European Commission

JRC TECHNICAL REPORTS

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

TECHNICAL REPORT

Draft second criteria proposals

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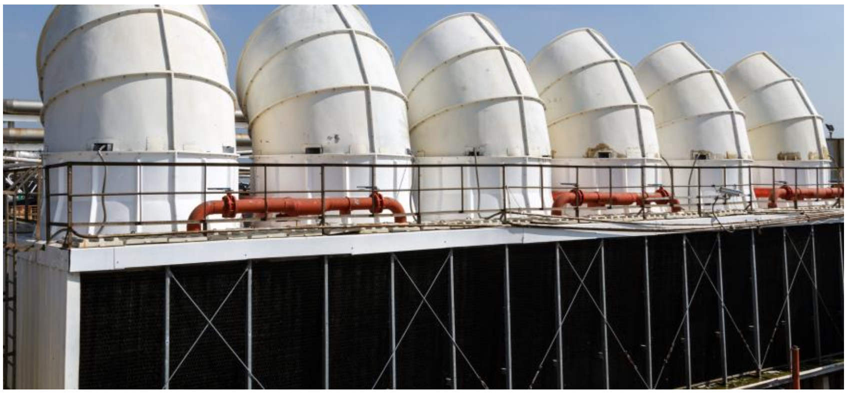
Version 2.0 May 2018



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How to cite: Dodd, N., Alfieri, F., Maya-Drysdale, L., Flucker, S., Tozer, R., Whitehead, B., Wu, A., Viegand, J.

Abstract

Development of the EU Green Public Procurement (GPP) Criteria for Data Centres and Server Rooms, Technical report: draft criteria

The development of the Green Public Procurement (GPP) criteria for Data Centers 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
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

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, 3.1.14; EN 50174-2:2009/A1:2011, 3.1.8]
CRAC/CRAH	Equipment that provides cooling airflow volumes into a computer room as a means of environmental control	CLC/TR 50600-99-1-2016
Co-location Data Centre	A data centre facility in which multiple customers locate their own network(s), servers and storage equipment	[SOURCE: EN 50600-1:2012, 3.1.6; EN 50174-2:2009/A1:2011, 3.1.3]
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 50600-99-1-2016
Virtualisation	Creation of a virtual version of physical ICT equipment or resource to offer a more efficient use of ICT hardware	CLC/TR 50600-99-1-2016
Network Telecommunications Equipment (NTE):	Equipment dedicated to providing 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 refers to the area where IT equipment are placed. Whereas grey space in the data centres is the area where 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 and Server Rooms. 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 Directorate-General for Environment.

EU GPP criteria aim at facilitating public authorities the 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 a contract and may relate to:
    - (a) suitability to pursue the professional activity;
    - (b) economic and financial standing;
    - (c) 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 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 where they relate to the works, supplies or services to be provided under that contract in any respect and 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 cycle,

even 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 of a contract and how it shall be carried out and monitored, provided that they are linked to the subject-matter of the contract.

The criteria are split into Technical Specifications and Award Criteria. 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, focussing 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 second 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[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 scope was sent out to a wide range of stakeholders. The target groups were government, industry, NGOs, academics and public procurers. The input provided has been incorporated in the preliminary report, and together with the proposed criteria presented in this report, is the basis for continuing the consultation with the stakeholders. Once this is finalised, a final version of this report and a final set of criteria will be established. The consultation process has been done primarily with further input from industry, Member States, NGOs, academics and collaborative projects such as EURECA [2].

This draft report will form the basis for the second Ad-Hoc Working Group (AHWG) meeting, which will take place in May 2018.

II. Structure of this report

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

- The definition of the proposed scope
- The identified procurement routes that occur when public organisations purchase data centre products and/or services

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

[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 estimated market volumes in the EU for the proposed scope
- The key environmental impacts of data centres, and the potential improvement areas which led to the focus areas and draft proposed criteria
- The key life cycle costs associated with investment in data centres
- The draft proposed criteria divided by focus areas

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

For each focus area, one or more criteria are proposed, supported by a discussion in summary of the evidence as argumentation to support 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 costs implications and trade-offs with potential environmental improvements
- Possibilities for verification
- Market implications and functionality
- Applicability to public procurement

III. 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 ranging from different sizes, 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 has been the reason to extend the scope for this product group.

A definition of this product group is proposed (see Table 1) that combines 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 fits the product group classification presented in next section. 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 made in the scope 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 put on using non-commercial references to develop data centre definition and categories.

Data centres are typically formed of three groups of systems: IT 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.

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[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 Center 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 Centers. Third ISC Public Review (January 2016).

[8] US Data Center 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 the product group (data centres and server rooms).

Data centre and server rooms definition
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. This definition includes server rooms (see Table 2).
Server rooms referred to also as computer rooms or server closets, are rooms or portions of a building serving an IT load less than or equal to 10 kW. Server rooms have usually IT control and may have some dedicated power and cooling capabilities. Server rooms are enterprise data centres but in a smaller scale, usually housed in an area indicatively less than 46m^2 [10] based on an assumption of a power density of 215 W/m^2.

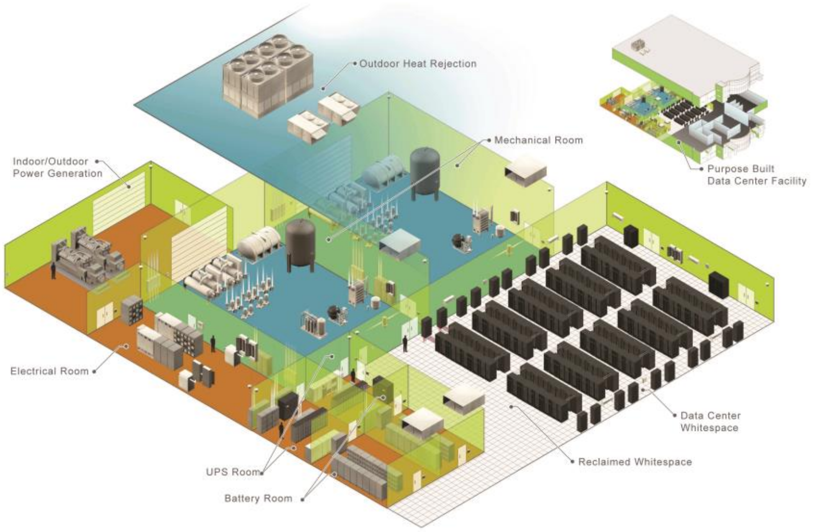

Figure 1. Typical data centre layout[11].

ii. Product group classification

[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

The server room and data centre types proposed to be included within the scope of the criteria are presented in Table 2, as well as their proposed definitions.

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].
Colocation 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	Server and data storage services where the customer pays for a service and the vendor provides and manages required IT hardware/software and data centre equipment. This includes the co-hosting of multiple customers, which may take the form of a cloud application environment. Generic providers are those offering non-proprietary applications (such as Hosted Exchange) while specialized providers offer proprietary applications (such as G Suite).

iii. Proposed scope of the criteria

The proposed scope encompasses the main functional components of a data centre, including the Mechanical & Electrical (M&E) equipment and the IT equipment, the two being important sources of impacts to 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).

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

13 From EN 50600

For the purposes of these GPP criteria it is proposed to exclude the building infrastructure because evidence shows that it is of low relevance to the overall environmental impacts of a data centre.

As well as its components, the scope covers also the product group performance characteristics at system level. Finally, the applicability of the criteria can be done 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 chapter 2. The provision of services is included within the data centre classifications as identified in Table 2.

Table 3. Proposed scope of the data centre GPP criteria.

<table>
<tr><th>Proposed data centres and server rooms criteria scope</th></tr>
<tr><td>For the purposes of this GPP criteria set the scope shall encompass performance aspects of:

The IT equipment and associated network connections that carry out the primary function of the datacentre, including the servers, storage and network equipment;
The Mechanical & 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[14];
Data centre systems as a whole or a managed data centre service.

The building fabric (i.e. physical structure of the building and its respective building materials) is not included in the proposed scope.</td></tr>
</table>

iv. Summary of stakeholders comments following AHWG1

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

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 (80%) are up to 25

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

racks. Considering an average $2m^2$ per rack and $215W/m^2$, the 25 racks threshold is more or less comparable with the server room definition. At the same time, these data centres run an aging IT infrastructure, with 40% of servers being older than 5years old, yet, accounting for 66% of energy consumption, while only producing 7% of the compute capacity.

EURECA provided a breakdown of annual energy consumption from 2016, showing a large improvement potential by replacing old servers with new ones and secondly by virtualization of on-premise 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 at consolidation processes of small server rooms.

IV. 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[15] project team and other identified examples of procurement practices in the EU.

15 https://www.dceureca.eu/

When public organisations procure data centre products and/or services, these are typically fitting 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[16] of existing server rooms and/or data centres into new or existing data centres
   c. virtualisation[17] of existing server capacity
   d. services to expand existing building with new data centre and server rooms infrastructure
3. Outsourcing to a hosted and/or cloud application environment, which means procuring a service and not a physical product
4. Operation and/or maintenance of the facility, e.g.:
   a. specification of data center and server room operational requirements, or
   b. arrangements to locate and/or operate your IT equipment from within a colocation data centre

Based on the procurement needs the public organisations have, 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 a usual practice such as 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 a potential to audit server rooms to identify inefficiencies and opportunities for consolidation. This could be done internally or

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

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

externally, through a procured auditing service which could be included in the scenario described in Figure 3, but in a step before consolidating.

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 and provide guidance on the applicability of the GPP criteria. They are the assumed routes based on current knowledge on the market, and have been corroborated with stakeholders during the consultation process. In the specific case of procuring server rooms, these will have similar routes as 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 or product and/or service that the data centre provide.

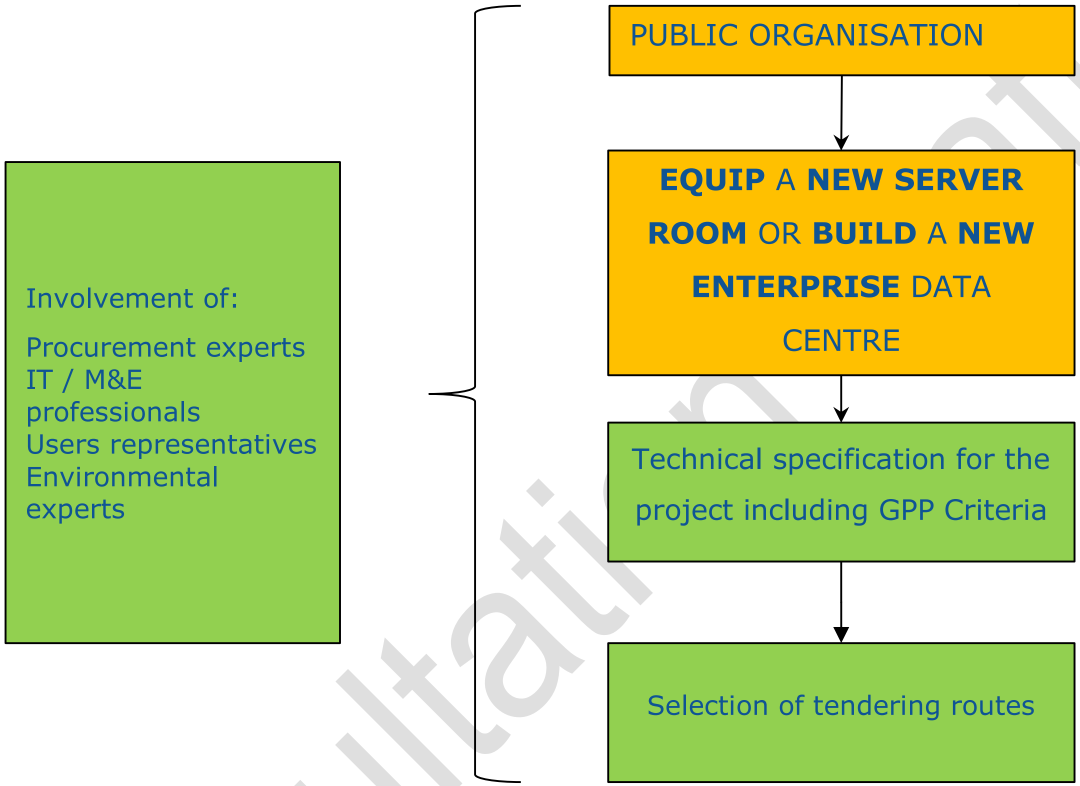

Figure 2. Mapping of potential procurement routes for scenario 1 when public organisations equip a new server room or build a new Enterprise data centre..

