Study for the review of Commission Regulation 2019/424 (Ecodesign of servers and data storage products)

Phase 2 – Update of the preparatory study

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1 Introduction to Task 1 Scope

The aim of Task 1 is to classify and define the products covered by the review of Commission Regulation (EU) 2019/424. The classification and definitions shall be in line with European Union (EU) product harmonisation legislation as well as from a technical, functional, economic, and environmental viewpoint. This classification and definition will be used as the basis for the review study.

The general scope of Regulation (EU) 2019/424 has been defined by the European Commission to cover servers and data storage products The objective of this chapter is to determine the product groups that are within Regulation (EU) 2019/424. In the following sections product scope, measurement and test standards and current legislation relating to Regulation (EU) 2019/424 will be discussed in detail. The project team intends to define this basic product scope with a focus on the environmental and economic aspects of servers and data storage products.

1.1 Product Scope

1.1.1 Product Classification

The product classification and definitions should be based on those provided within relevant Union harmonisation legislation, PRODCOM categories, other categories according to EN or ISO standards or other product specific categories drawn from labelling or sector specific categories, if not already defined by the above.

1.1.2 Prodcom categories (Eurostat)

There are seven categories defined by PRODCOM that cover servers and data storage products[1]. PRODCOM classifies servers and data storage products in the categories:

- NACE 26.20 “Manufacture of computers and peripheral equipment” and
- NACE 26.30 “Manufacture of communication equipment”[2].

The products covered under these categories which are relevant to this study, are presented below separated out by product type:

Servers:

- **26201400 –** Digital data processing machines: presented in the form of systems;
- **26201500 –** Other digital automatic data processing machines whether or not containing in the same housing one or two of the following units: storage units, input/output units;

Storage equipment:

- **26202100 –** Storage units;
- **26203000 –** Other units of automatic data processing machines (excluding network communications equipment (e.g. hubs, routers, gateways) for LANs and WANs and sound, video, network and similar cards for automatic data processing machines);

[1] https://ec.europa.eu/eurostat/web/main/home

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2119

- **26202200** - Solid-state, non-volatile data storage devices for recording data from an external source (flash memory cards or flash electronic storage cards), unrecorded

Servers and storage-related network equipment:

- **26302320** – Machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus;
- **26302370** – Other apparatus for the transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network (such as a local or wide area network), other than transmission or reception apparatus of HS 84.43, 85.25, 85.27 or 85.28.

These categories include a wide range of products, and it is not clear exactly which devices each category covers, as the aggregation level of data remains relatively high. There are some concerns when using the PRODCOM data, where the codes and their scope are not completely clear:

- The scope of 26.20.14.00 code is not completely clear but is more likely to be coding for computer mainframes.
- The scope of 26.20.15.00 code is not completely clear but is more likely to be coding for computer servers.
- 26.20.21.00 storage units may not apply to data storage devices as intended in the study. This is because it is possible the code is covering units such external hard drives, or USB keys.

1.1.3 Definitions

1.1.3.1 Servers, Data storage & Network equipment

Ecodesign Regulation 617/2013 for computers and computers servers

Previously, servers were captured within the Ecodesign Regulation 617/2013 for computers and computer servers [3]. This regulation introduced the following definitions: computer server, small-scale severs, blade system and components, server appliance, multi-node server, dual-mode server and computer servers with more than four processor sockets.

Ecodesign Regulation 2019/424 for servers and data storage products

Previous regulations only captured computer servers and no definitions were provided for data storage products. The Ecodesign Regulation 2019/424[4] covers servers and data storage products. The regulation provides the following definitions:

- '**server'** means a computing product that provides services and manages networked resources for client devices, such as desktop computers, notebook computers, desktop thin clients, internet protocol telephones, smartphones, tablets, tele-communication, automated systems or other servers, primarily accessed via network connections, and not through direct user input devices, such as a keyboard or a mouse and with the following characteristics:

[3] ttp://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:175:0013:0033:EN:PDF

[4] EUR-Lex - 32019R0424 - EN - EUR-Lex (europa.eu)

- it is designed to support server operating systems (OS) and/or hypervisors, and targeted to run user-installed enterprise applications;
- it supports error-correcting code and/or buffered memory (including both buffered dual in-line memory modules and buffered on board configurations);
- all processors have access to shared system memory and are independently visible to a single OS or hypervisor.

- '**server with more than four processor sockets'** means a server containing more than four interfaces designed for the installation of a processor. For multi-node servers, this term refers to a server having more than four processor sockets in each server node.
- '**server appliance'** means a server that is not intended to execute user-supplied software, delivers services through one or more networks, is typically managed through a web or command line interface and is bundled with a pre-installed OS and application software that is used to perform a dedicated function or set of tightly coupled functions
- **'resilient server'** means a server designed with extensive reliability, availability, serviceability and scalability features integrated in the micro architecture of the system, central processing unit (CPU) and chipset.
- '**multi-node server'** means a server that is designed with two or more independent server nodes that share a single enclosure and one or more power supply units. In a multi-node server, power is distributed to all nodes through shared power supply units. Server nodes in a multi-node server are not designed to be hot-swappable.
- **'network server'** means a network product which contains the same components as a server in addition to more than 11 network ports with a total line rate throughput of 12 Gb/s or more, the capability to dynamically reconfigure ports and speed and support for a virtualized network environment through a software defined network
- '**fully fault tolerant server'** means a server that is designed with complete hardware redundancy (to simultaneously and repetitively run a single workload for continuous availability in mission critical applications), in which every computing component is replicated between two nodes running identical and concurrent workloads (i.e., if one node fails or needs repair, the second node can run the workload alone to avoid downtime);
- **'server product family'** means a high-level description referring to a group of servers sharing one chassis and motherboard combination that may contain more hardware and software configurations. All configurations within a server product family must share the following common attributes:
  - a) be from the same model line or machine type;
  - b) either share the same form factor (i.e., rack-mounted, blade, pedestal) or share the same mechanical and electrical designs with only superficial mechanical differences to enable a design to support multiple form factors;
  - c) either share processors from a single defined processor series or share processors that plug into a common socket type;
  - d) share the power supply unit(s);
  - e) have the same number of available processor sockets and number of available processor sockets populated;
- **'High Performance Computing (HPC) server'** means a server which is designed and optimized to execute highly parallel applications, for higher

performance computing or deep learning artificial intelligence applications. HPC servers must meet all the following criteria:

- a) they consist of multiple computing nodes, clustered primarily to increase computational capability;
- b) they include high speed inter-processing interconnections between nodes;

- **'data storage product'** means a fully-functional storage system that supplies data storage services to clients and devices attached directly or through a network. Components and subsystems that are an integral part of the data storage product architecture (e.g., to provide internal communications between controllers and disks) are considered to be part of the data storage product. In contrast, components that are normally associated with a storage environment at the data centre level (e.g. devices required for operation of an external storage area network) are not considered to be part of the data storage product. A data storage product may be composed of integrated storage controllers, data storage devices, embedded network elements, software, and other devices.
- '**data storage device'** means a device providing non-volatile data storage, with the exception of aggregating storage elements such as subsystems of redundant arrays of independent disks, robotic tape libraries, filers, and file servers and storage devices which are not directly accessible by end-user application programs, and are instead employed as a form of internal cache;
- **'online data storage product'** means a data storage product designed for online, random-access of data, accessible in a random or sequential pattern, with a maximum time to first data of less than 80 milliseconds;
- '**active state efficiency'** (Eff_{server}) means the numerical value for server efficiency as measured and calculated according to Annex III point 3 of the Regulation.
- **'Idle state'** means the operational state in which the OS and other software have completed loading, the server is capable of completing workload transactions, but no active workload transactions are requested or pending by the system (i.e., the server is operational, but not performing any useful work). For servers where Advanced Configuration and Power Interface standards are applicable, idle state corresponds only to System Level S0;
- '**Active state'** means the operational state in which the server is carrying out work in response to prior or concurrent external requests (e.g., instruction over the network). Active state includes both active processing and data seeking/retrieval from memory, cache, or internal/external storage while awaiting further input over the network;
- **'server performance'** means the number of transactions per unit of time performed by the server under standardised testing of discrete system components (e.g. processors, memory and storage) and subsystems (e.g. RAM and CPU);
- '**maximum power'** (P_{max}) means the highest power, in Watts, recorded on the eleven worklet scores according to the standard;
- '**CPU performance (PerfCPU)**' means the number of transactions per unit of time performed by the server under standardised testing of the CPU subsystem;
- **'power supply unit' (PSU)** means a device that converts alternate current (AC) or direct current (DC) input power to one or more DC power outputs for the purpose of powering a server or a data storage product. A server or data storage

product PSU must be self-contained and physically separable from the motherboard and must connect to the system via a removable or hard-wired electrical connection;

- **'direct current server'** means a server that is designed solely to operate on a DC power source;
- **'direct current data storage product'** means a data storage product that is designed solely to operate on a DC power source;
- '**Auxiliary Processing Accelerator' (APA)** means a specialized processor and associated subsystem that provide an increase in computing capacity such as graphical processing units or field programmable gate arrays. An APA cannot operate in a server without a CPU. APAs can be installed in a server either on Graphics or Extension add-in cards installed in general-purpose add-in expansion slots or integrated into a server component such as the motherboard;
- '**Expansion APA'** means an APA that is on an add-in card installed in an add-in expansion slot. An expansion APA add-in card may include one or more APAs and/or separate, dedicated removable switches;
- '**Integrated APA'** means an APA that is integrated into the motherboard or CPU package;

Definitions are also provided for disassembly, secure data deletion and firmware but were not included here because these will be discussed in greater detail by the project team in Task 3 and Task 4.

The following products are not currently covered by the Ecodesign Regulation for servers and data storage products:

a) servers intended for embedded applications;
b) servers classified as small scale servers in terms of Regulation (EU) No 617/2013;
c) servers with more than four processor sockets;
d) server appliances;
e) large servers;
f) fully fault tolerant servers;
g) network servers;
h) small data storage products;
i) large data storage products.

U.S. Environmental Protection Agency's (EPA) ENERGY STAR Program

Definitions in version 4.0 ENERGY STAR® specification for computer servers

The current specification[5] provides a comprehensive set of definitions for types of server products, server form factors, server components, other data centre equipment, operational aspects and power states, product families and their testing

5 https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.0%20Computer%20Servers%20Final%20Specification.pdf

configurations and a list of key terms. The definitions covered by ENERGY STAR are very similar to those covered by the Regulation 2019/424.

The ENERGY STAR® specification for computer servers captures a broad taxonomy of useful definitions of server types and subcategories which will be useful for this review study:

- **'Computer Server'**: "A computer that provides services and manages networked resources for client devices (e.g., desktop computers, notebook computers, thin clients, wireless devices, PDAs, IP telephones, other computer servers, or other network devices). A computer server is sold through enterprise channels for use in data centers and office/corporate environments. A computer server is primarily accessed via network connections, versus directly-connected user input devices such as a keyboard or mouse […]" The ENERGY STAR certification specifies in detail the characteristics of a computer server, this is provided in A1.1.
- **'Resilient Server'**: "A computer server designed with extensive Reliability, Availability, Serviceability (RAS) and scalability features integrated in the micro architecture of the system, CPU and chipset". The ENERGY STAR certification specifies in detail the characteristics of a resilient server, this is provided in A1.1.
- **'Blade System'**: "A system comprised of a blade chassis and one or more removable blade servers and/or other units (e.g., blade storage, blade network equipment). Blade systems provide a scalable means for combining multiple blade server or storage units in a single enclosure, and are designed to allow service technicians to easily add or replace (hot-swap) blades in the field".
- **'Blade Server'**: "A computer server that is designed for use in a blade chassis. A blade server is a high-density device that functions as an independent computer server and includes at least one processor and system memory, but is dependent upon shared blade chassis resources (e.g., power supplies, cooling) for operation. A processor or memory module that is intended to scale up a standalone server is not considered a Blade Server."
- **'Fully Fault Tolerant Server'**: "A computer server that is designed with complete hardware redundancy, in which every computing component is replicated between two nodes running identical and concurrent workloads (i.e., if one node fails or needs repair, the second node can run the workload alone to avoid downtime). A fully fault tolerant server uses two systems to simultaneously and repetitively run a single workload for continuous availability in a mission critical application".
- **'Storage Heavy Server'**: "A computer server with greater storage capacity than a standard computer server. As shipped, these computer servers support 30 or more internal storage devices. These servers differ from Storage Products in that they run computer server operating systems and software stacks".
- **'Server Appliance'**: "A computer server that is bundled with a pre-installed OS and application software that is used to perform a dedicated function or set of tightly coupled functions. Server appliances deliver services through one or more networks (e.g., IP or SAN), and are typically managed through a web or command line interface. Server appliance hardware and software configurations are customized by the vendor to perform a specific task (e.g., name services, firewall services, authentication services, encryption services, and voice-over-IP (VoIP) services), and are not intended to execute user-supplied software";

- **Hyperconverged Server**: Hyperconverged Server: A highly integrated server which contains the additional features of large network equipment and storage products.
- '**High Performance Computing (HPC) System'**: A computing system which is designed, marketed, sold, and optimized to execute highly parallel applications for high performance, deep learning, or artificial intelligence applications. HPC systems consist of multiple clustered computer servers, primarily for increased computational capability, high speed nter-processing interconnects, large and high bandwidth memory capability and often auxiliary processing accelerators. HPC systems may be purposely built, or assembled from more commonly available computer servers.

Full definitions are provided in Annex 1 of this document. The specification also defines sub-categories according to components, form factor, other key terms relating to servers, common product family attributes and product family tested configurations. The definitions are the result of a complex and long stakeholder process, making them current and sensible.

The following products scope is eligible under Version 4.0: "*Blade-, Multi-node, Rack-mounted, or Pedestal form factor computer servers with no more than four processor sockets in the computer server (or per blade or node in the case of blade or multi-node servers)".*

The following products are explicitly excluded from Version 4.0:

1. Computer Servers shipped with Integrated APAs;
2. Computer Servers which are only shipped with at least one APA;
3. Fully Fault Tolerant Servers;
4. Server Appliances;
5. High Performance Computing Systems;
6. Large Servers;
7. Hyperconverged Servers;
8. Storage Products including Blade Storage; and
9. Large Network Equipment.

Definitions in v2.1 ENERGY STAR® specification for data centre storage equipment

The Version 2.1 ENERGY STAR® Specification for Data Centre Storage[6] took effect on March 15, 2021. It belongs to the suite of data centre equipment specifications, which currently includes Computer Server, Uninterruptible Power Supply, and Large Network Equipment specifications.

This specification aims to differentiate energy efficient data centre storage equipment to help data centre operators select products that will save them money on their energy bills, assist manufacturers of efficient equipment in increasing sales, and drive down the energy use of data centres, estimated to be more than 2% of total US electricity consumption.

The Version 2.1 Specification requires all products to test and submit data using the Storage Networking Industry Association (SNIA) Emerald Power Efficiency Measurement Specification V4.0.0.

The specification provides the following useful definitions relating to data storage products:

[6] ENERGY STAR Data Center Storage Version 2.1 Final Specification

- **'Storage product:** '"A fully-functional storage system that supplies data storage services to clients and devices attached directly or through a network. Components and subsystems that are an integral part of the storage product architecture (e.g., to provide internal communications between controllers and disks) are considered to be part of the storage product. In contrast, components that are normally associated with a storage environment at the data center level (e.g., devices required for operation of an external SAN) are not considered to be part of the storage product. A storage product may be composed of integrated storage controllers, storage devices, embedded network elements, software, and other devices. For purposes of this specification, a storage product is a unique configuration of one or more SKUs, sold and marketed to the end user as a Storage Product."
- **'Storage Device':** "A collective term for disk drives (HDDs), solid state drives (SSDs), tapes cartridges, and any other mechanisms providing non-volatile data storage. This definition is specifically intended to exclude aggregating storage elements such as RAID array subsystems, robotic tape libraries, filers, and file servers. Also excluded are storage devices which are not directly accessible by end-user application programs and are instead employed as a form of internal cache."
- **'Storage Controller'**: "A device for handling storage request via a processor or sequencer programmed to autonomously process a substantial portion of I/O requests directed to storage devices (e.g., RAID controllers, filers)."
- **'Direct-attached Storage (DAS)':** One or more dedicated storage devices that are physically connected to one or more servers.
- **'Network Attached Storage (NAS)':** One or more dedicated storage devices that connect to a network and provide file access services (File I/O) to remote computer systems.
- **'Storage Area Network (SAN)':** A network whose primary purpose is the transfer of data between computer systems and storage products. A SAN consists of a communication infrastructure, which provides physical connections, and a management layer, which organizes the connections, storage controllers / devices, and computer systems so that data transfer is secure and robust. The term SAN is usually (but not necessarily) identified with block I/O services rather than file access services.
- **'Capacity Optimising Methods (COMs)':** The reduction of actual data stored on storage devices through a combination of hardware and / or software.
- **'Non-volatile Solid State (NVSS) Set Disk Access Storage':** Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short response time. All data stored in NVSS Set Disk Access Online storage must be accessible MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. NVSS Set Disk Access Online storage is typically comprised of one or more SSDs and a storage controller and provides primary data storage to supplement a Computer Server's internal memory.
- **'NVSS Set Memory Access Storage'**: Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short response time. All data stored in NVSS Set Memory Access Online storage must be accessible MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. NVSS Set Memory Access Online storage is typically comprised of one or more

banks of Solid State Storage devices and a storage controller and provides primary data storage to supplement a Computer Server's internal memory.

- **'Ready Idle'**: "The state in which a storage product is able to respond to arbitrary I/O requests within the MaxTTFD limits for its taxonomy category but is not receiving external I/O requests. The storage product may perform routine housekeeping tasks during Ready Idle, provided such operations do not compromise the product's ability to meet MaxTTFD requirements".
- **'Deep idle'**: "A state in which one or more storage product components or subsystems have been placed into a low-power state for purpose of conserving energy. A storage product in Deep Idle may not be able to respond to I/O requests within the MaxTTFD limits for its taxonomy category and may need to perform a managed 'wake-up' function in order to return to a Ready Idle or Active State. Deep Idle capability must be a user-selected, optional feature of the storage product."
- **'Power Supply Unit (PSU**)': "A device that converts ac or dc input power to one or more dc power outputs for the purpose of powering a storage product. A storage PSU must be self-contained and physically separable from the system and must connect to the system via a removable or hard-wired electrical connection. Note: Storage PSUs may be Field Replaceable Units (FRUs), but in some cases may be further integrated with the storage product."
- **'Ac-dc Power Supply'**: "A PSU that converts line-voltage ac input power into one or more dc power outputs."
- **'Dc-dc Power Supply'**: "A PSU that converts line-voltage dc input power to one or more dc power outputs. For purposes of this specification, a dc-dc converter (also known as a voltage regulator) that is internal to a storage product and is used to convert a low voltage dc (e.g., 12 V dc) into other dc power outputs for use by storage product components is not considered a dc-dc power supply."

The following products are specifically excluded from certification under this specification:

I. Personal / Portable Data Storage Products;
II. Computer Servers;
III. Blade Storage Products;
IV. Direct Attached Storage Products
V. Storage Products capable of only object-based storage; Storage devices in the following categories of the taxonomy: Disk Set Near-Online, RVML Set Removable Media Library, RNML Set Virtual Media Library and NVSS Set Memory Access.

Definitions in v1.1 ENERGY STAR® specification for large networking equipment

The Version 1.1 ENERGY STAR® Specification for Large Network Equipment[7] took effect on March 1, 2016. The Version 1.1 specification provides the following useful definitions:

- **Network Equipment**: "A device whose primary function is to pass Internet Protocol traffic among various network interfaces/ports."

[7] ENERGY STAR LNE Final Version 1.1 Specification

- **Large Network Equipment (LNE)**: "Network Equipment that is mountable in a Standard Equipment Rack, supports network management protocols (e.g. SNMP) and contains at least one of the following features:
  - Contains more than eleven (11) Physical Network Ports.
  - Total aggregate port throughput of the product is greater than 12 Gb/s"
- **Small Network Equipment (SNE):** Network Equipment that is intended to serve users in either small networks or a subset of a large network. SNE includes a) all Network Equipment with integral wireless capability and b) other Network Equipment meeting all of the following criteria:
  I. Designed for stationary operation ENERGY STAR Program Requirements for Large Network Equipment – Eligibility Criteria Page 3 of 10
  II. Contains no more than eleven (11) wired Physical Network Ports; and
  III. Primary configuration for operation outside of standard equipment racks

The products explicitly excluded from Version 1.1 include the following:

- Products that contain greater than four Physical Network Ports that have 100 Gb/s or higher link rate capability.

The following products are not eligible for certification under the ENERGY STAR Program:

- Small Network Equipment;
- Computer Servers, including blade switches sold within a Blade Server configuration;
- Storage Products, including Blade Storage; iv. Storage Networking Products;
- Security Appliances;
- Access Point Controllers;
- DSLAM/CMTS equipment;
- Network Caching Devices; and
- Load Balancing Devices.

Storage Networking Industry Association (SNIA)

Version 4.0.0 of the SNIA Emerald™ Power Efficiency Measurement Specification[8] was released in July 2020. This specification has defined storage products in terms of their operational profiles and supported features. It provides a method for assessing the energy efficiency of commercial storage products in active and idle states.

In 2019, ISO published the international standard, ISO/ IEC 24091:2019 Information Technology – Power Efficiency Measurements Specification for data centre storage[9]. This converted the SNIA standard into an international standard which describes an internationally standardised methos to assess the energy efficiency of data storage products.

The SNIA Green Storage TWG Taxonomy makes the distinction of six product group categories with differing operational profiles:

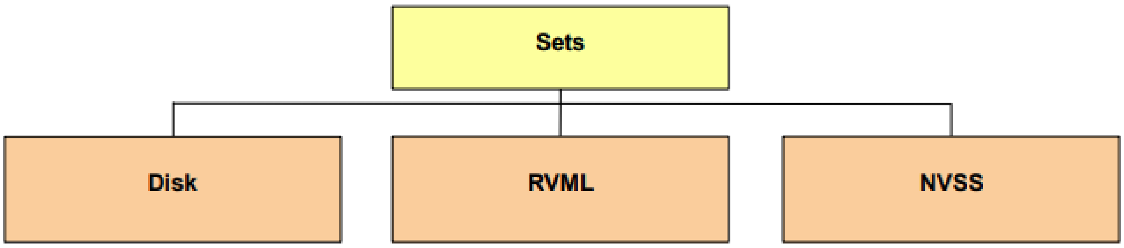
[8] SNIA Emerald™ Power Efficiency Measurement Specification

[9] ISO/IEC 24091:2019 - Information technology — Power efficiency measurement specification for data center storage

- **Disk Set Online**: Storage system for very fast random or sequential I/O request. The main distinction type is the maximum TTFD of <80ms.
- **Disk Set Near-Online:** Storage system for moderate random or sequential I/O request. The main distinction type is the maximum TTFD of >80ms.
- **RVML Set Removable Media Library:** System for sequential I/O request with a long response time (maximum TTFD <5 min). This is an automated or manual media loader such as a tape or optical library.
- **RVML Set Virtual Media Library**: System for very fast sequential I/O request with maximum TTFD of <80ms. The media are not removeable and are for long term data storage.
- **NVSS Set Disk Access**: Storage system for very fast random or sequential I/O request with a maximum TTFD of <80ms. Defines the features and functionalities for an online, random access, Solid State Storage-based disk access storage product. Offers disk access if it provides data access using storage paradigm. Products provide any combination of block, file or object interfaces.
- **NVSS Set Memory Access:** Storage system for very fast random I/O request with a maximum TTFD of <80ms. Defines the features and functionalities for an online, random-access, Solid-State Storage-based memory access storage product. Offers memory access if it provides host access to storage using memory primitives. Products provide a memory interface.

SNIA also define a broad set of groupings of storage products. Figure 1.1 below gives more information on these grouping which all share a similar system of characteristics. Products within different sets are generally not comparable in performance or power efficiency characteristics.

Figure 1.1 Taxonomy Overview defining the grouping of storage products[10]



Top-Runner Program (Japan)

The Japanese Top-Runner-Program currently covers Computer and Magnetic Disk Units[11]. This legislation has been in place since 2007 with no revisions conducted on this technology since then. There is also a legislation for Small Routers & L2 Switches, this was published in 2008 and has not been revised since[12].

[10] SNIA Emerald™ Power Efficiency Measurement Specification

[11] tr_computers_magneticdiscunits_dec2009.pdf (eccj.or.jp)

[12] https://www.eccj.or.jp/top_runner/pdf/tr_small_routers-apr_2008.pdf

Definition of Server Computers and classification

The following relevant definitions for servers are provided within Top Runner:

- Server-type computers refer to a computer that is designed to operate 24 hours a day and provide services on a network, and which can be accessed only via a network.
- Server computers are classified and distinguished by the CPU type and number of I/O slots.
- Dedicated CISC (Complex Instruction Set Computer): Used in high-functionality processors with a diverse instruction set. It is primarily used in mainframe servers and similar products.
- RISC (Reduced Instruction Set Computer): This type of processor uses a simplified instruction set in order to prioritize high speed, and is primarily used in UNIX servers and similar devices.
- IA64, IA32: These are typical architectures for general-purpose CISC microprocessors that are universally used in products from personal computers to high-functionality servers. IA32 is a 32-bit microprocessor architecture, and is primarily used in products such as IA servers. IA64 is a 64-bit microprocessor architecture, and is primarily used in products such as high-functionality servers.

Definition of data storage Hard Disk Drives

The following definitions are provided by the Top-Runner Program for storage equipment:

- Individual disk: refers to a single disk drive. For individual disks, cases that bear a type name shall be considered 1 unit.
- Sub-system: refers to a product with multiple disk drives. For sub-systems, the magnetic disk control unit and HDD shall together be considered 1 unit. (For products that only use a magnetic disk controller that is built into a computer, cases that bear a type name shall be considered 1 unit.).

Definition from the Small Router

The following definition of relevance to this study is provided in the Top Runner Legislation for small routers and L2 switches:

- Small routers: Targeted routers are all of those intended mainly to relay network data using the third layer (network layer), among models whose communication function is structured in layers based on OSI (Open System Interconnection) established by ISO (International Organization for Standardization). To be specific, they are products which relay network data referring to IP addresses. Here, this relay operation means that a router counts TTL of IP address header information backward and relays data to other data links. Among routers defined in the above, small routers are those with effective transmission rate of 200 Mbit/s or below (100 Mbit/s or below for wireless routers).

1.1.4 Preliminary product scope and definitions

Regulation 2019/424 scope covers servers and data storage products, which encompasses a broad range of products. As per Article 8 of 2019/424 the Commission shall assess this regulation, presenting the results of the assessment and if appropriate suggest draft revisions. Effective from March 2020, the Lot 9 regulation introduced minimum requirements for servers and data storage products on the EU market. From January 2023 the requirements for applicable power supply efficiency and power factor limits were made more stringent.

1.1.4.1 Product scope criteria

Servers and data storage products are understood as professional equipment which are marketed and sold through enterprise channels in a business-to-business environment. Servers and data storage products are comprised of a minimum hardware and software configuration. The 19-inch computer rack cabinet is the most widely used way to mount servers, data storage products and network equipment.

The preliminary criteria used in the last preparatory study to specify in more detail the scope of Regulation 2019/424 were reassessed and are still applicable under this review, therefore more detail is presented in the following section.

Operating location

- This considers where the equipment is operated and by whom. Often servers and data storage products are collated in large number fulfilling their intended service within the same room. Collectively this is known as a data centre. Data centres often have a customised infrastructure for power distribution, air conditioning, monitoring, safety, and administration. The Regulation 2019/424 primarily targets servers and data storage products in a professional environment (server rooms or data centres).

Product vs. system approach

- The Ecodesign Directive (2009/125/EC) implements a product approach. Thus, all implementing measures address single products only and not interactive systems or complete installations. Consequently, Regulation 2019/424 covered fully functional singular products and not complete installations, such as a data centre. Servers and data storage products despite their interdependencies will be analysed at the product level during this study.

  System performance considerations are discussed in greater detail within the Phase 1 report, see Section 2.10. A system in this case is considered the server and the Data Centre. The Phase 1 report considers two parameters which affect the energy consumption of data centres. These parameters include reducing the energy consumption of servers and the operating conditions of the servers themselves.

Volume vs. custom made products

- Currently on the EU market original equipment manufacturers (OEM) offer different product types and configurations for various purposes. Allowing the purchaser to choose a configuration that is best suited to their requirements. OEMs can customise product solutions according to the specification of the purchaser and their service level agreement (SLA) requirements. Since the EE Directive primarily focuses on products with significant sales and market impacts and that it is not practical to implement custom made products within the current Regulation. The Regulation will focus on typical volume products.

  The Phase 1 report highlights the issue of custom-made products within items c, e and f, this is covered in Section 2.2 of the report. It was recommended that custom made products remain exempt from the Regulation's energy efficiency information and criteria. However, a definition for custom servers should be added to the Regulation. This ensures that server configurations are not inappropriately deemed as ‘custom made’.

B2B-market

- This considers the market channels through which servers and data storage products are sold and purchased. Regulation 2019/424 targets professional servers and data storage products with small scale servers explicitly excluded from the regulation. Therefore, these products are sold in a Business-to-Business environment.

Quality of service:

- The legal framework and service condition under which servers and data storage products operate within are considered within the scope of the Regulation.

1.1.4.2 Servers

Preliminary product definition and scope

Regulation 2019/424 provides the definitions for servers as a computing product that provides services and manages networked resources for client devices. They include products that have the following characteristics:

- Servers are designed to support server operating systems and/or hypervisors, and targeted to run user-installed enterprise applications.
- Support error-correcting code and/or buffered memory
- All processor have access to share system memory and are independently visible to a single OS or hypervisor.

Server appliances, large servers, fully fault tolerant servers and network servers were exempt from the scope of the regulation.

Resilient servers, High Performance Computing (HPC) servers and servers with integrated APA were exempt from the energy efficiency requirements of active efficiency and idle state power consumption, which are set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

Recommendations from the Phase 1 report

Section 2.2 of the Phase 1 report covers the recommendations put forward for updating the definitions for servers.

To ensure clarity and harmonisation, it is recommended to align product definitions with Energy Star, EPEAT, ISO/IEC 21836:2020 and ETSO EN 303 470. In particular, an update should be considered for the definitions of resiliency under the resilient server definition and the High-Performance Computing (HPC) servers as these do not align with ENERGY STAR. Furthermore, definitions specifically for resilient servers’ recovery section and HPC servers should be updated to align with the latest industry standard. We also recommend the inclusion of the following definitions:

- Storage heavy servers: A computer server with greater storage capacity than a standard computer server. As shipped, these computer servers support 30 or more internal storage devices. These servers differ from Storage Products in that they run computer server operating systems and software stacks.

- Hyperconverged Server: Hyperconverged Server: A highly integrated server which contains the additional features of large network equipment and storage products.
- For large servers, we recommend for their exclusion from the regulation to be maintained.

We recommend the inclusion of fully fault tolerant servers, and hyperconverged servers into the regulation, with an exemption granted for energy efficiency requirements set out in Annex II point 2.1 and point 2.2, where these products are not yet in the test standard scope.

For custom servers, we recommend creating a definition within the regulation in order to ensure that server configurations are not inappropriately deemed as “custom made”. The regulation has an exemption for the provision of energy efficiency information for custom made servers, the same exemption should be extended for energy efficiency criteria as these devices are not in scope for the SERT testing standard. The definition for custom made servers needs to be careful not to allow for market loopholes.

With regards to server appliances, these are out of scope of both SPEC SERT tool and ISO/IEC 21836:2020 standard which makes their inclusion into energy efficiency criteria difficult. Our recommendation is to include server appliances into the regulation, with specific exclusions for energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

As networks servers may be better defined as large network equipment, they are not in scope for the SERT test standard. They can therefore not be included in the active efficiency and idle score metrics, and that exemption should be maintained. We recommend investigating if network servers can be included into a regulation for network equipment in order for them to be measured under the ATIS test method.

As resilient servers are included in the scope of SPEC SERT, we recommend removing their exemption from the energy efficiency criteria. Research can be done to consider accommodations with regards to their higher uptime availability.

We recommend maintaining the exclusions on energy efficiency metrics (from annex II point 2.1 and point 2.2) granted to High Performance Computing (HPC) servers and servers with integrated APA as these devices are out of scope of the testing standards SPEC SERT tool and the ISO/IEC 21836.2020. The definition of servers with integrated APAs should be updated for clarity.

SPEC has shared that SERT V3 will be developed over the next two years, which should address HPC servers and those with many types of integrated APAs. The commission could look to include HPC servers and servers with integrated APAs into the regulation after SERT has updated the standard.

Section 2.11 of the Phase 1 report is recommending developing definitions for liquid cooled servers. The following definitions are recommended by the study team:

- liquid cooled servers are defined as servers where cooling liquid is in direct thermal contact with server components.

For indirect cooling systems applying to the rack, these are simple and cost effective, but are sold as separate equipment to the server and are therefore out of scope of the Ecodesign regulation. In addition, liquid cooling to the chips is largely limited to HPC systems, which are also out of scope of the Regulation. Therefore, no definitions are required for either of these

Regulated server products are currently tested under SERT in an air-cooled configuration. As the implementation of liquid cooling onto those servers is likely to increase efficiency and their low market share, no action is required on this front at this time. However, this technology should be monitored to ensure that if market share grows, the next Ecodesign revision may need to review regulatory action. A definition for liquid-cooled servers is needed, to ensure that servers that are only manufactured in liquid cooled versions are exempt from energy efficiency criteria of the regulation.

Functional unit

Servers contain hardware and software elements that provide computing services or task specific applications via a network. The design and configuration of a server is defined by the functionality and performance, the scalability and form factor, and the configuration for a specific service level.

The parameters that are used to characterise servers are provided below Table 1.1.

Table 1.1 Server characterisation parameters

Process Architecture	Form factor and modularity	Serviceability	Performance/Application
• x86 (Intel, AMD) • Unix (SPARC RISC) • Other (e.g. ARM)	• Pedestal (tower) • Rack-optimised • Blade system • Multi-node • Large/ Mainframe • Embedded/ Barebone	• Managed • Operation System • Resilient server	• Micro server • HPC server • Fully fault tolerant server • Server appliances • Large/ Mainframe

The energy consumption and product performance over its lifetime is defined by the configuration and utilisation aspects. Due to heterogenous nature of server configurations and actual utilisation, it is not possible to define specific functional units that are based on certain performance parameters.

1.1.4.3 Data Storage Products

Product definition and preliminary scope

Regulation 2019/424 provides the definitions for data storge products as a fully functional storage system that supplies data storage services to clients and devices either directly or through a network. The components and subsystems that are an integral part of the data storage product architecture are considered to be part of the data storage product. Whereas components that are not associated with a storage environment at the data centre level are not considered to be part of the data storage product. A data storage product may be composed of integrated storage controllers, data storage devices, embedded network elements, software and other devices.

