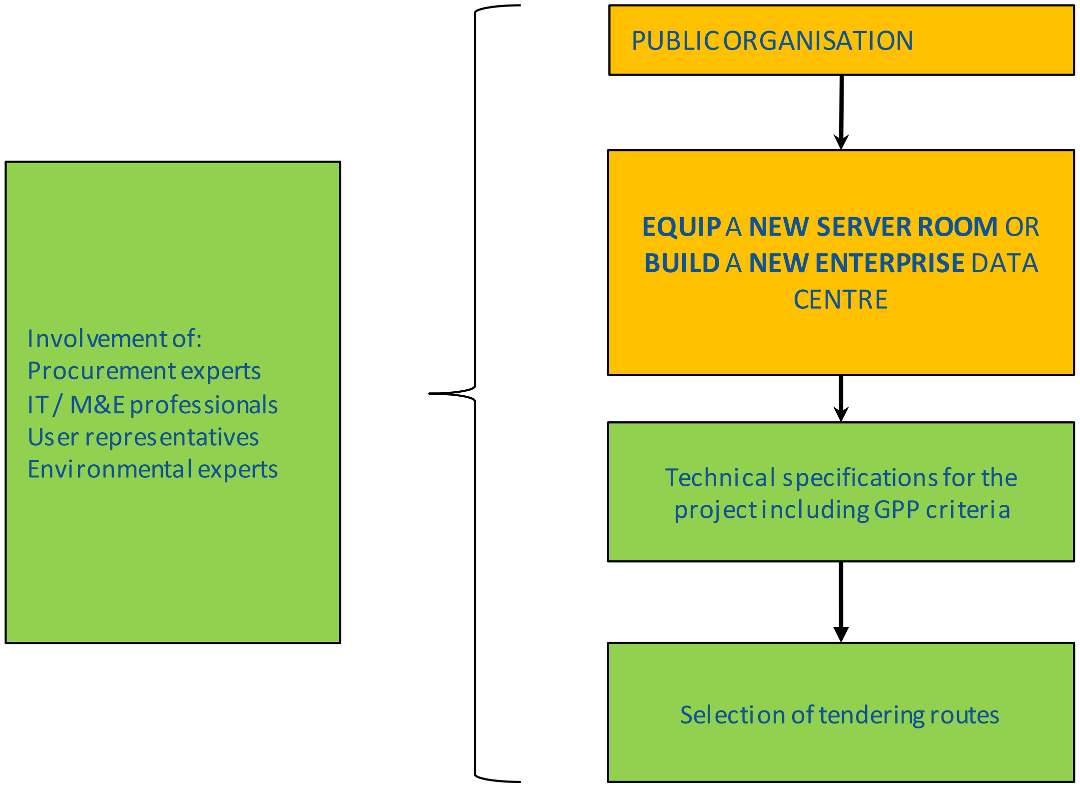


Figure 2: Mapping of potential procurement routes for scenario 1 when public organisations equip a new server room or build a new enterprise data centre.

N.B.: In orange the procured product or service. In green those activities controlled by the procurer.

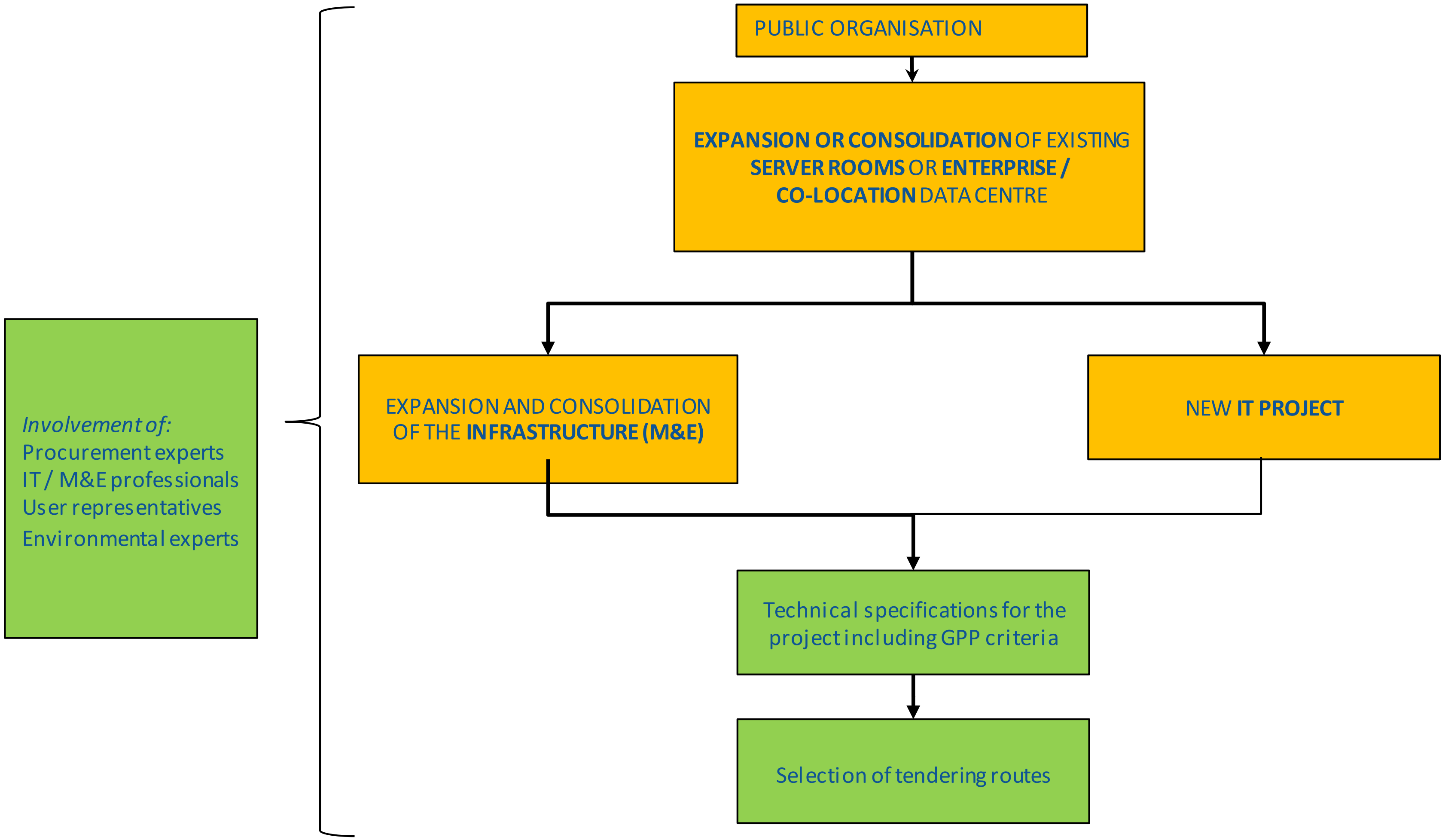


Figure 3: **Mapping of potential procurement routes for scenario 2 when public organisations expand and/or consolidate infrastructure or start a new IT project for server rooms and enterprise and co-location data centres.**

N.B.: In orange the procured product or service. In green those activities controlled by the procurer.

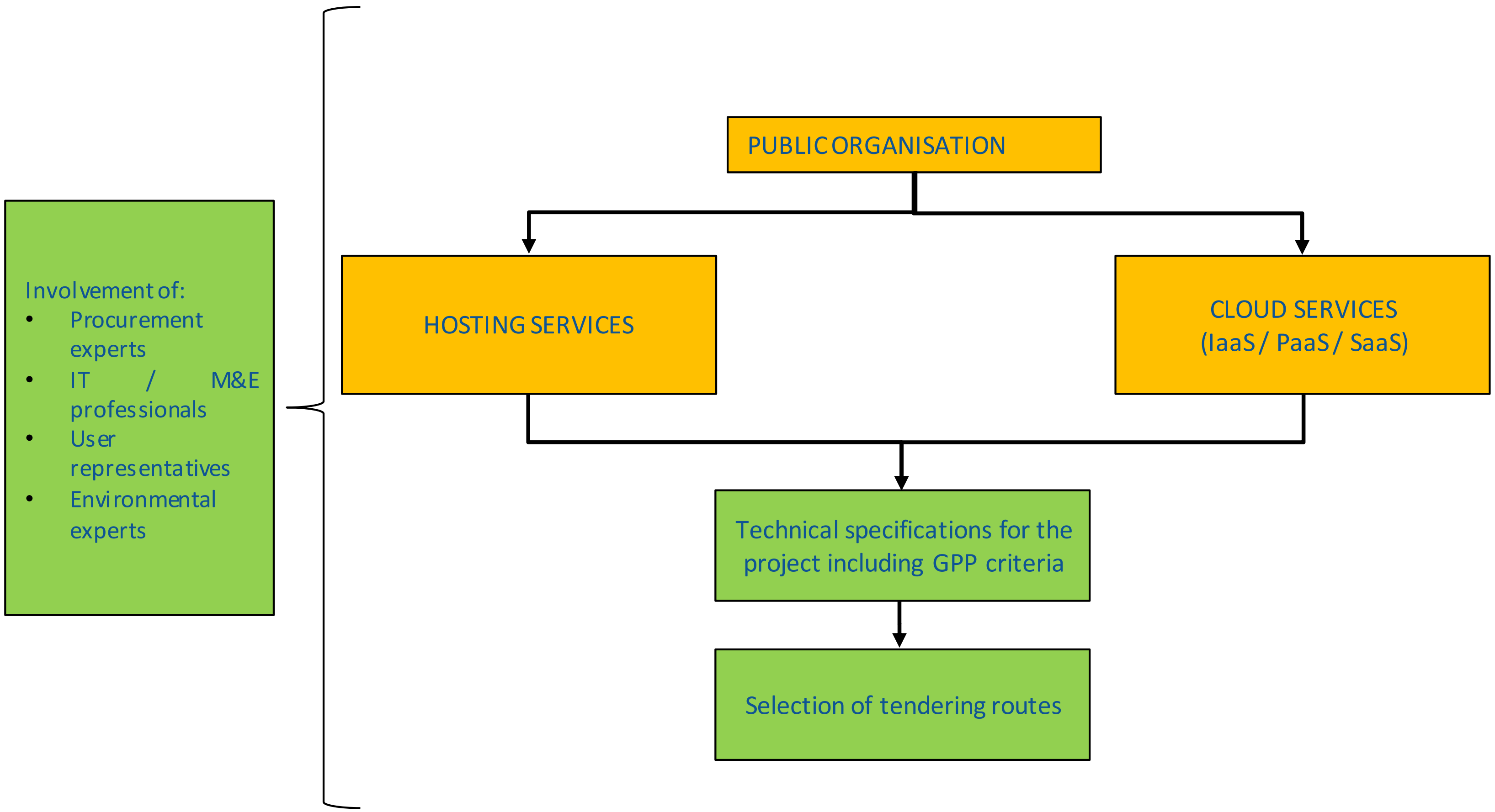


Figure 4: **Mapping of potential procurement routes for scenario 3 when public organisations outsource to a hosted or cloud application environment through MSP data centres.**

N>B.: In orange the procured product or service. In green those activities controlled by the procurer.

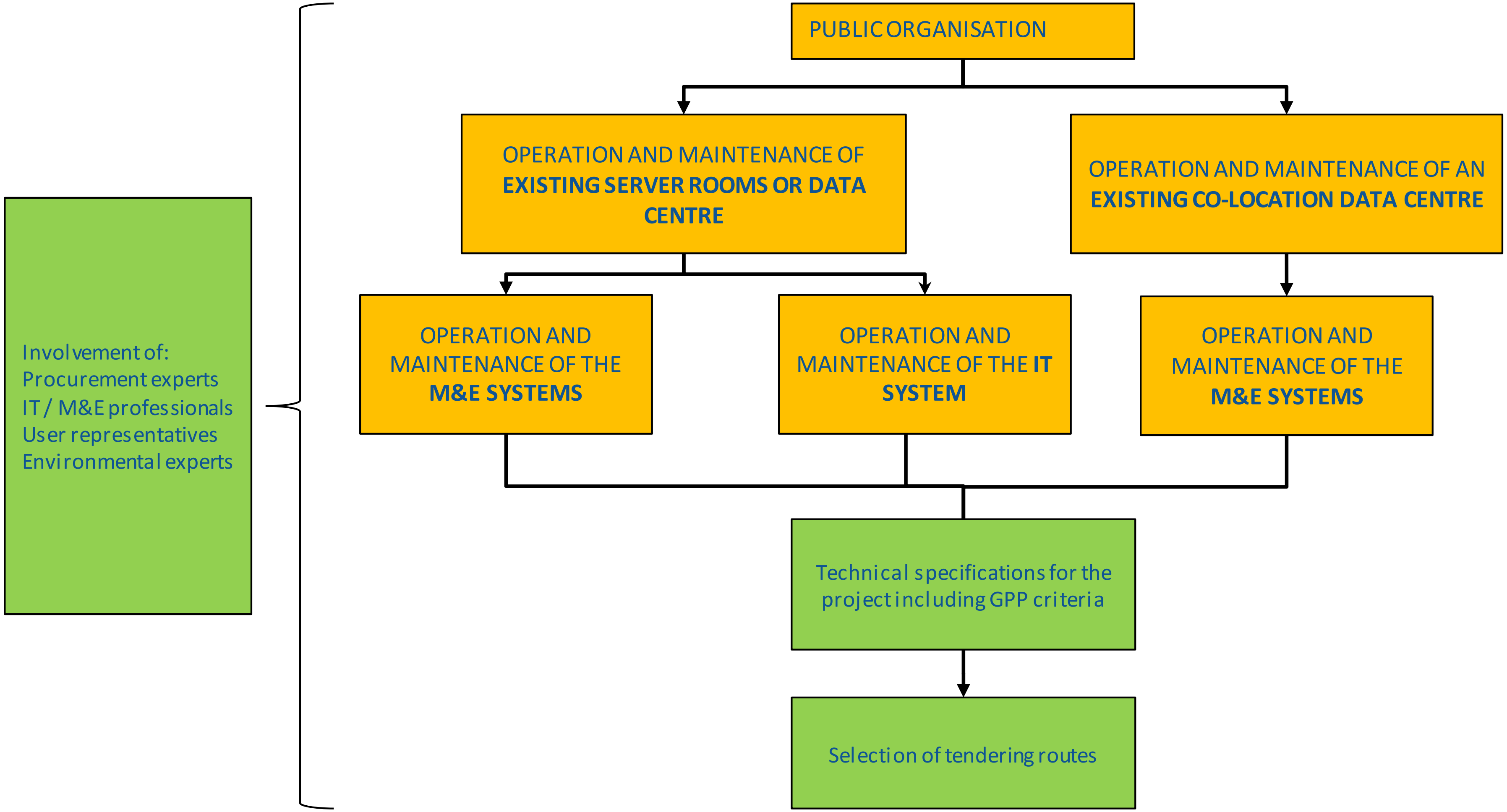


Figure 5: **Mapping of potential procurement routes for scenario 4 when public organisations purchase operation and/or maintenance services for server rooms and data centres.**

N.B.: In orange the procured product or service. In green those activities controlled by the procurer.

An overview of the applicability of the criteria proposals for the specific procurement routes a public organisation wants to follow is provided below. The aim is that a public organisation can easily identify criteria suitable for use for its specific tender.

In Figure 6, Figure 7, Figure 8 and Figure 9 the applicability of the specific criteria to the procurement routes from Section IV are presented. The criteria are then introduced in Chapters 1, 2 and 3 related to the following criteria areas respectively: IT System Performance, M&E System Performance and Reduction of GHG Emissions.

I. Equipping a server room or a data centre

A public organisation equipping a server room or a data centre (Figure 6) can include green criteria requiring:

- a minimum active efficiency of the server model (TS1);
- servers and data storage equipment with a design for repair and upgrading (TS3);
- implementation of a control of hazardous substances along the supply chain of the ICT product procured (SC2);
- ICT equipment allowing specific operating conditions (TS2)

Award Criteria can be based on the idle power of the servers (AC1 only in combination with the active efficiency specification) and/or the deployed power of the servers (AC.2).

II. Procurement of a new-build data centre

The procurement of a new-build data centre (Figure 6) can include:

- a selection criterion based on the relevant competencies and experience in the minimisation of cooling energy use (SC3);
- an award criteria based on the designed PUE (AC5) for new data centres including a demonstration of the PUE at handover (CPC4);
- technical specifications requiring:
    - the implementation of EU-level best practices for cooling and monitoring of operating conditions (TS6 and TS5),
    - (if opportunities are available) connection to a district heating system and the reuse of a relevant share of the waste heat (TS8);
- criteria awarding additional points to design solutions ensuring:
    - lower energy consumption (AC7),
    - highest reuse of waste heat (AC8),
    - cooling plants using refrigerants with a lower GWP (AC11);
- the following criteria regarding the ICT equipment can also be applied if the tender also includes the procurement of ICT equipment: TS1– TS2 – TS3 – SC2.

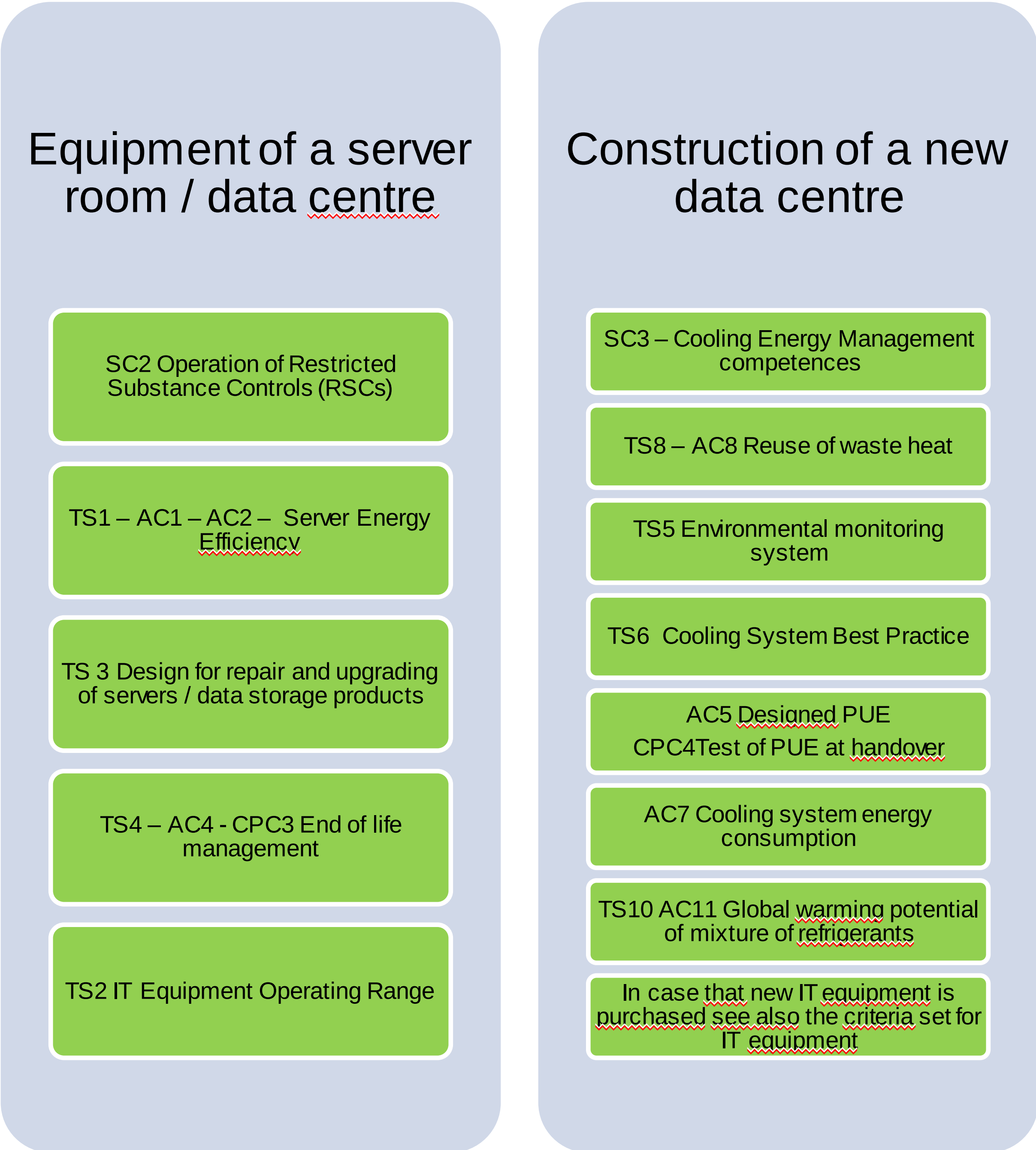


Figure 6: Applicability of GPP criteria to the building of a new data centre or equipping of a server room

III. Expansion of existing building with new data centre and server room infrastructure

In the case of expansion of an existing building with new data centre and server room infrastructure, the same criteria are applicable except AC5 which has to be replaced by AC6.

IV. IT consolidation/virtualisation

In the case of IT consolidation/virtualisation, applicable procurement criteria include (Figure 7):

- a selection criterion based on competencies and experience in optimisation of the server's utilisation (SC1);
- award criterion based on the anticipated utilisation rate (AC3);
- a contract performance clause can require the monitoring of the achievements in terms of utilisation rate (CPC2);
- criteria regarding the ICT equipment in the event that the project also includes the management of the ICT equipment life (TS1– TS2 – TS3 – AC1 –AC2 – SC2);
- criteria regarding the ICT equipment end of life (TS4 – AC4 – CPC3) in the event that end-of-life services are procured.

In the case of a project to consolidate existing distributed server rooms in a new data centre, all the criteria listed above are potentially applicable (Figure 7).

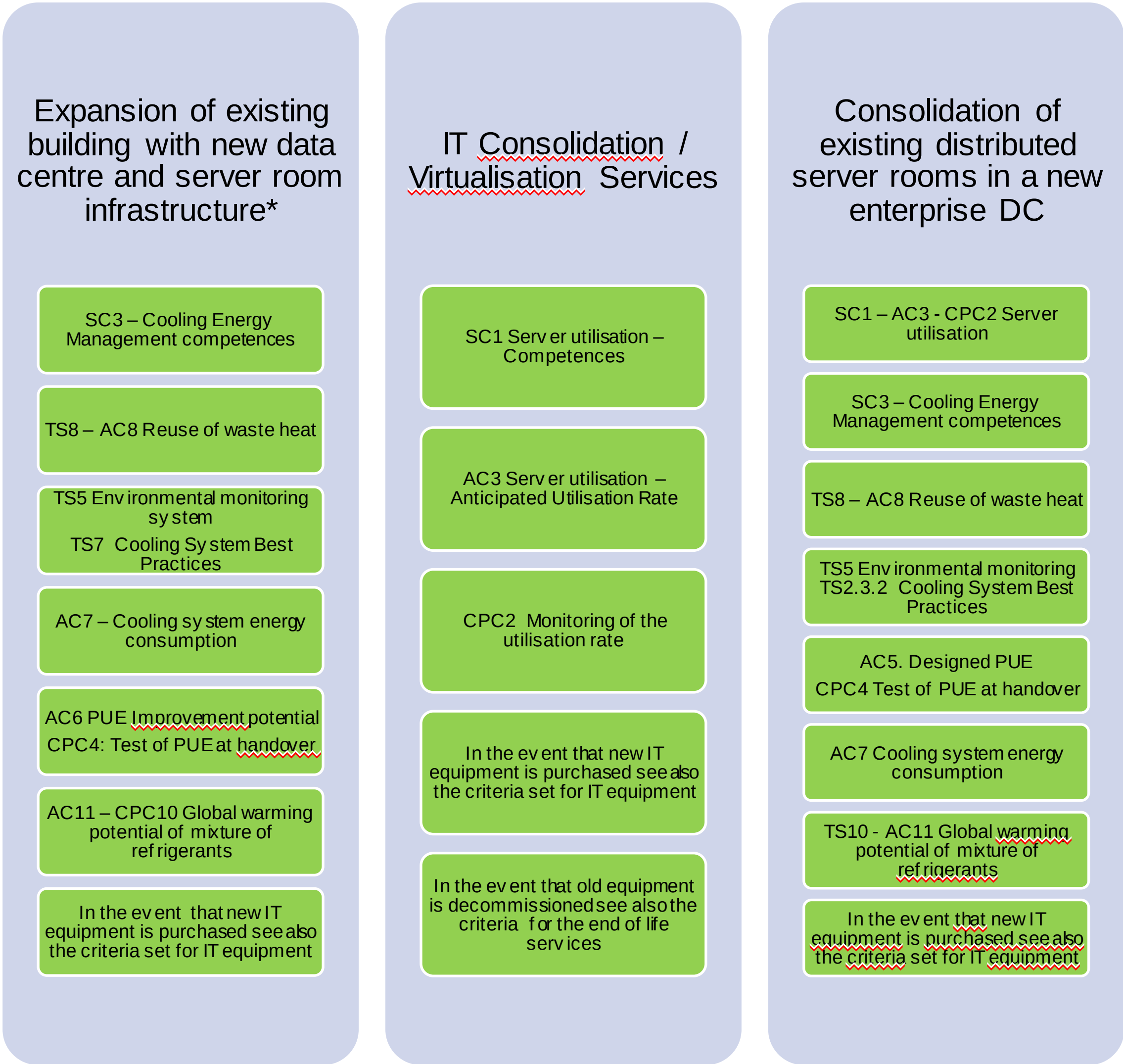


Figure 7: Applicability of GPP criteria to retrofitting, expansion, consolidation and virtualisation services[19]

[19] this includes retrofitting such as upgrading electrical equipment or cooling system optimisation

V. Procurement of hosting services or cloud services

Public organisations procuring hosting services or cloud services (Figure 8) can include in their tenders criteria awarding the services based on the offered performance for the following environmental metrics:

- Renewable Energy Factor (TS9 and AC10);
- Energy Reuse Factor (AC9);
- Global Warming Potential of the mixture of refrigerants used (TS10 - AC11).

Moreover, public organisations can require:

- the implementation of EU-level best practices for cooling (TS7).

The supplier may be requested to monitor and report, over the duration of the contract, the compliance with the offered environmental performance, in particular:

- the Renewable Energy Factor (CPC9);
- the Energy Reuse Factor (CPC8);
- the status of implementation of the EU best practices for data centres (CPC6);
- the Global Warming Potential of the mixture of refrigerants used (CPC10).

In the case of cloud services, the services can involve more than one data centre and cannot be tracked to the exact data centres being used in the provision of the services.

In order to apply green criteria, the bidder has to disclose the data centre fleet which may be used in the provision of the service. The GPP criteria set by the procurer have to apply only across that portfolio of data centres in order to be linked to the subject matter of the contract. The applicable performance metrics (REF, ERF, GWP) have to be calculated and aggregated only for the fleet of data centres providing the service. This can be supplemented with a requirement to report to the tenderer/client when major changes take place at the Managed Service Provider (MSP), such as the services being delivered from another data centre or undergoing major replacement of equipment.

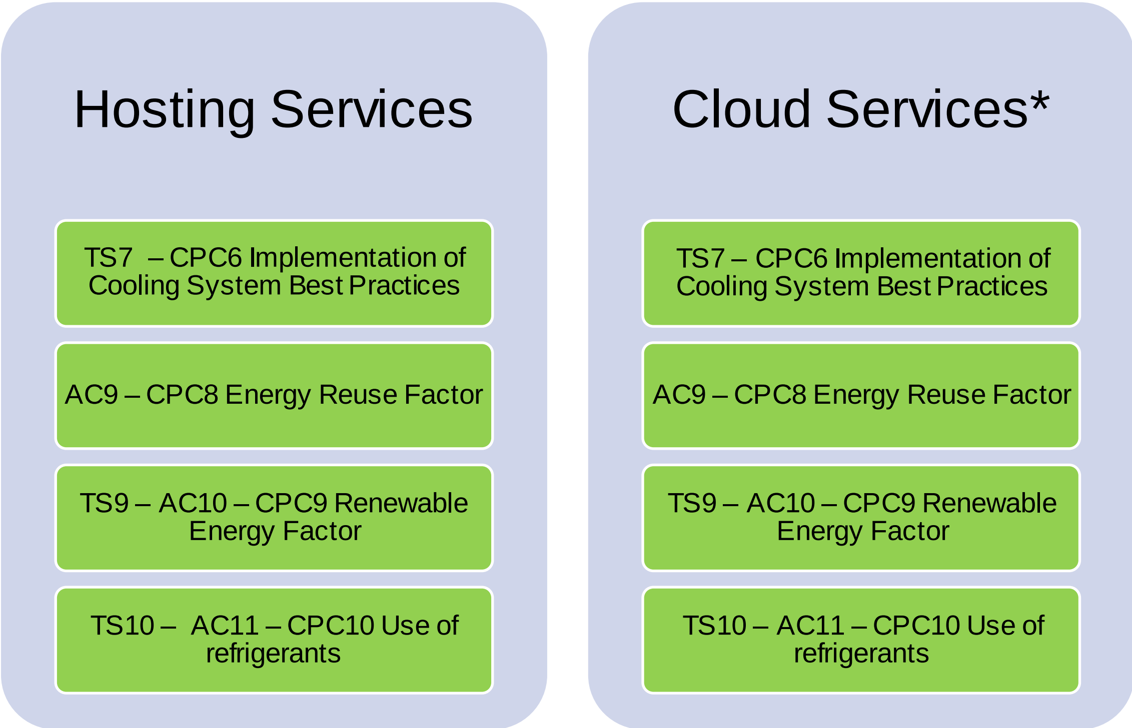


Figure 8: Applicability of GPP criteria to hosting and cloud services

** In the case of cloud services, the environmental performance metrics shall be provided as an aggregated value and the following conditions shall be met during the contract performance:*

- *the list of data centre sites that may be used in the provision of the service has to be disclosed;*

the service provider shall report any major changes such as the services being delivered from another data centre or undergoing major replacement of equipment.

VI. Operation and maintenance

In tendering for operation and maintenance services regarding the IT system, the public authorities can:

- require specific competences and experience in the optimisation of the server's utilisation (SC2);
- award points based on the anticipated utilisation rate (AC3);
- criteria regarding the ICT equipment in the event that the project also includes the management of the ICT equipment ((TS1– TS2 – TS3 – AC1 – AC2 – SC2);
- criteria regarding the ICT equipment end of life (TS4 – AC4) in the event that end-of-life services are procured.

During the performance of the contract, the public authorities can require the monitoring of several parameters including:

- the IT system energy consumption (CPC1);
- the server's fleet utilisation level (CPC2);
- the end of life of the decommissioned ICT equipment (CPC3) in the event that end-of-life services are provided.

For the operation and maintenance services covering the M&E system, the public organisation can:

- apply a selection criterion based on the relevant competencies and experience in the minimisation of cooling energy use (SC3);
- apply award criteria based on:

    - the PUE improvement potential (AC6),
    - the expected REF during the contract performance (AC10),
    - the expected ERF during the contract performance (AC9);
- include contract performance clauses requiring the monitoring and reporting of:
    - Power Usage Effectiveness (CPC7);
    - Energy Reuse Factor (CPC8);
    - Cooling energy consumption (CPC7);
    - Renewable Energy Factor (CPC9).

VII. Procurement of co-location services

In the case of procurement of co-location services (Figure 9), the tenderer can require the incorporation of 'expected' EU best practices for existing DCs (TS7).
Points can be also awarded based on:

- the expected REF during the contract performance (AC10);
- the expected ERF during the contract performance (AC9).

The procurer can also include a contract performance clauses requiring monitoring and reporting of:

- cooling energy consumption (CPC7);
- Renewable Energy Factor (CPC9);
- Energy Reuse Factor (CPC8);
- Implementation of best practice designs (CPC6).