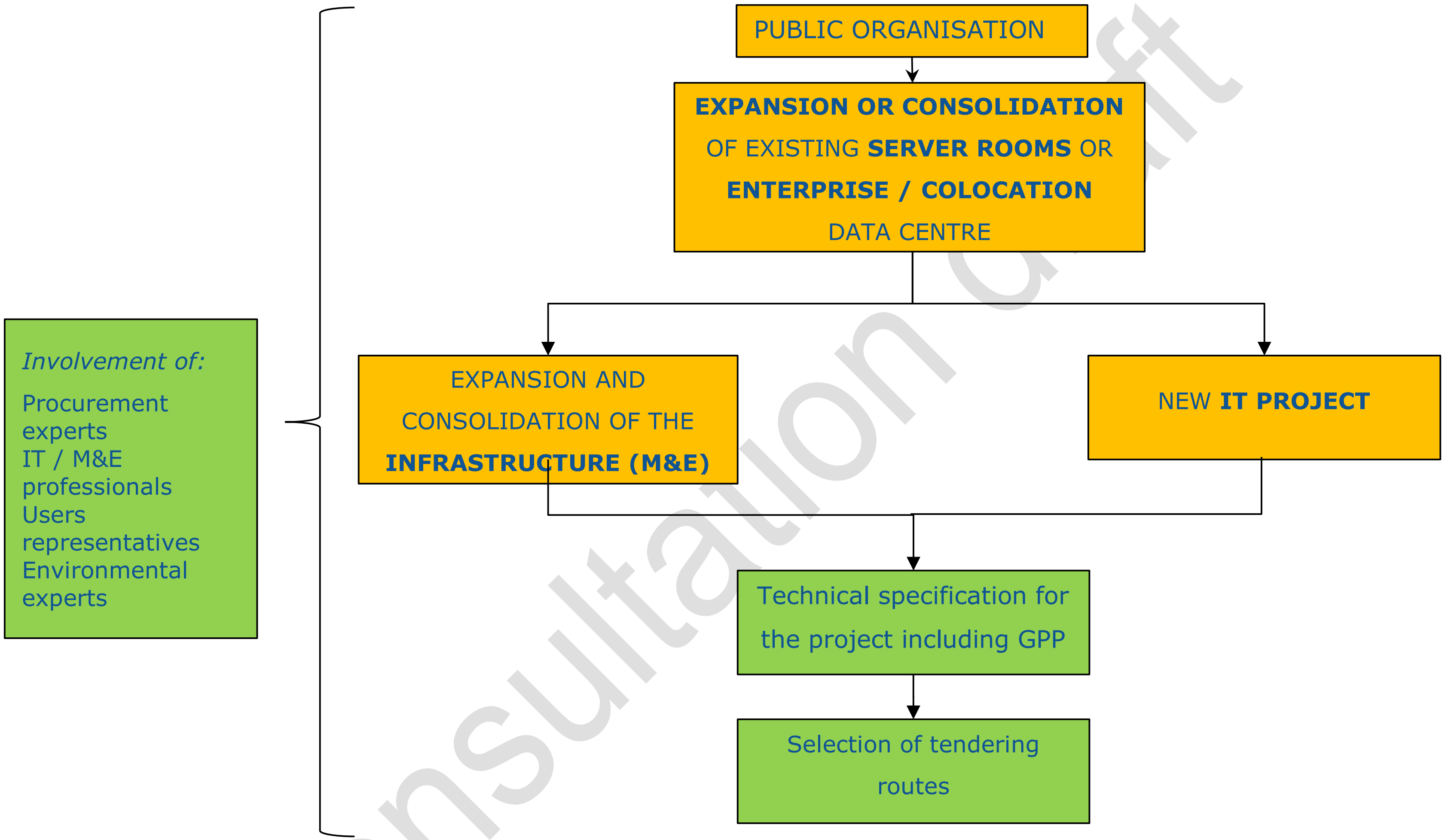

Figure 3. Mapping of potential procurement routes for scenario 2 when public organisations expand and/or consolidate infrastructure or start a new IT project for server rooms and Enterprise and Colocation data centres..

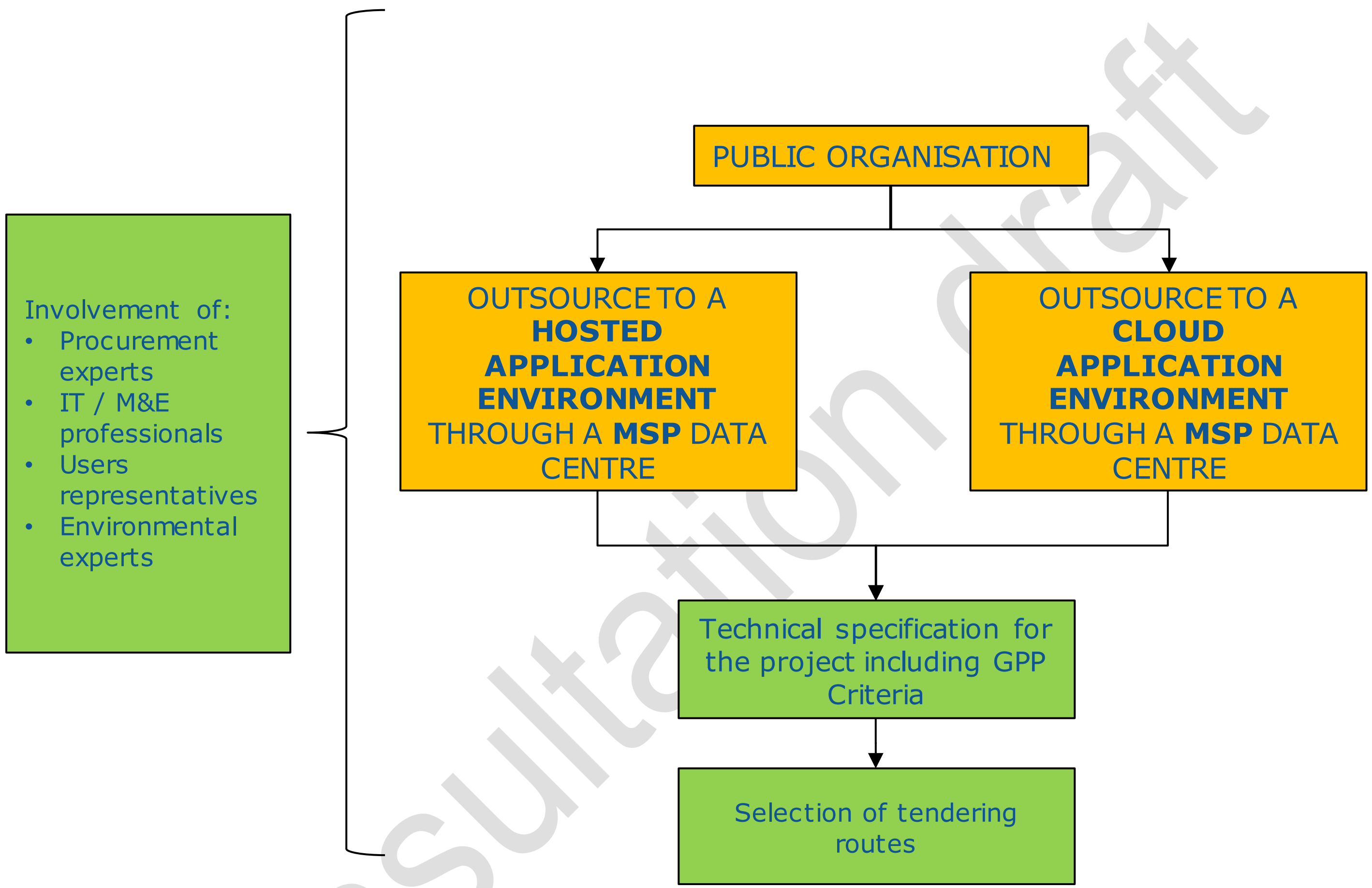

Figure 4. Mapping of potential procurement routes for scenario 3 when public organisations outsource to a hosted or Cloud application environment through MSP data centres..

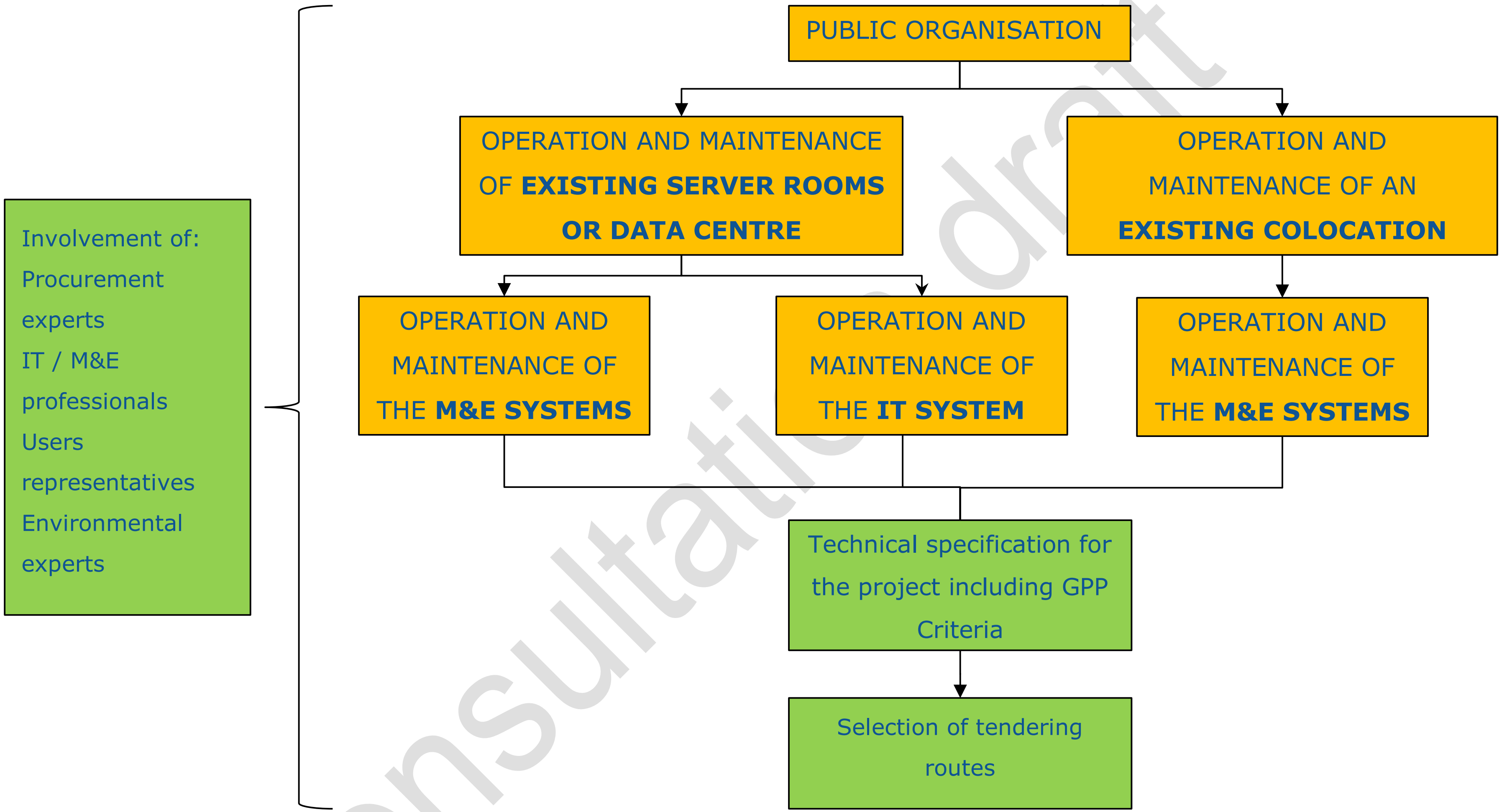

Figure 5. Mapping of potential procurement routes for scenario 4 when public organisations purchase operation and/or maintenance services for server rooms and data centres..

V. Application of GPP criteria to the procurement of server rooms and data centres

An overview of the applicability of the second draft criteria proposals has been established according to the procurement routes defined in section 1.4 (see Table 4,

Table 5 and Table 6). The criteria are then introduced in chapter 1.

Table 4. Applicability of GPP criteria to server room operation and consolidation projects.

Criteria Proposal	Operation and maintenance of a server room	Consolidation of existing distributed server rooms in a new Enterprise DC
1.1 Server energy efficiency	Procurement of servers	Procurement of servers
1.2 IT Equipment Utilization	Procurement of IT Consolidation services	Procurement of IT Consolidation services
1.3 Lifetime, Reparability, Recyclability, End-of-life Management, Hazardous substances	Procurement of servers / management of server fleet services / end of life services	Procurement of servers / management of server fleet services / end of life services
1.4 Temperature and Humidity Range	Procurement of servers / management of server fleet services	Procurement of servers / management of server fleet services / end of life services
2.1 Power Utilization Effectiveness	N.A.	Design and construction of a new data centre
2.2 Reuse of waste heat	N.A.	Design and construction of a new data centre
2.3 Cooling System Best Practices	Services for the operation and maintenance of the server rooms	Construction and management of a new data centre
3.1.Renewable Energy Factor	N.A.	Procurement of new electricity generating capacity to supply data centre's needs
3.2. Use of refrigerants and their Global Warming Potential	N.A.	Design of the cooling system of the new data centre including the following operation

Table 5. Applicability of GPP criteria to large data centres.

Criteria Proposal	Operation and maintenance of a data centre	Construction of a new data centre Or expansion of an existing data centre
1.1 Server energy efficiency	Procurement of servers / services for the management of server fleet / end of life services	Procurement of servers / services for the management of server fleet / end of life services
1.2 Server utilisation	Procurement of IT Consolidation services	Procurement of IT Consolidation services
1.3 IT Material Efficiency	Procurement of servers / management of server fleet services / end of life services	Procurement of servers / management of server fleet services / end of life services
1.4 Temperature and Humidity Range	Procurement of servers / services for the management of server fleet / end of life services	Procurement of servers / services for the management of server fleet / end of life services
2.1 Power Utilization Effectiveness	N.A.	The design and construction of the data centre
2.2 Reuse of waste heat	N.A.	The design and construction of the data centre
2.3 Cooling System Best Practices	Applicable to service for the operation and maintenance of the server rooms	Construction and management of a new data centre
3.1 Renewable Energy	N.A.	Procurement of new electricity generating capacity to supply data centre's needs
3.2 Use of refrigerants	N.A.	Design of the cooling system of the data centre

Table 6. Applicability of GPP criteria to colocation, hosting and Cloud services.

