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Access, Terminals, Transmission and Multiplexing (ATTM); Comparison of sustainability parameters between internal and external, including "cloud-based", ICT hosting solutions

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Traditional Users of ICT services such as banks, telecommunications operators, insurance companies and public services are increasingly outsourcing part or all of their ICT services to a 3rd party Service Provider (SP) providing co-location or co-hosting solutions or a Cloud Service Provider (CSP) providing cloud hosting solutions.

A decision to migrate a User's ICT services to an external host is mainly driven by economic considerations. However, it is now becoming associated with the outsourcing of sustainability goals and this is now becoming the subject of scrutiny by regulators and legislators keen prevent "green washing" of corporate activity.

While it is easy to compare the solutions in terms of capital and operational expenditure, any analysis of sustainability parameters such as energy consumption, Green House Gas (GHG) emissions, water consumption and the End of Life (EoL) processing of electrical and electronic equipment is much more difficult - due to the large number of variables involved which can affect dramatically the comparison, some of which may not be known.

For example, co-location solutions are geographically defined, enabling more direct parametric comparison, co-hosting and cloud-based infrastructures are not necessarily geographically defined.

The present document defines the information necessary to undertake a comparison of sustainability parameters between conventional, internal, hosting of ICT services by an organization and the various external hosting solutions using tools which are either already standardized or in late stages of standardization at international level.

The present document, albeit a Technical Report, provides a framework upon which regulators can build a formal assessment system requiring hosts (both internal and external) to provide the required data to enable sustainability analyses and subsequent comparisons.

The present document does not address methods of improving resource management within data centres/ICT sites (reference should be made to ETSI EN 305 174-2 [i.8] and ETSI TS 105 174-2 [i.12].

1 Scope

The present document provides methods to enable a comparison of sustainability parameters between both internal and external (including "cloud-based") ICT hosting solutions addressing:

- energy consumption;
- Green House Gas (GHG) emission;
- water consumption;
- treatment of electrical and electronic equipment including maintenance at End of Life (EoL).

The present document does not address:

- technical aspects of whether a given external hosting solution is able to provide a functional replacement of Users ICT needs;
- methods of improving resource management within data centres/ICT sites (reference should be made to ETSI EN 305 174-2 [i.8] and ETSI TS 105 174-2 [i.12].

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the User with regard to a particular subject area.

[i.1] Directive 2002/96/EC (currently 2012/19/EU), referred to as the "WEEE Directive".

[i.2] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. .

[i.3] CENELEC EN 50600-4-2: "Information technology - Data centre facilities and infrastructures - Part 4-2: Power Usage Effectiveness".

[i.4] CENELEC EN 50600-4-3: "Information technology - Data centre facilities and infrastructures - Part 4-3: Renewable Energy Factor".

[i.5] CENELEC EN 50600-4-6: "Information technology - Data centre facilities and infrastructures - Part 4-6: Energy Reuse Factor (ERF)".

[i.6] CENELEC EN 50600-4-8: "Information technology - Data centre facilities and infrastructures - Part 4-8: Carbon Usage Effectiveness (CUE)".

[i.7] CENELEC EN 50600-4-9: "Information technology - Data centre facilities and infrastructures - Part 4-9: Water Usage Effectiveness (WUE)".

[i.8] ETSI EN 305 174-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 2: ICT sites".

[i.9] ETSI EN 305 174-8: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Management of end of life of ICT equipment (ICT waste/end of life)".

[i.10] ETSI EN 305 200-2-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 1: ICT sites".

[i.11] ETSI EN 305 200-3-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 3: ICT sites; Sub-part 1: DCEM".

[i.12] ETSI TS 105 174-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 2: ICT Sites: Implementation of energy and lifecycle management practices".

[i.13] ETSI TS 105 174-8: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Implementation of WEEE practices for ICT equipment during maintenance and at end-of-life".

[i.14] ISO/IEC 30134-2: "Information technology - Data centres - Key performance indicators -- Part 2: Power usage effectiveness (PUE)".

[i.15] ISO/IEC 30134-3: "Information technology - Data centres - Key performance indicators - Part 3: Renewable Energy Factor (REF)".

[i.16] ISO/IEC 30134-6: "Information technology - Data centres - Key performance indicators - Part 3: Energy Reuse Factor (ERF)".

[i.17] ISO/IEC 30134-8: "Information technology - Data centres - Key performance indicators - Part 8: Carbon Usage Effectiveness (CUE)".

[i.18] ISO/IEC 30134-9: "Information technology - Data centres - Key performance indicators - Part 9: Water Usage Effectiveness (WUE)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

cloud: set of ICT equipment including compute, storage and network capacities, accessible through Internet and used to store, manage, and process data and replacing User's internal ICT resources

cloud-based infrastructure: basis of a cloud, which provides capabilities for computing, storage and network resources, including resource orchestration, virtualization and sharing

cloud computing: model for enabling service User's ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or Cloud Service Provider interaction

cloud hosting: computing resources from a cloud computing provider or facility to host data, services and/or solutions via an Infrastructure as a Service (IaaS) cloud delivery model that provides a suite of remote/virtual services

NOTE: These are delivered on an on-demand basis and hosted on top of a cloud computing infrastructure.

Cloud Service Provider (CSP): organization offering services based on cloud infrastructures

co-hosting data centre: data centre in which multiple customers are provided with access to network(s), servers and storage equipment on which they operate their own services/applications

NOTE: Both the information technology equipment and the support infrastructure of the building are provided as a service by the data centre operator.

co-location data centre: data centre in which multiple customers locate their own network(s), servers and storage equipment

NOTE: The support infrastructure of the building (such as power distribution and environmental control) is provided as a service by the data centre operator.

data centre/ICT site: site containing structures or group of structures dedicated to the accommodation, interconnection and operation of ICT equipment 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

NOTE: Term defined in ETSI EN 305 200-2-1 [i.10].

GHG profile: national-specific equivalence of carbon dioxide emissions resulting from the production of grid electricity

ICT site: site containing structures or group of structures dedicated to the accommodation, interconnection and operation of ICT equipment 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

ICT equipment: equipment providing data storage, processing and transport services

NOTE: A combination of information technology equipment and network telecommunications equipment.

Information Technology Equipment (ITE): equipment providing data storage, processing and transport services for subsequent distribution by Network Telecommunications Equipment (NTE)

Network Telecommunications Equipment (NTE): equipment within the boundaries of, and dedicated to providing connection to, core and/or access networks

renewable energy: energy produced from dedicated generation systems using resources that are naturally replenished and for which the energy required for production does not exceed 10 % of the energy produced

NOTE: Directive 2010/31/EU [i.2] defines "energy from renewable sources" as energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.

Service Provider (SP): organization offering services based on co-location or co-hosting infrastructures

user: organization migrating all or part of their data centre(s)/ICT site(s) to an external hosted solution

water consumption profile: location-specific significance of water consumption taking into account the applicable level of the water stress

3.2 Symbols

For the purposes of the present document, the following symbols apply:

$CO2_{internal}$	Total annual carbon emissions of internally hosted data centre centres/ICT sites
$CO2_{external}$	Total annual carbon emissions of hosting data centre centres/ICT sites
$CUE1_{\_internal}$	Carbon Usage Effectiveness (CUE) of an internally hosted data centre centre/ICT site
$CUE1_{\_external}$	Carbon Usage Effectiveness (CUE) of a hosting data centre centre/ICT site
$E_{DC\_internal}$	Annual energy consumption of internally hosted data centre centre/ICT site from all energy sources
$E_{DC\_internal(renewable)}$	Annual energy consumption of internally hosted data centre centre/ICT site from locally generated renewable sources
$E_{DC\_external}$	User's share of the annual energy consumption of a hosting data centre centre/ICT site

$E_{DC\_external(renewable)}$ Annual energy consumption of a hosting data centre centre/ICT site from locally generated renewable sources
$E_{IT\_internal}$ Annual energy consumption of the ICT equipment of an internally hosted data centre centre/ICT site
$E_{IT\_external}$ Annual energy consumption of the User's ICT equipment of a hosting data centre centre/ICT site
$H2O_{internal}$ Total annual weighted water consumption of internally hosted data centre centres/ICT sites
$H2O_{external}$ User's share of the total annual weighted water consumption of hosting data centre centres/ICT sites
KPI_{REN} Renewable energy KPI of ICT sites
KPI_{REUSE} Energy reuse KPI of ICT sites
KPI_{TE} Task efficiency KPI of ICT sites
$PUE_{\_internal}$ Power Usage Effectiveness (PUE) of an internally hosted data centre centre/ICT site
$PUE_{\_external}$ Power Usage Effectiveness (PUE) of a hosting data centre centre/ICT site
$v_{WATER\_internal}$ Annual water consumption of an internally hosted data centre centre/ICT site
$v_{WATER\_external}$ User's share of the annual water consumption of an internal hosted data centre centre/ICT site
$WUE1_{\_internal}$ Water Usage Effectiveness (WUE) of an internally hosted data centre centre/ICT site
$WUE1_{\_external}$ Water Usage Effectiveness (WUE) of a hosting data centre centre/ICT site

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BWS Baseline Water Stress
CFC ChloroFluoroCarbons
CPU Central Processor Unit
CSP Cloud Service Provider
CUE Carbon Usage Effectiveness
EN European Norm
EoL End of Life
ERF Energy Reuse Factor
EU European Union
GHG Green House Gas
HCFC HydroChloroFluoroCarbons
HFC HydroFluoroCarbons
I/O Input/Output
IaaS Infrastructure as a Service
ICT Information and Communication Technology
IT Information Technology
ITE Information Technology Equipment
KPI Key Performance Indicator
MIPS Million Instructions Per Second
NTE Network Transmission Equipment
OS Operating System
PaaS Platform as a Service
PUE Power Usage Effectiveness
QoS Quality of Service
REF Renewable Energy Factor
SaaS Software as a Service
SLA Service Level Agreement
SP Service Provider
TR Technical Report
TS Technical Specification
UK United Kingdom
WEEE Waster Electrical and Electronic Equipment
WUE Water Usage Effectiveness

4 External hosting solutions for data centres/ICT sites

4.1 General

The present document considers three type of external hosting:

- co-location - sharing of the 3rd party data centre/ICT site infrastructures (including power distribution and environmental control) by multiple Users using their own ICT equipment installed in rented floor space;
- co-hosting - sharing of the 3rd party data centre/ICT site infrastructures (including power distribution and environmental control) by multiple Users that rent a certain number of physical (or virtual) servers and a volume of storage on which they operate their own applications and store their own data;
- cloud hosting - where all the 3rd party data centre/ICT site infrastructure is considered as a global sharable compute load, as well as the storage capability and a part of these resources are allocated to the different Users to cover their instant need.

Both co-hosting and cloud hosting solutions avoids the User having to need procure, operate, maintain and manage the EoL of a large amount of ICT equipment in its own data centre(s)/ICT site(s).