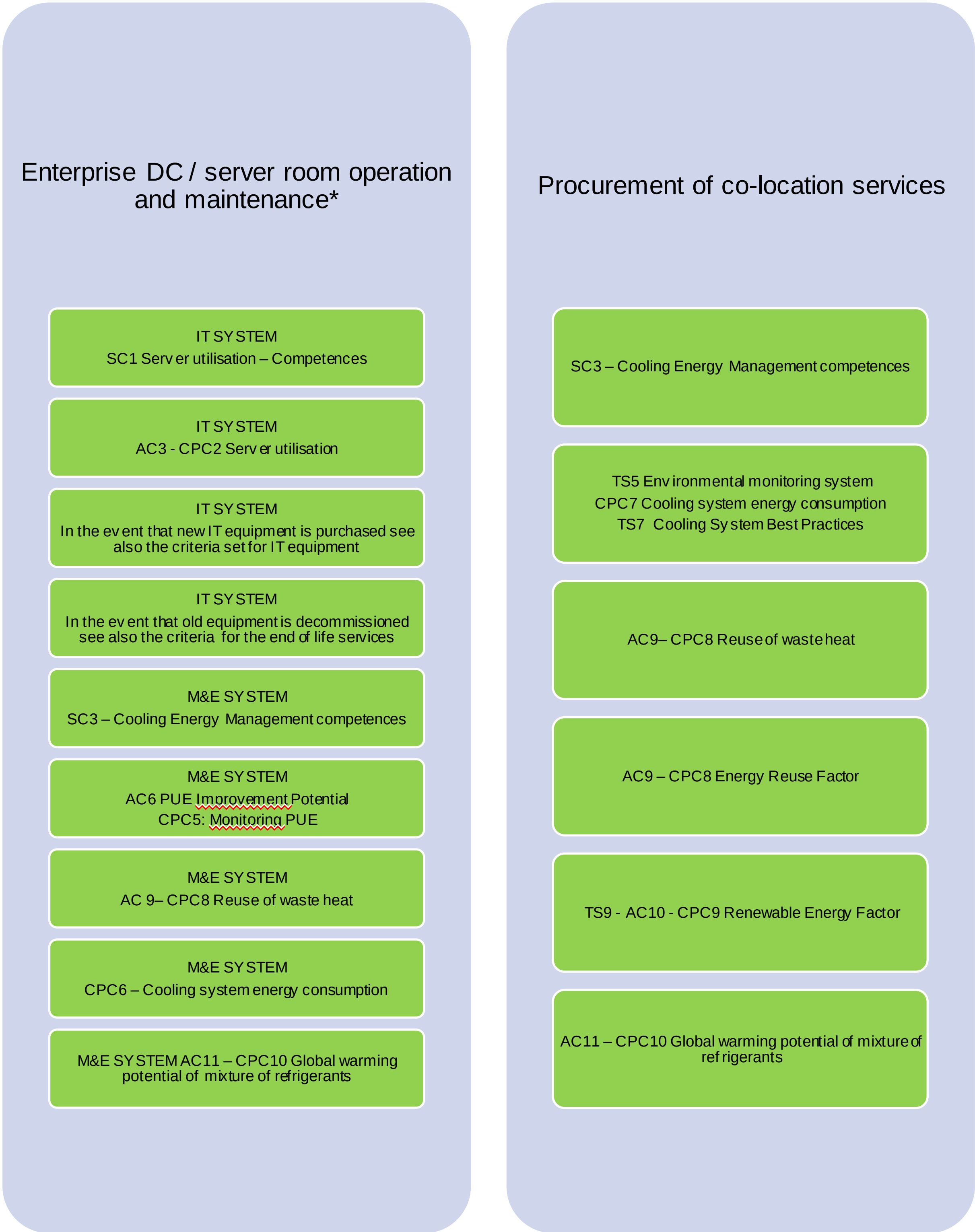


Figure 9: Applicability of GPP criteria to operation and maintenance and procurement of co-location services

MARKET VOLUMES AND ENERGY CONSUMPTION

I. Current market volumes for data centres

Market volumes on data centre white space and the estimated number of EU data centres were provided by Data Centre Dynamics (DCD)[20]. The market data is broken down per data centre type according to the data centre classification shown in Section 1.3.2. The estimated white space and number of data centres in the EU can be seen in Table 4 and Table 5. These estimates provide an indication of larger data centres, as an exclusion criteria of an IT capacity equal to or lower than 25 kW was applied considering the previous narrower scope excluding small data centres/server rooms. Data provided was established by Data Centre Dynamics based on the following main assumptions:

- Data from DCD Census and other research samples were used as the basis for computing the numbers, space, power and/or rack profile within markets, regionally and globally.
- The definition of data centre includes the characteristics of a conglomeration of IT and networking equipment and the infrastructure to support these components (power distribution, cooling/ventilation, UPS, connectivity, security).
- Self-reported information has been provided by data centre owners and it is considered accurate within the limitations of information that may be collected as ranged rather than itemised data points.
- The representation of the enterprise market by the Census sample was calculated as a statistical function and applied to the sample data generated.
- Where possible, statistics have been validated by other media and published sources.

The estimates exclude data centres that do not have provision for power and environmental management separate from other areas or that do not have a dedicated building. These are often referred to as server rooms. In spite of the limitations of these estimates, they can be used as an indication of the relative market volumes for different data centre types. It is expected that the number of server rooms will be even larger than that of enterprise data centres, particularly those used by the public sector. According to EURECA, 80% of data centres used by public authorities in Ireland, the Netherlands and the UK have a floor area of about 50 m^2 [21]. Considering the typical floor area for server rooms of 46.4 m^2 in the BEMP document for Telecommunications[4], this would mean that in these three countries, the majority of the data centres used by public authorities are server rooms.

The initial data was collected for data centre white space, and from that the number of data centres was derived. The data shows that most of the data centres in the EU are enterprise (i.e. 96% of the total number of data centres in the EU). However, when looking only at data centre white space, co-location data centres are also important in the total white space in the EU (i.e. 57% of the total white space for enterprise and 40% for co-location). These numbers show enterprise data centres are much smaller than co-location and MSP. The average white space for Enterprise is of 60 m^2/data centre, while for co-location it is 1 152 m^2/data centre and for MSP it is 1 123 m^2/data centre. Enterprise data centres often include legacy ICT equipment according to information from data centre experts. Quantitative forecasts were not available as, according to experts, issues on data centre definition, scope and nomenclature have prevented future predictions. Data centre experts assume that public organisations often have their own legacy products, but that the future is to expand, consolidate or build new IT projects outside their property boundaries.

[20] http://www.datacenterdynamics.com/

[21] According to 2 m^2 per rack, assumption provided by EURECA.

Table 4: Estimated data centre white space (m^2) in the EU

Market	Enterprise data centres	Co-location data centres	Managed Service Provider data centres
Austria	52500	22100	2200
Belgium	61500	31900	3700
Bulgaria	32550	13700	1500
Croatia	19350	17500	1320
Cyprus	10800	11000	800
Czech Republic	31500	19200	1050
Denmark	36000	40300	3600
England	772500	474500	24000
Estonia	13200	8100	1000
Finland	48750	83200	8900
France	577500	305500	21000
Germany	825000	409500	27900
Greece	41250	29900	2600
Hungary	30900	31900	2400
Ireland	43500	188500	10300
Italy	201000	84500	5700
Latvia	30750	12800	300
Lithuania	50250	21000	2050
Luxembourg	15300	62400	5100
Malta	12900	11700	700
Netherlands	210000	351000	15800
Poland	70500	61100	2400
Portugal	33000	16900	1200
Romania	40500	17200	1200
Slovakia	34500	14600	640
Slovenia	15750	9700	700
Spain	270000	136500	14600
Sweden	48000	75400	8000
Total	**3 629 250**	**2 562 000**	**170 660**
% of total	**57**	**40**	**3**

Table 5: Estimated number of data centres in the EU

Market	Enterprise data centres	Co-location data centres	Managed Service Provider data centres
Austria	330	60	4
Belgium	345	65	6
Bulgaria	265	20	2
Croatia	160	15	1
Cyprus	90	15	0
Czech Republic	450	40	2
Denmark	680	40	5
England	11500	450	25
Estonia	135	10	1
Finland	220	35	4
France	8700	270	20
Germany	13200	410	30
Greece	330	20	2
Hungary	260	15	1
Ireland	350	40	2
Italy	6500	95	7
Latvia	160	20	0
Lithuania	220	10	0
Luxembourg	115	25	3
Malta	80	10	0
Netherlands	5600	250	15
Poland	1600	70	3
Portugal	275	25	2
Romania	650	30	2
Slovakia	260	15	0
Slovenia	140	10	0
Spain	6300	100	10
Sweden	1300	50	5
Total	**60 215**	**2 215**	**152**
% of total	**96.2**	**3.5**	**0.3**

II. Server room stock

As noted in Section 1.3, smaller server rooms are considered to be of importance in the public sector, as they offer a significant number of opportunities for consolidation projects to improve operating efficiencies.

A US report[22] estimated that 72% of the installed stock of servers in buildings registered in the Commercial Buildings Energy Consumption Survey (CBECS) in the US is installed in server rooms. This covers a wide range of industries across the public and private sectors; however, it shows that the majority of servers registered are installed in server rooms.

Quantitative estimations of the current number of server rooms in the whole EU do not exist due to issues of nomenclature and classification; Table 4 and Table 5do however indicate that server rooms have an important share of the total number of data centres in Europe. According to information from data centre experts, such a focus on server rooms is even more relevant for public organisations.

III. Market trends in public organisations

The preliminary conclusion is thus that server rooms and enterprise data centres still represent a significant share of the present server and data processing capacity operated by public organisations, but that the trend is to move towards more co-location data centres and/or services. Concerning MSP, data centre experts have a conservative assumption that this type of data centre service may be still relatively restricted at public level due to data security issues.

There is a general trend towards Managed Service Providers in the private sector, but the public sector is more conservative so the amount of white space serving public authorities may still be greater within server rooms and enterprise data centres. It is therefore important to focus efforts, when developing GPP criteria, on the shift towards more efficient technologies and best practices for these two categories in the product group.

With regards to cloud services, there are examples of public-facing cloud services such as Google Apps and Microsoft Office 365 now being delivered by mega data centres dominated by large dedicated service providers who have the resources and scale and expertise to design, build and deliver services at higher efficiency and lower cost. It is expected that more public sector services will be delivered by larger and larger data centres, which may include managed services such as the cloud, although there is also counter pressure due to data security issues and public acceptance. Moreover, legacy equipment will always exist since some services are too sensitive, complex or expensive to decommission.

IV. Current and predicted energy consumption

Based on different data sources[23,24,25,26,27], the estimated energy consumption of data centres and server rooms in the EU was established, as well as projected consumption up to 2030. Furthermore, these data sources provided evidence which made it possible to do a breakdown

[22] Shining a Light on Small Data centres in the US, June 2017. Energy Analysis and Environmental Impacts Division Lawrence Berkeley National Laboratory.

[23] https://www.dotmagazine.online/issues/powering-and-greening-IT/Sustainable-Energy-Transformation

[24] Figures presented by Paolo Bertoldi in November 2016 related to the European Programme for Energy Efficiency in the Data Centres Code of Conduct.

[25] Ongoing ecodesign work on servers and storage.

[26] US Data centre Energy Usage Report. Ernest Orlando Lawrence Berkeley National Laboratory. June 2016.

[27] CBRE Marketview. Europe Data Centres, Q1 2017.

for each data centre type in the proposed scope, as well as for the corresponding consumption for the ICT equipment in comparison with the rest of the infrastructure (including M&E equipment). The breakdown per data centre type (and server room) was done by collecting data on the total annual energy consumption of data centres in the EU by the European Commission[24] (including small data centres, assumed to also include server rooms), and deducting the estimated annual energy consumption by MSP and co-location data centres based on the other data sources. Some data centre experts believe these figures are overestimated, but they were found to be the only ones available that represent consumption figures at the macro level.

The overall energy consumption for the period 2010 to 2030 is shown in Table 6. In 2015, the amount of electricity consumed corresponded to around 2.25% of the total EU electricity[28] and this amount is expected to double by the 2030. It is remarkable how the EU DC energy consumption has increased over a period (2010-2015) when the total EU energy consumption has instead shown stability or almost a decline[29]. The main reason that consumption growth rate is expected to slow down after 2015 is the increased efficiency of servers and storage units.

Table 6: Estimated EU data centre energy consumption (2010-2030)

	2010	2015	2020	2025	2030
Total EU DC energy consumption (TWh/year)	55	74	104	134	160
Annual increase (%)	-	9%	6%	5%	3%

The breakdown per data centre type (enterprise category shown in Figure 10 and Table 7 includes server rooms) is shown in Figure 10. The data shows a slowdown in consumption by enterprise data centres, which is solely based on predictions by the US Lawrence Berkeley National Laboratory[26]. This indicates that the MSP data centre market in the US will grow rapidly, in particular after 2020. These predictions are not aligned with information provided by data centres in the EU as explained in Section 1.5.1, especially concerning data centre products and services procured by public organisations. It is thus assumed that this breakdown somehow underestimates the future consumption by enterprise and server rooms and co-location data centres, and overestimates that of MSP data centres. However, it provides an indication of the current consumption levels, showing that enterprise and co-location dominate the energy breakdown in 2017 (i.e. 52% by enterprise and server rooms and 15% by co-location data centres), which is expected to change in the future as more MSP data centres appear on the market.

These figures have been established as indicative numbers to obtain an overview of the energy consumption trends in the future. In spite of the rapid and disruptive technology evolution of this sector, and the diversity in business and ownership models that also affects energy consumption, the established trend in the EU showing increased energy consumption concurs with global trends[30].

[28] https://docstore.entsoe.eu/Documents/Publications/Statistics/electricity_in_europe/entso-e_electricity_in_europe_2017_web.pdf

[29] Bertoldi P., Diluiso F., Castellazzi L., Labanca N. and Ribeiro Serrenho T., Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2015, EUR 29104 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-79372-1, doi:10.2760/6684, JRC110326.

[30] Andrae, A.S.G. (2017). Total Consumer Power Consumption Forecast. Presentation at the Nordic Digital Business Summit. Helsinki, Finland, October 5, 2017. Available at: https://www.researchgate.net/publication/320225452_Total_Consumer_Power_Consumption_Forecast

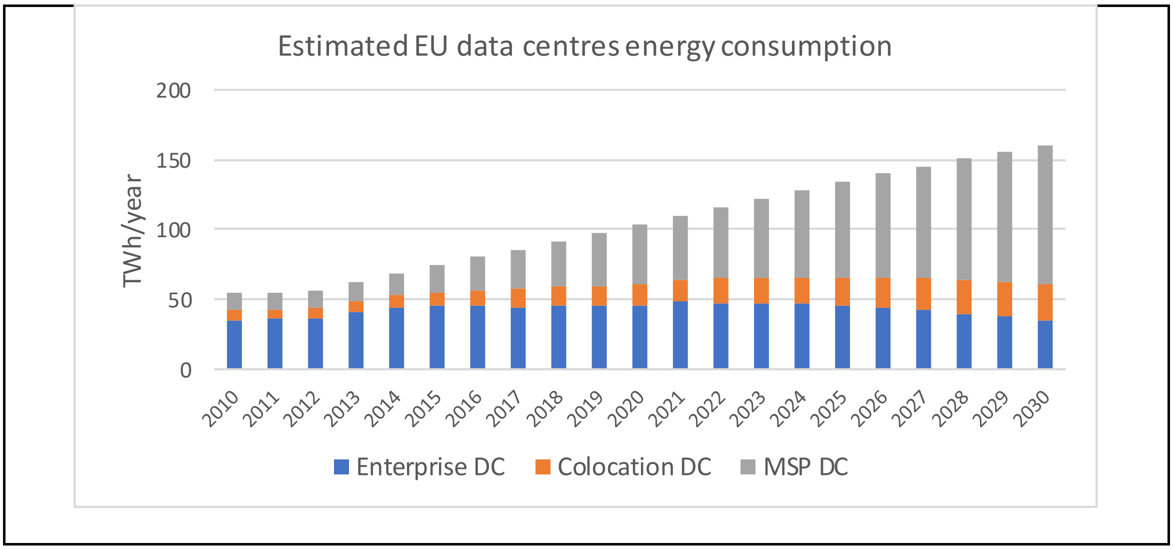


Figure 10: Estimated EU data centres' energy consumption per data centre type

Establishing the significance of IT and infrastructure electricity consumption could help identify where the largest savings could come from. The internal energy consumption breakdown for the data centres in the EU was established based on that observed in the US[26] for the period 2010 to 2020, assuming that technologies and data centre configurations are somewhat similar. However, these figures are only indicative as best practices in the EU may be different. Figures are those only broken down by IT and infrastructure in order to identify the energy consumption hotspots. In the period of 2020 to 2030, this was calculated based on an interpolation considering a PUE factor of 1.5 in 2030. This PUE factor was estimated by an EU impact assessment for servers and storage equipment as a moderate policy scenario. This estimated breakdown is presented in Table 7, showing that, while in 2010 the energy consumption by ICT equipment compared to the rest of the data centre was fairly similar, by 2020 the consumption by ICT equipment is predicted to be significantly higher with a rapid slowdown for the rest of the infrastructure up to 2030 when the consumption by ICT equipment will be almost double. This clearly already identifies IT equipment as the most important hotspot now, but even more so in the future.

Table 7: Internal breakdown of the energy consumption for the whole EU

	Data centre type	**2010**	**2015**	**2020**	**2025**	**2030**
Total EU DC energy consumption (TWh/year)	**All**	**55**	**74**	**104**	**134**	**160**
ICT equipment consumption (TWh/year)	**Enterprise and server rooms**[31]	18.3	26.2	29.7	29.8	23.2
Infrastructure consumption (TWh/year)		17.2	19.8	16.1	15.5	11.6
ICT equipment consumption (TWh/year)	**Co-location**	3.6	5.1	9.3	13.6	17.7
Infrastructure consumption (TWh/year)		3.4	3.8	5.1	7.1	8.8
ICT equipment consumption (TWh/year)	**MSP**	6.1	10.9	28.4	44.6	65.8
Infrastructure consumption (TWh/year)		5.8	8.2	15.4	23.3	32.9

[31] Annual energy consumption for enterprise data centres and server rooms could not be split as these figures were deducted from the total annual energy consumption minus figures from co-location and MSP data centres.

KEY ENVIRONMENTAL IMPACTS OF DATA CENTRES AND SERVER ROOMS

I. Life cycle assessment (LCA) of data centres and server rooms and life cycle environmental hotspots

An overview of 10 LCA studies for data centres, including server rooms, is presented in the preliminary report (Chapter 6), which helped to identify the life cycle hotspots. This assessment was done by identifying the life cycle stages of the data centres that show the highest environmental impacts and which present opportunities for improvement. Whether there are opportunities or not was assessed by expert judgment considering the design, operational, decommissioning and end-of-life activities that can take place to reduce the environmental impact(s).

Of the 10 LCA studies, 7 assessed the whole life cycle of data centres, 1 assessed servers and storage, 1 only servers and another only a specific cooling technology[32]. The environmental impacts assessed varied widely across the 10 studies, with all looking at Global Warming Potential (GWP) 100 years (i.e. Climate Change[33]), and 7 looking at other environmental impacts beyond Climate Change but at different damage points and assessed with different life cycle impact assessment methodologies[34]. However, for the purpose of the LCA review which was to identify life cycle environmental hotspots, the 10 LCA studies provided a good indication as they all concurred on the biggest sources of impact. It was important to include all 10 studies in the review due to the limited amount of studies looking at the performance of the data centre as a whole and beyond Climate Change (i.e. only 3 studies). Finally, this was done to have a wider geographical coverage as most of the studies assessed typical data centres at a specific location.

The LCA studies reviewed indicate that the main environmental impacts (i.e. life cycle hotspots) stem from the electricity use of IT and cooling systems in the use phase, in particular from the following:

- The energy mix used to supply the electricity, which is greatly influenced by the location of the data centre.
- The energy consumption and related energy efficiency of the ICT equipment and the mechanical and electrical (M&E) systems, which determines the amount of energy consumption.
- Climatic conditions and heating infrastructure influence cooling demand, thus the location of the data centre also has an impact on energy consumption.
- The use of refrigerants with a high Global Warming Potential, that could generate higher impacts due to their leakage during operation of cooling systems.
- The manufacture (including raw materials extraction and transport) of the ICT equipment (i.e. their embodied impacts) and, in particular, the disposal of waste arising from the mining, extraction and refining of metals used to manufacture printed circuit boards of IT components (in particular of servers mostly due to their higher energy consumption).
- The end of life of the equipment (in particular of servers), especially focusing on the possibilities for reuse and recycling which are alternatives to other routes and which can avoid some of the environmental impacts from manufacturing.

[32] https://www.seecooling.com/files/2016-02/the-teliasonera-green-room-concept.pdf

33 Category recommended by the European Commission at the Product Environmental Footprint. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013H0179&from=EN

34 Midpoint and endpoint. For an explanation see: https://www.openlca.org/wp-content/uploads/2015/11/LCIA-METHODS-v.1.5.4.pdf

- The trade-off between extended lifetime and energy efficiency. According to results from EURECA[3,64], older data centres (over 3 years old) have a significantly higher annual energy consumption[35], which can be higher than the embodied energy of manufacturing new ICT equipment.
- The right-sizing of the data centre capacity, availability and redundancy, which can be achieved by increasing IT utilisation and/or by consolidating ICT equipment.

Note that EN50600 99-2 describes recommended practices for environmental sustainability of data centres; this excludes energy efficiency best practices which are addressed in EN50600 99-1.

II. System design and operation

Measures to improve data centre sustainability must not compromise reliability. There can be a perception that the two are mutually exclusive; however, it is important to demonstrate that measures to improve environmental performance do not necessarily increase risk. This is because concerns relating to reliability may hamper efforts to implement best practices, e.g. through resistance to change legacy practices and designs such as low operating temperatures. Reliability must therefore be considered both at a component and system level.

To achieve high reliability levels, redundant components and systems are installed. Where two systems are installed for redundancy (2N), each system may only be loaded to 50% maximum so that in a failure event the alternative system is not overloaded. Designers and operators often build additional margins into this, resulting in low loads during normal operation. This is compounded by partial loads – most facilities never reach 100% design load and operate for years at 50% load or lower. Also, ICT equipment is often installed with overprovisioned capacity. Extra capacity means additional embodied impact and equipment operating at low loads is usually not at its most efficient condition. In order to avoid overprovisioning, the data centre owner/user should determine the desired availability of the overall set of facilities and infrastructures using business risk analysis and downtime cost analysis. The European Standard EN 50600-1 Information technology - Data centre facilities and infrastructures - Part 1: General concepts includes the description of Availability Classes and examples of different availability classes' implementation

One way in which the environmental impact of data centre cooling systems can be reduced is by being adaptive to climatic conditions through free or economised cooling designs. Data centres with free or economised cooling designs use cool ambient conditions to meet part or all of the facilities' cooling requirements hence compressor work for cooling is reduced or removed, which can result in a significant energy consumption reduction. Economised cooling can be retrofitted to some facilities. Provided the air delivered to the ICT equipment is managed and kept within recommended and allowable environmental ranges, this only marginally affects hardware failure rates.

The LCA studies reviewed, however, do not specifically address the importance of air and thermal management (although studies focusing on energy consumption do). In practical terms, to improve the energy efficiency of a data centre, it is normally the most cost-effective option to start with, allowing maximum savings for minimum investments, when compared to other energy efficiency measures.

A theme that is common to both reliability and energy efficiency in data centres is the impact of the human element, as the majority of failures and inefficiencies are down to human error and

[35] EURECA reports as much as double the annual energy consumption in 2016 from data centres located in Ireland, the Netherlands and the UK used/managed by public authorities.

unawareness. The best mitigation is considered to be the creation of a learning environment culture[36].

[36] http://www.dc-oi.com/blogs/Managing_Risk_The_Human_Element.pdf

III. Key areas of potential for improvement

Overall, key areas of potential for improvement were defined focusing on the life cycle environmental hotspots presented in Section 1.6.1 of the Preliminary Report. Key improvement areas are aspects of the overall system performance of a data centre and of the IT and mechanical and electrical systems which can reduce the life cycle environmental impacts identified and which are known not to reduce the data centre functionality.

These are presented in Table 8, which also shows the priority ranking performed. This ranking was necessary in order to select the most relevant improvement areas which could lead to potential GPP criteria. The ranking considered four important aspects:

a. Potential environmental benefits based on the LCA review performed, showing 1 as the lowest benefits, 2 as medium and 3 as the highest.
b. Readiness of availability on the EU market, indicating the availability of data centre technologies already applying the specific improvement strategies, using the same ranking scale as for environmental benefits.
c. Potential incurred life cycle costs, which were based on expert judgment and information provided by other data centre experts, starting with 1 as low life cycle costs and ending with 3 as high.
d. Degree of difficulty of verification, indicating the availability of a potential metric or measure to implement the improvement area, using the same scale.

The results from this ranking show:

- in green the key improvement areas with the highest potential benefits, that do not incur high life cycle costs and where technologies with these improvements can be found on the EU market; however, the verification may be not straightforward;
- in yellow the key improvement areas with lower but still important potential benefits, where technologies are readily available on the EU market and that are relatively easy to verify without incurring high life cycle costs (in yellow);
- in orange the key improvement areas with lower but still important potential benefits, that are relatively easy to verify without incurring high life cycle costs but where technologies are not yet widely applied (in orange);
- in grey the key improvement areas with the lowest potential benefits, and which are difficult to verify and in some cases incur high life cycle costs (in grey) – in the specific case of increasing efficiency for storage units, the potential benefits are not ranked as low, but the verification is considered difficult.

Those improvement areas in green, yellow and orange were suggested as those to focus on for proposing potential GPP criteria. A further analysis of these is presented in Chapters 2, 3 and 4 of this report where the four elements used for ranking are elaborated in more detail.

Those in grey were considered not relevant for the effort to develop GPP criteria, presenting low potential environmental benefits or relevant barriers. In the case of storage efficiency, this was also considered too difficult to verify. These were not considered further in the analysis to develop GPP criteria.

Criteria to address these areas of improvement are clustered under three broad areas that relate to the design and operation of a data centre:

1. Data centre and/or server room level.
2. IT system level.
3. M&E systems level.

Table 8: Priority ranking of improvement areas

Life cycle hotspots	Improvement strategy	Application level (i.e. focus area)	Potential environmental benefits	EU market readiness	Life cycle costs	Verification	Total scoring
Energy mix to supply electricity	Procurement of on-site/near-site electricity	Whole data centre	3	2	2	2	
	Hosting/location of server and data storage services in data centre with high renewable electricity share	Whole data centre	2	2	2	3	
Energy consumption in the use phase	Ensure a high rate of utilisation of IT equipment	IT system	3	2	1	3	
	Select highly energy efficient server(s)	IT system	3	2	1	2	
	Select ICT equipment operating at higher temperature	IT system	2	3	2	1	
	Ensure continuous monitoring of the energy consumption of the IT and M&E components of the data centre	Whole data centre	2	3	3	2	
	Hosting/location of server and data storage services in data centre with low Power Usage Effectiveness (PUE)	M&E systems	2	3	2	1	
	Implement Cooling System Best Practices	M&E systems	3	3	2	3	
	Reduce energy consumption for cooling systems (operating more hours in free cooling conditions)	M&E systems	2	2	2	1	
	Minimise waste heat by reuse in a district heating	M&E systems	2	1	2	1	
	Increase energy efficiency of storage unit(s)	IT system	2	1	2	3	
	Increase energy efficiency of network equipment	IT system	1	2	1	2	
	Report data centre productivity	IT system	1	1	1	3	
	Improve data centre design and management	Whole data centre	1	3	3	3	
	Reduce energy consumption of UPS	M&E systems	1	3	3	2	
Global Warming Potential in the use phase	Reduce the use of refrigerants with a high GWP	M&E systems	2	3	1	1	
Manufacturing	End-of-life management – Collection, resale and tracking	IT system	3	2	2	2	
	Design for dismantling & recyclability – Select ICT dismantling test reports to facilitate the disassembly	IT system	2	2	3	3	
	Design for disassembly and reparability – Select ICT with clear disassembly and repair instructions	IT system	2	1	3	3	
	Emissions of hazardous substances – halogen-free Printed Circuit Boards	IT system	2	1	2	2	

	Emissions of hazardous substances – implementation of Restricted Substances Control	IT system	1	2	2	3	
	Emissions of hazardous substances – hazardous substances declaration	IT system	1	2	2	1	
	Maintenance strategy to maximise system lifetime	M&E systems	1	1	2	1	
	Renovate/refurbish existing facility instead of new build	M&E systems	1	3	2	3	
	Maintenance strategy to maximise system lifetime	M&E systems	1	1	2	1	
	Hardware / plant leasing to increase product lifetime	Whole data centre	1	1	1	2	
	Renovate/refurbish existing facility instead of new build	M&E systems	1	3	2	1	
	Avoid overprovisioning of resilience	Whole data centre	3	1	1	1	
	Hardware/plant leasing to increase product lifetime	Whole data centre	1	1	3	2	
	Asset management	Whole data centre	1	3	1	2	
	Avoid overprovisioning of resilience	Whole data centre	3	1	3	1	
	Data storage policy	IT system	1	3	3	2	
	Use of open source hardware	IT system	1	1	1	2	
	Evaluate environmental impact of design options	M&E systems	2	1	1	3	
	Hardware providers following BEMP for Electrical Equipment Manufacturing Sector / EMAS-registered companies	IT system	1	1	1	2	
	Power cord materials	IT system	1	1	1	2	
	Responsible facility decommissioning	Whole data centre	1	1	3	3	
	Recyclability of plastic components of hardware	IT system	1	1	3	2	
Trade-off energy efficiency and extended lifetime	Find optimal refresh rate	IT system	3	2	1	3	
Right-sizing of data centre capacity, availability and redundancy	Increase IT utilisation	IT system	3	2	2	2	
	Consolidation of IT equipment	IT system	2	1	3	3	

LIFE CYCLE COSTS OF DATA CENTRES

Typically, life cycle costs of products are the sum of the acquisition costs, running costs (i.e. operational/maintenance/repair costs) and end-of-life costs. The quantification of life cycle costs for data centres, including server rooms, can vary, typically without considering decommissioning and end of life and in many cases excluding some pieces of equipment. However, the costs are usually divided into:

- CAPEX: Capital Expenditure, referring to the purchase and installation of the IT, mechanical and electrical equipment in the building, together with the building infrastructure; and
- OPEX: Operational Expenditure, referring to the running costs, decommissioning refers to shutting down the facility once it reaches its end of life, and the end-of-life costs are related to disposal, recycling and WEEE treatment

The differences between the costs for data centre and server room owners and those for customers were established, since those for customers of co-location and managed service provider data centres are expected to be different. This assessment was done semi-quantitatively due to a lack of harmonised quantitative data, which provides an indicative understanding of a data centre's and server room's life cycle cost structure. See Table 9.

From the owner's perspective, the CAPEX of purchasing and building facilities is medium to high and this is universal for all data centre types. The CAPEX for purchasing IT hardware, including installation and testing, is medium to high for enterprise and MSP data centre owners, as they could be purchasing mainframe servers and more specialised servers customised for their applications, depending on the services the data centre should provide. At the same time, the requirement for resilience for co-location data centres is often high and therefore much more expensive facilities are needed.

According to some stakeholders, OPEX costs can be significantly reduced (from 50-80%) by moving to third-party maintenance, which can be seen in the co-location and MSP OPEX cost ranges provided in Table 9. For enterprise data centres, third-party maintenance can also be considered by outsourcing this particular activity to reduce software support costs.

Server room facilities costs are lower than those for enterprise data centres since in many cases server rooms share cooling infrastructure with the rest of the building. These costs would mainly imply purchasing and running an UPS. IT costs are the dominant factor.

Table 9: Indicative life cycle costs for data centre owners and customers

Cost category	Cost range for DC owners (% breakdown of total life cycle cost)				Cost range for DC customers (% breakdown of total life cycle cost)			
	Server rooms	Enterprise	Co-location	MSP	Server rooms	Enterprise	Co-location	MSP
CAPEX Facilities	1-5%	15-20%	60-80%	15-20%	1-5%	15-20%	1-5%	0%
CAPEX IT	30-60%	30-40%	10-20%	30-40%	30-60%	30-40%	40-50%	0%
OPEX Facilities	10-30%	10-15%	1-10%	10-15%	10-30%	10-15%	5-15%	35-50%
OPEX IT	20-40%	25-35%	1-5%	25-35%	20-40%	25-35%	30-40%	50-70%
Decommissioning	5-10%	5-10%	1-5%	1-5%	5-10%	5-10%	1-5%	0%
Facilities' end of life	1-5%	1-5%	1-2%	1-2%	1-5%	1-5%	N/A	N/A

1 CRITERIA AREA 1: ICT SYSTEM PERFORMANCE

ICT performance concerns the ICT equipment and this criteria area covers aspects related to the IT system design and/or operation which significantly affect its environmental performance. These aspects address the identified hotspots at an IT system level.

The key areas of improvement at an ICT system level are as follows:

a. ICT energy efficiency.
b. ICT utilisation.
c. ICT Equipment Operating Range.
d. ICT material efficiency and hazardous substances.

1.1 Criterion proposal: Server energy efficiency

1.1.1 Background

Servers are the main contributors towards the energy consumption and environmental impacts of a data centre. An indication of the split between ICT equipment and M&E infrastructure is illustrated in Figure 11. It can be seen that, according to projections from the US, servers will continue to account for the majority of ICT equipment electricity consumption, followed by storage.