Criteria Areas	Move To a Colocation DC	Move To an hosting data centre	To the cloud
1.1 Server energy efficiency	NA	NA	NA
1.2 Server utilisation	NA	The procurement of hosting services in a specific data centre	Procurement of hosting services in the cloud
1.3 IT Material Efficiency	Procurement of servers / management of server fleet services / end of life services	Procurement of servers / management of server fleet services / end of life services	Procurement of servers / management of server fleet services / end of life services
1.4 IT Operating Range	Procurement of servers / management of server fleet services	NA	NA
2.1 Power Utilization Effectiveness	NA	NA	NA
2.2 Reuse of waste heat	The Procurement of co-location space	Procurement of hosting services in a specific data centre	Procurement of hosting services in the cloud
2.3 Cooling System Best Practices	NA	NA	NA
3.1 Renewable Energy	The Procurement of co-location space and services	Procurement of hosting services in a specific data centre	Procurement of hosting services in the cloud
3.2. Use of refrigerants	The Procurement of co-location space and services	The Procurement of co-location space and services	Procurement of hosting services in the cloud

VI. Market volumes and energy consumption

i. Current market volumes for data centres

Market volumes on data centre white space and estimated number of EU data centres have been provided by Data Center Dynamics[18]. 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 7 and Table 8. These estimates provide an indication of larger data centres, as an exclusion criteria of an IT capacity equal or lower than 25 kW has been applied considering the previous narrower scope excluding small data centres/server rooms.

Furthermore, the estimates exclude data centres which do not have provision for power and environmental management separate from other areas nor not having a dedicated building. These are often referred to server rooms. In spite of the limitations of these estimates, they can be used as indicative to the relative market volumes between different data centre types. It is expected that the number of server rooms will be even larger than 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 50m^2 [19]. 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 3 countries, the majority of the data centres used by public authorities are server rooms.

The initial data was collected for data centre whitespace, 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, colocation data centres are also important of the total white space in the EU (i.e. 57% of total white space for

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

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

Enterprise and 40% for Colocation). These numbers show Enterprise data centres are much smaller than Colocation and MSP. The average white space for Enterprise is of 60 m^2/data centre, while for Colocation is 1152 m^2/data centre and for MSP is 1123 m^2/data centre. Enterprise data centres include often legacy IT 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 to establish 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.

Table 7. Estimated data centre white space (m^2) in the EU.

Market	Enterprise data centres	Colocation data centres	Managed Service Providers 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 8. Estimated number of data centres in the EU

Market	Enterprise data centres	Colocation data centres	Managed Service Providers 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 rooms stock

As notes 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[20] estimated that 72% of 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 current number of server rooms in the whole EU do not exist due to issues of nomenclature and classification, these two figures do however indicate that server rooms have an important share of the total number of data centres in two different regions of the world. 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 Colocation data centres and/or services. Concerning MSP, data centre experts have a conservative assumption that this type of data centre service may be still quite 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

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

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 economies 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[21,22,23,24,25], 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 possible to do a breakdown for each data centre type in the proposed scope as well as for the corresponding consumption for the IT equipment in comparison with the rest of the infrastructure (incl. M&E equipment). The breakdown per data centre type (and server rooms) was done by collecting data on total annual energy consumption of data centres in the EU by the European Commission[22] (including small data centres, assumed to include also server rooms), and deducting estimated annual energy consumption by MSP and Colocation data centres based on the other data sources.

The overall energy consumption for the period 2010 to 2030 is shown in Table 9. The main reason why consumption slows down after 2015 is the increased efficiency of servers and storage units.

Table 9. 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 break down per data centre type (Enterprise category shown in Figure 6 and Table 10 includes server rooms) is shown in Figure 6. The data shows a slow down on consumption by Enterprise data centres, which is solely based on predictions by

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

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

[23] Ongoing ecodesign work on servers and storage

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

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

the US Lawrence Berkeley National Laboratory[24]. This indicates that the MSP data centres 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, specially concerning data centre products and services procured by public organisations. It is thus assumed that this breakdown is somehow underestimating the future consumption by Enterprise and Server rooms and Colocation data centres, and overestimating that by MSP data centres. However, it provides an indication of the current consumption levels showing that Enterprise and Colocation dominate the energy breakdown in 2017 (i.e. 52% by Enterprise and Server rooms and 15% by Colocation data centres).

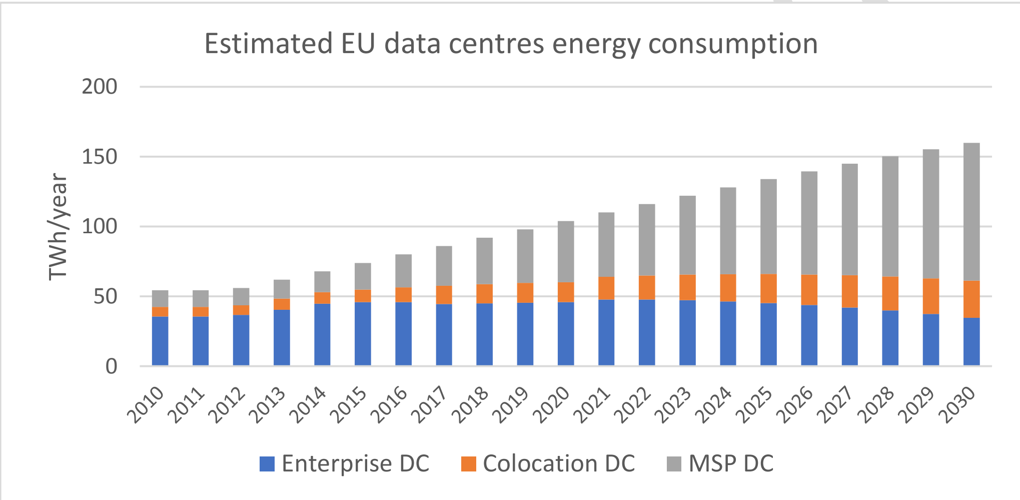

Figure 6. Estimated EU data centres energy consumption per data centre type.

Establishing the significance of IT and infrastructure electricity consumption could help identifying 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[24] 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 quite 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 EU impact assessment for servers and storage equipment as a moderate policy scenario.

This estimated breakdown is presented in Table 10, showing that while in 2010 the energy consumption by the IT equipment compared to the rest of the data centre was quite similar, by 2020 the consumption by the IT is predicted to be significantly higher with a rapid slow down by the rest of the infrastructure up to 2030 when the consumption by the IT will be almost double. This clearly identifies the IT equipment as the most important hotspot already now, but even more in the future.

Table 10. Internal breakdown 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**
IT consumption (TWh/year)	**Enterprise and Server rooms**[26]	18.3	26.2	29.7	29.8	23.2
Infrastructure consumption (TWh/year)		17.2	19.8	16.1	15.5	11.6
IT consumption (TWh/year)	**Colocation**	3.6	5.1	9.3	13.6	17.7
Infrastructure consumption (TWh/year)		3.4	3.8	5.1	7.1	8.8
IT 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

VII. The 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 ten LCA studies for data centres, including small data centres classified as 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,

[26] 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 Colocation and MSP data centres

decommissioning and end-of-life activities that can take place to reduce the environmental impact(s).

Seven of the ten LCA studies assessed the whole life cycle of data centres, one assessed servers and storage, one only servers and another only a specific cooling technology[27]. The environmental impacts assessed varied widely across the ten studies, with all looking at Global Warming Potential (GWP) 100 years (i.e. Climate Change[28]), and seven looking at other environmental impacts beyond Climate Change but at different damage points and assessed with different life cycle impact assessment methodologies[29]. However, for the purpose of the LCA review which was to identify life cycle environmental hotspots, the ten LCA studies provided a good indication as they all concurred on the biggest sources of impact. It was important to include all ten studies in the review due to the limited amount of studies looking at the whole data centre and beyond Climate Change (i.e. only three 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 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 overall data centre including IT and the mechanical and electrical (M&E) systems, which determines the amount of energy consumption. Climatic conditions and

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

28 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

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

heating infrastructure influence cooling demand, thus the location of the data centre has also an impact over energy consumption.

- The use of refrigerants with a high Global Warming Potential due to their leak during operation of cooling systems.
- The manufacture (incl. raw materials extraction and transport) of the IT 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), specially focusing on the possibilities for reuse and recycling that are alternative to other routes and that can avoid some of the environmental impacts from manufacturing.
- The trade-off between extended lifetime and energy efficiency. According to results from EURECA[3,43], older data centres (over 3 years old) represent significantly higher annual energy consumption[30], which can be higher than the embodied energy of manufacturing new IT equipment.
- The right-sizing of the data centre capacity, availability and redundancy, which can be achieved by increasing IT utilisation and/or by consolidating IT equipment.

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

[30] 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.

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 IT equipment is also 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 centers 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 significant energy 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 does only marginally affect 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 errors and unawareness. The best mitigation is considered to be the creation of a learning environment culture[31].

iii. Key areas of potential for improvement

Overall, key areas of potential for improvement have been defined focusing on the life cycle environmental hotspots presented in section 1.6.1. Key improvement areas aspects of the overall system performance of a data centre, and of the IT and Mechanical & 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 11, which show also the priority ranking done. This ranking was needed in order to select the most relevant improvement areas which could lead to potential GPP criteria. The ranking was done considering 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 in the EU market, indicating how available are data centre technologies applying already 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 for verification, indicating the availability of a potential metric or measure to implement the improvement area, using same scale.

The results from this ranking show:

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

- 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 could be not straightforward (in green)
- in yellow the key improvement areas with lower but still important potential benefits, where technologies are readily available in 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 gray) – in the specific case of increasing efficiency for storage units, the potential benefits aren't ranked as low, but the verification is considered difficult

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

Those in grey have been 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 have not been 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 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 11. 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 an high rate of utilisation of IT equipment	IT system	3	2	1	3	
	Select high energy efficient server(s)	IT system	3	2	1	2	
	Select ICT Equipment operating at higher temperature	IT system	2	3	2	1	
	Ensure a 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	
	Implementing 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	
	Minimize 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	

Life cycle hotspots	Improvement strategy	Application level (i.e. focus area)	Potential environmental benefits	EU Market Readiness	Life cycle costs	Verification	Total Scoring
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 Compute 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	IT system	1	1	1	2	

Life cycle hotspots	Improvement strategy	Application level (i.e. focus area)	Potential environmental benefits	EU Market Readiness	Life cycle costs	Verification	Total Scoring
	companies						
	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	

VIII. The 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 in:

- 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 switching 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 rooms owners and those to customers have been established, since those for customers of colocation and managed service provider data centres are expected to be different. This assessment has been done semi-quantitatively due to lack of harmonised quantitative data, which provides an indicative understanding of a data centres' and server rooms' life cycle cost structure. See Table 12.

From the owner's perspective, 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 colocation data centres is often high and therefore much more expensive facilities are needed.

Server rooms 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.

Table 12. Indicative Life Cycle Costs for data centres 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**	**Colocation**	**MSP**	**Server rooms**	**Enterprise**	**Colocation**	**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: IT SYSTEM PERFORMANCE

IT performance concerns the IT 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 a IT system level.

The key areas of improvement at a IT system level are:

a. IT Energy efficiency

   Criterion 1.1: Server efficiency

b. IT utilisation

   Criterion 1.2: IT equipment utilisation

c. IT material efficiency

   Criterion 1.3.1 Optimisation of server lifetime

   Criterion 1.3.2 Design for disassembly and repair of servers

   Criterion 1.3.3 End of life management of servers

   Criterion 1.3.4 Emissions of hazardous substances – restricted substance controls in servers

d. IT Equipment Operating Range

   Criterion 1.4: ICT Operating Range

Second criteria proposals for discussion are provided under each improvement area.

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 IT equipment and M&E infrastructure is illustrated in Figure 7. It can be seen that according to projections from the US, servers will continue to account for the majority of IT equipment electricity consumption, followed by storage.