Recommendations from the Phase 1 report

Phase 1 report, Section 2.2, covers the recommendations put forward for updating the definitions for data storage products. It is recommended that all definitions are updated so they align with the definitions provided in ENERGY STAR, EPEAT, ISO/ IEC 21836:2020, ETSI EN 303 470 and SNIA Emerald. For data storage products it is recommended that definition are to be updated in line with SNIA Emerald taxonomy.

The SNIA Emerald benchmark provides valuable data on energy efficiency in storage systems. This can inform the creation of new active levels and can be designed to match the workload requirements of storage devices more accurately, allowing for more efficient power management. Given the smaller size of the storage market and limited number of unique models, care should be taken not to create requirements as aggressive as may be developed for servers which are far greater in number and variety.

The Ecodesign PSU requirement applies to both servers and data storage products. For servers, the PSU maximum efficiency has been reached. We recommend keeping the power supply efficiency requirements for storage products as they are to align with servers.

Energy consumption of storage products in data centres is primarily driven by the number of physical storage devices present (HDDs, SDDs, etc.), which can be reduced by using higher capacity devices and implementing capacity optimisation methods. It is recommended to require the availability of capacity optimisation methods data, specifically related to deduplication and data compression.

Additionally, the Commission should provide users/operators with information on the benefits of utilising these methods. Educating consumers about the benefits of energy-efficient storage products and providing guidance on selecting and using such products can drive demand for energy-efficient options.

Functional unit

The design and configuration of a data storage products is defined by the provided functionality and performance, storage media, scalability and form factor, as well as service level. Typically, data storage products are free standing (pedestal) or in a cabinet (rack-mounted) and are usually installed in a data centre. The characterisation parameters are specified below in Table 1.2.

Table 1.2 Data Storage Products Characterisation Parameters

Storage Product System	Chassis (Form factor)	Storage Media/ Device	Storage Application
• Network Attached Storage (NAS) • Storage Area Network (SAN) • Direct Attached Storage (DAS) • Tape Library	• Pedestal (stand-alone) • Rack-optimised (rack-mounted) • Blade system	• Hard Disk Drive (HDD) • Solid State Devices (SSD) • Hybrid SSD-HDD • Magnetic Tape (Tape Library) • Optical Disk (OD)	• Online Storage • Near-online Storage • Virtual Media Library • Removable Media Library

Like servers the energy and resource consumption of a data storage product over its lifetime is determined by the specific configuration and utilisation aspects. In addition, due to the large variability with respect to data storage products configuration and actual utilisation, it is not viable to define the functional units of each of these.

1.1.4.4 Network Equipment

Network equipment are devices that provide connectivity and passes data through a wired or wireless network interface. It can work based on physical layer (OSI layer 1), on data link layer (OSI layer 2), or on network layer (OSI layer 3).

Network equipment includes bridges, switches, routers, gateways, etc. and can be utilised in different networks, by modifying the configuration and operation setting of such equipment. The following aspects should be considered with regards to the definition of network equipment:

- The type of network equipment it is. There are many different types of network equipment which can make one definition very difficult. These include devices the apply different transmission technologies (wired, wireless) and work on the physical, data link or network layer (transmitting, switching, routing, etc.,)
- Often the same type of networking equipment will be operated in different networks under different operative conditions and quality of service requirements.
- Network equipment by nature does not operate independently and usually interacts with one or multiple links. This makes it difficult to measure the performance because this must be judged based on the performance of the overall network system.

Product definition and preliminary scope

The scope of the initial preparatory study in 2014 also included network equipment. However due to the complexity and variability of network equipment, establishing a regulation that would define and set standards for these devices was deemed difficult. However, there is interest to review if there may be simple measures which could be applied to improve sustainability of network equipment devices, notably with regards to material efficiency requirements.

Recommendations from the Phase 1 report

Within the Phase 1 report, item c covers the recommendations put forward for updating the definitions for network equipment. For more information, please see Section 2.2 of the Phase 1 report.

Auxiliary Processing Accelerators (APAs)

Servers with integrated APAs are still waiting for SERT to develop a new test standard, and therefore should be maintained in this exemption. However, it is noted that the technology is developing quickly, such newer CPU designs with accelerator blocks may be confused under the current EU regulation server with integrated APA definition. This definition therefore needs to be updated. The Energy Star Version 4 definition can be taken as a first definition update.

ENERGY STAR Version 4.0 for computer servers defines APAs in the following way:

‘They are additional compute device installed in the computer server that handles parallelised workloads in place of the CPU. This includes, but is not limited to, General Purpose Graphics Processing Units (GPGPUs) and Field Programmable Gate Array (FPGA) chips. There are two specific types of APAs used in servers:

- Expansion APA: An APA that is an add-in card installed in an add-in expansion slot (e.g., GPGPUs installed in a PCI slot). An expansion APA add-in card may include one or more APAs and/or separate, dedicated removeable switches.
- Integrated APA: An APA that is integrated into the motherboard or CPU package.'

Recommendations from the Phase 1 report

Within the Phase 1 report, item c covers the recommendations put forward for updating the definitions for APA's. The Phase 1 report has recommended that the exclusions on energy efficiency metrics granted to servers with integrated APA's is maintained. This is because these devices are out of scope of the testing standards SPEC SERT tool and the ISO/IEC 21836.2020. The definition of servers with integrated APAs should be updated for clarity, to align with the definition given by Energy Star above.

1.2 Measurement & Test Standards

This sub-task identifies relevant measurement and test standards for servers and data storage products and is comprised of a description of each of the identified standards together with a comparative analysis.

This section identifies and describes the existing test standards and test procedures, specifically addressing the EU Regulation 2019/424:

- Primary and secondary functional performance parameters
- Resources use (energy and materials, incl. waste) and emissions
- Safety (flame retardancy, electric safety, EMC, stability, etc.)
- Noise and vibrations (if applicable)
- Other product-specific test procedures possibly posing barriers for Ecodesign measures.

1.2.1 Identification and Description of Relevant Standards

EN-, ISO-, IEC- test standards Commission Regulation 2019/424 lays down the Ecodesign requirements for servers and data storage products[13]. This regulation was the first to specifically cover different types of servers and data storage products. There has been a large number of ENs published or being developed by CENELEC in support of European Legislation as laid down in the WEEE, RoHS, EMC and LVD Directives and the REACH Regulation. With some of these relevant to servers and data storage products. For example, the Technical Committee CENELEC TC 215 has transposed the ISO/IEC standards developed into EN standards for electrotechnical aspects of telecommunication equipment[14]. This covers the energy consumption of servers and data equipment. In 2015 the Commission issued mandate M543 to the European Standardisation Organisations requesting standards to support requirements on material efficiency aspects of energy related products. M543 was initially rejected by ESO, CEN and CENELEC,

[13] https://eur-lex.europa.eu/legal content/EN/TXT/?uri=CELEX%3A32019R0424#:~:text=Commission%20Regulation%20(EU)%202019%2F,(Text%20with%20EEA%20relevance.)

[14] https://standards.iteh.ai/catalog/tc/clc/d8429a65-36a6-4cc7-9a70-a9aa104350d9/clc-tc-215

however, it was eventually accepted. The Technical Committee CEN-CENELEC TC10 was responsible for producing the standards which resulted from mandate M543. CENELEC published these standards in April 2020. These standards are discussed in more detail within Section 1.2.1.3.

1.2.1.1 EN-, ISO-, IEC- test standards developed at product level

ISO/IEC has recently adopted international standards for both SPEC SERT and SNIA Emerald. These standards are:

- SNIA Emerald was adopted as **ISO/ IEC 24091: 2019**
- SPEC SERT was adopted as **ISO/ IEC 21836: 2020**

The Phase 1 report provides more information on why it has recommended that these test standards are used within the Regulation for servers and data storage products. Items a and b of Section 2.1 of the Phase 1 report lays out the recommendations for using SPEC SERT, which serves as the foundation for ISO/IEC 21836:2020, as the benchmark or server requirements.

In addition, Item i of Section 2.3 of the Phase 1 report provides more information on why the study team wishes to introduce the use of SNIA Emerald under the ISO/ IEC 24091: 2019 standard to calculate the energy and performance efficiencies for data storage products.

ISO/ IEC 24091: 2019

ISO/ IEC 24091:2019 was developed from the SNIA Emerald industry test standard. ISO/ IEC adopted V3.0.3 of the SNIA Emerald power efficiency measurement specification in 2019. The standard provides a recognised method to assess the energy efficiency of data storage products. The resulting power efficiency metrics are defined as ratios of idle capacity or active operations during selected stable measurement intervals to the average measurement power[15].

The purpose of the ISO/ IEC 24091:2019 is to provide public access to storage system power usage and efficiency. This is achieved through the use of a well-defined testing procedure, and additional information related to system power. The measurement procedure, the SNIA Emerald™ Power Efficiency Measurement Specification, was developed and released, and is maintained by the Green Storage Technical Working Group under the guidance of the Green Storage Initiative (GSI) of the SNIA.

The ISO/ IEC 24091:2019 benchmark provides valuable data on energy efficiency in storage systems. This can inform the creation of new active levels and can be designed to match the workload requirements of storage devices more accurately, allowing for more efficient power management. A discussion on adopting ISO/ IEC 24091: 2019 in the legislation has been discussed in Section 2.3 of the Phase 1 report.

The SNIA Emerald Program is sponsored, operated, and promoted by the SNIA GSI. The SNIA is a non-profit, international organisation of manufacturers, systems integrators, developers, systems vendors, industry professionals, and end users. The GSI is responsible for managing the SNIA Emerald Program, providing input

[15] https://www.iso.org/obp/ui/#iso:std:iso-iec:24091:ed-1:v1:en

and guidance to the Green Storage TWG, and general marketing of energy efficiency activities within the SNIA and the storage networking industry.

ISO/ IEC 21836:2020

ISO/ IEC 21836:2020 collects measurements and efficiency metrics to assess a servers energy efficiency for the ENERGY STAR®. SPEC SERT became ISO 21836 compliant in 2020, with international agencies standardising the SERT 2 suite for measuring server efficiency on a global scale. The SERT 2 suite utilises the SPECpower Committee’s modular architecture, which allows integration of the latest version of the Chauffeur benchmark harness and the PTDaemon Interface. This new method helps to reduce the time required for developing future workloads[16]. Ultimately, this next generation measurement standard enables the energy efficiency of single and multi-node servers across the latest server architectures and processors.

It was designed to be simple to configure and use via a comprehensive graphical user interface, ISO/ IEC 21836: 2020 is organised around eleven worklets which fall under three categories: CPU based, memory based and storage based. The results from the tested worklets are aggregated into a single score with a weighting of 65% for CPU, 30% for memory, and 5% for storage worklets[17]. The power demand of these worklets at idle and several other utilisation levels are also captured.

Results are provided in both machine- and human-readable forms, enabling automatic submission to government-sponsored certification programs as well as both summary and detail reports for use by potential customers. ISO/IEC 21836:2020 can test both x86 and IBM Power servers with up to eight processors, as well as multi-node servers. It hopes to expand the tool soon to include ARM- and Sparc-based servers. Characteristics of SERT include:

- Synthetic worklets that test discrete system components such as memory and storage, providing detailed power consumption data at different load levels.
- Automatic collection of system configuration data with a graphical user interface to review and edit the information.
- Automatic validation of results at both runtime and upon completion of testing.
- Multi-threading and multiple-system runs, providing scalability across a wide range of servers.
- Portability to various computing platforms.
- Run-time behaviour that can be changed for research purposes.
- Results available in both machine- and human-readable forms, enabling automatic submission to government-sponsored certification programs.

A discussion on adopting ISO/ IEC 21836: 2020 in the legislation has been discussed in Section 2.3 of the Phase 1 report.

1.2.1.2 EN-, ISO-, IEC- test standards developed at system level

ISO/IEC JTC 1/SC 39 has developed a suite of effective key performance indicators (KPI) in relation to the ISO/ IEC 30134 series on IT equipment. In order to determine

[16] https://aithority.com/it-and-devops/cloud/spec-releases-new-iso-iec-21836-compliant-sert-suite/

[17] https://www.energystar.gov/products/ask-the-experts/how-to-measure-server-efficiency-with-sert-

the overall effectiveness or efficiency of data centre these KPIs provide. This includes the following KPIs:

- ISO/IEC 30134-1: Part 1 - Overview and general requirements
- ISO/IEC 30134-2: Part 2 - Power usage effectiveness (PUE)
- ISO/IEC 30134-3: Part 3 - Renewable energy factor (RES)
- ISO/IEC 30134-4: Part 4 - IT equipment energy efficiency for servers (ITEE)
- ISO/IEC 30134-5: Part 5 - IT equipment utilisation for servers (ITEU_SV)
- ISO/IEC 30134-6: Part 6 - Energy reuse factor (ERF)

The objective of Part 2 of ISO/ IEC 30134 series is to support data centre operators by defining the power usage effectiveness of a data centre[18]. The PUE can be used to determine improvements of the operational efficiency, designs and processes of the data centre.

Part 3 of ISO/ IEC 30134 series aims to support data centre operators by defining the renewable energy factor (REF) of a data centre[19]. According to Part 3 "*The REF provides a quantitative metric for the actual use of renewable energy in the form of electricity in a data centre*". Thus, providing an assessment of the mitigation of carbon emissions that originated from the data centre and is useful in improving the sustainability of data centres by enhancing the use of renewable energy.

The objective of Part 4 is to support data centre operators to optimise the energy efficiency of their servers[20]. This series quantifies the energy efficiency characteristics of servers in data centre. IT equipment energy efficiency for servers (ITEEsv) helps users improve energy effectiveness of their servers by providing a measure of work performed per unit of power consumed[21]. This will allow the user to compare the performance of their servers, identifying the inefficient ones. ITEEsv is intended for self-improvement of a data centre and not for comparison of other data centres.

Part 5 has the objective to support data centre operators to optimise the utilisation of its servers[22]. IT equipment utilisation for servers (ITEUsv) describes the utilisation of servers in operational conditions. This was developed with the knowledge that server energy efficiency tends to be greater with higher utilisation[23]. ITEUsv consider the utilisation and power management aspects of the server. It can identify underutilized servers and increase energy efficiency by turning servers off.

The ITEUsv requires processing a considerable amount of data from the system management and practical experiences are still lacking.

[20] https://www.iso.org/standard/66191.html

[21] https://www.ictfootprint.eu/en/isoiec-30134-00-factsheet

[22] https://www.iso.org/standard/66934.html

[23] https://www.ictfootprint.eu/en/isoiec-30134-00-factsheet

1.2.1.3 Mandates issued by the EC to the European Standardisation Organisations

Mandate M/573

In 2021 the Commission issued mandate M573 to the European Standardisation Organisations (CEN, CENELEC and ETSI) requesting to support Regulation (EU) 2019/424 as regards ecodesign requirements for servers and data storage products[24]. In August 2021, ETSI accepted the mandate.

The requirements of the specific standards to be adopted involve:

- Measurement and calculations of the power supply unit efficiency, the power factor, and its rated power output.
- The calculation of energy efficiency measurements and metrics for servers.
- Measurement and calculation of the opening condition class.
- A way to verify the compliance of products with the requirement on the secure data deletion functionality for servers and data storage products.
- Ensuring verification of compliance with the requirements for the availability of firmware and of security updates to firmware.
- Verifying the compliance of a server with the requirements of the supply of information on the weight range of critical raw materials
- Ensure that servers verify the compliance with requirements on its ability to be disassembled
- A deliverable on the assessment of the efficiency, performance, and power demand of data storage products.

The Commission requested that the output of the mandate be adopted by the end of January 2023. The technical body EE EEPS is responsible for producing the standard resulting from the mandate. Since the Commission issued mandate M573 to the European Standardisation Organisations in 2021, all seven standards are yet to be published. Table 1.3 features the complete lists of standards under the mandate progress against which is published on the ETSI website[25].

Table 1.3 Status of Ecodesign Requirement Standards for M573

Reference	Title	Draft
DEN/ EE-EEPS44	Energy efficiency metrics and measurements for data storage equipment.	✓
DEN/ EE-EEPS47-5	Server and data storage product disassembly and disassembly instruction	✓
DEN/ EE-EEPS47-4	Server and data storage product critical raw materials	✓
DEN/ EE-EEPS47-3	Server and data storage product availability of firmware and of security updates to firmware	✓
DEN/ EE-EEPS47-2	Server and data storage product secure data deletion functionality	✓
DEN/ EE-EEPS47-1	General for server and data storage products	✓
REN/ EE-EEPS42	Energy efficiency measurement methodology and metrics for servers	✓

Since this mandate was issued by the Commission ETSI have planned a separate deliverable for CPU power management. In addition, the critical raw material

[24] https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=597

[25] Work Programme - EWP on the Web - Query Result (etsi.org)

requirements that were originally to be included in ETSI standard will instead be included in CEN-CLC EN 45558 standard as a Z-annex.

Item I of the Phase 1 report covers the recommendations put forward by this review for including the standards originating from M/573 within the scope of the Regulation. Section 2.8 of the Phase 1 report provides more information on the recommendations put forward by the study team.

Mandate M/543

In 2015 the Commission issued mandate M543 to the European Standardisation Organisations (CEN, CENELEC and ETSI) requesting standards to support Ecodesign requirements on material efficiency aspects for energy-related products[26]. In January 2016, the ESOs, CEN and CENELEC accepted the mandate – which had previously been rejected[27]. This mandate aims to ensure the mandatory regulation of these practices across the EU, as the EU pushes to achieve the targets set out by the Circular Economy Action Plan of 2015.

The standardisation request relates to the following three material efficiency aspects:

- Extending product lifetime;
- The ability to re-use components or recycle materials from products at end-of-life; and
- The use of re-used components and/or recycled materials in products

The Commission has requested that the outputs from the mandate deal with the following topics:

- The definition of parameters and methods relevant for assessing durability, upgradability and ability to repair, re-use and re-manufacture of products;
- Provision of guidance on how standardisation deliverables for assessing durability, upgradability and ability to repair and re-manufacture of products can be applied to product-specific standards;
- Ability to access or remove certain components, consumables or assemblies from products to facilitate repair or remanufacture or reuse;
- Reusability/recyclability/recoverability (RRR) indexes or criteria, preferably taking into account the likely evolution of recycling methods and techniques over time;
- Ability to access or remove certain components or assemblies from products to facilitate their extraction at the end-of-life for ease of treatment and recycling;
- Method to assess the proportion of re-used components and/or recycled materials in products;
- Use and recyclability of Critical Raw Materials to the EU, listed by the European Commission;

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[26] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=select_attachments.download&doc_id=1611

[27] http://www.endseurope.com/article/44907/green-light-for-resource-efficiency-standards?utm_source=07/01/2016&utm_medium=email&utm_campaign=ENDS%20Europe%20editorial%20bulletin?utm_source=07/01/2016&utm_medium=email&utm_campaign=ENDS%20Europe%20editorial%20bulletin

- Documentation and/or marking regarding information relating to material efficiency of the product taking into account the intended audience (consumers, professionals or market surveillance authorities).

Table 1.4 features the complete list of standards under the mandate, progress against which is published on their committee website[28]. All standards are now published as of April 2020, with the exception of 45551 which has been discontinued.

Table 1.4 Status of Material Efficiency Standards

Reference	Title	Published
45550	Definitions related to material efficiency	CLC/ TR 45550:2020
45551	Guide on how to use generic material efficiency standards when writing ErP product specific deliverables	Discontinued
45552	Method to assess durability of ErPs	EN 45552: 2020
45553	Method to assess ability to remanufacture ErPs	EN 45553: 2020
45554	Method to assess ability to repair, reuse and upgrade ErPs	EN 45554: 2020
45555	Method to assess the recyclability and recoverability of ErPs	EN 45555: 2019
45556	Method to assess proportion of reused components in ErPs	EN 45556: 2019
45557	Method to assess proportion of recycled content in ErPs	EN 45557: 2020
45558	Method to declare use of critical raw materials in ErPs	EN 45558: 2019
45559	Method to provide information on material efficiency of ErPs	EN 45559: 2019

Of particular interest to this review study is the recent adoption of M/543 within the recently drafted Smartphone and Tablets Ecodesign requirements. This is the first-time material efficiency has been adopted by an Ecodesign Regulation and this adoption will be used to support this part of the review study. Thus, ensuring that servers and data storage products successfully adopt these horizontal standards. Accelerating the development of standards on various aspects of material efficiency.

Item j a) of the Phase 1 report covers the recommendations put forward by this review for including the standards originating from M/543 within the scope of the Regulation. Section 2.8 of the Phase 1 report provides more information on the recommendations put forward by the study team.

Mandate M/462

In addition to M/543, the Commission has issued the standardisation mandate M/462 – "Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of ICT to enable efficient energy use in fixed and mobile information and communication networks"[29]. The standardisation is not only limited to networks but extends to data centres and other ICT nodes with broadband deployment[30]. It

[28] https://www.cenelec.eu/dyn/www/f?p=104:22:1183738753089601::::FSP_ORG_ID,FSP_LANG_ID:2240017,25

[29] https://portal.etsi.org/portals/0/tbpages/ee/docs/eso%20response%20to%20m462%20phase%201%20.pdf

[30] https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/ict-environmental-impact-0

provides standards for measurement, monitoring, and definitions of energy efficient KPIs. The actions requested by the commission include:

- **Action 1:** Definition of Global KPIs for Energy Management of Fixed and Mobile access, and Core networks.
- **Action 2:** Guidelines for the use of Global KPIs for Data Centres.
- **Action 3:** Definition of Global KPIs for Data Services.
- **Action 4:** Guidelines for the definition of Green Data Services.
- **Action 5:** Definition and guidelines of KPIs for ICT networks.
- **Action 6:** SDOs to identify needs and develop standards to support UN SDGs, in particular KPI for both synergies and conflicts in Digital transformation and Green transition projects.
- **Action 7:** ETSI, in collaboration with the EGDC, to consider possible paths for ITU L.1480 and L.1333 to be made available for European standardisation to meet EU policy objectives.

1.2.2 Industry-Based Specifications

1.2.2.1 Standard Performance Evaluation Corporation (SPEC)

The Standard Performance Evaluation Corporation (SPEC) was founded in 1988 by workstation vendors who realised that the marketplace needed realistic, standardised performance tests[31]. The key realisation was that an ounce of reliable data was worth more than a pound of marketing hype. The goal of SPEC is to ensure that the marketplace has a fair and useful set of metrics to differentiate candidate systems. The path chosen is an attempt to balance requiring strict compliance and allowing vendors to demonstrate their advantages.

Under the Open System Group (OSG), SPEC is structured into six working groups: Cloud, CPU, Java, Power, Storage and Virtualization. Relevant to this study is the subcommittees, Power.

SPEC SERT

SPEC developed the Server Efficiency Rating Tool (SERT)[32], in collaboration with the US Environmental Protection Agency. SERT is also adopted within the EU Lot 9 Ecodesign regulation and Japan's Top Runner program for computer servers, creating a harmonised way to evaluate server efficiency in different geographies[33]. Additionally, they are required for cloud service providers deployments in the EU. The China National Institute of Standardisation (CNIS) is also considering SERT for inclusion in its upcoming mandatory server energy regulations.

ISO 21836:2020 was developed as an international test standard from the industrial test method SPEC Server Efficiency Rating Tool (SERT)[34]. For more information on the SPEC test standard please see Section 1.2.1.1.

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31 https://www.spec.org/

32 https://www.spec.org/sert/docs/SERT-Design_Document.pdf

33 https://www.energystar.gov/products/ask-the-experts/how-to-measure-server-efficiency-with-sert-

34 https://www.spec.org/sert/docs/SERT-Design_Document.pdf

In comparison to SPECpower_ssj2008, SERT does not provide comparative scores. SERT is designed to test server systems without the previous tuning. This “tuning” of products in order to achieve high scores has been a point of critique with respect to SPECpower.

There exist limitations of SPECPower and SERT with regards to comparability of data from more populated configurations and the impact of adding components that add power without adding performance. The testing results are dependent on the product categories or server types and the configuration dependency.

SPECpower

Since this measurement standard was not utilised in Regulation 2019/424, it will not be included within this section of the report. It was not included in the previous Regulation because SPEC SERT was used instead, which also included an idle measurement. Thus, SPECpower was made redundant. The SPECpower overview has been included in the Annex A1.2.

1.2.2.2 SNIA Emerald™ Power Efficiency Measurement Specification

SNIA (Storage Networking Industry Association) Emerald™ Program[35] provides public access to storage system power usage and efficiency. With international agencies standardising the Emerald power efficiency measurement specification V3.0.3. The measurement procedure, the SNIA Emerald™ Power Efficiency Measurement Specification, was developed and released, and is maintained by the Green Storage Technical Working Group under the guidance of the Green Storage Initiative (GSI) of the SNIA.

The SNIA Emerald Power Efficiency Measurement Specification is used in the V2.1 ENERGY STAR® Data Centre Storage specification. GSI and the Green Storage TWG have been strongly involved with the EPA in creating the EPA's specification. SNIA defined workload tests can be found in the “SNIA Emerald™ Power Efficiency Measurement Specification” Version 4.0.0. In addition, the definitions for data storage products within the EU Lot 9 Ecodesign regulation were developed by SNIA. In particular, the definitions for small data storage products and large data storage products[36].

ISO 24091:2019 was developed as an international test standard from the industrial test method SNIA Emerald. For more information on the SNIA Emerald test standard please see Section 1.2.1.1.

1.2.2.3 Energy Consumption Rating (ECR Initiative 2010)

The original ECR (Energy Consumption Rating) is a peak metric and intended for a general description of network efficiency:

$$ECR = Ef / Tf,$$

Where:

- *Ef* represents the energy consumption (Watts),
- *Tf* represents the effective maximum system throughput (Gbps).

[35] https://www.snia.org/technology-focus/power-efficiency

[36] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0424

ECR is normalised to W/Gbps and has a physical meaning of energy consumption to move one Gigabit worth of line-level data per second[37]. It reflects the best possible platform for a fully equipped system with a chosen application. However, the power consumption of current network devices typically adapts according to the actual work load. To get a more accurate understanding of the energy efficiency of modern network equipment, a load variable testing of the devices is necessary.

The enhanced ECR-VL (Energy Consumption Rating Variable Load) is a variable load metric and intended to differentiate energy efficiency under various workload conditions.

$$ECR\text{-}VL = (\alpha*E_{100}+\beta*E_{50}+\gamma*E_{30}+\delta*E_{10}+\varepsilon*E_{i}) / (\alpha*T_{f}+\beta*T_{50}+\gamma*T_{30}+\delta*T_{10}),$$

Where:

- T_f = maximum throughput (Gbps) achieved in the measurement cycle,
- $T_{50} = T_f * 0.5$,
- $T_{30} = T_f * 0.3$,
- $T_{10} = T_f * 0.1$,
- E_{100} = energy consumption (watts) under highest load,
- E_{50} = energy consumption (watts) under fifty percent offered load,
- E_{30} = energy consumption (watts) under thirty percent offered load,
- E_{10} = energy consumption (watts) under ten percent offered load,
- E_i = energy consumption (watts) measured under idle run (removes the load and runs for another 1200 seconds),
- $\alpha, \beta, \gamma, \delta, \varepsilon$ are weight coefficients selected such as $(\alpha + \beta + \gamma + \delta + \varepsilon) = 1$.

Finally, a last metric, ECR-EX (extended-idle), can be used as an average energy rating in a reference network, where non-real time (extended) energy savings capabilities are enabled.

1.2.2.4 Third country Test Standards

PAS 141:2011 - Reuse of used and waste electrical and electronic equipment

PAS 141 is a standard developed by the UK's Department for Business, Innovation and Skills (BIS) now the Department for Energy Security and Net Zero, in 2011. It sets out the requirements to successfully manage the process of preparing used and waste electrical and electronic equipment for reuse. By managing electrical waste, it is aiming to reduce the generation of waste by encouraging reuse and properly treating the waste by recycling and recovery decreasing the amount to landfill.

IEC TR 62635:2012 – Guidelines for end-of-life information provided by manufacturer and recyclers and for recyclability rate calculation of electrical and electronic equipment.

This standard provides a methodology for information exchange involving manufacturers and recyclers, and for calculating the recyclability and recoverability rates[38]. In addition, it provides a description of the end-of-life principles of electrical

[37] final LATEST ENERGY EFFICIENCY22MARCH.pdf (tec.gov.in)

[38] https://webstore.iec.ch/publication/7292

and electronic waste, including the scope, terms and definitions and description of a generic treatment process of electronic waste[39].

The standard also provides a calculation which helps to describe the method of recyclability and recoverability rates of each part:

$$Rcyc = \frac{sum\ of\ recyclable\ masses\ of\ each\ part}{total\ product\ mass} \times 100\% = \Sigma\ (m(i) \times RCR\ (i)\ MEEE\ \times 100\%$$

Where:

- m(i): the mass of part i.
- RCR: recycling rate of the i^{th} part in corresponding end of life treatment scenario
- MEEE: total product mass.
- Included within standard is a list of recyclability and recoverability rates.

NSF/ ANSI 426-2017: Environmental Leadership and Corporate Social Responsibility Assessment of Servers.

This standard defines environmental and corporate social responsibility performance criteria for computer servers as defined in the ENERGY STAR Server specification[40]. Providing performance objectives which consider the energy and material efficiencies to reduce the environmental impact of servers[41]. It establishes a set of criteria on environmental leadership and corporate social responsibility throughout the products life cycle, these relate to:

- Energy efficiency;
- management of substances;
- preferable materials use;
- product packaging;
- design for repair;
- reuse and recycling;
- product longevity;
- responsible end of life management;
- corporate responsibility

ITU-T Standards

The international Telecommunications Union provide standards to improve the circular economy of ICT equipment. The ITU standards are carried out by technical study groups in the past they have published standards that are focused on power supply series, e-waste management and recycling of rare metals in ICT. Since 2017 Study Group 5 has developed standards regarding the environmental impacts, end of life impacts and circular economy structures[42].

1.2.3 Comparative Analysis of Relevant Test Standards

One of the major driving forces behind improved efficiency of serves in the last decade has been from the use of SPEC. Other industry initiatives including SNIA and ATIS have also developed benchmarks and test for assessing the functional performance of the energy consumption of a server, storage or network product.

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[39] https://webstore.iec.ch/publication/7292

[40] https://webstore.ansi.org/standards/nsf/nsfansi4262017

[41] A SITUATIONAL ANALYSIS OF A CIRCULAR ECONOMY IN THE DATA CENTRE INDUSTRY (weloop.org)

[42] https://www.itu.int/en/Pages/default.aspx

Due to their recognition as accurate ways to measure the energy performance of servers, these benchmarks have been adopted by ENERGY STAR, Ecodesign and Japan's Top Runner program.

The SPECpower test standard is widely used since its introduction in the year 2008 but has been criticised recently for being not very realistic. The main point of criticism is the possible tuning of the product under test, meaning a reduction of its hardware configuration to an absolute minimum. This results in comparably low power consumption when running the performance benchmark. To overcome this issue SPEC SERT was developed alongside the US Environmental Protection Agency. SERT is able to provide a much more realistic power consumption and performance data and therefore helps customers in their procurement decisions.

1.2.4 New Standards Under Development

The study team conducted extensive research to discover if there were any new standards under development in the EU and in third party countries. It was concluded that no new standards were under development at the time of writing this report.

1.3 Existing Legislation

This section identifies existing legislation that may affect servers and data storage products. This is considered at the European and Member State level as well as Third Countries (e.g. UK and USA).

1.3.1 Legislation at European Union Level

1.3.1.1 Commission Regulation 2019/424 for Servers and Data storage Products

Ecodesign Regulation 2019/424 establishes the requirements for servers and online data storage products placed on the EU market. This regulation was published on 18th March 2019, with the first set of requirements coming into effect from 1st March 2020 for servers and data storage products. These requirements were then uplifted for on the 1st March 2021 and then again on the 1st March 2023.

The scope of Regulation 2019/424 does not include server appliances, large servers, fully fault tolerant servers and network servers. While resilient servers, High Performance Computing (HPC) servers and servers with integrated APA are exempt from the energy efficiency requirements of active efficiency and idle state power consumption, which are set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424. In addition, the initial preparatory study had included networking equipment within its scope. However, due to the complexity and variability of network equipment, establishing a regulation that would define and set standards for these devices was deemed difficult.

Within this review study we have provided our recommendations for the scope of the Regulation within Section 2.2 of the Phase 1, Task 1 report.

The Regulation sets requirements for the following parameters: PSU efficiency (%), power factor, idle state power and maximum power, and active state efficiency and performance in active state. In addition, there are a material efficiency requirements required in the Regulation. These requirements will be described in the following text.

Since January 2023 servers and data storage products have had to reach the PSU efficiency requirements values set in Table 1.5. These requirements are measured at 10%, 20%, 50% and 100% of the rated load level and power factor at 50% of the rated load level. Direct current server and data storage products are exempts from the requirements.

Table 1.5 Minimum PSU efficiency and power factor requirements for servers.

	Minimum PSU Efficiency				Minimum Power factor
% of Rated Load	10%	20%	50%	100%	50%
Multi-output	-	90%	94%	91%	0.95
Single Output	90%	94%	96%	91%	0.95

Regulation 2019/424 provides specific requirements for servers. From March 2020, the idle state power (P_{idle}) of servers (excluding resilient servers, HPC servers and servers with integrated APA), are required to be calculated using the following equation.

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

Where:

- P_{base} is the basic idle state power allowance, as determined below by Table 1.6
- ΣP_{add_i} is the sum of idle state power allowance for applicable and additional components as determined below by Table 1.7.

Table 1.6 Basic Idle State Power Allowance

Product Type	Basic Idle Power Allowance P_{base} (W)
1-socket servers (neither blade nor multi-node servers)	25
2-socket servers (neither blade nor multi-node servers)	38
Blade or multi-node servers	40

Table 1.7 Additional Idle Power Allowances for Extra Components

System Characteristics	Applies to	Additional idle power allowance
CPU Performance	All servers	1 socket: 10 x $Perf_{cpu}$ W 2 socket: 7 x $Perf_{CPU}$ W
Additional PSU	PSU installed explicitly	10 W per PSU
HDD or SDD	Per installed HDD or SDD	5.0 per HDD or SDD
Additional Memory	Installed memory greater than 4 GB	0.18 W per GB
Additional buffered DDR channel	Installed buffered DDR channels greater than 8 channels	4.0 W per buffered DDR channel
Additional I/O devices	Installed devices greater than two ports of ≥ 1 Gbit, on board Ethernet	< 1 Gb/s: No Allowance
		= 1 Gb/s: 2.0 W/ Active Port
		> 1 GB/s and < 10 Gb/s: 4.0 W/ Active Port

System Characteristics	Applies to	Additional idle power allowance
		≥ 10 Gb/s and < 25 Gb/s: 15.0 W Active Port
		≥ 25 Gb/s and < 50 Gb/s: 20.0 W Active Port
		≥ 50 Gb/s: 26.0 W Active Port

Active state efficiencies (Eff_{server}) for servers have been in enforced by the regulation since March 2020. Servers, with the exception of resilient servers, HPC servers and servers with integrated APA, shall have an active state efficiency value no lower than the values in Table 1.8.