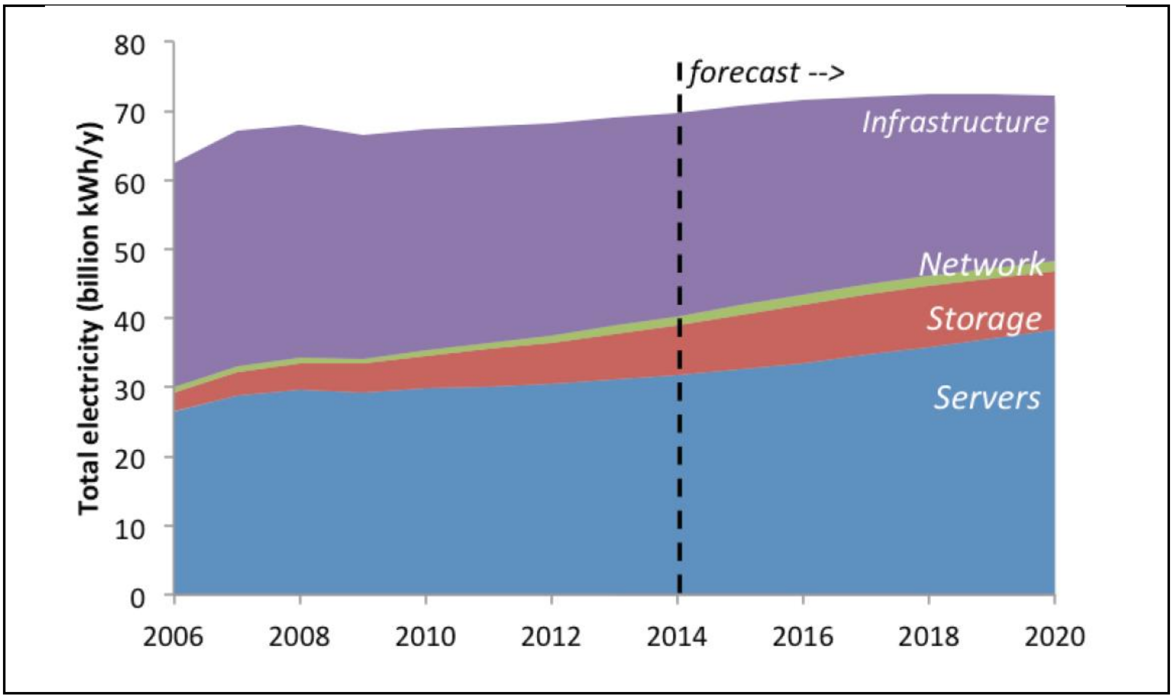


Figure 11: Total electricity consumption by technology type in a data centre[37]

Higher efficiency products can complete the same amount of work for less energy. However, since the major energy-consuming components within a server (CPU, RAM, storage) tend to be sourced from the same suppliers there is a limited possibility to differentiate between products and the efficiency difference between similar competing server models is relatively small. However, higher *performance* products, i.e. products that are able to complete work faster, tend

[37] Source: US Department of Energy (2016).

to have significantly higher *efficiency*, i.e. they complete the work using less energy, (see Figure 12) and increasing the performance and efficiency of servers by ensuring utilisation levels are maintained or increased can reduce the total number of servers and achieve significantly higher energy savings. The total energy consumed by the fleet of servers is called the deployment power and can be calculated if there is sufficient data. This is generally based on an assessment of the amount of work to be done and calculating the number of servers needed and the server configuration, i.e. the speed and quantity of the components installed in the server such as CPU, RAM, and storage. The power consumption can then be tested directly from the server or assessed using server efficiency metrics.

The variation in efficiency for the same performance in servers shown in Figure 12 is due to configurations that have different characteristics. The two variables in Figure 12 form part of the proposed metrics for server efficiency described further in this section and in Annex I.

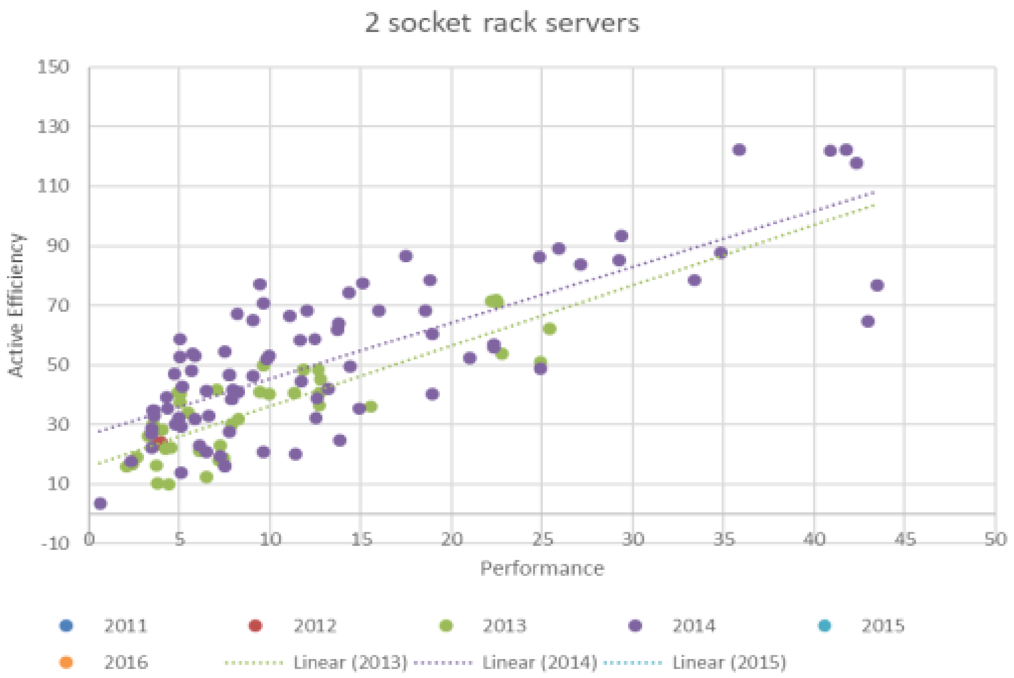


Figure 12: Relationship between performance (transactions/second) and active efficiency for two-socket servers (transactions/Joule) (higher is more efficient)[38]

There are two main criteria for assessing the efficiency of a server, the idle power efficiency and the active power efficiency. Both the idle and active power can be tested using the SERT methodology. SERT v2.x is the test method used by the new EU enterprise server Ecodesign Implementing Regulation (EU) 2019/424[39] and the ENERGY STAR for Enterprise Servers Version 3.0. The test method is currently in the process of standardisation by ISO under the Server Energy Efficiency Metric (ISO 21836).[40]

The SERT test method measures the active power and performance of the server under 12 different worklets that test the performance of three subsystems, the CPU, memory and storage. The performance is tested at a number of different utilisation levels, generally 25% and above.

[38] Comments from European Commission on ENERGY STAR specification for Computer servers v3.0 Draft 1.

[39] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 617/2013 (Text with EEA relevance).

[40] https://www.iso.org/standard/71926.html

The worklets are associated with common types of operations performed by the server and each worklet tests the server at a number of different utilisation levels. The test output for a single server produces around 100 data points to give a detailed description of the server's active performance and power consumption. The volume of data means that comparing servers using the test data is difficult, and a metric is required to help interpret the test results.

SERT also measures the idle power which is a simple measurement of the server not actively doing useful work. Idle MEPS (Minimum Energy Performance Standard) criteria have been proposed for EU Ecodesign as well as ENERGY STAR.

The ENERGY STAR v2 specifications are currently in effect; however, they were developed in 2013 and due to the rapid rate of improvement and technology development may no longer represent a performance improvement. The ENERGY STAR Computer Server Specifications Version 3.0 were approved in September 2018 and took effect on June 2019 and computer servers should be tested using SERT Version 2.0.1. However, already during this transition period, manufacturers may elect to have their Certification Body (CB) certify eligible products to the Version 3.0 requirements.

The ENERGY STAR v3.0 introduces Active State efficiency score (Eff_{ACTIVE}) thresholds for different server types. EPA believes that the active state efficiency metric adequately incorporates idle power behaviour and therefore there is no longer a stand-alone idle state efficiency target. The active state thresholds have been used as the basis for the proposal of a core technical specification on Active State efficiency.

Draft metrics for evaluating server active efficiency have been developed which use the power and performance test data produced by the SERT test. The metric is based on the geometric mean of the SERT v2 worklet test results and this extended approach has been proposed for use as the basis for both ENERGY STAR and Ecodesign. The combination of the extended SERT v2 test method and the metric sometimes also referred to as SEEM (Server Efficient Metric) will form the basis for a new standard, EN 303 470:2018, which has been mandated by the European Commission to support the forthcoming Ecodesign implementing measure and which is currently under development by the European Telecommunications Standards Institute (ETSI).

SERT and the metrics do not test the efficiency of specialist products and components such as graphics cards and high-performance computers.

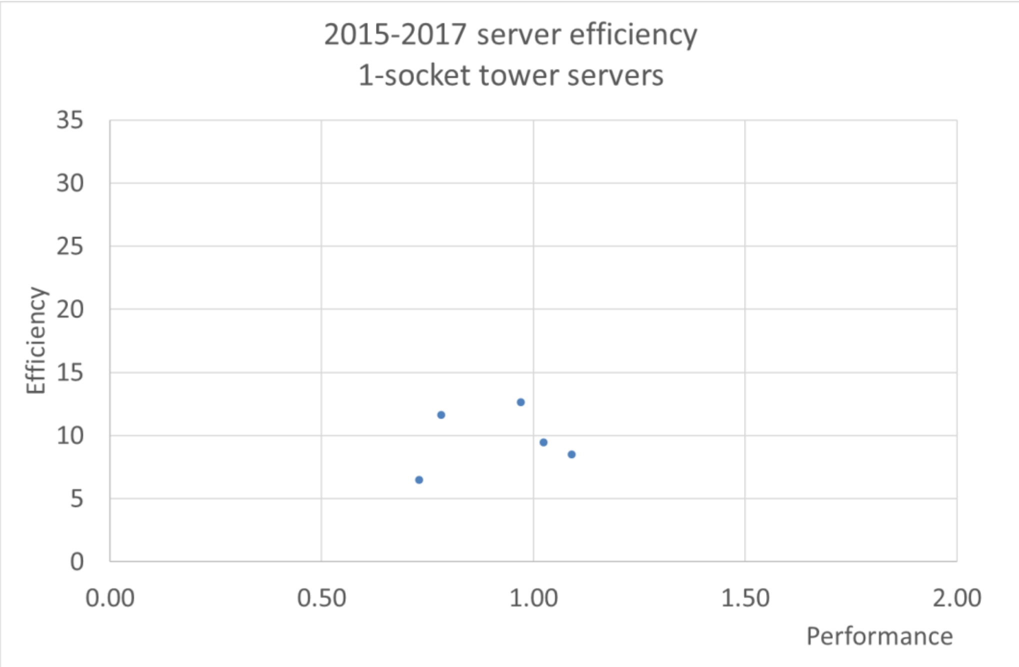
The advantage of the SERT-based active efficiency metric is that it has been designed to compare the efficiency of both a single server as well as a large number of servers being deployed. A higher active efficiency will indicate a lower active deployment power for an 'average' workload. However, if the aim is to match the anticipated workloads under a contract as accurately as possible, other approaches such as the use of 'workload traces' would be required.

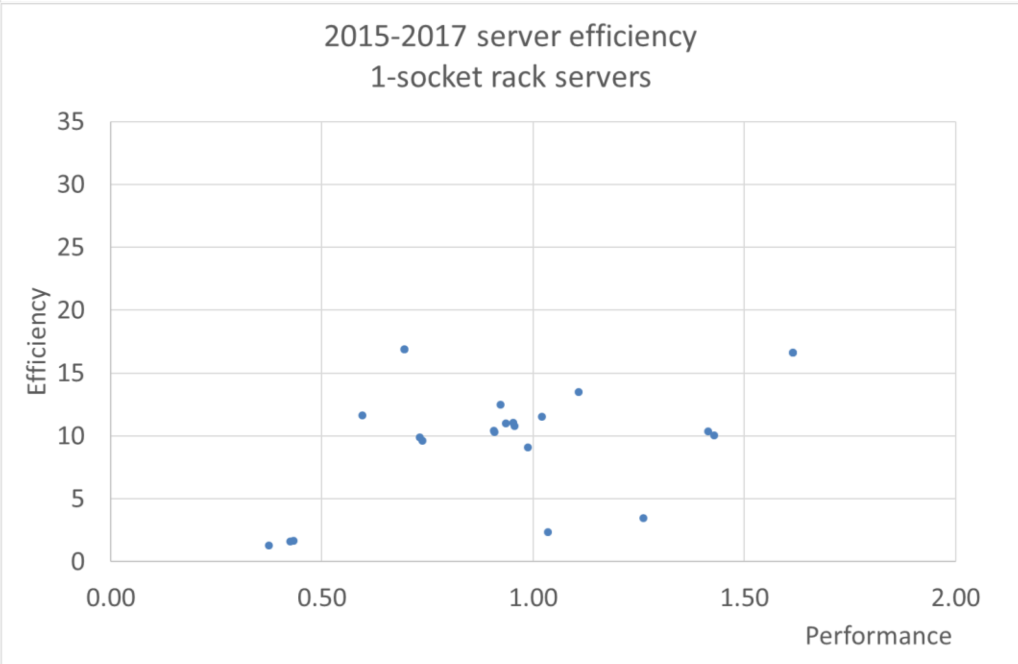
This simulates the behaviour of the server under a specific workload, generally by analysing and replicating the existing workload on the current servers, but it will need to be developed and standardised by the procurer for each individual contract before contracting. For large procurement processes, this may be a useful option. However, historic workloads are not always available for new services and may not always be a good indication of future needs if new technology and service approaches are adopted. Therefore, it is not effective for every situation and would require a relatively in-depth level of understanding which may only be available from an independent contractor to help advise and design the procurement process.

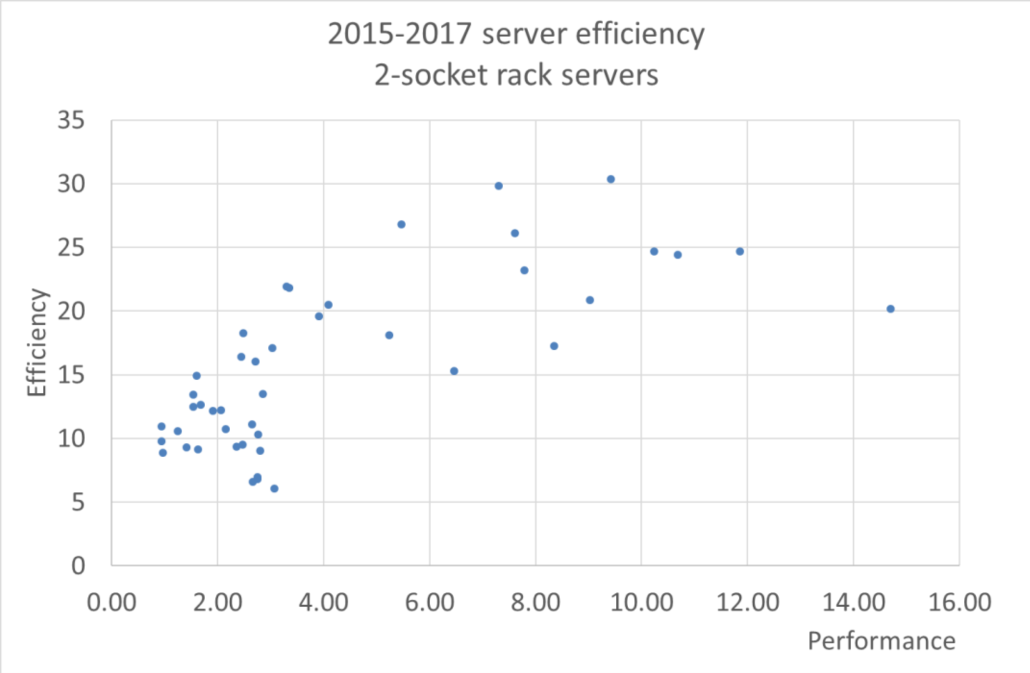
Pending the new Ecodesign implementing measure, there are currently no active efficiency criteria in effect for servers. The ENERGY STAR v2 database provides aggregated test results but these are based on SERT v1 and are calculated using a method which is weighted towards 100% utilisation and is considered unrepresentative of real-life utilisation and efficiency.

Commission Regulation (EU) 2019/424 includes a minimum requirement on both active efficiency and idle power and requires the reporting of idle and active efficiency information. By providing information about active efficiency, the market may become more aware of the difference between low- and high-performance servers. They may therefore be more likely to purchase high-performance servers and maintain utilisation levels through virtualisation and similar technologies.

Different server types (one-, two- or four-socket) or rack / tower / blade or multi-node) are characterised by different active state performance (Figure 13). Data collected in the framework of the EU Ecodesign preparatory studies for servers and data storage products has been used as the basis for the proposal of a comprehensive criterion, aiming for the highest level of environmental performance available on the market. Thresholds are provided in the criteria for those products that are understood to be relevant for the data centre's procurements.







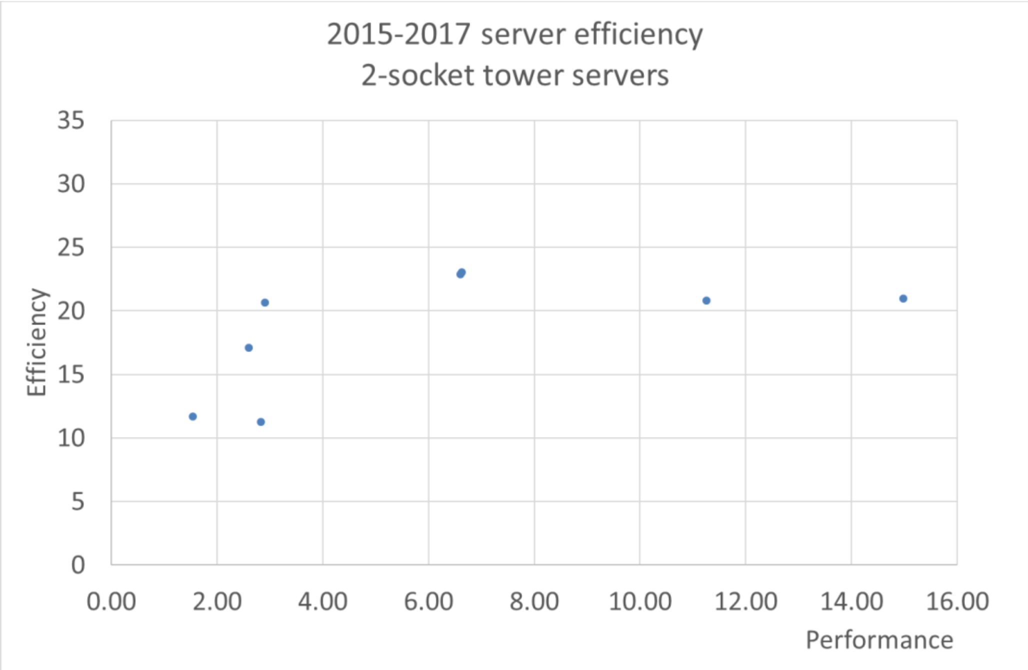


Figure 13: Analysis of server efficiency by server type carried out in the framework of the Commission Regulation for servers and data storage

1.1.2 Life cycle environmental hotspots and potential improvements

Servers are the most energy-consuming product in the data centre and reducing IT equipment consumption consequently also reduces the energy consumed in the mechanical and electrical systems. In total, ICT equipment is responsible for approximately 60% of the energy consumption of a data centre (considering a PUE of 1.65[41]), and servers account for the largest share of this overall ICT equipment consumption; therefore, it is important to address server efficiency. In addition, higher performance in servers reduces the manufacturing impacts, since fewer servers are needed. While there are potential improvements in storage and network equipment, the relatively small impact in relation to total data centre impacts mean they are not considered.

However, because efficiency and performance improve so rapidly, the use of the most cost-effective solutions together with frequent replacement of servers results in an increase in impacts from manufacturing, including greater resource and toxic emission impacts. Conversely, improved efficiency and performance may also avoid the need for data centre expansion and the manufacturing of new mechanical and electrical equipment since more work can be done within the limited data centre power infrastructure capacity and space available. The refresh rate with the minimum environmental impact will depend on the specific operating conditions, including the utilisation, server configuration and its associated embodied energy and resource use.

Selecting an efficient server does not mean a new server must be purchased. It is possible to upgrade existing servers or purchase refurbished servers which could reduce the life cycle impact and costs. However, server upgrades are not considered in the GPP criteria due to the additional operational complexity and sometimes limited life cycle benefit. A major upgrade includes the replacement of the majority of the electronic components, leaving only the motherboard and case. Since these can have the highest environmental impact in manufacturing, the overall life cycle savings may not be as significant. During operation, component upgrades can cause the server to behave abnormally if there are compatibility issues or if the components are not handled properly. Due to the high reliability requirements, the potential problems are generally not considered to be worth the risk. Instead, it is better to upgrade during refurbishment where professional handling and testing can be performed.

The impact assessment carried out for the Ecodesign preparatory study shows that an energy labelling requirement on server efficiency would yield on average an approximately 4-6% overall reduction in server energy consumption and diminish over 7 years, while a labelling requirement and a minimum requirement on server efficiency would yield a roughly 5-8% overall reduction in server energy consumption and diminish over 7 years. The cutting edge of the market is estimated to have two to three times higher savings potential (around 8-18%).

1.1.3 Life cycle cost implications and trade-offs with potential environmental improvements

Higher efficiency servers may incur higher costs but reduce life cycle energy consumption, leading to varying levels of net savings. The Ecodesign impact assessment for servers and data storage products shows that a typical two-socket rack server with an average efficiency costs around EUR 4 160 per unit, and by increasing its efficiency, the purchase cost is increased by EUR 3-178 depending on the stringency of the minimum requirements. However, during a product lifetime of 5 years, there are still net savings to be obtained in the range of EUR 176-236 euros. Higher performance servers tend to be higher cost but fewer servers are needed and energy savings are even greater. This means that there are also net savings.

[41] Expected value for a new enterprise data centre according to the Ecodesign impact assessment for servers and storage.

Because efficiency improves very rapidly and servers are operating continuously, it is often cost-efficient to replace servers every 3-4 years. This also increases the computing capacity of the data centre and avoids the need to expand the infrastructure and its associated costs.

1.1.4 Verification

The calculations of active state efficiency and idle power for the procured server models must be based on the ETSI EN 303470[42] standardised methodology and provided as proof of performance. If different configurations of the same server model are provided by the bidder then the test results of a randomly selected configuration(s) can be requested (and the declared value shall be the value of the high-end configuration)[43]. Alternatively, the verification can be performed by checking test results against a similarly configured server of the same model.

For deployed power demand, the tests performed according to the methodology in Annex B detailed in ETSI EN 303470 can be provided for verification.

It could be possible to apply this criterion to managed services if the equipment models used to provide the service can be listed together with proof of performance and their purchase can be verified by an auditor. The result of the audit could be provided as proof of performance.

1.1.5 Market implications and functionality

An estimation of the average active efficiency pass rate for the servers in the EU market (based on a dataset including server configurations from 2015) is provided in Table 10. It shows that servers meeting the thresholds set in the core and comprehensive criteria TS1 are commonly available in the EU market.

Table 10: Average pass rate for the proposed active efficiency thresholds

	Core criteria % pass	Comprehensive criteria % pass
1-socket	43%	21%
2-socket	48%	33%

Server efficiency in the market changes rapidly, therefore a periodic revision of the active efficiency threshold is necessary.

Setting an efficiency target based on a static metric could result in a lower efficiency of servers for special applications, because in order to meet this metric target the server may no longer be fit for the specific applications, and therefore no longer energy-efficient for the specific tasks. Lower efficiency results in less work being done since the total power consumption is limited by the infrastructure.
A more specific test using workload traces would not impact functionality since testing is based on the desired functionality, assuming this functionality does not change in the future.

[42] Final Draft of ETSI EN 303 470 V1.1.0 (2019-01) "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for servers" available at: https://www.etsi.org/deliver/etsi_en/303400_303499/303470/01.01.00_30/en_303470v010100v.pdf

[43] According to the Ecodesign implementing measure for servers, high-end configuration means a server with the combination of two data storage devices, processor with the highest product of core count and frequency and memory capacity (in GB) equal to or greater than 3 times the product of the number of CPUs, cores and hardware threads that represents the highest performance product model within the product family. All memory channels shall be populated with the same DIMM raw card design and capacity; if the verification is performed on a randomly selected or ordered model configuration, the declared values shall be the values for the high-end performance configuration.

1.1.6 Applicability to public procurement

A criterion aimed at improving server energy efficiency would be relevant to contracts that require the IT equipment to be specified. These would include, or accompany, enterprise and co-location data centres but not cloud or managed services. A technical specification could be appropriate given that both ENERGY STAR and the forthcoming Ecodesign legislation[39] establish performance metrics and thresholds for the Best Available Technology (BAT) in the market that would differentiate performance in the market.

Instead, award criteria could be used to encourage higher efficiency. A focus on idle state could also be chosen in the case of a low anticipated utilisation pattern of the servers. A low or sporadic level may suggest a focus on idle state whereas a medium to high level may suggest a focus on active state. Moreover, in the case of the latter, a test approach based on the actual workload could be specified in larger contracts, so as to predict as accurately as possible the likely performance. Reporting of the anticipated deployment power in conjunction with the efficiency level gives a complete picture of the energy consumed by the servers, which can also be used to inform other criteria and to compare with metered energy consumption.

For central government purchasing in the EU, server models that meet the highest performance or Ecodesign benchmarks shall be purchased. This requirement is laid down in Annex III to the Energy Efficiency Directive.

Such a criterion would be difficult to apply to scenarios where data centre services are outsourced. This is because in practice it may be difficult to establish a relationship between the service and specific servers used to provide the service.

1.1.7 Summary of stakeholders' comments following AHWG1

In general, the stakeholders welcomed criteria which addressed the server power consumption. However, there were a number of concerns about the metrics and criteria used. Stakeholders were concerned that ENERGY STAR, particularly idle power, does not reflect real energy consumption and would not minimise energy use, and that active efficiency benchmarks had yet to be developed. The power is also very dependent on the configuration, which is not reflected by ENERGY STAR or Ecodesign requirements. There was also concern about the use and complexity of SERT and whether it would be replaced by SEEM. It was recommended instead that a KPI was used that enabled the estimation of the total power consumed by the server fleet to deliver the workload required.

In addition, one stakeholder raised the influence of software on the efficiency and the importance of software criteria.

There appears to be confusion around the use of SERT and the accompanying active efficiency metric. This has been clarified and reference to ETSI EN 303 470 has been made instead. The criteria have also been aligned with Ecodesign rather than ENERGY STAR and award criteria rather than technical specifications have been proposed.

In addition, three award criteria are proposed which provide different options for assessing the server efficiency and recommended use cases, all of which include an assessment of the individual server and deployed power. This addresses the differences in the utilisation levels and the capabilities of the contracting authority to develop workload-specific KPIs and testing protocols.

The complexity of assessing software means that it has not been covered in these GPP criteria.

1.1.8 Summary of stakeholders' comments following AHWG2

Most of the stakeholders agreed to refer to the active efficiency thresholds from ENERGY STAR computer server requirements Version 3. SERT testing individual configurations for procurement purposes would be prohibitively expensive and time-consuming.

Several stakeholders commented that setting idle power limits is not a productive means of distinguishing server efficiency and that it may lead to unwanted outcomes and reduce data centre efficiency.

However, minimum thresholds for idle state power are introduced by the Ecodesign Regulation (Commission Regulation 2019/424) and the award criterion AC1 is proposed based on the level of improvement upon the minimum performance thresholds required by this Commission Regulation. Moreover, in order to avoid unintended consequences, it was clarified that this criterion is only applicable after the active efficiency criterion (TS1).

1.1.9 Final criteria proposal

A Technical Specification is proposed for the server active efficiency. Active efficiency thresholds applied under ENERGY STAR Version 3 (approved in September 2018) are taken into consideration to set the core criterion (TS1 core).

The comprehensive criterion for active efficiency (TS1 core) includes more ambitious thresholds compared to the values applied by ENERGY STAR Version 3.0. Servers complying with these thresholds for active efficiency are considered commonly available on the market and the application of these thresholds is not considered an obstacle to the opening up of public procurement to competition.

Ecodesign minimum requirements for servers' idle state power are taken into consideration as a reference for the proposal of an Award Criterion on idle state (AC1)..

Award criteria are developed based on the relative efficiency and deployed power (AC2). This is split into two possible criteria, based on EN 303 470 or using a contract-specific testing method.

Some stakeholders highlighted that verification for installed servers is not practical and should not be mandated. A verification option is suggested allowing the testing under the configuration (processor SKU, memory capacity and DIMM size, storage device type and I/O devices) to be used.

Summary rationale for the final proposal
The revised version of this criteria area includes the following:

- A core Technical Specification for the active efficiency based on ENERGY STAR v.3 thresholds. These thresholds are considered to provide performance benchmarks that reflect the most recent market analysis for well-performing servers.
- A comprehensive Technical Specification for the active efficiency based on more ambitious thresholds. These thresholds provide performance benchmarks that reflect the current cutting edge of the market based on analysis in support of the Commission Regulation (EU) 2019/424 for Servers and Data Storage. In the case of multiple server configurations available for the same model, the verification can be based on the high-end model or on the specific configuration to be used.
- A criterion awarding additional points based on the idle state power performance of the servers. This criterion should only be used in combination with the active efficiency criterion because improved idle state performance should not be at the expense of active efficiency given the objective of the GPP criteria to support higher equipment utilisation.

- Considering the Ecodesign Commission Regulation ((EU) 2019/424) for servers and data storage, test results obtained for the purpose of CE marking may also be used as verification. This is because the proposed GPP criteria reflect the metrics and methods introduced in this Regulation.
- Server deployed power demand has been retained as it is considered to be the best method for understanding the performance of the whole collection of servers to be deployed in the data centre. Reference has been added to server configurations in order to make the analysis more representative.

Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATION	
TS1 Server active state efficiency For each server model deployed in the data centre the calculated active state efficiency score (Eff_{ACTIVE}) must be greater than or equal to the minimum Active State efficiency thresholds as listed below.	**TS1 Server active state efficiency** For each server model deployed in the data centre the calculated active state efficiency score (Eff_{ACTIVE}) must be greater than or equal to the minimum Active State efficiency thresholds as listed below.

Core criteria thresholds:

Product Type	**Minimum Eff_{ACTIVE}**
1 socket	
Rack	11.0
Tower	9.4
2 sockets	
Rack	13.0
Tower	12.0
Blade or Multi-Node	14.0
4 sockets	
Rack	16.0
Blade or Multi-Node	9.6

Comprehensive criteria thresholds:

Product Type	**Minimum Eff_{ACTIVE}**
1 socket	
Rack	13.0
Tower	11.0
2 sockets	
Rack	18.0
Tower	12.0
Blade or Multi-Node	20.0
4 sockets	
Rack	16.0
Blade or Multi-Node	9.6

Core criteria	**Comprehensive criteria**
Verification The tenderer must provide the calculation of ctive state efficiency for each server model based on the EN 303470 measurement methodology. If different configurations of the server models are proposed to be used then the tested performance of the high-end configuration must be declared. Alternatively, verification can take the form of test results for a model with the specific configuration to be used. Test results obtained for the purpose of CE marking or label qualification carried out according to equivalent test standards may be used as verification.	**Verification** The tenderer must provide the calculation of active state efficiency for each server model based on the EN 303470 measurement methodology. If different configurations of the server models are proposed to be used then the tested performance of the high-end configuration must be declared. Alternatively, verification can take the form of test results for a model with the specific configuration to be used. Test results obtained for the purpose of CE marking or label qualification carried out according to equivalent test standards may be used as verification.

AWARD CRITERIA

AC1 Server idle state power

(same for core and comprehensive criteria)

This criterion should only be used in combination with TS1. Servers that comply with TS1 may then be awarded additional points for their idle state power performance.

It is only applicable if the product type (e.g. rack or tower servers, 1-socket or 2-socket servers) and the system characteristics affecting power consumption (e.g. CPU performance, server with or without power redundancy, memory, drives, additional devices) are described in the technical specification.

With the exception of resilient servers, HPC (high-performance computing) servers and servers with integrated APAs (auxiliary performance accelerators) may be awarded a maximum of x points [to be specified]. Points are to be awarded to server models based on the level of improvement upon the minimum performance thresholds, as calculated for a server type in accordance with Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products.

Verification

The tenderer must detail the calculation of the individual server idle power based on EN 303470 testing and in line with Commission Regulation (EU) 2019/424 (see also the accompanying explanatory note). If different configurations of the server models are proposed for use, then the tested performance of the high-end configuration must be declared. Alternatively, the tenderer can demonstrate compliance by providing a test report for a similarly

configured server of the same model.	
EXPLANATORY NOTE: Calculating the idle state power according to Commission Regulation (EU) 2019/424 EN 303 470 is based on the SERT Version 2 testing methodology and includes a specific idle power test, active power calculation and active efficiency metric. Under the Ecodesign requirements, this information must be made publicly available by manufacturers. In order to use the core criteria, the minimum threshold for each server type must be calculated based on the additional server components that are to be included in the offer and included in the call for tender. The Ecodesign method is detailed in Appendix III of this criteria document. Each threshold must be determined according to the following equation: $P_{idle} = P_{base} + \sum P_{add\_i}$ where Pbase is the basic idle state power allowance in Table 3, and ∑Padd_i is the sum of the idle state power allowances for applicable, additional components, as determined per Table 4. For blade servers, Pidle is calculated as the total measured power divided by the number of installed blade servers in the tested blade chassis.	
	AC2 Server deployed power demand *This criterion is recommended if the contracting authority wishes to invite bids based on the power consumption of the anticipated IT workload and then to monitor this during operation. To be used in conjunction with CPC1.* Points will be awarded based on the deployed power estimate calculated for all the server types and their configurations to be deployed in the data centre. The performance of the different server configurations may be interpolated from high- and low-end test data for the configurations. The calculation may be based on the workloads specified by the contracting authority. Maximum points will be awarded to the offer with the lowest deployed power. All other offers will be awarded points in proportion to the best offer. **Verification** The tenderer must detail the calculation of the deployment power based either on [*to be specified*]: • the EN 303470 deployed power method with standardised workloads, or • a testing protocol to be specified by the contracting authority. Where the performance of configurations has been interpolated from test data, information on the methodology used must be provided.
CONTRACT PERFORMANCE CLAUSES	
	CPC1 Monitoring of IT energy consumption *To be included when the data centre is operated by a third party. To be used in conjunction with AC2.* The contractor must provide monthly and annual data for the IT equipment that is located in the data centre. Monitoring of energy consumption must be in line with the requirements and recommendations of standard EN 50600-2-2.