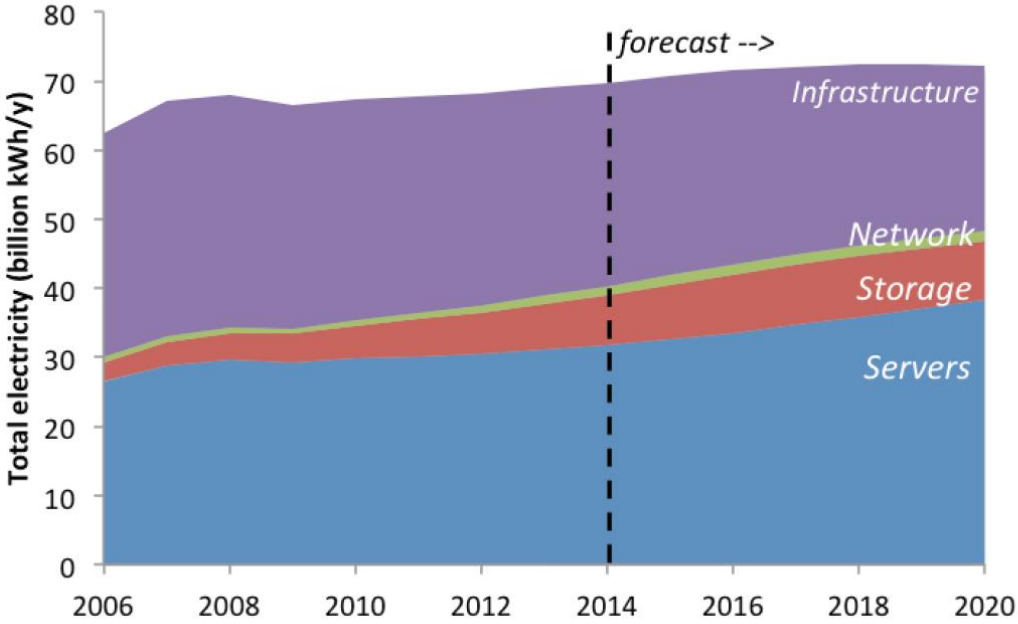

Figure 7. Total electricity consumption by technology type in a data centre[32]

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 limited ability to differentiate products and the efficiency difference between similar, competing server models is relatively small. However, higher *performance* products, i.e. products that , i.e. are able to complete work faster, tend to have significantly higher *efficiency*, i.e. they complete the work using less energy, (see Figure 8) 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

[32] Source: US Department of Energy (2016)

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 8 is due to configurations that have different characteristics. The two variables in Figure 8 form part of the proposed metrics for server efficiency described further in this section and in Annex I.

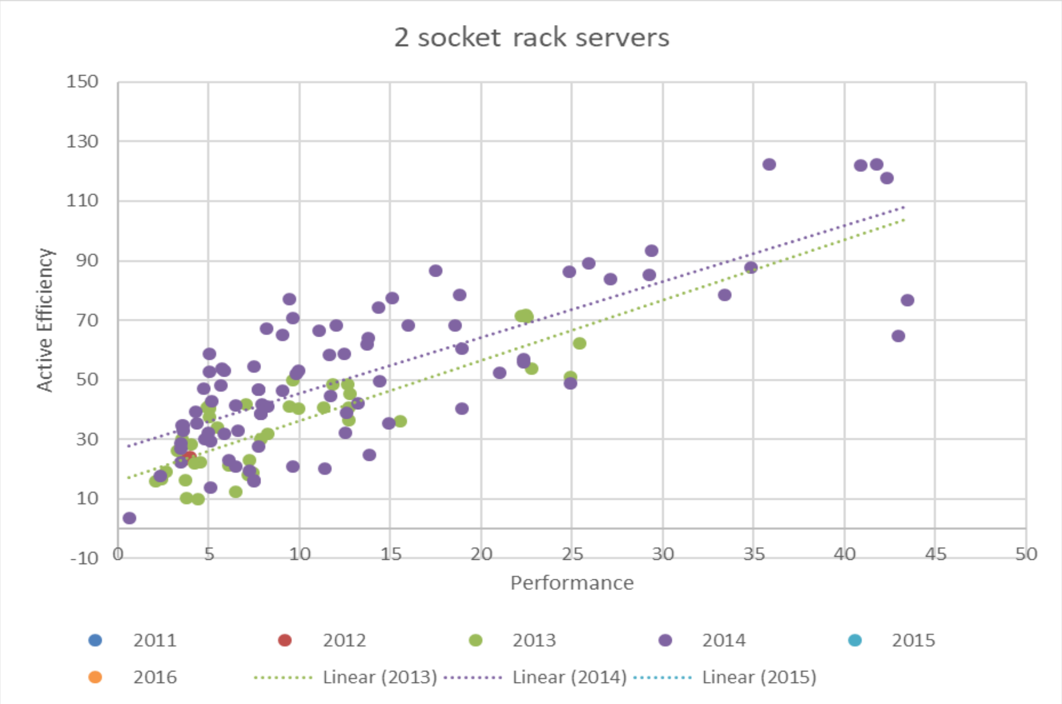

Figure 8. Relationship between performance (transactions/second) and active efficiency for 2 socket servers(transactions/Joule) (higher is more efficient)[33].

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

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

proposed EU enterprise server Ecodesign Regulations and the proposed 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 (IS 21836)

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. 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 servers 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 idle power proposals in their current draft are expected to be revised substantially before publication due to additional evidence supplied by stakeholders. 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.

Draft metrics for evaluating server active efficiency have been developed .which uses the power and performance test data produced by the SERT test. on 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).

A detailed description of the test method and calculations for the active efficiency metric can be found in Annex I. SERT and the metrics do not test the efficiency of specialist products and components such as graphics cards and high-performance computing.

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. ENERGY STAR v2 database provides aggregated test results but these 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. The current Ecodesign draft regulations only proposes requirements to provide active efficiency information, and there are no associated MEPS or labelling proposals. 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.

The proposed ENERGY STAR v3.0 draft 1 criteria propose setting an active state efficiency target of 50 transactions/J across all servers, regardless of performance. If it is assumed that efficiency improves at the same rate as 2013 to 2014 in Figure 8, by 2018 the impact will be very small i.e. the technology is improving faster than the regulatory process. It is expected that these criteria will also undergo substantial changes before being finalised and will result in more challenging requirements reflecting the top 25% performing products in the market. The ENERGY STAR v3.0 draft 3 introduces Active State efficiency score (Eff_{ACTIVE}) thresholds for different server types. EPA believes that the active state efficiency metric adequately incorporates idle power behavior and therefore, there is no longer a standalone idle state efficiency target.

1.1.2. Life cycle environmental hotspots and potential improvements

Servers are the highest consuming energy product in the data centre and reducing IT consumption consequently also reduces energy consumed in the mechanical and electrical systems. In total, IT equipment are responsible for approximately 60 % of the energy consumption of data centre (considering a PUE of 1.65[34]), and servers accounts for the largest share of this overall IT consumption, therefore it is important to address server efficiency. In addition, higher performance in servers reduces the manufacturing impacts, since fewer servers are needed.

However, because efficiency and performance improve so rapidly, 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

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[34] Expected value for a new enterprise data centre according to the Ecodesign Impact Assessment for servers and storage

environmental impact will depend on the specific operating conditions, including the utilisation, server configuration and its associated embodied energy and resource use.

The Impact Assessment carried out for the Ecodesign Preparatory study shows that an energy labelling requirement on server efficiency would yield on average ca. 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 ca. 5 – 8 % overall reduction in server energy consumption and diminish over 7 years. The leading edge of the market is estimated to have 2-3 times as high savings potential (ca 8 - 18%).

1.1.3. Life cycle costs implications and trade-offs with environmental potential 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 show that a typical 2 socket rack server with an average efficiency costs ca. 4160 euros per unit and increasing its efficiency, the purchase cost is increased by 3 – 178 euros 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 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.

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

In reality, it is virtually impossible to verify with certainty due to confidentiality issues and because access to the data centre is highly restricted so it may not be possible to enter the data centre simply to check the servers. In the case of managed services it could be checked if the equipment purchased has been audited, and to consult the audited results. However, the audit information could be inaccurate and there is limited incentive to improve accuracy if one is not able to check the servers in practice. Nevertheless, this is the main possible verification method and it could be added to the criteria that access to data centre servers should be allowed if the operator declares that they have met the criteria.

For reporting server efficiency, the above mentioned verification can be supplemented by checking if efficiency measured according to the proposed Ecodesign metric has been documented correctly via a corresponding SERT test result. In all cases the SERT test results and calculations should have accompanied the final efficiency and performance score to show the minimum efficiency is met. Moreover, it is anticipated that verification will be possible according to the new standard which is under development in support of the new Ecodesign metric - EN 303 470.

1.1.5. Market implications and functionality

Server efficiency in the market changes rapidly, therefore a dynamic metric that takes account of this is preferable. It is understood that such a standardised metric based on the SERT methodology will be available once the Ecodesign Regulation comes into force and will be required for all products.

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 purposely fit for the special 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.

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 colocation data centres but not cloud or managed services. A technical specification could be appropriate given that both ENERGY STAR and the forthcoming Ecodesign legislation establish performance metrics and thresholds for the Best Available Technology (BAT) in the market that would differentiate performance in the market.

However, since ENERGY STAR and Ecodesign have yet to be finalised, thresholds would need to be further discussed and verified.

Instead award criteria could be used to encourage higher efficiency. A focus on idle and/or active states could be chosen depending on the 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 of the Energy Efficiency Directive. ENERGY STAR is also formally referred to in this Annex.

Such a criterion would be difficult to apply to scenarios where data centre services are outsourced. This is because it may in practice 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, 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 requriements. There was also concern about the use and complexity of SERT and whether it will be replaced by SEEM. It was recommended instead that a KPI was used that enabled the total power consumed by the server fleet to deliver the workload required is estimated.

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

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.

Software efficiency may be partially addressed with AC2.3 but in general the complexity of assessing software means that it has not been covered in this GPP.

1.1.8. Second criteria proposal

A Technical Specification for the server active efficiency is proposed. However it has to be considered that ENERGY STAR and Ecodesign criteria for server efficiency are all currently in draft phase, therefore it is difficult to specify efficiency thresholds at this point in time. Award criteria are developed based on the relative efficiency and deployed power.

This is split into two possible critiera, based on the EN 303 470 or using a contract specific testing method.

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">TECHNICAL SPECIFICATION</td></tr>
<tr><td></td><td>
TS1.1.1 Server active efficiency

Calculated Active State efficiency score (Eff_{ACTIVE}) must be greater than or equal to the minimum Active State efficiency thresholds listed below.

<table>
<tr><th>Product Type</th><th>Minimum Eff_{ACTIVE}</th></tr>
<tr><td>One Installed Processor</td><td></td></tr>
<tr><td>Rack</td><td>11.0</td></tr>
<tr><td>Tower</td><td>9.4</td></tr>
<tr><td>Blade or Multi-Node</td><td>9.0</td></tr>
<tr><td>Resilient</td><td>4.8</td></tr>
<tr><td>Two Installed Processors</td><td></td></tr>
<tr><td>Rack</td><td>13.0</td></tr>
<tr><td>Tower</td><td>12.0</td></tr>
<tr><td>Blade or Multi-Node</td><td>14.0</td></tr>
<tr><td>Resilient</td><td>5.2</td></tr>
<tr><td>Greater Than Two Installed Processors</td><td></td></tr>
<tr><td>Rack</td><td>16.0</td></tr>
<tr><td>Blade or Multi-Node</td><td>9.6</td></tr>
<tr><td>Resilient</td><td>4.2</td></tr>
</table>
Verification

The tenderer must detail the calculation of the individual server active state efficiency based on EN 303470 measurement methodology.

Models that have qualified for US Energy Star and are registered on the programme's database must be deemed to comply.
</td></tr>
<tr><td colspan="2">AWARD CRITERIA</td></tr>
<tr><td>
AC1.1.1 Server idle power

Only applicable in case the Product type (e.g. rack or tower servers, 1-socket or 2-sockets servers) and the system characteristics affecting power consumption (e.g. CPU performance, server with or without power redundancy, memory, drives, additional devices) are fixed in the technical specification.

Not applicable for High Performance Computing (HPC) servers and servers with integrated APA (Auxiliary Performance Accelerator).

This criterion is recommended in case of anticipated low utilization pattern of the servers (typically in the range 10% - 25%).

A maximum of x points [to be specified] may be awarded. Points shall be awarded in proportion to the improvement in idle state power in comparison to the
</td><td></td></tr>
</table>

relative idle state power (P_{idle}) threshold foreseen by the Ecodesign Directive • over 80% lower: x points • 60-79% lower: 0.8x points • 40-59% lower: 0.6x points • 20-39% lower: 0.4x points • 10-19% lower: 0.2x points **Verification** The tenderer shall detail the calculation of the individual server idle power based on EN 303470 testing and in line with the Ecodesign requirements on Idle State Power. Upon request the contracting authority shall be provided with access to the equipment once on site for auditing purposes.	
AC1.1.2 Server active efficiency *Only applicable in case the Product type (e.g. rack or tower servers, 1-socket or 2-sockets servers) and the system characteristics affecting active efficiency (e.g. CPU performance, server with or without power redundancy, memory, drives, additional devices) are fixed in the technical specification.* The active efficiency of each distinct server model and configuration to be supplied must be declared. Points must be awarded based on the declared active efficiency for each model or configuration, weighted to the number to be supplied. A maximum of [to be specified] points may be awarded. Points must be awarded in proportion to the active efficiency of the best performing offer: • over 80% lower: [specified] points • 60-79% lower: 0.8 x [specified] points • 40-59% lower: 0.6 x [specified] points • 20-39% lower: 0.4 x [specified] points • 10-19% lower: 0.2 x [specified] points **Verification** The tenderer must detail the calculation of the individual server active efficiency based on EN 303470 testing and in line with the Ecodesign requirements on Active Efficiency. Upon request the contracting authority must be provided with access to the equipment once on site for auditing purposes	
	AC1.1.3 Data centre IT annual energy consumption (deployed power) *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 CPC 1.1 Points must be awarded based on the workload specific deployment power calculated for all the servers to be deployed in the data centre. The calculation must be based on the workloads specified by the contracting authority. Maximum points must be awarded to the offer with the lowest energy consumption. All other offers must be awarded points in proportion to the best offer. **Verification** The tenderer must detail the calculation of the deployment power either [*to be specified*]: • based on EN 303470 deployed power method the standardised workloads, or • based on a testing protocol to be specified by the contracting authority. Upon request the contracting authority must be provided with access to the equipment once on site for auditing purposes.
CONTRACT PERFORMANCE CLAUSES	
	CPC1.1 Monitoring of IT energy consumption *To be included when the data centre is operated by a third party. To be used in conjunction with AC 1.1.* The operator of the data centre facility must provide monthly and annual data for the IT equipment that is located in the data centre. Monitoring of energy consumption must in line with the requirements and recommendation of the standard EN 50600-2-2
EXPLANATORY NOTE	
Idle power is recommended if utilisation is under 25% because this is generally the lower threshold of the SERT worklet testing and suggests that a significant amount of time is spent idle. 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 draft Ecodesign requirements, this information will be made publicly available. Deployed power is calculated from the power consumed in the desired power state multiplied by the number of servers required.	

