

JRC TECHNICAL REPORTS

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

TECHNICAL REPORT

Draft first criteria proposals

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Abstract

Development of the EU Green Public Procurement (GPP) Criteria for Data Centres, 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 it delivers 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
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAPEX	Capital Expenditure
CPC	Contract performance clause
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handler
EN	European Norm
ERF	Energy Reuse Factor
ETSI	European Telecommunications Standards Institute
GHG	Greenhouse gas
GO	Guarantee of Origin
GWP	Global Warming Potential
HDD	Hard Disk Drive
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
PUE	Power Utilisation Effectiveness
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 that is operated by an enterprise which has the sole purpose of the delivery and management of services to its employees and customers.	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.	

1. INTRODUCTION

This document is intended to provide the background information for the development of the EU Green Public Procurement (GPP) criteria for Data Centres. 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".

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.

1.1 The criteria development process and evidence base

The main purpose of this document is to present the first 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 addressing¹:

- 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, academy and public procurers. The input provided has been incorporated in the preliminary report, and together with the proposed criteria presented in this report, will form the basis for continuing a future consultation with the stakeholders. After the consultation process is finalised, this report will be revised and a final set of criteria will be established.

This draft report will be the basis for the first Ad-Hoc Working Group (AHWG) meeting, which will take place in November 2017.

1.2 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 scenarios that occur when public organisations purchase data centre products and/or services
- The estimated market volumes in the EU for the proposed scope

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

- 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

1.3 Scope and definition

1.3.1 Definition of a data centre

A definition of data centre is proposed (see Table 1) that combines the definitions from the EU Code of Conduct² and NACE³, and that fits the data centre classification presented in next section. Data centres are typically formed of three systems: IT equipment, electrical and mechanical equipment, and a building infrastructure (Figure 1. Typical data centre layout.)

Table 1. Proposed definition a data centre.

Data centre definition
Data centre means a structure, 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.

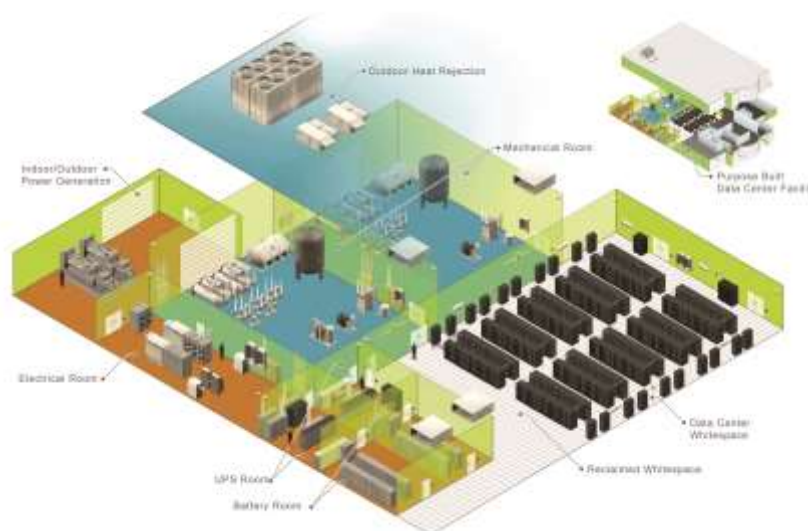


Figure 1. Typical data centre layout⁴.

² <https://ec.europa.eu/jrc/en/energy-efficiency/code-conduct/datacentres>

³ Nomenclature Générale des Activités Économiques dans les Communautés Européennes

⁴ Reproduced with permission of Schneider Electric

1.3.2 Data centre classification

The 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

Data centre type	Description
Enterprise	A data centre that is operated by an enterprise which has the sole purpose of the delivery and management of services to its employees and customers ⁵ .
Colocation	A data centre facility in which multiple customers locate their own network(s), servers and storage equipment ⁶ .
Managed Service Providers (MSP)	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).

1.3.3 Proposed scope of the criteria

The proposed scope of the criteria is presented in Table 3, which encompasses the main functional components of a data centre, including the Mechanical & Electrical equipment and the IT equipment, the three being important sources of impacts to the life cycle environmental hotspots of the data centre.

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 (<0.5% life cycle environmental impacts).

As well as its components, the scope covers also the data centre 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

⁵ From EN 50174-2:2009/A1:2011, 3.1.8

⁶ From EN 50600

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.

Proposed data centre criteria scope
<p>For the purposes of this GPP criteria set the scope shall encompass performance aspects of:</p> <ul style="list-style-type: none"> • 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 space⁷; • Data centre systems as a whole or a managed data centre service. <p>The building fabric (i.e. physical structure of the building and its respective building materials) is not included in the proposed scope.</p>

1.4 Public procurement routes for data centres

The identified routes for the public procurement of data centres, according to the proposed scope presented in section 1.3, have been established from initial information collected from the EURECA⁸ project team and other identified examples of procurement practices in the EU. This will need to be supplemented by further input from public authorities and contractors in order to ensure that the criteria provide guidance that accurately reflects current procurement practices.

⁷ 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.

⁸ <https://www.dceureca.eu/>

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

1. Building a new data centre
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. consolidating⁹ existing data centres estates
 - c. virtualisation¹⁰ of existing server capacity
 - d. services to expand existing building with new data centre 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 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, which in turn influences the type of data centre product and/or service they will purchase (Figure 2, Figure 3, Figure 4).

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 data centre 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

⁹ 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.

¹⁰ Virtualisation refers to the act of creating a virtual (rather than actual) version of computer hardware platforms, storage devices, and computer network resources

market, but they need to be further corroborated with procurers and stakeholders during the consultation process.

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.

Consultation draft

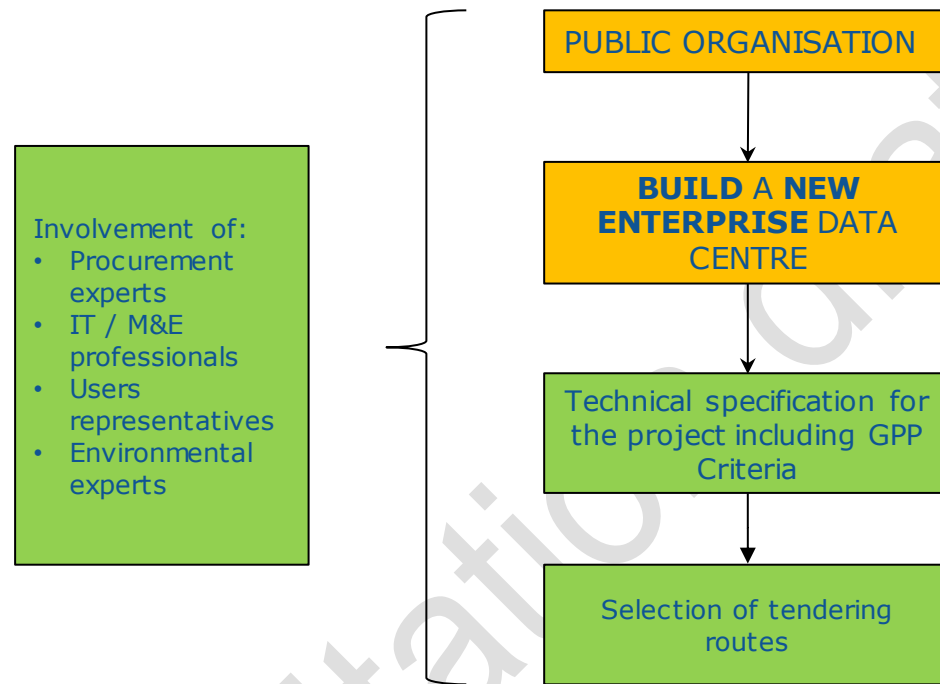


Figure 2. Mapping of potential procurement practices for scenario 1 when public organisations build a new Enterprise data centre in the EU.

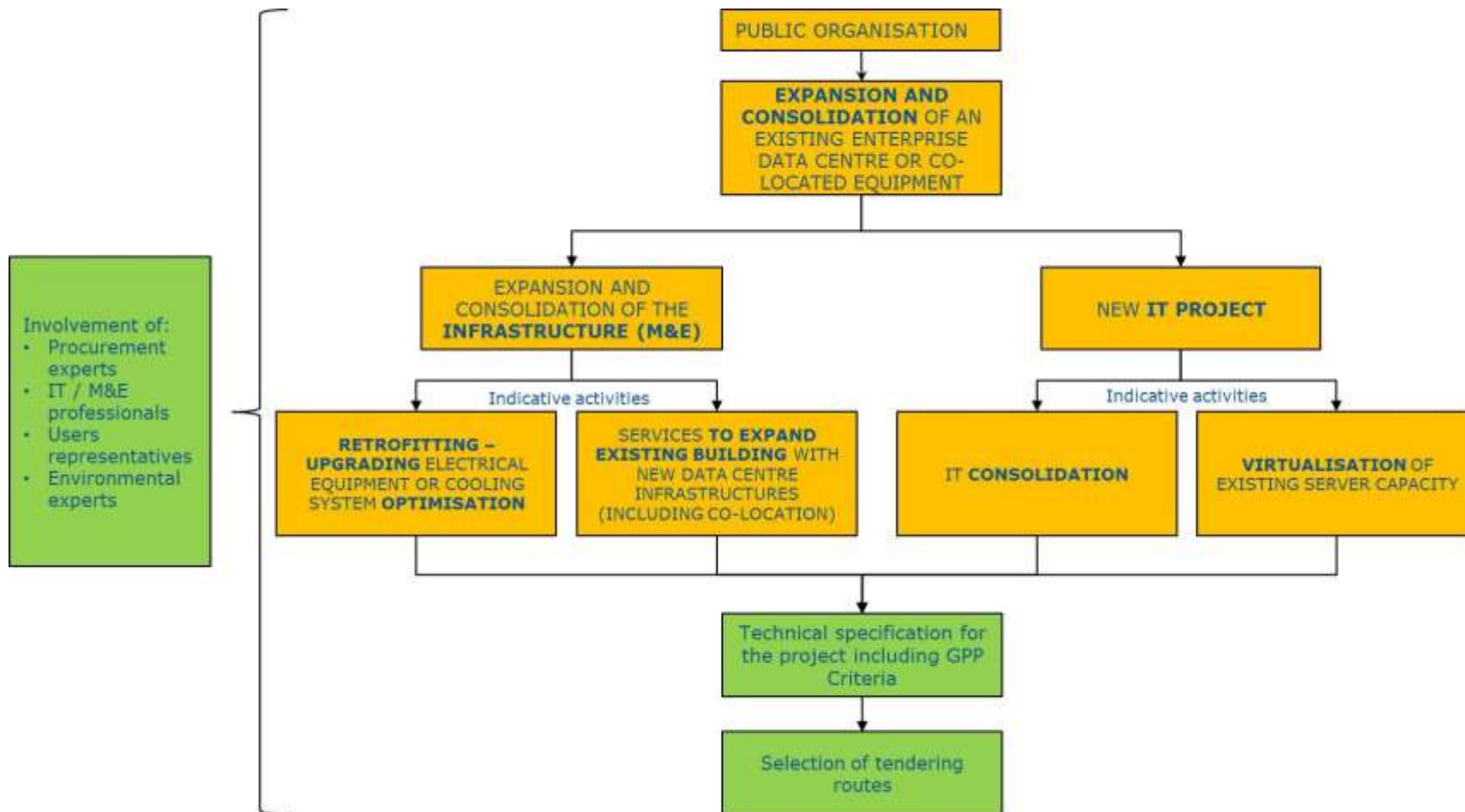


Figure 3. Mapping of potential procurement practices for scenario 2 when public organisations expand and/or consolidate infrastructure or start a new IT project for Enterprise and Colocation data centres in the EU.