1.2 Criterion proposal: IT equipment utilisation

1.2.1 Background

IT utilisation refers to the amount of work being done as a proportion of the total IT capacity. Historically utilisation has been very low, estimated at 10% or below since each physical server was being used for only one job or application at a time. Utilisation of IT equipment can be increased in a number of ways. For servers, which are the most significant energy consumer, virtualisation[44] and cloud computing can be used which allows multiple virtual servers and applications to be run on a physical server with minimal risk of interfering with each other or creating security risks. Capacity optimisation methods for storage equipment, in particular thin provisioning, can ensure that available physical storage space is used to store data rather than being left as spare capacity in anticipation of future requirements. These approaches are already very commonly applied to current server set-ups due to the cost and environmental benefits. The maximum utilisation rate that can be achieved will depend on the work being performed on the server, including serviceability and maintenance metrics.

There are no widely applied utilisation metrics currently in use by current data centres. CPU utilisation is most frequently referenced as an indicator of utilisation and has been formalised in in the standard ISO 30134-5 'IT Equipment Utilization for Servers'. This is a simple measurement of the CPU utilisation taken at fixed intervals and averaged over a period of time, typically a year, by use of a performance monitoring tool provided by a server operating system. As stated within the standard, 'comparison between data centres should be approached with caution'. In order to address this, it would be required to develop more guidance. The risk is that the limited focus of the metric is not relevant for all types of workloads which may be limited by other factors. In particular, the memory capacity and memory bandwidth can also cause bottlenecks in the overall server performance, which means the data cannot get to the CPU in time. Conversely, too much memory capacity will be underutilised and result in additional energy consumption for no additional performance benefit.

Virtualisation ratios, which calculate the average number of virtual servers per physical server, are also used as an indicator of utilisation. This is even more difficult to compare between data centres due to the large number of factors influencing the ratio, in particular the type of applications and work being done and the type of hardware used. In addition, this could also notbe applicable to cloud computing.

A more complete measure of utilisation can be determined by measuring the four main components of an IT service whose capacity and utilisation can be measured; these are CPU, memory, network[45] and storage. The utilisation of each component will vary depending on the specific application(s). Based on this, The Green Grid have proposed a metric for the efficiency of IT utilisation across a data centre[46]:

ICT Capacity (ICT_C) – provisioned at theoretical maxima:
$ICT_C = \{CPU_C, MEM_C, STOR_C, NET_C\}$
ICT Utilisation (ICT_U) – percentages used of theoretical maxima:
$ICT_U = \{CPU_U, MEM_U, STOR_U, NET_U\}$

The metric proposes a method to estimate the total computing capacity of the data centre, consisting of the processing, memory, storage and network. This recognises that storing and transporting data within and outside the network is an important aspect of the overall data centre function and efficiency as well as the processing occurring within the CPUs, and more useful to

[44] Virtualisation refers to the act of creating a virtual (rather than actual) version of computer hardware platforms, storage devices, and computer network resources.
[45] Referring to internal and external network bandwidth.
[46] https://www.thegreengrid.org/en/resources/library-and-tools/436-WP#72---ICT-Capacity-and-Utilization-Metrics

the data centre operator seeking to optimise utilisation. While The Green Grid metric appears to be more complete, it is also not widely adopted and may be less mature than ISO 30134-5.

In addition to monitoring utilisation, there are a number of services, software and tools which can provide ongoing optimisation and management of utilisation for cloud and virtualised platforms by moving workloads across servers to ensure that servers are highly used and in theory reducing the total number of servers required or switching unused servers into lower power states. However, discussion with industry experts suggests that in reality servers are never switched off even when unused.

Optimisation can be achieved manually but more sophisticated automated capacity optimisation services such as Densify and TSOLogic are able to monitor use patterns and through highly automated statistical and deep learning techniques can forecast future use and optimise the servers more effectively than other options. Automated platforms such as VMWare VSphere provided centralise monitoring, management and reallocation which makes more frequent improvements easier. Although these services are primarily aimed at cost savings on public clouds, enterprise data centres and server rooms, they also create energy savings as well as provide monitoring and reporting of utilisation.

The maximum utilisation rate that can be achieved will depend on the work being performed on the server, including serviceability and maintenance metrics. This means that the utilisation achieved must be considered within the context of the contract.

1.2.2 Life cycle environmental hotspots and potential improvements

One of the LCA studies reviewed identified best practices for enterprise data centres with virtualisation, showing a reduction of about 15 times in environmental impacts compared to the worst case and about 7 times compared to the average data centre performance.

Utilisation levels for IT equipment may be as low as 10-15% but could be raised to above 50%, although not for all workloads, suggesting that hardware could be reduced by 3-4 times and energy consumption reduced by approximately 50% (see Table 11).

Virtualisation reduces IT equipment requirements, increases IT utilisation and M&E part loads, and tends to encourage good data centre designs, which are well managed (low PUE, etc.). Older case studies based on virtualising physical servers show energy savings of 40% or greater[47,48]. However, these comparisons are all made against unvirtualised servers which does not reflect the current market situation.

Since storage and network equipment is a small proportion of the total data centre energy consumption (see figure 11), their utilisation rate is not included in this criterion.

1.2.3 Life cycle cost implications and trade-offs with potential environmental improvements

Increasing utilisation reduces costs because more work is achieved with the same amount of hardware. In addition, the energy costs are reduced since there is less hardware which also reduces mechanical and electrical costs. It is very difficult to estimate specific costs due to the lack of information on current utilisation and possible utilisation levels.

[47] https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/e-server_e_server_case_studies_en.pdf

[48] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.465.6398&rep=rep1&type=pdf

Case studies quoted by the US EPA on virtualisation in best case scenarios have shown cost savings of approximately 60% [49] taking into account all factors including software and administration costs. Again, these comparisons are made against unvirtualised servers.

1.2.4 Verification

Verification can be complicated since measurement of the IT equipment utilisation is difficult and requires data to be collated almost in real time from every piece of hardware equipment. Moreover, to verify the performance of a Managed Service Provider providing cloud services would suppose a verification across a portfolio of sites and according to a standard protocol. Ensuring the data is gathered and reported correctly requires expert knowledge. In addition, utilisation metrics are currently not considered to be suitable for comparing data centres on an arbitrary basis. Some data centre service providers may also consider utilisation commercially sensitive and confidential as it provides them a competitive advantage.

However, there are simple tools for monitoring and reporting CPU utilisation from the server which are suggested in ISO 30134-5. ISO 30134-5 also provides clear guidelines regarding the measurement and calculation of the CPU utilisation at intervals of between 1 minute and 1 hour. Medium and larger data centres will have Data Centre Infrastructure Management (DCIM) tools which can automate collection and reporting of utilisation while software is available for smaller data centres.

The US Government Data Centre Optimisation Initiative requires utilisation targets to be met by the end of 2018. Servers in Government-operated data centres must not be idle for more than 35% of the time on average. This must be continuously monitored and data collected by an automated system. However, it does not specify a CPU utilisation, but instead a virtualisation ratio of 4:1.

1.2.5 Market implications and functionality

Although most data centre operators and owners are aware of their utilisation and they have methods to calculate and measure it, it is not known precisely how many data centres are measuring utilisation and how many apply the Green Grid utilisation metric (although Gartner predicts server virtualisation to be achieving a high uptake[50]). It appears that the market has moved to improve and in some cases measure utilisation but a standard metric does not appear to exist. Since the Green Grid's metric was only proposed in 2017 it is highly unlikely that it is widely used. The currently under publication ISO 30143-5 metric accounts for only one aspect of server performance, although this could be a starting point, for example, on CPU utilisation.

Recent estimates of utilisation (not based on the Green Grid metric) for data centres of different sizes are as shown in Table 11. There is a clear trend for higher utilisation as size increases and setting utilisation criteria may limit the market to larger data centres where it appears progress has been made.

[49] https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center/server_virtualization

[50] http://www.gartner.com/newsroom/id/3315817

Table 11: Recent estimates of utilisation rates for different server types[51]

Server type	Utilisation 2000-2010	Utilisation by 2020
In-house	10%	15%
Managed Service Providers	20%	25%
Hyperscale servers	45%	50%

While almost all current applications are suitable for consolidation or virtualisation, there are still some applications, particularly legacy applications, which cannot be virtualised or moved to newer equipment without high risk or difficulty. It may therefore not be possible to achieve very high utilisation levels in all cases, depending on the business and the amount of risk they can accept.

1.2.6 Applicability to public procurement

This metric, which although commonly measured has only recently acquired a standardised basis in ISO 30134-5, could have potential for use in contracts for the consolidation and virtualisation of existing data centres, thereby enabling assets to be used more efficiently, and in the contracting of managed services. Requirements have been put in place by the US Government but for internal data centres.

Whilst generalised thresholds cannot be set, tenderers could be encouraged through an award criterion to propose optimisation routes in response to the contracting authorities' data handling and processing needs. Moreover, the deployment of specific tools to optimise utilisation on an ongoing basis could also be rewarded.

In general, because there is not yet a consensus on a standardised metric at data centre level, instead only currently an industry proposal and a forthcoming standard for servers, utilisation may be suitable to introduce as an award criterion to encourage a focus on this performance aspect.

1.2.7 Summary of stakeholders' comments following AHWG1

In general, there was strong support for a criterion to maximise utilisation since it has a large impact on efficiency and current utilisation is very low but there were concerns regarding the criterion proposed.

Stakeholders' comments stated that CPU and memory utilisation were most important and that it was simple to monitor and report CPU (and memory) utilisation in line with ISO/IEC 30134-5 rather than the Green Grid metric. The importance of a short monitoring interval was also raised, with a criterion suggested to award more granular monitoring. A power management criterion in conjunction with utilisation was also suggested.

One stakeholder was concerned that utilisation targets were not appropriate because different workloads have different optimal utilisation and felt ongoing utilisation optimisation would be a more appropriate criteria. This should reward the best continuous optimisation strategy, i.e. using services such as Densify.

A number of comments were made about the relationship between correctly configuring the server to maximise utilisation level and reducing energy consumption. Beyond the server utilisation, the importance of the process used to choose from different options such as co-location, cloud or MSP to deliver the service was also raised.

[51] https://www.thegreengrid.org/en/resources/library-and-tools/443-Applying-ICT-Capacity-and-Utilization-Metrics-to-Improve-Data-Center-Efficiency

1.2.8 Summary of stakeholders' comments following AHWG2

In general, there was strong support for a criterion to maximise utilisation and to refer to an ISO standard. It was highlighted that utilisation should be stated as an annual average.

Some stakeholders also highlighted the role of software management tools in minimising and optimising the IT footprint and delivering capital and operating cost reductions, if properly utilised.

1.2.9 Final criteria proposal

Summary rationale for the final proposal

- Tenderers are to be encouraged through an award criterion to propose optimisation routes in response to the contracting authorities' data handling and processing needs.
- Only minor further changes have been made. It has been clarified that the utilisation rate should be evaluated as 'annual' average. Reference has been left open in the Selection Criteria to previous contracts or the experience of personnel. A clear reference to utilisation management tools and software is included.

Final criteria proposal

Core criteria	Comprehensive criteria
SELECTION CRITERIA	
(same for core and comprehensive criteria) *To be included when the data centre is operated by a third party.* **SC1 Server utilisation** The tenderer must have relevant competencies and experience in optimisation of a server's utilisation. This must include server virtualisation services, utilisation management tools and software[52] and the consolidation of IT assets in data centres. **Verification** Tenderers must provide evidence of previous projects with similar workloads to achieve, maintain and improve the utilisation of IT equipment. This includes descriptions of methods used to optimise utilisation. Evidence accepted includes information and references related to relevant contracts in the last 3 years in which the above elements have been carried out. This evidence may relate to either relevant contracts or key personnel who will be involved in providing the service. This must also be supported by CVs for personnel who will work on the project and their relevant project experience.	
AWARD CRITERIA	
To be included when the data centre is operated by a third party. To be used in conjunction with CPC 4.2. *(same for core and comprehensive criteria)* **AC3 Server utilisation** Points will be awarded based on the anticipated annual average server utilisation level based on the contracting authorities' data handling and processing requirements. Points will be awarded in line with the following ranges: >70%: [specified] points 40-70%: 0.8 x [specified] points 25-40%: 0.5 x [specified] points **Verification** The tenderer must provide the modelling, calculations or estimations of the anticipated utilisation based on the tools described in SC1.	

[52] This could include virtualisation and optimisation of stored data through the use of compression, data de-duplication, thin provisioning, storage tiering and software-defined storage systems.

CONTRACT PERFORMANCE CLAUSES
CPC2 Monitoring of IT equipment utilisation *(same for core and comprehensive criteria)* *To be included when the data centre is operated by a third party. To be used in conjunction with AC3.* The contractor must provide periodical reporting of optimisation analysis and the achievement of utilisation targets agreed with the client during the specific IT project. The service provider must measure and report monthly the utilisation rate of the servers in the data centre based on ISO 30134-5.
EXPLANATORY NOTE: IT Capacity and Utilisation metric calculation method
Annual average IT server utilisation is calculated as follows: $$ITEUsv = \frac{1}{a}\sum_{i=1}^{a}[ITEUsv(t_0 + e \times i)]$$ Where: 'a' is the number of ITEUsv(t) measurements intervals over a year (all intervals should be same length); 't_0' is the starting time of measurement; 'e' is the interval of measurement, where e x a = one year. The interval should be between 1 min and 1 h (10 min default).

1.3 Criteria proposal: Temperature and humidity operating range

1.3.1 Background

The IT equipment creates the demand for power and cooling in the data centre. Selecting ICT hardware which is able to operate at higher temperatures can result in a reduction in the energy requirements for refrigeration and more free cooling hours. The specifications of IT equipment operating at temperature and humidity ranges in this section do not indicate that the white space should be continuously operated at the upper bound of these ranges; instead it allows greater flexibility in operating temperature and humidity to the data centre operator. See Section 2.3 for additional information.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has produced guidelines on temperature and humidity for air-cooled equipment. The recommended and allowable ranges for both temperature and humidity under the four ASHRAE classes are provided in the technical specifications table in Appendix I and Appendix II of this report.

The suggested operating mode is to control within the recommended range during everyday operation but with excursions permitted into the allowable range, for example during the hottest days of the year / during an interruption of power to cooling systems between mains failure and generator start-up / cooling recovery. Guidelines have also been produced for liquid-cooled equipment[53].

Given the entry into the market of server equipment with integrated water cooling circuits, ASHRAE introduced liquid cooling classes (W1 to W5)[54] with the following temperature ranges for each class: W1 2-17 °C , W2 2-27 °C , W3 2-32 °C, W4 2-45 °C, W5 > 45 °C (supply to IT equipment).

In terms of applicability, ASHRAE also describes the typical cooling technology needed to keep the water temperature within the classes. In the case of equipment operating in the W1 and W2 classes the temperature is controlled by the use of chillers and a cooling towers, but, depending on the data centre location, the use of an optional water-side economiser to improve energy efficiency is possible. In the case of Class W3 equipment, for most locations, the data centres may be operated without chillers. Some locations will still require chillers.

In the event that Class W4 equipment is used, to take advantage of energy efficiency and reduce capital expense, these data centres are operated without chillers.

In case of Class W5 equipment, the water temperature is high enough to make use of the water exiting the ITE for heating local buildings during the heating season and also potentially using technologies such as adsorption chillers for space cooling during the cooling season.

Several implementations of liquid cooling could be deployed, such as the coolant removing a large percentage of the waste heat via a rear door heat exchanger, or a heat exchanger located above or on the side of a rack. Another implementation involves totally enclosing a rack that uses air as the working fluid and an air-to-liquid heat exchanger to transfer the heat outside the rack. Another alternative uses coolant passing through cold plates attached to components within the rack. The coolant distribution unit (CDU) can be external to the datacom rack or within the datacom rack.

[53] ASHRAE Liquid Cooling Guidelines for Datacom Equipment Centers, Second Edition, 2013.

[54] ASHRAE's Evolving Thermal Guidelines. ASHRAE Journal, December 2011. Available at: https://datacentermanagement.nl/wp-content/uploads/2016/12/ASHRAE%E2%80%99s-Thermal-Guidelines.pdf

Innovative solutions on the market include immersed cooling systems. Servers operating in the W5 operating temperature range may trigger the use of immersed computer systems which could also have an impact on the district heating systems criteria elsewhere in the GPP.

1.3.2 Life cycle environmental hotspots and potential improvements

Selecting ICT hardware which is able to operate at higher temperatures can allow for a reduction in the energy consumption from mechanical and electrical (M&E) systems, determining the amount of energy consumption. Moreover, more free cooling hours and sizing for a higher maximum temperature can reduce the need for M&E equipment; a reduced refrigeration capacity may be installed and in some cases zero refrigeration design is possible.

A reduced maximum load also reduces the installation size for the supporting electrical infrastructure. This dematerialisation reduces the embodied impacts of the M&E plant. Reducing the M&E installed capacity can also allow the capital costs to be reduced.

1.3.3 Life cycle cost implications and trade-offs with potential environmental improvements

Cooling costs are one of the major contributors to the total electricity bill of large data centres. The reduction of cooling demand has a positive impact on the life cycle costs of a data centre under OPEX Facilities. Reducing the M&E installed capacity can also allow the capital costs to be reduced.

Designing servers which are able to operate at higher temperature costs an additional estimated EUR 30 per unit, therefore the purchase price is expected to be higher. However, the energy cost savings will outweigh this initial increase in purchase price.

1.3.4 Verification

The ASHRAE guidelines do not specify any test methods for the verification of the operating classes. However, the applicability of several test methodologies has been investigated. The ETSI EN 300 019-2-3 standard specifies test severities and methods for the verification of the required resistibility of telecommunications equipment according to the relevant environmental class. Operating Class 3.1 is defined according to ETSI EN 300 019-1-3 and applies to a permanently temperature-controlled enclosed location (e.g. data centres). In this class humidity is usually not controlled. The corresponding climatogram is shown in Figure 14.

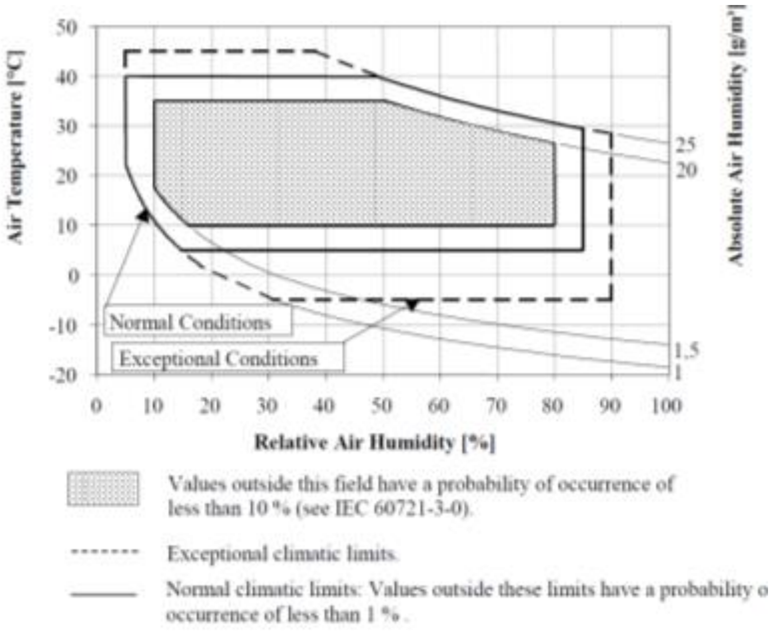


Figure 14: Climatogram chart

Source: ETSI standard EN 300 019-1-3, version 2.4.1

Tests specified by ETSI EN 300 019-2-3 for the temperature and humidity include tests within normal and exceptional climatic limits, in particular:

- air temperature (lowest and highest temperature conditions): 16-hour test;
- air temperature change: 0.5 °C/min: 3-hour test;
- humidity test (lowest and highest humidity conditions): 4-day test.

ICT product manufacturers usually evaluate the reliability performance of their products based on defined use conditions (operating environment) and using accelerated models for simulating specific numbers of years for the specific stress. The test conditions in Table 12 are provided only as examples[55] and are representative of thermal and moisture stress conditions for a server's processor.

Table 12: Example of stress test for a server's processor

Use Environment	Speculative Stress Condition	Example Use Condition	Example 7 yr. Stress Equivalent	Example 10 yr. Stress Equivalent
Slow small internal gradient changes due to external ambient (temperature cycle or externally heated) Fast, large gradient on/off to operating temp. (power cycle or internally heated including power save features)	Temperature Cycle	D T = 35 - 44°C (solder joint)	550-930 cycles Temp Cycle (-25°C to 100°C)	780-1345 cycles Temp Cycle (-25°C to 100°C)
High ambient moisture during low-power state (operating voltage)	THB/HAST	T = 25 -30°C 85%RH (ambient)	110-220 hrs at 110°C 85%RH	145-240 hrs at 110°C 85%RH
High Operating temperature and short duration high temperature exposures	Bake	T = 95 - 105°C (contact)	700 - 2500 hrs at 125°C	800 - 3300 hrs at 125°C

[55] https://www.intel.com/content/dam/www/public/us/en/documents/guides/xeon-e5-v4-thermal-guide.pdf

Source: Intel ® Xeron ® E5 v4 Product family: thermal mechanical specification and design guide (June 2018)

Due to the different nature of stress events that could occur in a data centre, testing should be designed to simulate:

- short-duration gradient changes influenced by the cooling equipment, for example the changeover from free cooling to a mechanical system;
- short-term intense exposure periods influenced by ambient conditions, for example during prolonged summer heat waves; and
- an indicative frequency of occurrence for both of the above events during an operational year.

The unit being tested is placed at a temperature corresponding to the highest allowable temperature for the specific operating condition class (A1, A2, A3 or A4) which the model is declared to be compliant with. The unit should be tested with SNIA Emerald Power Efficiency Measurement Specification and run test cycle(s) for a duration of 16 hours. The unit shall be considered to comply with the declared operating condition if SNIA Emerald Power Efficiency Measurement Specification reports valid results for the whole duration of the test (i.e. if the unit being tested is in its operational state for the whole duration of the 16-hour test).

1.3.5 Market implications and functionality

It is important to procure hardware which permits operation in wider operating conditions. The Ecodesign Regulation ((EU) 2019/424)[39] on servers and data storage products will introduce (from March 2020) a requirement on declaring the operating condition class for servers and storage products, with Classes A1 to A4 corresponding to the ASHRAE classes for air cooling described above. The manufacturer shall also indicate that 'this product has been tested in order to verify that it will function within the boundaries (such as temperature and humidity) of the declared operating condition class'. Regulation (EU) 2019/424 also provides indicative benchmarks referred to as best available technologies for the servers and storage systems on the market.

Table 13: Benchmark for operating conditions according to Commission Regulation (EU) 2019/424

Product type	Operating condition class
Tower server, 1 socket	A3
Rack server, 1 socket	A4
Rack server, 2 socket, low-performance	A4
Rack server, 2 socket, high-performance	A4
Rack server, 4 socket	A4
Blade server, 2 socket	A3
Blade server, 4 socket	A3
Resilient server, 2 socket	A3
Data storage products	A3

Server manufacturers should provide sufficient information about the limitations of operation in the ASHRAE allowable range, including the rate of change of the data centre temperature, for a given server product so that the data centre operator can determine the impact of their decisions to operate for periods of time in the allowable range on the operation of individual servers.

Some manufacturers (e.g. HPE) provide information[56] on the allowed number of hours in a specific operating range before operational reliability is impacted and the acceptable rate of

[56] https://support.hpe.com/hpsc/doc/public/display?docId=emr_na-a00026969en_us&docLocale=en_US

change for the inlet temperature range. In particular, HPE reports on temperature and operation time restriction, claiming 100% availability of yearly operation time for the HPE ProLiant Gen10 server models under Class A3[57] and 1% yearly operation time for the models under Class A4. A rate of temperature change of 20 °C/hr is claimed for both models. Other manufacturers provide information on the increased failure rates for equipment operated at higher temperatures, without specific limits on operating times in those temperature ranges.

Also, ICT equipment compliant with NEBS-3[58] operating conditions reports 'short-term' operating conditions as a period of no more than 96 consecutive hours and no more than 15 days in 1 year. This refers to a total of 360 hours in any given year, but no more than 15 occurrences during the 1-year period. NEBS-3 operating conditions are claimed for some networking equipment.

Air management is important in all cases to avoid hotspots and ensure control of the inlet air temperature to IT equipment (see section 2.2).

ASHRAE research suggests that increased risk of component failure when operating at higher temperatures is insignificant when the number of hours of exposure is limited (e.g. just at the hottest times of the year).

High relative humidity was found to have a higher impact on hard disk drive failures than high temperatures[59] and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failures at higher temperatures[60].

ICT hardware has a temperature above which its internal fan speeds increase which increases power consumption, which can partially offset potential benefits. For some equipment this may be above 27 °C; experience has shown that for other equipment fan speeds increase at much higher temperatures. ICT hardware manufacturers should publish fan speed increase with inlet temperature performance information to assist with informed procurement decisions (this is a required practice in the EU Code of Conduct for Data Centres and forms part of EN50600 TR99-1).

Network equipment in particular can be challenging to manage due to non-standard airflow direction and cabling blocking the airflow. ASHRAE recommends a design for front to rear cooled networking equipment to a minimum of ASHRAE Class A3 (40 °C), preferably Class A4 (45 °C)[61]. For some networking equipment on the market, compliance with NEBS-3 conditions is reported (e.g. switches[62,63]).

IT equipment operating at higher fan speeds may increase room sound levels such that operators working in the space require ear protection.

Higher temperatures within the data hall exceed those used in spaces designed for human occupation. This may be mitigated by using hot aisle or chimney rack containment, where the hot air is separated from the rest of the space. It is also possible to temporarily reduce set points to allow people to comfortably work in the space. Potential derating of any cables in hot air streams at high temperatures should also be considered.

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[57] Only systems containing an earlier generation of the HPE Smart Storage Battery (727258-B21; 782958-B21; 727261- B21; or 782961-B21) are restricted to 10% (or less) of available yearly operational time.

[58] https://www.qats.com/Download/Qpedia_Jan10_NEBS_Compliance_Testing.ashx

[59] Environmental Conditions and Disk Reliability in Free-cooled Datacenters, USENIX conference 2016).

[60] University of Virginia paper (Datacenter Scale Evaluation of the Impact of Temperature on Hard Disk Drive Failures, Sankar et al 2013.

[61] Data centre Networking Equipment – Issues and Best Practices Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Data centres, Technology Spaces, and Electronic Equipment.

[62] https://www.cisco.com/c/en/us/products/collateral/routers/asr-920-series-aggregation-services-router/datasheet-c78-732103.html

[63] https://www.juniper.net/assets/us/en/local/pdf/datasheets/1000632-en.pdf

1.3.6 Applicability to public procurement

The criteria are considered to be generally applicable to the procurement of new ICT hardware, including server, storage products and networking equipment.

1.3.7 Summary of stakeholders' comments following AHWG1

As not all facilities are air-cooled, equivalent criteria for liquid-cooled facilities were suggested and added. One opinion was to avoid core criteria as the impact was not clearly understood; another was that as ASHRAE A2 equipment was agreed to be widely available, A3/A4 should be the focus. However, most facilities are operating at low temperatures despite the ability of ICT hardware to accommodate higher ranges and therefore procuring hardware which can accommodate very high temperatures would not deliver a benefit. Reference to the equivalent EU Code of Conduct / EN50600 TR99-1 Best Practices was added.

Additional text was added to clarify that having the capability to operate at higher temperatures does not mean continuous operation at high temperatures and that air management is important. There is no requirement to heat air to high temperatures in locations with a cold climate; the temperature range caters for colder as well as warmer operation. A description of how human comfort may be managed with higher operating temperatures has also been added. One stakeholder believed there was no energy saving when operating at these levels due to server fan speed increases. This may be true in the short term (depending on the temperature and the ICT equipment); however, the recommendation is not for continuous operation at higher temperatures but to allow excursions in order to allow an overall reduction in energy consumption.

There was a proposal to make reference to the new Eurovent certification programme (due early 2018); however, in February 2018 the only available programmes related to certification of cooling plants. EN 50600-2-3 and EN 50600-1 were also suggested; however, these relate to M&E systems and do not specify operating temperatures.

1.3.8 Summary of stakeholders' comments following AHWG2

A suggestion was made to make reference to the Green Grid free cooling maps, an online tool and mapping resource designed to help European data centre and facilities managers to easily identify the amount of time that free cooling is available for their data centres. However, this was not added as they are no longer freely available.

Some stakeholders queried the temperature ranges proposed for liquid cooling of servers. These were reviewed and increased following additional information about usage in the market.

Some stakeholders also commented that the impact of moving to ASHRAE A3 was uncertain in terms of energy efficiency and deployed power. This is due to the likelihood of server fan speeds increasing with temperatures above 25 °C, and for this reason it was requested to report on the impact in terms of the power use of fans.

1.3.9 Final criteria proposal

The criteria proposal is reshaped in order to be coherent with the information requirements on the declared operating condition class as detailed in Commission Regulation (EU) 2019/424.

As not all facilities are air-cooled, liquid cooling temperature ranges are also provided.

Summary rationale for the final proposal

The revised version of this criteria area includes the following:

- Specific operating conditions aiming to ensure that the equipment can be placed in data centres with economised and/or free cooling (air cooling technologies) or has the necessary flexibility in operating temperature and humidity.
- Specific operating conditions for equipment to be placed in data centres with liquid cooling support operation in temperature ranges are required for different configurations. This is to support future innovation in cooling technologies and designs.
- The proposed Technical Specification requires that ICT equipment shall be able to withstand the extreme values of the allowable range declared for a minimum of tested operating hours. In order to provide a temporal dimension for the simulation of the test conditions, the ICT equipment shall be tested in the following conditions:
  - to operate in extreme conditions for at least 16 hours (core criteria), in line with the proposed transitional methods of the Ecodesign Regulation, and
  - 88 hours according to the ETSI standard EN 300 019-1-3 (comprehensive criteria) - corresponding to 1% – exceptional conditions.
- Information and test results provided for the purpose of CE marking could be used as verification. Moreover, in the absence of standardised methods, an explanatory note is added to guide procurers on how to make an assessment of the representativeness of test results provided as proof of compliance.
- Fan power consumption reported and impacts in terms of deployed power are to be considered.

Final criteria proposal

TECHNICAL SPECIFICATIONS	
Core criteria	**Comprehensive criteria**

TECHNICAL SPECIFICATIONS	
Core criteria	**Comprehensive criteria**
TS2 ICT operating range – temperature and humidity *A Applicable in the case of air cooling and where the data centre is designed for economised and/or free cooling. Applicable operating condition classes are described in Appendix I.* ICT hardware must support operation within the allowable humidity and dry bulb temperature range of operating condition Class A2 of Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products. The equipment must be tested to function in the allowable range for a minimum of 16 operating hours (high-temperature operation is not intended for continuous use). The testing must be designed to be representative of real operating conditions (see the accompanying explanatory notes). Testing methods contained in European standards on the operating condition class of servers, developed in reply to the draft standardisation mandate under Commission Regulation (EU) 2019/424, could also be suitable to this extent. The fan power consumption under normal and increased inlet temperatures must also be reported in order to validate that energy will be saved. *Applicable in the case of liquid cooling* ICT hardware must support operation within the facility supply water temperature ranges indicated in the tender with reference to Classes W2 and W3 in Appendix II. **Verification** The tenderer must provide manufacturer specifications and declarations for each piece of ICT equipment. The tenderer must declare that the server models have been tested to operate for an estimated number of hours during a specified time period in the allowable range. The test specification must be provided. Information and test results provided for the purpose of CE marking may be used as verification.	**TS2 ICT operating range – temperature and humidity** *Applicable in the case of air cooling and where the data centre is designed for economised and/or free cooling. Applicable operating condition classes are described in Appendix I.* ICT hardware must support operation within the allowable humidity and dry bulb temperature range of operating condition Class A3 of Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products. The equipment must be tested to function in the allowable range for a minimum of 88 operating hours (high-temperature operation is not intended for continuous use). The testing must be designed to be representative of real operating conditions (see the accompanying explanatory notes). Testing methods contained in European standards on the operating condition class of servers, developed in reply to the draft standardisation mandate under Commission Regulation (EU) 2019/424, could also be suitable to this extent. The fan power consumption under normal and increased inlet temperatures must also be reported in order to validate that energy will be saved. *Applicable in the case of liquid cooling* ICT hardware must support operation within the facility supply water temperature ranges indicated in the tender with reference to Classes W4 and W5 in Appendix II. **Verification** The tenderer must provide manufacturer specifications and declarations for each piece of ICT equipment. The tenderer must declare that the server models have been tested to operate for an estimated number of hours during a specified time period in the allowable range. The test specification must be provided. Information and test results provided for the purpose of CE marking may be used as verification.
EXPLANATORY NOTE 1: Representative thermal testing of ICT equipment	
• This note identifies the basis for the **representative thermal testing of ICT equipment**. In order for the testing to be representative of real operating conditions, it must be designed to simulate: short-duration gradient changes influenced by the cooling equipment, for example the changeover from free cooling to a mechanical system; • short-term intense exposure periods influenced by ambient conditions, for example during prolonged summer heat waves; and • an indicative frequency of occurrence for both of the above events during an operational year.	
EXPLANATORY NOTE 2: Thermal performance and deployed power	
It is important to note that awarding extra points for A3 capable servers needs to be considered in the context of whether designating a A2 or A3 servers reduces the total power deployed. If the loss of capacity, driven by supporting the operation of servers at 40 ºC, results in more deployed servers, extra points should not be awarded.	