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 raised in a number of ways. For servers, which are the most significant energy consumer, virtualisation[35] 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 setups due to the cost and environmental benefits.

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’. This would require development of significantly more guidance to address. 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

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

underutilised and result in additional energy consumption for no additional performance benefit.

Virtualisation ratios, which calculates 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. This could also not be applied 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[36] 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[37]:

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 the processing occurring within the CPUs, and more useful to the data centre operator seeking to optimise utilisation. . A detailed description of the proposed metric for IT utilization can be found in Annex II. 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

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[36] Referring to internal and external network bandwidth

37 https://www.thegreengrid.org/en/resources/library-and-tools/436-WP#72---ICT-Capacity-and-Utilization-Metrics

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 suggest that in reality servers are never switched off even when unused.

Optimisation can be achieved manually but more sophisticated 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. Although these services are primarily aimed at cost saving on public clouds they also create energy savings as well as provide monitoring and reporting of utilisation.

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 about 15x times reduction in environmental impacts compared to worst case and about 7x times compared to 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 13).

Virtualization reduces IT equipment requirements, increases IT utilization 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[38,39]. However, these comparisons are all

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

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

made against unvirtualized servers which does not reflect the current market situation.

1.2.3. Life cycle costs implications and trade-offs with environmental potential 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 cost. It is very difficult to estimate specific costs due to the lack of information on current utilisation and possible utilisation levels.

Case studies quoted by the US EPA on virtualisation in best case scenarios have shown cost savings of approximately 60%[40] 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 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 on an arbitrary basis data centres. 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 13034-5. ISO13034-5 also provides clear guidelines regarding the measurement and calculation of the CPU utilisation at

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

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 will require utilisation targets to be met by the end of 2018. Servers in Government operated data centres on average must not be idle for more than 35% of the time. This must be continuously monitored and 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[41]). It appears that the market has moved to improve and in some cases measure utilisation but a standard metric is not apparent. Since the Green Grid's metric was only proposed in 2017 it is highly unlikely that it is widespread. The currently under publication ISO 30143-5 metric accounts only for one aspect of server performance, although this could be a starting point given attention, 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 13. 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.

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

Table 13. Recent estimates of utilisation rates for different server types[42].

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 not in all cases therefore be possible to achieve very high utilisation levels, 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 a standardised basis by the ISO 13034-5, 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 under by the US Government but for internal data centres.

Whilst generalised thresholds cannot be set, tenderers could be encouraged through an award criteria to propose optimization 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 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 criteria to encourage a focus on this performance aspect.

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

1.2.7. Summary of stakeholders comments following AHWG1

In general there was strong support for criteria to maximise utilisation for since it has a large impact on efficiency and current utilisation is very low but concerns regarding the critieria 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 ITEUsv rather than the Green Grid metric. The importance of a short monitoring interval was also raised, with criteria suggested to award more granular monitoring. Power management criteria in conjunction with utilisation was also suggested.

One stakeholder was concerned that utilisation targets are not appropriate because different workloads have different optimal utilisation and ongoing utilisation optimisation is more appropriate criteria. This should reward the best continuous optimisation strategy, ie using services such as Densify.

A number of comments were made about the relationship between correctly configuring the server to maximise utilisation level. Beyond the server utilisation, the importance of the process used to select between different options such as colocation, cloud or MSP to deliver the service was also raised.

1.2.8. Second criteria proposal

Core criteria	**Comprehensive criteria**
SELECTION CRITERIA	
To be included when the data centre is operated by a third party. **SC1.2.1 Server utilisation** The tenderer must have relevant competencies and experience in optimization of a server's utilization. This must include server virtualization services, utilisation management tools and the consolidation of IT asset in data centres. Bidders must provide evidence of previous projects with similar workloads to achieve, maintain and improve utilisation of IT equipment. This includes descriptions of methods used to optimise utilisation. **Verification:** Evidence in the form of information and references	*To be included when the data centre is operated by a third party*. **SC1.2.1 Server utilisation** The tenderer must have relevant competencies and experience in optimization of a server's utilization. This must include server virtualization services, utilisation management tools and the consolidation of IT asset in data centres. Bidders must provide evidence of previous projects with similar workloads to achieve, maintain and improve utilisation of IT equipment. This includes descriptions of methods used to optimise utilisation. **Verification:** Evidence in the form of information and references

related to relevant contracts in the last 3 years in which the above elements have been carried out. This must also be supported by CVs for personnel who will work on the project and their relevant project experience.	related to relevant contracts in the last 3 years in which the above elements have been carried out. 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. **AC1.2.1 Server utilisation** Points must be award based on the anticipated server utilisation level based on the contracting authorities data handling and processing requirements. Points will be awarded in line with the following ranges: • >70% lower: [specified] points • 40-70% lower: 0.8 x [specified] points • 25-40% lower: 0.5 x [specified] points **Verification** The rate will be supported by modelling, calculations or evidence provided in the selection criteria to achieve the anticipated utilisation.	*To be included when the data centre is operated by a third party*. **AC1.2.1 Server utilisation** Points must be award based on the anticipated server utilisation level based on the contracting authorities data handling and processing requirements. Points will be awarded in line with the following ranges: • >70% lower: [specified] points • 40-70% lower: 0.8 x [specified] points • 25-40% lower: 0.5 x [specified] points **Verification** The rate will be supported by modelling, calculations or evidence provided in the selection criteria to achieve the anticipated utilisation.
CONTRACT PERFORMANCE CLAUSES	
CPC1.2.1 Monitoring of IT Equipment Utilization *To be included when the data centre is operated by a third party*. The service provider must provide periodical reporting of optimisation analysis and about the achievement of utilisation targets agreed with the client during the specific IT project The service provider must measure and monthly report the utilization rate of the servers in the data centre based on ISO 13034-5.	**CPC1.2.1 Monitoring of IT Equipment Utilization** *To be included when the data centre is operated by a third party*. The service provider must provide periodical reporting of optimisation analysis and about the achievement of utilisation targets agreed with the client during the specific IT project The service provider must measure and monthly report the utilization rate of the servers in the data centre based on ISO 13034-5.
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 1h (10 min default).

1.3. Criteria Proposals: Lifetime, Reparability, Recyclability, End of life management, Hazardous substances

1.3.1. 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 have been 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 have been developed to go beyond minimum requirements defined in relevant legislation, i.e. WEEE Directive 2012/19/EU and the RoHS Directive 2011/65/EU, in order to set a higher level of ambition.

1.3.2. Life cycle environmental hotspots and potential improvements

As discussed in the chapter one 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 from manufacturing 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 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 burden shift.

This is illustrated by one of the studies presented in the LCA review of the preliminary report that shows that a server with reused components (HDDs, memory cards, CPUs and main boards) could have 22% higher energy consumption compared to a brand new server, while still having the same climate change impact of a brand new server. However, the environmental payback time varies - improved energy performance of newer models may mean that the decommissioning of an old model has 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[43]. 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[44]: when refurbishing a server 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

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[43] 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.

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

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 have identified that around 75% or more of the energy consumption and efficiency opportunities are determined by 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[45]. 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 (incl. servers) to China and other developing countries. According to a report on illegal shipment of e-waste from the EU[46], this is not because of lack of coherence between the two major policy measures (WEEE Directive and Waste Shipment Regulation), but to the lack of 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 the equipment via existing collection and take back schemes. According to information gathered from stakeholders, these schemes are already well in place for stock existing since the implementation of the legal framework (2012). However, potential leaks exist at the collection stage (see Figure 9 for a representation of a

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

[46] 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

typical recovery/recycling chain of WEEE waste, exemplified by Umicore's). According to JRC[44], reusable parts are harvested and tested before reaching recycling facilities. This could increase the risk illegal exports exemplified in Figure 9, although this figure represents all WEEE and thus risk of illegal exports may be lower for server components.

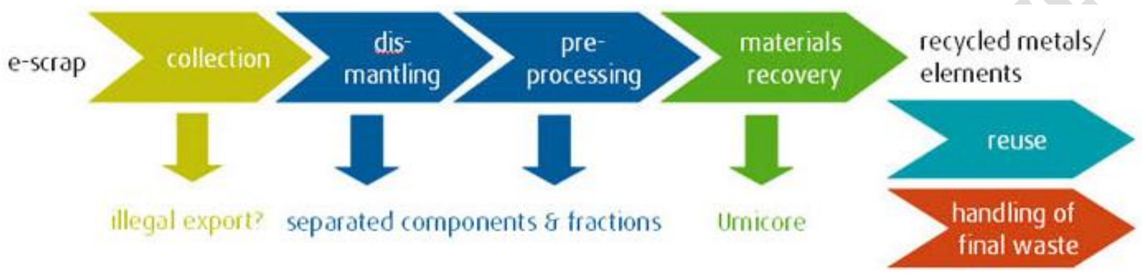

Figure 9. Typical recovery and recycling chain for WEEE waste[47].

Older WEEE equipment (manufactured before 2012) which is to be disposed, is still covered by the producer responsibility principle essential 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 be 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 all WEEE is shipped to WEEE and e-scrap certified (pre) processing companies[48] (via AATF – approved authorized treatment facilities and AE – approved exporters). Ongoing efforts are focusing on increasing the availability of these facilities across the EU, which will prevent illegal shipments[49]. Concerns relating to the end-of-life phase of electrical products has driven action by

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

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

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

manufacturers to phase-out materials and flame retardants for which evidence exists of the potential for toxic emissions. Examples: metals and alloys that are used in solders, connectors, switches and relays, plastic additives that impart a function that 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. Concerns relating to the end-of-life phase of electrical products has driven action by computer manufacturers to phase-out those materials and flame retardants for which evidence exists of the potential for toxic emissions [50].

In terms of the scale of the issue the European Environment Agency estimate that 16-38% of the EU's WEEE waste (between 550,000 and 1,300,000 tonnes) was exported in 2008[51]. 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 highlight that there are no restrictions on the export of goods for re-use, 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 has shown that there is the potential for a range of toxic emissions to arise from unregulated treatment processes, including species of

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[50] 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

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

Polychlorinated and Polybrominated dibenzo-p-dioxins and furans (PCDD/DF and PBDD/DF) [52] [53] and carcinogenic Polycyclic Aromatic Hydrocarbons (PAHs) [54]. 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 [55] [56], 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[57,58].

1.3.3. Life cycle costs implications and trade-offs with environmental potential 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 life time of a data centre equal the initial capital expenditure. Conversely a reduction in the OPEX IT can result in an increase in OPEX Facilities increasing, as greater expenditure on electricity is needed to run older, inefficient equipment.

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[52] 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

[53] 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

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

[55] 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

[56] 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

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

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

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 Waste Electrical Equipment (WEEE) will have to be met as part of these costs.

1.3.4. 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 conformance. 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 standard, 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, 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 doesn't stop operators from shipping abroad (incl. 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, and nor are older (pre WEEE 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 authorized treatment facilities and AE

– approved exporters[59]) 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[60]. 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 facilitates will support ease of verification by complying with other policy measures and schemes.

1.3.5. Market implications and functionality

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

Also, reliability and service availability remain priorities for data centres, so criteria are avoided which present unacceptable risks. 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. 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 [61] was an example of a collaboration with industry to create a certification scheme for proper treatment according to WEEE

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

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

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

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 of EN 50625-1 identifies specific components of equipment that shall be removed for the purposes of depollution, mapping onto 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 re-use/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 re-used or recycled, and in some cases where a re-used item is destined for (but not the actual buyer/recipient).

It does not appear to be possible to obtain reporting 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 only to report at organisational level on 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 [62] and E-Stewards [63], which may be available at global, national or regional level.

1.3.6. Applicability to public procurement

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 IT equipment lifespan through its re-use 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 re-use 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 re-use, as well as dismantling for recycling and proper treatment is proposed to be defined according to Article 8 and Annexes VII and VIII of 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.

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

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

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

1.3.7. 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 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 40% of public sector servers in Ireland, the Netherlands and the UK were older than 5 years old. Furthermore, they represented only 7% of compute capacity, and yet accounted for 66% of energy consumption. We have therefore deleted this criterion and instead replaced it by an award criterion for the optimisation of a server's lifetime based on 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 life times (as discussed previously), as it's 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 has therefore been 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, being this non-compulsory, it doesn't give access to all servers.

Current regulations (WEEE) 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 authorized 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 when 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), 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's clear that the right processes are available to effectively disassemble, recycle and reuse servers, but the biggest end-of-life problem is ensuring this happens. Criteria have therefore been 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 of the regulations time frame/from a different manufacturer.