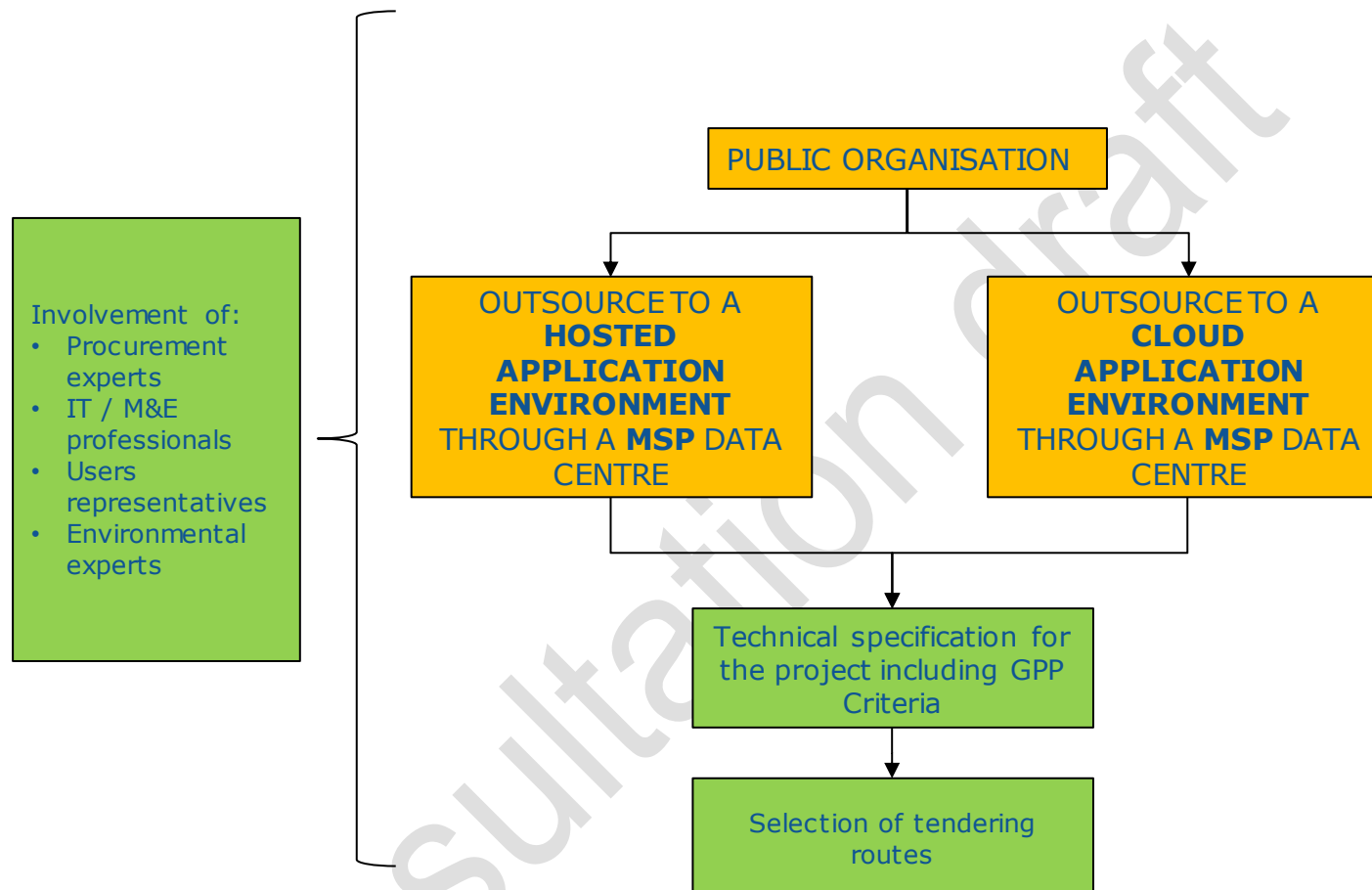


Figure 4. Mapping of potential procurement practices for scenario 3 when public organisations outsource to a hosted or Cloud application environment through MSP data centres in the EU.

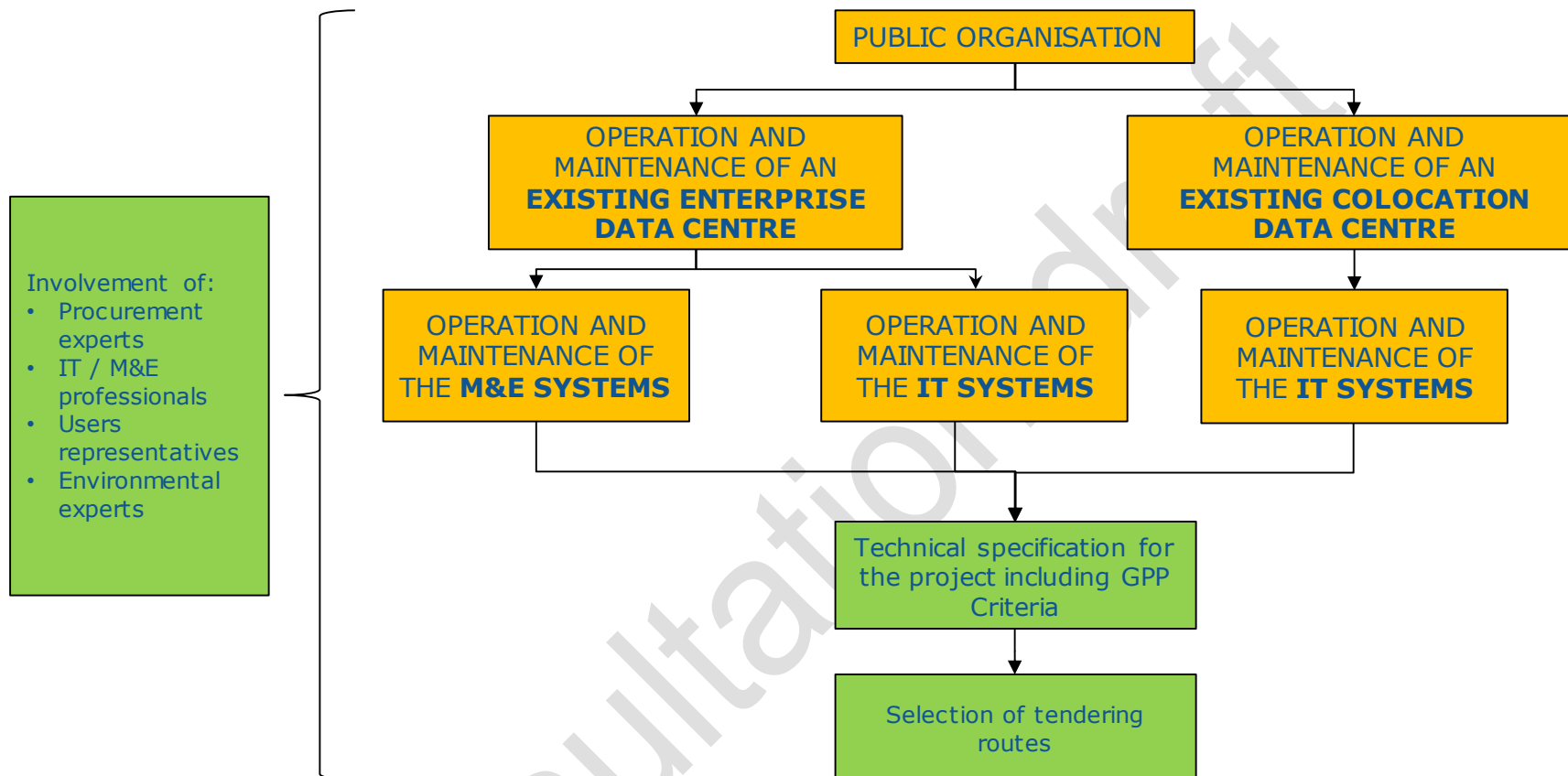


Figure 5. Mapping of potential procurement practices for scenario 4 when public organisations purchase operation and/or maintenance services for data centres in the EU.

1.5 Data centre market volumes and energy consumption

1.5.1 Current market volumes

Market volumes on data centre white space and estimated number of EU data centres has been provided by Data Center Dynamics¹¹. The data market data is broken down per data centre type according to the data centre classification shown in section 1.3.2. The estimated white space and number of data centres in the EU can be seen in Table 4 and Table 5.

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 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 m²/data centre, while for Colocation is 1152 m²/data centre and for MSP is 1123 m²/data centre. Enterprise data centres exclude small server rooms as the criteria for establishing this quantification was to have an IT capacity equal or greater than 25 kW, have provision for power and environmental management separate from other areas and a dedicated building. However, 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. Although 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. The preliminary conclusion is thus that Enterprise still represent a significant share of the present number of data centres operated by public organisations, but that the trend is to move towards more Colocation data centres

¹¹ <http://www.datacenterdynamics.com/>

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 enterprise data centres. It is therefore important to focus efforts when developing GPP criteria, on the shift towards more efficient technologies and best practices for enterprise data centres.

With regards to cloud services, there are examples of public facing cloud services 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.

Table 4. Estimated data centre white space (m²) 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 5. 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%

1.5.2 Current and predicted energy consumption

Based on different data sources^{12,13,14,15,16}, the estimated energy consumption of data centres 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 overall energy consumption for the period 2010 to 2030 is shown in Table 6. The main reason why consumption slows down after 2015 is the increased efficiency of servers and storage units.

Table 6. Estimated EU data centre energy consumption 2010 – 2030.

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

The break down per data centre type is shown in Figure 6. The data shows a slow down on consumption by Enterprise data centres, which is solely based on predictions by the US Lawrence Berkeley National Laboratory¹⁵, which indicate 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 Colocation data centres, and overestimating that by MSP data centres. However, it provides an indication of

¹² <https://www.dotmagazine.online/issues/powering-and-greening-IT/Sustainable-Energy-Transformation>

¹³ Figures presented by Paolo Bertoldi in November 2016 related to the European Programme for Energy Efficiency in the Data Centres Code of Conduct

¹⁴ Ongoing ecodesign work on servers and storage

¹⁵ US Data Center Energy Usage Report. Ernest Orlando Lawrence Berkeley National Laboratory. June 2016.

¹⁶ CBRE Marketview. Europe Data Centres, Q1 2017.

the current consumption levels showing that Enterprise and Colocation dominate the energy breakdown in 2017 (i.e. 52% by Enterprise and 15% by Colocation data centres).

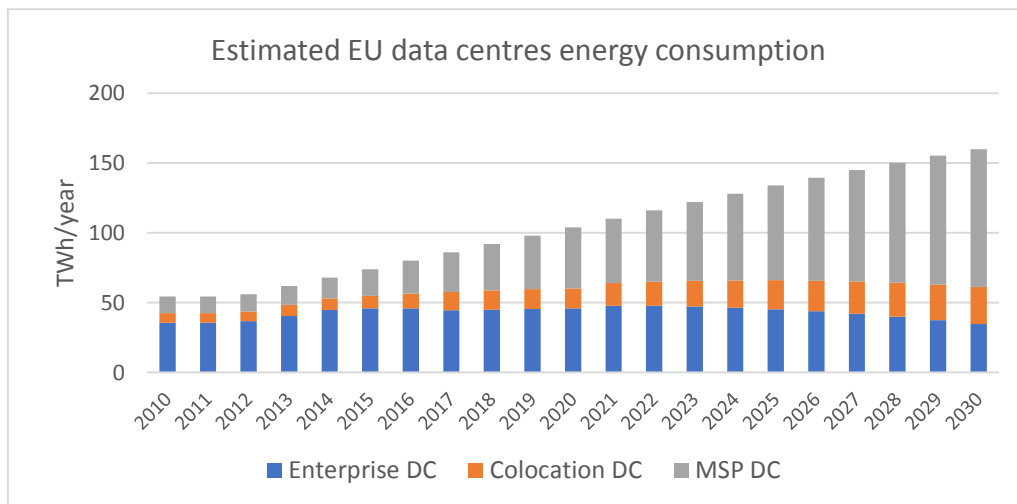


Figure 6. Estimated EU data centres energy consumption per data centre type.

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 US¹⁵ 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 7, 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 7. 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	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

1.6 The key environmental impacts of data centres

1.6.1 Life cycle assessment (LCA) of data centres and life cycle environmental hotspots

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

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

technology¹⁷. The environmental impacts assessed varied widely across the ten studies, with all looking at Global Warming Potential (GWP) 100 years (i.e. Climate Change¹⁸), and seven looking at other environmental impacts beyond Climate Change but at different damage points and assessed with different life cycle impact assessment methodologies¹⁹. 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.
- 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.
- The manufacture (incl. raw materials extraction and transport) of the IT and M&E equipment (i.e. their embodied impacts), and in particular due to the disposal of waste arising from the mining, extraction and refining of metals used to manufacture printed circuit boards of IT components.

¹⁷ <https://www.seecooling.com/files/2016-02/the-teliasonera-green-room-concept.pdf>

¹⁸ 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>

¹⁹ Midpoint and endpoint. For an explanation see: <https://www.openlca.org/wp-content/uploads/2015/11/LCIA-METHODS-v.1.5.4.pdf>

- The end of life of the equipment, 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.

1.6.2 System design and operation

Measures to improve data centre sustainability must not compromise reliability.

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

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 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 culture²⁰.