The ultimate migration is for the organization to get all the ICT services for its internal and business needs via a "cloud-based" solution which employs specific software such as orchestration, virtualisation (servers, storage, network, …), with the capability to support rapid deployment, scalability and agility. These are also linked to "as a service" oriented solutions such as the following outlined in Annex A and dimensioned for the instant needs of the client:

- Infrastructure as a Service (IaaS).
- Platform as a Service (PaaS).
- Software as a Service (SaaS).

This can be considered to be a "pay as you use" or "pay as you go" operational expenditure model.

4.2 The benefits of migrating to external hosting

There are many reasons which encourage an enterprise to outsource whole or part of its data centre(s)/ICT site(s). It could be driven by a financial motivation by an organization or alternatively a management decision to consolidate the functions provided by those data centre(s)/ICT sites.

In addition to these financial or management benefits, some resource efficiency gains can be expected by a migration to external hosting due to the sharing of those resources with other hosted Users.

However, a number of factors can affect the sustainability benefits including:

- the location of the hosting facility(ies) which:
  - can impact the GHG emissions associated with the grid supply (based on the carbon dioxide equivalence parameter $kgCO_2/kWh$);
  - in conjunction with the type of cooling used, can impact the consumption of scarce water resources;
  - can affect the EoL treatment of the electrical and electronic equipment;
- the presence of locally generated renewable energy resources;

All comparisons of the sustainability parameters of internal and external hosting should take these factors into account.

A major challenge is the determination of the realistic split of the resources for each User within cloud-hosted solutions which requires data relating the resource usage by location.

NOTE: The present document does not address reuse of waste energy from the facilities.

4.3 Co-location

In the case of co-location, all or part of the User's data centre(s)/ICT site(s) is re-located to an external site where the necessary space is rented by the User.

This allows the User to re-deploy all, or part of their, premises previously used to accommodate their data centre(s)/ICT site(s). The operational teams are generally required to continue to manage and maintain their own ICT equipment remotely.

Users within co-location facilities share the infrastructures for power supply and distribution, environmental control and physical security.

Any comparative benefits result from reduced energy consumption, GHG emissions and water consumption profiles within these infrastructures. However, as the User enters into a commercial arrangement with the Service Provider (SP) based on their resource consumption plus an appropriate overhead, there is an implicit assumption that the sharing of the resources promotes improved efficiency as compared with the internally hosted solution.

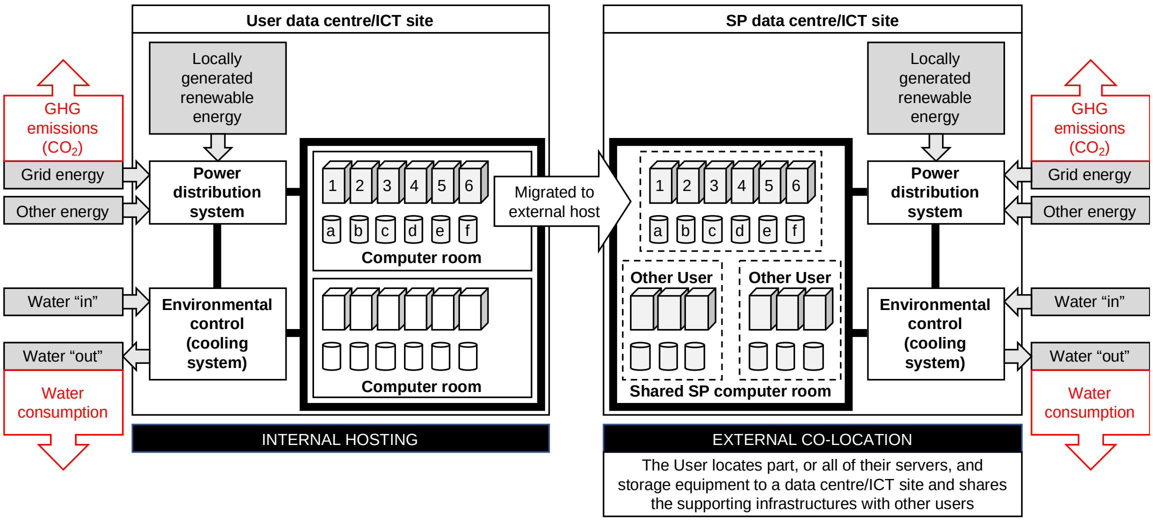

Figure 1: Migration to co-location facilities

However, the overall comparison of sustainability parameters can also be affected by the factors listed in clause 4.2.

4.4 Co-hosting

In the case of co-hosting, the external facility provides all the User's data processing, storage and transport services including, where appropriate, other services related to IT management including data security, duplication, backups and disaster recovery.

Users rent racks of data processing and storage equipment upon which they deploy their own ICT services.

This allows Users to re-deploy all, or part of their, data centre spaces and re-deploy or dispose of all, or part of their ICT equipment.

As the User enters into a commercial arrangement with the SP based on the energy consumption of the rented ICT equipment plus an appropriate overhead, there is an implicit assumption that the sharing of the resources promotes improved efficiency as compared with the internally hosted solution. This is further enhanced by the scale of co-hosting data centre(s)/ICT site(s) and the more efficient use of shared equipment for data processing, storage and transport.

However, in order to achieve higher levels of service availability, the SP may choose to design and operate high levels of redundancies within the supporting infrastructures (e.g. power supply, power distribution and environmental control) or deliver services from multiple, independent, data centres/ICT sites. This may counteract the reductions in energy consumption resulting from the use of more energy efficient ICT equipment.

As shown in Figure 2, if the external facility(ies) is/are located in an area with the same GHG and water consumption profiles as the internal solution then such efficiency improvements are based on the design and operation of the external facilities (taking into account the impact of any additional design features providing additional infrastructure availability).

However, the overall comparison of sustainability parameters can also be affected by the factors listed in clause 4.2.

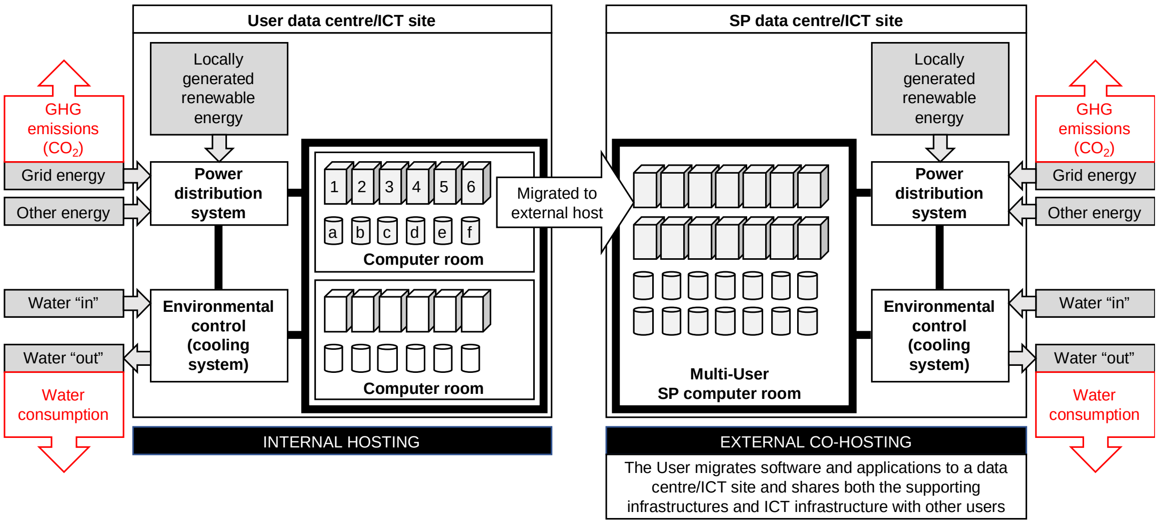

Figure 2: Migration to co-hosting facilities

4.5 Cloud hosting

Cloud hosting enhances the services offered by a co-hosting facility of clause 4.4. The cloud-based infrastructure stands on a global set of resources proposed "as a service" which can range from basic compute power up to the delivery of a global service or application.

A cloud hosting infrastructure is founded on:

- a set of generic server farms and other compute equipment;
- a shared storage infrastructure;
- network bandwidth and I/Os.

This infrastructure represents a total capacity of processing, storing and transport which is not dedicated to a unique User but is shared by Users supported by the CSP.

The intrinsic characteristics of the model allow Users to grow and deploy their services across geographical regions rapidly with the guarantee to be able to access the necessary ICT resources as necessary.

This allows Users to re-deploy all, or part of their, data centre spaces and re-deploy or dispose of all, or part of their data processing, storage and transport equipment.

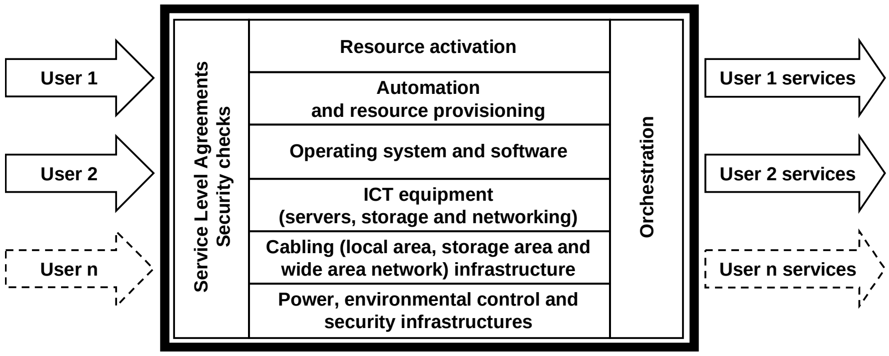

Figure 3: The cloud-based architecture

As shown Figure 3 cloud hosting can be seen as a "User/services" infrastructure in which the cloud service provider (CSP) allows the User access to required services, providing resources with associated guarantees for security, operability, and execution of the service with a Quality of Service (QoS) in accordance with the contractual Service Level Agreement (SLA).

Similar to the external hosting of clause 4.4, cloud hosting runs multiple Operating System (OS) instances, on many virtual servers (on fewer physical servers), which maximizes the server efficiency as compared with servers used for only one instance which are more often under-utilized.

However, cloud hosting differs from external hosting of clause 4.4 as the resources for data processing, storage and transport are generally accommodated in several data centres/ICT sites in different locations and even in different countries. For example, a CSP that offers its Users a service accessible worldwide on a 24/24 and 7/7 basis will have to face peak demand during the day and will have to be able to move the services to locations with less demand at those times.