1.4 Criteria proposals: Material efficiency and hazardous substances

1.4.1 Background

As discussed in the preliminary report, and based on the LCA evidence evaluated, data centre production stage impacts are significant; primarily those associated with IT hardware. In part, these impacts arise due to the relatively short refresh rates of IT equipment.

A large number of potential criteria were evaluated and reduced to those presented in this section based on their life cycle environmental and cost implications, the verification methods available and the market implications of the whole criteria area. The criteria were developed to go beyond minimum requirements defined in relevant legislation, i.e. the WEEE Directive (2012/19/EU) and the RoHS Directive (2011/65/EU), in order to set a higher level of ambition.

1.4.2 Life cycle environmental hotspots and potential improvements

As discussed in Chapter 1 of this report, LCA is a relatively new area for data centres and limited information is available. However, studies have identified that the environmental impacts from the manufacturing of IT equipment and mechanical and electrical systems are significant. The dominant impacts around toxicity and resource depletion relate to the manufacture of server components, in particular of integrated circuits and other electronic components for printing wiring boards and the associated processes including extraction and processing of raw materials (refining gold and copper, disposal of sulphidic tailings, tin, arsenic and cadmium ions). Hence criteria have been developed which:

- optimise servers' lifetime by reducing the demand for whole new products before they become inefficient (e.g. promoting upgrade of existing ones, finding an optimal refresh rate and improving repairability and dematerialisation);
- support responsible disposal (e.g. ease of disassembly to increase recycling rates by certified facilities).

It is important to consider the trade-off between production and use stage impacts, e.g. to weigh up whether an increased production stage impact due to equipment replacement is justified by an improvement in operational energy use, avoiding a burden shift.

This is illustrated by one of the studies presented in the LCA review of the preliminary report which shows that a server with reused components (HDDs, memory cards, CPUs and main boards) could have a 22% higher energy consumption compared to a brand new server, while still having the same climate change impact as a brand new server. However, the environmental payback time varies – the improved energy performance of newer models may mean that the decommissioning of an old model has a reduced impact.

EURECA has developed a model to calculate the optimal refresh time once the embodied energy of the new server becomes lower than the energy consumption of the existing server[64]. The model is based on an optimisation metric requiring minimum input data which has been tested with public procurers. The metric assesses different times to purchase new server(s) in order to find the optimal, based on the new server's embodied energy and the existing server's energy consumption.

Independently of the optimal refresh time for servers, some non-IT components such as the chassis can remain while other components that have an effect on the server's efficiency can be replaced. Such components are assessed in the JRC report on potential material efficiency requirements of enterprise servers[65]: when refurbishing servers with reused hard disk drives, memory cards, CPUs and main boards, their GWP are comparable to a new server with 22% higher energy efficiency; when refurbishing only with reused hard disk drives and memory cards, their GWP are comparable to a new server with 7% higher energy efficiency. Furthermore, the Ecodesign work on servers identified that around 75% or more of the energy

[64] Bashroush, R. (201x). A comprehensive reasoning framework for hardware refresh in data centres. IEEE transactions on sustainable computing. Vol. xx, no. xx, month 201x. Accepted for publication in a future issue of this journal.

[65] JRC Science and Policy report (2015). Environmental footprint and material efficiency support for product policy.Analysis of material efficiency requirements of enterprise servers.

consumption and efficiency opportunities are determined by the Power Supply Unit (PSU), CPU, Random Access Memory (RAM) and storage.

This would reduce the need to replace the whole product without affecting the server's energy efficiency. The US National Science Foundation has developed a standard to facilitate design for repair, reuse and recycling[66]. These are to some extent similar to those identified by the ongoing Ecodesign work for enterprise servers.

Concerning end-of-life management, the current legal framework is not stopping illegal exports of WEEE (including servers) to China and other developing countries. According to a report on illegal shipment of e-waste from the EU[67], this is not because of lack of coherence between the two major policy measures (WEEE Directive and Waste Shipment Regulation), but due to the lack of a level playing field within Europe as a result of differences in implementation and interpretation at Member State level. Significant differences between them continue to exist with respect to enforcement and inspections, so illegal e-waste exporters and other key actors are able to exploit this lack of a level playing field by choosing those ports in Europe where control is regarded to be the weakest.

Manufacturers and retailers in the data centre business already provide a way to dispose of equipment via existing collection and take-back schemes. According to information gathered from stakeholders, these schemes are already well established for stock existing since the implementation of the legal framework (2012). However, potential leaks exist at the collection stage (see Figure 15 for a representation of a typical recovery/recycling chain of WEEE, exemplified by Umicore's). According to the JRC[65], reusable parts are harvested and tested before reaching recycling facilities. This could increase the risk of illegal exports exemplified in Figure 15, although this figure represents all WEEE and thus the risk of illegal exports may be lower for server components.

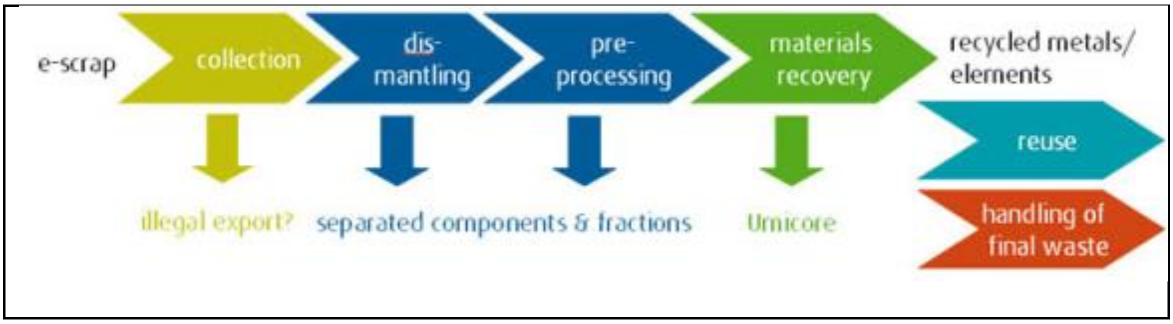

Figure 15: Typical recovery and recycling chain for WEEE[68]

Older WEEE (manufactured before 2012) which is to be disposed is still covered by the obligation to mark the equipment with the WEEE symbol and in this way the equipment can be collected after decommissioning. This is applicable to WEEE manufactured since 2005, which is assumed to cover many of the old servers found in public offices. However, due to disparities of implementation between different Member States, it is proposed to leave the existing technical specification criterion and strengthen the award criterion by giving points to tenders demonstrating that all WEEE is shipped to WEEE and e-scrap certified (pre)processing companies[69] (via AATF – approved authorised treatment facilities and AE – approved exporters).

[66] NSF International Standard/American National Standard. NSF/ANSI 426-2017. Environmental Leadership and Corporate Social Responsibility Assessment of Servers.

[67] Geeraerts, K., Illes A. and J-P Schweizer (2015). Illegal shipment of e-waste from the EU: A case study on illegal e-waste export from the EU to China. A study compiled as part of the EFFACE project. London: IEEP

[68] http://pmr.umicore.com/en/recyclables/electronic-scrap/recycling-chain/

[69] http://ec.europa.eu/environment/waste/framework/pdf/Checklists/3.%20Checklist_WEEE%20treatment.pdf

Ongoing efforts are focusing on increasing the availability of these facilities across the EU, which will prevent illegal shipments[70].

Concerns relating to the end-of-life phase of electrical products has driven action by manufacturers to phase out materials and flame retardants for which evidence exists of the potential for toxic emissions[71]. Examples include metals and alloys that are used in solders, connectors, switches and relays, plastic additives that impart a function which may be physical/mechanical, safety- or design-related e.g. colourants, fillers, plasticisers, stabilisers, flame retardants. A number of substances formerly used in electrical devices, or that are being phased out, including the flame retardant HBCDD, plasticiser DEHP and lead solder are now classified in the EU as Substances of Very High Concern or are restricted under the RoHS Directive (211/65/EU) which applies to electronic equipment.

A number of criteria relating to hazardous substances featured in the EU GPP Criteria for Computers and Monitors, some of which have been adapted for the data centre ICT hardware proposals where relevant..

In terms of the scale of the issue, the European Environment Agency estimates that 16-38% of the EU's WEEE (between 550 000 tonnes and 1 300 000 tonnes) was exported in 2008[72]. Moreover, whilst illegal WEEE shipments are classified as hazardous waste under the Basel Convention and are the subject of controls under the recast WEEE Directive, the EEA highlights that there are no restrictions on the export of goods for reuse, for which the end-of-life phase may not comply with expected EU norms for WEEE disposal.

Analyses of emissions from fire simulations and samples of environmental pollution from WEEE treatment sites have shown that there is potential for a range of toxic emissions to arise from unregulated treatment processes, including species of polychlorinated and polybrominated dibenzo-p-dioxins and furans (PCDD/DF and PBDD/DF)[73,74] and carcinogenic polycyclic aromatic hydrocarbons (PAHs)[75]. These uncontrolled emissions have led to the exposure of communities and the pollution of local environments, as evidenced by studies that have sampled the environment around WEEE treatment sites[76,77], and by programmes of the UNEP and the World Health Organisation developed under the auspices of the Basel Convention that aim to monitor e-waste movements and to protect the health of workers and communities[78,79].

[70] https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/certification-recycling-facilities-weee-and-spent-batteries-project-under-weee-2020

[71] Chem Sec, *Leading Electronics companies and Environmental organisations urge EU to restrict more hazardous substances in electronic products in 2015 to avoid more global dioxin formation*, 19th May 2010, http://www.chemsec.org/images/stories/publications/ChemSec_publications/ RoHS_restrictions_Company__NGO_alliance.pdf

[72] European Environment Agency, *Movements of waste across the EU's internal and external borders*, Report No 7/2012

[73] Gullett, B.K.; Linak, W.P.; Touati, A.; Wasson, S.J.; Gatica, S.; King, C.J *Characterisation of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations*, Journal of Material Cycles & Waste Management 9: 69-79, 2007

[74] Duan et al, *Characterization and Inventory of PCDD/Fs and PBDD/Fs Emissions from the Incineration of Waste Printed Circuit Board*, Environmental Science & Technology, 2011, 45, 6322–6328

[75] Blomqvist,P et al, *Polycyclic Aromatic Hydrocarbons (PAHs) quantified in large-scale fire experiments*, Fire technology, 48 (2012), p-513-528

[76] Sepúlveda,A et al, *A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India*, Environmental Impact Assessment Review 30 (2010) 28–41

[77] Wang,Y et al, *Polycyclic aromatic hydrocarbons (PAHs) in soils and vegetation near an e-waste recycling site in South China: Concentration, distribution, source, and risk assessment*, Science of the Total Environment 439 (2012) 187–193

[78] UNEP, *E-waste in Africa*, Accessed October 2015 http://www.basel.int/Implementation/Ewaste/EwasteinAfrica/Overview/tabid/2546/Default.aspx

[79] World Health Organisation, *Childrens environmental health: Electronic waste*, http://www.who.int/ceh/risks/ewaste/en/

1.4.3 Life cycle cost implications and trade-offs with potential environmental improvements

Measures to improve the durability and repairability of IT equipment can have the benefit of reducing the operational expenditure for maintenance of the equipment (OPEX IT). This expenditure can over the lifetime of a data centre equal the initial capital expenditure. Conversely, a reduction in the OPEX IT can result in an increase in OPEX Facilities, as greater expenditure on electricity is needed to run older, inefficient equipment.

The end-of-life stage is of less overall relevance in cost terms. Different end-of-life strategies are not therefore likely to affect the total costs significantly. The cost of data erasure and proper disposal of WEEE will have to be met as part of these costs.

1.4.4 Verification

In some cases, existing mechanisms, e.g. standards compliance / third-party certification, may be used for tenderers to demonstrate and for procurers to validate compliance. In others, self-declaration is required; however, this may make it difficult for the procurer to assess due to lack of skills / resources to validate. The required method is provided for each criterion. In the second criteria proposal, based on input received from stakeholders, specific standards, policy measures and metrics are referenced in the criteria.

In the case of the EURECA metric, this is included as explanatory note. The metric is newly developed but it has been tested with public procurers involved in the EURECA project (in Ireland, the UK, the Netherlands and Germany).

The criteria on design for disassembly and repair and design for dismantling and recycling have been partially aligned with the NSF standard and ongoing Ecodesign work on enterprise servers and storage to reflect current and future practice in the industry.

The criteria on end of life considers that current regulation does not stop operators from shipping abroad (including illegally). Therefore, although suppliers should provide a way for customers to dispose of the equipment via collection and take-back schemes, there is nothing obliging the operator to send the equipment back via these options, nor is older (pre-WEEE Directive obligation) equipment accounted for. Points should therefore be awarded for contracts where all WEEE is shipped to WEEE and e-scrap authorised treatment facilities (ATF – approved authorised treatment facilities and AE – approved exporters[80]) in order to deter companies from shipping elsewhere. There is currently an ongoing project for increasing the number of certified recycling facilities for WEEE and spent batteries[81]. The timeframe is until 2020. This project will likely increase the number of ATF and AE in the EU.

Overall, alignment with existing policy measures, initiatives and schemes will support ease of verification by compliance with other policy measures and schemes.

1.4.5 Market implications and functionality

It is important to note that the criteria proposals were not identified solely based on the life cycle environmental potential they present, but also regarding the feasibility of implementation.

[80] http://ec.europa.eu/environment/waste/framework/pdf/Checklists/3.%20Checklist_WEEE%20treatment.pdf

[81] https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/certification-recycling-facilities-weee-and-spent-batteries-project-under-weee-2020

Also, reliability and service availability remain priorities for data centres, so criteria which present unacceptable risks are avoided. It is possible to improve reliability and sustainability simultaneously; any potential or perceived risks are highlighted and mitigating actions identified.

There are also potential risks associated with reuse of hardware, principally addressing security concerns. Methodologies for data erasure are available which support this, e.g. NIST guidelines SP800-88[82], The Common Criteria[83]). Extending the service life of older equipment may also allow second-hand market users access to services they would not otherwise have. However, when the equipment eventually reaches the end of its useful life, it is important to ensure that it is disposed of responsibly, avoiding problems associated with uncontrolled disposal as described previously.

The EU LIFE-funded WEEElabex project[84] is an example of a collaboration with industry to create a certification scheme for proper treatment according to WEEE requirements. Projects such as this have now been superseded by the development of the EN 50625 series which, informed by the approach developed by WEEElabex, defines WEEE collection logistics and treatment requirements. Annex A to EN 50625-1 identifies specific components of equipment that shall be removed for the purposes of depollution, complementing the listing within the recast WEEE Directive. Relevant components from Annex A are capacitors, printed circuit boards, backlights containing mercury, batteries and plastics.

Feedback from some recyclers is that their operations are certified under national schemes that implement the WEEE Directive. These certification schemes require reporting on the minimum recovery targets contained within Annex V of the recast WEEE Directive. It is also the case that some enterprises carry out both preparation for reuse/remarketing and dismantling for recycling, whereas others outsource the dismantling and recycling step. Valid certifications of the facility handling the items are obtained in order to provide assurance to clients.

The tracing of equipment is important for public and private clients. It appears that both manufacturers and social enterprise recyclers operate advanced tracking systems either at the level of individual items of IT equipment or, in the case of some manufacturers, individual parts. The individual ID for an item of equipment may originate from the client's inventory to ensure continuity. Such systems will allow a public authority to identify whether the item has been reused or recycled, and in some cases where a reused item is destined for (but not the actual buyer/recipient).

It does not appear to be possible to obtain data on what proportion of an individual item or batch of items has been recycled and/or disposed of unless it is equipment taken back by the same manufacturer. Recyclers tend to only report at organisational level tonnages sent to different streams.

It is therefore proposed that guidance is given that when IT equipment reaches its end of life that treatment is, as a minimum, carried out according to the requirements of the EU WEEE Directive Annex VII, but with reference to EN 50625-1 as a standard, or equivalent certification and compliance schemes such as WEEElabex, R2 [85] and E-Stewards [86], which may be available at global, national or regional level.

1.4.6 Applicability to public procurement

[82] NIST (2014) Guidelines for Media Sanitization. SP 800-88 Rev. 1. Available at https://csrc.nist.gov/publications/detail/sp/800-88/rev-1/final

[83] https://www.commoncriteriaportal.org/

[84] WEEElabex, http://www.weeelabex.org/

[85] Sustainable Electronics Recycling International (SERI), *R2 Standard*, https://sustainableelectronics.org/

[86] E-Stewards, http://e-stewards.org/learn-more/for-enterprises

When replacing and purchasing new IT equipment for an enterprise data centre or a co-location data centre, the public authority will likely want to dispose of its used equipment. Typically, however, at least a part of this equipment can still be used for an additional period of time by other users.

Opportunities to extend the IT equipment lifespan through its reuse may be best achieved through the distribution of serviced and upgraded IT equipment by specialist third parties. Therefore, a separate contract may be required to procure end-of-life management services independent of the contract to supply new equipment, with a requirement to extend the life of the equipment and to guarantee proper treatment upon the end of life.

Secure data sanitisation and erasure of drives is an important first step in facilitating the reuse of servers. However, this is subject to very specific requirements which are set by the customer.

In terms of core technical specifications, the preparation of equipment for reuse, as well as dismantling for recycling and proper treatment is proposed to be defined according to Article 8 of and Annexes VII and VIII to the WEEE Directive.

The standard ETSI EN 305 174-8 provides a reporting standard for the percentage of IT and electrical equipment that once decommissioned is disposed of through formally recognised responsible entities. At a comprehensive award level, the use of tracking systems and the dismantling of equipment according to EN 50625-1 are suggested, reflecting best practices amongst IT equipment manufacturers and social enterprise recyclers.

Contract performance clauses should be used in order to monitor execution of contracts, with a specific focus on reporting on reuse/recycling.

1.4.7 Summary of stakeholders' comments following AHWG1

Concerning design for durability, stakeholders reported that defining a default minimum time period for refresh through a minimum warranty criterion was inappropriate, and should be based on the balance of energy savings and additional embodied impact from the upgrade. Generally, stakeholders mentioned that the criteria could be misleading to public procurers where the majority of servers are already old (> 5 years) and inefficient. This is backed up by the research of the EURECA project that found that 40% of public sector servers in Ireland, the Netherlands and the UK were more than 5 years old. Furthermore, they represented only 7% of computing capacity, and yet accounted for 66% of energy consumption. This criterion was therefore deleted and instead replaced by an award criterion for the optimisation of a server's lifetime based on the metric developed by EURECA.

Concerning design for disassembly and the repair of servers, stakeholders commented that this was already common practice and had no added value. Furthermore, the stakeholder prefers to discourage operators from extending server lifetimes (as discussed previously), as it is already accepted that the majority of the sector has old, inefficient equipment. However, if the inefficient part can be replaced, leaving the remaining components unchanged, then the environmental impact will be lower. The criterion was therefore amended to make this point clear.

Concerning design for dismantling and recycling, it was considered valuable to report on compliance with WEEE concerning dismantling, plus internal PSUs and HDDs/SSDs which are additional components containing valuable substances such as copper, gold and Rare Element Resources.

Concerning end-of-life management, the Technical Specification is aligned with EPEAT. However, this being voluntary, it does not give access to all servers.

Current regulations (e.g. WEEE Directive) do not stop operators from shipping outside the EU. Retailers must provide a way for customers to dispose of the equipment via collection and take-back schemes, but there is nothing preventing leaks of equipment before it reaches the recycling facility. Points should therefore be awarded for contracts where all WEEE is shipped to WEEE and e-scrap certified (pre)processing companies (via AATF – approved authorised treatment facilities and AE – approved exporters) in order to deter companies from shipping elsewhere. Data protection was considered a huge barrier in the area and would be controlled by using a competent waste handler (as described above). High-end equipment was considered valuable to the market. Further comments from the stakeholders felt the criteria provided little value over existing legislation (lots at EU and national level – WEEE and RoHS Directives), yet added to reporting requirements. This is justified as explained above.

It was recommended that further information be obtained from recycling companies to find out what disassembly happens/is possible. Through contact with Umicore and stakeholders, it is clear that the right processes are available to effectively disassemble, recycle and reuse servers, but the biggest end-of-life problem is ensuring that this happens. Criteria were therefore strengthened (in line with stakeholder recommendations) to prevent the export of servers/key components – via documentation of proper dismantling, depollution and recycling standards in certified WEEE treatment facilities – and to include the recovery of any older equipment that is outside the regulations' timeframe/from a different manufacturer.

Current regulations such as the RoHS Directive and the REACH SVHC List limit the use of hazardous materials. Stakeholders therefore felt that a hazardous substances criterion based on this added to reporting, whilst adding no real value, as most equipment does not enter the usual electrical waste stream. They felt that take-back schemes were more appropriate (though difficult to apply to the cloud). This is valid and was considered in the end-of-life criteria. However, one stakeholder wanted the inclusion of a restricted substances criterion in line with NSF/ANSI 426-2017 Clause 6.2.1 of the Computers and Monitors GPP document. The criterion was therefore added as a selection criterion.

One stakeholder said that work for the US NSF standard (by INEMI) shows that it is not possible to use the same flame retardant substitutions for enterprise servers as for consumer goods. They suggested: (a) points for end-of-life aligned with EPEAT (covered in previous criteria), and (b) points for the exclusion of toxic halogens (not all halogens because of risky alternatives), although research in the HFR-free High Reliability PCB Project focused on halogen-free alternatives in the high-reliability market segment and found that the eight tested halogen-free flame retardant laminates outperformed the traditional FR-4 laminate control. The criterion for the emissions of hazardous substances with regards to PCBs was therefore retained, or (c) points for restriction of other toxic chemicals, which as discussed above, would add to reporting.

It was felt that power cables should be covered as well as PCBs; however, it was not added to the report because (and as noted in the computers and monitors document) the hazardous phthalates that are under consideration are set to be restricted from 2019 under an amendment to the RoHS Directive, and as discussed above should therefore be omitted.

1.4.8 Summary of stakeholders' comments following AHWG2

Regarding the criterion on optimisation of server lifetime, the collected input from stakeholders generally expressed their doubts on the representativeness of the proposed metric, in particular regarding the use of embodied energy default values for new servers and the expected energy performance of existing servers. There were also concerns that the factors in the metric were not tested enough to represent average correlations. Finally, a stakeholder pointed out that other important factors such as risk and resilience should be also part of the metric.

Generally, the application of this metric was limited to some of EURECA's project participants, and it is thus indeed uncertain whether the established correlations in the metric are representative. Moreover, it should be subject to further testing at other server rooms and data centres for public institutions. Indeed, embodied energy values for new servers are difficult to get, and using a default value from one manufacturer as representative for all procurers in the EU would bring more uncertainties to the calculation of the optimised server lifetime.

It is thus concluded that the applicability of this metric should be limited only to the cases where there are verified LCA or EPD results from where embodied energy values can be used. In this case, as one stakeholder suggested, the criterion and metric were removed from the GPP criteria and presented in the Procurement Guidance instead. In the guidance it is also encouraged to monitor the servers' lifetime versus their performance by applying this metric periodically to server rooms and enterprise data centres.

Regarding the criteria on end-of-life management, a stakeholder proposed to extend these to storage and network equipment. This was considered feasible since server and storage units are handled similarly at their end of life. Including network equipment would also ensure that small and large equipment which may be exported out of the EU which may still be functioning may either be used partially for repair activities (especially large equipment) or as a last resort may be used for recycling of materials. Some stakeholders pointed out that tenderers should be rewarded when providing refurbishment and remarketing services, with recycling the last option.

Regarding the criterion on emissions of hazardous substances, input from stakeholders pointed in different directions. Some said this criterion is meaningless as all vendors will comply with relevant legislation, while others said not all Substances of Very High Concern (SVHC) are covered in legislation because of exemptions. It is important to highlight that the proposed criterion is about the implementation of a substance control system which provides information to public procurers, not a criterion to set limits. Therefore, the implementation of such a control and information system is an addition.

1.4.9 Final criteria proposal

Whilst a formula for the optimisation of server lifetime is considered an innovative approach, it is not yet considered well proven or a mature indicator. Moreover, it is considered that the use of default values could provide results that are not comparable or necessarily accurate. The criteria on optimisation of server lifetime were therefore removed. It is, however, proposed to provide in the accompanying guidance a suggested formula for calculating the optimal server lifetime so as to encourage management of server lifetimes. Furthermore, public authorities may wish to consider using this approach in conjunction with their managed service providers for their data centre server fleets.

The title of the criterion 'Emissions of hazardous substances – restricted substance controls in servers' has now been changed to 'Control of hazardous substances – restricted substance in servers, data storage and network equipment' to better reflect the content of the criterion and to highlight that the proposal is not about setting restrictions of substances, but about the implementation of a substance control system.

The Technical Specification on 'Design for disassembly and repair of servers' has now been changed to 'Design for the repair and upgrading of servers and data storage'. This reflects the new Ecodesign information requirement for servers and data storage products that will be mandatory from March 2020, with the expansion of the scope to include fans. Inclusion of this criterion will serve to increase public procurer awareness about the parts that are possible to repair/upgrade.

An explanatory note has been added to the end-of-life management of servers, data storage and network equipment about the requirements for the international shipment of electrical equipment (EEE) included in Annex VI to the WEEE Directive. Moreover, the new revision includes a Contract Performance Clause requiring the providers of end-of-life management services to report on the final destination of servers, data storage and network equipment during the contract performance.

Summary rationale for the final proposal

- A Selection Criterion aims to ensure that manufacturers have in place a hazardous substance control system for the design and supply chain for their products. Such a system should be aligned with the relevant IEC standards that are followed by industry.
- A specific focus has been placed on REACH Candidate List substances and RoHS restricted substances and exemptions. This to ensure a priority focus on substances that are under regulatory scrutiny.
- A technical specification of design for the repair and upgrading of equipment is considered appropriate to reflect new information requirements that are expected under the Ecodesign Implementing Regulation. The scope is extended and targeted at authorised third parties, including brokers, spare parts repairers, spare parts providers, recyclers and maintenance providers.
- A technical specification for the end-of-life management of servers, data storage and network equipment can be used to require the provision of collection services for end-of-service-life equipment that can maximise its reuse, refurbishment and recycling.
- A contract to take away old IT equipment may be drawn up in parallel with, or in combination with, a contract for the supply of new IT equipment. A separate contract may be created with the specific intention of attracting bidders that are specialised in the reuse and recycling of used IT equipment.

Final criteria proposal

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">SELECTION CRITERIA</td></tr>
<tr><td></td><td>SC2 Control of hazardous substances – restricted substances in servers, data storage and network equipment

To be included when IT equipment is to be procured.

The tenderer must demonstrate the operation of Restricted Substance Controls (RSCs) along the supply chain for the products to be supplied. The RSCs should, as a minimum, cover the following areas:
- product planning/design;
- supplier conformity;
- analytical testing.

Implementation should follow the guidelines in IEC 62476 and use the IEC 62474 material declaration database [87] as the basis for identifying, tracking and declaring specific information about the composition of the products to be supplied.

The RSCs (Restricted Substance Controls) must apply, as a minimum, to:
• REACH Candidate List substances;
• restricted substances and exemptions in the Restriction of Hazardous Substances Directive.
Supporting material declarations must be kept up to date for the relevant materials, parts and sub-assemblies of the products to be supplied.</td></tr>
</table>

[87] International Electrotechnical Commission (IEC), IEC 62474: Material declaration for products of and for the electrotechnical industry: http://std.iec.ch/iec62474/iec62474.nsf/index

Core criteria	Comprehensive criteria
	Verification The tenderer must provide documentation, which describes the system, its procedures and proof of its implementation.
TECHNICAL SPECIFICATIONS	
	TS3 Design for the repair and upgrading of servers and data storage *This criterion is only applicable to the procurement of new servers and data storage in an enterprise data centre* The tenderer must provide clear instructions to enable a non-destructive repair or replacement of the following components: – data storage devices, – memory, – processor (CPU), – motherboard, – expansion cards/graphic cards, – Power Supply Unit (PSU), – fans, – batteries. As a minimum, the instructions should include for each necessary repair operation and component: 1 the type of operation; 2 the type and number of fastening technique(s) to be unlocked; 3 the tool(s) required. The instructions must be made available to authorised third parties, including brokers, spare parts repairers, spare parts providers, recyclers and maintenance providers via registration on the manufacturer's webpage. These instructions must be made available for a minimum of 8 years after the placing on the market of the server product. **Verification** The tenderer must provide access to the repair instructions for the purpose of verification. Repair information must be provided according to EN 45559:2019: Methods for providing information relating to material efficiency aspects of energy-related products. Test results obtained for the purpose of CE marking may be used as verification.

Core criteria	Comprehensive criteria

TS4 End-of-life management of servers, data storage and network equipment

(same for core and comprehensive criteria)

This criterion should be used in conjunction with contract performance clause CPC3.

Tenderers must provide a service for:

- the reuse and recycling of the whole product; and/or
- the selective treatment of components in accordance with Annex VII to the WEEE Directive for equipment that has reached the end of its service life;
- the recycling of components in order to recover Critical Raw Materials.

The service must comprise the following activities:

- collection;
- confidential handling and secure data erasure (unless carried out in-house);
- functional testing, servicing, repair and upgrading to prepare products for reuse[88];
- the remarketing of products for reuse;
- dismantling for component reuse, recycling and/or disposal.

In providing the service, they must report on the proportion of equipment prepared or remarketed for reuse and the proportion of equipment prepared for recycling.

Preparation for reuse, recycling and disposal operations must be carried out in full compliance with the requirements of Article 8 of and Annexes VII and VIII to the (recast) WEEE Directive (2012/19/EU) and with reference to the list of components for selective treatment [*see accompanying explanatory note*].

Tenderers must also provide evidence of all the actions performed in order to improve the recycling of the Critical Raw Materials cobalt (in batteries) and neodymium (in hard disks), in line with the available information on cobalt and neodymium content, as foreseen in Annex II.3.3.a to Commission Regulation (EU) 2019/424.

Verification

The tenderer must provide details of the arrangements for collection, data security, preparation for reuse, remarketing for reuse and recycling/disposal. This must include, during the contract, valid proof of compliance of the WEEE handling facilities to be used and the separation and handling of specific components that may contain Critical Raw Materials.

EXPLANATORY NOTE: Components requiring selective treatment

The following are components requiring selective treatment in accordance with Annex VII to the WEEE Directive:

- mercury-containing components,
- batteries,
- printed circuit boards greater than 10 cm^2,
- plastic containing brominated flame retardants,
- chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) or hydrofluorocarbons (HFCs), or hydrocarbons (HC),
- external electric cables,
- polychlorinated biphenyls (PCB)-containing capacitors,
- components containing refractory ceramic fibres,
- electrolyte capacitors containing substances of concern,
- equipment containing gases that are ozone-depleting or have a Global Warming Potential (GWP) above 15,
- ozone-depleting gases must be treated in accordance with Regulation (EC) No 1005/2009.

AWARD CRITERIA

[88] Some Member States have developed standards and/or schemes that public authorities may wish to refer to in order to provide greater detail on how equipment is to be made suitable for reuse and resale.

Core criteria	Comprehensive criteria

AC4 End-of-life management of servers

(same for core and comprehensive criteria)

To be used in conjunction with criterion TS4

Points will be awarded to providers of reuse and recycling services who ensure that printed circuit boards and external cables that are not suitable for reuse are separated and recycled.

Verification

The tenderer must provide certification that the components identified have been recycled.

CONTRACT PERFORMANCE CLAUSE

CPC3 Reporting on the final destination of servers, data storage and network equipment

(same for core and comprehensive criteria)

To be used in conjunction with TS4.

The contractor must provide a report on the status of the equipment in the inventory once all items have been processed for reuse, recycling or disposal. The report must identify the proportion of items reused or recycled, and whether they remained in the EU or were exported.

For equipment and components recycled in the EU, the following means of proof for the handling facilities must be accepted:

- a permit issued by the national competent authority in accordance with Article 23 of the Directive 2008/98/EC, or
- a third-party certification of compliance with the technical requirements of EN 50625-1 or an equivalent compliance scheme.