²⁰ http://www.dc-oi.com/blogs/Managing_Risk_The_Human_Element.pdf

1.6.3 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 8, 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 3 as low life cycle costs and ending with 1 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 as for life cycle costs..

The results from this ranking show:

- in green the key improvement areas with the highest potential benefits, that do not incur high life cycle costs and where technologies with these improvements can be found on the EU market, however, the verification 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 level
2. IT system level
3. M&E systems level

Table 8. Priority ranking of improvement areas

Life cycle hotspots	Improvement strategy	Application level(i.e. focus area)	Potential environmental benefits	EU Market Readiness	Life cycle costs	Verification	Total Scoring
Energy mix to supply electricity	Hosting/location of server and data storage services in data centre with high renewable electricity share	Whole data centre	3	2	2	2	
	Hosting/location of server and data storage services in data centre with low GHG emissions	Whole data centre	2	3	3	3	
Energy consumption in the use phase	Ensure an high rate of utilisation of IT equipment	IT system	3	2	3	1	
	Select high energy efficient server(s)	IT system	3	2	3	2	
	Select ICT Equipment operating at higher temperature	IT system	2	2	2	3	
	Hosting/location of server and data storage services in data centre with low Power Usage Effectiveness (PUE)	M&E systems	2	3	2	3	
	Reduce energy consumption for cooling systems (operating at higher temperatures)	M&E systems	2	2	2	3	
	Minimize waste heat by reuse in a district heating	M&E systems	2	1	2	3	
	Increase energy efficiency of storage unit(s)	IT system	2	1	2	1	
	Increase energy efficiency of network equipment	IT system	1	2	3	2	
	Report data centre productivity	IT system	1	1	3	1	
	Improve data centre	Whole data	1	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
	design and management	centre					
	Reduce energy consumption of UPS	M&E systems	1	3	1	2	
Manufacturing of IT	End of life management – Collection, resale and tracking	IT system	3	2	2	2	
	Design for durability – Select ICT with an extended warranty	IT system	2	2	2	3	
	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	
	Optimise hardware refresh rates	IT system	3	1	3	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	1	
	Hardware / plant leasing to increase product lifetime	Whole data centre	1	1	3	2	
	Avoid overprovisioning of resilience	Whole data centre	3	1	3	1	
	Asset management	Whole data centre	1	3	3	2	
	Data storage policy	IT system	1	3	3	2	
	Use of Open Compute hardware	IT system	1	1	3	2	
	Evaluate	M&E	2	1	3	3	

Life cycle hotspots	Improvement strategy	Application level(i.e. focus area)	Potential environmental benefits	EU Market Readiness	Life cycle costs	Verification	Total Scoring
	environmental impact of design options	systems					
	Refrigerant global warming potential review	M&E systems	1	2	3	2	
	Hardware providers following BEMP for Electrical Equipment Manufacturing Sector / EMAS registered companies	IT system	1	1	3	2	
	Power cord materials	IT system	1	1	3	2	
	Responsible facility decommissioning	Whole data centre	1	1	1	3	
	Recyclability of plastic components of hardware	IT system	1	1	1	2	

1.7 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 can vary, typically without considering decommissioning and end of life and in many cases excluding some pieces of equipment. However, typically the costs are 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 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' life cycle cost structure. See Table 9.

From the data centre 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.

Table 9. Overview of main 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)		
	Enterprise	Colocation	MSP	Enterprise	Colocation	MSP
CAPEX facilities	15-20%	40-50%	15-20%	15-20%	1-5%	0%
CAPEX IT	30-40%	1-10%	30-40%	30-40%	35-45%	0%
OPEX facilities	10-15%	35-45%	10-15%	10-15%	15-20%	35-50%
OPEX IT	25-35%	1-10%	25-35%	25-35%	30-40%	50-70%
Decommissioning	5-10%	1-5%	1-5%	5-10%	1-5%	0%
Facilities end of Life	1-5%	1-2%	1-2%	1-5%	N/A	N/A

2. CRITERIA AREA 1: 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: Facility Greenhouse Gas inventory

2.1 Greenhouse gas emissions – Criterion proposal: Renewable Energy Factor

2.1.1 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 (approximately 75%) 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 85²¹% 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 EN50600-4²². 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.

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

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

²¹ 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>

²² Information technology. Data centre facilities and infrastructures. 1: Overview of and general requirements for key performance indicators. 2: Power Usage Effectiveness. 3: Renewable Energy Factor.

RE certificates, and the portion of utility renewable energy for which the data centre has obtained documented written evidence from the source utility provider(s) that the energy supplied is from renewable sources.

There are several purchasing mechanisms for securing 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 company 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. The generation is connected directly to the data centre and the electricity is used directly. However, a grid connection is still required since generation often does not match demand perfectly.

- b. Grid connected. The generation is on the same grid 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 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 (retires) them.

2.1.2 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.

However, from a wider perspective, there is a difference in the environmental impacts according to the way it 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.
- Contracting PPAs is the preferred approach promoted by Renewable Energy Buyers Alliance²³ 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.

2.1.3 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

²³ <http://rebuyers.org/>

prices according to an Oeko study²⁴, 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 perceived to fix the risk from fluctuating energy prices²⁵. 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 data centre, but a high end data centre will vary from a few MW to tens of MW. LBNL²⁶ 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.

²⁴ 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

²⁵ <http://www.bakermckenzie.com/-/media/files/insight/publications/2015/12/the-rise-of-corporate-ppas/rise-corporate-ppas.pdf?la=en>

²⁶ https://eta.lbl.gov/sites/default/files/publications/lbnl-1005775_v2.pdf

2.1.4 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.

2.1.5 Market implications and functionality

In practice, on site renewables are not as practical if the size the data centre is not large enough to pay off for the high amount of energy consumed and the amount of land needed to supply it. If data centres are small, rooftop solar or similar projects have a very minimal effect of the overall energy mix. Furthermore, 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 renewables are limited. For example, a large MSP, Apple, has built a 20MW, 5,000m² data centre in North Carolina that includes an on-site solar farm whose area is 80 times that of the building at 400,000m² as well as landfill biogas powered fuel cells which are together expected to supply approximately 60% of the energy required²⁷. Even with such a large site, another 400,000m² of solar farms nearby are required to supply the remaining energy.

There are limited data centres currently using renewables, and fewer still using PPAs. Only the largest data centres service providers, including Google, Microsoft, HP,

²⁷ <http://www.datacenterknowledge.com/the-apple-data-center-faq-part-2/>

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 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 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 be a practical option for SMEs and many other DCs. For smaller data centres, it may be possible to join consortia to sign PPAs. This has been led by the US and there are very few examples of this currently in Europe. A consortium of Akzo Nobel, DMS, Philips and Google purchasing from a wind farm in The Netherlands²⁸ 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.

2.1.6 Applicability to public procurement

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

²⁸ <http://www.ppa-experts.com/krammer-akzonobel-dsm-google-philips-wind4ind/>

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. 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 the subject matter. 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, which would go beyond the scope of the subject matter and potentially be discriminatory within the market.

2.1.7 First criterion proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
	<p>AC1.1 Renewable Energy Factor</p> <p><i>To be included when the data centre is operated by a third party.</i></p> <p>The contractor shall maximise the amount of renewable electricity used to provide the service. Points shall be awarded in proportion to the bidder that offers the highest REF for their electricity use.</p> <p>The Renewable Energy Factor (REF) for energy supplied and consumed in the data centre shall be calculated according to EN 50600-4-3.</p> <p>The electricity contributing to the REF must come from renewable sources as defined by Directive 2009/28/EC.</p> <p>Verification:</p> <p>The REF and the electricity supply and usage data on which the calculations are based shall be declared.</p> <p>Relevant documentation from a Guarantee of Origin Scheme shall be submitted. Alternatively, any other</p>

Core criteria	Comprehensive criteria
	equivalent proof shall be accepted.* * Please see the Explanatory note for further information.
CONTRACT PERFORMANCE CLAUSES	
	CPC1.1 Renewable Energy Factor <i>To be included when the data centre is operated by a third party.</i> The operator of the data centre facility shall provide monthly data for the renewable energy purchased and the total metered energy consumption of the data centre.
EXPLANATORY NOTE	
<p>Guarantee of Origin:</p> <p>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.</p> <p>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 ²⁹). 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.</p>	

2.2 Greenhouse gas emissions – Criterion proposal: Facility Greenhouse Gas inventory

2.2.1 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. Although the biggest source of impact to Climate Change is in the use phase, additional impacts arise when considering other life cycle stages.

²⁹ See RECS (Renewable Energy Certificates System), www.recs.org. The Association of Issuing Bodies also provides a listing of schemes at national and regional level, see fact sheet 4, www.aib-net.org/eees

2.2.2 Life cycle environmental hotspots and potential improvements

As a starting point, the declaration of the data centre's greenhouse gas emissions for the whole data centre's life cycle could be split into the three scopes as defined in EN ISO 14064-1³⁰ which are also reflected in the Greenhouse Gas Protocol – Corporate Standard³¹:

- Direct emissions: Direct GHG emissions from facilities within its organisational boundaries.
- Energy indirect GHG emissions: Indirect GHG emissions from the generation of imported electricity, heat or steam consumed by the organisation.
- Other indirect GHG emissions: Activities of the organisation that might result in indirect GHG emissions, other than GHG emissions from the generation of imported electricity, heat or steam consumed by the organization e.g. transport, production, outsourced activities.

However, in most cases a data centre could be more accurately considered as a discrete project to be developed according to ISO 14064-2, for which design stage assumptions and modelling of performance would need to be carried out in order to declare a projected GHG emissions performance in a tender. Whereas declaration of inventory emissions according to ISO 14064-1 relates to existing operational facilities.

ISO 14064-2 specifies two stages in reporting – validation at design stage and verification upon monitoring at implementation stage. Emissions reported on may relate to those:

- a) controlled by the project proponent (direct emissions),
- b) related to the GHG project (indirect emissions), or

³⁰ prEN 14064-1:2017, *Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

³¹ <http://www.ghgprotocol.org/corporate-standard>

c) affected by the GHG project (carbon leakage).

In this way, the procurer would be able to differentiate between the biggest sources of impact related to the direct and indirect emissions under the contract (i.e. on site fuel consumption, electricity consumption) or to sources of carbon leakage associated with the project (i.e. indirect land use change). This keeps the focus on the hotspots and tracks development for improvement.

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

Since the methodology for corporate accounting of emissions is already established and the methodology is available, 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. But the extra costs are in reality tied up to higher energy/material efficiency at a data centre and/or equipment level which corresponds to other GPP criteria.

2.2.4 Verification

It is proposed to use EN ISO 14064-3³² as the basis for verification. Other corporate standards such as the Greenhouse Gas Protocol have a focus on inventories of existing emissions rather than design and implementation of a new project so equivalence in the approach is difficult to establish. The Greenhouse Gas Protocol is notable for having been used by some USA actors in the data centre industry to quantify their carbon footprint^{33,34,35}. However, it is not clear how the Protocol would

³² ISO 14064-3: Specification with guidance for the validation and verification of greenhouse gas assertions.

³³ https://www.nrdc.org/sites/default/files/NRDC_WSP_Cloud_Computing_White_Paper.pdf

³⁴ <http://www.ghgprotocol.org/blog/look-inside-facebook%E2%80%99s-carbon-footprint>

overcome the need for a process of project level estimation emissions which according to ISO 14064-2 require validation.

The advantage of EN ISO 14064, as opposed to a product-based standard such as ISO 14067 is that it is organizational based and provides a guideline for quantification set on the organisational boundaries, which would be more straightforward to follow than using a product-based approach. Moreover, the ISO 14064-2³⁶ presents a methodology to establish a baseline and quantify improvements which can be used by industry to track development and by procurers to monitor metrics during contract performance in the case of long contracts.

2.2.5 Market implications and functionality

It is expected that many 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.

2.2.6 Applicability to public procurement

The approach described in section 2.3.4 and 2.3.5 could be appropriate for both Enterprise data centres and MSP data centres (see procurement routes in Figure 2 and Figure 4) by setting the operational boundaries of the facility, as defined in EN ISO 14064 within the project description as the:

' project location, including geographic and physical information allowing the unique identification and delineation of the specific extent of the project.

In this case a reporting could be requested encompassing all three of the operational boundaries described in section 2.2.2 thereby allowing for IT equipment to be addressed. The technical specification would provide the functional basis for making

³⁵ https://www.bsr.org/reports/BSR_Future_of_Internet_Power_GHG_Emissions_Report.pdf

³⁶ ISO 14064-2: Specification with guidance at the project level for quantification. Monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

comparisons between offers. An award criterion could then assign points to the offer with the lowest carbon emissions, thereby encouraging innovation.