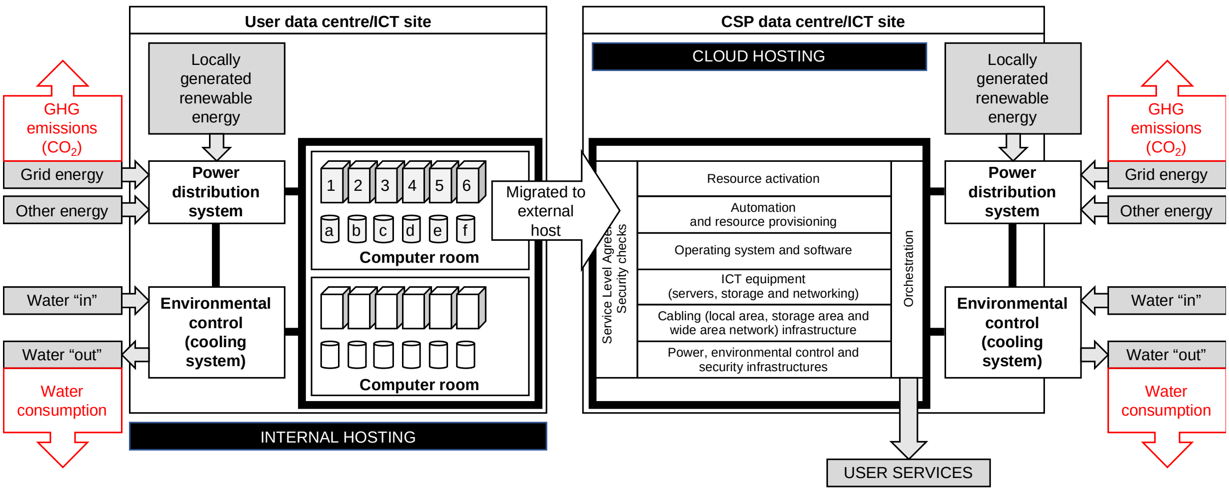

Figure 4: Migration to cloud-based facilities

Any comparison of sustainability parameter benefits result from reduced energy consumption, GHG emissions and water consumption profiles within these infrastructures and the energy efficiency improvements resulting from the type and operation of the ICT equipment used. However, a CSP generally provides some figures concerning the global energy consumption, GHG and water consumption profiles but such information applies to the overall infrastructure and any comparison of sustainability parameters can also be affected by the factors listed in clause 4.2.

Obtaining the information for a specific User is very difficult since the User generally does not know where the resources are located at any particular time. This is a very important point that can influence migration to cloud solutions, particularly if the sensitivity of the data is critical.

For this reason, and to some extent in response to regional and national governmental concerns, some CSPs are now offering "sovereign" cloud services, which guarantee that the resources and the data are in the same region or country as the User. This is a major point, due to the legal aspects concerning owner of the data, the security and confidentiality and should facilitate the assessment in terms of comparison of sustainability parameters with internal and other external hosting solutions.

5 A general comparison

5.1 The qualitative benefits

For Users operating their own data processing, storage and transport equipment and infrastructures in their own premises, it is clear that migrating to an external shared model of hosting and management will have some advantages.

The first, and most obvious, advantage is economic enabling re-deployment or disposal of space, equipment and skills bring associated benefits to both operational and future capital expenditure.

However, the scope of the present document does not address the financial motivation and focusses on the comparison of sustainability parameters between internal and external hosting of data processing, storage and transport based upon:

- energy consumption (taking to account locally generated renewable energy resources);
- Green House Gas (GHG) emissions associated with the supply of power from the grid;

NOTE: Green House Gas (GHG) emissions associated with locally generated energy (e.g. combined heat and power and diesel generators) are not separately considered in the present document.

- water consumption;
- waste management from production to end-of-life management.

The present document defines the information required to allow a comparison of sustainability parameters of internal and external hosting solutions.

If any of the information specified in the present document cannot be obtained then it is not possible to assess the sustainability parameters of the solution and comparison with other solutions cannot be evaluated.

5.2 Relevant Key Performance Indicators

The present document references ETSI and CENELEC standards for Objective Key Performance Indicators (KPIs) addressing resource management in data centres (ICT sites) which are used to determine performance of internal and external hosting solutions.

These are:

- PUE (Power Usage Effectiveness) as defined in CENELEC EN 50600-4-2 [i.3] (transposed from ISO/IEC 30134-2 [i.14]) - this is similar to the KPI_{TE} (Task Efficiency) of ETSI EN 305 200-2-1 [i.10] and ETSI EN 305 200-3-1 i.11];
- REF (Renewable Energy Factor) as defined in CENELEC EN 50600-4-3 [i.4] (transposed from ISO/IEC 30134-3 [i.15]) - this is similar to the KPI_{REN} (Renewable Energy) of ETSI EN 305 200-2-1 [i.10] and ETSI EN 305 200-3-1 i.11];
- ERF (Energy Reuse Factor) as defined in CENELEC EN 50600-4-6 [i.5] (transposed from ISO/IEC 30134-6 [i.16]) - this is similar to the KPI_{REUSE} of ETSI EN 305 200-2-1 [i.10] and ETSI EN 305 200-3-1 [i.11];

NOTE: The present document does not address reuse of waste energy.

- CUE (Carbon Usage Effectiveness) as defined in CENELEC EN 50600-4-8 [i.6] (transposed from ISO/IEC 30134-8 [i.17]);
- WUE (Water Usage Effectiveness) as defined in CENELEC EN 50600-4-9 [i.7] (transposed from ISO/IEC 30134-9 [i.18]).

PUE (or KPI_{TE}) and CUE requires knowledge of the total annual energy consumption of the data centre/ICT site from all sources and the total annual energy consumption of the ICT equipment within it.

REF or KPI_{REN} requires knowledge of the total annual energy consumption of the data centre/ICT site from all local renewable sources.

WUE (as defined in the present document) requires knowledge of the total annual water consumption used for the operation of the data centre/ICT site and the total annual energy consumption of the ICT equipment within it.

NOTE: The annual values for the parameters listed above is critical to avoid seasonal variations which can be misleading.

5.3 Facility location

As a fundamental principle, comparison of sustainability parameters is not simply a matter of improvements in energy efficiency or reduction of energy consumption that may be achieved by external hosting.

GHG (and specifically CO_2) emissions are dependent upon the geographical location of the ICT site. Annex B provides examples for the variation of kg/CO_2 per kWh in certain European countries. Table B.1 indicates substantial differences in terms of CO_2 equivalence between the European countries. For example, the figure for Greece is 48 times higher than that for Sweden.

The impact of water consumption is dependent upon the geographical location of the ICT site. The present document takes this impact into account by the application of regional Baseline Water Stress values as defined in Annex C.

These aspects are addressed by the formulae of clauses 6.2.2 and 6.3.2 and any resulting comparisons of clause 7 and clause 8.

5.4 Energy consumption

5.4.1 General

Calculation of the energy consumption of the ICT equipment within a data centre/ICT site and also its supporting infrastructure (e.g. power distribution and environmental control) represents a challenge for internal and external hosting solutions.

5.4.2 Internal hosting

$E_{DC\_internal}$ is the annual energy consumption of a User's data centre/ICT site prior to migration and is therefore a fundamental parameter to allow comparison with any external hosting solution (see clause 6). Also, if a value for $E_{DC\_internal}$ for each hosting site cannot be determined then it is generally not possible to quantify any comparison of GHG emissions (see clause 5.5).

$E_{DC\_internal}$ combines the energy consumption of the ICT equipment ($E_{IT\_internal}$) with the additional energy consumption of supporting infrastructures of the data centre/ICT site.

Using the standard KPI of clause 5.2:

$$E_{DC\_internal} = E_{IT\_internal} \text{ x } PUE_{\_internal}$$

NOTE 1: PUE is not a measure of energy consumption, but represents the multiplication factor which indicates the additional energy consumption of the supporting infrastructures (e.g. power distribution and environmental control).

NOTE 2: $E_{DC\_internal}$ takes no account of the energy source and is not influenced by local generation of renewable energy or reuse of waste energy (typically in the form of heat) from the data centre/ICT site). The local generation of renewable energy is counted in GHG emission of clause 5.5. The present document does not consider reuse of waste energy.

The present document recognizes that many smaller Users:

- do not measure and record $E_{IT\_internal}$ separately from that of the premises in which the data centre/ICT site is accommodated;
- may not have relevant data concerning the additional energy consumption of supporting infrastructures because those infrastructures are typically shared within the location.

In such cases, the User should install appropriate temporary metering systems and $E_{IT\_internal}$ should be approximated by a sample measurement of total relevant energy consumption over a period not less than 30 days. A default value of PUE of 3,0 should be applied to obtain $E_{DC\_internal}$. This approach, when applied, should be recorded as being a "sample"value.

5.4.3 External hosting

$E_{DC\_external}$ is a fundamental parameter to allow comparison with any internal or other external hosting solution (see clause 7 and clause 8). Also, if a value for $E_{DC\_external}$ for each hosting site cannot be determined then it is generally not possible to quantify any comparison of GHG emissions (see clause 5.5).

For co-location, it can be assumed that the energy consumption of the ICT equipment ($E_{IT\_external}$) is the same as the internal hosted scenario.

For co-hosting and cloud hosting solutions, even if the same architecture and the same generation equipment is used in both internal and external sites, there will be inevitable duplication/multiplication in processing, storage and transport if the external host has many sites in order to improve service availability. However, it is more likely that the external host will adopt newer technologies which reduce energy consumption for the same task.

For all external solutions, the additional energy consumption for the supporting infrastructures of the data centre/ICT site is influenced by:

- more efficient, or better use of, components and subsystems such as uninterruptible power systems which tend to reduce PUE;
- more granular control and new techniques of cooling in the environmental control systems which tend to reduce PUE;
- redundant systems targeted to improve availability of the infrastructures, intended to provide improved service to the User, which tend to increase PUE.

These factors combine as $E_{DC\_external}$, the annual energy consumption of the hosting data centre/ICT site associated with the services provided to the User. If the energy consumption of the hosted ICT equipment or services ($E_{IT\_external}$) is available then, in order to quantify the additional energy consumption, it is necessary to obtain the PUE (as defined in clause 5.2) of each external hosting site.

Using the standard KPI of clause 5.2:

$$E_{DC\_external} = E_{IT\_external} \text{ x } PUE_{\_external}$$

NOTE 1: PUE is not a measure of energy consumption, but represents the multiplication factor which indicates the additional energy consumption of the supporting infrastructures (e.g. power distribution and environmental control).

NOTE 2: $E_{DC\_external}$ takes no account of the energy source and is not influenced by local generation of renewable energy or reuse of waste energy (typically in the form of heat) from the data centre/ICT site). The local generation of renewable energy is counted in GHG emission of clause 5.5. The present document does not consider reuse of waste energy.

For all external solutions, the challenge is to obtain from the SP, or CSP, an assessment of the share of the energy consumption between each User, related to the hosted services ($E_{DC\_external}$). The problem is exacerbated where the SP or CSP has multiple sites and is further complicated in situations where these sites are distributed globally.