Table 1.8 Active state efficiency requirements

Product type	Minimum active state efficiency
1-socket servers	9.0
2-socket servers	9.5
Blade or multi-node servers	8.0

The Regulation also requires manufacturers to provide information regarding the material efficiency of servers and data storage products. These requirements have been enforced since March 2020. Manufacturers are required to ensure that the joining, fastening, or sealing techniques used on their product do not prevent the repair or reuse of the following components:

- Data storage devices
- Memory
- Processor (CPU)
- Motherboard
- Expansion card/ graphic card
- PSU
- Chassis
- Batteries

In addition, the regulation required data storage products to have a function to delete all secure data contained within it, to allow for the safe reuse of products. This was enforced from March 2020.

From March 2021, the latest version of the firmware shall be made available from two years after first being placed on the market. From this point the firmware should be available free of charge or at a fair transparent and non-discriminatory cost, for a minimum of eight years after placing on the market. Similarly, for security updates the firmware, these should be made available, free of charge, until at least eight years after first being placed on the market.

Furthermore, the Regulation includes general information requirements that have been enforced since March 2020. Within Annex II, Section 3.1 there is a list of the type of product information that must be included in the server's instruction manuals for installers and end users. This information should also be made available on a free access website. This information must be accessible for at least eight years after the product is placed on the market. It should be noted that this does not apply to custom made servers. Within Annex II, Section 3.2 of the Regulation there is also list of the information requirements for the instruction manuals for data storage products. Again, this excludes custom built data storage products. Within Section

3.1 and 3.2 of Annex II, the Regulation requires manufacturers to declare the operating conditions inm which the product was tested at. The products must be tested within the boundaries of the operating conditions displayed in Table 1.9 in order to comply with the Regulation.

Table 1.9 Operating Condition Classes defined by EU Regulation 2019/424

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

**DP = dew point, **RH = relative humidity.*

There are additional production information requirements for servers and online data storage products. The following information shall be made available from the time the product is on the market until at least eight years after. The manufacturers authorised representatives and importers to third parties who deal with repair, reuse, recycling and upgrading of servers (including brokers, spare parts repairers, spare parts providers, recyclers and third-party maintenance). Must be provided with the following information regarding servers and online data storage products placed on the market from March 2020:

- indicative weight range (less than 5 g, between 5 g and 25 g, above 25 g) at component level, of the following critical raw materials:
  - Cobalt in batteries
  - Neodymium in the HDDs
- instructions on the disassembly operations referred to in point 1.2.1 of Annex II, including, for each necessary operation and component:
  - The type of operation
  - The type and number of fastening technique(s) to be unlocked
  - The tool (s) required

For servers if a product model is part of a server product family, the production information displayed above shall be reported for either the product model or alternatively, the low end and high end configurations of the server product family.

1.3.1.2 Ecodesign and Energy Labelling Working Plan (2022-2024)

The European Commission adopted the Ecodesign and Energy Labelling Working Plan 2022-2024 on 30th March 2022. This working plan will act as a bridge to future 'sustainable product policy initiatives'[43]. The main aim of the working plan is to increase the ambitions of existing Ecodesign and energy label regulations covering energy-related products.

Servers and data storage products are within the scope of the workplan, the deadline for the review was the 31st March 2022. In addition, the Working Plan emphasises work on the following standards which are of high interest:

- The Commissions' standardisation request M/543
- EN 45554: 2020
- Methodology of Ecodesign for Energy-related Products.

Mandate M/543 will play a significant role in ensuring that servers can become more sustainable and reduce their life-cycle environmental impact. Hence, with the Working Plan putting a stronger emphasis on achieving a circular economy in the EU this is likely to have a significant impact on severs and data storage products in the near future.

1.3.1.3 **Energy Efficiency Directive** (2012/27/EU) and recast (2023)

The European Union has prioritized energy savings and efficiency in its strategy, aiming to enhance security, reduce emissions, and ensure affordable transitions. The Energy Efficiency Directive (EED) strengthens the legal framework for achieving the objectives of the "Fit for 55 package" and "REPowerEU" plan.

The Energy Savings Obligation (ESO) is the central pillar of the EED and, more broadly, a key element of the whole EU energy efficiency framework. Since 2021, Member States must achieve each year 0.8% new end-use energy savings. The 2023 EED recast introduces a progressive increase in ambition with an annual rate of 1.3% from 1 January 2024 to 31 December 2025, 1.5% from 1 January 2026 to 31 December 2027 and 1.9% from 1 January 2028 to 31 December 2030 (EED Art. 8.1).33 This progressive increase corresponds to a constant annual rate of 1.49% over the period 2024-2030, which is almost a doubling of the 0.8% current annual objective.34 The 1.9% savings rate will be maintained for the next obligation periods, starting with 2031-2040 (EED Art. 8.13)[44]. As of September 2023 the updates to the Directive have now been published[45].

The Ecodesign Regulation for servers and data storage products, works alongside the overarching and parallel perspective of the EED while contributes in the achievement of those targets. The two should work in parallel and this study is taking this into account.

[43] https://eurovent.eu/?q=articles/ecodesign-and-energy-labelling-working-plan-2020-2024-gen-113900

[44] The-new-2023-EED-Guidance-for-national-planning-and-implementation.pdf (energycoalition.eu)

[45] Directive - 2023/1791 - EN - EUR-Lex (europa.eu)

Reporting requirements on the energy performance and sustainability of data centres for the Energy Efficiency Directive

With regards to the sustainable development in the ICT sector, the recast proposal of the EED[46] asks data centres to make information about their energy performance publicly available as well as report it to the Commission. These reporting requirements would apply to all Data Centres, old and new, that have a significant energy consumption.

A study was undertaken for the European Commission, DG ENER, that proposes 'Reporting requirements on the energy performance and sustainability of data centres for the Energy Efficiency Directive'[47]. The report proposes definitions, classification, and scope of reporting obligations. The latter include the demand for a available information on IT power demand for data centres with installed IT power demand equal to or greater than 100kW (including colocation data centres). Other information obligations proposed are relevant to building information, reporting organisation domain of control, operation and Key Performance Indicators (KPIs). Reporting KPIs aims to later establishing a set of "data centre sustainability indicators". Indicators proposed for reporting purposes are Total DC energy consumption and data functions and ICT equipment energy consumption compared to total DC energy consumption. Additionally, other indicators include ICT equipment capacity and ICT equipment utilisation. Ancillary metrics are also taken into account such as indicators on water usage, energy/heat reuse, renewable energy and server age.

Task B of the report[48] explores the introduction of an EU-wide labelling scheme for the sustainability of data centres and/or the introduction of minimum performance standards for data centres, especially new and significantly refurbished ones.

1.3.1.4 The WEEE Directive (2012/19/EU)

The objective of the waste electric and electronic equipment (WEEE) Directive is to promote the collection of waste electrical and electronic equipment and recovery, recycling, and preparation for reuse of this waste[49]. Servers are within the scope of the WEEE Directive. Due to the ever-increasing quantity of WEEE waste there are serious concerns about environmental and health risks caused by the incorrect disposal of WEEE waste due to the hazardous components contained within them. Furthermore, the collection, treatment, and recycling of WEEE is essential to improve environmental management and its contribution to circular economy and enhancing resource recycling efficiency.

The WEEE set a collection target of 65% collection by 2019 in the EU. It is estimated that only Bulgaria, Croatia and Poland have achieved that target in the EU. However, once collected, electronic waste under the scheme is estimated to be recovered/recycled at 80% rate[50].

[46] European Commission (2021). Directive of the European Parliament and of the Council on energy efficiency (recast). COM(2021) 558 final

[47] Reporting requirements on the energy performance and sustainability of data centres for the Energy Efficiency Directive, Task A and B, Viegand Maagøe and COWI, February 2023

[48] Reporting requirements on the energy performance and sustainability of data centres for the Energy Efficiency Directive, Task A and B, Viegand Maagøe and COWI, February 2023

[49] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704

[50] Waste statistics - electrical and electronic equipment - Statistics Explained (europa.eu)

The product must meet the following three main criteria to be within the scope of the WEEE legislation scope:

- Main power source is electricity (including batteries);
- Less than 1 000 V AC or 1 500 V DC; and
- Electricity is needed for primary function.

Since 2019, all EEE are classified within 6 product categories set out in Annex III of the Directive. Servers and data storage products meet the criteria of the following product categories defined by the directive:

- Large equipment (any external dimension more than 50 cm);
- Small equipment (no external dimension more than 50 cm);
- Small IT and telecommunication equipment (no external dimension more than 50 cm)

Alongside the high energy use of servers and data storage products, the replacement of IT equipment every three to five years results in a large amount of post-consumer plastic waste, all with an embodied impact. Despite this, increasing the lifespan of a server is not encouraged because the operational phase energy consumption of older products heavily outweighs the standard such that extending the life of servers has a net negative impact, because of the generational improvements in the efficiency of severs. Thus, highlighting the importance of effective decommissioning and the re-using of materials found in servers. At present the end-of-life processing is inadequate due to the complexities of management routes required to effectively manage the recycling and decommissioning routes

1.3.1.5 The REACH Regulation (No 1907/2006)

The regulation of the Registration, Evaluation, Authorisation and Restriction (REACH) of chemicals purpose is to ensure high level protection of human health and the environment[51]. This is achieved through better and earlier identification of the intrinsic properties of chemical substances. The regulation places greater responsibility on industry to manage the risks of the chemical substances found within products. While also enhancing competitiveness and innovation including the development of alternative methods for the assessment of hazards.

REACH provides criteria to identify “substances of very high concern” (SVHC) included on the candidate list, which are then subject to an authorisation procedure to be used or put on the market after they have been included in a “List of Substances subject To Authorisation”.

Substances with the following hazardous properties may be identified as SVHCs:

- Substances meeting the criteria for classification as carcinogenic, mutagenic or toxic for reproduction category 1A or 1B in accordance with Commission Regulation (EC) No 1272/2008 (CMR substances);
- Substances which are persistent, bioaccumulative and toxic (PBT) or very persistent and very bioaccumulative (vPvB) according to REACH (Annex XIII);

[51] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:136:0003:0280:en:PDF

- Substances identified on a case-by-case basis, for which there is scientific evidence of probable serious effects that cause an equivalent level of concern as with CMR or PBT/vPvB substances.

1.3.1.6 The RoHS Directive (2011/65/EU)

The Restriction of Hazardous Substances (RoHS) Directive was developed by the EU in 2011[52]. It places restriction on the use of hazardous substances in electrical and electronic equipment. These restrictions include ensuring all new EEE contain the permitted levels of certain substances listed in Annex II ((lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenylethers (PBDEs)). With the possibility for exemptions given in Annex III, when their use in certain applications is justified/necessary. Of particular interest for servers is exemption 7(b). This exemption concerns *"lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission, and network management for telecommunications'*[53].

The objective is to contribute to the protection of the human health and the environment, which involves the environmentally sound recovery and disposal of electrical and electronic waste. It applies to any business in the EU selling electric and electronic equipment that contains any of the 10 restricted substances.

Servers and data storage products are within the scope of the RoHS Directive because they meet the two main criteria, given in the EEE definition:

- Electricity is needed for at least one intended function; and
- Less than 1 000 V AC or 1 500 V DC.

Servers and data storage products belong to Category 3 defined in Annex I. This category covers "IT and telecommunications equipment". For Ecodesign RoHS will assist in the delivery of providing information for recycling and disassemblability for products in the EU.

1.3.1.7 The Electromagnetic Compatibility Directive (EMC) (2014/30/EU)

The Electromagnetic Compatibility Directive limits the electromagnetic emission from equipment to ensure that when in use the equipment does not interfere with radio and telecommunications equipment[54]. It also ensures that there is sufficient immunity of such equipment to interference to ensure that the equipment is not disturbed by radio emissions. The directive applies to severs and data storage products, as they meet the criteria of being a finished product and system that includes electrical and electronic equipment that may generate or be affected by electromagnetic disturbance.

The main objective of the directive is to regulate the compatibility of equipment regarding the EMC. In order to meet this objective, equipment must comply with EMC requirements when places on the market and/ or taken out of service. For fixed installations such as servers, the application of good engineering practice is

[52] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0030

[53] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipmentText with EEA relevance (europa.eu)

[54] https://single-market-economy.ec.europa.eu/sectors/electrical-and-electronic-engineering-industries-eei/electromagnetic-compatibility-emc-directive_en

required, with the possibility that EU member states may impose measure in instances of non-compliance.

1.3.1.8 Low Voltage Directive (2014/35/EU)

The Low Voltage Directive (LVD) ensures that electrical equipment within certain voltage limits, reducing the risk to human health[55]. The Directive requires ensure that electrical equipment has protection against hazards that could arise within the electrical equipment itself or from external sources. This encompasses all risks including mechanical and chemical (emission of aggressive substance). The LVD covers the risks on electrical equipment operating with an input or output voltage between:

- 50 and 1000 V for alternating current
- 75 and 1500 V for direct current

Since these voltages ratings refer to the voltage of the electric input or output and not to voltages that appear inside the equipment, this Directive scope encompasses servers and data storage products.

1.3.1.9 Regulation (EU) No 327/2011 on ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW: Ventilation Fans

Regulation (EU) 327/ 2011 sets the minimum energy efficiency requirements for industrial fans in the EU[56]. The regulation covers fans that are equipped with an electric motor with an electrical input power between 125 W and 500 kW, which is used to drive an impeller. The fan must be either an axial fan, centrifugal fan, cross flow fan or mixed flow fan.

Initially when this ecodesign Regulation came into effect it only applied to 'ventilation fans', which explicitly excluded fans used in IT. Thus, excluding all products under the scope of Lot 9. From January 2015, the second tier of regulation requirements were released. The regulation now encompasses all fans. Requiring all fans to meet the energy efficiency requirements displayed in Table 1.10 below from January 2015.

Table 1.10 Energy Efficiency Requirements for all Fans from Regulation (EU) 327/2011

Fan Types	Measurement Category (A-D)	Efficiency category (static or total)	Power rating range in P in kW	Target energy efficiency	Efficiency Grade (N)
Axial Fans	A, C	Static	$0.125 \leq P \leq 10$	$\eta_{target} = 2.74 \cdot \ln(P) - 6.33 + N$	40
			$10 < P \leq 500$	$\eta_{target} = 0,78 \cdot \ln(P) - 1.88 + N$	

[55] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0035

[56] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1521113646166&uri=CELEX:32011R0327

Fan Types	Measurement Category (A-D)	Efficiency category (static or total)	Power rating range in P in kW	Target energy efficiency	Efficiency Grade (N)
	B, D	Total	$0.125 \leq P \leq 10$	$\eta_{target} = 2.74 \cdot \ln(P) - 6.33 + N$	58
			$10 < P \leq 500$	$\eta_{target} = 0,78 \cdot \ln(P) - 1.88 + N$	
Centrifugal forward curved fan and centrifugal radial bladed fan	A, C	Static	$0.125 \leq P \leq 10$	$\eta_{target} = 2.74 \cdot \ln(P) - 6.33 + N$	44
			$10 < P \leq 500$	$\eta_{target} = 0,78 \cdot \ln(P) - 1.88 + N$	
	B, D	Total	$0.125 \leq P \leq 10$	$\eta_{target} = 2.74 \cdot \ln(P) - 6.33 + N$	49
			$10 < P \leq 500$	$\eta_{target} = 0,78 \cdot \ln(P) - 1.88 + N$	
Centrifugal backward curved fan without housing	A, C	Static	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	62
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	
Centrifugal backward curved fan with housing	A, C	Static	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	61
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	
	B, D	Total	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	64
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	
Mixed flow fan	A, C	Static	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	50
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	
	B, D	Total	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	62
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	
Cross flow fan	B, D	Total	$0.125 \leq P \leq 10$	$\eta_{target} = 1.14 \cdot \ln(P) - 2.6 + N$	21
			$10 < P \leq 500$	$\eta_{target} = N$	

1.3.1.10 Directives on electronic communications networks and services

The Electronic Communications Framework is a regulatory framework that applies to all transmission and services for electronic communications[57]. It originally consisted of the following EU Directives and regulations:

- the Framework Directive (2002/21/EC) - (Directive 2002/21/EC on a common regulatory framework for electronic communication networks and services);
- the Access Directive (2002/19/EC) - (Directive 2002/19/EC on access, to and interconnection of, electronic communication networks and associated facilities);
- the Authorisation Directive (2002/20/EC) - (Directive 2002/20/EC on the authorisation of electronic communication networks and services);
- the Universal Service Directive (2002/22/EC) - (Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services);
- the E-Privacy Directive (2002/58/EC) - (Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector); and,
- the BEREC Regulation - (Regulation (EC) No 1211/2009 establishing the Body of European Regulators for Electronic Communications (BEREC) and the Office).

The objective of the Framework is to harmonise the regulation of electronic communications services across the whole EU. It aims to achieve this by strengthening competition in the electronic communication section; stimulate investment and foster freedom of choice for customers.

To ensure that the Framework continues to meet these objectives and keeps up to pace with the technological development within the electronic communication sector and changing market dynamics. The Framework contains an Article with the provision for regular review.

In November 2007 the EC published a series of legislative proposals for updating the framework. These proposals were contained within the "Citizens' Rights" amending Directive and the "Better Regulation" amending Directive. The EU Regulation 1211/2009 was established called the Body of European Regulators in Electronic Communications (BEREC)[58]. The revisions that were put forward in this Framework were adopted in 2009. These revisions brought new rights and protections for consumers and citizens in the EU.

Based on the review conducted in 2009, the 2002/21/EC Framework Directive was amended by Directive 2009/240/EC[59].

In September 2016, the Directive was revised again. The EC proposed the establishment of a European Electronic Communications code (EECC) and a proposal for a Regulation on the BEREC, to ensure the EU was prepared for its digital future[60]. On this basis, the EU Directive 2018/1972 was established in

[57] Official Journal L 337/2009 (europa.eu)

[58] https://www.ofcom.org.uk/cymru/about-ofcom/international/telecoms/framework-review

[59] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:337:0011:0036:en:PDF

[60] https://denmark.dlapiper.com/en/news/electronic-communication-networks-and-services#_ftn1

December 2018, also known as the EECC Directive[61]. This came into force in December 2020, meaning member states have to ensure that their telecommunications regulation is in accordance with the EECC Directive.

Overall, the EECC Directive maintains the objectives set in 2002, with the Directive ensuring that it keeps up to pace with technological advancement. For example, it now aims to stimulate competition and investments in high-capacity networks, especially 5G[62]. It comprises both traditional telecommunications companies and over-the-top provides such as WhatsApp and Facebook.

The Directive thus underlies regulations with respect to different aspects such as competition, affordable accessibility, or security. National legislations of the Member States have to ensure the confidentiality of communications and the related traffic data by means of a public communications network and publicly available electronic communications services.

An additional related Directive is the Data Retention Directive 2006/24/EC[63]. It requires EU members to store citizens' telecommunications data for retained periods of not less than six months and not more than 2 years. However, in 2014 the Court of Justice of the EU decaled this Directive invalid. The court ruled that, "*despite the Directive's legitimate purpose of fighting against serious crime and the protection of public security, it does not meet the principle of proportionality and should provide more safeguards regarding the protection of fundamental rights such as respect for private life and the protection of personal data*"[64].

1.3.1.11 Other Regulations in the European Union

There are several other regulations in Europe that support the increased energy efficiency of data centres and are focused on extending the lifetime of products[65]. These include the following list of regulations with a description of what they target provided as well:

- Medium Combustion Plant Directive, 2015 – Energy efficiency
- Industrial Emissions Directive, 2010 – Energy efficiency
- European Parliament resolution on a longer lifetime for products: benefits for consumers and companies (2016/2272(INI)) – Extended lifetime.

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[61] https://eur-lex.europa.eu/eli/dir/2018/1972/oj#:~:text=Directive%20(EU)%202018%2F1972,Recast)Text%20with%20EEA%20relevance.

[62] https://denmark.dlapiper.com/en/news/electronic-communication-networks-and-services#_ftn1

[63] LexUriServ.do (europa.eu)

[64] https://curia.europa.eu/jcms/upload/docs/application/pdf/2014-04/cp140054en.pdf

[65] A SITUATIONAL ANALYSIS OF A CIRCULAR ECONOMY IN THE DATA CENTRE INDUSTRY (weloop.org)

1.4 Voluntary Agreements

1.4.1 Voluntary Agreements at the European Union Level

1.4.1.1 The EU Code of Conduct on data centres

The EU Code of Conduct (CoC) for data centres is a voluntary scheme developed by the Joint Research Centre in 2008[66]. It was created to help reduce the environmental, economic and energy security impacts of data centres. The main objective is to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner without hampering the mission critical function of data centres. By growing the understanding of the energy demand of data centres, raising awareness, and recommending energy efficient best practices the CoC hopes to reduce the energy consumption of data centres.

The core of the programme is a registration form, signed by the participants, in which they commit to:

- an initial energy measurement, and energy audit to identify the major energy saving opportunities.
- an Action Plan must be prepared and submitted, once the Action Plan is accepted the Participant status will be granted.
- implement the Action Plan according to the agreed timetable. Energy consumption must be monitored regularly, to see overtime progresses in the energy efficiency indicator related to the data centre.

This initiative includes the typical elements of environmental management schemes. Progress reporting is required to be done on an annual basis to the responsible management body. However, the CoC partnership is issued for three years and the data centre is reassessed in a three years cycle.

The energy saving focus of the Code of Conduct covers two main areas:

1. **IT Load** - this relates to the consumption of the IT equipment in the data centre.

Facilities Load - this relates to the mechanical and electrical systems that support the IT electrical load.

These practices are relevant to both servers and data storage products.

1.4.1.2 Report on Critical Raw Materials and the Circular Economy

The EU has defined 27 materials as CRMs under the economic importance and supply risk criteria[67]. The report was produced in 2018 under the Action Plan on Circular Economy. These materials are regarded as important electrical equipment including servers with the table below highlighting in bold the CRMs relevant to servers.

[66] https://joint-research-centre.ec.europa.eu/scientific-activities-z/energy-efficiency/energy-efficiency-products/code-conduct-ict/code-conduct-energy-efficiency-data-centres_en#:~:text=The%20European%20Code%20of%20Conduct,100%20TWh%20in%20year%202020).

[67] https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1

Table 1.11 List of CRMs defined by the EU in 2018[68]

Critical Raw Materials (CRMs)			
Antimony	Fluorspar	**LREEs***	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs**	PGMs***	Vanadium
Coking coal	Indium	Phosphate rock	

**LREE = Light Rare Earth Elements (this includes neodymium), **HREEs = Heavy Rare Earth Elements, ***PGMs = Platinum Group Metals.*

Within the Phase 1 report, item j b). analyses the benefits of the information requirement for CRMs such as cobalt and neodymium. Section 2.8 of the Phase 1 report also provides the study team's recommendations. This includes keeping the current requirement for cobalt and neodymium, while also expanding the list of CRMs reported to include germanium, silicon, tantalum, gold and dysprosium. In addition, it is recommended that the indicative weight of these materials are provided, to facilitate recovery and recycling activities of these CRMs.

1.4.2 Voluntary Agreements at Member State Level

1.4.2.1 Blue Angel (Germany)

The German ecolabel Blue Angel[69] has developed an award criteria for "Servers and Data Storage Products" called DE-UZ 213. The award criteria were published in March 2022[70]. This ecolabel closely aligns with the requirements of the current Ecodesign legislation. The new Blue Angel eco-label for servers and data storage products sets a standard for ecological and energy-efficient top-of-the-range products in this area.

The Award Criteria for the Blue Angel apply to servers and data storage products that are designed for use in server rooms or data centres[71]. The basic requirements to achieve the Award Criteria for Blue Angel require the applicant must declare that the product meet the following relevant standards:

- 2019/ 424 (EU) Ecodesign for Servers and Data Storage Products
- V4.0 ENERGY STAR for Computer Servers
- V2.1 ENERGY STAR for Data Center Storage.

The energy efficiency requirements for servers in active state must be determined according to the most recent SERT version. Servers must comply with the requirements referred to in Table 1.12 to achieve the Blue Angel:

68 https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1 -p6

69 https://www.blauer-engel.de/en

70 Blue Angel eco-label for servers and data storage products | Federal Environment Agency (umweltbundesamt.de)

71 DE-UZ 213-202001-en-criteria-V3.pdf

Table 1.12 SERT Requirements in Blue Angel criteria

Number of CPU Sockets	Energy Efficiency in Active state
1-socket server	$Eff_{ACTIVE} \geq 15$
2-socket server	$Eff_{ACTIVE} \geq 25$
4-socket server or more	$Eff_{ACTIVE} \geq 27$

Blue Angel looks at the following specifications to measure the energy efficiency of servers and data storage products:

- **Power supply units**: For all internal and external power supply units that are designed to convert AC voltage from mains power supply to DC voltage for supplying the power to the device, the power supply unit (PSU) efficiency and power factor must be measure the same as defined in Regulation 2019/424.
- **For data storage products** the energy efficiency of these products must be determined in accordance with SNIA Emerald Power Efficiency Measurement Specification.
- **Monitoring data interface:** server and data storage products must provide the following data in real time:
  - power consumption (W),
  - inlet temperature of cooling medium (e.g. air/water) (°C)
  - data transfer via the network interface (Mbit/s)
  - for servers: Load state for every logical CPU (%)

Blue Angel looks at the following specifications to assess material requirements of servers and data storage products. This includes restricting the contents of certain substances within the plastic used in the housing and housing parts. The properties of these components include:

- Substances which are identified as particularly alarming under the European Chemicals Regulation REACH (1907/2006/EC) and which have been incorporated into the list drawn up in accordance with Article 59, Paragraph 1 of the REACH Regulation#
- Substances that according to the CLP Regulation have been classified in the following hazard categories or which meet the criteria for such classification
  - carcinogenic in categories Carc. 1A or Carc. 1B
  - germ cell mutagenic in categories Muta. 1A or Muta. 1B
  - reprotoxic (teratogenic) in categories Repr. 1A or Repr. 1B

In addition, there are restrictions on halogenated polymers in the housing and housing parts.

Other requirements that are involved in the Blue Angel criteria include:

- Product Durability
  - Availability of spare parts
  - Resetting capability for reuse
- Product documentation
- Applicants and parties involved
- Use of the Environmental Label

1.4.2.2 Future Thinking initiative

The data centre initiative Future Thinking was established in 2010 and has three main objectives: to enhance innovation, knowledge transfer and networking. This exchange platform promotes energy efficient thinking and sustainable resource use. Furthermore, the German Data Centre Price was introduced in 2011 in order to further incentivize innovative thinking.

1.4.2.3 Triple E programme (Ireland)

The Sustainable Energy Authority of Ireland (SEAI) is responsible for the list of energy equipment entitled Triple E34[72]. Triple E sets the minimum criteria that different products have to meet in order to be listed. These criteria are updated on a regular base with the goal that only the top 10-15% of the most energy efficient products in any technology are listed. The Triple E includes 52 technologies containing nearly 31,000 products on the register.

Concerning the Lot 9 scope, this Triple E list covers Rack Mounted Servers, Enterprise Storage Equipment, Blade Servers and ICT communication equipment. The Triple E programme is based on the existing Accelerated Capital Allowance (ACA) list of eligible products and eligibility criteria. The ACA is a tax incentive to encourage enterprises to invest in more energy efficiency technologies. It allows purchasers to write off 100% of the purchase value of the qualifying equipment against their profit for the year. The ACA sets the following eligibility criteria (which must be all met) for these technologies.

Rack Mounted Servers[73]

Table 1.13 ACA Rack Mounted Servers Eligibility Criteria

No	Condition	Supporting Documentation Requirements
1	Marketed and sold as an enterprise Rack Mounted Server.	Official and published manufacturer's technical data sheet or brochure that demonstrates compliance with the requirements of the condition.
2	Designed for, and listed as, supporting Enterprise Server operating Systems and/or Hypervisors, and targeted to run user-installed enterprise applications.	
3	Be capable of remote power-down.	
4	Meet the relevant minimum performance to power ratios in Table 1.14	Test report completed according to the SPEC industry standard benchmark performance test, SPECpower_ssj2008. Test reports must be of the format as required by SPECpower and published on the SPECpower website.
5	Be supplied with a software management system which renders the server virtualisation capable	Official and published manufacturer's technical data sheet or brochure that demonstrates compliance with the requirements of the condition.

[72] Categories & Criteria | Triple E Register for Products | SEAI

[73] Enhanced Capital Allowances (seai.ie)

Table 1.14 Minimum server performance to power ratios

Server Application	Minimum Ratio
Performance at low utilisation of less than or equal to 30%.	> 700
Performance at moderate utilisation of greater than 30%, but less than 70%.	> 1650
Performance at high utilisation of greater than or equal to 70%.	> 2150

The Performance to Power Ratio is based on the SPEC industry standard benchmark performance test, SPECpower_ssj2008.

Enterprise Storage Equipment[74]

Enterprise storage equipment is considered to include one or both of the following: solid state drive storage and disk drive storage.

Table 1.15 ACA Enterprise Storage Equipment's general Eligibility Criteria

<table>
<tr><th>No</th><th>Condition</th><th>Supporting Documentation Requirements</th></tr>
<tr><td>1</td><td>Be supplied with management software capable of two of the following:
A. Data de-duplication, data compression or single instancing
B. Thin/Virtual Provisioning
C. Array Virtualisation</td><td rowspan="2">Official and published manufacturer's technical data sheet or brochure that demonstrates compliance with the requirements of the condition.</td></tr>
<tr><td>2</td><td>Must form part of one of the following enterprise storage solutions:
A. Storage Area Network (SAN)
B. Direct Attached Storage (DAS)
C. Network Attached Storage (NAS)</td></tr>
</table>

In addition, a criteria has been developed at storage level. In order to meet this criteria Solid State Storage Drives must:

- Be designed to form part of an enterprise storage solution and have a minimum storage capacity of 120 Gb.

Disk Drive Storage must meet the following eligibility requirement:

- When idle be capable of intelligent power down and drive spin down or slow spin (MAID 2/IPM)
- Have a disk tiering strategy capable of supporting storage media with multiple power / capacity points with a factor of at least 2X between the slowest and fastest

[74] https://www.seai.ie/publications/Enterprise_storage.pdf

Blade Servers[75]

Table 1.16 ACA Blade Server Eligibility Criteria

No	Condition	Supporting Documentation Requirements
1	Marketed and sold as an enterprise Rack Mounted Server.	Official and published manufacturer's technical data sheet or brochure that demonstrates compliance with the requirements of the condition.
2	Designed for, and listed as, supporting Enterprise Server operating Systems and/or Hypervisors, and targeted to run user-installed enterprise applications.	
3	Be capable of remote power-down.	
4	Meet the relevant minimum performance to power ratios in Table 1.17	Test report completed according to the SPEC industry standard benchmark performance test, SPECpower_ssj2008. Test reports must be of the format as required by SPECpower and published on the SPECpower website.
5	Be supplied with a software management system which renders the server virtualisation capable	Official and published manufacturer's technical data sheet or brochure that demonstrates compliance with the requirements of the condition.

Table 1.17 Minimum server performance to power ratios

Server Application	Minimum Ratio
Performance at low utilisation of less than or equal to 30%.	> 900
Performance at moderate utilisation of greater than 30%, but less than 70%.	> 1900
Performance at high utilisation of greater than or equal to 70%.	> 2500

ICT Communications Equipment[76]

ICT Communications Equipment is considered to include the following: network routers, network switches, network firewalls and optical transmission equipment. Therefore, it does not fall within the scope of Lot 9.

1.5 Third Country Legislation & Voluntary Measures

1.5.1.1 ENERGY STAR® programme (U.S)

Launched in 1992, ENERGY STAR was originally a voluntary labelling program controlled by the U.S EPA and the U.S Department of Energy which supported energy efficiency products and practices. The blue ENERGY STAR label indicates that products comply with the performance criteria set

[75] https://www.seai.ie/publications/Blade_servers.pdf

[76] https://www.seai.ie/publications/ICT_Communications.pdf

by ENERGY STAR. It provides simple, credible, and unbiased information that consumers and businesses rely on to make informed decisions[77].

In 2001, the EU signed an Agreement with the US EPA to introduce the ENERGY STAR in Europe for IT and office equipment. This allowed potential partners in the European Union to sign up through the European Commission, who were responsible for the EU ENERGY STAR Programme. However, in 2018 the agreement between the U.S and the EU lapsed. This meant that the ENERGY STAR logo cannot be used on any EU products apart from those in stock already[78].

There are separate ENERGY STAR requirements documents for server and storage systems. ENERGY STAR server V4 specifies submission of SERT data, among other criteria, for the certification of server systems. The Data Center Storage requirements were published on March 15th of 2021 and are titled "Version 2.1 ENERGY STAR Data Center Storage Specification.

Version 4.0 ENERGY STAR® specification for computer servers was published in April 2023 and will take effect from January 12, 2024 and aims to differentiate energy efficient computer servers in order to support a more environmental-oriented procurement of products. Version 4.0 is a considerable enhancement of the previous 3 versions (2009, 2013, 2018) and reflects the deep analysis and development work that has been done by the U.S. Environmental Protection Agency (EPA). The most important aspect in conjunction with the ENERGY STAR® specifications is the joint development of energy-performance test standards in collaboration with industry stakeholders. It needs to be underlined that the development of energy-performance test standards for servers and storage equipment demanded a thorough analysis of typical products, their performance and application specific properties, as well as system implementation and operator aspects. The knowledge and conclusions derived from the test standard development process are a major source of information and demands therefore significant consideration within the Regulation (EU) 2019/424 study.

The current ENERGY STAR requirements for servers, storage systems and networking equipment are listed below. These include:

- Version 4.0 ENERGY STAR® specification for computer servers was published in April 2023 and will take effect from January 12, 2024.
- Version 2.1 ENERGY STAR Data Center Storage specification was published on March 15th of 2021.
- Version 1.1 ENERGY STAR® specification for Large Network Equipment[79] took effect on March 1, 2016.

1.5.1.2 Specification for Version 4.0 Computer Servers

The specification for computers servers covers: Blade, Multi-node, Rack-mounted, or Pedestal form factor computer servers with no more than four processor sockets in the computer server. The qualifications criteria include:

- Power supply efficiency criteria (Table 1.18) and power supply factor criteria (Table 1.19) for all power supply units. These units must meet the following the

[77] https://www.energystar.gov/about

[78] https://www.greenbiz.com/article/scrapping-energy-star-labels-leaves-vacuum-europe

[79] ENERGY STAR LNE Final Version 1.1 Specification

requirements when tested using the *Generalised Internal Power Supply Efficiency Test Protocol, Rev. 6.7*[80].