However, it would not be possible to set such criteria for the contracting of services. This is because there would be a problem making comparisons between offers since the boundary for the project would be difficult to control e.g. the project may not be dedicated to meeting only the contracting authorities technical specification.

The purchase of new equipment in the case of expansion or consolidation of infrastructure or a new IT project (see Figure 3) is a different case altogether. The product-level standard ISO 14067 would have to be used instead as a data centre project is not being requested.

2.2.7 First criterion proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
	<p>AC1.2 Facility greenhouse gas inventory</p> <p><i>This criteria is only appropriate for the procurement of a whole new data centre facility.</i></p> <p>Points shall be awarded in proportion to the bidder that offers the lowest greenhouse gas emissions per year operation of the project.</p> <p>Bidders shall estimate the greenhouse gas emissions for one year's operation of their data centre design according to the contracting authorities technical specification.</p> <p>The emissions shall be compiled in accordance with EN ISO 14064-2 or equivalent. The boundary for emissions from the project shall comprise direct, indirect and carbon leakage related emissions..</p> <p>Verification:</p> <p>The assumptions upon which estimation of the emissions are based shall be provided. They shall be validated by a third party independent assessment in accordance with the principles and requirements of ISO 14064-3.</p>
CONTRACT PERFORMANCE CLAUSES	
	<p>CPC1.2 Project greenhouse gas inventory</p> <p><i>To be included if criterion AC1.3 is used.</i></p> <p>The operator of the data centre project shall monitor and verify the project emissions as estimated at bid stage.</p> <p>The actual monitored emissions shall be reported for each year of operation, based on metered energy consumption with the possibility for third party verification if requested.</p>

3. CRITERIA AREA 2: 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. Energy efficiency

Criterion 2.1: Server efficiency

b. IT utilisation

Criterion 2.2: IT equipment utilisation

c. IT material efficiency

Criterion 2.3: Emissions of hazardous substances

Criterion 2.4: Design for durability

Criterion 2.5: Design for repairability

Criterion 2.6: Design for disassembly and recyclability

Criterion 2.7: End of life management

d. IT Equipment Operating Range

Criterion 2.8: Temperature and Humidity Range

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

3.1 IT energy efficiency – Criterion proposal: Server energy efficiency

3.1.1 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.

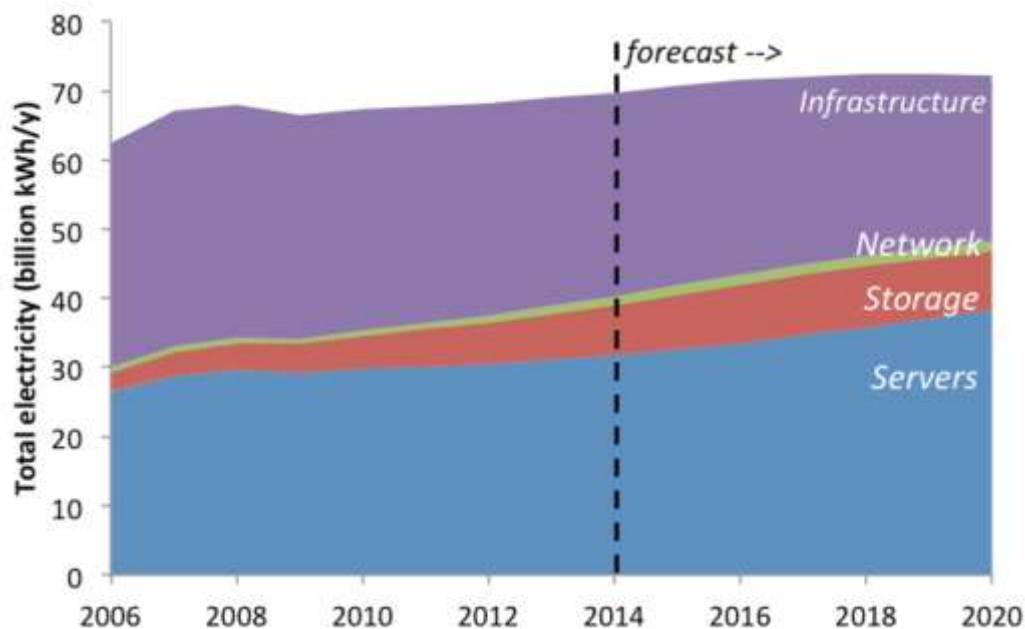


Figure 7. Total electricity consumption by technology type in a data centre³⁷

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 tend to have significantly higher efficiency (see Figure 8) and increasing the performance and efficiency of servers while ensuring utilisation levels are maintained or increased can reduce the total number of servers and achieve significantly higher energy savings. 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

³⁷ Source: US Department of Energy (2016)

section and in Annex I.

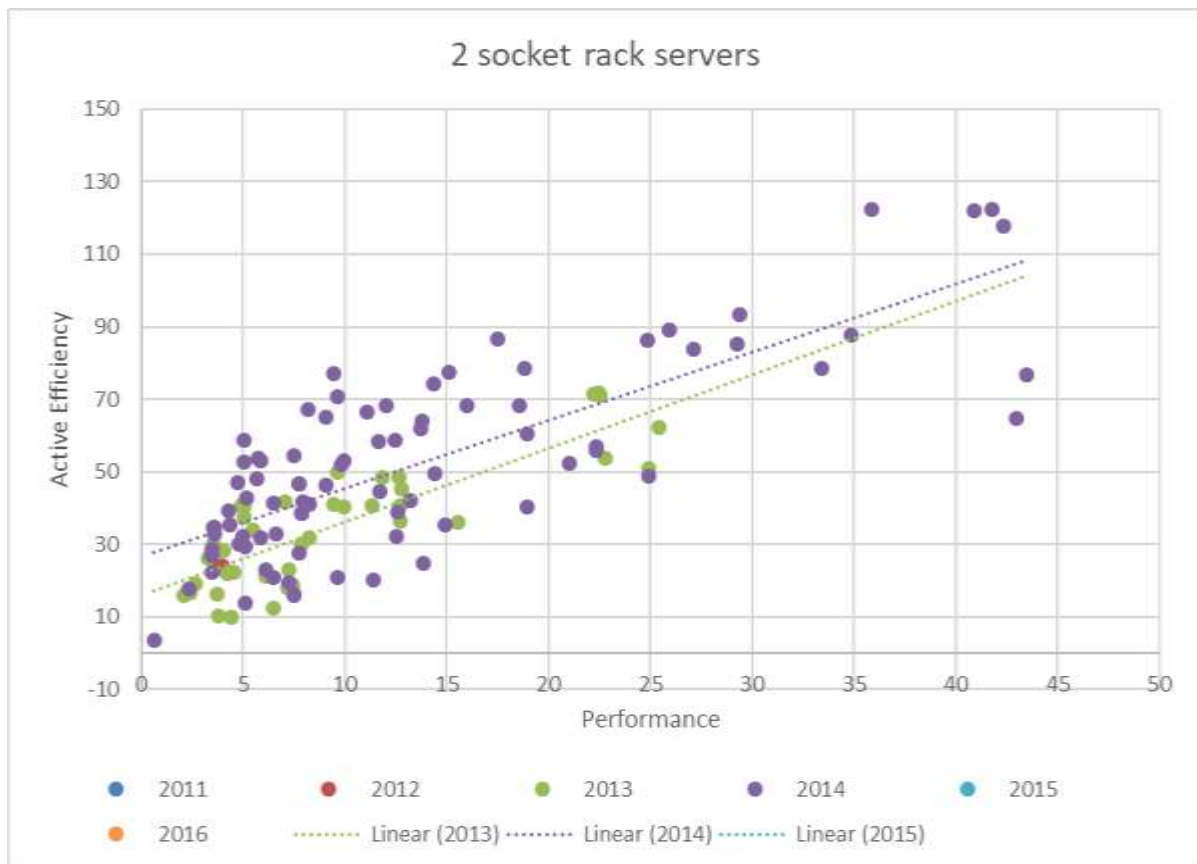


Figure 8. Relationship between performance and active efficiency for 2 socket servers (higher is more efficient)³⁸.

There are two main criteria for assessing the efficiency of a server, the idle power efficiency and the active power efficiency. Both the idle and active power can be tested using the SERT methodology. SERT v1.x is the test method used by the 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.

The SERT test method measures the idle power and the active power and performance of the server under 12 different worklets that test the performance of

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

three subsystems, the CPU, memory and storage. 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 datapoints to give a detailed description of the server active performance and power consumption. The volume of data means that comparing servers using the test data is extremely difficult, and a metric is required to help interpret the test results.

Compared to active efficiency, the idle power 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 based on the SERT v1.x test methodology and used for both ENERGY STAR and Ecodesign. ENERGY STAR. These metrics are based on well-defined worklet tests and are not related to any single application. Server efficiency, server performance and server power demand in active state can be declared according to data output from SERT testing³⁹, which is also used for the metrics described above. 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.

There are currently no active efficiency criteria in effect for servers. ENERGY STAR v2 database provides aggregated SERT test results but these are calculated using a

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http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=2334&language=en-US&PortalId=0&TabId=353

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 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 set an active state efficiency target of 50 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.

In addition to new criteria, a new revision to the SERT test methodology, v2 has been developed and industry have proposed that this version is adopted for ENERGY STAR, with new test data including the most recent server models and technology. The test results from v1 and v2 are incompatible and if adopted, would require the both metric and all active efficiency criteria to be revised. This could affect both ENERGY STAR and Ecodesign, including delaying timelines for adoption, and may result in the two policies adopting different test methods and metrics.

3.1.2 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, 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 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%).

3.1.3 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.

3.1.4 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 audit 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.

As an alternative, if an efficiency criterion equivalent to ENERGY STAR is adopted, qualification can additionally be verified against the US and EU ENERGY STAR databases, though not all qualifying servers may be registered and furthermore, the registration only implies a limited registration check of the data reported.

3.1.5 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 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.

3.1.6 Applicability to public procurement

A criterion aimed at improving server energy efficiency would be relevant to enterprise and co-location data centres because they require the IT equipment to be specified. A technical specification could be appropriate given that both ENERGY STAR and the forthcoming Ecodesign legislation establish performance metrics and thresholds that would differentiate performance in the market. An award criterion could additionally be used to encourage higher performance against a minimum threshold.

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.

3.1.7 First criterion proposal

Given that the ENERGY STAR and Ecodesign criteria for server efficiency are all currently in draft phase, with a high chance of changes and perhaps including changes to the test method itself, it is difficult to specify criteria at this point in time. The upcoming ENERGY STAR v3 is expected to produce challenging requirements and is considered to provide the most realistic basis for leading edge server efficiency criteria. However, even here the new SERT test method may still change and therefore that also used in ENERGY STAR v3. Award criteria cannot therefore be proposed without knowing the final metrics to be used in ENERGY STAR and the relevant version of the underlying test method that will be used.