5.5 Green House Gas emissions

5.5.1 General

Regarding GHG emissions, the primary constituents are:

- water vapor (H_2O);
- carbon dioxide (CO_2);

- methane (CH_4);
- nitrous oxide (N_2O);
- ozone (O_3);
- chlorofluorocarbons (CFCs);
- hydrofluorocarbons including hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs).

With regard to data centres/ICT sites, the present document only considers CO_2 emissions.

5.5.2 Internal hosting

In order to calculate the GHG emissions of an internal hosted data centre/ICT site, a value for $E_{DC\_internal}$ is required.

If a portion of the $E_{DC\_internal}$ of clause 5.4.2 is provided by locally generated renewable energy ($E_{DC\_internal(renewable)}$) then the GHG emissions are calculated by:

$$\text{GHG emission } (CO_2 \text{ equivalence}) = (E_{DC\_internal} - E_{DC\_internal(renewable)}) \text{ x average ratio of kg}CO_2\text{/kWh}$$

or equivalently:

$$\text{GHG emission } (CO_2 \text{ equivalence}) = (E_{IT\_internal} \text{ x PUE}_{internal} \text{ x REF}_{internal}) \text{ x average ratio of kg}CO_2\text{/kWh}$$

NOTE: The average ratio of $kgCO_2$/kWh for grid electricity can be found in annually updated documents concerning Emission Factors published by the International Energy Agency. Selected national-specific values are shown in Annex B.

5.5.3 External hosting

In order to calculate the GHG emissions of an external hosted data centre/ICT site, a value for $E_{DC\_external}$ is required.

If a portion of the $E_{DC\_external}$ of clause 5.4.3 is provided by locally generated renewable energy ($E_{DC\_external(renewable)}$) then the GHG emissions are calculated by:

$$\text{GHG emission } (CO_2 \text{ equivalence}) = (E_{DC\_external} - E_{DC\_external(renewable)}) \text{ x average ratio of kg}CO_2\text{/kWh}$$

or equivalently:

$$\text{GHG emission } (CO_2 \text{ equivalence}) = (E_{IT\_external} \text{ x PUE}_{external} \text{ x REF}_{external}) \text{ x average ratio of kg}CO_2\text{/kWh}$$

However, the SP/CSP may report the relevant KPI, i.e. CUE as defined in clause 5.2, for the external hosted data centre(s)/ICT site(s) and which modifies the general formula to read:

$$\text{GHG emission } (CO_2 \text{ equivalence}) = E_{IT\_external} \text{ x CUE}_{external} \text{ x REF}_{external}$$

The present document only considers CUE Category CUE_1 as defined in ISO/IEC 30134-8 [i.17] which only considers the CO_2 emitted from external electricity suppliers (CUE Categories CUE_2 and CUE_{2e} as defined in ISO/IEC 30134-8 [i.17] include additional energy supplies generated at the data centre/ICT site (e.g. use of diesel generators, etc.).

NOTE: Green House Gas (GHG) emissions associated with locally generated energy (e.g. combined heat and power and diesel generators) are not separately considered in the present document.

Reported values of CUE_1 can be multiplied by $E_{IT\_external}$ to obtain the total CO_2 emission based on average ratio of $kgCO_2$/kWh of the country (see Annex B).

This will be the main driver for evaluation of carbon emissions and can have some large effects on CO_2 emissions when comparing two solutions as shown in the examples of Table 1.

Table 1: Examples of CO_2 equivalence calculation for zero REF

	The data centre has an annual energy consumption ($E_{DC\_external}$) of 8,76 GWh
Example 1 **A data centre in France**	The average ratio of gCO_2/kWh in France is 0,059 kg/kW (see Annex B) so the annual CO_2 = 516 840 kg. If the PUE of the data centre is 2,00 then CUE_1 = 516 840/4 380 000 = 0,118. If the $E_{IT\_external}$ for a given User = 0,2 GWh then the GHG emission (CO_2) = 23 600 kg.
Example 2 **A data centre in Greece**	The average ratio of gCO_2/kWh in Greece is 0,623 kg/kW (see Annex B) so the annual CO_2 = 5 457 480 kg. If the PUE of the data centre is 2,00 then CUE_1 = 5 457 480/4 380 000 = 1,246. If the $E_{IT\_external}$ for a given User = 0,2 GWh then the GHG emission (CO_2) = 249 200 kg.

However, when using CUE the presence of locally generated renewable energy needs to be factored into the calculations.

If REF (defined in clause 5.2) is non-zero then part of the annual energy consumption is subject to zero CO_2 contribution. An example of this is shown in Table 2.

Table 2: Examples of CO_2 equivalence calculation for non-zero REF

	The data centre has an annual energy consumption ($E_{DC\_external}$) of 8,76 GWh. REF = 0,2 The externally supplied consumption is 7,008 GWh.
Example **A data centre in France**	The average ratio of gCO_2/kWh in France is 0,059 kg/kW (see Annex B) so the annual CO_2 = 413 472 kg. If the PUE of the data centre is 2,00 then CUE_1 = 413 472/4 380 000 = 0,0944. If the $E_{IT\_External}$ for a given User = 0,2 GWh then the GHG emission (CO_2) = 18 880 kg.

For all external solutions, the challenge is to obtain any of the relevant data from the SP, or CSP. The problem is exacerbated where the SP or CSP has multiple sites and is further complicated in situations where these sites are distributed globally.

5.6 Water consumption

5.6.1 General

With regard to data centres/ICT sites, main element of water usage is linked to the type of cooling used in the environmental control system and the KPI is WUE as defined in clause 5.2.

Some cooling technologies have zero or limited water consumption whereas others consume significant quantities of water.

It is necessary for the User, SP or CSP to separate the water consumed for the purposes of environmental control of the data centre/ICT site facilities from any overall water consumption.

5.6.2 Internal hosting

WUE as defined in clause 5.2 is a ratio of annual volume of water used by a data centre/ICT site divided by the annual energy consumption of the ICT equipment. However, to compare internal and external hosting solutions it is only necessary to determine the volume of water used ($v_{water\_internal}$), rather than the ratio of WUE.

Without using WUE, but using its boundary conditions:

$$v_{water\_internal} = \text{incoming volume of water (annual) - returned volume of water (annual)}$$

However, it is not acceptable to consider the total volume of water consumption without taking account of the scarcity of the water in the geographical location. The present document uses Baseline Water Stress (BWS) as a weighting factor (see clauses 6.2.2 and 6.3.2) when undertaking a comparison of sustainability parameters of data centres/ICT sites in different geographical locations.

5.6.3 External hosting

The formula of clause 5.6.2 can be applied to each external data centre/ICT site. However, it may be that external hosted data centre(s)/ICT site(s) provide a relevant KPI, WUE as defined in clause 5.2.

The present document only considers WUE Category WUE_1 as defined in ISO/IEC 30134-9 [i.18] which only considers the the water used for cooling (WUE Categories WUE_2 as defined in ISO/IEC 30134-9 [i.18] includes water used to provide all the energy consumed by the data centre/ICT site (including that of local provision of renewable energy).

Without using WUE, but using its boundary conditions:

$$\text{Total } v_{water\_external} = \text{incoming volume of water (annual) - returned volume of water (annual)}$$

Reported values of WUE_1 can be multiplied by $E_{IT\_external}$ to obtain the water usage for the User as shown in the examples of Table 3.

Table 3: Example of water consumption

The data centre has an annual energy consumption of 8,76 GWh. Incoming volume of water (annual) = 600 000 m^3 Returned volume of water (annual) = 450 000 m^3 Total $v_{water\_external}$= 150 000 m^3 If the PUE of the data centre/ICT site is 2,00 then WUE_1 = 150 000/4,380 000 = 0,034. If the $E_{IT\_External}$ for a given User = 0,2 GWh then the $v_{water\_external}$= 6 850 m^3.

WUE focusses on the volume of water used - but also refers to the "value" of water in the various locations which is described as "water significance". WUE refers to the Falkenmark Indicator to assess "water significance" (annual surface runoff (m^3) and population).

The present document uses a different approach and uses Baseline Water Stress (BWS) as a weighting factor (see clauses 6.2.2 and 6.3.2) when undertaking a comparison of sustainability parameters of data centres/ICT sites in different geographical locations.

For all external solutions, the challenge is to obtain any of the relevant data from the SP, or CSP. The problem is exacerbated where the SP or CSP has multiple sites and is further complicated in situations where these sites are distributed globally.

5.7 End of Life

The EoL processing of ICT equipment and the related KPIs are described in ETSI EN 305 174-8 [i.9].

- $WEEE_{\text{processed}}$;
- $WEEE_{prepared\ for\ reuse}$;
- $WEEE_{reused\ by\ parts}$;
- $WEEE_{recycled}$;
- $WEEE_{recovered\ energy}$;
- $WEEE_{destroyed}$.

NOTE: The WEEE Directive [i.1] applies in the European Economic Area.

An internal hosted data centre/ICT is able to report against these KPIs.

For the co-location solution and the ICT equipment remains the property of the User, the commitment to report the KPIs remains unchanged.

For the co-hosting and cloud hosting solutions and the ICT equipment is the property of, and the responsibility for its EoL treatment lies with, the SP and CSP respectively.

If the geographical location of the hosting facilities is subject to the EU WEEE Directive then ETSI EN 305 174-8 [i.9] and ETSI TS 105 174-8 [i.13] provide requirements and guidance for processing.

6 Comparison of operational parameters

6.1 General

This clause defines the information required to allow a comparison of sustainability parameters of internal and external hosting solutions.

If any of the information specified in the present document cannot be obtained then it is not possible to assess the sustainability parameters of the solution and comparison with other solutions cannot be evaluated.

6.2 Internal hosting

6.2.1 General

For the User, the following parameters should be obtained before any decision to migrate is reached:

- $E_{DC\_internal}$ for each of the Users data centre(s)/ICT site(s) to be migrated;

NOTE: This can be a supplied value or calculated from a supplied value of $E_{IT\_internal}$ and the PUE (or KPI_{TE}) for the data centre(s)/ICT site(s).

- $E_{DC\_internal(\mathrm{renewable})}$ for each of the Users data centre(s)/ICT site(s);
- CO_2 emission equivalence based on $E_{DC\_internal}$ - $E_{DC\_internal(\mathrm{renewable})}$ for each of the Users data centre(s)/ICT site(s) to be migrated using the values for average ratio of $kgCO_2/kWh$ relevant to their location;
- $v_{WATER\ DC\_internal}$ for each of the Users data centre(s)/ICT site(s) to be migrated;
- the *BWS* (See Annex C) at each of the Users data centre(s)/ICT site(s) to be migrated.

If only part of services is to be migrated then the User should apportion the parameter on the basis of the ratio of $E_{IT\_internal}$ being migrated.