Table 1.18 ENERGY STAR Efficiency Requirements for PSUs

Power Supply Type	Rated Output Power (W)	10% Load	20% Load	50% Load	100% Load
Multi-output (Ac-Dc)	750 watts or greater	N/A	90%	92%	89%
Multi-output (Ac-Dc)	Less than 750 watts	N/A	87%	90%	87%
Single-output (Ac-Dc)	750 watts or greater	90%	94%	96%	91%
Single-output (Ac-Dc)	Less than 750 watts	83%	90%	94%	91%

Table 1.19 ENERGY STAR Power Factor Requirements for PSUs

Power Supply Type	Rated Output Power (W)	10% Load	20% Load	50% Load	100% Load
Ac-Dc Multi-output	All Output Ratings	N/A	0.80	0.90	0.95
Ac-Dc Single-output	Output Rating ≤ 500 W	N/A	0.80	0.95	0.95
	Output Rating ≥ 500 W and Output Rating ≤ 1000 W	0.65	0.80	0.95	0.95
	Output Rating ≥ 1000 W	0.80	0.90	0.95	0.95

- Power Management Requirements: Computers server must offer processor power management that is enabled by default in the BIOS and/or through management controller, service processor and/or the operating system shipped with the computer server.
- Supervisor Power Management: products which offer a pre-installed supervisor system must offer supervisor system power management that is enabled by default.
- Power Management Reporting: all power management techniques must be detailed in certification submission.
- Blade and Multi-node Thermal Management and Monitoring: real-time chassis or blade/node inlet temperature monitoring and fan speed management capability that is enabled by default.
- Blade and Multi-node Server Shipping Documentation: one that is shipped to a customer independent of the chassis must be accompanies with documentation to inform the customer that the blade or multi-node server is ENERGY STAR qualified only if installed in chassis meeting requirements set out in Section 3.4.1 of V4 Computers Servers specification.

[80] http://www.efficientpowersupplies.org/

- Active State Efficiency Criteria: Products must be submitted with the following information disclosed in full in context of the complete Active State efficiency rating test report:
  - Final SERT rating tool results, which include the result files and all result charts; and
  - Intermediate SERT rating tool results over the entire test run, including the results-details files

Calculate Active State efficiency requirements shall be greater than or equal to the minimum Active State efficiency thresholds listed below in Table 1.20.

Table 1.20 Active State Efficiency Thresholds for all non-SHS Computer Servers

Product Type	Minimum Eff_{ACTIVE}
One Installed Processor	
Rack	26.4
Tower	24.4
Resilient	6.6
Two Installed Processor	
Rack	30.4
Tower	26.5
Blade or Multi-Node	29.1
Resilient	6.0
Greater Than Two Installed Processors	
Rack	31.9
Blade or Multi-Node	26.8

- Idle State Efficiency Criteria: Idle State power shall be measured and reported for all computer server types. In addition, for blade and multi-node products, $P_{TOT\_BLADE\_SYS}$ and $P_{TOT\_NODE\_SYS}$ shall also be reported respectively. Calculation of single blade power shall be done by:

$$P_{NODE} = \frac{P_{TOT\_BLADE\_SYS}}{N_{INST\_BLADE\_SRV}}$$

Where:

- P_{NODE} - is the per-Node Server Power.
- $P_{TOT\_NODE\_SYS}$ - is total measured power of the Multi-Node Server,
- $N_{INST\_NODE\_SRV}$ - is the number of installed Multi-Node Servers in the tested Multi-Node Chassis.

1.5.1.3 Specification for Version 2.1 Date Center Storage

The ENERGY STAR defines a for data centre storage product as one a “a fully-functional storage system that supplies data storage services to clients and devices attached directly or through a network” the full definition can be found in Definitions in v2.1 ENERGY STAR® specification for data centre storage equipment. This type of data centre storage systems fits within the EU Lot 9 scope. The qualification criteria for data centre storage products looks at power supply requirements, energy efficiency feature requirements and information requirements.

Power supply units (PSU) which are used in storage products are able to qualify for ENERGY STAR if they meet the following requirements when tested using EPRI Generalised Internal Power Supply Efficiency Test Protocol.

The efficiency and power factor in primary embedded equipment requirement include: embedded PSUs that power components of the storage product, including controllers and drawers, must meet the requirements set forth in Table 1.21 and Table 1.22.

Table 1.21 Efficiency Requirements for PSUs

Power Supply Type	Rated Power Output	20% Load	50% Load	100% Load
Multi-output (Ac-Dc)	All Output Levels	88%	92%	88%
Single-output (Ac-Dc)	All Output Levels	90%	94%	91%

Table 1.22 Power Factor Requirements for PSUs

PSU Type	Rated Power Output	20% Load	50% Load	100% Load
Single and Multi-Output PSU	All Output Levels	0.80	0.90	0.95

To certify the optimal configuration point submitted for a block I/O storage product or storage product family must meet the following active state requirements in Table 1.23.

Table 1.23 Active State Requirements for Block I/O Storage Products

Workload Type	Specific Workload Test	Minimum Performance/ Watt Ratio	Applicable Units of Ratio
Transaction	Hot Band	28.0	IOPS/watt
Streaming	Sequential Read	2.3	MiBS/watt
Streaming	Sequential Write	1.5	MiBS/watt

Energy Efficiency Feature Requirements: storage products must contain adaptive active cooling features that reduce the energy consumed by the cooling technology in proportion to the current cooling needs to the storage product. The storage product shall also make available to the end user configurable / selectable features listed in Table 1.24 and in quantities great than or equal to those listed in Table 1.25.

Table 1.24 Recognised COM features.

Feature	Verification Requirements
COM: Thin Provisioning	SNIA Verification test
COM: Data Deduplication	SNIA Verification test
COM: Compression	SNIA Verification test
COM: Delta Snapshots	SNIA Verification test

Table 1.25 COM Requirements for Disk Set and NVSS Set Access Online Systems

Storage Product Category	Minimum number of COMS required to be made available
Online 2	1
Online 3	2
Online 4	3

Included within the data centre ENERGY STAR specification is an extensive set of information requirements which covers the following:

- Active and idle state efficiency disclosure: all products are requires to state the test results based on workloads listed in section 3.5 of Version 2.1 Data Center Storage specification[81]. There are 6 different workloads for block I/O configurations and 5 different workloads for file I/O configurations.
- Workload weighting requirements: the weighted percentages presented according to the Optical workload ratings provided in section 3.5.2 of Version 2.1 Data Center Storage specification.
- Testing data requirements for all scale-up storage products must be submitted for certification.
- Testing data requirements for all scale-out storage products must be submitted for certification.

1.5.1.4 Specification for Version 2.1 Large Network Equipment

This specification applies to large network equipment which is mountable in a standard equipment rack, supports network management protocols and contains either more than 11 physical network port or a total aggregate port throughput greater than 12 Gb/s[82].

The qualification criteria includes power supply requirements, energy efficiency feature requirements and active state efficiency.

The Power Supply Requirements include:

- Power supply efficiency criteria: power supplies used in products that are eligible for the specification must meet the requirements set out in Table 1.26.

Table 1.26 Efficiency Requirements for PSUs

PSU Type	Rated Power Output	10% Load	20% Load	50% Load	100% Load
Multi-output	All Output Levels	N/A	85%	88%	85%
Single-output	All Output Levels	80%	88%	92%	88%

- Power supply power factor criteria: Ac-Dc power supplies used in the large networking equipment must meet the requirements set out in Table 1.27.
- **Fixed large networking** equipment and **modular large networking** equipment should meet the all the Ac-Dc PSUs requirements set out in Table 1.27 prior to

[81] ENERGY STAR Data Center Storage Version 2.1 Final Specification -p10

[82] ENERGY STAR LNE Final Version 1.1 Specification

shipment under all loading conditions when output power is greater than or equal to 75 Watts.

Table 1.27 Power factor requirements for Ac-Dc PSUs

PSU Type	Rated Power Output	10% Load	20% Load	50% Load	100% Load
Multi-output	All Output Levels	N/A	0.80	0.90	0.95
Single output	Output Rating ≤ 500 W	N/A	0.80	0.90	0.95
	Output Rating ≥ 500 W and Output Rating ≤ 1,000 W	0.65	0.80	0.90	0.95
	Output Rating ≥ 1,000 W	0.80	0.90	0.90	0.95

The energy efficiency feature requirements for large networking equipment requires these products to have the following features:

- Remote port administration
- Adaptive active cooling
- Energy efficient ethernet

In addition, ENERGY STAR has looked into providing a set of active state efficiency criteria for all large networking equipment. ENERGY STAR are current pursuing an approach to encourage further testing of the energy efficiency of large networking equipment. Currently ENERGY STAR requests that active state data is reporting in order for it gain certification.

1.5.1.5 The Certified Energy Efficient Data Centre Award – BCS (UK)

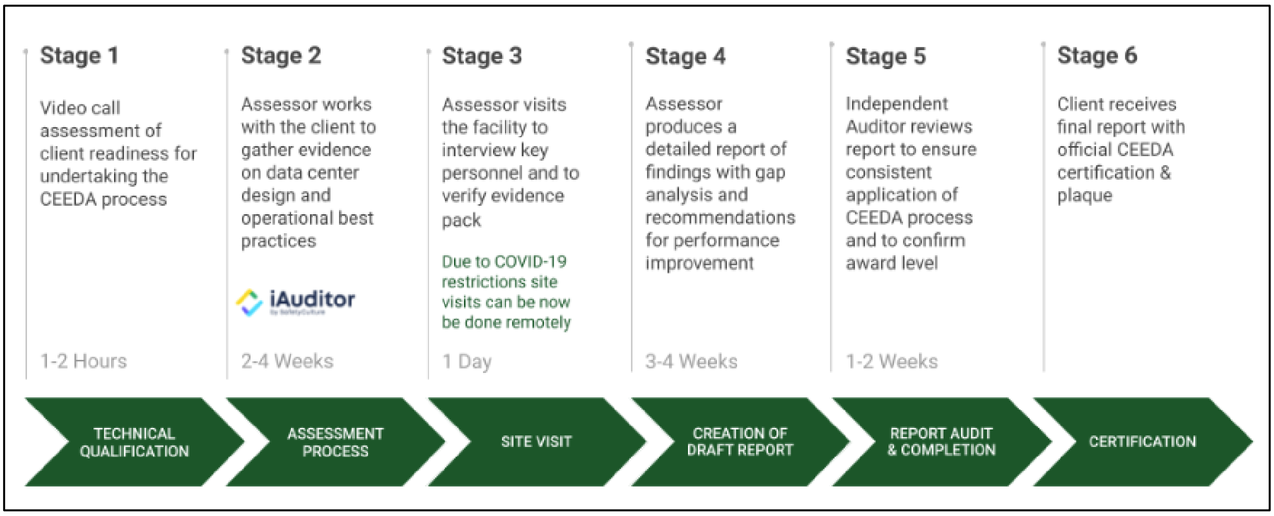
The Certified Energy Efficient Data Centre Award (CEEDA) is an assessment and certification program which is ratified by the BCS (the Chartered Institute for IT)[83]. CEEDA is an independently evaluated global certification program designed to recognise the implementation of energy efficiency best practices in data centres.

CEEDA applies an assessment framework based on energy efficiency best practices in: M&E and IT infrastructure; operational management; the management of IT services and software. The framework is base on a combination of standards from: ASHRAE, ENERGY STAR, ETSI, ISO, European Code of Conduct and the Green Grid metrics. CEEDA also validates the method of measurement and calculated values for a set of energy efficiency performance metrics, primarily those defined by the Green Grid, such as PUE, WUE (source, onsite) or ERE.

The CEEDA assessment and certification process is summarised below by the diagram shown in Figure 1.2.

83 https://www.datacenterdynamics.com/en/ceeda/

Figure 1.2 The 6-stage process from CEEDA Certification[84]



The certification period is two years' and includes a follow-up assessment one year after the certification date. The purpose of the follow-up assessment is to determine the impact of any implemented recommendations from the gap analysis and note any significant changes in the facility, services provisioned, operational management or IT infrastructure.

1.5.1.6 UK Data Centres Climate Change Agreement

The UK's Data Centre Climate Change Agreement was started in 2015, with the aim to encourage energy efficiency at the system level[85]. Recently the agreement was revised in February 2022. As of 2020 it covers 129 facilities from 57 target units, representing 42 companies[86]. The total energy use by these facilities was 2.573 TWh p/a, all these facilities have a PUE of < 1.80. Being an approved data centre means exempts the facilities from paying an extra tax on energy use. In exchange the operators have to commit to increase energy efficiency of the facilities.

1.5.1.7 1EPEAT

The Electronic Product Environmental Assessment Tool (EPEAT)[87] is a ISO 14021 Type-1 ecolabel for technology products, managed by the Global Electronics Council (GEC). It covers the complete lifecycle and thus combines comprehensive criteria for design, production, energy use and recycling with ongoing independent verification of manufacturer claims. It is used by multiple governments around the world (such as US, Canada, UK, France, Poland, Australia, New Zealand, Singapore) and awards more than 3,000 products from more than 50 manufacturers registered in 43 countries.

Products must meet certain requirements and optional EPEAT criteria to be considered EPEAT-registered. It rates products Bronze, Silver or Gold, based on how many of the optional criteria they meet (while meeting all required criteria). The Standard is a environmental leadership and corporate responsibility standard.

[84] https://www.datacenterdynamics.com/en/ceeda/about-ceeda/

[85] https://www.gov.uk/government/publications/climate-change-umbrella-agreement-for-the-data-centre-sector

[86] https://ukerc.ac.uk/news/uk-data-centres-carbon-neutral-by-2030

[87] https://www.epeat.net/

Therefore, approximately 25-35% of the products on the market are expected to qualify to the Bronze level and even fewer for Silver and Gold. Products registered as EPEAT products are subject to unannounced audits at any time, with results publicly reported. Requirements of the ENERGY STAR® programme are considered in the criteria. The EPEAT certified products are continuously monitored with last round of monitoring for servers and network equipment finishing in March 2023[88].

The EPEAT register currently includes ratings for Servers[89] (published in 2021) and Network equipment[90] (published in 2019). The EPEAT criteria cover the reduction or elimination of environmentally sensitive materials, materials selection, design for end of life, lifecycle extension, energy conservation, end of life management, corporate performance, and packaging.

1.5.1.8 80 PLUS certification

The 80 PLUS programme is a voluntary certification programme launched by Ecos Consulting (now Ecova) in 2004, to promote energy efficiency technology products[91]. The 80 PLUS performance specification requires power supplies in computers and servers to be 80% or greater energy efficient at 10%, 20%, 50% and 100% of rated load. Additionally, It requires products to have a true power factor of greater than 0.9 at with a true power factor of 0.9 or greater 10%, 20%, 50% and 100% of rated load. This makes an 80 PLUS certified power supply substantially more efficient than typical power supplies. The programme differentiates further levels of high efficiency, through the Bronze, Silver, Gold, Platinum and Titanium awards.

Table 1.28 Efficiency Level Requirements of the 80 Plus Programme

80 Plus Certification	115V Internal Non-Redundant				115V Industrial			
% of Rated Load	10%	20%	50%	100%	10%	20%	50%	100%
80 PLUS	-	80%	80%	80% PFC ≥ 0.90	-			
80 PLUS Bronze	-	82%	85% PFC ≥ 0.90	82%	-			
80 PLUS Silver	-	85%	88% PFC ≥ 0.90	85%	80%	85% PFC ≥ 0.90	88%	85%
80 PLUS Gold	-	87%	90% PFC ≥ 0.90	87%	82%	87% PFC ≥ 0.90	90%	87%

88 https://www.epeat.net/about-epeat#accessing-epeat-criteria

89 https://globalelectronicscouncil.org/wp-content/uploads/NSF-426-2019.pdf

90 https://globalelectronicscouncil.org/wp-content/uploads/EPEAT-Network-Equipment-Criteria_FINAL-April-2021.pdf

91 https://www.clearesult.com/80plus/

80 Plus Certification	115V Internal Non-Redundant				115V Industrial			
% of Rated Load	10%	20%	50%	100%	10%	20%	50%	100%
80 PLUS Platinum	-	90%	92% PFC ≥ 0.95	89%	85%	90% PFC ≥ 0.95	92%	90%
80 PLUS Titanium	90%	92% PFC ≥ 0.95	94%	90%	-			

In addition, to the requirements displayed in Table 1.28 there are specific 80 Plus requirements for the following types of servers:

- 230V EU Internal Non-Redundant
- 230V EU Internal Redundant
- 380V DC Internal Redundant

These can be found on the 80 Plus website (Program Details | CLEAResult)

1.5.1.9 Top Runner Program in Japan

The Japanese Top Runner Program is managed by the Energy Conservation Center, Japan. It is a mandatory policy instrument that targets the energy consumption during the use phase through market transformation. The idea is that the product with the highest energy efficiency sets the standard and all other appliances are required to reach that level within an agreed time scale[92]. If the required level is achieved or surpassed by the manufacturers and importers before the deadline, the process starts again, starting a new cycle. If targets aren't met the government will propose recommendations, which can be enforced in the event of further non-compliance.

There is currently only one Top Runner standard that fits within the EU Lot 9 scope. That is the standard for Computers & Magnetic Disk Units, with the most recent version of this standard dating back to 2009[93]. The standard provides the following definition for a computer server: ""*Server computer" refers to a computer that is designed to operate 24 hours a day and provide services on a network, and which can be accessed only via the network"*[94].

The following products are excluded from the legislation for computers in Top Runner are:

- Products with a composite theoretical performance of 200,000 mega calculations or more p/s.
- Products capable of performing calculations using arithmetic processing unit composed of more than 256 processors.
- Products with more than 512 or more I/O signal transmission lines

[92] https://www.asiaeec-col.eccj.or.jp/

[93] https://www.eccj.or.jp/top_runner/pdf/tr_computers_magneticdiscunits_dec2009.pdf

[94] https://www.eccj.or.jp/top_runner/pdf/tr_computers_magneticdiscunits_dec2009.pdf - p5

- Products with composite theoretical performance of less than 100 mega calculations per second.
- Products powered exclusively by an internal battery during use and never operate based on a power supply from a power line and do not contain a HDD.

In 2019, Japan's Ministry of Economy, Trade and Industry (METI) indicated that they had accepted a change in the computer server energy conservation standard[95]. This update to the updated SERT suite version 2 now demonstrates the performance per watt of computer servers. This will further promote energy conservation by setting energy conservation standards based on energy consumption efficiency rates taking into account changing capabilities and environments. Previously the calculation method for efficiency was derived from a calculation based solely on the electricity consumption and performance of CPUs.

For hard disk drives, requirements are set at the individual device level, and not at the storage product level considered in this study; they are therefore not presented in detail here. The program has been looking into updating a new version of this standard however, it is not clear when.

1.5.1.10 The National Australian Built Environment System (NABERS) for Data Centres

The NABERS was developed to ensure that data centres operate efficient, assess where power is being consumed and to ensure that cooling capacity is correctly aligned to IT loads[96]. It aims to provide an indication of the operational energy efficiency and environmental impact of data centres in Australis. It scores data centres from one to six stars (see Figure 1.3) based on its power usage effectiveness (PUE) and is based on the facilities operational data, not design. With rating then used to help identify areas for operational improvement and cost savings, as well as to promote environmental credentials[97].

Figure 1.3 NABERS Star Rating Guide[98]

There are three different levels of rating streams these include:

- **IT Equipment** – This rating is for organisations who own or manage their IT equipment and don't control building amen such as A/C, lighting and security.

[95] New Energy Conservation Standards for Electronic Computers Formulated (meti.go.jp)
[96] https://www.energy.gov.au/business/equipment-and-technology-guides/data-centres
[97] https://www.nabers.gov.au/ratings/spaces-we-rate/data-centres
[98] Fact Sheet - Data Centres.pdf (nabers.gov.au)

- **Infrastructure –** This rating is for data centre owners and managers. It allows the self-determination of a facilities energy efficiency in supplying infrastructure to IT
- **Whole Facility –** This rating combines IT equipment and infrastructure tools. This is for organisations that managed and occupy their data centre or where internal metering arrangement don't permit separate IT equipment or infrastructure ratings.

1.5.1.11 Voluntary CQC Certification, China

The CQC certification is a voluntary product certification scheme implemented by the Chinese Environmental United Certification Centre[99]. Products that do not fall under scope of the mandatory China Compulsory Certification (CCC) can obtain a CQC certification on a voluntary basis. The aim is to provide an indication to the end user in China that the product meets the Chinese quality standards and corresponding GB standards.

The scheme defines rules and criteria for servers (CQC3135-2011)[100]. The scope includes tower-type and rack-mounted servers using power supply from 220V/50Hz power grid, with 1 and 2 processor slots while blade servers and multi-node servers are excluded from the scheme. Requirements concern the idle-state consumption:

- 1 socket server: ≤ 65 W
- 2 sockets server: ≤ 150 W

With some allowance:

- 2 W per additional GB
- 20 W for a power supply module
- 8 W per hard disk drive
- 2 W per network port

1.5.1.12 The Swiss Datacentre Efficiency Association (SDEA)

The Swiss Datacenter Efficiency Association (SDEA) provides a measure of a datacentre's operational efficiency and environmental impact. It not only considers traditional elements such as PUE, but it also evaluates the IT infrastructure utilisation and heat recycling aspects of the datacentre. This Full-Stack Efficiency approach provides a comprehensive and quantifiable evaluation of operational efficiency and environmental impact[101]. The SDEA provide each datacentre that applies with a label to demonstrate their efficiency.

The baseline label encapsulates a datacentre's efficiency journey from energy intake to heat recycling and captures datacentre and IT infrastructure as well as workload utilisation and technology excellence. The premium variant of the label measure, the datacentres carbon emissions, factoring in emissions from imported energy sources. There are three grades which decipher how the datacentre performs, Gold, Silver and Bronze. The label thresholds are displayed below in Figure 1.4.

[99] https://www.china-certification.com/en/china-cqc-certification-ccap-certification/

[100] https://www.cqc.com.cn/www/chinese/c/2011-08-02/492857.shtml

[101] https://www.sdea.ch/

Figure 1.4 Label thresholds from the SDEA[102]

	GOLD Plus	SILVER Plus	BRONZE Plus
DC Efficiency Index (DCE)	1.20	1.35	1.50
Carbon Index (CUE)	100g CO_2e/kWh	100g CO_2e/kWh	100g CO_2e/kWh
	GOLD	**SILVER**	**BRONZE**
DCE	1.20	1.35	1.50

[102] https://www.sdea.ch/certification

2 Introduction to Task 2 Markets

The prime objective of this report is to outline the economic, market and stock data of the products covered by the Ecodesign Regulation 2019/424 on servers and data storage products.

2.1 Generic Economic Data

The European Union's (EU) official source of statistics is PRODCOM and data are published annually by EUROSTAT[103]. PRODCOM data is based on manufactured goods whose definitions are standardised across the EU, therefore guaranteeing consistency and comparability between Member States. Although these statistics are often used and referenced in other EU policy documents when it comes to trade and economic policy, they have their limitations. Many data points are unreported, estimated, or confidential. There is also a lot of overlap of products with the same PRODCOM code. Thus, it can be difficult to get an accurate statistic for servers and data storage products. The study team has chosen the following PRODCOM codes which it feels best represent servers and data storage products.

There are seven categories defined by PRODCOM that cover servers and data storage products[104]. PRODCOM classifies servers and data storage products in the categories:

- NACE 26.20 "Manufacture of computers and peripheral equipment" and
- NACE 26.30 "Manufacture of communication equipment"[105].

The products covered under these categories which are relevant to this study are presented below separated out by product type:

2.1.1 Servers

- **26201400** – Digital data processing machines: presented in the form of systems;
- **26201500** – Other digital automatic data processing machines whether or not containing in the same housing one or two of the following units: storage units, input/output units;

2.1.2 Servers and storage-related network equipment

- **26302320** – Machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus;
- **26302370** – Other apparatus for the transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network (such as a local or wide area network), other than transmission or reception apparatus of HS 84.43, 85.25, 85.27 or 85.28.

[103] https://ec.europa.eu/eurostat/web/prodcom

[104] https://ec.europa.eu/eurostat/web/main/home

[105] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2119

2.1.3 Storage equipment

- **26202100** – Storage units;
- **26203000 –** Other units of automatic data processing machines (excluding network communications equipment (e.g. hubs, routers, gateways) for LANs and WANs and sound, video, network and similar cards for automatic data processing machines);
- **26202200** - Solid-state, non-volatile data storage devices for recording data from an external source (flash memory cards or flash electronic storage cards), unrecorded

These categories include a wide range of products, and it is not clear exactly which devices each category covers, as the aggregation level of data remains relatively high. There are some concerns when using the PRODCOM data, where the codes and their scope are not completely clear:

- The scope of 26.20.14.00 code is not completely clear but this code is more likely to represent coding for computer mainframes.
- The scope of 26.20.15.00 code is not completely clear but it is more likely to represent coding for computer servers.
- 26.20.21.00 storage units may not apply to data storage devices as intended in the study. This is because it is possible the code is covering units such external hard drives, or USB keys.

Table 2.1 Market data for servers and data storage equipment in 2021 (EU-27)[106].

PRODCOM NACE Code	Quantity in 1000 units				Value in million €			
	Production	Import	Export	Apparent EU consumption[107]	Production	Import	Export	Apparent EU consumption
26201400	3,720	1,064	1,000	3,784	48,800	10,910	14,706	45,004
26201500	2,000	16,868	6,508	12,360	1,671	6,690	6,472	1,889
26202100	6,000	95,120	21,794	79,326	590	8,555	3,548	5,597
26203000	3,325	n/a*	n/a	n/a	428	n/a	n/a	n/a
26202200	390	5,187	640	4,937	144	2,616	574	2,186
26302320	53,625	n/a	n/a	n/a	3,558	27,958	14,075	17,441
26302370	13,735	n/a	n/a	n/a	1,408	640	654	1,394

**n/a – Data not available.*

The data presented in Table 2.1 represents the overall EU-27 production, trade, and apparent consumption in 2021 according to the seven PRODCOM categories. The 2021 data are the latest available at the time of writing this report. These values are compared below in Figure 2.1 and Figure 2.2.

[106] Source: PRODCOM

[107] Apparent EU Consumption = EU production + EU imports – EU exports

Figure 2.1 Market size for servers and data storage products in the EU-27 in 2021[108]

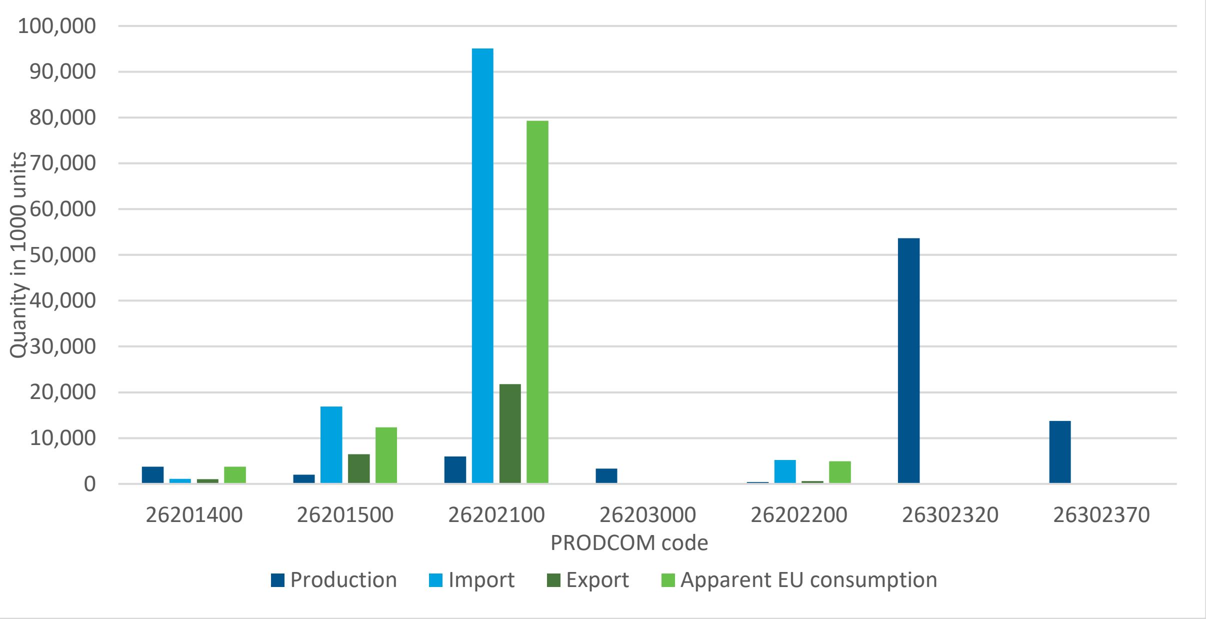


Figure 2.1 demonstrates that data storage products have the highest unit sales. However, due to the discrepancies in the PRODCOM code for 26202100 "Storage Units", it is not clear what type of storage units are specifically included. It should also be noted that it is common practice to count storage products in terms of GB of storage, rather than number of devices as is presented by PRODCOM. Consequently, this may explain the order magnitude difference for this category.

For servers, imports are greater than exports, which is expected, with most servers manufactured outside of the EU, as described in Section 2.4. Figure 2.1 demonstrates that production of servers and storage related network equipment is also one of the major markets for the EU regulation. However, there was no data on imports/ exports for these PRODCOM codes Thus, a full picture of the EU market is not available for servers and storage related network equipment.

108 Source: PRODCOM

Figure 2.2 Market value for servers and data storage products in the EU-27 in 2021[109]

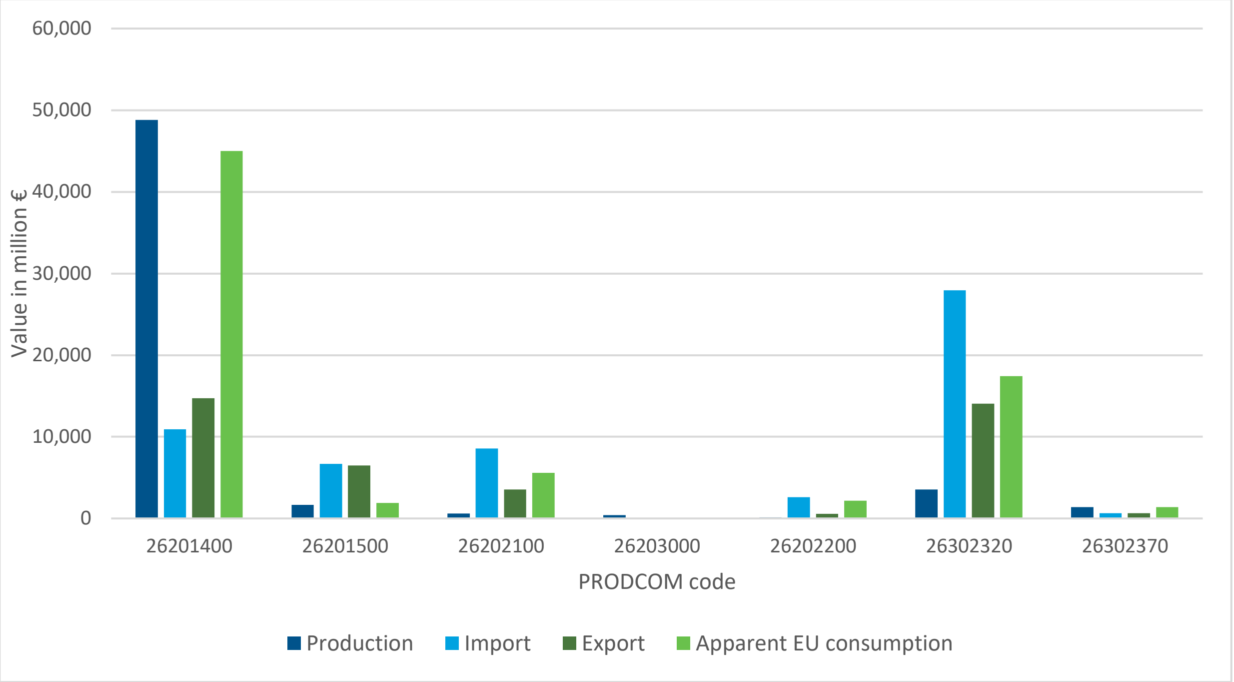


Figure 2.2 demonstrates the market value of imports, exports. From Figure 2.2 it is clear that the values of imports are far superior than exports for servers and storage-related network equipment. In addition, for the individual categories for servers and data storage products imports, imports appear to be greater. There is a significantly high production value for the "*Digital data processing machines: presented in the form of systems*". However, it is difficult to determine how servers impact this value, judging by the import values in Figure 2.1 it looks to be quite small, as imports are high in the EU.

Overall, due to the heterogenous nature of the data collected from PRODCOM this data does not present the best available source of sales, production, and trade. However, PRODCOM does provide a reference point to ensure that data utilised later on in the document is accurate. This breakdown limitation that the PRODCOM codes presented above will only serve for informational purposes. PRODCOM data will not be considered in the environmental and life cycle assessment analysis during this study.

2.2 Market and stock data

This section looks to provide the market analysis for servers and data storage products further than the PRODCOM data. Providing market and stock data for servers and data storage products covered by the Regulation 2019/424.

2.2.1 Manufacturer and Supplier Engagement

To collect data, we have circulated qualitative and quantitative questionnaires with over 150 stakeholders. Table 2.2 demonstrates the level of engagement received for both the questionnaires.

[109] Source: PRODCOM

Table 2.2 Number of responses to questionnaires circulated.

Type of Questionnaire	Number of responses
Qualitative Questionnaire	19
Quantitative Questionnaire	3

Off the back of this, we very much hope stakeholders will engage further with the study, in light of this information. Following the publication of the draft Task 2 report and the data requests that were highlighted by the draft reports, the study team has received significantly more feedback.

2.2.2 Sales data at global and EU level

2.2.2.1 Servers

Sources such as Statista, provide figures for the global and EU server market value and shipments. Table 2.3 below presents this data. Calculations have also complemented certain gaps in the data, such as by assuming that the EU percent share of the global market has continued to decrease at the same rate since 2019, and that the average price per unit has not changed significantly since 2020.

Table 2.3 Server market and Shipment data (Statista and ICF calculations)[110]

	2019	2020	2021	2022	2023	2024	2025	2026	2027
Global server market revenue ($bn)	87.18	91.02	*90.94*	*90.86*	90.78	96.04	101.60	107.48	113.70
Global server shipments (million units)	11,74	12,15	*12,14*	*12,13*	*12,12*	*12,82*	*13,56*	*14,35*	*15,18*
EU server market revenue ($bn)	*12,68*	*13,18*	*13,10*	*13,03*	12,95	13,63	14,35	15,10	15,9
EU server shipments (million units)	*1,71*	*1,76*	*1,75*	*1,74*	*1,73*	*1,82*	*1,92*	*2,02*	*2,12*
EU percent of global market share	*14,55%*	*14,48%*	*14,41%*	*14,34%*	*14,27%*	*14,19%*	*14,12%*	*14,05%*	*13,98%*

Figures in italics have been calculated from the statista data

The data shows how the server market is currently expected to grow until 2027. This has changed since 2020, as the Covid-19 pandemic slowed sales between 2020 to 2022. The EU share of the global market is approximately 14%, but has been decreasing, despite continued growth of the EU revenue. This is due to the strong growth of the Asian market. Additionally, the UK exit from the EU has had a

[110] Servers - EU-27 | Statista Market Forecast ; Servers - Worldwide | Statista Market Forecast ; Server shipments worldwide 2020 | Statista; Server market revenue worldwide 2020 | Statista ; End user server spend worldwide 2019-2024 | Statista

significant impact on the EU's server market because it was found that around 24% of the EU's total datacentre equipment was located in the UK, in 2019[111].

2.2.2.2 Data Storage Products

Data storage units can either be host based or external controller based as displayed in Table 2.4.