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
<p>TS2.1 Server energy efficiency</p> <p>Servers shall meet the energy efficiency requirements of the latest version of the ENERGY STAR standard</p> <p>The version in force at the time of publication is 2.0 and updates can be followed at this weblink: http://www.eu-energystar.org/specifications.htm</p> <p>Annex III of Directive 2012/27/EU on energy efficiency, requires that servers purchased by central government shall meet the latest EU version of ENERGY STAR.</p> <p>Verification:</p> <p>The tenderer shall detail the server models supplied and corresponding test reports carried out according to the test methods laid down in the latest version of the ENERGY STAR. These shall be provided upon award of the contract or prior to that upon request.</p> <p>Upon request the contracting authority shall be provided with access to the equipment once on-site at the data centre for auditing purposes.</p> <p>Models that have qualified for EU ENERGY STAR and are registered on the programme's database shall be deemed to comply. ENERGY STAR registrations under the latest version in the USA shall also be accepted provided that testing according to European input power requirements has been carried out.</p>	<p>TS2.1 Server energy efficiency</p> <p>Servers shall meet the energy efficiency requirements of the latest version of the ENERGY STAR standard.</p> <p>The version in force at the time of publication is 2.0 and updates can be followed at this weblink: http://www.eu-energystar.org/specifications.htm</p> <p>Annex III of Directive 2012/27/EU on energy efficiency, requires that servers purchased by central government shall meet the latest EU version of ENERGY STAR.</p> <p>Verification:</p> <p>The tenderer shall detail the server models supplied and corresponding test reports carried out according to the test methods laid down in the latest version of the ENERGY STAR. These shall be provided upon award of the contract or prior to that upon request.</p> <p>Upon request the contracting authority shall be provided with access to the equipment once on-site at the data centre for auditing purposes.</p> <p>Models that have qualified for EU ENERGY STAR and are registered on the programme's database shall be deemed to comply. ENERGY STAR registrations under the latest version in the USA shall also be accepted provided that testing according to European input power requirements has been carried out.</p>
AWARD CRITERIA	
<p>AC2.1. Improvement in the energy consumption upon the Energy Star active efficiency</p> <p><i>It is recommended to use this criterion in conjunction with TS2.1.</i></p> <p><i>* Please see the Explanatory note for further information.</i></p> <p>Points will be awarded If the product is more energy efficient than the threshold laid down in the latest version of the ENERGY STAR for servers.</p> <p>The energy efficiency value shall be calculated according to the test methods laid down in the latest version of the ENERGY STAR.</p> <p>Maximum points shall be awarded to the offer with the highest performance. All other offers shall be awarded points in proportion to the best offer.</p> <p>Verification:</p> <p>The tenderer shall detail the server models supplied and corresponding test reports carried out according to the test methods laid down in the latest version of the ENERGY STAR. These shall be provided upon award</p>	<p>AC2.1. Improvement in the energy consumption upon the Energy Star active efficiency</p> <p><i>It is recommended to use this criterion in conjunction with TS2.1.</i></p> <p><i>* Please see the Explanatory note for further information.</i></p> <p>Points will be awarded If the product is more energy efficient than the threshold laid down in the latest version of the ENERGY STAR for servers.</p> <p>The energy efficiency value shall be calculated according to the test methods laid down in the latest version of the ENERGY STAR.</p> <p>Maximum points shall be awarded to the offer with the highest performance. All other offers shall be awarded points in proportion to the best offer.</p> <p>Verification:</p> <p>The tenderer shall detail the server models supplied and corresponding test reports carried out according to the test methods laid down in the latest version of the ENERGY STAR. These shall be provided upon award</p>

of the contract or prior to that upon request. Upon request the contracting authority shall be provided with access to the equipment once on-site at the data centre for auditing purposes.	of the contract or prior to that upon request. Upon request the contracting authority shall be provided with access to the equipment once on-site at the data centre for auditing purposes.
EXPLANATORY NOTE	
The current ENERGY STAR v2 doesn't have a metric for active efficiency. Instead it gives 12 worklet efficiencies, and these are not derived using the same calculation method as proposed for the new SERT methodology. The award criteria for active efficiency only works when verification is based on Energy Star Version 3 and following versions which will be based on the new SERT methodology and includes a specific metric on active efficiency.	

3.2 IT utilisation – Criterion proposal: IT equipment utilisation

3.2.1 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, virtualisation⁴⁰ 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 the standard ISO 30134-5, which is due to be

⁴⁰ Virtualisation refers to the act of creating a virtual (rather than actual) version of computer hardware platforms, storage devices, and computer network resources.

published in October 2017⁴¹. 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 drives the wrong behaviour within the data centre as an unintended consequence.

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, network⁴² 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 centre⁴³:

ICT Capacity – provisioned at theoretical maxima:

$$ICT_C = \{CPU_C, MEM_C, STOR_C, NET_C\}$$

ICT Utilisation – 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

⁴¹ <https://www.iso.org/standard/66934.html>

⁴² Referring to internal and external network bandwidth

⁴³ <https://www.thegreengrid.org/en/resources/library-and-tools/436-WP#72---ICT-Capacity-and-Utilization-Metrics>

found in Annex II. While TGG metric appears to be more complete, it is also not widely adopted and may be less mature than ISO 30134-5.

3.2.2 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%, suggesting that hardware could be reduced by 3-4 times and energy consumption reduced by approximately 50% (see Table 10).

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^{44,45}. However, these comparisons are all made against unvirtualized servers which does not reflect the current market situation.

3.2.3 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.

⁴⁴ https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/e-server_e_server_case_studies_en.pdf

⁴⁵ <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.465.6398&rep=rep1&type=pdf>

Case studies quoted by the US EPA on virtualisation in best case scenarios have shown cost savings of approximately 60%⁴⁶ taking into account all factors including software and administration costs. Again, these comparisons are made against unvirtualised servers.

3.2.4 Verification

Verification is 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.

3.2.5 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 uptake⁴⁷). 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.

⁴⁶ https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center/server_virtualization

⁴⁷ <http://www.gartner.com/newsroom/id/3315817>

Recent estimates of utilisation (not based on the Green Grid metric) for data centres of different sizes are as shown in Table 10. 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.

Table 10. Recent estimates of utilisation rates for different server types⁴⁸.

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.

3.2.6 Applicability to public procurement

This relatively new metric 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.

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. It is to be discussed whether it is appropriate, based on the currently available metrics, whether an award criterion could be set at a data centre or server level.

⁴⁸ <https://www.thegreengrid.org/en/resources/library-and-tools/443-Applying-ICT-Capacity-and-Utilization-Metrics-to-Improve-Data-Center-Efficiency>

3.2.7 First criteria proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
	<p>AC2.2 IT equipment utilisation</p> <p><i>Selection criteria shall be also applied to managed services in order to ensure that capacity to deliver high utilisation rates based on historical performance is evidenced.</i></p> <p>Points will be awarded based on the anticipated average utilisation rate for the IT equipment [or servers].</p> <p>Points shall be awarded in proportion to the bidder that offers the highest utilisation.</p> <p>Verification:</p> <p>The anticipated utilisation rate shall be supported by modelling and calculation according to the provided method for ICT Capacity and Utilisation [or for servers ISO/IEC 30134-5].</p>
CONTRACT PERFORMANCE CLAUSES	
	<p>CPC2.2 Monitoring of IT Equipment Utilization values</p> <p><i>To be included when the data centre is operated by a third party.</i></p> <p>The operator of the data centre facility shall provide average monthly data for the total IT [or servers] utilization rate of the data centre.</p>
Explanatory note: IT Capacity and Utilisation metric calculation method	
<p>If an overall IT equipment utilisation rate forms the basis for the criterion then the Green Grid IT Capacity and Utilisation metric calculation will need to be reproduced within an Annex of the criteria document.</p> <p>ICT Capacity – provisioned at theoretical maxima:</p> $ICT_C = \{CPU_C, MEM_C, STOR_C, NET_C\}$ <p>ICT Utilisation – percentages used of theoretical maxima:</p> $ICT_U = \{CPU_U, MEM_U, STOR_U, NET_U\}$	

3.3 IT material efficiency – Criteria Proposal: Durability, Repairability, Recyclability, Hazardous substances

3.3.1 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.

3.3.2 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 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:

- reduce the demand for products (e.g. promoting upgrade of existing ones, improving durability and repairability, dematerialisation).
- support responsible disposal (e.g. ease of disassembly to increase recycling rates).

End of life management may be considered to be the most important of the technical specification criteria in this section; the others relate to design to facilitate the above but do not necessarily ensure that these best practices are undertaken.

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.

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. 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 2002/95/EC which applies to electronic equipment.

A number of criteria relating to hazardous substance feature in the EU GPP Criteria for Computers and Monitors; some of which have been adapted for the data centre ICT hardware proposals where relevant. This includes criteria addressing criteria addressing the improper disposal of computers in the end of life phase. The environmental impacts associated with the informal recycling and improper treatment

of printed circuit boards and cables to recover precious metals and copper ⁴⁹ are of particular concern. Moreover, 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 Polychlorinated and Polybrominated dibenzo-p-dioxins and furans (PCDD/DF and PBDD/DF) ^{52 53} and carcinogenic Polycyclic Aromatic Hydrocarbons (PAHs) ⁵⁴.

⁴⁹ Oeko-Institut, *Recycling critical raw materials from waste electronic equipment*, Commissioned by the North Rhine-Westphalia State Agency for Nature, Environment and Consumer Protection, 24th February 2012 and Oeko-Institut, *Informal e-waste management in Lagos, Nigeria – socio-economic impacts and feasibility of international recycling operations*, UNEP SBC project, June 2011

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

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

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}.

3.3.3 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.

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.

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/>

3.3.4 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 first criteria proposals.

The initial proposals are largely a reflection of those used in the EU GPP criteria set 'Computers and Monitors'. This means that they may already be familiar to IT equipment suppliers and/or be incorporated into a contracting authorities GPP criteria, allowing for easy cross referencing. Discussion with stakeholders is required to understand how effectively these translate for data centres.

3.3.5 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 difficult to ensure that it is disposed of responsibly.

3.3.6 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.

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

3.3.8 First criteria proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
<p>TS2.4 Design for durability</p> <p>The tenderer shall provide a minimum two-year warranty effective from delivery of the servers. This warranty shall cover repair or replacement and include a service agreement with options for pick-up and return or on-site repairs.</p> <p>The warranty shall guarantee that the products are in conformity with the contract specifications at no additional cost.</p> <p>Verification:</p> <p>The tenderer shall provide a written declaration that the products supplied will be warrantied in conformity with the contract specifications and service requirements.</p>	<p>TS2.4. Design for durability</p> <p>The tenderer shall provide a minimum three-year warranty effective from delivery of the servers. This warranty shall cover repair or replacement and include a service agreement with options for pick-up and return or on-site repairs.</p> <p>The warranty shall guarantee that the products are in conformity with the contract specifications at no additional cost.</p> <p>Verification:</p> <p>The tenderer shall provide a written declaration that the products supplied will be warrantied in conformity with the contract specifications and service requirements.</p>
<p>TS2.5 Design for disassembly and repair</p> <p>The tenderer shall 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 key components or parts for upgrades or repairs. This shall be made available in hard copy or via the manufacturer's webpage.</p> <p>Verification:</p> <p>A manual shall be provided by the tenderer, which shall include an exploded diagram of the device illustrating the parts that can be accessed and replaced, and the tools required. It shall also be confirmed which parts are covered by service agreements under the warranty.</p>	<p>TS2.5 Design for disassembly and repair</p> <p>The tenderer shall 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 key components or parts for upgrades or repairs. This shall be made available in hard copy or the manufacturer's webpage.</p> <p>Verification:</p> <p>A manual shall be provided by the tenderer which shall include an exploded diagram of the device illustrating the parts that can be accessed and replaced, and the tools required. It shall also be confirmed which parts are covered by service agreements under the warranty.</p>

Core criteria	Comprehensive criteria
	<p>TS2.6 Design for dismantling and recycling</p> <p>For each server model to be used in execution of the contract the bidder shall provide a 'dismantling test report' detailing the specific steps and tools required to recover:</p> <ul style="list-style-type: none"> • Printed Circuit Boards relating to computing functions with a size of >10cm² • Internal Power Supply Units • HDD/SSD drives <p>Verification:</p> <p>The tenderer shall upon award provide a 'dismantling test report' for the relevant models of IT equipment. The test shall be carried out by a specialised WEEE recycling firm that is a permitted electrical waste treatment operation in accordance with Article 23 of the Waste Framework Directive or that are certified under equivalent national or international WEEE regulations or standards. Third party verification of the timing shall be accepted as an alternative to providing a recording.</p>

Core criteria	Comprehensive criteria
<p>TS2.7 End of life management</p> <p>Tenderers shall provide a re-use and recycling service once the servers have reached the end of its service life. They shall report on the proportion of equipment re-used or recycled, supported by details of the following:</p> <ul style="list-style-type: none"> - Collection; - Confidential handling and secure data erasure (Unless carried out in-house); - Testing, servicing and upgrading ⁵⁹; - Remarketing for re-use in the EU; - Dismantling for recycling and/or disposal. <p>Preparation of items for re-use, as well as recycling and disposal operations shall 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 60.</p> <p>Verification:</p> <p>The tenderer shall provide details of the arrangements for collection, data security, testing, remarketing for re-use and recycling/disposal. This shall include, during the contract, valid certifications of compliance for the WEEE handling facilities to be used.</p>	<p>TS2.7 End of life management</p> <p>Tenderers shall provide a re-use and recycling service once the servers have reached the end of its service life. They shall report on the proportion of equipment re-used or recycled, supported by details of the following:</p> <ul style="list-style-type: none"> - Collection; - Confidential handling and secure data erasure (Unless carried out in-house); - Testing, servicing and upgrading; - Remarketing for re-use in the EU; - Dismantling for recycling and/or disposal. <p>Preparation of items for re-use, as well as recycling and disposal operations shall 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.</p> <p>Verification:</p> <p>The tenderer shall provide details of the arrangements for collection, data security, testing, remarketing for re-use and recycling/disposal. This shall include, during the contract, valid certifications of compliance for the WEEE handling facilities to be used.</p>
AWARD CRITERIA ⁶¹	
	<p>AC2.4 Design for durability</p> <p>Points shall be awarded to each additional year of warranty and service agreement offered for servers that is more than the minimum technical specification (see criteria TS2.4).</p> <p>Points shall be awarded in proportion to the bidder that offers the longest warranty.</p> <p>Verification:</p> <p>A copy of the warranty and service agreement shall be provided by the tenderer. They shall provide a declaration that they cover the conformity of the goods with the contract specifications.</p>

⁵⁹ 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.