All EoL process are the responsibility of the User. Appropriate KPIs (see clause 5.7) and as defined and described in ETSI EN 305 174-8 [i.9] and ETSI TS 105 174-8 [i.13] should be produced by the User.

The following information can be useful but is not necessary:

- cost per kWh for grid electricity at each of the Users data centre(s)/ICT site(s) to be migrated;
- cost/m^3 of water at each of the Users data centre(s)/ICT site(s) to be migrated.

6.2.2 Formulae to enable comparisons

For energy consumption:

$$E_{DC\_internal} = \sum_{i=1}^{i=N} E_{DC\_internal_i} \equiv \sum_{i=1}^{i=N} E_{IT\_internal_i} \times PUE_i$$

where:

$E_{DC\_internal}$ = total energy consumption of data centres (*1* to *N*) to be migrated

$E_{DC\_internal_i}$ = energy consumption of data centre *i* to be migrated

$E_{IT\_internal_i}$ = energy consumption of the ICT equipment at data centre *i* to be migrated

PUE_i = PUE (in accordance with CENELEC EN 50600-4-2 [i.3]) of data centre *i* to be migrated

NOTE: KPI_{TE} in accordance with ETSI EN 305 200-2-1 [i.10] or ETSI EN 305 200-3-1 [i.11] may be used in place of PUE.

For GHG emissions:

$$CO2_{internal} = \sum_{i=1}^{i=N} \left[E_{DC\_internal_i} \times \left(1 - REF_{internal_i}\right)\right] \times CO_2equiv_{internal_i}$$

$$\equiv \sum_{i=1}^{i=N} E_{IT\_internal_i} \times CUE1_{internal_i} \times \left(1 - REF_{internal_i}\right) \times CO_2equiv_{internal_i}$$

where:

$CO2_{internal}$ = total CO_2 equivalence of grid supply to all data centres (*1* to *N*) to be migrated

$E_{DC\_internal_i}$ = energy consumption of data centre *i* to be migrated

$REF_{internal_i}$ = renewal energy factor at data centre *i* to be migrated

$CO_2equiv_{internal_i}$ = CO_2 equivalence of grid supply at data centre *i* to be migrated

$E_{IT\_internal_i}$ = energy consumption of the ICT equipment at data centre *i* to be migrated

$CUE1_{internal_i}$ = CUE_1 (in accordance with CENELEC EN 50600-4-8 [i.6]) of data centre *i* to be migrated

NOTE: The present document does not address reuse of waste energy.

For water consumption:

$$H2O_{internal} = \sum_{i=1}^{i=N} v_{water\_internal_i} \times BWS_i \equiv \sum_{i=1}^{i=N} E_{IT\_internal_i} \times WUE1_{internal_i} \times BWS_i$$

where:

$H2O_{internal}$ = total water consumption to all data centres (*1* to *N*) to be migrated

$v_{water\_internal_i}$ = energy consumption of data centre *i* to be migrated

$E_{IT\_internal_i}$ = energy consumption of the ICT equipment at data centre *i* to be migrated

$WUE1_{internal_i}$ = WUE_1 (in accordance with CENELEC EN 50600-4-9 [i.7]) of data centre *i* to be migrated

and

BWS_i = BWS (industrial) at data centre *i* to be migrated (see Annex C)

6.3 External hosting

6.3.1 General

Following migration to external hosting facilities, the following parameters should be obtained.

- $E_{DC\_external}$ for the Users services at each data centre/ICT site where the Users equipment or services are hosted;

NOTE: This can be a supplied value or calculated from a supplied value of $E_{IT\_external}$ and the PUE (or KPI_{TE}) for the data centre(s)/ICT site(s).

- CO_2 emission equivalence based on $E_{DC\_external}$ - $E_{DC\_external(\mathrm{renewable})}$ for each data centre/ICT site where the Users equipment or services are hosted using the values for average ratio of $kgCO_2/kWh$ relevant to their location;
- $v_{water\_external}$ for each data centre/ICT site where the Users equipment or services are hosted;
- the *BWS* (See Annex C) at each data centre/ICT site where the Users equipment or services are hosted.

For co-location solutions, as the User is still the owner of its ICT equipment, any change in the responsibility of the EoL management is the same as in clause 6.2.

For co-hosting and cloud hosting solutions, the ICT equipment is property of the SP or CSP respectively and the entire EoL process is also the responsibility of the property of the SP or CSP. The User should investigate the situation before any decision to migrate is taken since, if the recycling process (if it exists) is not in line with the European standards for WEEE treatment, it can inflict reputational damage on the User.

The following information can be useful but is not necessary:

- cost per kW/h for grid electricity at each data centre/ICT site where the Users equipment or services are hosted;
- cost/m^3 of water at each of data centre/ICT site where the Users equipment or services are hosted.

6.3.2 Formulae to enable comparisons

6.3.2.1 Co-location and co-hosting

For energy consumption:

$$E_{DC\_external} = \sum_{i=1}^{i=N} E_{DC\_external_i} \equiv \sum_{i=1}^{i=N} E_{IT\_external_i} \times PUE_i$$

where:

$E_{DC\_external}$ = total energy consumption of data centres (*1* to *N*) supporting migration

$E_{DC\_external_i}$ = energy consumption of data centre *i* supporting migration

$E_{IT\_external_i}$ = energy consumption of the ICT equipment at data centre *i* supporting migration

PUE_i = PUE (in accordance with CENELEC EN 50600-4-2 [i.3]) of data centre *i* supporting migration

NOTE: KPI_{TE} in accordance with ETSI EN 305 200-2- [i.10] or ETSI EN 305 200-3-1 [i.11] may be used in place of PUE.

For GHG emissions:

$$CO2_{external} = \sum_{i=1}^{i=N} E_{DC\_\_external_i} \times \left(1 - REF_{external_i}\right) \times CO_2 equiv_{external_i}$$
$$\equiv \sum_{i=1}^{i=N} E_{IT\_\_external_i} \times CUE1_{internal_i} \times \left(1 - REF_{external_i}\right) \times CO_2 equiv_{external_i}$$

where:

$CO2_{external}$ = total CO_2 equivalence of grid supply to all data centres (*1* to *N*) supporting migration

$E_{DC\_external_i}$ = energy consumption of data centre *i* supporting migration

$REF_{external_i}$ = renewal energy factor at data centre *i* supporting migration

$CO_2equiv_{external_i}$ = CO_2 equivalence of grid supply at data centre *i* to be migrated

$E_{IT\_external_i}$ = energy consumption of the ICT equipment at data centre *i* supporting migration

$CUE1_{external_i}$ = CUE_1 (in accordance with CENELEC EN 50600-4-8 [i.6]) of data centre *i* supporting migration

NOTE: The present document does not address reuse of waste energy.

For water consumption:

$$H2O_{external} = \sum_{i=1}^{i=N} v_{water\_external_i} \times BWS_i \equiv \sum_{i=1}^{i=N} E_{IT\_external_i} \times WUE1_{DC\_external_i} \times BWS_i$$

where:

$H2O_{external}$ = total water consumption to all data centres (*1* to *N*) supporting migration

$v_{water\_external_i}$ = energy consumption of data centre *i* supporting migration

$E_{IT\_external_i}$ = energy consumption of the ICT equipment at data centre *i* supporting migration

$WUE1_{DC\_external_i}$ = WUE_1 (in accordance with CENELEC EN 50600-4-9 [i.7]) of data centre *i* supporting migration

and

BWS_i = BWS (industrial) at data centre *i* supporting migration (see Annex C)

6.3.2.2 Cloud hosting

Cloud hosting solutions, being elastic, scalable and based on virtualized environments, allow optimal usage of servers via automatic provisioning and capacity management can smooth the activity peaks of the various Users have different peak profiles, occurring at different times.

When migrated to a cloud hosting solution, the total energy consumption of the User's services, $E_{IT\_external}$, comprises:

- $E_{IT\_external\_server}$ = the total annual energy consumption for servers (ITE) in all CSP locations;
- $E_{IT\_external\_storage}$ = the total annual energy consumption for storage (ITE) in all CSP locations;
- $E_{IT\_external\_network}$ = the total annual energy consumption for network (ITE) and NTE in all CSP locations.

However, it may be impossible to obtain this information and alternative methods may be applied.

One potential solution is to use a system monitoring tool able to quantify the Users demand of IT resources by measuring the CPU, I/O disk and network "operations" (i.e. events triggering the use of each resource) and to compare this with the total "operation" capacity of the CSP facilities.

The migrated demand of the User are:

$$CSP_{total\_User} = operations_{compute} + operations_{disk\ I/O} + operations_{network\ I/O}$$

The total "operation" capacity of the CSP can be described as

$$CSP_{total\_capacity} = \sum_{i=1}^{i=N} capacity_{compute_i} + \sum_{i=1}^{i=N} capacity_{disk\ I/O_i} + \sum_{i=1}^{i=N} capacity_{network\ I/O_i}$$

where:

$CSP_{total\_capacity}$ = capacity for all operations of all data centres (1 to N) supporting migration

$capacity_{compute_i}$ = capacity for compute operations of data centre *i* supporting migration

$capacity_{disk\ I/O_i}$ = capacity for disk input/output (I/O) operations of data centre *i* supporting migration

$capacity_{disk\ I/O_i}$ = capacity for network I/O operations of data centre *i* supporting migration

This may be assessed in terms of operations undertaken by the ICT equipment using an aggregated value of "million instructions per second (MIPS)" or similar.

If the CSP applies appropriate tools to measure the Users demand and total capacity on an equivalent basis then, with reference to clause 6.3.2, an approximation may be made:

$$E_{DC\_external} = \frac{CSP_{total\_User}}{CSP_{total\_capacity}} \times \sum_{i=1}^{i=N} E_{DC_i}$$

However, this gives no information about the values of $CO2_{external}$ or $H2O_{external}$ unless the details of the CSP locations and associated values of $CO_2equiv_{DC\_external_i}$ and $H20_{DC\_external_i} \times BWS_i$ are known as per clause 6.3.3.

For GHG emissions see clause 6.3.2.1.

For water consumption see clause 6.3.2.1.

6.3.3 Averaging methods

If it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value. This can then be used to calculate $CO2_{external}$ using the average value of $E_{DC\_external_i}$ and $CO_2equiv_{external_i}$.

If it is impossible to obtain separate values for $H2O_{\_external}$ for each data centre/ICT site then it is possible to use an average value. This can then be used to calculate $H2O_{external}$ using the average value of $H2O_{DC\_external_i}$ and BWS_i.

7 Comparing internal and outsourced approaches

7.1 General

Clause 6 provides detailed formulae for the comparison of internal and external solutions.

In all cases, the User will have to provide its own survey based on the scale of its ICT assets that would be affected. However, there are some fundamental questions which need to be answered before decision on external hosting is reached. These include:

1) What is to be outsourced?

2) What type of hosting is required?

3) What are the geographic requirements for the hosting (this could be for legal reasons, security and confidentiality guarantees but can have a non-negligible effect on comparative outcomes)?