Table 2.4 Storage options for data storage products

Host Based	External Controller Based
Internal	All External
External	iSCSI
SATA	Fibre Channel
SCSI	
JBOD Enclosures	

Table 2.5 Data storage product market revenue data (Statista and ICF calculations)[112]

	2020	2021	2022	2023	2024	2025	2026	2027
Global data storage market revenue ($bn)	41,15	*43,41*	*45,79*	47,92	50,59	53,41	56,38	59,52
EU data storage market revenue ($bn)	*6,04*	*6,32*	*6,61*	6,86	7,18	7,52	7,87	8,23
EU percent of global market share	*14,68%*	*14,56%*	*14,44%*	*14,32%*	*14,19%*	*14,07%*	*13,95%*	*13,83%*

Figures in italics have been calculated from the statista data

As with servers, the data storage market is expected to continue growing until 2027. However, unlike for computer servers, the demand for storage did not decrease in 2021-2022 due to the covid-19 pandemic. The EU share of the global market is approximately 14%, but has been decreasing, despite continued growth of the EU revenue. This is due to the strong growth of the Asian market.

2.2.3 Sales growth rate

The global server market is estimated to grow by 5.79% Compound Annual Growth Rate (CAGR) from 2023 to 2027. For the EU, this growth is forecast to be 5.26% from 2023 to 2027, raising the market share from 12.95$bn to 15.9$bn.[113] It is noted that the growth rate of the EU market is lower than that of the global figure, as although the industry continues to develop, the Asian market is expected to grow at a faster rate, justifying the difference.

Similarly, the data storage market is expected to continue to grow by 5.57% CAGR globally, and by 4.67% in the EU, from the years 2023 to 2027. The EU market is expected to grow from 6.86$bn to 8.23$bn from 2023 to 2027.

[111] https://photonicsuk.org/wp-content/uploads/2016/12/ktn_a4_big-data_v9_released.pdf

[112] Storage Report 2021 | Statista ; Storage - EU-27 | Statista Market Forecast

[113] Source: Servers - EU-27 | Statista Market Forecast

2.2.4 Product Lifetimes

There are two different types of “lifetimes” that need to be clarified to avoid confusion:

- **The economic lifetime**: is the time after which equipment is renewed by the owner/operator for economic and business reasons; and
- **The technical lifetime**: is the time after which the product no longer functions and cannot be repaired. This is usually longer than the economic lifetime.

When considering the lifetime of a product it is important to consider both reliability and durability of a product. The *reliability of a product or part is the probability that it performs its intended function(s) under given conditions, including maintenance, for a given duration without failure.* The *durability of a product or a part is the ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached. Durability is a broader concept than reliability because it includes repair*[114]*.*

Servers and data storage equipment can have a technical lifetime of greater than 10 years for certain equipment. However, this can be impacted by the modularity of the equipment because this makes it difficult to determine the composition of the equipment. This can be caused by failing components (e.g., memory) which are replaced meaning after a several years in service the product could be composed of completely different components, while still being the same product.

There are several reasons why servers and data storage products may undergo early replacement before the end of the technical lifetime, and even before the end of their economic lifetime. This revolves around improving the energy efficiency of a data centre. It may become apparent that the latest technologies are significantly more efficient than current installations. Improvements include a new capacity, service contracts and operating system conversions. For example, technologies such as virtualisation and those arising from software defined hardware structures (e.g. Software Defined Data Centres, etc.) will reconfigure or accelerate retirement of older systems. An additional reason for early replacement is that end-users may want to avoid repairing products themselves.

Table 2.6 provides an overview of the estimated lifetime for servers and data storage products. This data had originally been extracted from the previous Task 2 preparatory study conducted for this regulation. However, following stakeholder feedback the below updates were made to the previous study’s values for lifetime. It is clear from Table 2.6 that there is a significant difference between the economic and average lifetime of these products.

Table 2.6 Average lifetime, by type of equipment[115]

Equipment type	Average economic lifetime (in years)	Average technical lifetime (in years)
Rack-blade, rack-mounted, tower/ standalone and multi-node servers	3 for lease 3 to 5 for primary users Up to 5 to 7 for secondary user	5 - 12

[114] Stakeholder feedback

[115] Source: Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 2: Markets, July 2015: Final report, bio by Deloitte & Fraunhofer IZM

Equipment type	Average economic lifetime (in years)	Average technical lifetime (in years)
Mainframe servers	7 - 15	20
Data storage products (HDD, SSD, storage shelf and hybrid drives)	5 – 7	HDD: 10-15 SDD: 7-10 Storage shelf: 15-20

2.2.5 Replacement rates and new sales

Overall sales figures are determined by the new sales and replacement sales. It is important to distinguish between these two sale types:

- **New sales:** result from new service needs
- **Replacement sales**: involve replacing products that reach their economic lifetime

The previous preparatory study indicated that the sales growth rates would diminish due to increased utilisation rates through virtualisation. However, stakeholder feedback indicates that utilisation rates have not significantly increased, meaning that server sales have continued to increase.

2.2.6 Installed base (stock)

The objective of this section is to present forecasts of the installed stock development of the different products in scope of Regulation 2019/424. The forecasted stocks are geographically limited to EU-27. It should be noted that that servers and data storage products undergo very fast technological changes. It is for this reason that the long estimations required by the MEErP tool must be considered with caution. These estimations are based on the current knowledge and perspectives of the market and new calculations based on updated data may result in variations to the outcome.

2.2.6.1 Installed stock for servers.

Installed stock data was collected from stakeholder feedback during the consultation process of this review. This data originated from the Borderstep Institutes 2020 report[116] on cloud services in the EU-28. The study team was able to extract stock data for servers from this report with actual data provided up to 2018 and forecasts up to 2025.

To calculate stock levels up to 2050 a linear growth approximation was applied to the existing data from the report. It should be noted that the data provided accounted for the EU-28. Thus, adjustments were made to ensure that it accounted for the EU-27 only. To remove the UK's influence on the EU's server stock data a 24% reduction was applied to the extracted values. This market split was sourced from a KTN (Knowledge Transfer Network) report published in 2019[117]. As a result, the size of the UK market was assumed to be 24% between 2010 and 2025. A linear

[116] https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market

[117] https://photonicsuk.org/wp-content/uploads/2016/12/ktn_a4_big-data_v9_released.pdf

growth was then applied to the values once the UK's market stock value was removed.

Table 2.7 illustrates the calculated data from the KTN report up to 2025 (excluding the UK) and ICF's calculated values for the EU's stock of servers from 2030 to 2050. The values 2010, 2015 and 2018 are actual data points, while the 2020 to 2050 are forecasts (2030-2050 ICF's assumptions).

Table 2.7 Servers stock in the EU-27 in thousands of units (forecast: 2020-2050)[118]

Server type	2010	2015	2018	2020	2025	2030	2035	2040	2045	2050
Volume servers	6841	7947	8066	8149	9467	9709	9957	10212	10473	10741

The report provided data for several types of servers for example the report included data for high and mid-range servers. However, it was felt only those presented by Table 2.7 represent the only relevant type of server for the Regulation.

Table 2.7 demonstrates the calculated linear growth of 2.56% in volume server stock from 2025 to 2050. Overall, there was a 57% increase in the market stock of volume servers between 2010 and 2050. However, Table 2.7 does not break down the servers by its form factor therefore, not closely aligning with the scope of the Regulation.

To ensure that the stock values we had for servers aligned with the Regulation we calculated a percentage market share for rack bladed and rack mounted servers. This percentage share was calculated based on the data provided in the previous preparatory study where in 2013, 14% of the market were rack bladed and 70% of the market were rack mounted servers. This market split for rack bladed and rack mounted was used to calculate the stock of these form factors up to 2050, based on the volume server values originally presented in Table 2.7. The market share was assumed to remain constant up to 2050.

Table 2.8 Rack bladed & rack mounted stock data for the EU-27 in thousands of units (2030-2050: ICF forecasts)

Form factor	2010	2015	2018	2020	2025	2030	2035	2040	2045	2050
Rack bladed	937	1088	1104	1116	1296	1329	1363	1398	1434	1471
Rack mounted	4757	5526	5609	5666	6583	6751	6924	7101	7283	7469
Total	5693	6614	6713	6782	7879	8080	8287	8499	8717	8940

2.2.6.2 Installed stock for data storage products.

Like servers, the stock data for data storage products was analysed from the Borderstep Institutes report[119]. The study team was able to extract stock data from this report with actual data provided up to 2018. The original data presented by the Borderstep Institute represented stock values for the EU-28. Therefore, the same

[118] Stakeholder feedback

[119] https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market

24% reduction in stock values was applied to the data storage products to ensure the UK's influence on the EU market was removed. A linear approximation was used in order to calculate the stock values for hard disk drives (HDD) and solid-state drives (SSD) from 2030-2050. For HDD, a 5% growth rate was calculated based on growth observed between 2010 and 2025 in the Borderstep Institute. Table 2.9. demonstrates that there was a significant increase in the stock levels of SSD between 2010 and 2025, however, this growth rate was not expected to continue. Thus, following market research, it was found that in Europe the growth rate for SSD products was 13.6%. This percentage value was extracted from a KBV research report on the European SSD market[120]. The study team felt that this value provided a more conservative value of market growth for SSD products and ensured that the large exponential growth experience up to 2025 did not continue. The data that was calculated for SSD and HDD stock is presented below in Table 2.9.

Table 2.9 Hard disk drives and solid-state drives stock in the EU-27 in thousands of devices (2030-2050: ICF forecasts).

Storage type	2010	2015	2018	2020	2025	2030	2035	2040	2045	2050
HDD	35119	54609	66228	68285	60915	77744	99224	126637	161625	206279
SSD	1078	10184	26325	38170	67313	127348	240926	455801	862317	1631393

Table 2.9 illustrates how the market is expected to switch from predominantly HDD products to mostly SSD products. Nevertheless, the HDD market is expected to continue to grow, although, the stock growth rate is much slower than the growth rate for SSDs. As a result, by 2025 SSD stock has overtaken HDD as the main storage product on the market in the EU. SSDs have become the popular choice over HDD because they have no moving parts. Thus, meaning they can access data at a much higher speed than HDDs. SSDs are also becoming more cost effective and developing at much faster rate than HDDs. For example, the highest capacity 7.2k RPM HDDs are around 20 TB while the highest capacity SSDs are around 100 TB and growing[121]. However, HDDs are expected to remain popular for many reasons such as, they have a longer lifespan and they are remain at a competitive price in comparison to SSDs.

2.3 Market channels

2.3.1 Link to Phase 1 report

The Phase 1 report introduced the procurement practices for servers and data storage products in Section 2.7. This section of the Task 2 report will introduce the procurement practices for servers and data storage products. Section 2.4 and Section 2.4 and Section 2.7 of this Task 2 report will also provide information on the procurement practices of servers and data storage products.

[120] https://www.kbvresearch.com/europe-solid-state-drive-ssd-market/

[121] Stakeholder feedback

2.3.2 Channels to market

Servers deliver a data service which can be delivered anywhere around the globe with an internet connection. However, despite the capability of delivering a service remotely, there are considerations for the market to be aware of around economic, political and security concerns.

- Servers are heavily tied to the financial sector, which relies on servers for processing financial information, and therefore regulations around servers may have impacts on the finance industry.
- On political matters, data privacy concerns, notably the development of GDPR, has led to the development of servers to host data domestically. For security reasons, countries may not only want servers to be hosted domestically but also manufactured domestically, as there may be concerns of the creation of backdoor access mechanisms created during the manufacturing process.

2.3.3 Direct sales to customers

There is mixed feedback from stakeholders on the route to market for servers and data storage products. The North American market is dominated by purchasing occurring directly from Original Equipment Manufacturers (OEM) to the end user client. These purchasing decisions are made primarily around the technical performance capabilities of the product. With regards to energy efficiency, the procurement metric in North American market is to ensure that devices meet the Energy Star criteria.

In Europe, purchasing decisions are similarly focused on technical performance. However, stakeholder feedback discussed in the Phase 1 report, provides a mixed picture that distributors may have a more active involvement in the sales of servers and data storage products, instead of sales coming directly from manufacturers.

2.3.4 Secondary Market for servers

Since a large focus of this study lies on the reuse of servers and data storage products the secondary use of these products should be discussed. In 2015 the ICT aftermarket was worth $46 billion in Europe and employed more than 220,000 people[122]. Third party companies control the majority of sales of equipment in ICT aftermarkets, with a clear separation between them and the original manufacturer of the hardware and software. Independent service providers account for 15% of the hardware support market and 5% of the software support market[123].

2.3.5 Distribution routes

The product distribution channels of the products eligible for Regulation 2019/424 are mostly business-to-business. This is because servers and data storage products usually require experience and engineering knowledge for proper installation and configuration. Within the Phase 1 report, stakeholder feedback has indicated that the route to market in Europe is directly from manufacturers and through distributors.

[122] Stakeholder feedback

[123] Stakeholder feedback

2.3.6 Installation services

Servers are expensive to not only purchase, but also to install. Therefore, installation costs must also be considered when purchasing the product. Installation services are usually offered by the manufacturer selling the product at an additional fee. In addition, most manufacturers include warranties within their purchase prices for servers and data storage products. Usually, these warranties stand for three years from the date of purchase. However, this can be as low as one year for low-end models or as high as seven years, in some instances.

Installation costs are discussed in greater detail in Section 2.7.3 of this report.

2.4 General market trends

There are several market trends that can influence the sales and stock of IT equipment, these include:

- **Cloud services:** this includes software as a service such as productivity software. It also relates to media and data storage, video streaming, customised media services and gaming platforms. Cloud services demand high volumes of storage capacity.
- **Big data:** this incorporates ubiquitous and automatic sensor data acquisition, automatic filing and analysis, software-defined IT resource utilisation and increased data security provisioning. In recent years there has been an increased collection of sensor data, transportation, energy grids, environmental applications, customer relationships and other end-user data. The development of these data sources has seen servers and data storage products evolve to adapt to the increased storage needs.
- **Fixed-mobile conversion:** mobile computing and communication is an important market driver for servers and data storage products.
- **Security and encryption:** the secure communication and data handling will always drive evolution of the design and architecture of products. Encryption technology continues to grow, especially with the likes of Crypto currency becoming ever popular. This growing trend has led to both software and hardware-based solutions. The SPEC SERT test standard reflects the demand in encryption technology by testing a specific encryption workload (worklet).
- **Real time computing:** immediate communication (latency and bandwidth) is continuing to increase in demand, especially post Covid-19 with hybrid working practices still being popular.

2.5 General trends in product design and product features

The key drivers with respect to product features are expandability, reliability, energy efficiency and cost. There is significant recognition of the resource limitations within a data centre, therefore, most market segments will aim to maximise useful output.

Servers tend to be hosted in two types of locations: distributed IT (where servers are used in offices or other buildings which are not dedicated for servers), and datacentres (which are specialised locations for server usage, with dedicated power and HVAC services).

The bulk of servers are operated within datacentres. The trend has been to consolidate data operations in data centres as their operation is optimised, allowing for better tracking of energy usage across devices and support systems. These buildings can also be reinforced in terms of data connectivity and power availability.

Within the datacentre ecosystem, there are a few different models: Enterprise IT (which are locations which are owned by a single operator, with only their servers present), Colocation IT (which are datacentre spaces which provide a space with appropriate temperature, power, and internet connection for operators to rent for their servers).

The services provided by servers may be directly for owners or could be provided under the following cloud services: Infrastructure as a Service (IaaS) or Platform as a Service (PaaS). IaaS provision allows for a user to hire the control over a virtual machine, with a set storage and workload capabilities. PaaS is used for general software development and hosting the software after development, for example to host a website. The markets of IaaS and PaaS are globally dominated by AWS, Microsoft Azure, Alibaba cloud and Google cloud (GCP), with a combined forecasted revenue estimated at 167.3 billion US dollars.

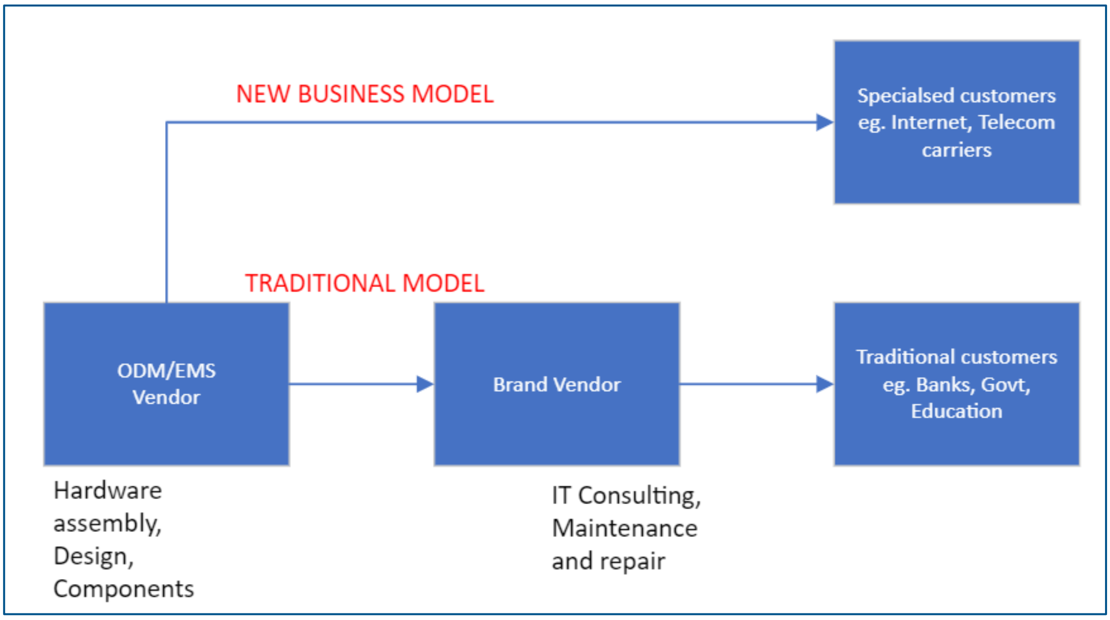
Lastly datacentres are crucial for the delivery of Software as a Service (SaaS), often called web services. SaaS makes applications available to the end user via the internet, such as Gmail, Microsoft 365, OneDrive, Netflix, etc.

It is important to note that nearly one third of the server market sales are comprised of white box original design manufacturers (ODM) servers which are customised by or for customers[124]. These products are produced by manufacturers including Quanta, Wistron, Inventec and shipped unbranded directly to customers. These products are currently exempt from providing information requirements within the regulation. They make up a notable portion of the market and are often deployed in hyperscale data centre environments where the server is designed to maximise efficiency for a specific corporate or research workload at reduced cost (typically 25-30%)[125]. Figure 2.3 illustrates the divergent pathways that split the servers and data storage market.

[124] https://datacenters.lbl.gov/sites/default/files/EnergyUsageWebinar12062016.pdf

[125] https://www.ventureoutsource.com/contract-manufacturing/focus-odm-quanta-it-shift-cloud-infrastructure-leaving-dell-hp-traditional

Figure 2.3 OEM vs. ODM sales channels in computer server market[126]



In terms of product diversity, it is expected that this will continue to increase through the EU. This is being driven by the big data, fixed-mobile conversion, encryption and secure communications and cost considerations. It is common for vendors to introduce new products approximately every 18 to 24 months. These products are usually much more power than the previous generation and cost roughly the same.

On a technical level there are several emerging technologies that the project team has identified and that it believes should be considered when updating the regulation requirements. These technological, market and regulatory evolutions include:

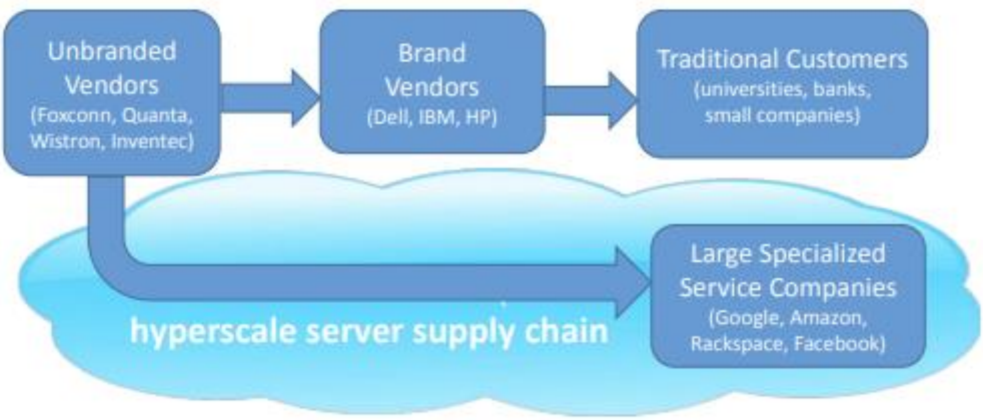
- The emergence of storage "heavy" servers, or servers with an abnormally high capacity of storage devices which make it difficult to distinguish with storage products.
- Persistent memory, and how that creates a grey area between DRAM and traditional storage in both servers and storage products.
- Better defining and addressing hyperconverged servers which perform server, storage, and network functions in a single enclosure, presenting a very challenging testing case as testing all functions simultaneously is not currently possible.
- Updates in HPC, AI, and machine learning architecture, and how those updates may allow those products to be regulated more easily.
- Ebbs and flows in the adoption of virtualisation in server deployments.
- Impacts of broader data centre consolidation, along with the recent push back towards the edge particularly in telecom operations due to increased bandwidth needs and 5G infrastructure support. Particularly how increased rack density is impacting both deployment models as well as product design.

Emerging from the growth of cloud platforms, social media and big data are large hyperscale data centres. These are large warehouse sized data centres which have

[126] Source: ICF

hyperscale servers with them. As a result, the server market is seeing a shift in the traditional sales channels involving different elements of the market. This new avenue of sales moves away from sales being made by the global computer companies (e.g., Dell, IBM, HPE). Instead, the hyperscale server sales are bypassing these brand vendors in the supply chain and brought directly from the manufacturing companies that build the servers (e.g., Quanta). The purchasers of these hyperscale servers are the large internet companies (e.g., Goggle, Facebook), who typically use these within their hyperscale data centres. Figure 2.4 illustrates this new approach to the supply chain for hyperscale servers. Branded vendors represent the global computer companies, unbranded vendors are the manufacturing companies.

Figure 2.4 Server supply chain[127]



2.6 Market segmentation

2.6.1 Market share

The market for servers and data storage products in the EU is dominated by a few large manufacturers, who are key global players and produce their products outside of the EU-27. Meanwhile, small, and medium enterprises (SMEs) have a low share of the EU market.

Manufacturers of OEM servers and storage products are mostly based in the US (HPE, IBM, Oracle, Cisco, Dell, NetApp) and the Far East (Lenovo, Fujitsu, NEC, Inspur, Huawei). This correlates with the data in Table 2.1,which demonstrates how the EU is dependent on imports. Sales for servers and storage are mostly conducted as a business-to-business transaction by manufacturers themselves.

Many of the manufacturers are well represented by industry associations at the Member State level, mainly through DIGITALEUROPE[128] and The Green Grid[129] in the U.S. DIGITALEUROPE represents the European digital technology industry, which includes large and small companies in the Information and Communications Technology and Consumer Electronics Industry sectors. Containing more than

[127] https://www.osti.gov/biblio/1372902

[128] https://www.digitaleurope.org/

[129] https://www.thegreengrid.org/

10,000 companies all over Europe. Key global equipment manufacturers of servers and data storage industry are listed below in Table 2.10.

Table 2.10 List of manufacturers of servers and data storage products.

Servers	Data storage equipment
• Cisco • Dell • Fujitsu • Hitachi • HP • IBM • Inventec • Lenovo • NEC • Oracle • Quanta • Supermicro • Wistron	• Dell • EMC • Fujitsu • HGST • Hitachi • HP • IBM • NEC • Netapp • Oracle • Seagate (Xyratex) • Western Digital

The product distribution channels of Regulation 2019/424 products are usually conducted via the business-to-business route. This is because these products usually require experience and engineering knowledge for proper installation and configuration.

The main customers for server manufacturers are hyperscale data centres and large business enterprises (LBE). Table 2.11 presents the server buyer market split, demonstrating that hyperscale and LBE account for 57% of EU's server purchases in 2022. SMBs and cloud service provides are the next largest purchasers account for 12% and 13% of the market split respectively.

Table 2.11 EU's server market split by purchaser type[130]

Server Buyer	EU Market Share (2022)
Hyperscale	31%
Large Business Enterprise	26%
Cloud Service Provider (Non-hyperscale)	13%
Small and Medium Business (SMB) Enterprise	12%
Communication Services	8%
Managed Services	5%
Digital Service Provider	4%

2.6.2 Manufacturer product ranges

Overall, it is expected that product diversity of the market for servers and data storage products will continue to increase. This is driven by specialised applications such as big data, fixed mobile conversion, encryption, and secure communication. Manufacturers introduce new products approximately every 18 to 24 months that are more powerful than the previous generation and at roughly the same price.

130 Stakeholder feedback

2.6.3 Market segmentation by technologies

2.6.3.1 Servers

The server's market is typically segmented by several factors such as its operating system (Windows, Linux, UNIX etc), server classification (high-end, mid-range, volume servers), server type (rack, blade, multi-blade and tower), end use (IT and telecommunications, retail, healthcare, media etc) and finally, geography[131].

The Regulation splits server types based on the form factor of the server. The form factor represents the size, configuration and physical arrangement of the server. Regulation 2019/424 covers the following four form factors for servers:

- Rack-blade servers
- Rack mounted servers
- Tower/ Standalone servers
- Multi-node servers.

2.6.3.2 Data storage products

Table 2.4 displayed the storage options that are present for data storage products, with storage options either host based, or external controller based. External based controller storage options are the focus of the Regulation, these are displayed below. External controller-based disk storages devices are a system that has one or more embedded controllers.

As discussed previously in Section 2.2.2.2, there are four dominant external controller-based storage units into the following four categories:

- Storage Area Network (SAN)
- Direct Attached Storage (DAS)
- Network Attached Storage (NAS)
- Content Addressed Storage (CAS)

2.6.3.3 Emerging datacentre operations

Cloud computing is changing the way that IT equipment is used, with cloud services becoming the dominant form of IT use globally[132]. This trend towards cloud services couples with an increase in the number of hyperscale data centres. As a result, the number of hyperscale data centres doubled between 2015 and 2020[133]. With the European hyperscale market expected to grow by 22.5% per year between 2023 and 2030[134]. More businesses that are now using cloud services has grown significantly in the last decade. Figure 2.5 demonstrates the global increase in cloud computing use within businesses. In Europe (including the UK) the number of businesses that use cloud computing has increased from 19% in 2014 to 39% in 2021.

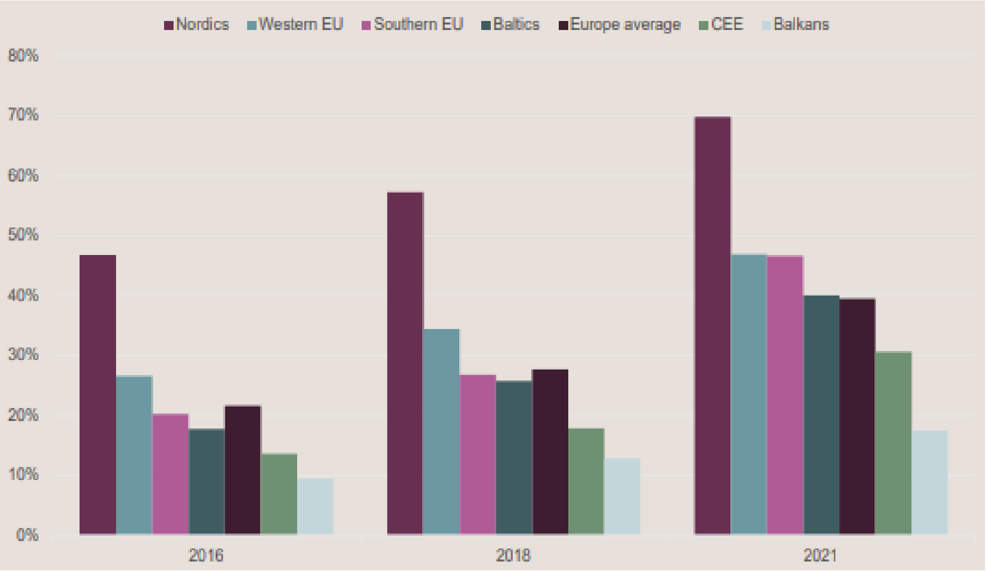
[131] https://www.mordorintelligence.com/industry-reports/enterprise-servers-market

[132] https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market

[133] https://pdf.euro.savills.co.uk/european/spotlight-european-data-centre---november-2020.pdf

[134] https://marketresearchcommunity.com/hyperscale-data-center-market/

Figure 2.5 Use of cloud computing by businesses globally[135]



2.6.4 SMEs

As discussed in Section 2.6.1 large manufacturers dominate the market, meaning that SMEs have a very small share of the EU market share of products. This was also confirmed by the manufacturer's responses in the questionnaires and is highlighted in the Phase 1 report. It was communicated with the study team that SMEs are a key driver for the secondary market for servers and are the experts in life-cycle extension.

2.7 Consumer expenditure base data

2.7.1 Prices as sold

2.7.1.1 Servers

Server price ranges were separated by the four form factors displayed below, with the number of sockets being considered as well. This data was obtained from the previous preparatory study, inflated to the 2022 rates rounded to the nearest 100[136] after being compared and adjusted with current market prices as advertised on company websites.

[135] https://pdf.euro.savills.co.uk/european/european-commercial-markets/spotlight-eu-data-centre---november-2022-.pdf

[136] Statistics | Eurostat (europa.eu)

Table 2.12 Purchase prices (excl. VAT) of typical server products in Euros (€) / unit[137]

Product Type		Range of purchase price (€/ unit)
Servers	Number of sockets	
Rack managed	1	1112-7880
Rack managed	2	6489-46,350
Tower managed	2	4635-27,810
Blade managed	4	3893-12,978
Rack resilient	2	5900-8000
Rack resilient	4	4000-85700

Table 2.12 illustrates that there is a wide range of prices for servers, in particular servers with two or four rackets. This again relates to the fact that servers are highly customisable products. Since there are many configurations that a consumer can choose for the same product, prices vary greatly. On the manufacturers websites there are often starting prices presented for simple configurations, with the prices increasing based on the configurations which are chosen. The following types of configurations are likely to have the greatest influence on the price of a server:

- Number and speed of CPUs;
- Type, speed and capacity of the memory;
- Type, number and size of disk drives;
- Operating system;
- Years of warranty included.

2.7.1.2 Data storage products

Price ranges for storage systems are given in Table 2.13 for the four different types, namely CAS, DAS, NAS and SAN. This data was obtained from the previous preparatory study, compared with current prices online and inflated to the 2022 rates rounded to the nearest 100[138].

Table 2.13 Purchase prices (excl. VAT) of typical data storage products

Type of storage system	Range of purchase price (€/ unit)
CAS	118,900 - 243,800
DAS	4,700 - 75,600
NAS	3,300 - 556,200[137]
SAN	5,800 - 370,800[137]

Like servers the price ranges for data storage products are very broad. This is dependent on several features related to the maximum amount of storage of the storage system. Additionally, the maximum number of drives and hence the capacity impacts the price. The number of drives is characterised by their type (HDDs or SDDs). Drive features and read/ write intensity significantly impact the price of drives. For example, a storage system with a write-intensive drive, with the same

[137] Source: Feedback from stakeholders provided in Dollars, converted to Euros on 09/02/2024 at 16:00 using (https://www.forbes.com/advisor/money-transfer/currency-converter/usd-eur/)

[138] Statistics | Eurostat (europa.eu)

speed and size costs twice as much as a drive without this[139]. This is because write drives are able to transfer large amounts of data to the drive.

Prices also vary because of the following two technical specifications: high performance tiering, which increases the array of input-output performance; and SSD cache, which accelerates application performance by utilising SSDs as extended controller read cache.

Table 2.13 illustrates that CAS are the most expensive storage products on the market. This is because CAS storage units have a high number of drives and hence, a large capacity. They are significantly more expensive than SAN and NAS storage products which have a smaller capacity.

2.7.2 Production costs

Manufacturers were invited to provide feedback on the production costs for servers and data storage products. This is commercially sensitive information, which most manufacturers did not report.

2.7.3 Installation costs

An estimate can be made from the fact that the cost of an IT professional is on average €90-100 per hour[140]. However, this is an estimate and not a certain total.

Installation costs for servers and data storage products are usually available via the manufacturer for an additional fee. Costs can vary dramatically depending on the size of the installation, while some manufacturers do not perform installations for certain types of servers. For example, Dell charges around €340 for the installation of a blade server, but they do no offer installations for rack and tower servers. It should also be noted that different labour requirements may be required depending on the product category.

Data storage product installation is a little more expensive than server installation, costing around €425 for installation of remote onsite hardware installation with remote configuration. The costs really depend on the type of size of the storage product being installed.

2.7.4 Energy & water costs

Electricity and water prices are presented in Table 2.14, this data has been extracted from the MEErP methodology. These values will be used during the modelling that is conducted in Task 5.

Table 2.14 Electricity and water prices in the EU-27, 2022 (Source: MEErP[141])

	Unit	Domestic incl. VAT	Long term growth p/a	Non-domestic excl.VAT
Electricity	€/ kWh	0.18	5%	0.11
Water	€/ m^3	3.70	2.50%	

139 https://www.dell.com/nl-be

140 https://www.serverpronto.com/spu/2019/04/how-much-does-a-server-cost-for-a-small-business/#:~:text=Cost%20of%20Installation&text=The%20average%20cost%20for%20an,talking%20about%20%24400-%24500.

141 MEErP Methodology Part 1 Final__(2).pdf

	Unit	Domestic incl. VAT	Long term growth p/a	Non-domestic excl.VAT
Energy escalation rate	%		4%	
VAT	%		20%	

Servers and data storage products require a lot of energy in order to maintain their functionality. Therefore, this section will describe how they consume large amounts of energy and what can be done to combat this soaring energy consumption. This is especially important given the increased energy security vulnerability that have arisen from the Ukraine War. With the EU's energy prices having been heavily impacted, saving energy in data centres is vital to ensure running a facility remains economically viable in the EU.

Current practice is that heat from servers in a data centre is not normally reused and is instead released externally into the atmosphere surrounding the exterior of the data centre, an action that increases the local and surrounding temperature. Sustainable or green IT is increasing in popularity and therefore the waste heat recovery is an aspect worth exploring within this study along current applications, possibilities and practice. This is more relevant to a building level requirement and less of a product consideration.

This niche application is being put in practice in certain situations such as at city/campus level. One of the innovators in this area, constructor of data centres, combines the locations of the centres to the surroundings, with the aim to utilise surplus heat[142]. Preference is integration with existing CHP plants or other electricity plants that enables energy recovery in combination with renewable energy. An existing example is the Main Site of EcoData centre in Falun, Sweden.