⁶⁰ 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.

⁶¹ 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
<p>AC2.5 Design for disassembly and repair</p> <p>The tenderer shall guarantee the availability of spare parts for servers for at least three years from the date of purchase.</p> <p>Verification:</p> <p>The tenderer shall provide a declaration that compatible spare parts will be made available to the contracting authority or through a service provider.</p>	<p>AC2.5 Design for disassembly and repair</p> <p>The tenderer shall guarantee the availability of spare parts for servers for at least five years from the date of purchase. Compatible parts with improved capacity or performance, where relevant, shall be made available.</p> <p>Verification:</p> <p>The tenderer shall provide a declaration that compatible spare parts will be made available to the contracting authority or through a service provider.</p>
	<p>AC2.7 End of life management</p> <p>Points shall be awarded to tenderers operating a tracking system for servers with a unique identifier for each item of IT equipment in their inventory. The system shall enable the proportion of items re-used or recycled to be verified, and whether they remained in the EU or were exported.</p> <p>Verification:</p> <p>The tenderer shall provide details of the tracking system that they operate.</p>
	<p>AC2.3 Emissions of hazardous substances – printed circuit boards</p> <p>Points shall be awarded where the main Printed Circuit Board of the server models used are 'halogen free' in conformance with IEC 61249-2-21 and a fire test simulating improper WEEE disposal shows carcinogenic Polycyclic Aromatic Hydrocarbon (PAHs) emissions to be ≤ 0.1 mg TEQ /g.</p> <p>Verification:</p> <p>Test reports for the board composition and emissions shall be provided upon award for the ready-to-install motherboard as relevant for the server models used.</p> <p>The fire test shall be carried out according to ISO 5660 in oxidative pyrolysis conditions (IEC 60695-7-1 fire type 1b with a heat flux of 50 kW/m²). Quantification of the PAHs emissions shall be made according to ISO 11338 (PAHs).</p>
CONTRACT PERFORMANCE CLAUSES	
	<p>CPC2.7 Reporting on equipment status</p> <p>The successful tenderer shall provide a report on the status of the server equipment in the inventory once all items have been processed for re-use or recycling/disposal. The report shall be made according to ETSI EN 305 174-8 and shall identify the proportion of items re-used or recycled, whether they remained in the EU or were exported.</p>

3.4 IT Equipment Operating Range – Criteria Proposal: Temperature and Humidity Range

3.4.1 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 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 immediately operated at the upper bound of these ranges; instead it allows greater flexibility in operating temperature and humidity to the data centre operator.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has produced a guideline⁶² describing “allowable” temperature and humidity ranges and for four environmental classes, two of which (Class A1 range of 15°C - 32°C and Class A2 range of 10°C to 35°C) have a direct focus on data centres:

3.4.2 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 more free cooling hours can reduce the need of M&E equipment (i.e. their embodied impacts)

⁶² ASHRAE TC 9.9 - 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Technology Spaces, and Electronic Equipment © 2011,

3.4.3 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.

3.4.4 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.

3.4.5 Market implications and functionality

It is important to procure hardware which permits operation at higher temperatures. Network equipment in particular can present issues⁶³. ASHRAE research suggests that increased risk of component failure when operating at higher temperatures is insignificant when the number of hours of exposure is limited (e.g. just at the hottest times of the year).

High relative humidity was found to have a higher impact on hard disk drive failures than high temperatures⁶⁴ and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failures at higher temperatures⁶⁵.

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.

⁶³ 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

⁶⁴ Environmental Conditions and Disk Reliability in Free-cooled Datacenters, USENIX conference 2016).

⁶⁵ University of Virginia paper (Datacenter Scale Evaluation of the Impact of Temperature on Hard Disk Drive Failures, Sankar et al 2013

3.4.6 Applicability to public procurement

The criteria are considered to be generally applicable to the procurement of enterprise data centres, as well for consolidation projects.

3.4.7 First criteria proposal

TECHNICAL SPECIFICATIONS	
Core criteria	Comprehensive criteria
TS2.8 Cooling Management –higher temperature hardware Select ICT hardware which is warrantied to operate within allowable temperature range of 15-32C. Verification: Manufacturers specifications and warranties shall be provided for each major IT hardware component..	TS2.8 Cooling Management –higher temperature hardware Select ICT hardware which is warrantied to operate within an allowable temperature range of 10-35C. Verification: Manufacturers specifications and warranties shall be provided for each major IT hardware component..

4. CRITERIA AREA 3: MECHANICAL & ELECTRICAL SYSTEMS PERFORMANCE

The criteria area Mechanical and Electrical (M&E) performance concerns all the system and equipment aiming 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 11. 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 11. 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

d. Water discharge:

Criterion 3.4: Water discharge

4.1 Mechanical & Electrical systems energy efficiency – Criterion proposal: Power Utilisation Effectiveness (PUE)

4.1.1 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. 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. 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 German Blue Angel⁶⁶ 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 Efficiency⁶⁷.

In most cases the largest opportunity and therefore priority for reducing PUE lies with the cooling systems. Relatively short paybacks can be achieved by 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

⁶⁶ www.blauer-engel.de

⁶⁷ <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104370/2017%20best%20practice%20guidelines%20v8.1.0%20final.pdf>

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 item to address is usually UPS efficiency.

When setting PUE maximum levels, discussions have arisen on whether the influence of climate should be considered when establishing minimum thresholds. In practice US ENERGY STAR analysis of data centres⁶⁸ 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 temperature⁶⁹.

According to ecodesign impact assessment for servers and data storage products, a variation of 30 % exists due to the climatic conditions between the warmest and the coldest locations in EU, which means that the variations of an average PUE could be set within the range of plus or minus 8-9 %. Figure 9 illustrates the indicative potential variation in heating and cooling degree days between major EU cities.

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 Centers⁷⁰, 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.

⁶⁸ https://www.energystar.gov/ia/partners/prod_development/downloads/DataCenters_GreenGrid02042010.pdf

⁶⁹ Zero Refrigeration for Data Centres in the USA, Robert Tozer, Sophia Flucker, ASHRAE Summer Conference San Antonio 2012.

⁷⁰ ANSI/ASHRAE Standard 90.4-2016

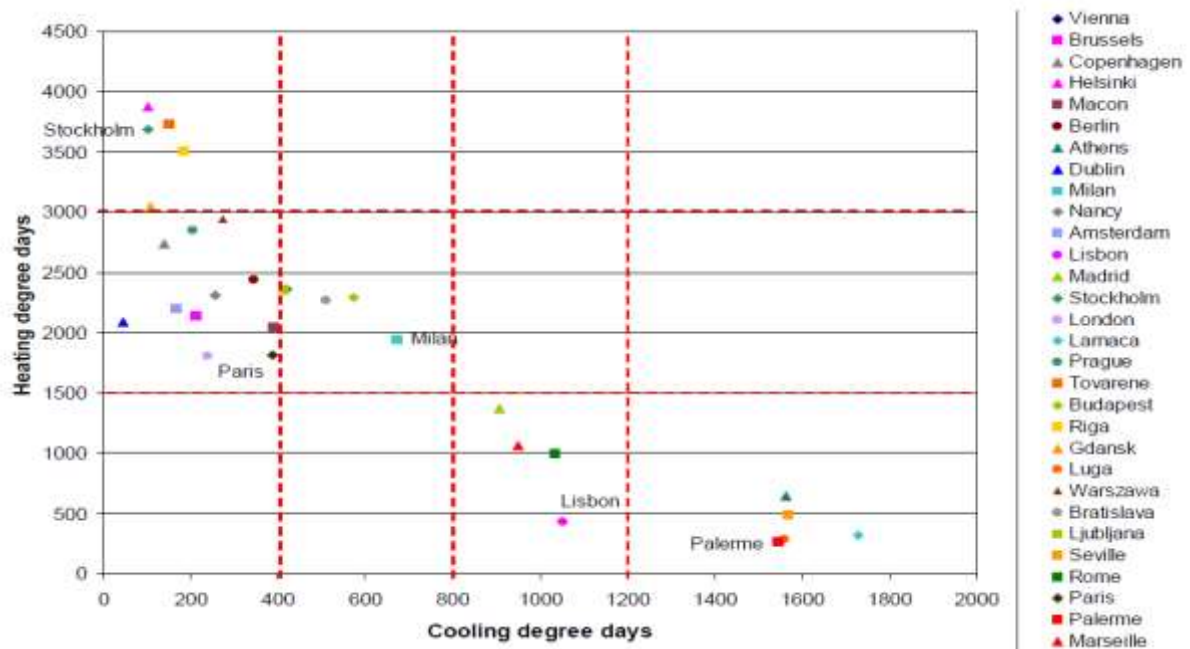


Figure 9. Heating and cooling degree-days for 30 European cities⁷¹.

4.1.2 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.

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 caution⁷². This is because theoretically

⁷¹ Source: Keepcool (2010)

⁷² 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

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 lead 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.

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.

4.1.3 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.

Another strategy is to design servers to be able to operate at higher temperature which cost is 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 (see criterion proposal 2.8).

4.1.4 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.

4.1.5 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.

4.1.6 Applicability to public procurement

The use of PUE could be mainly applicable to procurement routes where a new data centre is to be built or where expansion or consolidation of an existing site is being considered. In the case of co-location, 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.

It could be a technical specification in the case of a predicted design performance.

For example, the Blue Angel sets a benchmark of 1.4 for good performance.

Alternatively, an award criteria could leave performance open to the market, or relate the points awarded to a benchmark. In the case of a service a contract performance clause could be used to ensure that PUE is maintained within a range of below a specific threshold.

Services would only be applicable if provision of the service can be linked to a specific site(s), for which verification would then be needed. Procurement rules may in this way prohibit reference to an average PUE.

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. However the inclusion of PUEs technical specification in the tenders for the operation and/or maintenance of the facility could stimulate the implementation of a dedicated monitoring system.

4.1.7 First criterion proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
<p>TS3.1 Target Power Usage Effectiveness (PUE)</p> <p>The bidder shall demonstrate that the predicted design PUE of the data centre facility is lower than 1.4 at 100% IT equipment load (based on typical annual weather data).</p> <p>Verification:</p> <p>Design calculations which show how the target is met according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.</p>	<p>TS3.1 Target Power Usage Effectiveness (PUE)</p> <p>The bidder shall demonstrate that the predicted design PUE of the data centre facility is lower than 1.3. at 100% IT equipment load (based on typical annual weather data).</p> <p>Verification:</p> <p>Design calculations which show how the target is met according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.</p>
AWARD CRITERIA	
<p>AC3.1 Power Usage Effectiveness (PUE)</p> <p>For newly designed facilities (not yet operational) or existing facilities less than 1 year old (from start of operation), points could be awarded in one of two ways:</p> <ol style="list-style-type: none"> 1. Relative to the benchmark PUE value above (TS1.1 core) 2. Relative to the best performing PUE offer (full points) <p>For newly designed facilities (not yet operational), points could be awarded relative to the best predicted design PUE at 25% IT load.</p> <p>For existing facilities operational for between 1-5 years, points could be awarded where the bidder can demonstrate that the measured PUE of the data centre facility would be less than 1.6 at 100% load.</p> <p>For existing facilities operational for more than 5 years, points could be awarded where the bidder can demonstrate that the measured PUE of the data centre facility would be less than 1.8 at 100% load.</p> <p>Verification:</p> <p>Design calculations which show how the target is met</p>	<p>AC3.1 Power Usage Effectiveness (PUE)</p> <p>For newly designed facilities (not yet operational) or existing facilities less than 1 year old (from start of operation), points could be awarded in one of two ways:</p> <ol style="list-style-type: none"> 1. Relative to the benchmark PUE value above (TS1.1 comprehensive) 2. Relative to the best performing PUE offer (full points) <p>For newly designed facilities (not yet operational), points could be awarded relative to the best predicted design PUE at 25% IT load.</p> <p>For existing facilities operational for between 1-5 years, points could be awarded where the bidder can demonstrate that the measured PUE of the data centre facility would be less than 1.45 at 100% load.</p> <p>For existing facilities operational for more than 5 years, points could be awarded where the bidder can demonstrate that the measured PUE of the data centre facility would be less than 1.65 at 100% load.</p> <p>Verification:</p> <p>Design calculations which show how the target is met</p>

Core criteria	Comprehensive criteria
or measurements as applicable according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.	or measurements as applicable according to ISO/IEC 30134:2016 Part 2, EN 50600-4-2:2016 or equivalent.
CONTRACT PERFORMANCE CLAUSES	
CPC3.1 Monitoring of Power Usage Effectiveness (PUE) input values <i>To be included when the data centre is operated by a third party.</i> The operator of the data centre facility shall provide monthly data for the total metered electricity consumption of the data centre and the sub-metered electricity consumption for the IT equipment that is located in the data centre.	CPC3.1 Monitoring of Power Usage Effectiveness (PUE) input values <i>To be included when the data centre is operated by a third party.</i> The operator of the data centre facility shall provide monthly data for the total metered electricity consumption of the data centre and the sub-metered electricity consumption for the IT equipment that is located in the data centre.