Current regulation such as RoHS 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 has been 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 it's 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) (b) points for the exclusion of toxic halogens (not all halogens because of risky alternatives), however 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 has not been 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.

1.3.8. Second criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
	TS1.3.1 Optimisation of server lifetime *This criterion is only applicable to managed service providers* Bidders must refresh the servers they will manage according to calculation of the optimal server lifetime [*formula in the explanatory note to be included in the tender documentation*]. Both new and existing servers must deliver comparable workloads. **Verification:** Ongoing monitoring of the refreshment planning is detailed in CPC1.3.1

Core criteria	Comprehensive criteria
	TS1.3.2 Design for disassembly and repair of servers *This criterion is only applicable to the procurement of new servers in an enterprise data centre* The tenderer must provide clear disassembly and repair instructions (e.g. hard or electronic copy, video) to enable a non-destructive disassembly of servers for the purpose of replacing the following components for upgrades or repairs: – external enclosures, or those portions of the enclosures that must be removed to accomplish repair – HDD and SSD data drives, indicating the presence of rare earth elements in magnets, – memory, – processor (CPU), – motherboard, – expansion cards/graphic cards, – power supply and/or – fans – casing – wires and cables that connect to external sources of power The instructions must be made available in hard copy to end-users, and to reuse and recycling organisations upon request and via the manufacturer's webpage. The manufacturer must have a written procedure that requires the instructions to be made available for a minimum of 7 years following the end of production of the product. **Verification:** The instructions which must include an exploded diagram of the server(s) illustrating how the relevant parts can be accessed and replaced, and the tools required. The instructions must also inform which parts are covered by service agreements under the warranty.

Core criteria	Comprehensive criteria
TS1.3.3 End of life management of servers Tenderers must provide a re-use and recycling service once the servers have reached the end of its service life. They must report on the proportion of equipment re-used or recycled, supported by details of the following aspects of the service: - Collection; - Confidential handling and secure data erasure (unless carried out in-house); - Testing, servicing and upgrading [64]; - Remarketing for re-use in the EU; - Dismantling for recycling and/or disposal. Preparation of items for re-use, as well as recycling and disposal operations must be carried out in full compliance with the requirements in Article 8 and Annexes VII and VIII of the (recast) WEEE Directive 2012/19/EU [65] and with reference to the list of components for selective treatment [*see the explanatory note*]. **Verification:** The tenderer must provide details of the arrangements for collection, data security, testing, remarketing for re-use and recycling/disposal. This must include, during the contract, valid certifications of compliance for the WEEE handling facilities to be used. According to the location of the handling operations, the following means of proof must be accepted: - EU operators: A valid permit issued by the national competent authority according to Article 23 of the Directive 2008/98/EC or a third party certification of compliance with the technical requirements of EN 50625-1; - non-EU operators: A third party certification of compliance with the minimum WEEE requirements laid down in the criterion, the technical requirements of EN 50625-1 or another well-established compliance scheme [66].	

[64] 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 shall be made suitable for reuse and resale.

[65] If the public authority is aware that there are no recycling facilities within a reasonable radius then it may be more appropriate to ask for the equipment to be delivered to an official WEEE collection point.

[66] The following compliance schemes are considered, at the time of writing, to meet these requirements: WEEELABEX:2011 standard 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
AWARD CRITERIA [67]	
AC1.3.3 End of life management of servers *To be used in conjunction with criterion TS 1.3.3* Points must be awarded to reuse and recycling service providers that ensure that Printed Circuit Boards and external cables are separated and recycled. **Verification:** The tenderer must provide certification of the recycling of the components identified.	
SELECTION CRITERIA	
	SC1.3.4 Emissions of hazardous substances – restricted substance controls in servers *The criteria is applicable to projects where IT equipment is to be procured.* The tenderer must demonstrate implementation of a framework for the operation of Restricted Substance Controls (RSCs) along the supply chain for the products to be supplied. Product evaluations according to the RSCs should, as a minimum, cover the following areas: - Product planning/design; - Supplier conformity; - Analytical testing. Implementation should be with reference to the guidance in IEC 62476 or equivalent. The RSCs (Restricted Substance Controls) must apply, as a minimum, to the REACH Candidate List substances, and RoHS restricted substances. **Verification:** The tenderer must provide documentation, which describes the system, its procedures and proof of its implementation.

[67] Instead of setting two separate award criteria on spare parts and warranties, this could be merged into one criterion, evaluating the overall offer including the length of the warranty, its comprehensiveness and the spare parts offer.

Core criteria	Comprehensive criteria
CONTRACT PERFORMANCE CLAUSES	
	CPC1.3.1 Optimisation of server lifetime Calculation of the optimal server lifetime (i.e. server refresh) will be done using the EURECA metric. The tenderer must compile and manage data on calculated optimal server lifetime according to EURECA metric as well as data on the parameters that form part of this metric.

Explanatory note: Metric on optimisation of server lifetime (the 'EURECA metric')

The calculation of the optimal server lifetime in technical specification TS2.3.1 must be done according to equation below:

$$\mu = \frac{E_e^r}{E_u^c}\left(1 - \frac{1}{2\left(\frac{n}{1.5}\right)}\right)^{-1}$$

Where:

μ = optimal server lifetime when energy efficiency is achieved by the newly refreshed hardware (year x)

E_e^r = embodied energy of new server (MJ or kWh) – *use 1000 kWh as default*

E_u^c = total energy consumption of existing server at a fixed workload at time 'n' (MJ or kWh)

n = evaluation period which is normally > lifetime of existing server (x number of years)

Explanatory note: Components requiring selective treatment in accordance to Annex VII of the WEEE Directive

- Mercury containing components,
- Batteries,
- Printed circuit boards greater than 10 cm^2,
- [lastic containing brominated flame retardants,
- Chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), 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.

1.4. Criteria Proposal: Temperature Operating Range

1.4.1. Background

The IT equipment creates the demand for power and cooling in the data centre. Selecting ICT hardware which is warrantied to operate at higher temperatures allows higher temperatures set points which results 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 Cooling Management section 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 describing a recommended range (18°C - 27°C) and allowable ranges for four environmental classes; the A1 and A2 ranges are referenced in the criteria (Class A1 15°C - 32°C and Class A2 10°C to 35°C)[68].). 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 water cooled equipment[69].

1.4.2. Life cycle environmental hotspots and potential improvements

Selecting ICT hardware which is warrantied to operate at higher temperatures can allow for a reduction in the energy consumption from mechanical and electrical (M&E) systems, which determines the amount of energy consumption. Moreover

[68] ASHRAE Thermal Guidelines for Data Processing Environments, Fourth Edition 2015

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

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 dematerialization reduces the embodied impacts of M&E plant. Reducing the M&E installed capacity can also allow the capital costs to be reduced.

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

Cooling costs are one of the major contributors to the total electricity bill of large data centres. The reduction of cooling demand has 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 ca. 30 euros per unit, therefore the purchase price is expected to be higher. However, the energy costs savings will outweigh this initial increase in purchase price.

1.4.4. Verification

Equipment should be able to withstand and be within warranty for the full range of temperature defined by the ASHRAE Class A1 or A2, according to the test developed for the pending Ecodesign measures. The test specifies that the unit under test shall be placed in a thermal chamber at a temperature corresponding to the highest allowable in the ASHRAE Classes (A1 and A2) and run a complete active test cycle as defined in EN 303470 (see criterion AC 2.1 on server efficiency). EN 50564:2011 shall be used for measuring temperatures during testing. .

1.4.5. Market implications and functionality

It is important to procure hardware which permits operation at higher temperatures. Network equipment in particular can be challenging to manage due to non-standard airflow direction and cabling blocking airflow[70].

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

ASHRAE research**Error! Bookmark not defined.** suggests that increased risk of component ailure 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[71] and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failures at higher temperatures[72].

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. . 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

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[70] Data Center Networking Equipment – Issues and Best Practices Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Data Centers, Technology Spaces, and Electronic Equipment

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

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

space. Potential derating of any cables in hot air stream at high temperatures should also be considered.

1.4.6. Applicability to public procurement

The criteria are considered to be generally applicable to the procurement of new ICT hardware. Criterion 1.4.1. makes reference to the same ranges described in the EU CoC Best Practices 4.1.2 and 4.1.3 for air cooling; the temperature range for liquid cooling are based on the ASHRAE Thermal Guidelines.

1.4.7. Summary of stakeholders comments following AHWG1

As not all facilities are air cooled, equivalent criteria for liquid cooled facilities was suggested and have been added. One opinion were 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 Best Practices has been added.

Additional text has been 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 new Eurovent certification programme (due early 2018), however in February 2018 the only available programmes relate to certification of cooling plant. EN 50600-2-3 and EN 50600-1 were also suggested however these relate to M&E systems and do not specify operating temperatures.

1.4.8. Second criteria proposal

TECHNICAL SPECIFICATIONS	
Core criteria	**Comprehensive criteria**
TS1.4.1 ICT Operating Range –higher temperature hardware *Applicable in the case of air cooling* ICT hardware must be warrantied to operate within an allowable temperature range of 15-32C. *Applicable in the case of liquid cooling* ICT hardware must be warrantied to operate within a facility supply temperature range of 2-17C. **Verification:** Manufacturers specifications and warranties must be provided for each piece of ICT equipment.	**TS1.4.1 ICT Operating Range – higher temperature hardware** *Applicable in the case of air cooling* ICT hardware must be warrantied to operate within an allowable temperature range of10-35C. *Applicable in the case of liquid cooling* ICT hardware must be warrantied to operate within a facility supply temperature range of 2-27C. **Verification:** Manufacturers specifications and warranties must be provided for each piece of ICT equipment.

2. CRITERIA AREA 2: MECHANICAL & ELECTRICAL SYSTEMS PERFORMANCE

The criteria area Mechanical and Electrical (M&E) performance concerns all the system and equipment relating to the electrical supply and distribution to support 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
Localized (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 systems level are below, following the proposed criteria:

a. Mechanical & Electrical systems energy efficiency, with the following proposed criteria with associated metrics:

   Criterion 3.1: Power Utilisation Effectiveness (PUE)

b. Cooling

   Criterion 3.2: Reuse of Heat Waste

c. Cooling Management

   Criterion 3.3: Operating conditions control

   Criterion 3.4: Cooling System Best Practices

2.1. Criterion proposal: Power Utilisation Effectiveness (PUE)

2.1.1. Background

Power utilisation effectiveness (PUE) is the ratio of total amount of energy used by a data centre facility to the energy delivered to the IT equipment, based on annual data. PUE was a metric developed by The Green Grid for calculating and reporting energy efficiency of data centres i.e. of the mechanical and electrical systems 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 environmental impact).

PUE was published in 2016 as a global standard under ISO/IEC 30134-2:2016, and there is also a European standard under 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[73] label requirements provides 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 at the EU Code of Conduct on Data Centre Energy Efficiency[74].

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[75].

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 paybacks 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 COP and allows more free cooling. The next largest energy consumer within the power and cooling systems is usually UPS efficiency.

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[73] www.blauer-engel.de

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

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

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[76] 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 significantly enough to show up in the regression analyses that form the basis of EPA models, and variability in PUE as 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[77].

Target values can potentially be based on those in the Blue Angel scheme (further details in Preliminary Report). Adjustments were considered in line with the variability used in the ASHRAE Energy Standard for Data Centers[78], however as these showed little variation, e.g. 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. for 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 intent. The achieved performance can then be compared with the expected result from the calculation model for the same ambient conditions.

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76 https://www.energystar.gov/ia/partners/prod_development/downloads/DataCenters_GreenGrid02042010.pdf

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

78 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 TWh – 5.5 TWh annually depending on the combination of requirements. The assumption made was that 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 PUEs.

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 costs implications and trade-offs with environmental potential 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 cost. As energy prices rise, paybacks reduce.

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. The documentation of calculation in Annex 2, 2.1 of the criterion 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 has mapped the average PUE of different data centres and server rooms. In the Business As Usual (BAU) scenario where eco-design 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 servers 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 [79]. This is because theoretically reduction in PUE can mask low IT efficiency, utilisation or a shift in loads between M&E and IT. Some examples are:

- PUE values tend to improve with high IT loads, regardless of if any M&E 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 of energy consumption by the cooling system, but can led to an increase of 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 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.

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

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 given) but can create a design which minimizes M&E 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. Colocation 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 minimize energy wastage from power and cooling systems.

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

Small facilities such as server closets or server rooms that are typically enterprise data centers housed in converted space in a mixed use building, (e.g. an office) can pose greater difficulties in monitoring PUE. Energy consumption of IT System and M&E System are typically included in the overall energy consumption of the building and submetering may not exist 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 by M&E. Other concerns included: no facility operates at 100% IT load; it is an improvement metric; it shouldn't be used to compare facilities; open to manipulation; and difficulty in validating design PUE. Stakeholders felt smaller data centres would struggle to improve PUE (consolidation, applications, refresh rates and utilization 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. % of design maximum) is always specified with the PUE value.

Some stakeholders suggested focusing on cooling loads – for example 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 centers, is not widely adopted and is in competition with ISO 30134.