One of the most recent practices on waste heat from data centres is an initiative from Microsoft to build a new data centre region in Finland, which will support the digital transformation and at the same time enable large scale district heating. It is expected that the waste heat produced in the data centres will be converted to district heating, serving Finland's second largest city Espoo and neighbouring Kauniainen, and the municipality of Kirkkonumm. Microsoft plans to create the world's largest scheme to recycle waste heat from data centres[143]

Liquid cooling of servers typically provides higher energy efficiency when compared to air cooled systems and could enable the driving of data centre industry forward. Manufacturers state that liquid cooling allows optimum energy use within the IT suite so that more power drives the applications on the servers rather than the cooling systems[144]. At the same time there are free air-cooled data centres in the US and adoption of free air cooling (at least part time) is preferred at Government data centres where possible.

Proposing requirements around proper deployment or quality of water-cooled solutions could be the way forward, however as these systems are still at their infancy, comprising of less than 5% of the server market, to impose requirements on water cooled solutions in a regulatory setting requires further review and analysis. In addition, liquid cooling introduces several new considerations including safety,

[142] https://ecodatacenter.se/sustainability/

[143] Microsoft announces intent to build a new datacenter region in Finland, accelerating sustainable digital transformation and enabling large scale carbon-free district heating - Microsoft News Centre Europe

[144] Solving Data Center hunger, EiBi, issue June 2022

proper fluid handling and maintenance (to avoid mould and/or corrosion etc.) and proper system design to minimise long term problems that specifically arise with the complications of liquid cooled solutions. Liquid cooling recommendations for this review study have been put forward in Section 2.11 of the Phase 1 report.

2.7.5 Repair and Maintenance costs (€/product life);

Servers and data storage products not only have a high CAPEX but are also expensive to operate and maintain. Therefore, the cost of ownership is one of the top criteria in purchasing decisions. Often manufacturers offer a three-year repair warranty with servers, however, for the low-end products this can be as low as one year. An estimate can be made from the fact that the cost of an IT professional is on average €90-100 per hour[145]. However, the exact price of repair will be unique to each product.

2.7.6 Disposal tariffs/ taxes (€/product);

Electricity, fossil fuel, water, interest, inflation, and discount rates will use the values for Jan. 2011 in MEErP Chapter 2, including the average annual price increases mentioned there. For regional differentiation of consumer prices (for sensitivity analysis) also see Chapter 2 of the MEErP.

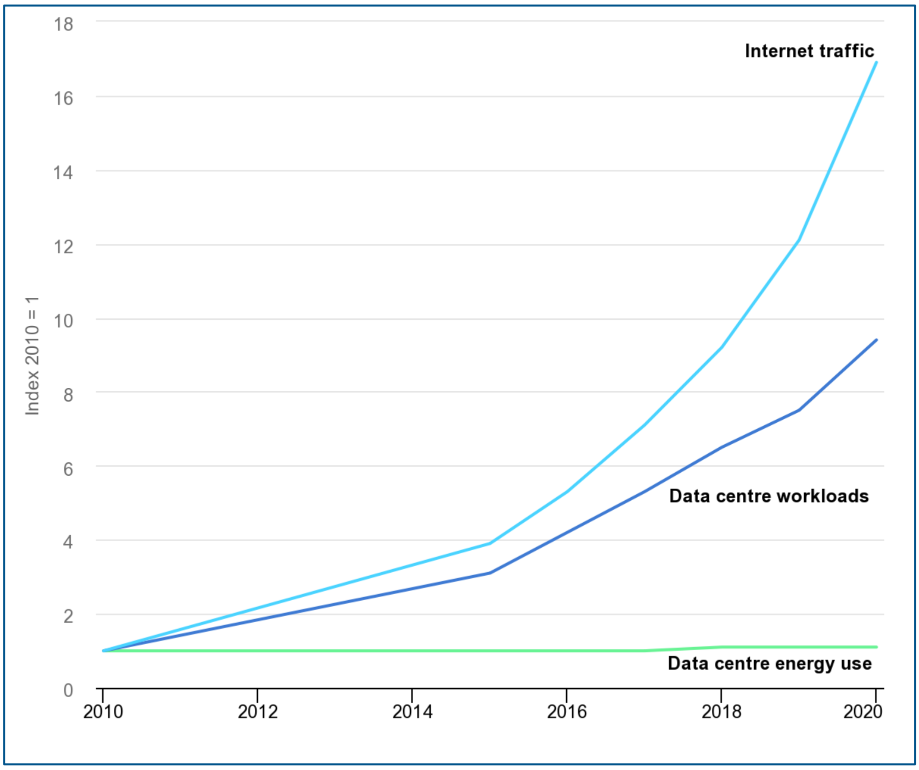
[145] https://www.serverpronto.com/spu/2019/04/how-much-does-a-server-cost-for-a-small-business/#:~:text=Cost%20of%20Installation&text=The%20average%20cost%20for%20an,talking%20about%20%24400-%24500

3 Introduction to Task 3 Users

3.1 System aspects of the use phase for ErPs with direct energy consumption

Computer servers and data storage products underpin the digital service economy. Since 2010, the number of internet users worldwide has more than doubled, while global internet traffic has expanded 20-fold (as shown in Figure 3.1). Table 3.1 further emphasises this by demonstrating how from 2015 to 2021, with 1.9 billion more users on the internet (60% increase), there was 440% increase in global internet traffic. Not only are there more users connecting to the internet, but operations, storage, and services are relying more and more on the internet.

Figure 3.1 Global trends in internet traffic, data centres workloads and data centre energy use, 2010-2020[146]



Datacentre workloads have followed a similar curve of development as internet traffic from 2010 to 2020, although at a less intense rate. This amounts to a 260% increase in workloads from 2015 to 2021. Yet the energy consumption of data centres has only grown by 60% in the same period (excluding crypto). Energy efficiency improvements have reduced the growth in energy demand from data centres, thanks to improvement in IT hardware capabilities and cooling technology. There has also been a shift away from small, inefficient data centres towards more efficiency cloud and hyperscale providers. Global data centre electricity use in 2021 was 220-320 TWh, or around 0.9-1.3% of global final electricity demand. This excludes energy used for cryptocurrency mining, which was 100-140 TWh in 2021.

[146] Nov 2021, IEA report, Global trends in internet traffic, data centres workloads and data centre energy use, 2010-2020 – Charts – Data & Statistics - IEA

Table 3.1 Global trends in digital and energy indicators, 2015-2021[147]

	2015	2021	Change
Internet users	3 billion	4.9 billion	+60%
Internet traffic	0.6 ZB	3.4 ZB	+440%
Data centre workloads	180 million	650 million	+260%
Data centre energy use (excluding crypto)	200 TWh	220-320 TWh	+10-60%
Crypto mining energy use	4 TWh	100-140 TWh	+2 300-3 300%
Data transmission network energy use	220 TWh	260-340 TWh	+20-60%

Although the global trend for data centre energy consumption has been moderate, as data services can be provided on a global scale, there can be strong impacts for their needs at the local level. For example, Irish data centre electricity use more than tripled since 2015, representing 14% of total electricity consumption in 2021. Similarly, in Denmark, data centre energy use is projected to triple by 2025 to account for around 7% of the country's electricity use.

This report will review how servers and data storage products, which are the primary service provider equipment in data centres (and for internet and data services at large), are being used, delivering their work outputs, and the associated energy consumption this work requires. Networking equipment will not be covered by this Task 3 report.

3.1.1 Strict product / component scope

3.1.1.1 Product introduction and work delivered

Servers

Enterprise servers deliver tasks similar to personal computers, however the distinction is that they are described as "servers" as they do these tasks in response to the request from another computer. The only way to request this is through their Input/Output socket, which is to mean the internet. There is no screen, keyboard or mouse directly associated to the computer server.

A computer server may be dedicated to a particular task (and hence have specific hardware to deliver it) or perform a variety of tasks as required. The software can also determine the functions of the server. However, this depends on the user specification and the nature of the workloads. An example of some typical tasks include:

- Mail servers: They move, store, and send email. Typical software platforms are Microsoft Exchange, Gmail, Yahoo.
- Web servers: They host the content of a website to a user's Web browser utilising Hypertext Transfer Protocol (HTTP). When a device connects to a website, these servers will respond to show the related content on the page.
- File servers: They store and manage data files for access between computers. Transfer over the internet is done using FTP (File Transfer Protocol) or Secure FTP.

[147] Sep 2022, Data Centres and Data Transmission Networks – Analysis - IEA

- Database servers: They provide database services to client computers (users). Typical software platforms include SQL, SAP, and Oracle.
- Application servers: They are dedicated to the execution of programs, routines, scripts and work. These are sometimes referred to as “middleware” servers as they provide a connection between database servers and the user. The application server is programmed via a software platform such as Java, PHP and Microsoft.
- Terminal servers: They support today dedicated remote (virtual) desktop services including graphical user interfaces (GUI). Typical software platforms are from Microsoft and Citrix.
- Proxy / communication / VPN servers: They are dedicated to filter communication requests (gateway/firewall), share connections, and improve and monitor performance.
- DNS: Standing for Domain Name Server, these have an enlarged database of IP addresses with their linked hostnames. They enable communication between devices across the network.
- Dedicated servers: they provide a service to a specific client, and nobody else. This ensures prioritisation of the client’s task.

Other server types of mention are online gaming servers, chat servers, groupware servers.

Server operations are needed for all sorts of business operations, such as financial services, telecommunications, internet services and media providers, but also providing computing facilities for sectors such as private businesses, government, health, education and industry.

The work delivered by computer servers is defined by the calculations and storage operations delivered. This work is varied and can be difficult to define. Unlike some other devices, the operation of a server is not as simple as describing when it is on or off. Servers are technically always “on”, however that is not the same as when they are delivering useful work. When the server is not delivering work, this is defined as “idle”. These are the different factors that define the energy consumption of a sever:

- The time spent in idle phase and at different operating load levels. This is averaged into the “utilisation” level of the server. This is developed further in section 3.1.1.2.
- The operations the server is delivering in that time.
- The efficiency of the server at delivering these tasks.

To determine the efficiency of a server at delivering various tasks, SPEC (Standard Performance Evaluation Corporation) have developed SERT, the Server Efficiency Rating Tool. The tool defines the different workloads under worklets. The workloads are defined as the different operations relating to CPU, Memory and Storage. The worklets are the different operations taken within these workloads. They are tested under different load levels. These worklets and the load levels of operation are set out in Table 3.2.

Table 3.2 SPEC SERT worklets

Workload	Load levels	Worklet
CPU	25% / 50% / 75% / 100%	Compress
CPU	25% / 50% / 75% / 100%	CryptoAES
CPU	25% / 50% / 75% / 100%	LU

Workload	Load levels	Worklet
CPU	25% / 50% / 75% / 100%	SHA256
CPU	25% / 50% / 75% / 100%	SOR
CPU	25% / 50% / 75% / 100%	SORT
CPU	25% / 50% / 75% / 100%	XMLValidate
Memory	Full/Half	Flood
Memory	4 / 8 / 16 / 128 / 256 / 512 / 1024 GB	Capacity
Storage	50.0% / 100.0%	Random
Storage	50.0% / 100.0%	Sequential
Hybrid	12.5% / 25.0% / 37.5% / 50.0% / 62.5% / 75.0% / 87.5% / 100.0%	SSJ
Idle	No load	Idle

SERT uses these results to provide the average performance of a server. The different workloads are weighted under a geomean to provide a representative score of the average time a server spends in each workload.

As the SERT test can be time consuming to perform, and servers are subject to a high variation of configurations within the same server family, SERT has determined five configurations to provide a representation of server family performance: minimum power, maximum power, low-end performance, typical performance, and high-end performance configuration. It is important to note that minimum and maximum power configurations are not analogous to the minimum and maximum energy efficiency scores. Indeed, these configurations are defined under their total energy consumption, which doesn’t include the factor of the amount of work delivered. Therefore, the minimum power configuration may consume less power, but does not deliver the same amount of work, and hence may be less efficient on a work delivered per Watt basis.

SERT metric is currently used by Energy Star, Blue Angel and Ecodesign as a performance requirement of active efficiency as discussed in Task 1. For server families, Blue Angel and Energy Star require for the criteria to apply to minimum performance, maximum performance and typical configuration servers. The Ecodesign regulation 2019/424 only applies this requirement on the low-end and high-end performance configurations.

ICF collaborated with Information Technology Industry Council (ITI) and The Green Grid, to create a database of SERT output results for 575 unique server families from 2017 to 2022. From this database, the Figure 3.2 was completed on the 2-socket rack servers server category types. These were chosen as they are the most common server configuration. Figure 3.2 shows how the average SERT score has continued to go up, indicating that the server market continues to increase in efficiency. This is driven by an increase in performance capability.

Figure 3.2 Average SERT server score and the average idle consumption from 2016-2021 for 2-socket rack servers[148]

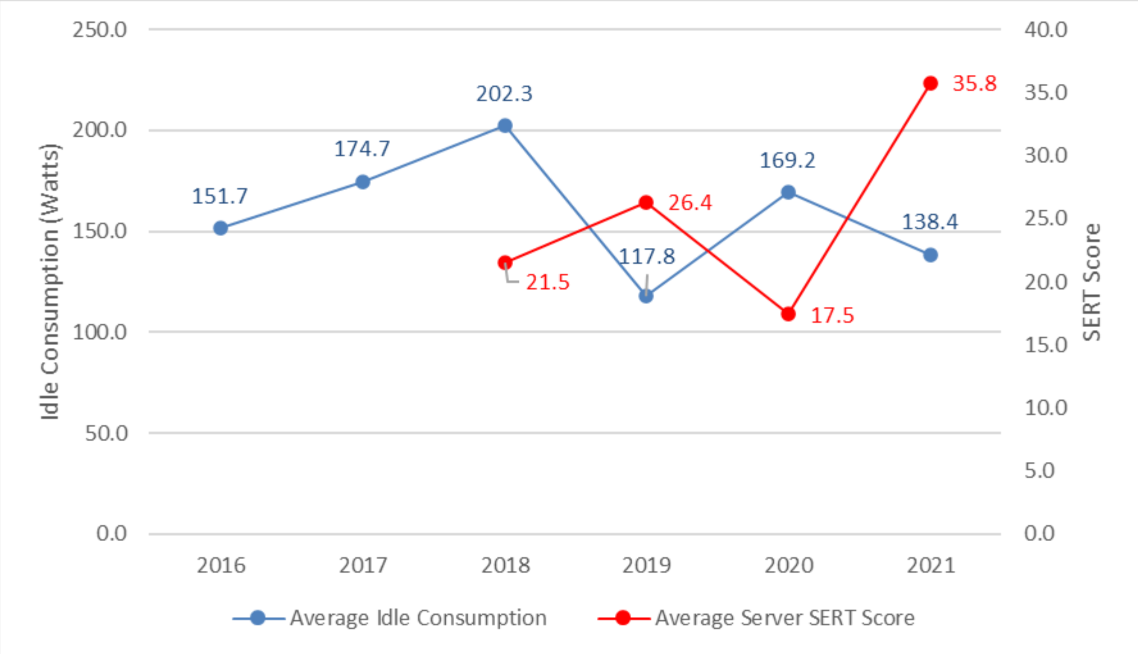


Figure 3.2 shows how the idle consumption is correlated with the server SERT score. Where the server active efficiency score is increased, the idle consumption decreases, as the improved idle score is a component of the final active efficiency score. It should be noted that although the SPEC SERT database is the most complete server energy efficiency database available, in some years there are a limited number of data points, and which types and numbers of servers are in the database significantly vary by year. For example, one year may include a much larger proportion of servers with high performance CPUs, and other years may mostly include servers with lower performing CPUs. Two factors which increased the year-to-year variation in Figure 3.2 are systems with large numbers of storage devices, systems with 1 of 2 CPUs installed and resilient servers[149]. For example, the SERT average in 2020 is artificially low because the database lacks AMD based servers (except one 8-core) and high-end Intel CPU based servers (only two), both of which had high active energy efficiency. All of the other servers included only had medium and lower performing CPUs with lower active energy efficiency[150].

The SSJ (server-side java) operation is a hybrid worklet designed to exercise the CPU and memory activities. Although this is not as comprehensive as the SERT score, it is therefore often used to have an indication of server capabilities.

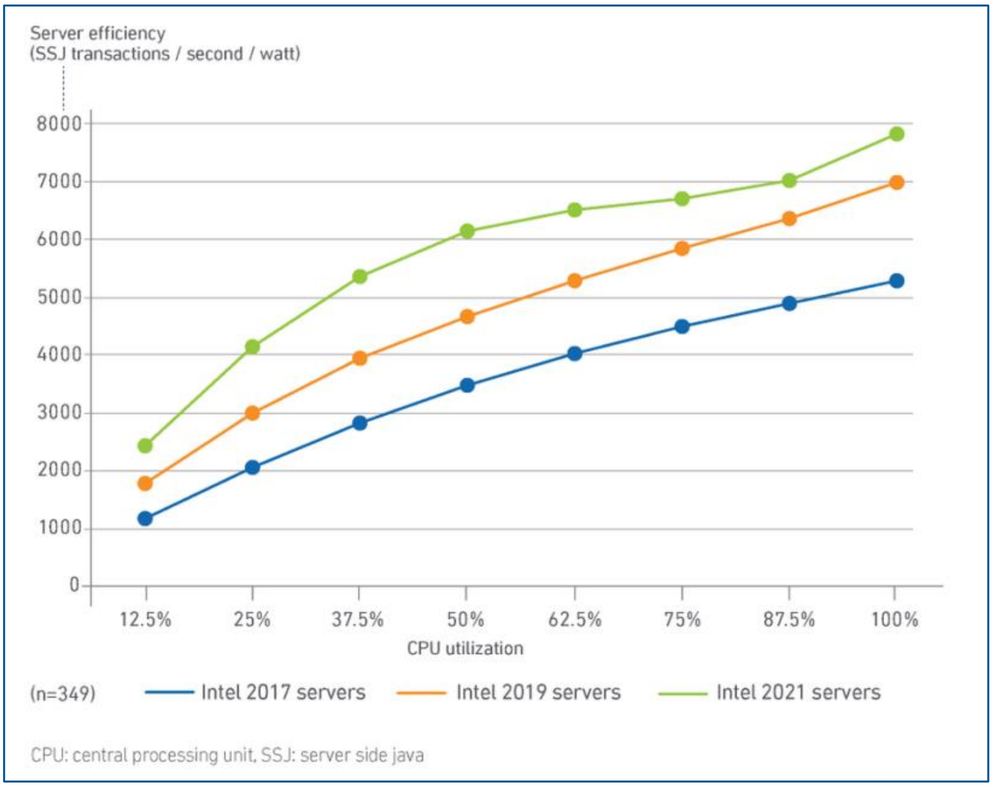
Figure 3.3 shows the trend for energy performance for Intel servers. There is a clear improvement in efficiency from the 2017, to 2019, to 2021 servers. Moreover, as the graph is set on an axis of CPU utilisation, it shows how servers are more efficient when operating at higher utilisation rates. Figure 3.3 also demonstrates that as the CPU utilisation rate grows the linear increase in server efficiency decreases.

[148] SPEC SERT server data set

[149] Stakeholder Feedback

[150] Stakeholder Feedback

Figure 3.3 Efficiency improves with each Intel server generation[151]



Data storage products

Data storage systems provide data storage services for devices either directly connected (host) and/or to remote computing devices (client) via a network connection. This service is meant to supplement the internal storage of servers.

The following insight on the classification of data storage products under SNIA taxonomy has remained largely constant since the 2015 Lot 9 Preparatory study[152]. These devices are mainly specified according to their capacity and access criteria, which would include latency and reliability. The Storage Networking Industry Association (SNIA) defines the storage taxonomy as follows:

- Access pattern (random or sequential);
- The maximum time to first data (max. TTFD in ms), required to start receiving data from a storage system;
- The requirement for user access;
- Connectivity over network or direct connection to a single or multiple hosts;
- Integrated storage controller (optional or integrated);
- The status (optional or required) of storage protection, non-disruptive serviceability, no single point of failure, and storage organisation;
- Maximum supported disk configuration.

These functionalities and features have resulted in SNIA creating six product group categories:

[151] Transactions per megawatt-hours: Keys to increasing data centre efficiency, Uptime intelligence, 27 June 2023

[152] Source: Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 3: User, July 2015: Final report, bio by Deloitte & Fraunhofer IZM

- Online: Storage system for very fast random or sequential I/O request. The main distinction criteria is a maximum TTFD of >80 ms.
- Near Online: Storage system for moderate response time with maximum TTFD of >80 ms.
- Removable Media Library: System for sequential I/O request with long response time. This is an automated or manual media loader such as tape or optical library.
- Virtual Media Library: System for very fast sequential I/O request with maximum TTFD of <80ms. The media are not removable and intended for long-term data storage.
- Adjunction Product: Special purpose storage service, dedicated data path from host to storage device, no end-user access, maximum TTFD of <80 ms.
- Interconnect element: Managed interconnect elements within a storage area network such as switch or extenders.

Figure 3.4 provides a visual overview on how these product categories are distributed. For the full taxonomy detail please review Annex 2.

Figure 3.4 SNIA Taxonomy overview table[153]

Category Level	**Online** (see 5.3)	**Near Online** (see 5.4)	**Removable Media Library** (see 5.5)	**Virtual Media Library** (see 5.6)
Consumer/ Component[1]	Online 1	Near Online 1	Removable 1	Virtual 1
Low-end	Online 2	Near Online 2	Removable 2	Virtual 2
Mid-range	Online 3	Near Online 3	Removable 3	Virtual 3
	Online 4			
High-end	Online 5	Near Online 5	Removable 5	Virtual 5
Mainframe	Online 6	Near Online 6	Removable 6	Virtual 6

The enterprise sector storage products are mainly found in the low-end to mid-range Online 2, Online 3, and Online 4 (and Near Online 2 and 3 to a lesser extent). They are designed for random and partially sequential I/O requests. Storage media are typically more economical HDDs or for certain purposes SSDs. The low to mid-range online systems are utilised in storage pools with defined redundancy (RAID) and respective control.

Other categories of note are:

• Online 5 and 6 are higher performing (specialised) storage systems. These have high performance requirements on capacity, computation and controls, which are used in specialised applications.

• Removable media libraries and virtual media libraries including tape libraries are data back-up systems. These have a small power usage and market share.

153 Taxonomy | SNIA

3.1.1.2 Utilisation rates for servers

A key metric for the energy consumption efficiency of a server is its utilisation rate. Indeed, as servers are always "online", they are technically always "on" and consuming power. The utilisation level is a metric calculated as the average operational level of a server, including the time spent idle and the time at varying operating levels.

This utilisation metric is important as it provides clarity on the level of operational capacity servers are delivering. Servers may always be switched "on", but the questions to be asked here are: how much power is being consumed in this time? and how much work is being delivered in this time?

A higher utilisation rate of servers results in a more efficient system, as fewer servers would be required to deliver the same amount of work (saving the cost of the resource to build those devices), but also as shown in Figure 3.3, servers at a higher utilisation rate tend to be more energy efficient on a watt per work delivered basis.

Current estimates for the average utilisation rates of servers are quite low, with the Uptime Institute Intelligence survey results showing that *"at least 40% of servers operate at <30% utilisation"*[154]*.* This low rate is generally justified by operators due to an abundance of caution to ensure that there is capacity to respond to peak demand times. Statements from IBM correlate this figure stating that the average rate of server utilisation is of 12-18% capacity.[155] Using a normal bell curve time distribution for a utilisation level of 12-18% would imply that the average server is in idle mode between 10-25% of the time. However, the Uptime Institute Intelligence indicates that for Enterprise and office applications, utilisation rates can be increased to 50% without any loss in performance. 50% utilisation rates should be used as a target best practice as increasing to higher utilisation levels may result performance failures.[156]

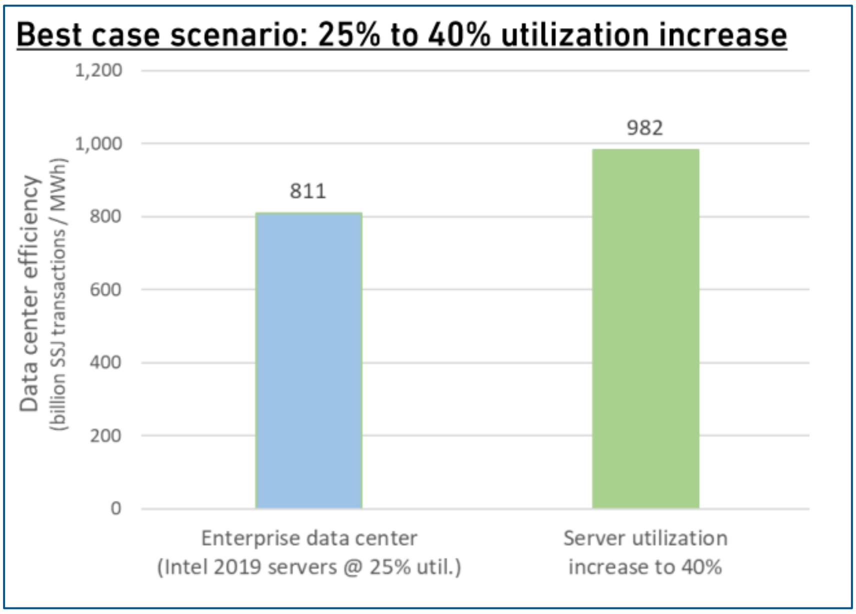
Furthermore, the Uptime Institute calculated in Figure 3.5 the efficiency benefits of shifting utilisation rates on the same hardware from 25% to 40%. This shows a 21% increase in efficiency of the SSJ transactions.

[154] Transactions per megawatt-hours: Keys to increasing data centre efficiency, Uptime intelligence, 27 June 2023

[155] Are Your Data Centers Keeping You From Sustainability? - IBM Blog

[156] Transactions per megawatt-hours: Keys to increasing data centre efficiency, Uptime intelligence, 27 June 2023

Figure 3.5 Efficiency savings from increased utilisation



The main concern from users with increasing the utilisation rates of an average server, is that in times of peak demand, the system would not cope with the additional demand and would crash. Therefore, additional buffer capacity is placed onto the system is provided to ensure the system is resilient. However, techniques are now emerging to ensure resilience at higher utilisation rates. For example, Intel has developed the concept of "effective resource utilisation", which reviews not only if devices are being used, but also if that use is effective. For example, if computational programs on a system have been terminating before completion, that utilization is useless for the operator. Targeting those programmes, to ensure they are appropriately delivered (rather repeated) will reduce the total demand for processing.[157]

3.1.1.3 Data storage products utilisation

Storage products have distinctive sub-systems to bear in mind when discussing utilisation, namely the distinction between the storage controller and the storage devices.

Storage controllers are either installed internally or externally as an extra controller enclosure (CE) with attached disk enclosures (DE) which can provide extra scalability. These systems are capable of organising hundreds to thousands of attached HDDs and SDDs. Therefore, the utilisation of controllers is likely to be higher than that of storage devices. Although the controller has the higher utilisation rates, the storage devices have the higher energy consumption, which can make up to 80% of the total device consumption. It is important to note that unlike with servers, tuning for the utilisation of storage systems for idle is not a priority. Higher controller utilisation may result in performance below the required 20ms latency, hence a balance needs to be struck between controller usage and the number of drives serviced.

Storage products are organised into two types: transaction and streaming products.

[157] IT@Intel: Data Center Strategy Leading Intel's Business Transformation, White paper, July 2020

Transactional data storage is optimized for running production systems (everything from websites to banks to retail). These are designed to read and write data quickly whilst maintaining integrity. Streaming data storage is optimised to better read and emit data (rather than quickly write). This data will be emitted at high volume in a continuous, incremental manner. The data storage therefore needs to be high volume, but not operation will not be as frequent. Both have varying use rates, though transactional systems typically have higher utilisations.

3.1.2 Extended product and systems approach

3.1.2.1 Presentation of server and data storage operation environments

Servers and data storage products can be operated in multiple different location types. These types of premises will influence the operations of the devices, their lifecycle and maintenance, along with the supporting infrastructure.

The two main categories to be aware of are data centre premises and distributed IT (also known as 'on-premise' datacentres or 'embedded data centres'). Distributed IT, also referred to as "closet IT" or "embedded IT", will host servers and data storage products in locales not dedicated to their use, such as a side room in an office, or a closet. These systems rely on the infrastructure facilities of the rest of the building, meaning that their usage and energy patterns may not be as closely monitored.

Data centres are premises dedicated to the operation of servers and data storage products. These will have supporting infrastructure designed for these devices: HVAC, power supplies, network equipment.

Data centres can be broken down into three different general types of premises: enterprise, managed services, colocation and hypercloud.

Enterprise data centres are built, owned and operated by companies, and optimised for their end users.

Managed services data centres are managed by a third company (or a managed services provider) on behalf of a company. The company leases the equipment and infrastructure instead of buying it.

A colocation data centre provides a space in a datacentre for a user to rent, where they can install their data equipment. The colocation data centre hosts the infrastructure: building, cooling, bandwidth, security, etc., while the company provides and manages the components, including servers, storage, and firewalls.

Hypercloud centres are off-premises form of data centre, where data and applications are hosted by a cloud services provider such as Amazon Web Services (AWS), Microsoft (Azure), or IBM Cloud or other public cloud provider.

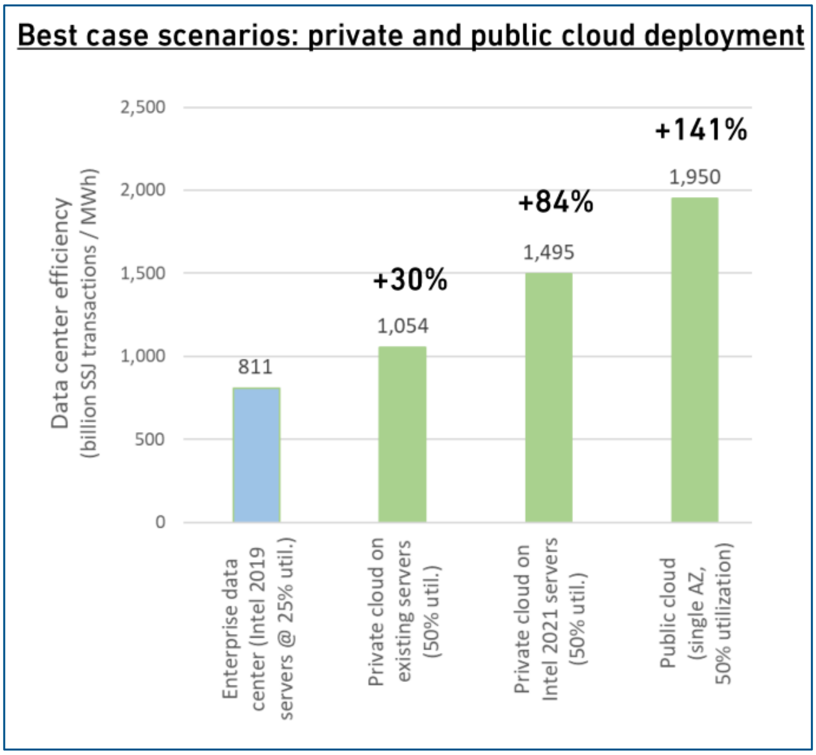
The distinction between these premises is required as the more specialised systems are most likely to be more efficient. Indeed, data centres with their dedicated power, connectivity and cooling facilities are likely to have the more efficient systems in that manner.

Locations such as enterprise datacentres or hypercloud centres, where the equipment is run by one entity, are also more likely to increase efficiency, as the server operation will be optimised, through IT equipment efficiency (improved server performance) and IT operational efficiency, such as using the latest by prioritising workloads to more efficient units (e.g. virtualisation). This is evidenced by Microsoft

Cloud facilities being between 22 and 93 percent more energy efficient than traditional enterprise data centres, depending on the specific comparison being made.[158]

The Uptime intelligence Institute has also exemplified these improvements in their analysis in Figure 3.6. This shows how the shift to a cloud system, where utilisation is increased from 25% to 50%, can result in an increased efficiency of 30%. Furthermore, these gains are compounding when shifting to newer, more efficient equipment, from Intel 2019 to Intel 2021, resulting in an increase efficiency of 84%. Moreover, this increase in utilization and server energy efficiency would also result in decreased space and IT equipment footprint by up to 50%.[159]

Figure 3.6 Model of efficiency gains through cloud deployment[160]



Stakeholder feedback indicate that the current trend is that users are currently migrating their primary operations away from cloud providers back to private enterprise structures. This drive is primarily driven by safety concerns. However, increases in the need for processing or storage capability, beyond core delivery operations, would be purchased on the cloud.

3.1.2.2 Discussion on consolidation and purchasing decisions

As quoted in the previous section, the workload of a server is something which can be redistributed to maximise asset utilisation and minimise the energy and IT equipment costs. This knowledge can be missed by a datacentre when equipment updates occur. Users will typically update their fleet of server equipment on a regular basis in relation to their age, rather than if they have technically failed. This

[158] The carbon benefits of cloud computing- A study on the Microsoft Cloud in partnership with WSP, 2020, [Download The Carbon Benefits of Cloud Computing: a Study of the Microsoft Cloud from Official Microsoft Download Center]

[159] Transactions per megawatt-hours: Keys to increasing data centre efficiency, Uptime intelligence, 27 June 2023

[160] Transactions per megawatt-hours: Keys to increasing data centre efficiency, Uptime intelligence, 27 June 2023

regular update ensures that the latest more powerful, and efficient, servers are used. However, users often will purchase replacement servers on a 1-to-1 basis. This buying behaviour is driven by a concern over avoiding failure risks. Yet this means that although the new equipment is more powerful, the same number of servers are installed. If the workload hasn't changed, this results in a lower utilisation rate on a per server basis.

Upon server fleet update, there is an opportunity to consolidate workloads. With new, more powerful servers installed, then the same amount of work can be consolidated onto fewer servers, resulting in higher utilisation rates for the servers (hence a higher energy efficiency for the work delivered), and lower IT equipment costs.

This approach can also be applied to storage equipment, where upon refresh, the storage footprint can be reduced by 25-50%. This can be done with higher capacity drives, and the use of capacity optimization methods (such as data deduplication and data compression).

In addition, to purchasing new equipment there is the option for a data centre operator to purchase refurbished systems. The exact size of this market in the EU is not clear and the study team is not aware of any research that has been done to look into this purchasing decision.

3.1.2.3 Explanation of the business models for data services

Servers and data storage products provide computing and data services to users. The base market for a user to have these services is to own the equipment themselves to deliver the work. However, the market for these services has now evolved. Rather than purchasing equipment, one can now purchase computational capacity directly. These are covered in three main groups: IaaS, PaaS and SaaS.

IaaS or Infrastructure as a Service refers to a system where one can hire the control over a virtual machine, with set storage and workload capabilities. This virtual machine can be accessed anywhere, and the contract would specify the storage and workload capability provided. These parameters can be flexed if the user finds they have an increase in their demand needs. This market structure is the closest thing to a remote data centre for business users.

PaaS or Platform as a Service relies on cloud computing to ensure that a particular application, or software, can be developed and hosted on the web. This can sometimes also be referred to aPaaS (application platform as a service). This market can be used to host a website online, without the need to have dedicated equipment to the task.