4.2 Cooling – Criterion proposal: Reuse of waste heat

4.2.1 Background

Significant potential exists for waste heat reuse from data centres since over 98%⁷³ 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:

- Colocation of the data centre to customers with suitable heat load profiles and needs
- Heat quality i.e. suitable temperature for the customer needs
- Infrastructure for transporting heat

Generally the heat is low grade (35-45°C and sometimes below 25 °C⁷⁴) and expensive to transport. To supply a district heating system, it must be concentrated

⁷³ <http://www.datacenterknowledge.com/archives/2016/05/10/how-to-reuse-waste-heat-from-data-centers-intelligently>

⁷⁴ Davies, Maidmont, 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>

using air to air or water heat pumps to raise the temperature to a suitable temperature (most district heating would be distributed at 70 °C). The DC must also be connected to the district heating system with well insulated pipes to minimise losses. The waste heat, however, can be sold to the district heating supplier if they are technically and contractually willing to accept it, which may not always be the case.

Smaller networks can be supplied with lower grade heat, particularly for internal use within a building. However, since the customer or demand may be small, the load profile and total demand is unlikely to match the heat generated. This means only a fraction of the heat is reused but the lower cost and ease of connection may mean this is worth pursuing. The technical requirements, costs and efficiency 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.



Figure 10. Mäntsälä district heating network, Finland⁷⁵

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

⁷⁵ . Source: Envirotech and Cloud & Heat (2017).

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.

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

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)

$L_n^{(k)}$ = 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

$C_n^{(k)}$ = 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.

4.2.2 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 neighbour 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 CO₂ 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, Germany⁷⁶.

The Stockholm city district heating network⁷⁷ has been actively encouraging the connection of data centres on the district heating network, and have worked to 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.

4.2.3 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).

⁷⁶ Source: Cloud &Heat (2017)

⁷⁷ <https://www.opendistrictheating.com/>

4.2.4 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.

4.2.5 Market implications and functionality

There are currently very few data centres in 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 considered to be affected.

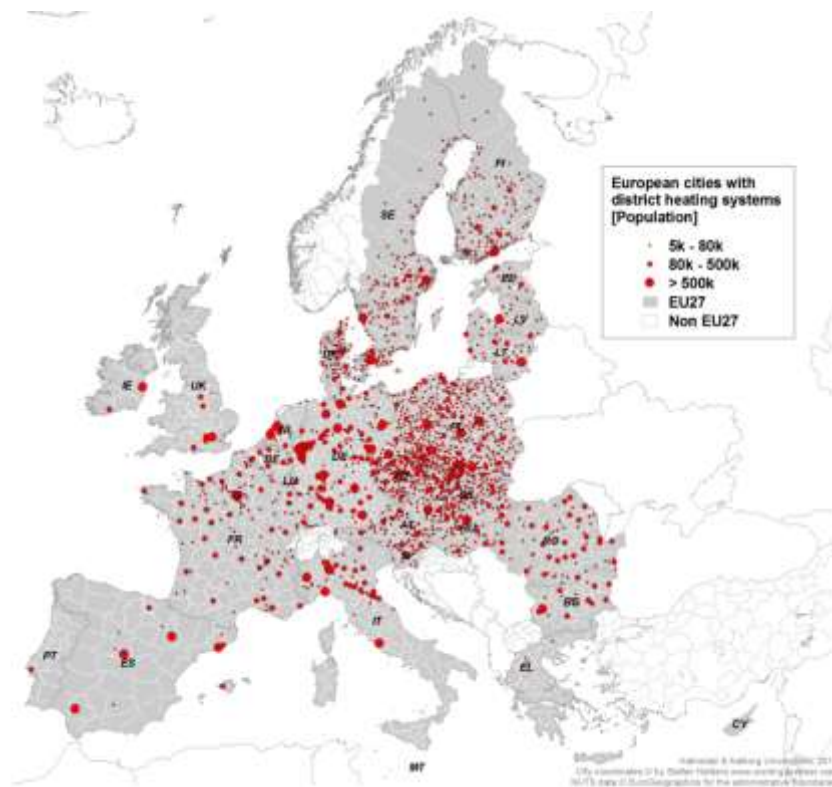


Figure 12. European cities with district heating.

4.2.6 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.

4.2.7 First criteria proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
	<p>TS3.2 Waste heat reuse</p> <p><i>The criterion should be adapted to the local availability of district heating systems and networks. It is recommended to set a comprehensive technical specification in the case that there is ready access.</i></p> <p>The data centre shall 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.</p> <p>Verification:</p> <p>The Energy Reuse Factor (ERF) shall be calculated for each facility according to ETSI ES 205 200-2-1.</p> <p>The tenderer shall provide design engineering drawings for the heat reuse systems and connection. Evidence of contractual arrangements or letters of intent shall be obtained from the network operator.</p> <p>Upon request the contracting authority shall be provided with access to the equipment and network connection on-site at the data centre for auditing purposes.</p>
AWARD CRITERIA	
	<p>AC3.2a Waste heat reuse (for new data centres)</p> <p><i>The criterion should be adapted to the local availability of district heating systems and networks. It is recommended to set a comprehensive award criterion in the case that there are local opportunities identified by a public authority.</i></p> <p>Points shall be awarded to bidders 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 shall be given for every 10% of extra waste heat the data centre supplies.</p> <p>Verification:</p> <p>The Energy Reuse Factor (ERF) shall be calculated for each facility according to ETSI ES 205 200-2-1.</p> <p>The tenderer shall provide design engineering drawings for the heat reuse systems and connection. Evidence of contractual arrangements or letters of intent shall be obtained from potential heat customers.</p> <p>Upon request the contracting authority shall be provided with access to the equipment and network</p>

Core criteria	Comprehensive criteria
	connection on-site at the data centre for auditing purposes.
	<p>AC3.2b Waste heat reuse (for managed services)</p> <p><i>It is recommended to use this comprehensive award criterion in the case that a service is being procured.</i></p> <p>Bidders shall declare their Energy Reuse Factor for the facilities that will be used to execute the contract.</p> <p>Points shall be awarded in proportion to the bidder that offers the highest Energy Reuse Factor.</p> <p>Verification:</p> <p>the Energy Reuse Factor (ERF) shall be calculated for each facility according to ETSI ES 205 200-2-1.</p>
CONTRACT PERFORMANCE CLAUSES	
	<p>CPC3.2 Monitoring of the heating supply and connection</p> <p><i>To be included when the data centre is operated by a third party.</i></p> <p>The operator of the data centre facility shall provide average monthly data for the heat supplied to the local district heating network.</p> <p>In addition the Energy Reuse Factor (ERF) shall be calculated according to ETSI ES 205 200-2-1 and reported on.</p>

4.3 Cooling management – Criteria proposal: Operating conditions control

4.3.1 Background

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 rates⁷⁸

Zero refrigeration designs are possible throughout Europe by designing systems for the reduction of energy consumption (lower PUE) and removal of electrical

⁷⁸ ⁷⁸ 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance, ASHRAE TC9.9 (2011)

infrastructure, including compressors (found in chillers and DX air conditioners) and their associated refrigerants, distribution systems and supporting. 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.

4.3.2 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 11). Facilities are often overcooled with colder than necessary air temperatures (and hence chilled water temperatures, where used), resulting in an energy penalty.

4.3.3 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.

4.3.4 Verification

The designers of new enterprise data centres, the operators of co-location facilities and Managed Service Providers should be able to warranty the operation of the data centre within the range of temperature defined by the ASHRAE Class A1 or A2.

4.3.5 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 temperatures⁷⁹ and research suggests that hardware with buried HDDs (in the middle of the chassis) are more susceptible to failures at higher temperatures⁸⁰.
- Increased IT equipment energy consumption of: IT equipment has a temperature above which its internal fan speeds increase which increases power consumption, which can partially offset potential benefits. For some

⁷⁹ Environmental Conditions and Disk Reliability in Free-cooled Datacenters, USENIX conference 2016).

⁸⁰ 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.

4.3.6 Applicability to public procurements

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 reduction in cooling equipment and refrigerant can be achieved by moving to alternative cooling systems, but there could be a trade-off if these systems require more electricity use. 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 3.1)

4.3.7 First criteria proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA ⁸¹	
	<p>AC3.3 Cooling Management – operating at higher temperatures</p> <p>The data centre designer (or operator) shall be awarded points based on the % of operating hours that that the environmental conditions will be maintained within the temperature range of 18-27°C.</p> <p>In the case of data centre operators, this proposed performance shall form part of a service level agreement (SLA)</p> <p>Verification:</p> <p>The tenderer shall state the operating conditions that they will provide supported by the calculations on which they are based..</p>
CONTRACT PERFORMANCE CLAUSES	
	CPC3.3 Reporting on environmental conditions

⁸¹ 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
	Under the service level agreement the successful tenderer shall monitor the hourly temperature at or near the air inlet of the white space and provide an annual report to the contracting authority with the % hours within range.

4.4 Cooling – Criterion proposal: Water discharge

4.4.1 Background

Water stress is increasing across some parts of Europe and so is the environmental impact of water use⁸². A measure of the water depletion stress is represented by the Water Exploitation Index (WEI), which is expressed as the percentage of fresh water available in a certain area that is withdrawn to fulfil the water needs of that area. The WEI forms part of the EU's dashboard of resource efficiency indicators.

According to the European Environment Agency, three different levels of water scarcity can be arbitrarily defined:

- WEI < 20%: a non-water stressed region
- WEI 20-40%: a water stressed region
- WEI >40%: a severely water stressed region.

At the national level, the countries with highest WEI factors are: Cyprus (ca.65%), Belgium (ca.32%), Spain (ca. 30%) and Italy (ca.25%). With the notable exception of Belgium, each of these countries also have the highest per capita domestic water consumption rates – further highlighting the importance of water efficiency measures in these countries.

Within many countries there may be significant local or regional differences in terms of climate and therefore it is possible that national level WEI factors may under- or over-estimate the degree of importance of water efficiency measures. For example,

⁸² Pfister, S., Koehler A., Hellweg S. 2009 Assessing the Environmental Impact of Freshwater Consumption in LCA. *Environmental Science & Technology*. 43(11):4098-4104

in 2009, a national WEI of 34% for Spain masked severely water stressed river basins in Andalusia and Segura, which had WEIs of 164% and 127% (see Figure 13).