In case of a proposed move to cloud hosting, the need could be to simply access an IT infrastructure offering compute, storage and networking (IaaS) or to have "ready to deploy" environments for its own applications (PaaS), or have internet access to a full end-to-end service (SaaS).

In all cases, migration to external hosting solutions enable re-deployment of space in the Users premises. The present document does not address any comparison of sustainability parameters relating to this factor.

Table 4 summarises the other general comparisons which are described more fully in this clause.

Table 4: Summary of migration comparisons

	Sharing technical infrastructure	Sharing ICT equipment	ICT infrastructure commoditization	Service-oriented model
Co-location	✓	×	×	×
Co-hosting	✓	✓	×	×
Cloud hosting	✓	✓	✓	✓

	Reduction of energy consumption	Reduction of GHG (CO_2) emissions	Reduction of water consumption	EoL
Co-location	Probable	Location dependent	Location dependent	No change
Co-hosting	Solution-specific			Unknown
Cloud hosting	Solution-specific			Unknown

While the financial analysis of capital and operational expenditure will be important, any comparison of sustainability parameters begins with the User obtaining the relevant information for the internal hosting solution. This will allow a comparison with the external hosting solution selected.

If any of the information specified in the present document cannot be obtained then it is not possible to assess the sustainability parameters of the solution and comparison with other solutions cannot be evaluated.

The comparison of sustainability parameters of the present document is based on four separate parameters which cannot be combined in any realistic manner.

See Annex D for some examples of comparison calculations.

7.2 Migrating from internal hosting to co-location

7.2.1 Example use case

In order to re-focus on core business, a User wishes to close one of its data centres and transfer its ICT equipment assets (except NTE) to a co-location facility.

This is the simplest case for a comparison of sustainability parameters since:

- the boundary of migration is clearly defined (the number of servers and storage devices);
- it is straightforward to evaluate the hosting accommodation required;
- $E_{IT\_external}$ is approximately the same as $E_{IT\_internal}$ (the only difference being that of NTE equipment);
- any difference of $E_{DC\_external}$ and $E_{DC\_internal}$ results from the different infrastructure overhead (which can be quantified by PUE);
- GHG (CO_2) emissions will be the difference in $E_{DC\_external}$ and $E_{DC\_internal}$ multiplied by the CO_2 equivalence of the country where the co-location data centre/ICT site is in the same country as the User's facilities;

NOTE: Where a co-location data centre/ICT site is in a different country to that of the User's facilities the applicable value of CO_2 equivalence will apply.

- any difference in water consumption will be driven by the cooling system of the User and the co-location host, taking into account the BWS of the two locations (which although probably being in the same country may have different values of BWS as shown in the examples of Annex C);
- EoL will be approximately the same for the User and the col-location host (the only difference being that of NTE equipment).

7.2.2 Energy consumption

The total value of $E_{IT\_internal}$ will reduce as all or part of the ICT equipment will be transferred to the SP facility. However, the total of $E_{IT\_internal} + E_{IT\_external}$ should not change materially as the ICT equipment has not changed (the only difference being that of NTE equipment).

NOTE 1: Migration to external hosting is often an opportunity renew the ICT equipment and also to initiate consolidation programs which will reduce $E_{IT\_external}$. In such cases, the User should undertake assessments to evaluate the gains generated by these actions.

If the PUE of the hosted facility is lower than that of the internally hosted facility(ies) the value of $E_{DC\_external}$ will be reduced. This will also impact GHG emissions.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-location solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- if it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value as described in clause 6.3.3;
- $E_{DC\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

Where $E_{IT\_external}$ or $E_{DC\_external}$ are difficult to obtain directly it is possible to base a value upon the percentage of the total computer room floor space that is allocated to the User's ICT equipment.

NOTE 2: This assumes that each co-location data centre/ICT site has an "all inclusive" energy consumption value/m², including the floor space and all the necessary supporting infrastructure hosting the ICT equipment.

7.2.3 GHG emissions

Co-location does not change the energy required by the re-located ICT equipment but any improvement in PUE of the SP facility (compared to that of the Users internal hosted facility(ies)) may reduce $E_{DC\_external}$.

In addition, any content of locally generated renewable energy will reduce the basis on which GHG emissions are calculated.

As it is probable that a co-location data centre/ICT site will be in the same country as the User, the overall difference in CO_2 emissions will reflect any reductions in $E_{DC\_external}$ and any contribution from locally generated renewable energy. Migration to a co-location solution should generally show a GHG emission reduction.

However, if the co-location data centre/ICT site is in a different country than that of the User, the difference in $CO2_{equiv}$ (see Annex B) may impact any reduction and may, in certain cases, reverse them.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $CO_{2\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ multiplied by the average value of $CO_2equiv_{external}$ across all data centres/ICT sites.

7.2.4 Water consumption

As highlighted in clause 5.6.1, water consumption depends on the cooling systems employed in the Users and the SP data centre/ICT site.

As a result, $v_{water\_external}$ may decrease or increase as compared to $v_{water\_internal}$ when migrating to the shared facilities of a SP. However, depending upon where the co-location facility is hosted, $H2O_{\_external}$, weighted using the BWS of clauses 6.2.2 and 6.3.2, may differ from that of the User's facilities.

As a result, water consumption can fall but because of differences in BWS, the overall situation as indicated by $H2O_{\_external}$ may be worse. However, it is unlikely that an SP would consider the use of facilities in areas of water scarcity due to the risk to service availability from such sites.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-location solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $H2O_{\_external}$ for each data centre/ICT site can be the average of the total $H2O_{\_external}$ multiplied by the average value of *BWS* across all data centres/ICT sites which use water for cooling.

7.2.5 EoL

The KPIs of clause 5.7 should be obtained.

7.3 Migrating from internal hosting to co-hosting

7.3.1 Example use case

The User has many small computer rooms and wishes to consolidate all the ICT equipment (except NTE) in a centralized location by renting several physical racks of servers and a storage capacity and transfer his systems, data and applications to the SP infrastructure.

A co-hosting solution:

- avoids the User having to retain (and maintain) the existing ICT equipment;
- changes the User's economic model from a combination of capital expenditure and operational expenditure to operational expenditure only.

In order to undertake a comparison of sustainability parameters, the User will have to evaluate the energy consumption, GHG emission and water consumption parameters for each computer room to be migrated using the formulae of clause 6.2.2.

However, the comparison of sustainability parameters of the co-hosting solution is more complex than for co-location since:

- the boundary of migration is not well defined (the number of servers and storage devices will not be comparable);
- $E_{IT\_external}$ is unrelated to $E_{IT\_internal}$ due to the selection and operation of the equipment which co-hosting solution uses to deliver the User's services;
- any additional difference of $E_{DC\_internal}$ and $E_{DC\_internal}$ from results from the different infrastructure overhead (which can be quantified by PUE);
- GHG (CO_2) emissions will be the difference in $E_{DC\_internal}$ and $E_{DC\_internal}$ multiplied by the relevant CO_2 equivalence values (a co-location host may not be in the same country as the User);
- any difference in water consumption will be driven by the cooling system of the User and the co-location host, taking into account the BWS of the locations;
- EoL will be not be comparable since the decision on EoL for ICT equipment moves from the User to the SP.

7.3.2 Energy consumption

The total value of $E_{IT\_internal}$ will reduce as all or part of the ICT equipment will be re-deployed or disposed of new ICT equipment rented at the SP facility.

In addition, the total of $E_{IT\_internal} + E_{IT\_external}$ may change due to standardization of the infrastructure, full shareability, mutualization of the resources, the use of server and storage virtualization techniques by the SP (balanced perhaps by data duplication and similar actions).

If the PUE of the hosted facility(ies) is lower than that of the internally hosted facility(ies) the value of $E_{DC\_external}$ will be reduced. This will also impact GHG emissions.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- if it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value as described in clause 6.3.3;
- $E_{DC\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

Where $E_{IT\_external}$ or $E_{DC\_external}$ are difficult to obtain directly it is possible to base a value upon the percentage of the total computer room floor space that is allocated to the User's resources.

NOTE: This assumes that each co-location data centre/ICT site has an "all inclusive" energy consumption value/m², including the floor space and all the necessary supporting infrastructure hosting the ICT equipment.

7.3.3 GHG emissions

Co-hosting uses new ICT equipment which may impact $E_{IT\_external}$ and any improvement in PUE of the SP facility(ies) (compared to that of the Users internal hosted facility(ies)) may reduce $E_{DC\_external}$.

In addition, any content of locally generated renewable energy will reduce the basis on which GHG emissions are calculated.

However, if at least some of the co-hosting data centre(s)/ICT site(s) are in a different country than that of the User, the difference in $CO2_{equiv}$ (see Annex B) may result in an increased level of GHG emissions despite a lower energy consumption.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $CO_{2\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ multiplied by the average value of $CO_2equiv_{external}$ across all data centres/ICT sites.

7.3.4 Water consumption

As highlighted in clause 5.6.1, water consumption depends on the cooling systems employed in the Users and SP data centre(s)/ICT sites.

As a result, $v_{water\_external}$ may decrease or increase as compared to $v_{water\_internal}$ when migrating to the shared facilities of a SP. However, depending upon where the co-location facility is hosted, $H2O_{\_external}$, weighted using the BWS of clauses 6.2.2 and 6.3.2, may differ from that of the User's facilities.

However, it is unlikely that an SP would consider the use of facilities in areas of higher levels of BWS level (see Annex C) due to the risk of service availability from such sites.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $H2O_{\_external}$ for each data centre/ICT site can be the average of the total $H2O_{\_external}$ multiplied by the average value of *BWS* across all data centres/ICT sites.

7.4 Migrating from internal hosting to cloud hosting

7.4.1 Example use case

There are many reasons which can encourage a User to migrate to a cloud hosting solution in place of the Users own IT resources and some typical use cases include:

- a User has a certain number of servers dedicated to development and wants to release all of them and have access to an appropriate infrastructure (i.e. IaaS);
- a User develops a new web-designed application or service for his clients or his internal users and wants to have access to "ready to deploy" environments as a service (i.e. PaaS);
- a User has an internal customer relationship management application running on a certain number of servers and wants to have full internet access to the application as a service (i.e. SaaS) offered by the CSP.

In the past, surveys published by major CSP and/or consulting offices frequently focus on commercial parameters such as cost, application efficiency, etc. but did not consider sustainability parameters (energy, CO_2, water) that may influence migration from internal hosting to cloud hosting solutions. More recently, CSPs are beginning to widen the scope of such survey to include sustainability factors.

In order to undertake a comparison of sustainability parameters of internally hosted and cloud hosted solutions, it is necessary to obtain data for the same parameters. Therefore, the CSP should provide the data required in clauses 6.3.2.and 6.3.3. While the CSP has knowledge of the energy consumption, CO_2 emissions and water consumption of each of its data centre(s)/ICT site(s), appropriate system monitoring tools are required to allocate the share to individual Users.