SaaS or Software as a Service is often called web services. This makes applications available to the end user via the internet. This could be for example through a subscription service, and would be the one which users are the most familiar with, and applies to services such as: Microsoft 365, Gmail, OneDrive, Dropbox, Netflix, etc.

The relevance of these different data service market models is that these may each result in more or less effective use of hardware. For example, IaaS are often under-utilised, with customers over-purchasing device capacity, meaning that utilisation is likely to stay around 20%. The lower utilisation rates also results in lower efficiencies for the work delivered.

For PaaS, the advantage is that one can develop the software or application, and not have any knowledge of the IT equipment required. The PaaS provider would then need to determine the machines required to provide the adequate computational power and data storage capacity. The PaaS provider can optimise this service over multiple servers to ensure a higher efficiency.

3.1.2.4 Wider systems considerations

Enterprise servers and data storage products have multiple impacts during their use phase. As we described in 3.1.1 and 3.1.2, their activity requires them to consume electricity as they operate. However, this consumption is only the first impact during their use phase, the other is the impact of the auxiliary infrastructure ensuring the appropriate working conditions for the IT equipment. This includes keeping the equipment cool at the right temperature, ensuring the power supply is of good quality (providing protection from any power surges), and providing adequate telecoms connection.

The efficiency of the IT equipment is doubly important as whatever electricity is consumed by the server is eventually converted into heat. This means that data centres create a lot of heat, requiring cooling facilities to ensure the equipment is kept at the right temperature.

The industry has developed the Power Usage Effectiveness metric to monitor how efficient the supporting cooling systems are. This is monitored under ISO 30134-2 and is calculated as the ratio of the total data centre energy consumption over the total IT equipment energy consumption. This provides a figure which has a theoretical minimum of 1.0, which is when all the datacentre consumption is equal to the IT equipment energy consumption only.

Table 3.3 shows how the energy consumption of the ICT sector in the EU27 has developed and is expected to the develop by 2025. Although server and storage consumption has gone up in real terms, the total data centre consumption has gone down in 2020 driven by the gains from improved facility infrastructure capabilities. These gains were pushed by a voluntary agreement of the industry to reduce the PUE figure, which has gone from 2.1 in 2010, to 1.46 in 2020 on average. This trend is expected to continue to reduce to 1.3 in 2025. The BAT for PUE is currently at 1.1, with some specialised data centres capable of going lower.[161]

Table 3.3 ICT Electricity Use EU27[162]

	2010	2015	2020	2025
Servers	18.66	18.66	22.05	27.24
Storage	1.80	1.80	4.35	4.45
Networks	0.53	0.53	0.74	1.06
Facility infrastructure (Cooling, Power protection, etc.)	23.74	23.74	12.4	10.07
Total Data Centre consumption	44.73	44.73	39.54	42.82

[161] The Idle Coefficients, EDNA 2021

[162] VHK and Viegand Maagoe. (2020). ICT impact Study.

	2010	2015	2020	2025
PUE	2.1	2.1	1.46	1.3

The gains in the PUE figure have been reached with investments into more efficient cooling units, fans, optimised ventilation layouts, heat recovery systems, improved power supplies and facilities lighting.

However, it should be noted that the PUE metric is only effective as a comparison to the IT equipment consumption. The PUE metric does not encourage the reduction in the IT equipment. Therefore, other metrics are required to ensure that the entire data centre system becomes more efficient.

Another considered metric is the WUE, Water Usage Effectiveness. This has been developed for data centres with regards to their consumption of water. This is because some cooling systems are reliant on water evaporative technologies. This consumption of water is of concern in water scarce regions, notably in western USA.

Beyond the scope of the PUE, users are considering the recuperation the heat generated by IT equipment under waste heat recuperation techniques. In section 2.12 of the Phase 1 report, we detail how this heat is considered “low grade” as the liquid recuperated from the cooling systems will reach a maximum of approximately 30°C. This is because the data centres aim to keep their premises at the low end of the ASHRAE A1 recommended temperature conditions 18 – 27°C (the justification to keep this temperature has been made in 3.3.2). This limits the direct application of this heat to residential, commercial areas or agricultural facilities: providing direct floor heating to residential or commercial buildings using 30°C water temperature (offices, houses, common spaces, etc.) or within agricultural facilities (greenhouses, fish farming). This requires for these applications to be close as the transport of such low-temperature water would incur losses as the distance grows. For other applications, the heat can be upgraded to higher temperatures through heat pump systems.

Waste heat recovery on datacentre could be a sustainable solution to heating, however it needs to be appropriately monitored in order not to encourage the development of inefficient datacentres. Although increasing the datacentre operating temperature would allow for more waste heat recovery applications, this temperature is recommended to be kept under 27°C as detailed in 3.3.2. as it would increase inefficiency in the total system. Another solution is to develop direct liquid-to-chip cooling systems which could recover heat better and operate at higher temperatures. These are discussed further in Task 4, under 4.1.3.4.

3.2 System aspects of the use phase for ErPs with indirect energy consumption effect

This part of the MEErP is not relevant for servers and data storage products. All indirect effects are investigated through the systems approach section.

3.3 Maintenance, Repairability and End-of-Life Behaviour

3.3.1 Product use and Stock life

The product use and stock life are defined within the MEErP as the time between purchase and disposal. The technical lifetime is defined as the time the device will last without need for repair. The economic lifetime is defined as the time the device will be used before it is replaced, which may be shortened from the technical lifetime by early replacement (due to newer more performant devices) or extended through repair.

As servers occupy valuable space in data centre facilities, it is assumed that there is no additional time lag between the end of the operational life of the asset and the disposal by the customer.

Table 3.4 indicates the estimated lifetimes for the servers and data storage products. This has been recovered from Table 2.6 of the Task 2 report.

Table 3.4 Average lifetime, by type of equipment[163]

Equipment type	Average economic lifetime (in years)	Average technical lifetime (in years)
Rack-blade, rack-mounted, tower/ standalone and multi-node servers	3 for lease 3 to 5 for primary users 5 to 7 for secondary user	5 - 12
Mainframe servers	7 - 15	20
Data storage products (HDD, SSD and hybrid drives)	5 - 7	HDD: 10-15 SDD: 7-10 Storage shelf: 15-20

Within section 2.7 of the Phase 1 report, the study team also indicate how providing an information sheet with the technical lifetime of the asset could be beneficial. Indeed, this could serve to increase the economic lifetime of the asset.

3.3.2 Good & bad practice in product use

Good practice for servers and data storage products can be broken down into 3 sections: maintaining appropriate ASHRAE operating conditions, providing power surge protection and maintaining firmware updates.

ASHRAE sets out the operating conditions of temperature and humidity for servers and data storage equipment. These operating conditions are set out in Table 3.5.

[163] According to DIGITLEUROPE in Lot 9 Ecodesign Preparatory study. 2015

Table 3.5 ASHRAE Operating condition classes[164]

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

The recommended range indicates the conditions in which a server or data storage product should be operated in. The allowable ranges can be used but are intended to be temporary operating conditions.

Within the Phase 1 report the study team have discussed how the energy consumption of a data centre can be managed by maintaining the set temperatures within the server rooms. In Section 2.10 of the Phase 1 report, we recommend not to increase servers operating temperatures above 27°C, as this can result in an increase in total data centre consumption caused by an increase in individual server fan energy consumption. This follows the advice from ASHRAE which shows how for every degree increase in the air inlet temperature from 17.7°C, 4% can be saved on cooling costs. However, beyond 27°C, although cooling costs continue to decrease, and PUE value decreases, the energy consumption of the IT equipment increases, resulting in a total data centre energy increase.

The datacentre company Equinix typically run their colocation datacentres at 23 degrees Celsius and has been moving operation towards 25 degrees Celsius without issue. In 2023, the company is now moving to trial a colocation datacentre at 27 degrees Celsius, which should be safe and within the ASHRAE recommended range. The colocation industry cannot push beyond the ASHRAE range, as their

[164] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products

servers are owned by others, and hence they cannot take too many risks.[165] However, there are efforts to push the operating temperature range beyond this, notably for Meta who has reportedly operated a datacentre at 32degrees Celsius. This is possible for Meta as they are operating their own servers.[166] Within section 2.7 of the Phase 1 report, the study team also indicate how operating conditions could be better labelled for datacentre operators, along with ASHRAE guidance. This can ensure that IT equipment operating temperature is not set too high (possibly damaging the asset) or too low (resulting energy loses) by the datacentre operator.

Surge protection for servers can be provided to ensure that electrical power supply is stable and does not damage equipment. Servers are equipped with internal power supplies in order to convert supplied alternative current to direct current, which provides some protection to the product. Additional grid surge protection can be provided by installing an uninterruptible power supply (UPS) at a data centre, in an on-line protection configuration. These UPS will provide filtering to smooth surges, spikes and dips in the power supply, and will also provide short-term power to critical loads to ensure alternative supply can be turned on in time.

Lastly, firmware updates are required to ensure that servers and data storage products continue to be operated in best conditions. The current Ecodesign regulation 2019/424 requires for these to be made available for products for a set period of time after being placed on the market. Updating these will ensure that product operation is appropriate.

3.3.3 Maintenance practices

Maintenance practices for servers and data storage products are typically covered by disk cleanup and scans (to detect potential for hard drive crashes), cleaning tape drives, monitoring fans and temperature systems performance (which is critical for CPU operation) or upgrading drivers and firmware.

The frequency is dependent on the components and sub-systems considered, the utilisation rates and the operating conditions (temperature and humidity). Hard disk drives, power supplies and memory components have a higher rate of failure and would therefore be maintained more often. Similarly, devices under high utilisation or operated at extreme temperatures are more likely to fail.

Maintenance rates can be included as part of vendor contracts between vendors and consumers. Most manufacturers would provide a three-year warranty in purchase prices, but some may go down to only one year. Third party maintenance is also a common practice in the EU, this entails that the user sources the up-keep of their products internally or via an engineer who does not work for the manufacturer. It has been communicated with the study team that third party maintenance has a substantial contribution to the overall market as users seek more cost-effective measures to extend the life of their products.

3.3.4 Repairability

As mentioned under maintenance practices, vendors may provide repair services as part of the original sales contract. The components with higher rate of failure would be replaced. This is mainly the case for memory and storage components. Other

[165] Is Raising Temperatures in Data Centers Good for Hardware? (datacenterknowledge.com)

[166] Meta thinks it has a great new way to save water in its data centers | TechRadar

elements in a server which can fail are the fan, CPUs and power supply, there tends to be multiple of each of these components therefore, if one fails the systems tends to remain functioning and a repair will likely be undertaken. However, these components can all be replaced. it is noted that servers have a much shorter economic life expectancy than technical one, therefore faulty products are more likely to be disposed of and upgraded rather than repaired by users. Repair or part recuperation is most likely to occur for servers during second-hand use by refurbishers.

Data from Intel shows that their HPC server fleet has an overall annualized failure rate of <1.37%, with only 1.22% in the first 4 years, and up to 1.56% in the year 4 to 8 of life. The main component failures seem to be from the PSU at 0.32% across the 0 to 4th year and 4th to 8th year brackets; and the motherboard which has a high rate of failure in the first 4 years of 0.55%, then subsequently dropping to 0.16%. Drives were third placed with failures of 0.18% across their lifetime. All other components had annualized failure rates below 0.1%.[167]

For data storage products, components are more likely to be repaired and replaced. Hard disk drives (HDD) are easily replaced with measures in place to ensure failures are managed as business-as-usual metrics, with repairs proceeding swiftly without any change in the quality of service delivered.

Solid State Drives (SSD) have a lower rate of failure than HDD, estimated failure rate after 2 million hours, versus 1.5 million hours for HDDs.[168]

Common warranty for drives is five years (43.800 hours).

Stakeholders indicate that spare parts are usually available for five years after the product is manufactured. The study team has recommended that this should be included in the Ecodesign regulation to ensure higher repair rates. This recommendation has been discussed in more detail within Section 2.8.4.4 of the Phase 1 report.

3.3.5 Second-hand use

Server products are generally disposed of before the end of their technical lifespan, which means they can be recuperated and repurposed for a second life. However, these practices are not standardised across the industry, and users have security concerns around their data, making it unclear to review what is the rate of recuperation and reuse of devices.

As mentioned above, servers and data storage products can be repaired and refurbished to provide a new life on their asset. Most hardware manufacturers have end-of-life facilities to adequately collect, repair, refurbish, recuperate parts and/or recycle servers and data storage products. These services are provided, but data on their implementation rate is unclear. There is also an existing IT Asset Disposal (or ITAD) third party industry who will recuperate these devices and guarantee that any data has been adequately erased, which ensures security for original device users.

Security of data can be ensured through two methods, either with software overwrite (known as “erasure”, which is distinct from “deletion”), or physical destruction of the drive. Software overwrite can be safe, notably using rigorous erasure services, as guaranteed by standards such as ADISA. However, there is a general mistrust in

[167] IT@Intel: Green Computing at Scale, August 2021

[168] Storage Review: SSD vs HDD. http://www.storagereview.com/ssd_vs_hdd

industry around these practices, meaning that software overwrites are used generally for internal reuse or non-critical data. Physical destruction is generally used for all other purposes, with customers insisting on physical destruction to ensure their data cannot be recovered. Recently there has been a clear movement to accept Secure Erasure which provides certificates of the removal of data, this ensures that destruction remains an alternative and only for those drives that have no reuse option.

Where some products may have been disposed of, as their users have upgraded to more performant products, recuperators will ensure data eradication, and either reuse, or refurbish devices by upgrading particular components (such as by replacing for a more powerful CPU). The product can then be re-sold, usually at a lower price. Stakeholder data shows how in Europe, the components recuperated and reused are: RAM memory (47% of units by weight) and processor (39.7% of units by weight).

3.3.6 Recycling, collection and disposal

Servers and data storage products are in the scope of the WEEE Directive. WEEE (or Waste electrical and Electronic Equipment), sets out communal collection and recycling targets under “extended producer responsibility”. This means that producers must take responsibility for the equivalent amount of waste they place on the market, and finance dismantling, depolluting, recycling and disposal of WEEE. Individual manufacturers/vendors may go beyond these requirements. This WEEE metric is measured based on total mass collected and recycled, and therefore does not prioritise the recovery of critical materials, but rather bulk components. Eurostat data tracks the recuperation rates for WEEE streams as a whole but does not distinguish between different electronic devices.

There is a clear boundary of the jurisdictions of WEEE and Ecodesign products with regards to reuse and recovery. Until a final decision on the recycling of a product has been made then its life-cycle continues and it remains under the jurisdiction of the Ecodesign regulation. Therefore, if a product is re-used rather than recycled the Ecodesign requirements remain applicable to it. However, when a product reaches end of life, it would be defined as “waste” which brings jurisdiction over to the WEEE. After its listing as WEEE some components of the product can still be re-used thus labelling it as REEE (recycled electronic and electrical equipment) and under the procedures associated with this.

Most hardware manufacturers have end-of-life mechanisms to recuperate products when customers no longer require these (whether due to failure or upgrade). These mechanisms will aim to reuse (or resell) the product, repair (or refurbish), recuperate functioning components and recycle remaining materials. Due to the modularity of the products, many of the components may still be functional and be removed directly at the customers location. However, the rate at which this is done is unclear.

Critical raw materials are of particular concern for these products. In particular, the recuperation of strong permanent magnets used in HDDs. These strong magnets use rare earth elements, which are critical materials. The use of a shredder is not appropriate as the Neodymium magnets would crack and stick to the shredder itself. Therefore, manual recovery is required for adequate material recovery. They can be recovered manually by dismantling the HDDS but requiring special fine mechanical tools to dismantle the device, whilst careful not to have the strong magnetic force not affect the tools themselves. This recovery is difficult and not always commercially viable. As IT products can be categorised under WEEE norms, it is the total mass of product recovered which is legally required, hence simpler bulk materials (such as the metal frames) are prioritised for recovery.

Table 3.6 below shows the breakdown of material usage, recycling, energy recovery and landfill for enterprise servers provided by a European waste disposal stakeholder in 2023. This data shows how 81% of collected server mass is either re-used or materially recycled. Including waste heat recovery, up to 99% of server materials value is recovered. Only 0.16% of material by mass is incinerated or sent to landfill.

Table 3.6 Inputs in the end-of-life phase of collected enterprise servers[169]

	Plastics	Metals	Electronics	Misc.
Mass ratio within server	0,97%	67,88%	30,88%	0,28%
Re-use	0%	0%	1%	0%
Material recycling	98%	98%	43%	50%
Heat recovery	0%	2%	56%	0%
Non-recovery incineration	0%	0%	0%	50%
Landfill	2%	0%	0%	0%
Total	100%	100%	100%	100%

Table 3.7 shows the inputs in the end-of-life phase of the storage systems assumptions from the 2015 Preparatory study.

Table 3.7 Inputs in the end-of-life phase of storage systems[170]

	Plastics	Metals	Electronics	Misc.
Re-use	25%			
Material recycling	5%	70%	50%	68%
Heat recovery	69%	0%	24%	1%
Non-recovery incineration	0.5%	0%	0.5%	5%
Landfill	0.5%	5%	0.5%	1%
Total	100%	100%	100%	100%

[169] Feedback from European electronics waste disposal stakeholder 2023

[170] Source: Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 3: User, July 2015: Final report, bio by Deloitte & Fraunhofer IZM

3.4 Local Infrastructure

3.4.1 Energy

The overall energy consumption and related energy costs are an extremely important factor that businesses in the EU consider. Especially given the recent spike in energy prices in the EU caused by the Ukraine War.

Geographic location will impact the reliability, availability and source of electricity that is provided to data centres situated in the EU. For example, data centres within Northern Europe have a particular advantage because the lower annual temperatures mean that less energy is required for maintaining. Lower ambient temperatures allow for free cooling, which reduces the overall cooling capacity needed. This will improve the data centres thermal efficiency meanwhile, due to the temperate, moderate to high rainfall climates in Northern Europe, there are more renewable energy sources from wind or hydropower, which are often less intermittent than solar power. There have been instances where free-cooling utilisation rates of greater than 50% are achieved in temperate regions. This is achieved when the raised floor temperatures are moved to the ASHRAE A2 Standard, and the cooling system is run with optimisation software.

However, it should be noted that despite the availability of free-cooling in northern regions of Europe, there is still a need for data centres to install compression refrigeration system. This will ensure that when the ambient temperatures are warmer and above the data centres set point temperatures, it is still able to maintain suitable environmental conditions inside to ensure full functionality of the servers and data storage products. Therefore, preserving this set point temperature and environment in the data centre requires significant amounts of energy, up to 40% of a data centres total energy use in warmer climates[171]. No matter the location, all data centres will need to cover this redundancy to ensure the facility is able to function all year round. Climate change is also having a significant impact on data centres across the EU, with more and more centres requiring active cooling as a result. In order to meet businesses' net zero goals, some data centre operators may choose to buy for example, solar panels in order to reduce their facilities carbon emissions.

The transparent metering of energy consumption is a necessity for the businesses in the EU. Therefore, energy metering for data centre facilities is encouraged by using the EN 50001 standard. However, this can be dependent on the equipment ownership and business models within the data centre, as often these locations are shared with other businesses.

Electricity supply for servers and data storage products is usually ensured through UPS units. UPS units will provide filtering to smooth surges, spikes and dips in the power supply, and will also provide short-term power to critical loads to ensure alternative supply can be turned on in time. This ensure that no damage or data is lost if there is a power surge or loss within the data centre. In addition, grid surge protection can also be provided by installing an UPS unit at data centres, in an on-line protection configuration. Usually, UPS products supply electricity via batteries. However, rotary or dynamic UPS products can utilise stored kinetic energy through a flywheel to provide electricity in case of a power supply failure.

[171] https://www.eolitservices.co.uk/2022/02/23/the-environmental-impact-of-our-data-storage/

Surge protection for servers can also be provided to ensure that electrical power supply is stable and doesn't damage equipment. Servers are equipped with internal power supplies to convert supplied alternative current to direct current, which provides some protection to the product.

3.4.2 Water

Water or another liquid can be used for cooling at both the product and system level. Liquid cooling of servers typically provides higher energy efficiency when compared to air cooled systems and could enable the driving of data centre industry forward. Manufacturers state that liquid cooling allows optimum energy use within the IT suite so that more power drives the applications on the servers rather than the cooling systems[172]. At the same time there are free air-cooled data centres in the US and adoption of free air cooling (at least part time) is preferred at Government data centres where possible.

Proposing requirements around proper deployment or quality of water-cooled solutions could be the way forward, however as these systems are still at their infancy, comprising of less than 5% of the server market, to impose requirements on water cooled solutions in a regulatory setting requires further review and analysis. In addition, liquid cooling introduces several new considerations including safety, proper fluid handling and maintenance (to avoid mould and/or corrosion etc.) and proper system design to minimise long term problems that specifically arise with the complications of liquid cooled solutions. Liquid cooling recommendations for this review study have been put forward in Section 2.11 of the Phase 1 report.

Product level liquid cooling

Indirect cooling is a system of liquid cooling where no liquid flows through the servers, but rather to the rack. These are usually set up as rear-door hybrid cooling, where a cooling liquid is set to flow at the back of the server rack. This allows for air to be cooled as is it removed from the server by the liquid flow. This liquid flow would then need to be cooled elsewhere, using technologies such as a chiller, or free cooling. These systems have a low to medium efficiency, require outlet water temperature to be under 50 ºC, are simple to install and have a medium total cost of ownership.

Another technology is immersion or submersion cooling. These systems have the entire server submerged in liquid which grants a high efficiency due to the liquid heat capacity. However, the installation is complex, and servicing the servers is difficult.

A direct-to-chip liquid cooling system will have liquid cooling flow provided directly in thermal contact with the hottest components of a server. These are highly efficient and allow for higher outlet temperatures, 60 – 75 ºC, which allows for more efficient waste heat recovery applications and the use of additional free cooling. These have low maintenance and low total cost of ownership. There are some installation concerns, but the main drawbacks are in the design of the specialised server to accommodate for the liquid heat exchange.

Since direct-to-chip liquid cooling can enable waste heat re-use above 60 – 70 °C, this waste heat could be used directly without the need for a heat pump cycle.

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[172] Solving Data Center hunger, EiBi, issue June 2022

Examples of such technologies and companies are Denmark based Asetek, and Canada based CoolIT.

System level liquid cooling

At a system level the utilisation of water in cooling systems is very common at data centres. However, the availability and efficiency of these systems can vary dramatically depending on geography.

Liquid cooling options discussed at the product level result in a more efficient cooling system, compared to air-based cooling solutions. Adopting more of the solutions described above would mean that fewer data centres have to use liquid cooled evaporative towers. Therefore, harnessing the high latent heat capacity of water to cool data centres, can mean that there is a lower water usage effectiveness score. This is major issue in areas where water scarcity is high and is vital to ensure the sustainable use of data centres in these areas. It is especially important with impacts of climate change beginning to mean more areas in the EU are experiencing longer drought periods. Particularly in regions where they usually do not occur, in the more temperate regions. Since data centres here are more likely to be less equipped for these types of environmental conditions.

In addition, to direct-to-chip liquid cooling providing cooling for the server, as described in the product level section. This type of liquid cooling would also provide a more efficient waste heat recovery solution. This could lower the data centre cooling energy consumption from a PUE of 1.2 to 1.12.

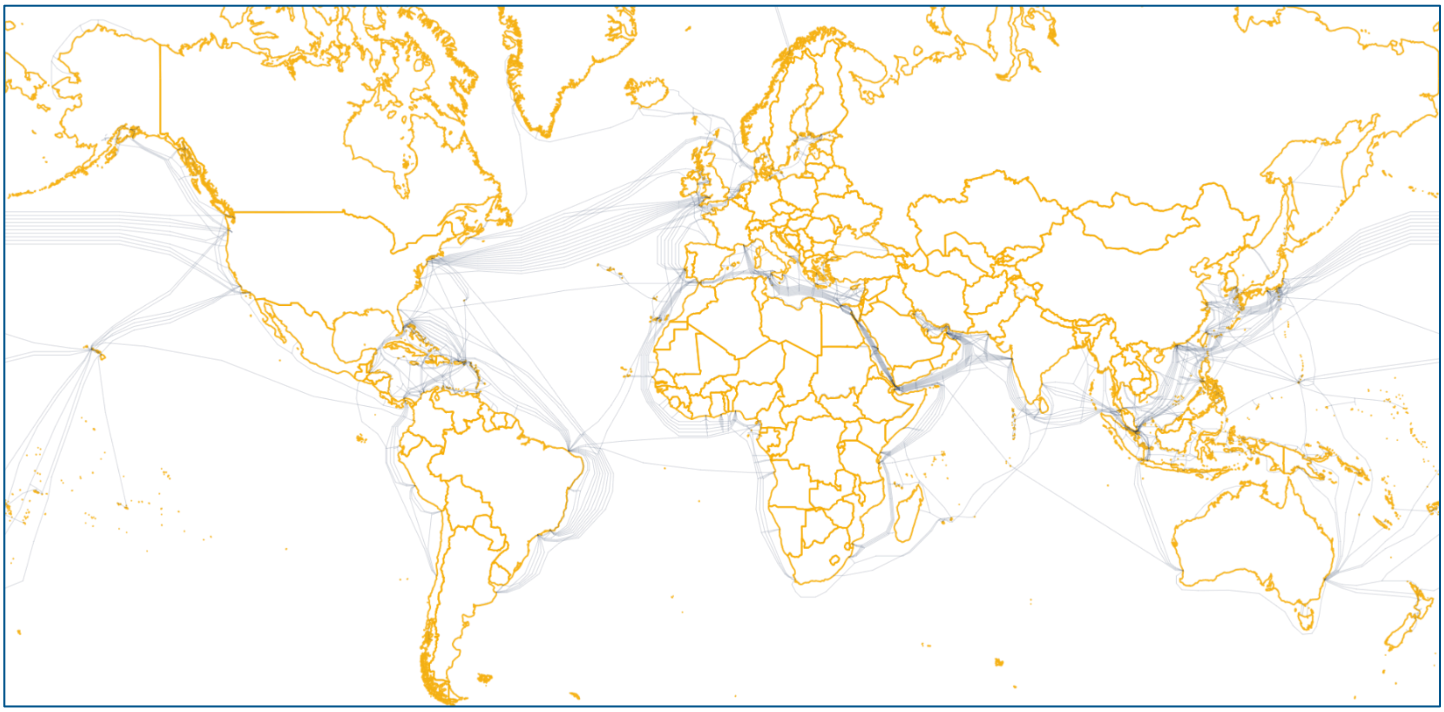
3.4.3 Telecommunications

A fixed-line broadband network access is crucial to the functionality of a data centre. This is has meant that over the years data centres have been specifically built closer to connection nodes or activity points to ensure connectivity is maintained Connection nodes are where intercontinental cables connect to the continent. For example, Figure 3.7 illustrates that there are many cables that go between the US and the UK, hence some may connect their data centres closer to that node. In this manner they can benefit from some of the higher bandwidth connections available closer to the connection nodes.

The previous preparatory study mentioned that wireless networks had not been implemented due to security and interference concerns. For servers and data storage products which fall within the scope of this Regulation this aspect has not changed. There has yet to be any serious development in connecting data centres wirelessly, due mainly to large amounts of data being processed. Therefore, larger data centres with will be connected via telecommunication cables. This continues trend is highlighted in Figure 3.7 which illustrates how widespread these cables are, connecting the EU with the North and South America, Africa, Asia, Middle East and Australia. The reliance on the use of the submarine telecommunication cables is emphasised by the fact that over 99% of international internet and telephone traffic passed through submarine cables in 2019[173].

[173] https://subtelforum.com/submarine-telecoms-industry-report-10th-anniversary-issue-now-available

Figure 3.7 Submarine telecommunications cables across the world[174]



Servers are heavily tied to the financial sector, which relies on servers for processing financial information such as updated stock prices. Therefore, this time sensitive data centre activity, such as this will need to be closer to connection nodes to ensure that data is received as quickly as possible. For this reason, data centres will be close to where the financial operations are taking place, to benefit from fastest response rates.

3.4.4 Installation

Installation of servers and data storage equipment is usually part of the service provided by the equipment vendor, typically this is charged as an additional fee. Task 2 describes this in more detail, with the contract often including warranties that can be between three to seven years depending on the manufacturer.

3.4.5 Physical environment

Servers and data storage products are installed and operated within server rooms. Server rooms are the individual rooms that servers operate within, at a data centre. The data centre represents the entire infrastructure in which a server room can be found in. Therefore, for data centres there are many more considerations to take into account, such as heating and cooling requirements, and power supplies and many more.

Servers will tend to be hosted in two types of locations: distributed IT (where servers are used in offices or other buildings which are not dedicated for servers), and data centres (which are specialised locations for server usage, with dedicated power and HVAC services).

[174] ITU: Committed to connecting the world (https://bbmaps.itu.int/bbmaps/)

The bulk of servers are operated within data centres. The trend has been to consolidate data operations in data centres as their operation is optimised, allowing for better tracking of energy usage across devices and support systems. These buildings can also be reinforced in terms of data connectivity and power availability.

The physical environment of a data centre is usually defined by the maximum energy density that can be safely handled. As discussed in Section 3.4.1 the location of the data centre has a significant impact on not only the energy consumption but also the environmental impact of a data centre. Geographic location will determine the data centres access to colder ambient temperatures, water, and renewable energy sources.

Not only will geography impact the amount of electricity consumed by a data centre, but since each EU Member State has its own unique electricity mix this means that the local physical geography of each member state plays a pivotal role in a data centres overall environmental impact[175]. For example, in 2022, 38.7% of the EU's electricity was generated from fossil fuels, such as oil, natural gas, and coal[176]. The geographic variation is highlighted by the fact that Malta generates 87% of its electricity from fossil fuels, whereas Denmark produced only 21% of its electricity from fossil fuels in 2022[177]. This is because Denmark harnesses a lot of its energy from offshore wind farms in the North Sea, with 79% of its electricity generated from renewable sources. Innovative solutions to reduce data centres energy consumption are seen across the EU. For example, in Nordic countries, district cooling facilities are installed to take advantage of the cold temperatures experienced here.

[175] https://iopscience.iop.org/article/10.1088/1748-9326/abfba1

[176] How is EU electricity produced and sold? - Consilium (europa.eu)

[177] How is EU electricity produced and sold? - Consilium (europa.eu)

4 Introduction to Task 4 Technologies

This report is produced in line with MEErP and serves to identify, retrieve, analyse data and report on a number of topics relevant to the Technologies of this study. These include the technical product description which also covers data on performance and impact of resources/emissions.

Furthermore, the report considers the production, distribution, and end of life aspects of the technologies.

Finally, the recommendations will be presented at the next stage of the report from a technical perspective with regards to product scope, barriers and opportunities for Ecodesign, along with the typical design cycle for the products and approximately appropriate timing of measures.

4.1 Technical product description

This section serves two main purposes which include the capacity building for the policy makers/stakeholders as well as a first assessment in a way of pilot/preview of the modelling work required as part of Task 6.

4.1.1 Existing products

The objective of this section is to outline the existing technology which will enable the work towards the definition of a Base Case(s).

4.1.1.1 Product overview

Servers and data storage products are equipment used for Information and Communication Technologies (ICT). Servers are different to data storage products as they offer additional functionalities, however they operate in an interconnected environment. Both are sold in a business-to-business market (B2B) environment with more complex procurement routes.

The ICT services offered are provided via connectivity and interoperability between the server and the data storage system. There are also additional hardware and software products that facilitate this connectivity and service. These are part of the network equipment products.

4.1.1.2 Servers

Description of key components

A server is a modular product (i.e., made up of more than housing element) which consists of the following key components. These remain unchanged from the previous preparatory study[178]:

- **Chassis**: A metal/plastic casing that encloses all components. It also incorporates mounting features for them.
- **Mainboard (server board)**: This is the main printed circuit board (PCB) of the server. It provides the firmware, processing units and points for mounting the

[178] Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 4: Technologies, July 2015 – Final report, Produced by bio by Deloitte and Fraunhofer IZM

memory modules and further active components. It also includes passive electronic components such as capacitors, resistors etc

- **Processor**: This is the central processor unit (CPU), the foundation of the server operation, which processes numerous software instructions to derive a required result. The processor works closely with memory, which both hold the software instructions and data to be processed as well as the results or output of those processor operations.
- **Memory (Random Access memory)**: RAM keeps the relevant instructions and data required by the processor. It also holds any output from the processor.
- **Storage devices/drives**: Hard disc drives (HDD) were the first ones to be produced as well as semiconductor-based solid state devices (SSD) that are integrated into a housing of a disk drive.
- **I/O control and network connectors**: Servers are remotely accessible via Ethernet connection and therefore feature multiple network interfaces and links (connectors) on the backside.
- **Cooling system**: The cooling of the active components (such as the CPU) is very important and is typically achieved by a combination of passive and active options. The active cooling includes in most cases a fan unit, while the passive cooling includes either a heat spreader attached to the processor, a large heat sink or heat pipes that distribute the thermal energy away from the processor. Both systems work in combination.
- **Power supply unit (PSU)**: This is typically a single unit or multiple unit coming in its own casing, usually metal.

The main components are discussed further below.

Chassis

The chassis (also typically called enclosure, case or housing) is in most cases, a simple metal box with a type of frame and mounting parts. The purpose of the chassis is to enclose and mount the main subassemblies including the server's printed circuit boards, storage devices, integrated fans and passive cooling devices, the power supply unit, and interfaces. The chassis may feature rails and cages (bays) for mounting different exchangeable devices such as disk drives or power supply units. The form factors, dimensions, and intended way of mounting dictates the design of the server's chassis. Servers can be stand-alone devices, where the chassis includes a pedestal. However, the majority of servers are mounted in 19-inch server racks. Each server is connected via cabling to the power distribution and network. The market shows a high diversity in terms of dimensions, form factors, and system configurations, however, with respect to the chassis, there are two main types:

- <u>Integrated single servers (e.g. rack server).</u> Within these, all components are in the man chassis of the server. The integrated server is fixed directly to the rack, while one rack fits multiple servers usually.
  The actual reck-mounted servers usually feature a display as user interface and openings at the front and back. Many of the key components such as power supply units and the disk drives are designed so that they can be exchanged while the server is in operation. The covers (top) are removable to provide easy access to the key components.
  The internal of the chassis incorporates frames/rails for mounting of the key components. The chassis is mounted on the rack with fasteners which are quick to open.

- Modular server systems (e.g. blade system). These systems consist of two housing elements which are the individual chassis of the server modules (motherboards with connectors for power and I/O) as well as the system enclosure. The individual servers are also call blade, cartridge or book and they are inserted into the larger enclosure. This also provides the shared resources for the blades eg. Network, storage, cooling and power supply. The modular system is also then mounted to a server rack. With regards to fastening mechanisms, these are in most cases base on rails and clips with the aim to ensure fast exchange.

Materials:

The materials used for the chassis vary depending on the dimensions, form and layout, however the main materials utilised are low-alloyed steel or chromium steel, brass and some plastic parts.

There are also several fasteners such as screws and clips which are not standard and vary from product to product.

Although there is a large variety of types and dimensions, there is opportunity for further recyclability of the materials used, due to the possibility of separating the different and main materials from each other as an end-of-life treatment.