Alternative suggestions to PUE targets:

1. Real-time, analytics-based cooling system management e.g. using wireless sensors for fixed speed units or IT management of 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 difference between theoretical and real life conditions). Also, use of centralised control is not recommended due to risk of a central controller disabling the cooling; a philosophy of 'global monitoring, local control' is preferred.
2. Add to core criteria the use of: EN 50600-99-1, ISO 9001/EN ISO 50001 or ISO 14001. Comprehensive criteria – EU CoC participant. Criteria have been modified to make reference to best practices from EN50600TR99-1 and EU CoC. The ISO standards suggested are broad in scope and may not result in 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 Systems Performance etc., and would be technology neutral, i.e. innovation-flexible.

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 optimize 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 PEP-ECO passport. http://www.pep-ecopassport.org, however a limited number of products are available for data centre applications.

2.1.8. Second criterion proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
Applicable in case of construction/retrofitting of a new/existing data centre when the IT power use can already be determined **AC2.1.1 Power Usage Effectiveness (PUE) – Design PUE** Points will be awarded relative to the best performing Design PUE (dPUE) offer (full number of specified points) at a given IT load (e.g. 50% of design). The PUE value must be determined according to the ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.**Verification:** 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.	

Core criteria	Comprehensive criteria
CONTRACT PERFORMANCE CLAUSES	
	CPC2.1.2 Demonstration of Power Usage Effectiveness (PUE) at handover The data centre systems / integrated systems commissioning must include a test where IT equipment load is simulated at part and full load with power and cooling systems operating in automatic mode. Total 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 AC2.1.1. Data to show instantaneous PUE based on measured values and part load according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.
CPC2.1.1 Monitoring of Power Usage Effectiveness (PUE) input values *To be used in conjunction with AC2.1.1*. The operator of the data centre facility must provide monthly data for the total metered energy consumption of the data centre and the sub-metered electricity consumption for the mechanical & electric systems and the IT equipment.	

2.2. Criterion proposal: Reuse of waste heat

2.2.1. Background

Significant potential exists for waste heat reuse from data centres since over 98%[80] 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. Colocation of the data centre to customers with suitable heat load profiles and needs

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

b. Heat quality i.e. suitable temperature for the customer needs

c. Infrastructure for transporting heat

Generally the heat is low grade (35-45^{o}C and sometimes below 25 ^{o}C[81]) and expensive to transport. To supply a district heating system, it must be concentrated using air to air or water heat pumps to raise the temperate to a suitable temperature (most district heating would be distributed at 70 ^{o}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 is 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.

[81] 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 10. Mäntsälä district heating network, Finland[82]

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.

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

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)

[82] . Source: Envirotech and Cloud & Heat (2017).

$Ln^{(k)}$ = 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

$Cn^{(k)}$ = 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 re-use of energy is considered a secondary objective, subject to the following conditions:

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

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

2.2.2. Life cycle environmental hotspots and potential improvements

There are no LCA studies quantifying the environmental benefits when waste heat is reused and comparing these to the environmental impacts arising from other life cycle stages. However, in countries and cities where there is 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 2.2.1.

For each 1MWh of heat reused from a data centre, the annual carbon reduction for a district heat 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 11 illustrates an energy flow chart for a small data centre that supplies heat to a number of apartment blocks.

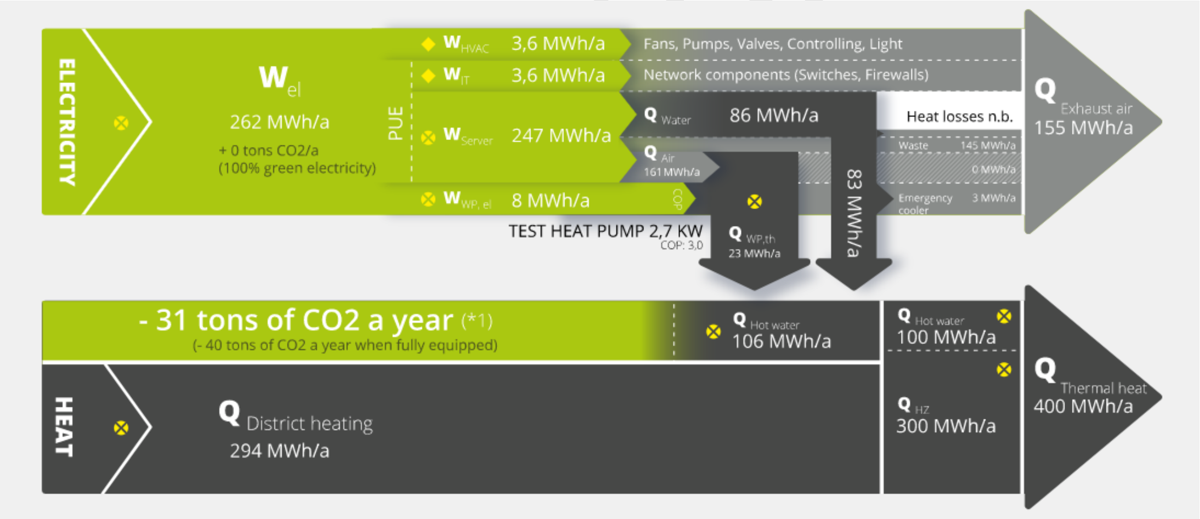

Figure 11. Example energy flow chart for a data centre in Dresden, Germany[83].

The Stockholm city district heating network[84] has been actively encouraging the connection of data centres on the district heating network, and have worked to

[83] Source: Cloud &Heat (2017)

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

simplify the technical and contractual issues. Ten data centres are currently understood to be connected and can sell their waste heat back to the network.

2.2.3. Life cycle costs implications and trade-offs with environmental potential 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).

2.2.4. 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 Report Energy Reuse Factor (ERF) calculated based on ETSI ES 205 200-2. Energy re-used 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.

2.2.5. 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 across Europe (see Figure 12). 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, which is one of the three biggest EU data centre markets but has very limited district heating networks. Functionality is not consided to be affected.

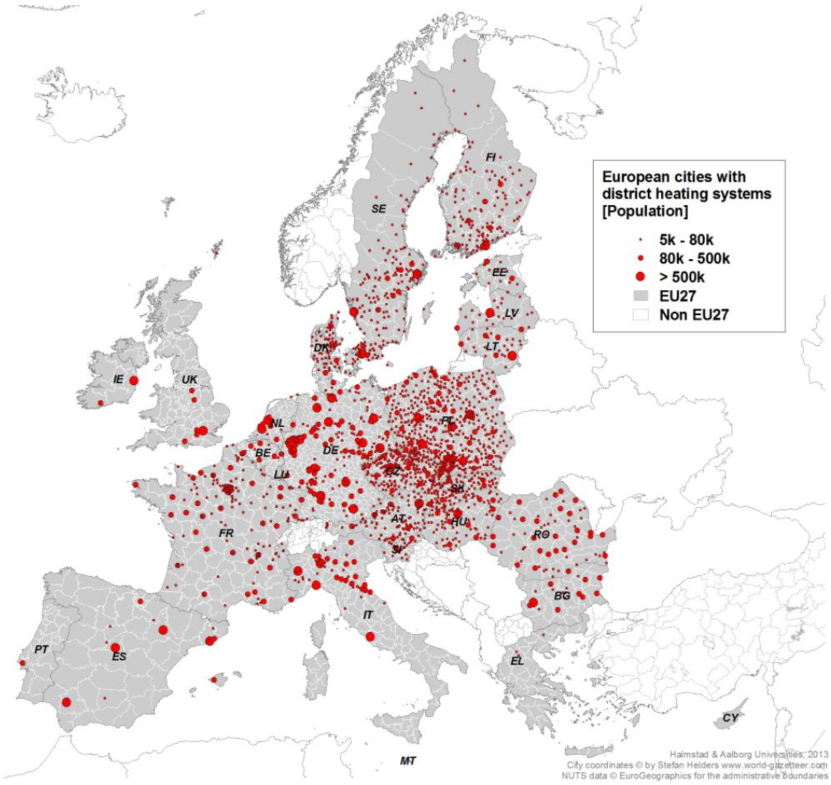

Figure 12. European cities with district heating.

2.2.6. Applicability to public procurement

There are relatively few data centres in the data centre market that re-use heat and these are currently concentrated in Northern Europe which actively encourage data centre connection and minimise administration costs. It is unlikely that a procurer could easily source a data centre which re uses 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 demands than an award criterion could encourage co-location and heat re-use.

In the case 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.

2.2.7. Summary of stakeholders comments following AHWG1

Stakeholders recognised the value of this proposal, but felt there were limited sites where it is possible. One stakeholder felt a rebound effect could lead to a reduced incentive to create more in the first place, therefore the type of use should be specified; and one felt the criteria should be deleted for this reason. However, the specified metric, KPIreuse accounts for this by specifying a preference for energy reduction (or non-use) over reuse. The section is 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 has been 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 or methods where no district heating system exists).

It was felt that the criteria should show a clear relationship to existing infrastructure and suitable end users include consideration of the economics of it (see the guidance document), and the effects of free cooling (the effects of 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 is 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, has therefore been added.

2.2.8. Second criteria proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
	TS2.2.1 Waste heat reuse *The criterion should be adapted to the local availability of district heating systems and networks as set out in the guidance document. It is recommended to set a comprehensive technical specification in the case that there is ready access.* The data centre must be connected to and supply at least 30% of the data centre's waste heat expressed as the Energy Reuse Factor to the local district heating network. **Verification:** The Energy Reuse Factor (ERF) must be calculated for each facility according to ETSI ES 205 200-2-1. The tenderer must provide 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. Upon request the contracting authority must be provided with access to the equipment and network connection on-site at the data centre for auditing purposes.
AWARD CRITERIA	
	AC2.2.1 Waste heat reuse (for new data centres) *The criterion should be adapted to the local availability of district heating systems and networks as set out in the guidance document. It is recommended to set a comprehensive award criterion in the case that there are local opportunities identified by a public authority.* Points must be awarded to tenderers that commit to supplying more than 30% of the data centre's waste heat expressed as the Energy Reuse Factor to local end-users. An additional point must be given for every 10% of extra waste heat the data centre supplies. **Verification:** The Energy Reuse Factor (ERF) must be calculated for each facility according to ETSI ES 205 200-2-1. The tenderer must provide design engineering drawings for the heat reuse systems and connection. Evidence of contractual arrangements or letters of intent must be obtained from potential heat customers. Upon request the contracting authority must be provided with access to the equipment and network connection on-site at the data centre for auditing purposes.

Core criteria	Comprehensive criteria
	AC2.2.2 Waste heat reuse (for managed services) *It is recommended to use this comprehensive award criterion in the case that a service is being procured.* Tenderers must declare their Energy Reuse Factor for the facilities that will be used to execute the contract. Points must be awarded in proportion to the bidder that offers the highest Energy Reuse Factor. **Verification:** the Energy Reuse Factor (ERF) must be calculated for each facility according to ETSI ES 205 200-2-1.
CONTRACT PERFORMANCE CLAUSES	
	CPC2.2.1 Monitoring of the heating supply and connection *To be included when the data centre is operated by a third party*. The operator of the data centre facility must provide average monthly data for the heat supplied to the local district heating network. In addition the Energy Reuse Factor (ERF) must be calculated according to ETSI ES 205 200-2-1 and reported on.

2.3. Criteria proposals: Operating conditions control, Cooling systems best practices

2.3.1. Background

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

Opportunities for improvement come from:

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 which 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 TS is proposed based on those Practices that are considered “Expected Practices” under the Code of Conduct for Data Centres and the CLC-TR50600:99-1(2017) 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 a 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 and economized and free cooling and ICT equipment do not exhibit significant increases in fan power consumption. A criterion for the inclusion of a comprehensive environmental monitoring is proposed.

d) Selection of cooling system: When refrigeration is used as part of the cooling system design 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 optimizes efficient operation, without compromising reliability. A TS is proposed based on Practices that are considered "Expected Practices" under the Code of Conduct for Data Centres and the CLC-TR50600:99-1(2017) 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 provide efficient operation in older facilities. A TS is proposed based on Practices that are considered "Expected Practices" under the Code of Conduct for Data Centres and the CLC-TR50600:99-1(2017) 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[85].

Higher temperature operation (of 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 possible 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

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[85] 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance, ASHRAE TC9.9 (2011)

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 Centre Energy Efficiency Best Practices 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 growth of the data centre. This defers cost and improves 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 are higher performing in terms of environmental impact, for example.

2.3.2. Life cycle environmental hotspots and potential improvements

Cooling of the Data Centre is frequently the largest 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 temperatures (and hence chilled water temperatures, where used), resulting in an energy penalty.

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

Cooling costs are one of the major contributors to the total electricity bill of large data centres. The reduction of cooling demand has 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.

2.3.4. 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 particular 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).

2.3.5. Market implications and functionality

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

- Air hot spots: Air management best practice is a key enabler which 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 energy consumption by the compressors for cooling and decrease 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 hottest times of year).
  - High relative humidity was found to have a higher impact on hard disk drive failures than high temperatures[86] and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failures at higher temperatures[87].
- 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

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

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

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 8759 hours of the year for example, the environmental (and operational cost) benefit from 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 colocation environments where shared cooling systems server 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.

2.3.6. Applicability to public procurements

These criteria complement the IT Equipment Operating Range – Cooling Management – higher temperature hardware criteria. 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 criteria is relevant when designing a new or upgrading / expanding an existing facility. It could also be used when choosing a colocation 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 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)

2.3.7. Summary of stakeholders comments following AHWG1

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

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 is normally operating 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[68].