7.4.2 Energy consumption

The total value of $E_{IT\_internal}$ will reduce as all or part of it will be transferred to the CSP facility.

If the PUE of the hosted facility(ies) is lower than that of the internally hosted facility(ies) the value of $E_{DC\_external}$ will be reduced. This will also impact GHG emissions.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the cloud hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.2 can be one of the following:

- the actual values for each site;
- if it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value as described in clause 6.3.3;
- $E_{DC\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

7.4.3 GHG emissions

Cloud hosting uses new ICT equipment which may impact $E_{IT\_external}$ and any improvement in PUE of the CSP facility(ies) (compared to that of the Users internal hosted facility(ies)) may reduce $E_{DC\_external}$.

In addition, any content of locally generated renewable energy will reduce the basis on which GHG emissions are calculated.

However, if at least some of the CSP data centre(s)/ICT site(s) are in a different country than that of the User, the difference in $CO2_{equiv}$ (see Annex B) may result in an increased level of GHG emissions despite a lower energy consumption.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the cloud hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $CO_{2\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ multiplied by the average value of $CO_2equiv_{external}$ across all data centres/ICT sites.

7.4.4 Water consumption

As highlighted in clause 5.6.1, water consumption depends on the cooling systems employed in the Users and CSP data centre(s)/ICT sites.

As a result, $v_{water\_external}$ may decrease or increase as compared to $v_{water\_internal}$ when migrating to the shared facilities of a CSP. However, depending upon where the co-location facility is hosted, $H2O_{\_external}$, weighted using the BWS of clauses 6.2.2 and 6.3.2, may differ from that of the User's facilities.

However, it is unlikely that an CSP would consider the use of facilities in areas of higher levels of BWS level (see Annex C) due to the risk of service availability from such sites.

The formulae of clauses 6.2 and 6.3 should be applied for each solution being considered.

If the cloud hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clauses 6.3.2.1 can be one of the following:

- the actual values for each site;
- $H2O_{\_external}$ for each data centre/ICT site can be the average of the total $H2O_{\_external}$ multiplied by the average value of *BWS* across all data centres/ICT sites.

8 Comparing hosting approaches

8.1 Comparing co-location solutions

8.1.1 Energy consumption

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-location solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- if it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value as described in clause 6.3.3;

- $E_{IT\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

See Annex D for some examples of comparison calculations.

8.1.2 GHG emissions

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-location solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- if it is impossible to obtain separate values for $E_{DC\_external}$ for each data centre/ICT site then it is possible to use an average value as described in clause 6.3.3;
- $CO_{2\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ multiplied by the average value of $CO_2equiv_{external}$ across all data centres/ICT sites.

8.1.3 Water consumption

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-location solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $H2O_{\_external}$ for each data centre/ICT site can be the average of the total $H2O_{\_external}$ multiplied by the average value of BWS across all data centres/ICT sites.

8.1.4 EoL

This information is related to the Users ICT equipment and is constant for all co-location sites.

8.2 Comparing co-hosting solutions

8.2.1 Energy consumption

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $E_{DC\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ across all data centres/ICT sites;
- $E_{IT\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

8.2.2 GHG emissions

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $CO_{2\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ multiplied by the average value of $CO_2equiv_{external}$ across all data centres/ICT sites.

8.2.3 Water consumption

The formulae of clause 6.3 should be applied for each solution to be compared.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.1 can be one of the following:

- the actual values for each site;
- $H2O_{\_external}$ for each data centre/ICT site can be the average of the total $H2O_{\_external}$ multiplied by the average value of *BWS* across all data centres/ICT sites.

8.2.4 EoL

No comparison is possible.

8.3 Comparing cloud hosting solutions

8.3.1 Energy consumption

The formulae of clause 6.3.2.2 should be applied for each solution to be compared.

If the co-hosting solution is housed in multiple data centres/ICT sites, the values enabling the calculations using the formula of clause 6.3.2.2 can be one of the following:

- the actual values for each site;
- $E_{DC\_external}$ for each data centre/ICT site can be the average of the total $E_{DC\_external}$ across all data centres/ICT sites;
- $E_{IT\_external}$ for each data centre/ICT site can be the average of the total $E_{IT\_external}$ multiplied by the average PUE across all data centres/ICT sites.

8.3.2 GHG emissions

See clause 8.2.2.

8.3.3 Water consumption

See clause 8.2.3.

8.3.4 EoL

See clause 8.2.4.

8.4 Comparing external hosting solutions

The appropriate approaches of clauses 8.1, 8.2 and 8.3 should be applied.

Annex A: Basic services of cloud-based hosting

A.1 General

This annex presents some of the main basic services offered by CSP, recognizing that it is not exhaustive and other features could be offered in an "as a Service" form.

Figure A.1 is a general schematic of the services of clauses A.2, A.3 and A.4 mapped to the relevant cloud-based infrastructures.

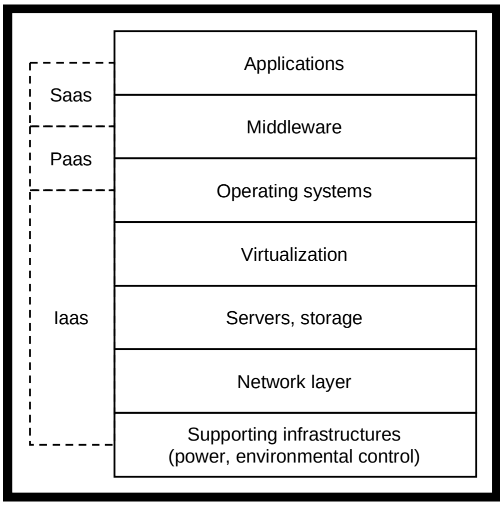

Figure A.1: Cloud hosting services and infrastructure

A.2 Infrastructure as a Service (IaaS)

IaaS are online services hosted on a cloud-based architecture which provide the various ICT infrastructure resources (including computing resources, location, data management, scaling up or down, security and backups) via remote application programming interfaces.

A.3 Platform as a Service (PaaS)

PaaS provides an environment for Users to develop, host and deploy and run their applications. This avoids the complexity of infrastructure management (setting up, configuring and managing elements such as servers, network and databases). When hosting on a PaaS, the Users continue to manage their own applications and data, while the CSP (in public PaaS) or ICT department (in private PaaS) manages runtime, middleware, OS, virtualization, servers, storage and networking. The CSP deliver a "ready to deploy" interface for applications services and tools. Users do not manage the underlying architecture including networks, storage, processing, servers, OS which are offered by the CSP.

A.4 Software as a Service (SaaS)

SaaS is an operating model for software in which it is executed on a remote cloud-based ICT infrastructure rather than on that of the User. Users do not pay the license fees and maintenance but can use it in "online service" mode and pay a subscription per User or an inclusive fee. The main current applications currently offered by CSPs on this model include:

- customer relationship management;

- e-commerce, e-learning;
- videoconferencing;
- human resources management;
- messaging and collaborative software;
- purchasing management.

SaaS is the delivery of resources and services that allow Users to fully outsource an aspect of their information systems and move to operating cost rather than invest in ICT equipment and license fees. SaaS is always associated with an SLA to define the level of QoS offered to Users.

Annex B: Generation of CO_2

The average ratio of kgCO_2/kWh for grid electricity in a large number of countries can be found in annually updated documents concerning Emission Factors published by the International Energy Agency. This is considered to be the appropriate source material for the formulae of clause 6.

Selected national-specific values are shown in Table B.1 (from https://www.rensmart.com/Calculators/KWH-to-CO2 and data from the European Environment Agency).

It is important to obtain the correct and most recent figures for the location of the data centre/ICT site under review.

Table B.1: Average ratio of kg/CO_2 per kWh in selected European countries

Country	CO_2 kg/kWh
Sweden	0,013
Lithuania	0,018
France	0,059
Austria	0,085
Latvia	0,105
Finland	0,113
Slovakia	0,132
Denmark	0,166
Belgium	0,17
Croatia	0,21
Luxembourg	0,219
Slovenia	0,254
Italy	0,256
Hungary	0,26
Spain	0,265
United Kingdom	0,281
Romania	0,306
Portugal	0,325
Ireland	0,425
Germany	0,441
Bulgaria	0,47
Netherlands	0,505
Czech Republic	0,513
Greece	0,623
Malta	0,648
Cyprus	0,677
Poland	0,773
Estonia	0,819

Annex C:
Baseline Water Stress (BWS)

Values for BWS covering world-wide regions are found at https://www.wri.org/applications/aqueduct/country-rankings/.

Baseline water stress measures the ratio of total water withdrawals to available renewable water supplies. Water withdrawals include domestic, industrial, irrigation and livestock consumptive and non-consumptive uses. Available renewable water supplies include surface and groundwater supplies and considers the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users.

Table C.1 defines the BWS levels.

Table C.1: BWS Levels

BWS	Stress level
0 - 1	Low
1 - 2	Low - medium
2 - 3	Medium - high
3 - 4	High
4 -5	Extremely - high

The present document uses BWS for industrial purposes and Table C.2 provides example information relating to the BWS (industrial) for different regions in selected European countries.

NOTE: The information may be subject to change (e.g. in line with climate change) and the latest data should be obtained for any comparisons.

Table C.2: Regional information of BWS (industrial)

Country	Region	BWS (industrial)
France	Hauts-de-France	3,70
	Bretagne	2,41
	Provence-Alpes-Côte d'Azur	1,42
Germany	Thüringen	3,46
	Baden-Württemberg	2,19
	Hamburg	0,84
Italy	Sicily	4,70
	Liguria	2,67
	Trentino-Alto Adige	1,31
United Kingdom	England	1,71
	Wales	0,25
	Scotland	0,21

Annex D: Example calculations for hosting solutions

D.1 General

This annex contains examples of application of the present document. The examples are for guidance purposes only and do not represent any specific real case.

D.2 Internal hosting data

The User's organisation operates two small/medium data centre/ICT sites: one in Hauts-de-France, France (with a PUE measured in accordance with CENELEC EN 50600-4-2 [i.3]) and another in Brussels, Belgium (with a default PUE of 3,0) and it is intended to combine the functions of both via external hosting. Neither site has a defined level of locally generated renewable energy. The data for energy consumption, GHG emissions (CO_2) and water consumption is shown in Table D.1 using the formulae of clause 6.2.2.