Where equipment and components are exported for reuse or recycling, contractors must provide the following shipment and treatment information:

- shipping information for equipment intended for reuse, in accordance with Annex VI to the WEEE Directive (2012/19/EU).

For WEEE exported to be treated outside the EU, a third-party certification of compliance with the minimum WEEE requirements laid down in the criterion, or with the technical requirements of EN 50625-1 or an equivalent compliance scheme[89].

EXPLANATORY NOTE: Requirements for the international shipment of electrical equipment (EEE)

Annex VI to the WEEE Directive (2012/19/EU) states that in order to distinguish between EEE and WEEE, where the holder of the object claims that they intend to ship or is shipping used EEE and not WEEE, Member States shall require the holder to have available the following to substantiate this claim:

(a) a copy of the invoice and contract relating to the sale and/or transfer of ownership of the EEE which states that the equipment is destined for direct reuse and that it is fully functional;

(b) evidence of evaluation or testing in the form of a copy of the records (certificate of testing, proof of functionality) on every item within the consignment and a protocol containing all record information according to point 3;

(c) a declaration made by the holder who arranges the transport of the EEE that none of the material or equipment within the consignment is waste as defined by Article 3(1) of Directive 2008/98/EC; and

(d) appropriate protection against damage during transportation, loading and unloading in particular through sufficient packaging and appropriate stacking of the load.

GUIDANCE NOTE: Optimisation of server lifetime

Public authorities are encouraged to refresh the servers they will manage, or which will be managed on their behalf, according to a calculation of the optimal server lifetime. The calculation requires a number of variables to be estimated and seeks to take into account:

- optimal server lifetime by calculating when the energy to manufacture a server is exceeded by the energy efficiency gains achieved by the newly refreshed hardware;
- the 'embodied' energy required to manufacture a new server (in MJ or kWh);
- the total energy consumption of an existing server at a fixed workload (MJ or kWh);

[89] The following compliance schemes are considered, at the time of writing, to meet these requirements: WEEELABEX:2011 requirement on 'Treatment of WEEE'; 'Responsible Recycling' (R2:2013) standard for electronics recyclers; e-Stewards standard 2.0 for Responsible Recycling and Reuse of Electronic Equipment; Australian/New Zealand standard AS/NZS 5377:2013 on 'Collection, storage, transport and treatment of end-of-life electrical and electronic equipment'.

Core criteria	Comprehensive criteria

- the evaluation period which is normally greater than the lifetime of an existing server.

Some of these variables, such as embodied energy, rely on life cycle data for production facilities, but for the purposes of procurement this may be variable in quality and is difficult to verify.

Public authorities may wish to consider using this approach in collaboration with the managed service providers for their data centre server fleets.

2 CRITERIA AREA 2: MECHANICAL AND ELECTRICAL SYSTEM PERFORMANCE

The criteria area mechanical and electrical (M&E) system performance concerns the whole system and all the equipment relating to the electrical supply and distribution to support the IT loads and thermal operation of a data centre (e.g. UPS, compressors, heat rejection fans, pumps, cooling unit fans (CRAH: Computer Room Air Handler, humidifiers, ventilation fans) and the management of the waste heat available at a data centre site).

Table 14: Energy consumption by M&E component presents the characteristic M&E equipment energy consumption by data centre component (transformer / UPS / cooling / lighting) normalised to the corresponding percentage IT energy consumption for different data centre types and sizes. According to the data from the US Department of Energy, cooling is the main energy consumption contributor in the M&E system and other energy consumption contributions are much less relevant.

Table 14: Energy consumption by M&E component

Space type	IT	Transformer	UPS	Cooling	Lighting
Closet (<10 m^2)	1.0	0.05	-	0.93	0.02
Room (10 – 100 m^2)	1.0	0.05	0.2	1.23	0.02
Localised (50 – 200 m^2)	1.0	0.05	0.2	0.73	0.02
Mid-Tier (200 – 2000 m^2)	1.0	0.05	0.2	0.63	0.02
High-end (>2000 m^2)	1.0	0.03	0.1	0.55	0.02
Hyperscale (>40000 m^2)	1.0	0.02	-	0.16	0.02

The key areas of improvement identified at M&E system level are below, following the proposed criteria:

a. Mechanical and electrical systems' energy efficiency, with the following proposed criterion with associated metrics:
    - Power Utilisation Effectiveness (PUE).

b. Cooling management
    - Operating conditions control; Cooling System Best Practices.
    - Reuse of Heat Waste.

2.1 Criterion proposal: Power Utilisation Effectiveness (PUE)

2.1.1 Background

Power Utilisation Effectiveness (PUE) is the ratio of the total amount of energy used by a data centre facility to the energy delivered to the IT equipment, based on annual data. PUE is a metric developed by The Green Grid for calculating and reporting the energy efficiency of data centres, i.e. of the mechanical and electrical system's energy efficiency. Note that where PUE is less than 2.0, the IT equipment uses the majority of the data centre energy; also, any reduction in IT energy consumption will have an associated reduction in M&E energy consumption. Reducing the energy consumption of the IT equipment is therefore considered a higher priority (previous sections address this). The metric must be used in the correct context and balanced with the overall strategy (i.e. taking a life cycle approach to the environmental impact).

PUE was published in 2016 as a global standard under ISO/IEC 30134-2:2016, and there is also a European standard, namely EN 50600-4-2:2016. The metric has been used as a tool to highlight energy wastage in M&E systems and encourage its reduction.

The German Blue Angel[90] label requirements provide an example of the use of PUE as criteria for data centres. PUE is referred to as 'Energy Usage Effectiveness' (EUE) in the Blue Angel programme. Best practice guidelines for reducing PUE can be found in the EU Code of Conduct on Data Centre Energy Efficiency[91].

In the UK, the Climate Change Agreement (CCA) for data centres uses target PUE values and penalties for missing them to encourage the implementation of energy efficiency improvements[92].

In most cases, the largest opportunity and therefore priority for reducing PUE lies with the cooling systems hence criteria include best practices which target their energy consumption. Relatively short payback times can be achieved by first addressing air management, which is an enabler to operating at higher temperatures and with reduced fan speeds whilst managing the potential risks. Where bypass air is minimised there is scope to reduce fan speeds and, by minimising recirculation, temperature set points can be increased which improves refrigeration Coefficient of Performance (COP) and allows more free cooling. The next largest energy consumer within the power and cooling systems is usually the UPS.

When considering PUE levels, discussions have arisen on whether the influence of climate should be considered when establishing thresholds. In practice, US ENERGY STAR analysis of data centres[93] does not show a statistically significant relationship between climate and energy consumption. Although climate can have an impact on energy consumption, this impact is not significant enough to show up in the regression analyses that form the basis of EPA models, and variability in PUE related to climate is less significant than variability caused by other factors (IT part load, air management, M&E system optimisation, etc.). However, analysis indicates a correlation between achievable PUE and average wet bulb temperature[94].

Target values can potentially be based on those in the Blue Angel scheme (further details in the preliminary report). Adjustments were considered in line with the variability used in the ASHRAE Energy Standard for Data Centres[95]; however, as these showed little variation, e.g. the Mechanical Load Component (i.e. cooling part of PUE) at 100% and IT load at 50% is 0.45 for climate zone 3A (e.g. Naples, Italy) and 0.43 for climate zone 6A (e.g. Helsinki, Finland), it was decided to retain common targets achievable throughout the region.

Design consultants are often asked to calculate the predicted PUE based on climate data for the given facility location. This could even vary between different locations within a locality, potentially being influenced by the Urban Heat Island (UHI) effect. This can be measured during the integrated systems test when the facility is given a dummy IT load to confirm whether the set-up and operation of the installation is in line with the design target. The achieved performance can then be compared with the expected result from the calculation model for the same ambient conditions.

According to the standard EN50600-4-2, designed PUE (dPUE) describes a predicted PUE for a data centre prior to its operation or to a specified change in operation. According to the same standard, the prediction of dPUE shall include supporting data like the boundaries of the data centre including resiliency level, the schedule of interim PUE and PUE based on target IT loads and environmental conditions and other PUE-supporting evidence available prior to operation including target commissioning date.

[90] www.blauer-engel.de

[91] https://e3p.jrc.ec.europa.eu/publications/2018-best-practice-guidelines-eu-code-conduct-data-centre-energy-efficiency

[92] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/336160/LIT_9990.pdf

[93] https://www.energystar.gov/ia/partners/prod_development/downloads/DataCenters_GreenGrid02042010.pdf

[94] Zero Refrigeration for Data Centres in the USA, Robert Tozer, Sophia Flucker, ASHRAE Summer Conference San Antonio 2012.

[95] ANSI/ASHRAE Standard 90.4-2016.

2.1.2 Life cycle environmental hotspots and potential improvements

The energy consumption savings estimated for the Ecodesign impact assessment for servers and data storage products show that reducing PUE could yield a total EU saving of 2.3-5.5 TWh annually depending on the combination of requirements. The assumption made was that the EU PUE level is reduced from 1.56 at the business-as-usual level to 1.52 or 1.46 by 2030 via requirements on higher operating temperature, but with only 30% of the data centres actually adopting the lower PUE levels.

As well as lower operational energy consumption, good PUE at low part loads also requires scalable, modular design principles to be used. This facilitates dematerialisation which is discussed further in the section on material efficiency.

2.1.3 Life cycle cost implications and trade-offs with potential environmental improvements

As explained in Section 4.1.1, several strategies can be followed to reduce PUE, such as combining improvements in M&E equipment efficiency, operating conditions and thermal design. Reducing energy consumption reduces operating costs. As energy prices rise, payback times are reduced.

2.1.4 Verification

The standardised method for calculating PUE is provided in ISO/IEC 30134:2016 Part 2 and EN 50600-4-2:2016. This then also allows other schemes that follow the same underlying method to be used for verification, for example that used by the Blue Angel scheme. The documentation of calculation in Annex 2, 2.1 of the Blue Angel Basic Criteria for Energy Efficient Data Center Operation - RAL-UZ 161 for 'Determining the Energy Usage Effectiveness at the time of application' could be taken to be equivalent.

2.1.5 Market implications and functionality

The Ecodesign impact assessment for servers and storage mapped the average PUE of different data centres and server rooms. In the business-as-usual (BAU) scenario where ecodesign does not come into force to push the PUE lower, by 2019 SME server spaces can be expected to have a PUE of 2.5, older legacy data centres can have a PUE of 1.9-2, newer enterprise data centres can achieve 1.65, and cloud or hyperscale data centres can achieve 1.35. SME server spaces and older legacy data centres are expected to cover up to 30% of the EU's data centre service needs in 2019, so criteria for minimising PUE could filter out most SME server spaces and older legacy data centres. However, it is expected that most SME server spaces are intended for the SME itself and not usually opened for tenders.

However, whilst PUE has value as a performance metric that takes into account the two major energy-using components of a data centre, its use to track improvement or make comparisons needs to be treated with caution[96]. This is because, theoretically, reduction in PUE can mask low IT efficiency, utilisation or a shift in loads between M&E and IT systems. Some examples are as follows:

[96] Van de Voort et al, *Analysis of performance metrics for data centre efficiency – should the Power Utilization Effectiveness PUE still be used as the main indicator?* REHVA European Journal, Vol.54(1), p-5, February 2017.

- PUE values tend to improve with high IT loads, regardless of whether any M&E system improvements have been made. When more efficient IT equipment is installed, the IT load (and total load) may decrease but this can also result in PUE increasing.
- When the cooling temperature set point is increased, this leads to a decrease in energy consumption by the cooling system, but can lead to an increase in IT equipment energy use as the server fans speed up which could offset the savings (usually only partially).

In all these cases the PUE value improves, but total energy consumption might be unchanged or could even increase. For the first example, this has been addressed in the criteria by always specifying a PUE at a given load level, e.g. 50% of design IT load. For the latter, this is further explored in the section 2.2 on cooling management (operating conditions control).

2.1.6 Applicability to public procurement

The use of PUE may be applied to the following procurement routes:

1. Where a new data centre is to be built or where expansion or consolidation of an existing site is being considered, i.e. in the use of targets for predicted design performance. Designers are not responsible for their clients' IT load (this is defined separately) but can create a design which minimises M&E system energy consumption.
2. When comparing co-location facilities, possible host sites could be asked to bid based on the efficiency of the M&E infrastructure, which would need to be verified based on monitored data. Co-location facilities which provide only M&E services are not responsible for their clients' IT equipment (IT load is given) but can specify and manage their facilities to minimise energy wastage from power and cooling systems.

PUE performance is written as an award criteria with points awarded for the best performance plus a corresponding contract performance clause.

Small facilities such as server closets or server rooms that are typically enterprise data centres housed in converted space in a mixed-use building (e.g. an office) can pose greater difficulties in monitoring PUE. The energy consumption of the IT system and M&E system is typically included in the overall energy consumption of the building and submetering may not be available to measure the required data. However, these types of facilities are not targeted by the PUE criteria proposal.

2.1.7 Summary of stakeholders' comments following AHWG1

Stakeholders recognised that PUE is a widely used metric which has been useful in driving energy efficiency. However, some stakeholders did not feel it should be included in the criteria as it is not an efficiency metric and can be lowered (improved) by increasing the IT load rather than improving the consumption of the M&E system. Other concerns included: no facility operates at a 100% IT load; it is an improvement metric; it should not be used to compare facilities; it is open to manipulation; and the difficulty in validating design PUE. Stakeholders felt smaller data centres would struggle to improve PUE (consolidation, applications, refresh rates and utilisation become important – though they should be for all facilities), and a Dutch example was given where it became a barrier to equipment replacement. This can be addressed by ensuring that IT part load (i.e. the percentage of the design maximum) is always specified with the PUE value.

Some stakeholders suggested focusing on cooling loads – for example Coefficient of Performance (COP) or adapting the M&E equipment to the IT cooling needs (predicted performance therefore becomes the focus, not just PUE). However, many of the difficulties with PUE are also true of alternative metrics (including DCIE which was also suggested).

It was felt that ASHRAE 90.4, a new standard that establishes the minimum energy efficiency requirements for data centres, is not widely adopted and is in competition with ISO 30134.

Alternative suggestions to PUE targets include the following:

1. Real-time, analytics-based cooling system management, e.g. using wireless sensors for fixed-speed units or IT management of the speed of variable-speed units. This solution is available from a limited number of vendors and may not achieve the results desired or improve on those achieved by simpler and cheaper alternatives (operator experience using a product in their facilities which already had best practices implemented resulted in marginal additional improvement and performance below that advertised due to the difference between theoretical and real life conditions). Also, the use of centralised control is not recommended due to the risk of a central controller disabling the cooling; a philosophy of 'global monitoring, local control' is preferred.
2. Adding to the core criteria the use of: EN 50600-99-1, ISO 9001/EN ISO 50001 or ISO 14001. It was also suggested to add to the comprehensive criteria – EU Code of Conduct (EU CoC) participant. Criteria were modified to make reference to best practices from EN 50600TR99-1 and the EU CoC. The ISO standards suggested are broad in scope and may not result in the desired performance.
3. The overall DC use stage energy consumption (primary energy, ideally weighted according to source energy) divided by its output (bits exchanged with the clients/users (called 'useful work' by The Green Grid - https://www.thegreengrid.org/)). This indicator set automatically considers the IT performance of all components and of the DC as a system, including otherwise difficult-to-consider issues such as consolidation, virtualisation, M&E system performance, etc. and would be technology-neutral, i.e. flexible in terms of innovation. This is difficult to measure in practice; no cases are known where this is used.

Another suggestion was to reward the use of CFD (computational fluid dynamics) thermal simulation to optimise cooling systems. This is a tool which can be useful, particularly at the design stage; however, simpler, cheaper alternatives can be used to improve air performance. It is not necessary to achieve a low PUE, does not guarantee a low PUE and requires software available from a limited number of vendors.

There was also a suggestion to reward the use of M&E equipment that is accompanied with ISO 14025 certified LCA data like a PEP-ECO passport (http://www.pep-ecopassport.org); however, a limited number of products are available for data centre applications.

2.1.8 Summary of stakeholders' comments following AHWG2

Some stakeholders highlighted the role of data centre operators. The data centre operator can take a range of actions to reduce the PUE of the data centre, which are largely covered by the cooling system best practices in Section 2.3. In the case of data centre operation and maintenance, a criterion based on an absolute value of PUE is not considered appropriate; however, it is considered appropriate to drive improvement based on the current PUE value of the data centre. The opinion on real-time, analytics-based cooling system management reported in the summary of stakeholders' comments in Section 2.1.7 is considered misinformed by a server manufacturer / service provider.

2.1.9 Final criterion proposal

Summary rationale for the final proposal
The revised version of this criteria area includes the following:

- The main focus is on encouraging a low design PUE for new data centres. However, care must be taken to only compare bids on the basis of a specified IT load. Monitoring is then specified as a CPC to ensure that the operational performance is checked against the design performance.
- An additional Award Criterion based on the bidder's estimated improvement potential relative to the historical baseline for the PUE has been added. This is particularly applicable in the case of operation and maintenance of an existing data centre where the historical PUE is known. This is particularly applicable to co-location data centres.

Final criteria proposal

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
AC5 Power usage effectiveness (PUE) – designed PUE *(same for core and comprehensive criteria)* *Applicable in the case of construction/retrofitting of a new/existing data centre when the IT power use can already be determined.* Points will be awarded for the best-performing designed PUE (dPUE) offer (full number of specified points) at a given IT load (e.g. 50% of design) and specific environmental conditions. The PUE value must be determined according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent. **Verification** The tenderer must provide design calculations which show how the PUE has been calculated according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.	
AC6 Power usage effectiveness (PUE) – PUE improvement potential *(same for core and comprehensive criteria)* *Applicable in the case of operation and maintenance of an existing data centre where the historical PUE is known. It may also be applicable to server rooms if they have a dedicated cooling infrastructure.* Points will be awarded based on the tenderer's estimated potential for improvement relative to the historical baseline for the PUE [to be provided by the contracting authority]. Bid estimates must be made based on the historical IT load and environmental conditions, as specified by the contracting authority. The PUE value must be determined according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent. **Verification** Tenderers must provide calculations which show how the PUE has been estimated according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.	

Core criteria	Comprehensive criteria
CONTRACT PERFORMANCE CLAUSES	
	CPC4 Demonstration of Power Usage Effectiveness (PUE) at handover *To be used in conjunction with AC5. The demonstration and reporting may be carried out on a modular basis where relevant to the data centre's design and phasing.* The data centre system / integrated system commissioning must include a test where the IT equipment load is simulated at part and full load, with power and cooling systems operating in automatic mode. The total or clearly identified module of data centre power consumption and IT equipment power consumption must be recorded along with the ambient conditions. Actual performance can then be compared with targets from AC5. Data to show instantaneous PUE is based on measured values and part load according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.
CPC5 Monitoring of power usage effectiveness (PUE) input values *(same for core and comprehensive criteria)* *To be used in conjunction with AC5 and AC6.* The operator of the data centre facility must provide an annual report containing the year's average and monthly disaggregated data for the total metered energy consumption of the data centre and the submetered electricity consumption for the mechanical and electric systems and the IT equipment.	

2.2 Criteria proposals: Operating conditions control and Cooling system best practices

2.2.1 Background

Cooling of the data centre is frequently the largest source of energy loss in a data centre facility and as such represents a significant opportunity to reduce energy consumption.

Opportunities for improvement come from the following:

a) Airflow management and design.
b) Cooling management.
c) Temperature and humidity settings.
d) Selection of cooling system.
e) Selection of Computer Room Air Conditioner/Computer Room Air Handling (CRAC/CRAH) equipment.

In particular, the European Code of Conduct for Data Centres identifies five main areas of improvement under each of which techniques are then listed that can be implemented at component or system level:

a) Airflow management and design: The objective of airflow management is to circulate only the amount of air through the data centre that is necessary to remove the heat created by the ICT equipment (i.e. no air circulates unnecessarily). Poor airflow management often results in attempts to compensate by reducing air supply temperatures or supplying excessive air volumes, which have an energy penalty. Improving airflow management will deliver more uniform ICT equipment inlet temperatures and will enable reductions in energy consumption without the risk of equipment overheating. A Technical Specification is proposed based on those practices that are considered 'Expected Practices' under the Code of Conduct for Data Centres and CLC/TR 50600:99-1-2018 which are listed under the following situations: New build or refurbishment of data centres.

b) Cooling management: The data centre is not a static system and the cooling systems should be tuned in response to fluctuations in environmental conditions. Improving monitoring will enable a faster and more accurate response to the fluctuations in environmental conditions (cooling management), enabling reductions in energy consumption without the risk of equipment overheating. A criterion for the design and installation of comprehensive environmental monitoring system is proposed.

c) Temperature and humidity settings: Operating overly restricted environmental controls (in particular, excessively cooled computer rooms) results in an energy penalty. Widening the set-point range for temperature and humidity can reduce energy consumption, especially when it allows the use of economised and free cooling and the ICT equipment does not exhibit significant increases in fan power consumption. A criterion for the inclusion of comprehensive environmental monitoring is proposed.

d) Selection of cooling system: When refrigeration is used as part of the cooling system design, a high-efficiency cooling system should be selected. Designs should operate efficiently at system level and employ efficient components. This demands an effective control strategy which optimises efficient operation, without compromising reliability. A Technical Specification is proposed based on practices that are considered 'Expected Practices' under the Code of Conduct for Data Centres and the CLC/TR 50600:99-1-2018 which are listed under the following situations: New build or refurbishment of data centres.

e) Computer Room Air Conditioner/Computer Room Air Handling (CRAC/CRAH) equipment: These are major components of most cooling systems within the computer room; they are frequently unable to operate efficiently in older facilities. A Technical Specification is proposed based on practices that are considered 'Expected Practices' under the Code of Conduct for Data Centres and the CLC/TR 50600:99-1-2018 which are listed under the following situations: New build or refurbishment of data centres.

One way in which the environmental impact of data centre cooling systems can be reduced is through operating at higher internal temperatures. Provided the air delivered to the ICT equipment is managed and kept within recommended and allowable environmental ranges, this does not adversely affect hardware failure rates[97].

Higher-temperature operation of the cooling medium (air and chilled water where applicable) reduces the energy consumption of the refrigeration cycle; operating at higher evaporating temperatures reduces the work. It also allows free cooling. Zero refrigeration designs are available throughout Europe. Designing systems for the reduction of energy consumption of power and cooling infrastructure (lower PUE) allows dematerialisation of compressors (found in chillers and DX air conditioners) and their associated refrigerants, distribution systems and supporting electrical infrastructure. In cases where free cooling is used but refrigeration is still installed for peak conditions, using free cooling reduces the operational energy consumption and the associated material impacts with refrigeration may be reduced. Best practices around good air management and operating at higher temperatures also need to be applied in order to maximise free cooling opportunities. The EU Code of Conduct for Data Centres contains additional details.

Another way to reduce plant requirements is to design the facility in a modular way so that additional power and cooling infrastructure is only added as required according to the growth of

[97] 2011 Thermal Guidelines for Data Processing Environments – Expanded Data centre Classes and Usage Guidance, ASHRAE TC9.9 (2015).

the data centre. This defers costs and improves the part load energy efficiency. It also allows flexibility; at such time as a future phase needs to be installed, alternative solutions may be available which perform better in terms of environmental impact, for example.

2.2.2 Life cycle environmental hotspots and potential improvements

Cooling of the data centre is frequently the largest source of energy loss in the facility and as such represents a significant opportunity to improve efficiency (Table 14). Facilities are often supplied with colder than necessary air (and hence chilled water, where used), resulting in an energy penalty.

2.2.3 Life cycle cost implications and trade-offs with potential environmental improvements

Cooling costs are one of the major contributors to the total electricity bill of large data centres. The reduction of the cooling demand has a positive impact on the life cycle costs of a data centre under OPEX Facilities. Reducing the M&E installed capacity can also allow the capital costs to be reduced.

2.2.4 Verification

The designers of new facilities should confirm that their design can support the temperature ranges defined in the criteria (e.g. in the mechanical specification). The operators of co-location facilities and Managed Service Providers should confirm that the facility in operation can support the temperature ranges defined in the criteria (e.g. in their Service Level Agreement contract).

2.2.5 Market implications and functionality

Operating at higher temperatures facilitates dematerialisation and operational energy reduction benefits; however, potential risks need to be managed:

- Air hotspots: Air management best practice aims to remove hotspots within the data hall caused by recirculation of exhaust air from the IT equipment, by separating hot and cold air streams and supplying the correct air volume where it is needed. This reduces the gap between the temperature supplied by the cooling units and received by the IT equipment. Once this is under control it is possible to raise set points, which reduces the energy consumption of the compressors for cooling and decreases fan speeds and air bypass.
- Risk of component failure:
  - ASHRAE research suggests that increased risk of component failure when operating at higher temperatures is insignificant when the number of hours of exposure is limited (e.g. just at the hottest times of year).
  - High relative humidity was found to have a higher impact on hard disk drive failures than high temperatures[98] and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failure at higher temperatures[99].

[98] Environmental Conditions and Disk Reliability in Free-cooled Datacenters, USENIX conference 2016).

[99] University of Virginia paper (Datacenter Scale Evaluation of the Impact of Temperature on Hard Disk Drive Failures, Sankar et al 2013.

- Increased IT equipment energy consumption: IT equipment has a temperature above which its internal fan speeds increase which increases power consumption, which can partially offset potential benefits. For some equipment, this may be above 27 °C; experience has shown that for other equipment fan speeds increase at much higher temperatures. In an environment where a zero refrigeration cooling system design supports ICT equipment inlet temperatures below 27 °C for 8 759 hours of the year for example, the environmental (and operational cost) benefit of allowing a short temperature excursion and avoiding refrigeration outweighs the risk of higher server fan energy consumption for one hour of the year. This may not be the case in an environment where there is a significant number of hours annual excursion; however, this should not be in the case in well-designed/managed facilties with European climate conditions.
- In co-location environments where shared cooling systems serve different end users, all stakeholders need to agree to higher temperature ranges in order to realise the benefits. This may be addressed in the contract Service Level Agreement; however, it may be difficult to change details in existing contracts.

2.2.6 Applicability to public procurements

These criteria complement the IT Equipment Operating Range (TS2). Cooling systems should be designed and operated at higher temperatures as well as procuring ICT hardware which can accommodate higher temperatures. The operation at higher temperatures criterion is relevant when designing a new facility or upgrading/expanding an existing facility. It could also be used when choosing a co-location facility. Using a Service Level Agreement (SLA) for operating at higher temperatures could form part of an outsourcing contract with contract performance clauses used to ensure this best practice is maintained.

A focus on reducing the overall electricity consumption for cooling is considered more performance-based. Such a reduction would already be reflected in a reduction in the PUE (see criterion proposal 2.1).

2.2.7 Summary of stakeholders' comments following AHWG1

Stakeholders felt that the draft criteria were too prescriptive; they were updated to better complement those around the ICT hardware operating range. Co-location data centre operators were concerned that it may not be possible to influence the conditions, and that more than just air management was required. The criteria were split into design and operation, and additional text specific to functionality for this application was added.

Concerns were raised that raising temperatures would result in an overall increase in energy consumption due to the ramping up of server fans. Data provided by IT equipment manufacturers indicates that if a data centre normally operates at a server inlet temperature of 15 °C and the operator wants to raise this temperature to 30 °C, it could be expected that the server power would increase in the range of 3% to 7%. If the inlet temperature increases to 35 °C, the IT equipment power could increase in the range of 7% to 20% compared to operating at 15 °C[100].

With regards to best practices, the EU Code of Conduct (also to be included in EN 50600 TR99 -1) or the EMAS BEMP, in its place, were cited as being important and that there are examples of it being used as a procurement tool. Some stakeholders emphasised that the real opportunities lie in the processes that take place before procurement. But there was also a concern that these

100 ASHRAE TC 9.9 - 2011 Thermal Guidelines for Data Processing Environments avaialbe at https://ecoinfo.cnrs.fr/IMG/pdf/ashrae_2011_thermal_guidelines_data_center.pdf

best practice listings, such as the EU CoC, which has a substantial number of criteria, may be too complex or not fit with the approach required for such criteria to include best practice in this way.

A focus on only cooling loads was raised by several stakeholders and the question asked – how best to measure cooling efficiency? Co-efficient of Performance (CoP) was put forward by one stakeholder. A more novel approach introduced by another stakeholder would be to focus instead on adapting the M&E equipment to the IT cooling needs. It was claimed that software and analytical tools are already being used to do this. Predicted performance values then become the focus of attention and not just a target PUE value. It was not clear if the methods are yet standardised, although it was claimed that through the EU CoC there is the possibility to review/qualify modelling. It was agreed that the JRC would follow this up with a number of the participants in the meeting.

2.2.8 Summary of stakeholders' comments following AHWG2

Some stakeholders suggested extending the applicability of the best practice requirements to the procurement of hosting space and co-location space, in which the contractor is in charge of operating the cooling system of the data centre. It was also suggested to accept participation in the EU Code of Conduct as proof of implementation of the best practices.

Moreover, the contribution of data centre dynamic control systems to the control of the environmental conditions of a data centre was noted.

Some stakeholders highlighted that most data centres in the EU should be capable of harvesting some free cooling (30-40% of the time with proper systems) and suggested the inclusion of a specific award criterion in order to be significantly more impactful in reducing energy consumption.

2.2.9 Final criteria proposal

Summary rationale for the final proposal
The revised version of this criteria area includes the following:

- A refinement of the Selection Criterion 3 with a specific reference to competencies related to the identification of energy reduction opportunities, the use of monitoring systems to inform energy reduction strategies, the implementation of EU Code of Conduct best practices related to 'cooling management' and 'temperature and humidity settings'.
- In order to be flexible to the competencies of different sized companies, this evidence may relate to either relevant contracts or key personnel who will be involved in providing the service. The criterion recognises that in practice improved performance can be obtained through a combination of the latest technologies (including software) and human expertise.
- Due to the different level of granularities that are possible to achieve in the environmental control of a data centre, the new proposal for Technical Specification TS5 requires that the granularity level is reported in accordance with EN 50600-2-3.
- The proposed Technical Specification on cooling system best practices has been refined (TS6 and TS7). The detailed list of practices has been removed in case of changes to the Code. The verification has been updated to expect participation in the EU Code of Conduct, to be verified by providing application documents. The implementation of free cooling / economised cooling is now requested whenever there is the opportunity. The option to carry out an on-site audit to verify implementation is also included.
- Acceptance as a participant in the EU Code of Conduct and implementation of the best practices will also be monitored under a contract performance clause (CPC6).

Final criteria proposal

Core criteria	Comprehensive criteria
SELECTION CRITERIA	

SC3 Cooling energy management

(same for core and comprehensive criteria)

To be included when the data centre is operated by a third party.

The tenderer must have relevant competencies and experience in minimising cooling energy use, identifying opportunities to reduce energy use and to use any remaining waste heat (e.g. for heating adjacent buildings or district heating networks). In particular, bidders must provide information on the following:

• The capability and skills of the bidding organisation and any contractors to successfully identify and implement energy reduction and energy reuse measures. This shall include the provision of a competent energy manager for each site covered by the contract.

• The operational experience in using monitoring systems and software to inform energy consumption reduction strategies, with particular reference to EU Code of Conduct [101] / EN 50600 TR99-1 best practices on 'cooling management' and 'temperature and humidity settings'.

Verification

Tenderers must provide evidence from previous data centre projects with similar characteristics that demonstrate how they have reduced or minimised the use of cooling energy.

Evidence in the form of information and references for specific data centre sites that have been serviced in the last 3 years. This evidence may relate to either relevant contracts or key personnel who will be involved in providing the service.

TECHNICAL SPECIFICATIONS

TS5 Environmental monitoring

(same for core and comprehensive criteria)

To be used in the case of new build or retrofit of data centres.

The tenderer must demonstrate that the facility has environmental control facilities and infrastructures that are in line with the requirements and recommendations of standard EN 50600-2-3 and are capable of measuring the following:

1) Computer room temperatures:

a) supply air temperature;

b) return air temperature;

c) cold aisle temperature (where used);

d) hot aisle temperature (where used).

2) Relative humidity:

a) external relative humidity;

b) computer room relative humidity.

3) Air pressure under the access floor (if an access floor is installed).

4) Coolant flow rates (if the design of the environmental control system relies on the movement of fluids, e.g. water cooling).

They must also report on the granularity of the measurement regime that they are proposing to install.

Verification

The tenderer must provide designs and technical specifications for the monitoring system that they will install and identify how this provides the reported measurement regime granularity in accordance with EN 50600-2-3. The contracting authority reserves the right to request a report of a suitable third-party audit of the data centre to verify implementation of the best practices.

[101] https://e3p.jrc.ec.europa.eu/publications/ict-code-conduct-reporting-form-participants-and-endorsers-guidelines

<table>
<tr><td></td><td>TS6 Cooling system best practices – new build or retrofit of data centres

The tenderer must demonstrate that the design incorporates the ‘expected’ best practices listed for the following design aspects in the most recent version of [EU Code of Conduct / EN50600 TR99-1]:

• air flow management and design;
• the cooling plant;
• computer room air conditioners / air handlers.

In addition, free cooling and economised cooling practices must be implemented where there is the opportunity (see also the accompanying explanatory note) and a future climate vulnerability and risk assessment must be carried out on the cooling systems.