With regards to best practices the EU Code of Conduct (also to be included in the 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 best practice listings, in the case of CoC with 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 JRC would follow this up with a number of the participants in the meeting.

2.3.8. Second criteria proposal

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">TECHNICAL SPECIFICATIONS</td></tr>
<tr><td>TS2.3.1 Environmental monitoring
The bidder must demonstrate that the facility has environmental control facilities and infrastructures in line with the requirements and recommendation of the standard EN 50600-2-3 capable of measuring:
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 (in case of access floor is installed)
4) Coolant flow rates (in case the design of the environmental control system relies on the movement of fluids, e.g. water cooling)
Verification:
The bidder must provide designs and technical specification monitoring system to be installed..</td><td></td></tr>
</table>

	TS2.3.2 Cooling systems best practices – new build or retrofit of data centres – Air Flow design and management The bidder must demonstrate that the design incorporates the expected best practices listed in the most recent version of [EU CoC reference / EN50600 TR99-1:2017 reference]. The list as of 2017 comprises the following • 5.1.1 / 5.17.57 Design – Hot /Cold aisle • 5.1.2 / 5.17.58 Design – Contained hot or cold aisle • 5.1.5 / 5.17.59 Cabinet air flow management – Other openings • 5.1.6 / 5.17.60 Provide adequate free area on cabinet doors • 5.1.11 / 5.17.49 Equipment segregation • 5.1.12 / 5.17.14 Separate environmental zones **Verification:** The bidder must provide designs and drawings for the airflow design.
	TS2.3.3 Cooling systems best practices – new build or retrofit of data centres – Cooling Plant Design The bidder must demonstrate that new Cooling Plant designs and/or installations must incorporate the expected best practices listed in the most recent version of [EU CoC reference / EN50600 TR99-1:2017 reference]. The list as of 2017 comprises the following: • 5.4.2.1 / 5.16.57 Chillers with high COP • 5.4.2.3 / 5.16.58 Efficient part load operation • 5.4.2.4 / 5.16.59 Variable speed drives for compressors, pumps and fans • 5.4.2.5 / 5.16.60 Select systems which facilitate the use of “Free Cooling” • 5.4.2.6 / 5.16.61 Do not share data centre chilled water system with comfort cooling • 5.4.2.7 / 5.16.62 Do not allow non IT equipment to dictate cooling system set • 5.4.2.8 / 5.16.63 Chilled water pump control strategy **Verification:** The bidder must provide designs and technical specification for the cooling plant to be installed.

	TS2.3.4 Cooling systems best practices – new build or retrofit of data centres – Air Conditioning / Air Handling • The bidder must demonstrate that new air conditioning / air handling systems within the computer rooms must incorporate the expected best practices listed in the most recent version of [EU CoC reference / EN50600 TR99-1:2017 reference]. The list as of 2017 comprises the following:5.5.1 / 5.16.64 Variable Speed Fans • 5.5.2 / 5.16.65 Control on CRAC / CRAH unit supply air temperature • 5.5.5 / 5.16.66 Do not control humidity at CRAC / CRAH unit • 5.5.6 / 5.16.67 Cooling unit sizing and selection **Verification:** The bidder must provide designs and technical specification for the air conditioning / air handling system to be installed.
AWARD CRITERIA	
	AC2.3.1 Cooling system energy consumption The bidders must be awarded points 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 relative to 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	
	CPC2.3.1 Monitoring of cooling system energy consumption *To be included when the data centre is operated by a third party. To be used in conjunction with AC 2.3.1.* The operator of the data centre facility must provide monthly and annual data for the cooling system energy consumption for the data centre. The monitoring must be specified according to the guidelines in EN 50600-4-2:2016 or equivalent.

3. CRITERIA AREA 3: DATA CENTRE PERFORMANCE

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. These aspects address the identified hotspots at a system level.

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:

Criterion 1.1: Renewable Energy Factor (REF)

Criterion 1.2: Use of refrigerants and Global Warming Potential

3.1. Criterion proposal: Renewable Energy Factor

3.1.1. Background

The actual environmental benefits of a 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 a higher amount of greenhouse gas emissions is released, with the emissions being dependant on the Member State's electricity grid mix and on the extent to which renewable energy has a share of that mix and/or if a data centre site has developed renewable energy generating capacity.

The major environmental impacts, primarily 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[88]%

[88] Emissions 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

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 straight forward. This argument can be applied to energy used by any product at any stage of the life cycle but there is currently not enough 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[89]. Equation 1.2.1 provides the equation for calculating REF. However, this does not consider additionality and care must therefore be taken to ensure that the market conditions result in real carbon reductions.

$$REF = (Energy_{grid\ renewable} + Energy_{onsite\ renewable} + Energy_{Energy\ certificate}) / Energy_{total\ Data\ Centre\ energy\ consumption} \quad (1.2.1)$$

As indicated in equation 1.2.1 this 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.

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

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

1. **Green tariffs from utility supplier (grid renewables)** are the simplest option where the electricity is purchased from the utility at retail rates. The utility then guarantees the electricity is sourced from renewable generation and in general the utility cancels (i.e. retires) the Guarantee of Origin (see next point) on the consumers behalf. In this case the renewable energy is then assigned to the utility which in some Member States have 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 energy generation. 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 generation. The most widely available is the Eko certificate.
4. **Corporate power purchase agreements (PPA)** 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 generation is installed as follows:
    a. Onsite/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 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 electricity 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) them.

5. **Private energy services agreement.** These 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 datacentre arranges financing for capital and installation costs. This tends to be large and out of the expertise of the datacentre operator. This will therefore mostly apply to small installations such as onsite. In addition, this sort of financing is likely to be beyond the scope of the datacentre 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% according to 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 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 generation.

A few Member States also have a very high renewable energy mix (Eurostat[90]) and there is little potential to increase this further with more renewable generation through PPAs since other policies or market forces are 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 2.1.1 signal to the market that there is demand for renewable energy and in theory drive greater supply and investment into renewable generation, however, in the short term it only shifts the renewable supply from one customer to the other 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 the use of renewables by businesses.

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

- Contracting PPAs is the preferred approach promoted by Renewable Energy Buyers Alliance[91] as it more directly demonstrates additionality. Since the PPA directly helps secure the capital investment for new generation capacity and it is easier to establish a direct link that the renewable generation would not have been installed without the PPA. However, as discussed earlier, additionality is not proven.

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

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

For green tariffs, GO and certified energy, the cost is generally higher because the cost of renewable generation has historically been higher than other generation. The GO are also tradable and the cost will vary depending on market supply and demand. GO were trading at approximately 15-30 ct/MWh, approximately 1% of electricity prices according to an Oeko Insitut study carried out for the European Commission [92], 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 they are currently used because they are lower cost. More importantly they are

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[91] http://rebuyers.org/

[92] 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

perceived to fix the risk from fluctuating energy prices[93]. 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 10MW 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[94] projections state approximately 50% of servers in 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-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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[93] http://www.bakermckenzie.com/-/media/files/insight/publications/2015/12/the-rise-of-corporate-ppas/risecorporateppas.pdf?la=en

[94] 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 than 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 very minimal effect of 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 which meet both the data centres network and access requirements (generally close to major cities and to a sufficiently capable power grid) as well as being suitable for significant sized renewables that could potentially be located near to the site – such as a solar farm or large wind turbines - are limited. For example, a large MSP, Apple, has built a 20MW, 5,000m^2 data centre in North Carolina that includes an 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[95]. 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 centres service providers, including Google, Microsoft, HP, Equinix, Digital Realty, Amazon, Switch, Cisco, BT have 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 UK, which has one of the most liberalised markets. Even in

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

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 has not been completed due to lack of resources.

PPAs currently agreed tend to be around 100MW for 10+ years, and the minimum economically viable PPA is considered to be around 10MW. For example, BT signed a 13 years 100GWh PPA for EUR 216m in 2017 and a 72MW 20yr PPA for 300m GBP in 2014 which required bespoke contractual mechanisms. As such only a few DC operators have PPAs and they may not 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 Akzo Nobel, DMS, Philips and Google purchasing from a wind farm in The Netherlands[96] is the most widely publicised example, however, none of these are SMEs.

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

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 criteria for renewables signals to the DC industry that it is an increasingly important factor to consider.

The use of REF as criteria 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 they have already made or propose to put in place upon location of the contracting authority's IT equipment.

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

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 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 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 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 new capacity has been built. As such the use of Guarantees of Origin and equivalent proof is not necessary.

An alternative approach could be where new electricity generating capacity is required to meet potential shortfall or address reliability issues on the local grid, or to ensure additionality by generating electricity that is supplied directly to the site over 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 criteria must fulfil the following criteria:

- Renewables must be located on-site of near-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 the difficulty in demonstrating this. The use of GOs and other independent eco-labels were encouraged but there 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 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 has been adopted in the award criteria AC1.2.

3.1.8. Second criterion proposal

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
AC3.1.1 Renewable Energy Factor *To be included when the data centre is operated by a third party and the Member State has <20% share of electricity generated from renewable sources.* *The share of renewable sources can be checked here: Eurostat nrg_ind_335a*[97]. Points must be awarded in proportion to the bidder that	

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

Core criteria	Comprehensive criteria
offers the highest REF for their electricity use above the Member State average share. The Renewable Energy Factor (REF) for energy supplied and consumed in the data centre must be calculated according to EN 50600-4-3[98]. The electricity contributing to the REF must come from renewable sources as defined by Directive 2009/28/EC[99]. **Verification:** The REF and the electricity supply and usage data on which the calculations are based must be declared.	
	AC3.1.2 Procurement of on- or near-site, directly supplied renewable energy *To be included when the data centre is operated by the public authority.* Points must be awarded based on the projected proportion of load matched by renewable energy supplied directly to the site over direct wires from an on- or near-site renewable generating capacity. The service contract must serve the purpose of underwriting the investment in new capacity. Points will be awarded in proportion to the REF contribution resulting from the PPA or energy service supply. Grid connected PPA supply, PPAs for a supply from existing renewables sites are ineligible. **Verification:** The REF and the electricity supply and usage data from the PPA or service agreement on which the calculations are based must be broken down and declared.
CONTRACT PERFORMANCE CLAUSES	
	CPC3.1.1 Renewable Energy Factor *To be included when the data centre is operated by a third party.* 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

[98] EUROPEAN STANDARD EN 50600-4-3 - Information technology - Data centre facilities and infrastructures - Part 4-3: Renewable Energy Factor

[99] 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
	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 so-defined renewable sources (e.g. a tradable certificate from an independent issuing body, which has been approved by government [100]. Another alternative would be if the electricity supplied carried a Type-1 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 a 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 brings usually 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 their basis of their life cycle GHG emissions would therefore be difficult.

Moreover, using fluorinated gases (i.e. F-gases) as refrigerants for the data center's cooling systems can increase the global warming potential of data centers if potential fugitive emissions occur due to the F-gases high global warming effect. Some of these gases have a warming effect stronger than 2500 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.

The Regulation (EU) No 517/2014 on F-Gas[101] specifies requirements to prevent leakages and to phase down the use of F-Gas, 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 from all F-gases, will be phased down but will not be totally removed. It is thus proposed to have a mandatory criterion which avoids their use. The F-Gas 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.

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 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[102], avoiding the use of F-Gases could reduce the GWP by about 15%.

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

[102] 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.

Incentivizing 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 on the market offered by different cooling solutions, including free-cooling systems.

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

Reporting the global warming potential of refrigerants would not add extra burdens to emission factors are well documented. Therefore, no major life cycle costs 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.

On the other hand, free cooling or economized 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[103]. Moreover the phasing out of F-gases refrigerants is going to affect the operating prices. For example, the prices of R-404A and R-507 (both with a GWP higher than 3900) have risen by 225% in Europe. In the same period, R-410A and R-134a prices (GWP of 2088 and 1430 respectively) have doubled, i.e. a 100% increase[104]. This will push the market to use other more climate friendly alternatives.

December, 2016. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/376/dokumente/climate-friendly_air-conditioning_with_natural_refrigerants_factsheet.pdf

[103] 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

[104] http://www.carel.com/blog

3.2.4. Verification

It is proposed to report following the Annex I and the Annex IV of 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 would 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

The criteria 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' view 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 aspiration 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 (kgCO_2/kwh). One stakeholder questioned why there was not instead a simple focus on metered energy use measured in kWh. It was also noted that the grid emissions factor will change over time, so this needs to be considered.

Forecast performance therefore needs to be handled carefully. Overall the feeling 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 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 of the F-Gas Regulation.

3.2.8. Second criteria proposal

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
AC3.2.1 Global warming potential of mixture of refrigerants Points must be awarded in proportion to the tenderer that offers the lowest global warming potential weighted average for the mixture of refrigerants that will be used calculated according the Annex IV of Regulation (EU) No 517/2014. **Verification:** Tenderers must report the calculation of the global warming potential weighted average, including the technical specifications of the refrigerants used, and show consistency with the method described in Annex IV of	

Core criteria	Comprehensive criteria
Regulation (EU) No 517/2014.	
CONTRACT PERFORMANCE CLAUSES	
	CPC3.2.1 Global warming potential of mixtures of refrigerants *To be included if criteria AC1.2 is used.* The operator of the data centre project must monitor and verify the cooling system's GHG of refrigerant emissions as estimated at bid 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.

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LF-NA-28199-EN-N

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