Table D.1: Internal hosting: energy consumption, GHG emission and water consumption

Site	$E_{IT\_internal}$	PUE	$E_{DC\_internal}$ ($E_{IT\_internal}$ x PUE)	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_internal}$ ($E_{DC\_internal}$ x (1-REF))
1	1,0 GWh	2,0	2,0 GWh	France	0,059	0	118,0 tonnes
2	0,75 GWh	3,0	2,25 GWh	Belgium	0,17	0	382,5 tonnes
Total	1,75 GWh	-	4,25 GWh	-	-	-	500,5 tonnes

Site	$E_{IT\_internal}$	$v_{water\_internal}$	Country	Location	BWS (see Annex C)	$H2O_{\_internal}$ ($v_{water\_external}$ x BWS)
1	1,0 GWh	0	France	Hauts-de-France	3.70	0
2	0,75 GWh	0	Belgium	Bruxelles	4,47	0
Total	1,75 GWh	0	-	-	-	0

It will be noticed that water consumption (using data from the reference provided in Annex C) is included in Table D.1. This is for completeness of analysis but the internal hosting data centres/ICT sites do not use water for cooling.

D.3 Co-location hosting data

In addition to moving their IT equipment to a more efficient data centre/ICT site infrastructure operated by an SP, the User desires to provide some degree of resilience by using two separate sites operated by the SP in France: one in Hauts-de-France and the other in Grand-Est.

Both sites have PUE and REF values measured in accordance with CENELEC EN 50600-4-2 [i.3] and CENELEC EN 50600-4-3 [i.4] respectively. The ratio of ICT equipment has been redistributed to prefer the lower PUE site and which also has a higher value for REF. The two proposed sites are close enough to allow a single operational and maintenance activity but they are subject to different values of BWS. The data for energy consumption, GHG emissions (CO_2) and water consumption is shown in Table D.2 using the formulae of clause 6.3.2.

Table D.2: Co-location hosting: energy consumption, GHG emission and water consumption

Site	$E_{IT\_external}$	PUE	$E_{DC\_external}$ ($E_{IT\_external}$ x PUE)	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
1	1,25 GWh	1,5	1,88 GWh	France	0,059	0,3	77,6 tonnes
2	0,5 GWh	1,8	0,9 GWh	France	0,059	0,1	47,8 tonnes
Total	1,75 GWh	-	2,78 GWh	-	-	-	115,4 tonnes

Site	$E_{IT\_external}$	$v_{water\_external}$ (see note)	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
1	1,25 GWh	700 m^3	France	Hauts-de-France	3,70	2 590 m^3
2	0,5 GWh	0	France	Grand-Est	2,32	0
Total	1,75 GWh	700 m^3	-	-	-	2 590 m^3
NOTE: A measured value (evaporative cooling approximates to 570 m^3 per GWh of $E_{IT\_external}$).						

When compared to the internal hosting solution of clause D.2, the proposed solution shows not only a benefit in terms of energy consumption and GHG emissions. However, Site 1 uses water for evaporative cooling and there is an environmental sustainability impact not present in the internal hosting solution.

Using averages as allowed in clauses 7.2.2, 7.2.3 and 7.2.4 provides the data in Table D.3.

Table D.3: Co-location hosting: "average" energy consumption, GHG emission and water consumption

Site	$E_{IT\_external}$	PUE	$E_{DC\_external}$ ($E_{IT\_external}$ x PUE)	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
All	1,75 GWh	1,65	2,89 GWh	France	0,059	0,2	136,4 tonnes

Site	$E_{IT\_external}$	$v_{water\_external}$[1]	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
All sites	1,75 GWh	700 m^3	France	Hauts-de France	3,70 (see note)	2 590 m^3
NOTE: Only one site has a measured water consumption and therefore the average is the value for that site.						

It is seen that the averaging method assumes an even division of ICT equipment, energy and water consumption across both sites. In this case, the method results in worse values for $CO2_{\_external}$ when compared to Table D.2. This indicates that there are clearly benefits to be obtained by preferentially locating the ICT equipment in Site 1 because its improved PUE and REF - but resilience requirements justify the use of multiple sites.

NOTE: The better value for BWS at Site 2 is irrelevant as it does not use water for cooling.

The analysis shown in Table D.2 and Table D.3 can be applied when comparing co-location solutions in accordance with clauses 8.1.1, 8.1.2 and 8.1.3.

It is important to note that the present document does not attempt, in any way, to compare or equate a reduced value for $CO2_{\_external}$ emissions with increased value for $H2O_{\_external}$.

D.4 Co-hosting data

Instead of the User moving the ICT equipment to the two separate co-location sites, the User is to rent space and ICT equipment in two sites operated by an SP: one in Grand-Est, France and the other in Wales, United Kingdom (UK).

Both sites have PUE and REF values measured in accordance with CENELEC EN 50600-4-2 [i.3] and CENELEC EN 50600-4-3 [i.4] respectively. The renting of new, more energy efficient, ICT equipment reduces both the energy consumption and the GHG emissions. The data for energy consumption, GHG emissions (CO_2) and water consumption is shown in Table D.4 using the formulae of clause 6.3.2.

Table D.4: Co-hosting: energy consumption, GHG emission and water consumption

Site	$E_{IT\_external}$	PUE	$E_{DC\_external}$ ($E_{IT\_external}$ x PUE)	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
1	0,90 GWh	1.4	1,26 GWh	France	0,059	0,1	66,9 tonnes
2	0,50 GWh	1,5	0,75 GWh	UK	0.281	0,3	147,5 tonnes
Total	1,40 GWh	-	2,01 GWh	-	-	-	214,4 tonnes

Site	$E_{IT\_external}$	$v_{water\_external}$ (see note)	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
1	0,90 GWh	500 m^3	France	Grand-Est	2,32	1 160 m^3
2	0,50 GWh	300 m^3	UK	Wales	0,21	63 m^3
Total	1,40 GWh		-	-	-	1 223 m^3
NOTE: A measured value (evaporative cooling approximates to 570 m^3 per GWh of $E_{IT\_external}$).						

When compared to the internal hosting solution of clause D.2, the proposed solution shows a benefit in terms of energy consumption and GHG emissions. However, as the larger sites operated by the SP use water for cooling, there is an environmental impact not present in the internal hosting solution but the selection of a location, Wales, with a low BWS value assists in this regard.

Where full data concerning the individual performance at the sites is not available it is possible to apply the "averaging" approach allowed in clauses 7.3.2, 7.3.3 and 7.3.4 as shown in Table D.5.

Table D.5: Co-hosting: "average" energy consumption, GHG emission and water consumption

Site	$E_{IT\_external}$	PUE	$E_{DC\_external}$ ($E_{IT\_external}$ x PUE)	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
All	1,40 GWh	1,45	2,03 GWh	France/ UK	0,17	0,2	276,1 tonnes

Site	$E_{IT\_external}$	$v_{water\_external}$ (see note)	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
All sites	1,40 GWh	800 m^3	France/ UK	Grand-Est/ Wales	1,7 (see note)	1 016 m^3
NOTE: Only one site has a measured water consumption and therefore the average is the value for that site.						

It is seen that the averaging method assumes an even division of ICT equipment, energy and water consumption across both sites. In this case, the method results in worse values for $CO2_{\_external}$ and $H2O_{\_external}$ when compared to Table D.4.

The analysis shown in Table D.4 and Table D.5 can be applied when comparing co-location solutions in accordance with clauses 8.2.1, 8.2.2 and 8.2.3.

It is important to note that the present document does not attempt, in any way, to compare or equate a reduced value for $CO2_{\_external}$ emissions with increased value for $H2O_{\_external}$.

D.5 Cloud hosting data

The User wishes to migrate to a hosting solution offered by a CSP. The CSP is known to operate from six separate sites in different regions of France and the UK and also in the Netherlands. Two of the three French sites do not use locally generated renewable energy (due to the low CO_2 equivalence of French grid supply) but the sites in the UK and the Netherlands use locally generated renewable energy.

Across the six sites, it has been identified that:

$$CSP_{total\_User} = 0{,}005 \times CSP_{total\_capacity}$$

In Table D.6 the value of $E_{DC\_external}$ applies the above factor to the total energy consumption of each site specified by the CSP.

Table D.6: Cloud hosting: energy consumption, GHG emission and water consumption

Site	Total site energy consumption	$E_{DC\_external}$	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
1	75 GWh	0,375 GWh	France	0,059	0	22,1 tonnes
2	60 GWh	0,300 GWh	UK	0,281	0,35	54,8 tonnes
3	90 GWh	0,450 GWh	France	0,059	0,15	22,6 tonnes
4	50 GWh	0,250 GWh	Netherlands	0,505	0,35	82.1 tonnes
5	80 GWh	0,400 GWh	UK	0,281	0,2	89,9 tonnes
6	35 GWh	0,175 GWh	France	0,059	0	10,3 tonnes
Total	390 GWh	1,95 GWh	-	-	-	281.8 tonnes

Site	$v_{water\_external}$ (see note)	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
1	187 m^3	France	Provence-Alpes-Côte d'Azur	1,42	266 m^3
2	0	UK	England	1,71	0 m^3
3	0	France	Bretagne	2.41	0 m^3
4	113 m^3	Netherlands	Zuid-Holland	0,69	78 m^3
5	189 m^3	UK	Wales	0,21	40 m^3
6	85 m^3	France	Hauts-de-France	3,70	315 m^3
Total	574 m^3	-	-	-	699 m^3
NOTE: A measured value (evaporative cooling approximates to 570 m^3 per GWh of $E_{IT\_external}$).					

It is clear that although the energy consumption is lowest for the cloud hosting solution, the use of multiple sites in different countries produces a total $CO2_{\_external}$ which, despite being lower than the internal hosting solution, is higher than it would be by accommodating all the sites in countries with lower values of CO_2 equivalence.

Where the CSP is only able to provide overall figures other than locations of the sites, Table D.7 shows the results when using the "averaging" approach as allowed in clauses 7.4.2, 7.4.3 and 7.4.4.

Table D.7: Cloud hosting: "average" energy consumption, GHG emission and water consumption

Site	Total site energy consumption	$E_{DC\_external}$	Country	CO_2equiv (see Annex B)	REF	$CO2_{\_external}$ ($E_{DC\_external}$ x (1-REF))
Total	390 GWh	1,95 GWh	France/UK/ Netherlands	0,207	0,175	333 tonnes

Site	$v_{water\_external}$ (see note)	Country	Location	BWS (see Annex C)	$H2O_{\_external}$ ($v_{water\_external}$ x BWS)
Total	574 m^3	France/UK/ Netherlands	Various	1,51 (see note)	861 m^3
NOTE: All sites have a measured water consumption and therefore the average is the value for those sites.					

It is seen that the averaging method assumes an even division of ICT equipment, energy and water consumption across all sites. In this case, the method results in worse values for $CO2_{\_external}$ and $H2O_{\_external}$ when compared to Table D.6.

The analysis shown in Table D.6 and Table D.7 can be applied when comparing co-location solutions in accordance with clauses 8.3.1, 8.3.2 and 8.3.3.

It is important to note that the present document does not attempt, in any way, to compare or equate a reduced value for $CO2_{\_external}$ emissions with increased value for $H2O_{\_external}$.

History

Document history		
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