Verification

The tenderer must provide designs and drawings that incorporate Code of Conduct / EN 50600 TR99-1 best practices. The contracting authority reserves the right to request a third-party audit of the data centre to verify implementation of the best practices.

In the case of participation in the EU Code of Conduct, the tenderer must provide the filled-in reporting form[102] submitted for registering with the EU Code of Conduct, including the description of the implementation plan for the expected practices. Proof of the participation status granted by the European Commission DG Joint Research Centre must also be provided.

Acceptance as a participant in the EU Code of Conduct and implementation of the best practices will also be monitored under a contract performance clause.</td></tr>
<tr><td colspan="2">EXPLANATORY NOTE: Free cooling and economised cooling practices

Free cooling and economised cooling are cooling plant designs that take advantage of cool ambient conditions to meet part or all of the facilities’ cooling requirements so that the dependency on any form of mechanical cooling including compressors is reduced or even removed entirely, thus allowing for a significant reduction in energy consumption.

The opportunities for utilising free cooling are increased in cooler and dryer climates and where increased temperature set points are used.</td></tr>
<tr><td></td><td>TS7 Cooling system best practices – existing co-location or hosting data centres

The tenderer must demonstrate that the data centre incorporates the ‘expected’ best practices listed for the following design aspects in the most recent version of [EU Code of Conduct or EN50600 TR99-1]:

• air flow management and design;
• the cooling plant;
• computer room air conditioners / air handlers.

In addition, free cooling and economised cooling practices must be implemented where there is the opportunity (see also the accompanying explanatory note).

Verification

The tenderer must demonstrate [up-to-date participation in the EU Code of Conduct or third-party verification of implementation of the expected practices as listed in</td></tr>
</table>

[102] https://e3p.jrc.ec.europa.eu/publications/ict-code-conduct-reporting-form-participants-and-endorsers-guidelines

Core criteria	Comprehensive criteria
	EN50600 TR99-1 reference]. The tenderer must provide the filled-in reporting form[103] describing the implementation status of the expected best practices for the design aspects listed above. The contracting authority reserves the right to request a report of a suitable third-party audit of the data centre to verify implementation of the best practices. Justification for omitting any of the listed 'expected' best practices must be provided.
Explanatory note Free cooling and economised cooling are cooling plant designs taking advantage of cool ambient conditions to meet part or all of the facilities' cooling requirements so that the dependency on any form of mechanical cooling including compressors is reduced or even removed entirely, which can result in significant energy reduction. The opportunities for the utilisation of free cooling are increased in cooler and dryer climates and where increased temperature set points are used.	
AWARD CRITERIA	
	AC7 Cooling system energy consumption Points will be awarded based on the estimated cooling energy consumption required to operate the data centre design under reference climatic conditions for the location. Points will be awarded for the best-performing design offer (full number of specified points). **Verification** The tenderer must provide documentation, modelling and calculations for the design estimation process.
CONTRACT PERFORMANCE CLAUSES	
	CPC6 Implementation of best practice designs *This criterion should be used in conjunction with technical specification TS6*. Based on the final design, the data centre must be [*accepted for EU Code of Conduct participation/third party verified with reference to EN 50600 TR99-1]* during execution of the contract. The tenderer must submit the final designs for participation in the EU Code of Conduct. Annual updated versions of the reporting form must also be copied to the contracting authority. The contracting authority reserves the right to request a third-party audit of the data centre to verify implementation of the best practices.
	CPC7 Monitoring of cooling system's energy consumption *To be included when the data centre is operated by a third party. To be used in conjunction with AC7*. The operator of the data centre facility must provide monthly and annual data for the energy consumption of the data centre's cooling system. The monitoring must be specified according to the guidelines in EN 50600-4-2:2016 or equivalent.

[103] https://e3p.jrc.ec.europa.eu/publications/ict-code-conduct-reporting-form-participants-and-endorsers-guidelines

2.3 Criterion proposal: Reuse of waste heat

2.3.1 Background

Significant potential exists for waste heat reuse from data centres since over 98%[104] of the energy consumed in the data centre is eventually dissipated as waste heat which is then rejected into the atmosphere. Finding a use for this heat and displacing energy that would otherwise be consumed to generate that heat could effectively drive up the overall energy system efficiency of the data centre.

Effectively reusing waste heat depends on the following criteria:

a. Co-location of the data centre to customers with suitable heat load profiles and needs.
b. Heat quality, i.e. suitable temperature for the customer needs.
c. Infrastructure for transporting heat.

Generally the heat is low-grade (35-45 °C and sometimes below 25 °C[105]) and expensive to transport. To supply a district heating system, it must be concentrated using air-to-air or air-to-water heat pumps to raise the temperate to a suitable temperature (most district heating would be distributed at 70 °C). The DC must also be connected to the district heating system with well-insulated pipes to minimise losses. The waste heat, however, can be sold to the district heating supplier if they are technically and contractually willing to accept it, which may not always be the case.

Smaller networks can be supplied with lower-grade heat, particularly for internal use within a building. However, since the customer or demand may be small, the load profile and total demand is unlikely to match the heat generated. This means only a fraction of the heat is reused but the lower cost and ease of connection may mean this is worth pursuing. The technical requirements, costs and efficiency are very dependent on the characteristics of each site and it is very difficult to estimate costs and benefits. Feasibility studies covering the financial, technical and contractual details are required for each case, to ensure there is a clear relationship between the data centre and any existing infrastructure. More detail on the scoping of location can be found in the guidance document.

[104] http://www.datacenterknowledge.com/archives/2016/05/10/how-to-reuse-waste-heat-from-data-centers-intelligently

[105] Davies, Maidment, Tozer, *Using data centres for combined heating and cooling: An investigation for London*, Applied Thermal Engineering, https://doi.org/10.1016/j.applthermaleng.2015.09.111

Figure 16: Mäntsälä district heating network, Finland

Source: Envirotech and Cloud & Heat (2017)

Other heat sinks could include leisure centres that include swimming pools and agricultural uses such as greenhouses and animal housing. Low-grade heat can also be stored in geothermal aquifers for later use and upgrading, allowing for interseasonal storage that can accompany district heating.

The amount of heat reused can be measured using the KPI_{REUSE} (Energy Reuse Factor) as defined in ETSI ES 205 200-2-1. The system boundaries and nomenclature used should align with those found in ETSI ES 205 200-2-1[106].

$$KPI_{REUSE}\left(t_k^{(REUSE)}\right) = KPI_{REUSE}^{(k)} = \sum_{i=1}^{N} \frac{\left\{\min\left\{RU_n^{(k)}, L_n^{(k)}\right\} + W_L \times \max\left\{0, RU_i^{(k)} - L_n^{(k)}\right\}\right\}}{C_n^{(k)}} \quad \text{for k = 1, 2, 3, …..}$$

n = data centre number (if the assessment is applied to a common set of data centres);
N = total number of data centres (if the assessment is applied to a common set of data centres);
$Ln^{(k)}$ = total energy consumed by ITE and/or NTE load in data centre n during the KPI; assessment interval between t_{k-1}^{begin} and t_{k-1}^{end} as described in detail in ES205 200-1;
$RU_n^{(k)}$ = total energy re-used from data centre n during the KPI assessment interval between t_{k-1}^{begin} and t_{k-1}^{end} end as described in detail in ES 205 200-1;
W_L= ratio of re-used energy taken into account for the portion that is above the load energy, if any;
min (x,y) = the smaller of x and y;
max (x,y) = the larger of x and y;

[106] An ISO Standard (ISO/IEC 30134-6 Information technology -- Data centres -- Key performance indicators -- Part 6: Energy Reuse Factor (ERF)) is expected to be published early 2019 with no major changes.

$Cn^{(k)}$ = total energy consumption by data centre n during the KPI assessment interval t_{k-1}^{begin} and t_{k-1}^{end} tk-1.

An important feature of the ERF calculation is that the reuse of energy is considered a secondary objective, subject to the following conditions:

- 'non-use' is better than 'reuse' and therefore the KPI_{REUSE} will reflect a preference for energy consumption reduction rather than reuse;
- any KPI_{REUSE} shall reflect a preference for reuse of energy in the form of heat generated by the ITE/NTE rather than from poorly designed facilities and infrastructures.

Consequently, the factor is also a reflection of the system efficiency of the data centre and how much heat is dissipated.

2.3.2 Life cycle environmental hotspots and potential improvements

There are no LCA studies quantifying the environmental benefits when waste heat is reused or comparing these to the environmental impacts arising from other life cycle stages. However, in countries and cities where there is a heating network infrastructure (e.g. district heating in Denmark and Sweden, cities such as Paris and Berlin), society carbon savings have been identified when the heat is utilised in neighbouring buildings or infrastructure (e.g. in district heating). This is not observed in countries where such an infrastructure does not exist.

There is no specific impact associated with hot air ejected to the atmosphere, although there may be impacts from hot water sent directly into the waterways. The impacts are mainly associated with the energy production. Heat reuse avoids additional energy consumption for the target being heated, hot water, etc. The savings will therefore depend on the energy source being displaced and will be site-specific. However, these are strongly net positive for district heating which match the requirements in Section 2.2.1.

For each 1 MWh of heat reused from a data centre, the annual carbon reduction for a district heating network assuming displacement of natural gas boilers for heating could be approximately 260 kg CO_2 eq as well as other associated emissions such as CO, NO_x and particulates. This is likely a best-case scenario. Figure 17 illustrates an energy flow chart for a small data centre that supplies heat to a number of apartment blocks.

Figure 17: Example energy flow chart for a data centre in Dresden, Germany

Source: Cloud & Heat (2017)

The Stockholm city district heating network[107] has been actively encouraging the connection of data centres on the district heating network and has worked to simplify the technical and contractual issues. A total of 10 data centres are currently understood to be connected and can sell their waste heat back to the network.

2.3.3 Life cycle cost implications and trade-offs with potential environmental improvements

The costs and benefits are highly site-specific and they become evident if district heating is already available or is being planned. It is assumed that waste heat is not reused where there is no demand.

Case studies estimate payback periods of around 3 years. This means that reusing waste heat has a net positive value for the contracting authority and/or the data centre operator. It can also generally be assumed that the cost of a new district heating network to facilitate heat reuse would be borne by a utility company or local authority (which could also be the contracting authority).

2.3.4 Verification

Heat reuse is generally easy to verify through contracts and should be monitored along the contract duration. The amount of heat reused can be verified by metering the heat at the point of supply entry to district heating or another network or building(s). The proposed metric is Energy Reuse Factor (ERF) calculated based on ETSI ES 205 200-1. Energy reused must be measurable in kWh at the intended point of supply to the network, i.e. any losses on the network shall not be included. In 2020, a new European Standard for the calculation of the Energy Reuse Factor was approved: EN 50600-4-6:2020 Information technology - Data centre facilities and infrastructures - Part 4-6: Energy Reuse Factor. This standard in currently considered the main technical reference.

2.3.5 Market implications and functionality

There are currently very few data centres in the EU with heat reuse, possibly less than 100. There is large potential for heat reuse in data centres based on the distribution of the district heating networks across Europe (see Figure 19). However, it is not clear whether these locations meet the other requirements for data centres such as physical space, network connectivity and energy supply. The UK for example is one of the three biggest European data centre markets but has very limited district heating networks. Functionality is not consided to be affected.

In response to stakeholder concerns about the financial implications of potentially requiring data centres to connect to district heating infrastructure, the example of Stockholm Data Parks was investigated. Two connection services are made available:

1. Cooling as a service: In the event that the excess heat load exceeds 10 MW then the district cooling system is offered for free in exchange for the waste heat. This arrangement is contained within a Service Level Agreement. However, the costs of the cooling supply rise steeply with lower cooling requirements.
2. Heat take off: The district heating operator purchases the excess heat at a price reflecting its ‘alternative’ heat production cost. Two contractual arrangements are offered [108]:

[107] https://www.opendistrictheating.com/

[108] Open district heating, *Recover your excess heat with Open District Heating*, https://www.opendistrictheating.com/our-offering/

- Call: A guarantee is provided that heat will be taken whenever the outdoor temperature is 12 °C or below. This is supported by a fixed capacity payment.
- Spot: Data centre operators decide when they supply heat, with no obligation. Payments are based on the amount of heat supplied and are indexed to outdoor temperatures. Supply temperatures may be variable, fixed or based on the flow/return delta.

The infrastructure required to supply the heat – for example, heat pumps to upgrade the heat to the DH supply temperature - must be financed by the data centre operator. A heat pump installation is quoted as costing EUR 494 000/MW. A 10-year supply contract is offered and in all cases the capital costs will be paid back within that timeframe.

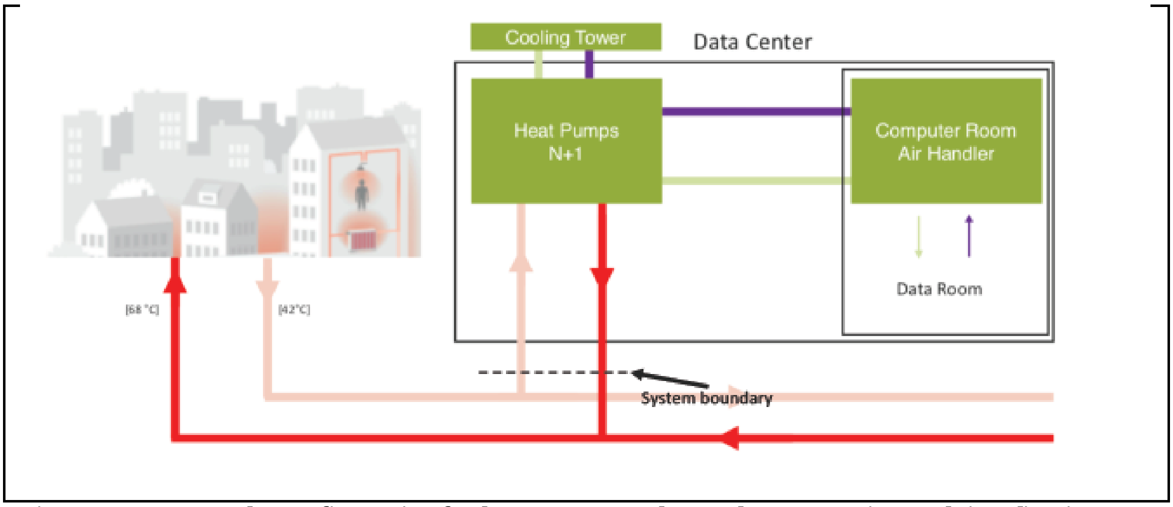

Figure 18: Example configuration for heat recovery when a data centre is supplying district heating to the city of Stockholm.
Source: Stockholm Exergi (2018)

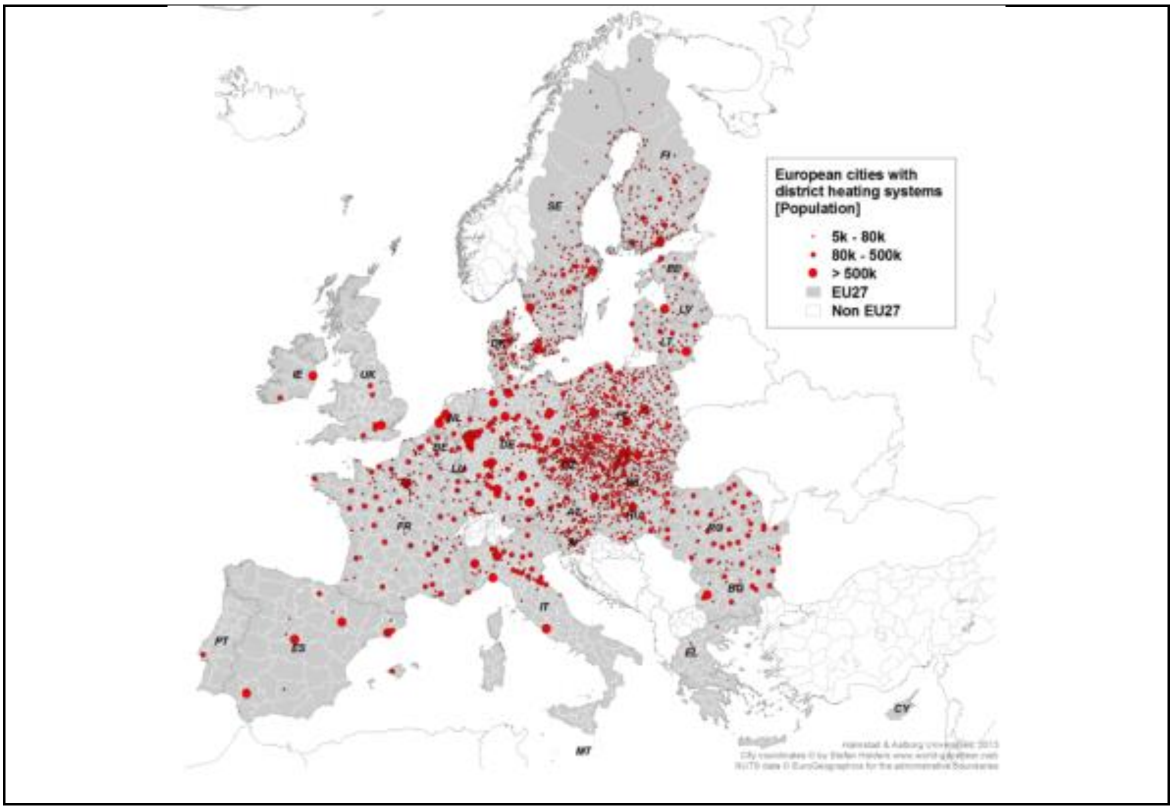

Figure 19: European cities with district heating
Source: (Halmstad and Aalborg University, 2013)

2.3.6 Applicability to public procurement

There are relatively few data centres in the data centre market that reuse heat and these are currently concentrated in northern Europe and they actively encourage data centre connection and minimise administration costs. It is unlikely that a procurer could easily source a data centre which reuses heat, so it is suggested instead that use of the criterion is adapted to local circumstances, i.e. if there is already a mature network which can accept the heat then a comprehensive criterion could be set, but if there is no existing network but potential large demand then an award criterion could encourage co-location and heat reuse.

In the event that heat cannot be supplied to the network a feasibility report would have to be provided showing why it was not feasible. It is also considered that it would be easier to integrate heat recovery equipment into the design of a new data centre, suggesting that the enterprise data centre procurement scenario would be the most appropriate for this criterion. An award criterion could also be used to encourage innovation amongst service providers, albeit potentially across many facilities.

2.3.7 Summary of stakeholders' comments following AHWG1

Stakeholders recognised the value of this proposal but felt there were limited sites where it would be possible. One stakeholder felt a rebound effect could lead to an increased incentive to create more heat in the first place, therefore the type of use should be specified; and one felt the criterion should be deleted for this reason. However, the specified metric, KPI_{REUSE} accounts for this by specifying a preference for energy reduction (or non-use) over reuse. The section was therefore retained. Alignment of system boundaries and nomenclature from the ETSI standards is important and is noted in Section 4.2.1. One stakeholder felt that reuse should be considered within the overall energy efficiency; however, it was retained in this section as it is a proven method for reducing emissions, but requires special consideration to adopt it (for example proximity to a district heating system).

It was felt that the criterion should require a clear relationship between existing infrastructure and suitable end users including consideration of the economics (see the guidance document), and the effects of free cooling (which are accounted for by using less energy).

Omitting criteria that could enable locations with no access to a district heating network from achieving points from their reuse of waste heat seemed unfair, when in reality some stakeholders felt that this reuse would be easy and should be implemented everywhere. A criterion to award points for the recovery and reuse of waste heat within the boundaries of the data centre was therefore added.

2.3.8 Summary of stakeholders' comments following AHWG2

It was remarked that the reuse of waste heat was a niche criterion that is economically viable in only a few cases. It was suggested to refer to ISO/IEC 30134:2016 Part 6, EN 50600-4-6. Although this standard is not yet published, it is very close to completion and will provide a definition and approach consistent with PUE; as a guide, GPP Criteria may be able to refer to the upcoming publication of this standard.

2.3.9 Final criteria proposal

Summary rationale for the final proposal

Due to the finalisation of new standards for the Energy Reuse Factor (ISO/IEC DIS 30134-6 and EN 50600-4-6), it is proposed to allow the use of this standard or equivalent.

The criterion TS8 has been modified at core level to request waste heat reuse readiness by providing routes for future heat transfer pipework. With the exception of this aspect, the criteria proposal has not been modified and it includes the following:

- A technical specification requiring the data centre's connection and heat supply to the local district heating network, adapted to the local availability of district heating systems and networks (comprehensive level). This ensures that use of the criteria always reflects local circumstances and infrastructure, which are critical to making the arrangements economically viable.
- An award criterion giving additional points to tenderers that commit to supplying more than x% (adapted to the local availability of district heating systems and networks) of the data centre's waste heat (expressed as the Energy Reuse Factor) to local end users is designed to incentivise higher levels of heat reuse, where feasible.
- An award criterion providing additional points in proportion to the bidder that offers managed services with the highest Energy Reuse Factor.
- A contract performance clause requires the monitoring of the heating supply and connection when the data centre is operated by a third party. This is to ensure that the infrastructure connection is made.
- Third-party-verified energy management systems (based on ISO 50001) or environmental management systems (based on EMAS or ISO 14001) reporting the calculated ERF have been included as possible accepted proof.

Final criteria proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
TS8 Waste heat reuse readiness *It is recommended that this technical specification only be set if there is ready demand on or near site for the heat or if the public authority has identified a clear planned or potential opportunity on or near the site.* The data centre or server room must provide for routings for future heat transfer pipework or other layout features to fit, or facilitate retrofitting of, a facility water system reaching each row of server rack so that liquid cooling of these could easily be retrofitted at a later stage. **Verification** The tenderer must provide design engineering drawings showing that a facility water system with branches to each row of server rack will be fitted or that the layout is so designed that it could be easily retrofitted. The contracting authority reserves the right to request a report of a suitable third-party audit of the data centre to verify implementation of this criterion.	**TS8 Waste heat reuse** *The criterion should be adapted to the local availability of district heating systems and networks. It is recommended that a comprehensive technical specification be set if there is ready access.* The data centre must be connected to and supply a [percentage to be specified by the contracting authority]% of the data centre's waste heat expressed as the energy reuse factor (ERF) to local heat consumers[109]. The ERF must be calculated for each facility according to EN 50600-4-6:2020 or an equivalent standard. **Verification** The tenderer must provide calculations and design engineering drawings for the heat reuse systems and connection. Evidence of contractual arrangements or letters of intent must be obtained from the network operator. The contracting authority reserves the right to request a report of a suitable third-party audit of the data centre to verify implementation of this criterion. A third-party verification of the ERF can be accepted as evidence. Third-party-verified energy management systems (based on ISO 50001) or environmental management systems (based on EMAS or ISO 14001) reporting the calculated

[109] This may include consumers on the same site or linked to the data centre via a district heating network.

Core criteria	Comprehensive criteria
	ERF can also be accepted as evidence.
AWARD CRITERIA	
	AC8 Waste heat reuse (for new data centres) *The criterion should be adapted to the local availability of district heating systems and networks. It is recommended that a comprehensive award criterion be set if a public authority identifies local opportunities.* Points will be awarded to tenderers that commit to supplying more than x% [percentage to be specified by the contracting authority] of the data centre's waste heat expressed as the energy reuse factor (ERF) to local end users. An additional point will be given for every 10% of extra waste heat the data centre supplies. The ERF must be calculated for each facility according to EN 50600-4-6:2020 or an equivalent standard. **Verification** The tenderer must provide calculations according to ETSI EN 50600-4-6:2020 or an equivalent standard and the design engineering drawings for the heat reuse systems and connection. Evidence of contractual arrangements or letters of intent must be obtained from potential heating customers.
	AC9 Waste heat reuse (for managed services) *It is recommended that this comprehensive award criterion be used if a service is being procured.* Points will be award based on the declared energy reuse factor (ERF) for the facilities that will be used to execute the contract. Points will be awarded in proportion to the tenderer that offers the highest energy reuse factor. The ERF must be calculated for each facility according to EN 50600-4-6:2020 or an equivalent standard. **Verification** The tenderer must provide calculations according to EN 50600-4-6:2020 or an equivalent standard. A third-party verification of the ERF can be accepted as evidence. Third-party-verified energy management systems (based on ISO 50001) or environmental management systems (based on EMAS or ISO 14001) reporting the calculated ERF can also be accepted as evidence.
CONTRACT PERFORMANCE CLAUSES	
	CPC8 Monitoring of the heating supply and connection *To be included when the data centre is operated by a third party in conjunction with technical specification TS8, and award criteria AC8 and AC9.* The operator of the data centre facility must provide average monthly data for the heat supplied to the local heat consumers. In addition, the energy reuse factor (ERF) must be calculated according to EN 50600-4-6:2020 or an equivalent standard and reported. Upon request, the contracting authority must be given access to the equipment and network connection on site at the data centre for auditing purposes.

3 CRITERIA AREA 3: REDUCTION OF GHG EMISSIONS

Data centre performance concerns the whole data centre and this criteria area covers aspects related to the whole system design and/or operation which affect its environmental performance.

The key area of improvement at a system level has been identified as relating to the greenhouse gas emissions emitted from the whole data centre throughout its life cycle, with the following proposed criteria with associated metrics:

- Renewable Energy Factor (REF).
- Use of refrigerants and Global Warming Potential.

These aspects address the identified hotspots at a system level.

3.1 Criterion proposal: Renewable Energy Factor

3.1.1 Background

The actual environmental benefits of lower electricity grid emissions, including more renewable energy sources, have been presented in Section 1.6. Despite this affecting a wide range of environmental impacts, all LCA studies reviewed have shown that as more electricity is used, more greenhouse gas emissions are released, with the emissions being dependent on the Member State's electricity grid mix and on the extent to which renewable energy has a share of that mix and/or whether a data centre site has developed renewable-energy-generating capacity.

The major environmental impacts, primarily the contribution to climate change, of a data centre arise from energy consumption in the use phase and this offers the biggest potential for improvement. The best approach to reduce this impact is to improve energy efficiency but major companies in the data centre industry have also committed to using 100% renewable electricity which has an approximately 85%[110] lower life cycle Global Warming Potential compared to brown- (fossil fuel) generated electricity, although this is very sensitive to the mix of renewables and fossil fuel sources.

Decarbonising energy generation can, in theory, create the single largest potential reduction in the environmental impact of a data centre. However, in practice, this approach is not so straightforward. This argument can be applied to energy used by any product at any stage of the life cycle but there is currently not a sufficient renewable energy supply to achieve this. To ensure that non-renewable energy is not simply being shifted from one consumer to another, additionality should be demonstrated. There is no strict definition for additionality, but it generally means that without the client buying the energy, the renewable energy would not otherwise have been generated.

A formula for calculating the amount of renewable energy – the Renewable Energy Factor (REF) – has been developed in EN50600-4-3[111].

Equation 1.2.1 provides the equation for calculating the REF. However, this does not consider additionality and care must therefore be taken to ensure that the market conditions result in real carbon reductions.

[110] Emission factors: https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-iii.pdf Energy mix: https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-2/assessment

[111] https://www.cencenelec.eu/standards/sectors/ict/pages/greendatacentres.aspx

$$REF = \frac{\sum_{i=1}^{n}\left(E_{DC\,grid\,used\,i}\ \frac{E_{ren\,i}}{E_{tot\,i}} + E_{DC\,on\,site\,i} + E_{DC\,ren\ \ cert\,i}\right)}{\sum_{i=1}^{n} E_{DC\,i}} \tag{1.2.1}$$

where:
$E_{DC\ grid\ used\ i}$ is the energy provided from the grid and consumed in a data centre during the period of time I (kWh);
$E_{(ren\ i)}/E_{(tot\ i)}$ is the RE portion of the grid power (provided by the energy supplier) in the period of time I;
$E_{DC\ on\ site}$ is the RE generated on site and consumed in the data centre in the period of time I (kWh);
$E_{DC\ ren\ cert\ i}$ is the RE obtained by procurement of RE certificates and retired by the data centre in the period of time I (kWh);.
N is number of intervals.

As indicated in equation 1.2.1, the REF could include a combination of renewable energy generated on site at the data centre, renewable energy obtained by procurement of RE certificates, and the portion of utility renewable energy for which the data centre has obtained documented written evidence from the source utility provider(s) that the energy supplied is from renewable sources.

There are several purchasing mechanisms for securing a supply of renewable energy:

1. **Green tariffs from the utility supplier (grid renewables)** are the simplest option where the electricity is purchased from the utility supplier at retail rates. The utility supplier then guarantees the electricity is generated from a renewable source and in general the utility supplier cancels (i.e. retires) the Guarantee of Origin (see next point) on the consumer’s behalf. In this case, the renewable energy is then assigned to the utility supplier which in some Member States has a legal obligation to supply a certain proportion of renewable energy.
2. **Purchase of renewable energy certificates / Guarantees of Origin (GO/energy certificates)**. GOs are the EU mechanism for proving the origin of generated energy. These are tradable and every MS is required to issue and manage GOs. A company can purchase and cancel (retire) the GO to demonstrate use of renewables.
3. **Independent green energy certifications** (grid renewables) verify the environmental claims of the energy supplier and may require additional criteria. These include minimising the other environmental impacts of the generation site, requiring sourcing from new renewable sites and funding new renewable energy generation. The most widely available is the Eko certificate.
4. **Corporate power purchase agreements (PPAs)** for new generation including on-site renewables. PPAs are contractual agreements whereby the customer agrees to buy the energy generated from a site for a long period of time, typically 15-20 years. For new generation, these contracts are signed before the energy generation facility is installed and as follows:
    a. On site/near site via direct-wire. The generation is connected directly on the meter side of the data centre and the electricity is self-consumed. However, a grid interconnection is still required since generation often does not match demand perfectly and the excess must be exported some of the time.
    b. Grid-connected. The generation is on the same portion of the grid as the data centre but contributes to the overall grid electricity mix. As national electricity grids are interlinked, the renewable energy is no longer necessarily used in the same country.
    c. Remote grid. The generation and the consumption are not on the same portion of the grid. Therefore, the renewable energy must be sold back via the grid without the GO and is classed as residual mix and electricity purchased from the local grid. The company retains the GO and can cancel (retire) it.

5. **Private energy services agreement** are generally used for smaller renewable contracts compared to PPAs such as on-site installations. The client does not pay any capital costs and instead long-term contracts for payments are based on the performance of the energy services and the savings realised on the utility bill.
6. **Direct purchase.** The data centre arranges financing for capital and installation costs. This tends to be large and outside the expertise of the data centre operator. This will therefore mostly apply to small installations such as those generating energy on site. In addition, this sort of financing is likely to be beyond the scope of the data centre operators' core expertise.

3.1.2 Life cycle environmental hotspots and potential improvements

At a data centre level, energy consumption in the use phase has the single biggest environmental impact along the data centre life cycle. Renewable energy has the potential to represent the single biggest improvement option, with the potential to reduce the amount of greenhouse gas emissions from the electricity consumption by approximately 100%. This would depend on the delivered electricity accounted for in the calculation of the Renewable Energy Factor (REF) which is equivalent to approximately 85% when life cycle emissions for renewable electricity technologies are taken into account.

It is hard to demonstrate additionality, i.e. that without the demand the renewable energy would not have been generated, especially when the EU and its Member States have renewable energy targets to increase the proportion of generation, which have not been achieved. In this situation, proving additionality is best achieved with on-site/directly connected renewables. The ability to achieve this would depend on the mechanisms used by the Member States to calculate renewable energy generation.

A few Member States also have a very high renewable energy mix (Eurostat[112]) and there is little potential to increase this further with more renewable energy generation through PPAs since other policies or market forces are already addressing this. In such cases, the improvement potential is low.

However, from a wider perspective, there are also differences in the environmental impacts according to the way the electricity is sourced:

- The first two sourcing mechanisms identified in Section 3.1.1 signal to the market that there is demand for renewable energy and in theory drive greater supply and investment in renewable energy generation; however, in the short term it only shifts the renewable supply from one customer to another and is not sufficient to determine additionality. However, GOs are a necessary condition to verify that the energy is renewable.
- The independent green energy certifications spur an increase in low-carbon energy generation through a commitment to add money into a fund for new renewables and demonstrate additionality. However, investment may also have been sourced elsewhere, especially given the EU Member States' renewable energy targets. There is an implicit assumption that there are more potential renewable projects seeking funding than available funds, which may not be true in all regions. This also depends on what policies the Member State has put in place to encourage businesses to use renewables.
- Contracting PPAs is the preferred approach promoted by the Renewable Energy Buyers Alliance[113] as it more directly demonstrates additionality. This is because the PPA directly helps secure the capital investment for new generation capacity and it is easier to demonstrate that the renewable energy generation would not have been installed without the PPA. However, as discussed earlier, additionality is not proven.

[112] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_335a&lang=en
[113] http://rebuyers.org/

3.1.3 Life cycle cost implications and trade-offs with potential environmental improvements

The costs will vary depending on the market, the supplier and the individual situation of the data centre.