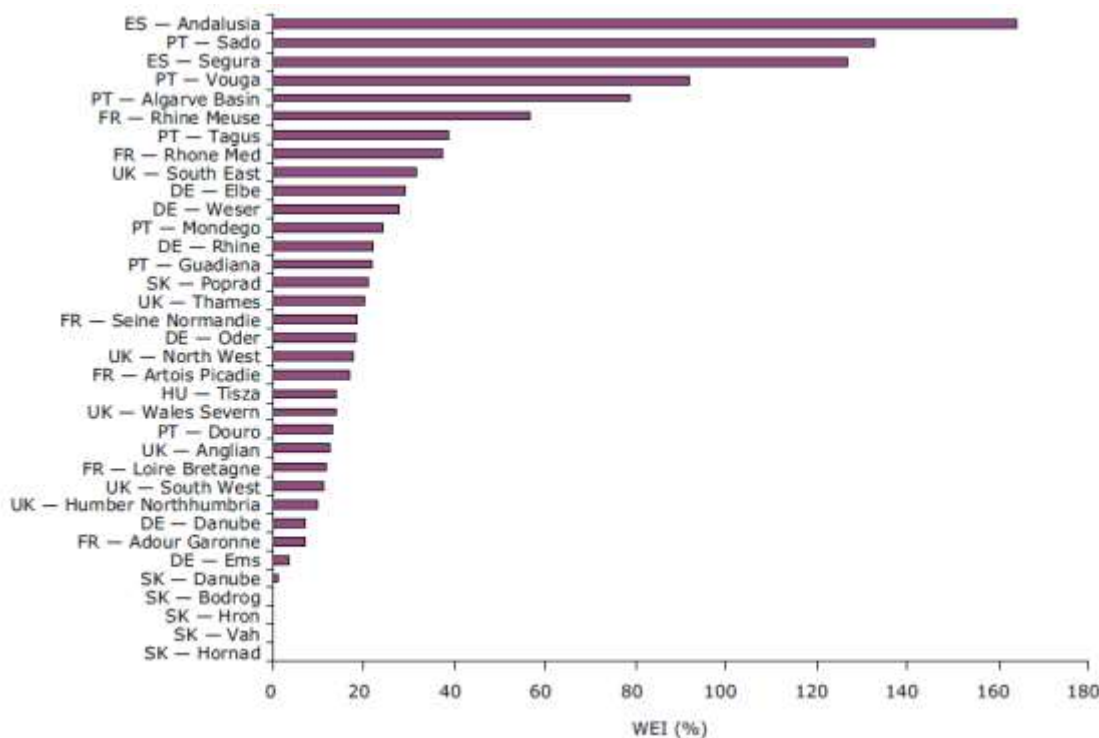


Figure 13 WEIs for different river basins in selected member states

Some traditional chilled water cooling systems employ cooling towers for heat rejection, which continually consume and discharge large volumes of water but use less energy compared with air cooled chillers using mechanical cooling systems. Evaporative cooling is used in modern, low energy data centre cooling solutions as this significantly reduces electricity consumption albeit with increased water consumption, compared with air cooled chillers.

In response to concerns about water consumption in data centres the Green Grid has developed the Water Usage Effectiveness (WUE) metric⁸³. However, as water is consumed in electricity generation in many cases, the overall impact of the reduction

⁸³ WP#35 – Water Usage Effectiveness (WUE): A Green Grid data centre sustainability metric.

in electricity consumption is a reduction in water consumption and thus the environmental impact.

Water quality needs to be controlled for both hygiene reasons (e.g. preventing Legionella), and protection of its storage and distribution system, i.e. to control scale, corrosion and biofouling which can impede system performance and reduce system life, for example through reducing heat exchange properties (e.g. condenser scaling). Water sampling can measure settled solids, suspended solids and “total” metals, dissolved solids, microbiology and dissolved oxygen. Chemical water treatment is used to maintain water quality within systems used for cooling / heat rejection and or humidification.

4.4.2 Life cycle environmental hotspots and potential improvements

Studies have indicated that the impact of water consumption is relatively low, however discharged water has a far higher environmental impact than tap water, as it requires processing (including dilution) to be converted from contaminated water which may contain iron, copper, corrosion inhibitors, biocides, chlorine, acids (added to control pH levels), salts (for softening), ozone etc., back to clean water.

Consider the volume of clean water which would be needed to render a cup of contaminated water drinkable by dilution; one study uses a factor of 250⁸⁴; and assumes that half of water consumed is evaporated and the remainder discharged, discharged water has 125 times the impact of water consumed. In reality the type of water treatment undertaken both on and off site, which could also include UV, ozone, reverse osmosis, would have different impacts. This is an area where the environmental impact is thought to be underestimated due to the limited LCA data and lack of focus on it. The impact categories associated with water are resource depletion and toxicity.

⁸⁴ Whitehead B, Tozer R, Andrews D, Flucker S, *Energy and Water Environmental Trade-Offs of Data Center Cooling Technologies*, ASHRAE Conference Las Vegas 2017

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

As previously discussed, there is limited life cycle data available in this area. Some solutions may have increased capital expenditure and operational expenditure requirements. In many cases reducing water discharged, e.g. by increasing how much water is reused, also decreases the water consumed and hence reduces water bills.

4.4.4 Verification

Metering is required and may already be in place. Existing metrics may be used along with processes employed as part of environmental management systems.

4.4.5 Market implications and functionality

Measurement is an important first step towards managing the volume of water discharged. One way in which water discharged could be reduced is by increasing the number of cycles in evaporative cooling systems before, where conditions allow, discharging to drain. This could be based on measured water quality rather than a prescribed number of cycles. It is difficult to be prescriptive on solutions to reduce water discharge as each local environment is different and water quality must be managed as an operational risk.

4.4.6 Applicability to public procurement

Water discharge volumes and measurement of them should be considered when designing a new or expanding / upgrading an existing facility. When facilities services are outsourced, the measurement and reporting of water discharged can be specified to track performance.

4.4.7 First criteria proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
<p>AC3.4 Minimise water discharged on site</p> <p>The data centre designer (or operator) shall be awarded points based on the volume of water discharged on site.</p> <p>Points shall be awarded to bidders that commit to discharge less than 2 litres per kWh of IT equipment electricity consumed (annually).</p> <p>Verification:</p> <p>The designer (or operator) shall report the projected and / or measured water discharged per kWh IT electricity consumed (annually).</p>	<p>AC3.4 Minimise water discharged on site</p> <p>The data centre designer (or operator) shall be awarded points based on the volume of water discharged on site.</p> <p>Points shall be awarded to bidders that commit to discharge less than 1 litre per kWh of IT equipment electricity consumed (annually).</p> <p>Verification:</p> <p>The designer (or operator) shall report the projected and / or measured water discharged per kWh IT electricity consumed (annually).</p>
CONTRACT PERFORMANCE CLAUSES	
<p>CPC3.4 Measurement and reporting of water discharged on site</p> <p>The water discharged shall be measured and reported on. Data shall be obtained from the water supplier, or in the case of co-location facilities sub metering shall be used.</p>	<p>CPC3.4 Measurement and reporting of water discharged on site</p> <p>The water discharged shall be measured and reported on. Data shall be obtained from the water supplier, or in the case of co-location facilities sub metering shall be used.</p>

ANNEX I – PROPOSED METRICS FOR SERVER EFFICIENCY

CRITERIA

Because servers provide a wide variety of services, the energy consumption, and efficiency, can vary depending on the server configuration and service. Since it is not possible to measure efficiency under every configuration and scenario, the metric is designed to capture the general energy efficiency of a single server rather than represent any specific use-case.

The metric is based on the results from the SERT v1.x testing tool, which measures the power consumption and performance of the server under a variety of different worklets designed to test different workloads, CPU, memory and storage. For each worklet, the power and performance is tested at different load levels which allows efficiency to be measured under partial load conditions, which are more representative of real life situations.

Table 12. Worklet names and associated workloads and load levels.

Workload	Load Level	Worklet Name
CPU	100%, 75%, 50%, 25%	Compress
		CryptoAES
		LU
		SHA256
		SOR
		SORT
		XMLValidate
Memory Storage Hybrid	Flood: Full, Half Capacity: 4GB, 8GB, 16GB, 128GB, 256GB, 512GB, 1024GB 100%, 50% 100%, 87.5%, 75%, 62.5%, 50%, 37.5%, 25%, 12.5%	Flood
		Capacity
		Random
		Sequential
		SSJ
Idle	Idle	Idle

The final metric combines the power and performance test results at different utilisation levels and for different worklets to produce a final efficiency score. The geometric mean is used to calculate the average performance and power. The geometric mean is given by the formula for n datapoints, x and weighting, w :

$$geomean = \left(\prod_{i=1}^n x_i^{w_i} \right)^{1/\sum_{i=1}^n w_i}$$

Stage 1: Calculating the efficiency for each worklet

At the worklet level, the efficiency calculation is identical to the SPEC approach:

$$worklet\ perf = geomean(Perf_{every\ utilisation\ level})$$

$$worklet\ power = geomean(Perf_{every\ power\ level})$$

$$worklet\ eff = \frac{worklet\ perf}{worklet\ power}$$

The weighting for all datapoints is 1.

Stage 2: Calculating the efficiency for each workload

For each workload, all the associated worklets are combined using the harmonic mean of the worklet efficiency results (Table 12) to calculate the workload efficiency.

$$\begin{aligned} CPU\ perf &= geomean(compress\ perf, CryptoAES\ perf, LU\ perf, SHA256\ perf, \\ &\quad SOR\ perf, SORT\ perf, XMLValidate\ perf, SSJ\ perf) \\ CPU\ pwer &= geomean(compress\ pwer, CryptoAES\ pwer, LU\ pwer, SHA256\ pwer, \\ &\quad SOR\ pwer, SORT\ pwer, XMLValidate\ pwer, SSJ\ perf) \end{aligned}$$

The CPU workload includes the SSJ worklet which is classified as a hybrid worklet in Table 1

$$\begin{aligned} Memory\ perf &= geomean(flood\ perf, Capacity\ perf) \\ Memory\ pwer &= geomean(flood\ pwer, Capacity\ pwer) \\ \\ Storage\ perf &= geomean(random\ perf, sequential\ perf) \\ Storage\ pwer &= geomean(random\ pwer, sequential\ pwer) \end{aligned}$$

The efficiency for each workload is then calculated by:

$$workload\ eff = \frac{workload\ perf}{workload\ power}$$

All weightings are 1.

Stage 3: Combining workload components into an average server efficiency metric

The server power, performance and efficiency are calculated using the geomean, with a weighting applied to the workloads based on the significance of the workload to the total performance and power.

$$\begin{aligned} server\ perf &= geomean(60\%\ CPU\ perf, 35\%\ Memory\ perf, 5\%\ storage\ perf) \\ server\ perf &= CPU\ perf^{0.6} \cdot Memory\ perf^{0.35} \cdot storage\ perf^{0.05} \end{aligned}$$

$$server\ pwer = geomean(60\%\ CPU\ pwer, 35\%\ Memory\ pwer, 5\%\ storage\ pwer)$$

$$server\ pwer = CPU\ pwer^{0.6} \cdot Memory\ pwer^{0.35} \cdot storage\ pwer^{0.05}$$

$$server\ eff = \frac{server\ perf}{server\ power}$$

A new test methodology will require reanalysis of the weightings for the server performance and power. Therefore the weightings may change under SERT v2 test method.

ANNEX II – PROPOSED METRICS FOR IT UTILISATION CRITERIA

The ICT Capacity and Utilisation metric developed by The Green Grid in White Paper #72 is proposed for the verification of the IT Utilisation Criteria.

ICT capacity is made of eight elements describing the total capacity and the level of utilisation of the computing, memory, storage and network.

Compute capacity, CPU_C

For all server CPUs in the data centres, total compute capacity is calculated by:

$$CPU_C = \sum_i ClockSpeed_i \cdot Cores_i \cdot Wt_i$$

Where Wt_i is the weighting for emerging technologies and currently 1.

Compute utilisation, CPU_U

$$CPU_U = \left(\sum CI_i \right) / CPU_C$$

Where CI_i is the total amount of compute services utilised by the data centre

Memory capacity, MEM_C

For all server CPUs in the data centres, total memory capacity is calculated by:

$$MEM_C = \sum_i (Mem_i \cdot Wt_i)$$

Where Wt_i is the weighting for emerging technologies and currently 1.

Memory Utilisation, MEM_U

$$MEM_U = \left(\sum MI_i \right) / MEM_C$$

Where MI_i is the amount of memory in use

Storage Capacity, $STOR_C$

The storage capacity measure the total physical addressable capacity of all the storage devices and systems. It does not include measures which change the effective capacity, such as data protection and capacity optimisations.

$$STOR_C = \sum_i (Stor_i)$$

Storage utilisation, $STOR_U$

$$STOR_U = \left(\sum STORI_j \right) / STOR_C$$

Where $STORI$ is the quantity of storage in use.

Network Capacity, NET_C

The network capacity is the sum of the bandwidth within the data centre between devices ($NetAccess$) and in/out of the data centre ($NetEdge$). It does not include fibre channels commonly used in storage area networks and general DC office network.

$$NET_C = \sum_i (NetEdge_i) + \sum_j (NetAccess_j)$$

Network utilisation, NET_U

$$NET_U = \left(\sum_i (NetEdgeI_i) + \sum_j (NetAccessI_j) \right) / NET_C$$

Where $NetEdge$ and $NetAccessI$ is the network bandwidth in use.

ICT utilisation, ICT_U

The ICT utilisation is the tuple of the four utilisation elements

$$ICT_U = \{CPU_U, MEM_U, STOR_U, NET_U\}$$

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