For green tariffs, GOs and certified energy, the cost is generally higher because the cost of renewable energy generation has historically been higher than other generation. The GOs are also tradable and the cost will vary depending on market supply and demand. GOs were trading at approximately EUR 0.15-0.30/MWh, approximately 1% of electricity prices according to an Oeko Insitut study carried out for the European Commission[114]; the low price was due to oversupply in the market. This will continue in the short term, but over the long term this situation may be corrected by the expiration of GOs and the new Renewables Energy Directive. Increased prices are expected to be passed onto the procurer.

For PPAs, the cost of the energy is generally fixed for a long term although an increasingly complex market of financial instruments is being developed. The competitiveness of the energy cost compared to grid electricity depends on the specific situation and contract. Conversations with companies having signed PPAs state that they are currently used because they have a lower cost. More importantly, they are perceived to fix the risk from fluctuating energy prices[115]. However, as renewable energy prices continue to fall, the long-term costs of a PPA may be higher than market rates. PPAs also have very high transaction costs associated with the contract negotiations, and it is estimated that PPAs below 10 MW and shorter than 10 years are not cost-effective. There is very limited data on the size of the average public sector data centre, but a high-end data centre will vary from a few MW to tens of MW. LBNL[116] projections state that approximately 50% of servers in the USA are installed in high-end or hyperscale data centres. This is equivalent to approximately 10% of data centres. Therefore PPAs may only be applicable to a very limited number of data centres or companies operating many data centres.

If the savings are passed onto the procurer, based on conversations with data centre operators, lower prices can be expected over the short to medium term for the procurer.

3.1.4 Verification

Verification of renewable energy purchase is relatively straightforward at a corporate level, as certificates should be issued by authorised authorities at Member State or regional level and contracts can also be checked. However, in the case of GOs and PPAs it may in some cases be difficult to demonstrate that the supply contract would cover a specific data centre site.

The purchase and cancellation of GOs by the data centre would mean that this renewable energy is over and above the grid average supply, which varies across regions, but is not necessarily additional. GOs for renewable sources as defined in Directive 2009/28/EC are referred to as the main source of proof in the EU GPP renewable electricity criteria. Other forms of proof are identified as including renewable energy certificates and Type I ecolabel declarations.

On-site renewables should be individually metered and therefore easily verified.

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[114] Oeko-Institut, *Green public procurement of electricity: Results of study on possible GPP criteria for RES-E*, Presentation made to the GPP Advisory Group Meeting Dublin, 4/5 April 2017, http://ec.europa.eu/environment/gpp/pdf/2017-04-05_GPP%20Electricity.pdf

[115] http://www.bakermckenzie.com/-/media/files/insight/publications/2015/12/the-rise-of-corporate-ppas/risecorporateppas.pdf?la=en

[116] https://eta.lbl.gov/sites/default/files/publications/lbnl-1005775_v2.pdf

3.1.5 Market implications and functionality

In practice, on-site renewables can only supply a small fraction of the total data centre energy consumption. A data centre consumes around 1-10 kW/m^2, while a solar panel generates around 0.1-0.15 kW/m^2, after taking into account inefficiencies and limited daylight hours, and therefore rooftop solar or similar projects may have a minimal effect on the overall energy mix. However, this also means that the proportion of self-consumption is generally high, reducing the requirements for additional technology such as energy storage systems. Sites that meet both the data centre's network and access requirements (generally close to major cities and to a sufficiently capable power grid) as well as being suitable for generating a significant amount of renewable energy near the site – such as a solar farm or large wind turbines – are limited. For example, a large MSP, Apple, has built a 20 MW, 5 000 m^2 data centre in North Carolina that includes a near-site solar farm whose area is 80 times that of the building at 400 000m^2 as well as landfill-biogas-powered fuel cells which are together expected to supply approximately 60% of the energy required[117]. Even with such a large site, another 400 000m^2 of solar farms nearby are required to supply the remaining energy.

There are limited data centres publicly reporting their use of renewables, and fewer still using PPAs. Only the largest data centre service providers, including Google, Microsoft, HP, Equinix, Digital Realty, Amazon, Switch, Cisco and BT, have made public information regarding the use of PPAs. This represents a very small proportion of the DC service providers identified in the EU. No information regarding the use of energy service agreements, GOs or independently certified green energy was found.

The EU energy market is not homogeneous and the mechanisms to purchase renewable energy are not available in every region. While GO registries are required, they have not been implemented in all Member States. The highest availability of PPAs appears to be in the UK, which has one of the most liberalised markets. Even in this situation, virtual PPAs are used since corporations are not able to enter a PPA directly. An exhaustive search of all EU MS' energy markets and feasibility studies has not been completed due to lack of resources.

PPAs currently agreed tend to be around 100 MW for 10+ years, and the minimum economically viable PPA is considered to be around 10 MW. For example, BT signed a 13-year 100 GWh PPA for EUR 216 million in 2017 and a 20-year 72 MW PPA for GBP 300 million in 2014 which required bespoke contractual mechanisms. As such, only a few DC operators have PPAs and they may not be a practical option for SMEs and many other DCs. For smaller data centres, it may be possible to join consortia to sign PPAs. This has been led by the US and there are very few examples of this currently in Europe. A consortium of AkzoNobel, DMS, Philips and Google purchasing from a wind farm in The Netherlands[118] is the most widely publicised example; however, none of these are SMEs.

Renewable energy use does not compromise the data centre's functionality. The electricity supplied is identical and cannot be distinguished.

On-site or near-site systems can reduce grid losses and also improve the reliability of the power supply, which means that data centres do not have to invest as much in back-up power supply systems. With on-site power generation, data centres can provide an additional layer of security to their power supply. While most utility grids are fairly reliable, they are occasionally subject to disruptions – caused by bad weather or damaged infrastructure for example. With conventional power grids, an issue in one area can completely shut down operations in a facility elsewhere. On-site power generation ensures that a facility can continue operations even when

[117] http://www.datacenterknowledge.com/the-apple-data-center-faq-part-2/

[118] http://www.ppa-experts.com/krammer-akzonobel-dsm-google-philips-wind4ind/

there are problems somewhere else[119]. For these reasons, a specific criterion addressing the procurement of on-site or near-site power were introduced.

3.1.6 Applicability to public procurement

The total use of renewable energy is a very important aspect of a DC environmental impact. A higher proportion of renewable energy reduces the impact of the DC even if a lack of additionality means there may be wider impacts beyond the boundaries of the DC. Including a simple criterion for renewables signals to the DC industry that it is an increasingly important factor to consider.

The use of the REF as a criterion could mainly be applicable to procurement routes where a data centre is to be built or operated as a service to the contracting authority. In the case of co-location, possible host sites could be asked to bid based on the REF and based on arrangements for obtaining renewable electricity that they have already made or propose to put in place at the location of the contracting authority's IT equipment. This would then need to be verified based on the renewable electricity procurement route adopted.

Since there is insufficient and variable market availability, a technical specification for the Renewable Energy Factor is not proposed. Instead, an award criterion is proposed to encourage service providers who use more renewable electricity. A contract performance clause would ensure the monitoring of the electricity supplied, metered and billed.

The possibility to achieve additionality from a contract is restricted because from a legal perspective it is difficult to relate a prescriptive requirement to a data centre contract because this would go beyond the scope of the subject matter and potentially be discriminatory within the market. Where the subject matter is the provision of data centre services, the focus must therefore be on the nature of the electricity being used to provide the data centre service, rather than the extent to which the new capacity has been built. As such, the use of Guarantees of Origin and equivalent proof is not necessary.

An alternative approach could be to focus on where new electricity-generating capacity is required to meet potential shortfalls or address reliability issues on the local grid, or to ensure additionality by generating electricity that is supplied directly to the site via direct wires. In this case, the subject matter would be different, relating to the procurement of generating capacity, or energy services based on new generating capacity and using local sites and energy resources. In this case, such a criterion must fulfil the following criteria:

- renewables must be located on or near the site;
- renewables must be connected by direct wire;
- the service contract must have directly underwritten the initial investment.

3.1.7 Summary of stakeholders' comments following AHWG1

In general, stakeholders agreed that renewables are an important factor to consider and should be included, even if just to raise awareness.

3.1.7.1 Additionality

Many comments addressed the importance of additionality but also the difficulty in demonstrating this. The use of GOs and other independent ecolabels were encouraged but there

[119] https://www.datacenterdynamics.com/opinions/addressing-the-issue-of-power-generation-in-data-centers/

was concern about the practicality of doing so. However, feedback from the other DGs indicated that the criteria should address the nature of generation rather than additionality. The award criteria are therefore structured to address the nature of generation through the REF and contracting of on-site renewables.

3.1.7.2 Market and applicability

There were concerns that the use of PPAs would limit the applicability to larger suppliers since this was not part of the core business. The revised criteria do not distinguish between the extent of new capacity via grid-connected PPAs and therefore should be more widely applicable.

Matching renewables generation to the actual use profile was recommended. This was adopted in the award criterion AC10 (comprehensive).

3.1.8 Summary of stakeholders' comments following AHWG2

It was suggested to make this criterion apply to all countries whatever the share of renewable energy they possess.

Some stakeholders suggested that repowering and extension of life contracts also be included under AC10 since this increases the likelihood and chance of direct renewables being used.

An increasing proportion of wind turbines in Europe are reaching their end of life and can be extended or repowered. Repowering replaces the old wind turbines with modern more efficient, higher-capacity turbines. This maximises the generating capacity of existing sites, which are often optimally located for generation, and becoming increasingly scarce. Apart from grid connection costs, repowering is similar in cost, technical and planning complexity to new generation. However, life extension is expected to occur where economically feasible and does not provide the additional benefits of repowering and is not considered new capacity.

Some stakeholders suggested expanding the criteria to require the reporting of the quantity of electricity consumption that could be matched to electricity consumption at the site. The intention of this would be to encourage the purchase of electricity generated at the same time as it is consumed. More points could be awarded based on the amount of renewables procured that could be matched to consumption.

Some stakeholders also asked for more flexibility in how the assessment and verification could be done for cloud services. This is because of the use of multiple sites to provide the service. They requested the possibility to report a mean value for the REF.

3.1.9 Final criterion proposal

Summary rationale for the final proposal
In the final proposal, the applicability has been extended to all European countries regardless of their share of the electricity produced. In addition to the quantity of renewable electricity, the proportion of load matching regardless of the geographical location has also been added. In the case of cloud services, the possibility to report on a mean value has been introduced.

The revised version of this criteria area includes the following:

- A comprehensive technical specification requesting 100% renewable energy (the Renewable Energy Factor of the data centre must be equal to 1). It is suggested to test the market with potential providers and local availability of supply before using this criterion.

- A core award criterion providing additional points based on how much renewable electricity is used to provide data centre services (i.e. the subject matter). It was generally agreed that, even though full additionality cannot be guaranteed because of weak incentives, this would encourage a focus on the electricity supply.
- A comprehensive award criterion based on the proportion of the power load matched with the power required to provide the data centre service.
- A contract performance clause to monitor the renewable energy generated should be used by the service provider.

Final criteria approved

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
	TS9 Renewable Energy Factor (REF) *To be included when the data centre is operated by a third party. The contracting authority is recommended to test the market with potential providers and local availability of supply before using this criterion.* The Renewable Energy Factor of the data centre must be equal to 1 (100% renewable). The REF for energy supplied and consumed in the data centre must be calculated according to EN 50600-4-3. The electricity contributing to the REF must come from renewable sources as defined by Directive 2009/28/EC. **Verification** The REF and the electricity supply and usage data and load profiles on which the calculations are based must be declared. A third-party verification of the REF can be accepted as evidence. Third-party-verified energy management systems (based on the ISO 50001) or environmental management systems (based on EMAS or ISO 14001) reporting the calculated REF can also be accepted as evidence.
AC10 Renewable Energy Factor *To be included when the data centre is operated by a third party. The points are only to be awarded to tenderers meeting the minimum requirements for IT and M&E system performance. For cloud services, the REF may be requested as a mean value for the sites providing the service.* Points are to be awarded in proportion to the tenderer that offers the highest REF for their electricity use. The REF for energy supplied and consumed in the data centre must be calculated according to EN 50600-4-3[120]. The electricity contributing to the REF must come from renewable sources as defined by Directive 2009/28/EC[121]. **Verification:** The REF and the electricity supply and usage data on which the calculations are based must be declared. A third-party verification of the REF can be accepted as	**AC10 Renewable Energy Factor** *To be included when the data centre is operated by a third party. The points are only to be awarded to tenderers meeting the minimum requirements for IT and M&E system performance. For cloud services, the load matched REF may be requested as a mean value for the sites providing the service.* Points are to be awarded in proportion to the tenderer that offers the highest load matched REF for their electricity use. The REF for energy supplied and consumed in the data centre must be calculated according to EN 50600-4-3. The load profile for the generating capacity must then be related to the projected load profile of the data centre. The electricity contributing to the REF must come from renewable sources as defined by Directive 2009/28/EC. **Verification** The REF and the electricity supply and usage data and load profiles on which the calculations are based must be

[120] EUROPEAN STANDARD EN 50600-4-3 - Information technology - Data centre facilities and infrastructures - Part 4-3: Renewable energy factor

[121] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

Core criteria	Comprehensive criteria
evidence Third-party-verified energy management systems (ISO 50001) or environmental management system (EMAS or ISO 14001) reporting the calculated REF can also be accepted as evidence.	declared. A third-party verification of the REF can be accepted as evidence. Third-party-verified energy management systems (based on the ISO 50001) or environmental management system (based on EMAS or ISO 14001) reporting the calculated REF can also be accepted as evidence.
CONTRACT PERFORMANCE CLAUSES	
CPC9 Renewable Energy Factor *To be used in conjunction with AC 3.1.1.* The operator of the data centre facility or on/near-site generating capacity must provide monthly data for the renewable energy purchased or the renewable energy generated. Third-party operators must also provide for comparative purposes the total metered energy consumption of the data centre.	
EXPLANATORY NOTE: Guarantee of origin	
All EU countries are legally obliged, under Directives 2009/28/EC and 2004/8/EC, to set up guarantee of origin schemes for electricity from renewable energy sources. These provide a good legal basis for verification. Please note that the current state of mandatory application of guarantee of origin schemes may vary between Member States. An alternative would be for the supplier to provide independent proof of the fact that a corresponding quantity of electricity has been generated from sources defined as renewable (e.g. a tradable certificate from an independent issuing body, which has been approved by the government). Another alternative would be if the electricity supplied carried a Type I ecolabel with a definition at least as strict as that in Directive 2009/28/EC.	

3.2 Criterion proposal: Use of refrigerants and their Global Warming Potential

3.2.1 Background

As shown in the preliminary report and in Section 1.6, it is common practice to quantify the GHG emissions to establish the possible impacts on climate change throughout the entire life cycle, once the operator or owner is engaged on disclosing life cycle environmental information. However, quantifying GHG emissions beyond the use stage usually brings more uncertainties due to the wide spread of life cycle inventory databases and their respective emission factors. This is also the case for end of life, as emission factors from different treatment routes across different Member States are established applying different methodologies. Comparing different tenderers on the basis of their life cycle GHG emissions would therefore be difficult.

Moreover, using fluorinated gases (i.e. F-gases) as refrigerants for the data centre's cooling systems can increase the global warming potential of data centres when potential fugitive emissions occur due to the F-gases' high global warming effect. Some of these gases have a warming effect stronger than 2 500 in relation to carbon dioxide. F-gases are often used as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons which are being phased out under the Montreal Protocol and EU legislation because their fugitive emissions do not damage the atmospheric ozone layer. Regulation (EU) No 517/2014 on F-gases[122] specifies requirements to prevent leakages and to phase out the use of F-gases, which includes restrictions on the marketing and use of some of these gases. In practice, this means that HFCs, most of them having the strongest warming effect of all F-gases, will be reduced but will not be totally removed. It is thus proposed to have a criterion which incentivises the use of refrigerants with a low GWP. The F-gases Regulation prohibits their use if their total global warming potential exceeds 750 CO_2 eq under certain conditions. However, if an award criterion relative to their GWP were to be introduced, it could encourage the use of other refrigerants with a weaker warming effect.

[122] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN

The Commission's preparatory study on certain fluorinated greenhouse gases[123] estimated market penetration rates up to 2030 of alternative refrigerants with low GWP profiles as abatement options. For air conditioning systems, the following alternatives were expected to be used in the EU market and completely phase out other refrigerants with higher GWP profiles:

- R-290;
- R-717;
- R-744;
- HFO 1234yf;
- HFO 1234ze,

all of them ranging from a 0 to 6 CO_2 eq GWP profile.

Data from industry[124] shows that these alternatives are being taken up in the market, partly because of the Kigali amendment to the Montreal Protocol[125] and partly because of the effect of Regulation (EU) No 517/2014 on F-gases.

3.2.2 Life cycle environmental hotspots and potential improvements

As a starting point, declaring GHG emissions from the use phase would not be difficult but it would be a repetition of other criteria that tackle the energy consumption and energy mix of data centres (i.e. criteria presented in Sections 1.1.7, 2.1.7 and 3.1.7). The Global Warming Potential of data centres would in this way be reduced by having criteria incentivising reduction of the overall energy consumption, increase of IT energy efficiency and use of renewable energy and/or on-site/near-site electricity.

However, the leak of F-gases as refrigerants in cooling systems could still increase the global warming potential of data centres. According to a study carried out in Germany[126], avoiding the use of F-gases could reduce the GWP by about 15%.

Incentivising the use of other refrigerants could reduce the data centre's overall global warming potential. Additionally, by reporting their GHG effect, the criteria could encourage data centre designers and operators to become more familiar with the impact of F-gases and would level the playing field in terms of the different cooling solutions on the market, including free-cooling systems.

3.2.3 Life cycle cost implications and trade-offs with potential environmental improvements

Reporting the global warming potential of refrigerants would not add extra burdens. Therefore, no major life cycle cost implications are expected from having this criterion as part of the GPP criteria. There is an initial cost investment to the data centre owner and/or operator when quantifying the greenhouse gas emissions for the first time, but this is not expected to be absorbed by the end user. However, the data centre owner and/or operator may sell their product and/or service at a higher price if the data centre has a competitive carbon footprint level in the market.

[123] Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases. Final Report. September 2011. Available at: https://ec.europa.eu/clima/sites/clima/files/f-gas/docs/2011_study_en.pdf

[124] http://www.shecco.com/; https://www.linde-gas.com/en/images/HCFC%20Phase%20Out%20Brochure_tcm17-115696.pdf

[125] https://ec.europa.eu/clima/news/eu-countries-trigger-entry-force-kigali-amendment-montreal-protocol_en

[126] Climate-friendly Air-Conditioning with Natural Refrigerants. Integrative concepts for non-residential buildings with data centres. Federal Ministry for the Environment, Building and Nuclear Safety (BMUB) and German Environment Agency. December, 2016. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/376/dokumente/climate-friendly_air-conditioning_with_natural_refrigerants_factsheet.pdf

On the other hand, free cooling or economised cooling solutions reduce operating costs compared to traditional air conditioning. Significant investment costs, especially for small server rooms and structurally integrated medium-sized data centres, have to be considered. However, it can be assumed that those will be paid back in less than 10 years[127]. Moreover, the phasing out of F-gas refrigerants will affect operating prices. For example, in 2017 the prices of R-404A and R-507 (both with a GWP higher than 3 900) have risen by 225% in Europe in only three months. In the same period, R-410A and R-134a prices (GWP of 2 088 and 1 430 respectively) have doubled, i.e. a 100% increase[128]. This will push the market to use other more climate-friendly alternatives.

3.2.4 Verification

It is proposed to report following Annex I and Annex IV to Regulation (EU) No 517/2014 (i.e. the F-Gas Regulation).

3.2.5 Market implications and functionality

It is expected that all new data centres will be able to quantify and report their greenhouse gas emissions as long as there is a market incentive, which the GPP can serve to accelerate considering it is already becoming a common practice. It has no impacts on data centre functionality.

3.2.6 Applicability to public procurement

This criterion could be used for new data centres and server rooms as well as consolidation of infrastructure (see Figure 2 and Figure 3 procurement routes). The amount and type of refrigerants use can be defined at the design stage and tracked through a contract performance clause.

3.2.7 Summary of stakeholders' comments following AHWG1

Stakeholders' views questioned the cost and practicality of providing a GHG inventory as proposed in the first draft of these criteria. Providing a carbon footprint is seen as expensive and time-consuming, depending on the exact scope and boundaries. The cost/benefit was questioned – it could restrict innovation if the application (functional) level is not also considered.

Some stakeholders requested clarification on whether other indirect emissions such as from coolant would be covered.

Most stakeholders agreed that if this was only concerned with the operational phase (for the time being – with the aim of addressing the whole life cycle in the future) and kept as simple as possible it could be useful. In this simplest case, the GHG emissions could be easily calculated based on the energy consumption (kWh) multiplied by the emission factor (kg CO_2/kWh). One stakeholder questioned why there was not a simple focus on metered energy use measured in kWh instead. It was also noted that the grid emissions factor will change over time, so this needs to be considered.

[127] Climate-friendly Air-Conditioning with Natural Refrigerants. Integrative concepts for non-residential buildings with data centres. Federal Ministry for the Environment, Building and Nuclear Safety (BMUB) and German Environment Agency. December, 2016. Available at: https://www.umweltbundesamt.de/dokument/climate-friendly-air-conditioning-natural

[128] https://www.coolingpost.com/world-news/price-of-r404a-to-double-next-month/

Forecast performance therefore needs to be handled carefully. Overall, the feeling was that this criterion should be retained but it should be kept as simple as possible.

Considering the input from stakeholders, no added value was perceived by reporting the global warming potential of energy use since this is already covered in other criteria. However, the GHG effect of potential leakage of some type of refrigerants is large. It was assessed that the restriction of F-gases could be used as a starting point, in particular since the F-Gas Regulation phases down (not out) the use of these gases. Additionally, a criterion on the potential GHG effect of these gases can be added to also incentivise those designers and operators that use cooling systems not relying on refrigerants. This methodology is described in Annex IV to the F-Gas Regulation.

3.2.8 Summary of stakeholders' comments following AHWG2

Comments from stakeholders expressed concern about the extra reporting burdens and the validity of the calculation methodology for small data centre operators on one hand, and on the other hand some others proposed to allow only natural refrigerants in the criterion.

It is important to emphasise that there are no additional burdens for calculating and reporting the GWP of refrigerants used. These are already requirements under Article 6 of Regulation (EU) No 517/2014. Moreover, the calculation of the GWP average mixture is based on the relative use of each refrigerant, thus no disadvantage exists for small data centre operators.

3.2.9 Final criteria proposal

Summary rationale for the final proposal
Incentivising the use of other refrigerants could reduce a data centre's overall global warming potential. Additionally, by reporting their GHG effect, the criteria could encourage data centre designers and operators to become more familiar with the impact of F-gases and would level the playing field on the market offered by different cooling solutions, including free-cooling systems.

The features of the final criterion proposal are as follows:

- In order to incentivise the use of refrigerants with a low GWP profile, a core award criterion has been designed to allocate specific points according to the GWP profile resulting from the total use of refrigerants in the cooling system for a given data centre.
- A comprehensive technical specification to request that the weighted average for the mixture of refrigerants that will be used in the data centre cooling system must not exceed 10 in terms of Global Warming Potential.
- The categories were established according to definitions of low, medium and high GWP profiles by industry[129], the current and expected use of refrigerants on the market and the requirements in Regulation (EU) No 517/2014. Three levels are required in order to capture the different alternatives of refrigerants with lower GWP.
- The points weighting per category is expected to incentivise the use of natural refrigerants.
- An explanatory note was added providing the method for calculating the total GWP of a mixture of refrigerants according to Annex IV to Regulation (EU) No 517/2014.
- Third-party-verified energy management systems (ISO 50001) or environmental management systems (EMAS or ISO 14001) reporting the use of refrigerants are accepted proof of compliance.

[129] http://www.linde-gas.com/en/legacy/attachment?files=tcm:Ps17-111483,tcm:s17-111483,tcm:17-111483

Final criteria approved

Core criteria	Comprehensive criteria
AWARD CRITERIA	
	TS10 Global warming potential of mixture of refrigerants *To be included when the data centre is operated by a third party.* *See also AC11.* The global warming potential (GWP) weighted average for the mixture of refrigerants that will be used in the data centre cooling system must not exceed 10, unless it is proven that those refrigerants cannot be used for exceptional reasons or would reduce the energy efficiency of the cooling systems. **Verification** Tenderers must report the calculation of the global warming potential weighted average, including for the inventory of the refrigerants used at the sites or to provide the service, and show consistency with the method described in Annex IV to Regulation (EU) No 517/2014. Third-party-verified energy management systems (ISO 50001) or environmental management systems (EMAS or ISO 14001) reporting the use of refrigerants can be accepted as evidence. Exceptional circumstances preventing the used of refrigerants with a GWP weighted average in the range of 0 to 10 are documented.
AC11 Global warming potential of mixture of refrigerants *(same for core and comprehensive criteria)* *To be included when the data centre is operated by a third party.* Points will be awarded to the tenderer according to the global warming potential (GWP) weighted average for the mixture of refrigerants that will be used in the data centre cooling system. This must be calculated in accordance with Annex IV to Regulation (EU) No 517/2014 (see explanatory note). The points will be awarded according to the next resulting GWP weighted average intervals. A maximum of x points [to be specified] may be awarded: • x points to resulting GWP weighted averages in the range of 0 to 10; • 0.6x points to resulting GWP weighted averages in the range of 11 to 150; • 0.2x points to resulting GWP weighted averages in the range of 151 to 750. **Verification** Tenderers must report the calculation of the global warming potential weighted average, including for the inventory of the refrigerants used at the sites or to provide the service, and show consistency with the method described in Annex IV to Regulation (EU) No 517/2014. The tenderer must provide evidence of the use of the refrigerants reported in the calculation. Third-party-verified energy management systems (ISO 50001) or environmental management systems (EMAS or ISO 14001) reporting the use of refrigerants can be accepted as evidence.	

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">CONTRACT PERFORMANCE CLAUSES</td></tr>
<tr><td></td><td>CPC10 Global warming potential of mixtures of refrigerants

To be included if criteria AC11 is used.

The operator of the data centre project must monitor and verify the cooling system's GHG of refrigerant emissions as estimated at the bidding stage.

The actual monitored emissions must be reported for each year of operation, based on metered energy consumption with the possibility for third party verification if requested.</td></tr>
<tr><td colspan="2">EXPLANATORY NOTE: Method of calculating the total GWP of a mixture of refrigerants according to Annex IV to Regulation (EU) No 517/2014</td></tr>
<tr><td colspan="2">The GWP of a mixture is calculated as a weighted average, derived from the sum of the weight fractions of the individual substances multiplied by their GWP, unless otherwise specified, including substances that are not fluorinated greenhouse gases. The formula is shown below:

$$\sum (Substance\ X\ \%\ x\ GWP) + (Substance\ Y\ \%\ x\ GWP) + \cdots (Substance\ N\ \%\ x\ GWP)$$

where % is the contribution by weight with a weight tolerance of ±1%. The GWP of refrigerants are listed in Annex I to Regulation (EU) No 517/2014.
Documentation on the quantity and type of fluorinated gas is already required by Article 6 of Regulation (EU) No 517/2014.</td></tr>
</table>

APPENDIX I: OPERATING CONDITION CLASSES FOR AIR COOLING

Table 15 below describes the operating condition classes according to Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products.

Table 15: Operating condition classes for servers and data storage products

	Dry bulb temp (°C)		Humidity range, non-condensing			
Operating condition class	Allowable range	Recommended range	Allowable range	Recommended range	Max dew point (°C)	Maximum rate of change (°C/hr)
A1	15- 32	18-27	–12 °C dew point (DP) and 8% relative humidity (RH) to 17 °C DP and 80% RH	–9 °C DP to 15 °C DP and 60% RH	17	5/20
A2	10-35	18-27	–12 °C DP and 8% RH to 21 °C DP and 80% RH	Same as A1	21	5/20
A3	5-40	18-27	–12 °C DP and 8% RH to 24 °C DP and 85% RH	Same as A1	24	5/20
A4	5-45	18-27	–12 °C DP and 8% RH to 24 °C DP and 90% RH	Same as A1	24	5/20

APPENDIX II: OPERATING CONDITION CLASSES FOR LIQUID COOLING

The table below describes the operating condition classes for the facility water supply temperature and the related cooling equipment required within the class specified in the ASHRAE Liquid Cooled Guidelines[130].

Table 16: Operating condition classes for liquid cooling

Class	Main heat rejection	Supplemental cooling equipment	Facility supply water temp (°C)
W2	Chiller/cooling tower	Water-side economiser (with dry-cooler or cooling tower)	2 – 27
W3	Cooling tower	Chiller	2 – 32
W4	Water-side economiser (w/dry cooler or cooling tower)	N/A	2 – 45
W5	Building heating system	Cooling tower	> 45

[130] ASHRAE (2011). Thermal Guidelines for Liquid Cooled Data Processing Environments

APPENDIX III: IDLE STATE POWER

According to Commission Regulation (EU) 2019/424 laying down ecodesign requirements for servers and data storage products, the idle state power (P_{idle}) of servers, with the exception of resilient servers, HPC servers and servers with integrated APA, is to be calculated using the following equation:

$$P_{idle} = P_{base} + \sum P_{add\_i}$$

where P_{base} is the basic idle state power allowance in Table 17, and $\sum P_{add\_i}$ is the sum of the idle state power allowances for applicable, additional components, as determined according to Table 18. For blade servers, P_{idle} is calculated as the total measured power divided by the number of installed blade servers in the tested blade chassis. For multi-node servers, the number of sockets is counted per node while P_{idle} is calculated as the total measured power divided by the number of installed nodes in the tested enclosure.

Table 17: Base idle state power allowances

Product type	Base idle state power allowance, P_{base} (W)
1-socket servers (neither blade nor multi-node servers)	25
2-socket servers (neither blade nor multi-node servers)	38
Blade or multi-node servers	40

Table 18: Additional idle power allowances for extra components

System characteristics	Applies to	Additional idle power allowance
CPU performance	All servers	1 socket: $10 \times Perf_{CPU}$ W 2 socket: $7 \times Perf_{CPU}$ W
Additional PSU	PSU installed explicitly for power redundancy	10 W per PSU
HDD or SSD	Per installed HDD or SSD	5.0 W per HDD or SSD
Additional memory	Installed memory greater than 4 GB	0.18 W per GB
Additional buffered DDR channel	Installed buffered DDR channels greater than 8 channels	4.0 W per buffered DDR channel
Additional I/O devices	Installed devices greater than two ports of ≥ 1 Gbit, onboard Ethernet	< 1 GB/s: No allowance
		= 1 GB/s: 2.0 W / Active port
		> 1 GB/s and < 10 Gb/s: 4.0 W/ Active port
		≥ 10 GB/s and < 25Gb/s: 15.0 W/Active port
		≥ 25 GB/s and < 50Gb/s: 20.0 W/Active port
		≥ 50 GB/s 26.0 W/Active port

APPENDIX IV: LIST OF REGISTERED STAKEHOLDERS

The following stakeholders were registered to follow the criteria development process during 2017-2018. They were regularly informed about the progress of the study, had access to preliminary results and draft documents, provided written comments in the three rounds of consultation and/or participated in the two stakeholder meetings. Here below the organisations registered as stakeholders are listed in alphabetic order:

Apple

ARM

Arris

BIO IS

Calefa Oy

Carbon3IT Ltd

Cavan County Council

CBRE Norland

Certios B.V.

COMPUTACENTER

Critical Facilities Consulting Ltd

Crowncommercial

CTO Alliance

Danfoss A/S

Danskerhverv

Defra, Dell Inc.

DigiPlex Group of Companies

DIGITALEUROPE

DKE Deutsche Kommission Elektrotechnik

Eaton

ebm-papst

ECD Technology Ltd

Ecofys

EEHPA - European Heat Pump Association

Emerson

EPEE - European Partnership for Energy and the Environment

Equinix

EUDCA

European Environmental Bureau (EEB)

Eurovent Certita Certification

e-Ready Building

Fraunhofer IZM

Frauscher Consulting

Free ICT Europe

Gartner

GEA

Gimélec

Green Electronics Council

Green IT Amsterdam Region

GREENSPECTOR

Hansheng

Hewlett Packard Enterprise

Huawei Technologies

IBM

ICF International

Intel Corporation

Intertek testing services hong kong ltd.

IRIT (Université Paul Sabatier)

JAEGGI Hybridtechnologie AG

maki Consulting GmbH

Microsoft

Minkels BV

Mizuho Information & Research Institute, Inc.

Nemko AS

NetApp, Inc.

Netherlands Enterprise Agency

Ochsner Energie Technik GmbH

Öko-Institut

Operational Intelligence

Oracle

Piraeus University of Applied Sciences

ReMa-MEDIO AMBIENTE S.L.

Sky UK

Smals

SNE (System and Network Engineering Group)institute for Informatics (IvI) Universiteit van Amsterdam

Sony Europe

Sustainable Procurement Limited

Swedish Energy Agency

Synelixis Solutions Ltd

Technological Educational Institution of Piraeus

techUK

Telehouse

The Beryllium Science and Technology Association

The European Data Centres Association

The Green Grid

Topten International Services

UEL

University of Leeds

University of Stuttgart

University of Tolouse

US Department of Energy

US EPA

VIRTUS Data Centres

Vodafone

Webresultaten

Yahoo

Zoekresultaten

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