The chassis contains ferrous and non-ferrous metals which are recyclable materials. It has been recommended in Section 2.8 of the Phase 1 report that rates of recyclability and recuperation of servers in the EU are investigated further. As within the scope of the Ecodesign regulation to improve the recycling rates of servers, we recommend investigating the inclusion of a more extensive product datasheet requirement which would track material content. This would mean that more information would be provided to recycler about the contents of the chassis, which will facilitate recovery and recycling activities.

Energy usage:

With servers being energy using products, the requirement to lower their energy consumption is a main consideration. In addition, optimising the PUE with managing the internal temperature and coordinate the air flow is a key consideration. Some chassis have baffle plates for better air flow. The chassis function sometimes as a heat spreader. The placement and utilisation of multiple servers in a rack also influences the surrounding thermal conditions.

Within the Phase 1 report the study team have discussed how the energy consumption of a data centre can be managed by maintaining the set temperatures within the server rooms. In Section 2.10 of the Phase 1 report, we recommend not to increase servers operating temperatures above 27°C, as this can result in an increase in total data centre consumption caused by an increase in individual server fan energy consumption. This follows the advice from ASHRAE which shows how for every degree increase in the air inlet temperature from 17.7°C, 4% can be saved on cooling costs. However, beyond 27°C, although cooling costs continue to decrease, and PUE value decreases, the energy consumption of the IT equipment increases, resulting in a total data centre energy increase.

Mainboard (server board)

This is the main printed circuit board (PCB) of the server. It provides the mounting for both the active components such as semiconductors devices (processor, memory, etc.), and the passive components (resistors, capacitors, inductions, etc.)

as well as various sockets (CPU socket, DIMM sockets, etc.) and connectors (Ethernet ports, USB ports, etc.). These together enable the computing and communication services.

The electronic devices are directly connected (soldered) on the mainboard mostly by Surface-Mount Technology (SMT) or Through-Hole Technology (THT). A serverboard is multi- layer printed with approximately 12 layers (plus/minus 4). The number of layers is not seen to be increasing due to the fact that many functional circuitries are nowadays realised as integrated circuits (ICs).

Materials used:

The mainboard is still made of the same materials which are FR-4 laminates and copper foils (cores).

FR-4 is a glass-reinforced epoxy laminate and its thickness is typically a few hundred micrometers (µm).

The copper cores are foils with a thickness of about 18 µm or 35 µm. The single copper layers are connected through small, copper-plated holes.

The mainboard’s outer layer is coated with a protective surface finish which varies according to materials utilised. Common technologies remain unchanged since the last study and these are Electroless Nickel Immersion Gold (ENIG) and Immersion Silver (Imm Ag) in higher end products and Immersion Tin (Imm Sn), Organic Solder Preservative (OSP) or lead-free Hot Air Solder Levelling (HASL) in more economic products. Currently Cu with solderability preservatives (CuOSP) is regarded as the established technology.

The dimensions of the printed circuit board and the number of its layers are important parameters for the material efficiency considerations.

Energy usage:

There are energy intensive processes in the manufacturing of printed circuit boards (Galvanic processes) and the lead-free soldering process (high temperatures) which have an increased energy demand.

Processor and memory

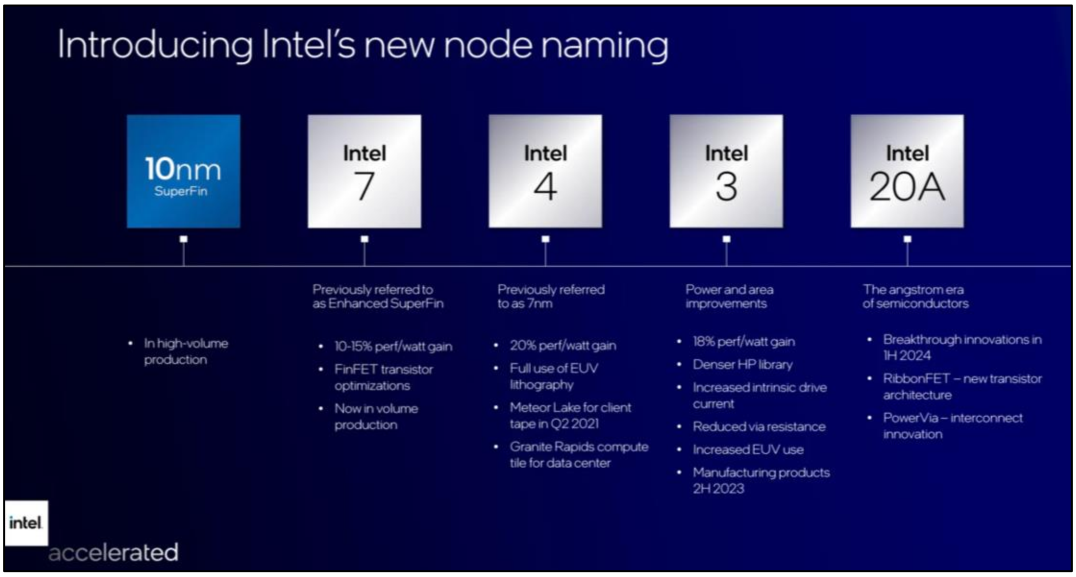
Processor: The central processor unit (CPU) in conjunction with the employed memory (RAM) and chipset is generally providing the computing functionality of the enterprise server. There are only a few processor architectures utilised in the server market:

- The x86 instruction set architecture is the most widely distributed and supports Microsoft Windows, Unix, Linux, AIX and Solaris operating systems. It is also compatible with virtualization software and most other software stacks employed in the industry. This processor architecture goes back to 1978.
- ARM processors are extensively utilized in mobile devices like smartphones and tablets due to their RISC architecture, which simplifies instruction cycles, resulting in lower power consumption and heat generation by the CPUs. In the server realm, ARM CPUs can match the computing prowess of top-notch x86 processors. For instance, the Ampere® Altra® CPU, which is a single-socket solution, boasts an impressive configuration of up to 80 cores in a single CPU. This feature makes it suited for handling enormous amounts of data. On the other hand, x86 processors, being based on CISC architecture, excel in executing complex instructions that may span through multiple clock cycles.

Consequently, despite having fewer cores compared to ARM processors, x86 CPUs can still deliver exceptional performance by employing techniques like multithreading.

There are other architectures which include Intel Atom, Intel Xeon Phi and FPGA-type Intel Xeon processors, ARM 64-bit SoC, GPGPUs from AMD and NVIDIA remain current. Upcoming trends of cloud computing being used for gaming purposes and similar applications result in adapted server configurations and technology implementations that relate to different requirements compared to common server configurations.

Figure 4.1 Example of current node development[179]



The CPU core serves as the central component where instruction cycles are executed. Within a single CPU, multiple cores can exist, each capable of performing its own set of instruction cycles. To handle larger workloads, parallel computing comes into play, enabling multiple cores to execute tasks simultaneously. While the number of cores significantly impacts the server processor's performance, factors like thread count, instructions per cycle/clock (IPC) and clock speed also come into play. Threads represent the smallest independent sequence of instructions that can be executed within each core. Leveraging multithreading, also known as hyperthreading, a core can effectively increase performance by roughly 30%. Clock speed, often referred to as clock rate, is a key metric for assessing a processor's speed. It denotes the frequency at which the processor generates clock signals, or "pulses," to synchronize operations internally. Clock speed is measured in hertz (Hz), indicating the number of clock cycles per second. Selecting the optimal processor for your server requires considering various factors, including throughput between processors and RAM, cache architecture, workload characteristics, and more.

The technical performance and features of a CPU is characterised by a number of factors including:

- Technology node, die dimensions and resulting number of transistors
- Number of cores per chip, threads per core, functional specialisation of the core

179 https://www.theverge.com/2021/7/26/22594074/intel-acclerated-new-architecture-roadmap-naming-7nm-2025

- Cache configuration and capacity, supported memory
- Number, type and control of I/Os System-on-chip or further integrated functionality such as power and memory control
- Maximum operating frequency, IPC, and frequency scaling per core,
- Operating voltage, power scaling options, intelligent throttling
- Packaging and mounting on the mainboard including type of socket

The Intel Xeon Scalable processors were based on various technology nodes, including 14nm and 10nm. The 14nm technology node was utilized for earlier generations of Intel Xeon Scalable processors, such as the Skylake and Cascade Lake architectures. However, Intel has also been transitioning to its 10nm technology node with subsequent generations, such as the Ice Lake architecture. The Xeon Scalable processors represented a shift to the 10nm process, offering improved performance and power efficiency compared to the 14nm-based predecessors. The AMD EPYC processors were based on a 7nm technology node. AMD made significant advancements with its Zen architecture, which included the Zen, Zen+, Zen 2, and Zen 3 microarchitectures used in different generations of EPYC processors. These microarchitectures were manufactured using a 7nm process technology. The 7nm process technology offered improvements in power efficiency, performance, and transistor density compared to larger nodes, enabling AMD to deliver high-performance server processors with a greater number of cores and enhanced capabilities. As technology nodes shrink to smaller dimensions, they approach the physical limits of atomic scale and quantum effects. This introduces challenges in maintaining the desired performance, power, and reliability of the transistors and circuits. As feature sizes decrease, the risk of defects increases. Even minor defects can impact the functionality and yield of chips. Maintaining high yield rates becomes more challenging, leading to increased costs and potential delays in production. To address these challenges, the semiconductor industry invests in research and development, exploring new materials, transistor designs, and manufacturing techniques. Techniques like EUV (Extreme Ultraviolet Lithography) have been adopted to overcome some of the challenges in photolithography. Moreover, new architectures and technologies, such as 3D stacking and specialized accelerators, are being explored to enhance performance while mitigating the limitations of miniaturisation.

Figure 4.2 provides a simplified overview of existing variety of CPUs on the example of the current versions of Intel Xeon Scalable processors. The list differentiates the Xeon processor families.

Figure 4.2 Intel Xeon process overview[180]

With respect to the performance, the elements remain unchanged and the clock frequency, number of individually addressable cores (and threads), cache capacity, input/output (I/O) speed and capacity are still very important design features of a CPU. In the past, CPU development addressed integrated GPUs. In order to further improve the performance of servers, two or more processors units are connected via a high speed bus or routing interface. Development since the last preparatory study are that there are few if any mainstream server CPUs that contain iGPUs, this space is nowadays better utilised for additional performance of its core function and/or ancillary on board accelerator chips.

Each processor consists of two or more cores allowing typically two threads per core. Multithreading aims to increase utilisation of a single core by using thread-level as well as instruction-level parallelism. The processor also features caches – memory buffers – on various levels (L1, L2, and L3) and other functional segments. Caches store information to avoid multiple computations and improve access times. The cache can be implemented as a hardware or software element. In a CPU, the cache answers many of the requests drastically lowering the effective load on the processor. Due to big and fast caches being rather uneconomic, there are usually several cache elements in a cache hierarchy. The smallest and fastest cache element is the first that attempts to answer a request; if the requested information is not stored, the request is handed to the next bigger and slower cache element. Caches utilise the faster SRAM to fulfil access time demands.

Static RAM (SRAM) retains data bits in its memory while power supply is connected.

Dynamic RAM (DRAM) stores bits by using capacitors and a transistor, that needs to be refreshed periodically. As SRAM does not have to be refreshed, it is much faster than DRAM but uses more parts resulting in a drastically lower memory per chip value. SRAM is also more expensive than DRAM.

[180] https://www.intel.com/content/www/us/en/products/docs/processors/xeon-accelerated/4th-gen-xeon-scalable-processors-product-brief.html

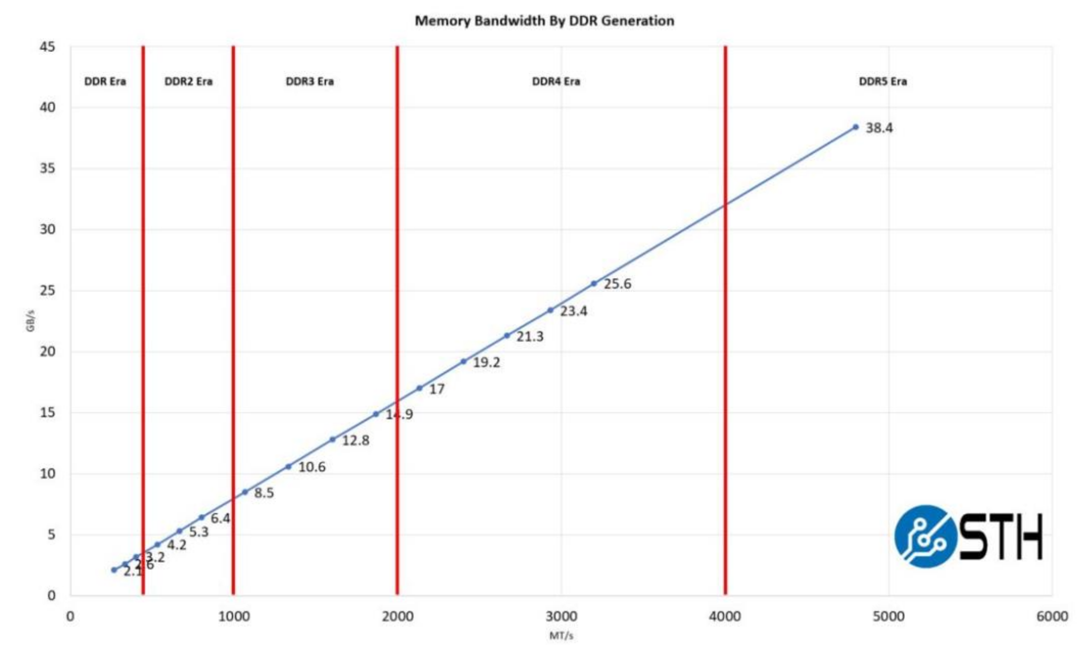
DDR SDRAM (Dual Data Rate Synchronous Dynamic Random Access Memory) is a DRAM package on a Dual In-line Memory Module (DIMM). DDR means that the data is transferred at both the rising and falling edge of the clock signal. SDRAM is different from Asynchronous RAM because it is synchronized to the clock of the processor and hence the bus. Today, virtually all SDRAM is manufactured in compliance with standards established by JEDEC, an electronics industry association that adopts open standards to facilitate the interoperability of electronic components. This makes DDR5 an important spec for any standard server.

DDR5 is the fifth major iteration of this standard. Compared to its predecessors, DDR5 provides higher bandwidth and increased bandwidth efficiency.

The core counts are growing with every new generation of CPU. DDR4 has reached its limit in terms of memory bandwidth and density. It can only support up to 16GB Density and 3200MT/s speed. This is where DDR5 technology offers solutions to meet customer needs for greater memory capacity per core, and bandwidth per core.

DDR5 offers a 50% increase in the bandwidth with 4800MT/s as compared to DDR4 with 3200MT/s. It also supports a maximum of up to 32Gb density (a density that is not available in the latest PowerEdhe generation launch), as compared to 16Gb in the previous generation. DDR5 also offers 2x the burst length, 2x bank groups, 2x banks, Decision Feedback Equalization, two independent 40-bit channels per DIMM, and optimized power management on DIMM.

Figure 4.3 Memory Bandwidth by DDR Generation[181]



DDR DDR2 DDR3 DDR4 And DDR5 Memory Bandwidth By Generation 1

The following Table 4.1 provides information about the latest Dell PowerEdge portfolio for DDR5, including capacity, bandwidth, DIMM type, and Dell part numbers. Note that Dell does not support DIMM capacity mixing on the latest generation. These represent maximum bandwidth at ideal configurations. CPU vendors may reduce bandwidth capability based on their respective DIMM

181 https://www.servethehome.com/why-ddr5-is-absolutely-necessary-in-modern-servers-micron

population rules. The total system bandwidth is expected to vary between platforms based on population capability, such as on 8 x 1 DPC Intel® CPU- based platforms.

Table 4.1 Details about the attest Dell PowerEdge portfolio for DDR5

Table 1. Details about the latest Dell PowerEdge portfolio for DDR5

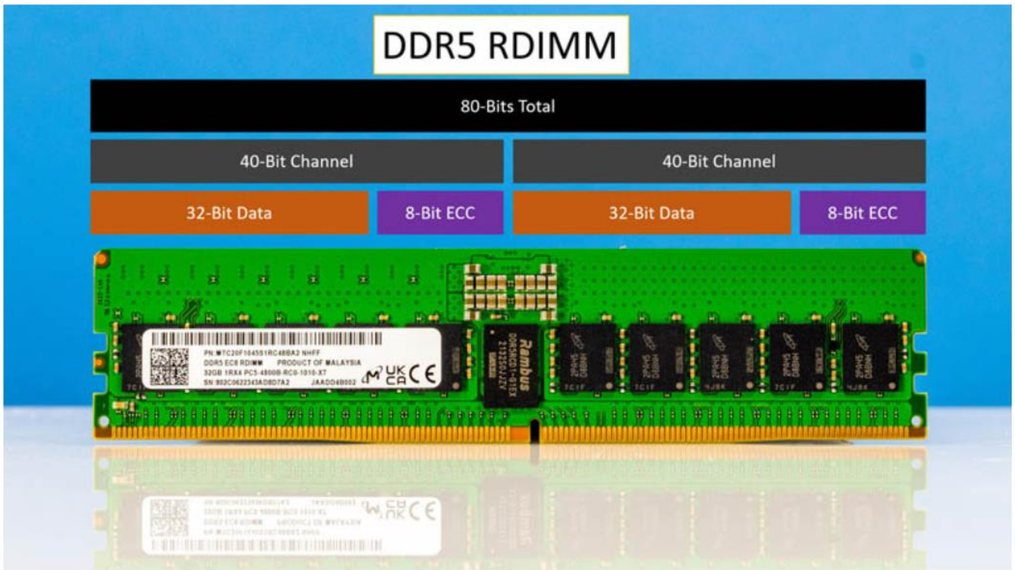
DIMM Capacity (GB)	DIMM Speed (MT/s)	DIMM Type	Dell PN*	Ranks per DIMM	Data Width	Density	Technology
16	4800	RDIMM	1V1N1	1	x8	16Gb	SDP
32	4800	RDIMM	W08W9	2	x8	16Gb	SDP
64	4800	RDIMM	J52K5	2	x4	16Gb	SDP
128	4800	RDIMM	MMWR9	4	x4	16Gb	3DS
256	4800	RDIMM	PCFCR	8	x4	16Gb	3DS

* Part numbers are subject to change. Additional part numbers may be required.

There are now two memory channels on the chip. Also, Error Correction Code (ECC) DDR5 unbuffered DIMM, is no longer compatible with platforms that support RDIMMs.

One of the biggest challenges with system scaling is the memory bandwidth. Having more cores and more PCIe devices is advantageous, but if portions of the system are sitting idle waiting for data, then they are being wasted. In the DDR3 and DDR4 generations, generally, one could use either unbuffered ECC (and often non-ECC) memory or RDIMMs in servers. That is no longer the case. The key reason for this is that the power delivery components are now on the DIMMs themselves. In servers, 12V power is supplied. In client systems, only 5V. This is converted to 1.1V for the DIMM and managed by the onboard power management IC, or PMIC. The PMIC moves a motherboard function to the DIMMs, but that means we have an added component on the modules. With DDR5, there are now two channels with a total of 80 bits. Each channel is half of that or 40 bits with 32 bits for data and 8 bits for ECC. The channels are split on the DDR5 DIMM with one channel on the left and one on the right. On one side, you will find the RCD or register clock driver. This is responsible for providing the clock distribution to the different chips on the memory module. DDR5 has on-chip ECC. As DRAM density increases and clock speeds increase as well, the folks designing the DDR5 spec realized that the combination has the potential to lead to more on-die errors. For those more familiar with flash technology, NAND has been going through this for years, and now we have higher bit density but also more error correction throughout the SSD. Still, the inherent on-chip ECC benefit is that issues that may not have been caught previously on consumer UDIMMs can potentially be caught.

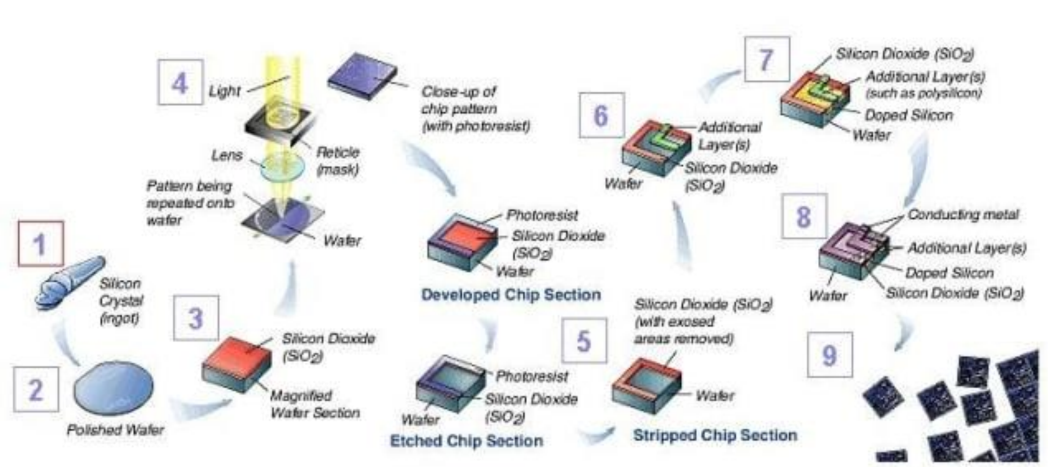
Figure 4.4 Micron DDR5 RDIMM Two 40 Bit Channels[182]



Micron DDR5 RDIMM Two 40 Bit Channels

Energy and Material use during the manufacturing phase: The CPU and memory are made of three major materials, which are silicon, copper and plastics. The steps of transforming these raw materials into the micro components and integrated circuits (IC) include a number of intensive processes. These require certain temperature and sanitation conditions, water, chemicals operated by complex machinery. Considerations for energy and resource efficiency during the manufacturing process is an important factor.

Figure 4.5 Silicon-to-chip process[183]



Energy demand during product use:

As discussed within Phase 1 section 2.4, Dynamic Voltage and Frequency Scaling (DVFS) is a technique used to reduce energy consumption in electronic devices by adjusting the operating voltage and frequency. DVFS allows for the dynamic

182 https://americas.kioxia.com/content/dam/kioxia/en-us/business/ssd/data-center-ssd/asset/KIOXIA_EDSFF_E3_Intro_White_Paper.pdf

183 What Raw Materials Are Used to Make Hardware in Computing Devices? | Engineering.com

adjustment of the supply voltage and clock frequency of a device based on its workload or performance requirements. By lowering the voltage and frequency during periods of low activity or idle states, energy consumption can be significantly reduced. This approach helps to optimise the power-performance trade-off and minimise unnecessary energy usage. By reducing voltage and frequency, the energy consumption and associated carbon footprint of electronic devices can be lowered.

The feedback from stakeholders suggested that servers should have processor power management enabled by default and at the time of shipment, with all processors capable of reducing energy consumption during low utilisation. Choosing one option (reducing voltage or frequency) was recommended instead of both, in order to avoid diminishing server resilience and increasing implementation complexity and cost. While P-states provide energy savings, it should be acknowledged that they introduce latency that may not be acceptable for certain customers.

Cooling system (active and passive)

The cooling system of enterprise servers is a combination of passive and active cooling elements. The aim of the system is to transport the heat generated by the CPU and other active components away from the devices in order to enable appropriate and reliable function. The cooling capacity is the main metric (W/cm^2) and is the rate at which heat is removed from the space producing it for example the CPU. The technology, design, and material characteristic of the cooling system is determined by various factors such as:

- The number, type, and thermal design power of the CPU, memory and other electronic components.
- The type, form factor, actual dimensions, and modularity of the server.
- The external (ambient) temperature conditions, air intake design, dust filter mats, and other aspects of the rack design.

There are two basic types of cooling system technology (air cooling system, liquid and their combination).

Passive cooling elements are considered to be heat spreaders, sinks and pipes with the aim of radiating away the heat from the active components. Other design features are also part of the passive system and these can include round shaped air intake which is considered more effective, air baffles for channelling the airflow and air flaps/valves at the rear of the chassis that prevent the air leakage when modules are pulled out of the system.

Active cooling elements are considered an array of fans which take the cool air from the cold aisle in the data centre through air intake holes. The two basic types of fans are the centrifugal fan or blower, and the axial flow fan. Adjusting the fan rotation speed according to the current temperature conditions is a standard technology.

Another method of cooling is the liquid cooling technology which utilises water, enclosed in cooling loop channels coupled within heat spreaders. It is often used alongside air cooling systems. In contrast to passive cooling, the liquid cooling system includes active components too. The heat is transported through the pipes to a heat exchanger in the server chassis (or outside). Still, this is not a commonly used technology due to its cost.

Material use:

Aluminium and/or copper are typically the main materials of the passive cooling elements (heat sinks and heat pipes). The material selection and the design of the cooling elements are influenced by the specific thermal conductivity (W/m*K) and the related form factor and costs.

With respect to material efficiency, the selection of the passive and active cooling elements including its material composition should be carefully considered. There is a preference to have to have mono-material design, which helps the end-of-life and separation of materials for the recycling process.

Power supply unit

The power supply unit (PSU) provides the electric current with which the server operates. It typically receives alternating current (AC) and converts this into direct current (DC) and specific voltages for the server. There are also PSUs on the market that can receive DC directly and downrate the input voltage for use within the server, though this application remains niche at this time.

There is a variety of PSUs on power capacity, conversion efficiency rating, input and output power as well as redundancy, hot-swap capability and failure monitoring options.

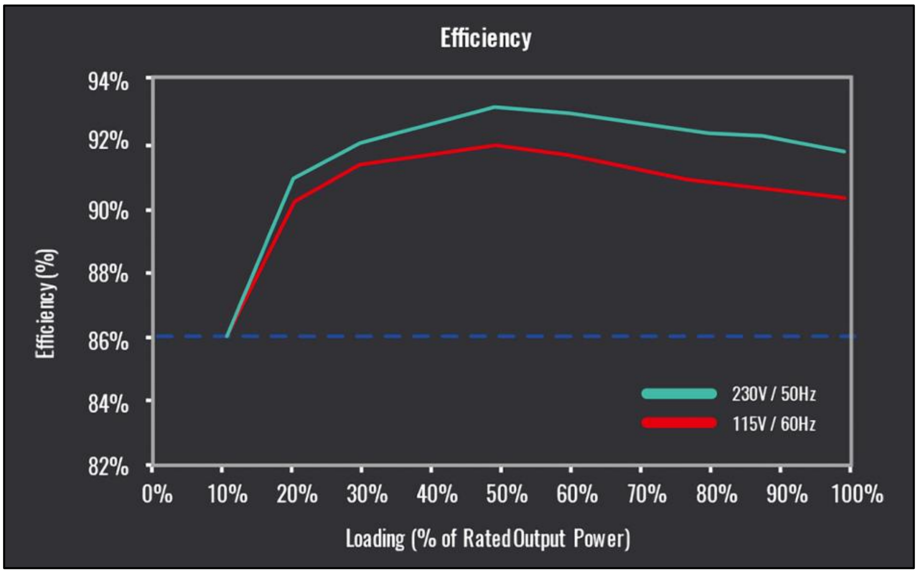
Still since the previous iteration of the study, the typical type of power supplies used are switched-mode power supplies (SMPS) with power factor correction (PFC).

Energy use:
All types of servers have multiple configuration options with regards to power supply in order to provide a wide customer selection. The capacity of power units ranges from 250W to 1500W and can be achieved with either one large or two smaller units in the same system. In any case an essential power supply unit is installed for cases of hardware failure of the main one(s).

The PSU’s rated output power and conversion efficiency in partial loads is influencing the baseline energy consumption of the server. The peak efficiency is typically somewhere between 50 and 100% loading.

Figure 4.6 shows how PSU performs under different loads and supply voltages.

Figure 4.6 An efficiency chart from Cooler Master for their V1300 Platinum PSU



The current Regulation under review introduces minimum PSU efficiency and power factor requirements from 1 January 2023 as follows:

Figure 4.7 2019/424 introduced minimum PSU efficiency and power factor requirements from 1 January 2023

	Minimum PSU efficiency				Minimum power factor
% of rated load	10 %	20 %	50 %	100 %	50 %
Multi output	—	90 %	94 %	91 %	0,95
Single output	90 %	94 %	96 %	91 %	0,95

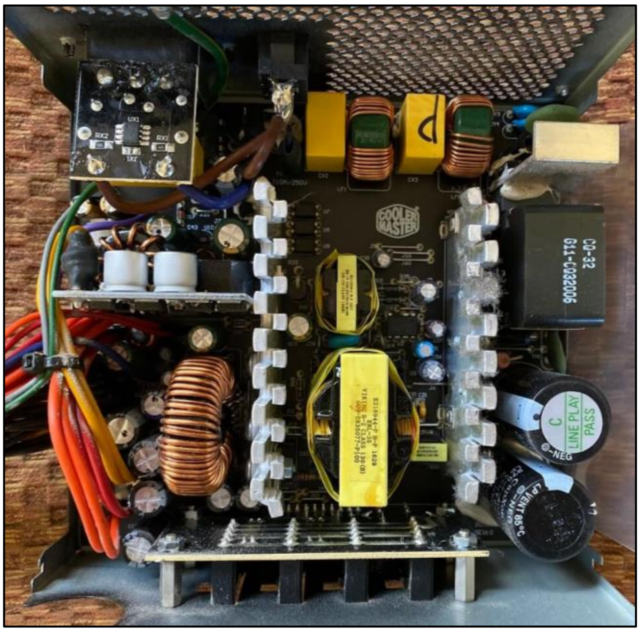
There are currently discussions on how to best enable that efficiency based on 80 PLUS certification scheme[184] as well as possible solutions that bring the best outcome[185] given the availability in the market of PSUs meeting the current Regulation's requirements.

Figure 4.8 demonstrates a typical layout of a PSU. There are many layouts, with different make and model of the parts inside, still serving the same functionality.

[184] 80 Plus Overview | CLEAResult

[185] https://www.clearesult.com/80plus/sites/80plus/files/news/230V%20ENTERPRISE%20PSU%20MARKET-READY%20EFFICIENCY%20STUDY_1.pdf

Figure 4.8 Parts comprising a PSU[186]



The main materials used are in the robust metal housing (steel alloy), the transformer and inductors (e.g. copper and ferrites), the passive cooling elements (aluminium), the fan (plastic) and the printed circuit boards (glass, epoxy, plastics, solder).

Prices: The sales price of a PSU is determined by certain factors such as:

- The number of output currents,
- connector configuration (pins),
- conversion efficiency (80plus certification),
- redundancy,
- hot plugging capability, and form factor.

The quality and performance are influenced by the component selection and thermal design of the PSU as well. Table 4.2 shows current price ranges for single PSUs according to various internet sources.

Table 4.2 Current price ranges for PSUs[187]

Single PSU	<400W	400-800W	850-1500W
80 Plus Gold	€ 99-115	€ 94- 200	€ 141-305
80 Plus Platinum	N/A	€ 153-282	€ 211-470
80 Plus Titanium	N/A	€ 294	€ 387-434
80 Plus Gold	€ 99-115	€ 94-200	€ 141-305

Please note prices ranges for this table were originally displayed in Pound Sterling. This was converted to Euros using Conversion factor extracted from https://www.exchangerates.org.uk/ on 23/05/2024. (1 GBP = 1.1742 EUR)

DC operated servers:

There is a perception that as the power supply unit has loses associated with the conversion from AC to DC, having DC operated servers which are provided with DC

186 Anatomy of a Power Supply Unit (PSU) | TechSpot

187 80 PLUS TITANIUM Certified,1500W and above Power Supplies | Newegg.com

power, can save on the PSU material cost and energy loses. The DC servers still have PSUs, they are just DC-DC and step down the voltage, associated with some cost to that conversion into DC that can be used by the server board as well.

It is noted however that although savings can be made at the PSU level, efficiency loses are typically passed on to another location in the data centre. Indeed, as utility power is primarily in AC, the AC-DC conversion will need to happen for the ICT equipment, which may mean a shift of the problem at the PSU server level to a centralised data centre conversion unit.

SPEC SERT currently does not support testing of DC servers.

Configuration options

The market offers a humongous variety of server products and configuration options. These translate into the technical and environmental performance of the server as well as in respective purchasing costs (CAPEX) and cost of utilisation (OPEX).

The various options for configurations are still relevant since the past study and outlined here:

- Type, dimensions, weight, and mounting options of the server chassis
- Mainboard type and dimensions
- CPU options including type, cores, threads, I/O, frequency, type and number of sockets, etc.
- Memory options including type, capacity, interfaces, number and type of memory sockets, etc.
- Internal storage (drives) including type, capacity, interfaces, number and storage bay space, etc.
- Connectivity (input/output) including network controller, connectors, expansion slots, etc.
- KVM (keyboard, video, mouse) interfaces, monitoring and service options, etc.
- Power requirements including rated power, power supply unit configuration, redundancy, etc.
- Power consumption values including maximum, sometimes idle or thermal design power of CPU (power-to-performance benchmarks e.g. SPEC are typically only offered on request)
- Active cooling elements such as fans and fan control
- Operational conditions and allowances including min and max temperatures, humidity in room
- Operation system and other software specifications including licenses

With respect to the current server market there are two rack-server main systems and blade systems as outlined in the section covering Chassis above.

4.1.1.3 Data storage products

Regulation 2019/424 provides the definitions for data storge products as a fully functional storage system that supplies data storage services to clients and devices either directly or through a network. The components and subsystems that are an integral part of the data storage product architecture are considered to be part of the data storage product. Whereas components that are not associated with a storage environment at the data centre level are not considered to be part of the data storage product. A data storage product may be composed of integrated storage controllers, data storage devices, embedded network elements, software and other device.

Data storage products provide non-volatile data services to connected servers and/or to remote computing devices via a network connection. A data storage product provides the server with more capacity, redundancy and flexible data management. With a data storage product there are large number of storage media and a controller than handles the input and output requests. Data storage products also need the capability to connect to networks for data transmission. They are connected to servers or clients by means of direct connection or network connections. These connections are achieved via the use of the following four form factors: direct attached storage (DAS), storage area networks (SAN), network attached storage (NAS) and content addressed storage (CAS).

Data storage systems have the following sub-systems:

- **Storage media and devices:** hard drive disc (HDDs), solid state devices (SSDs)
- **Storage controller:** Processors and other electronics that automatically process the input and output (IO) requests directed to the storage device.
- **Storage elements:** configuration of the data storage product. Such as a redundant array of independent disks (RAID) or robotic tape library with a number of storage devices and integrate storage controller for handling I/O requests.
- **Connectivity and network elements:** connectivity is based on various technologies such as: Serial Advanced Technology Advancement (SATA), Serial Attached SCSI (SAS), Fibre Channel (FC), Infiniband (IB) or Ethernet (TCP/IP)
- **Connectors and cables:** transmission between servers and data storage products requires interface controllers, connectors and cables.

Storage system form factor and configuration

Similar to servers, there is a very large number of possible configurations for the customer to choose, which are dependent entirely on the specific use case and workload profiles required. Therefore, the efficiency and product performance is distinctive to each product configuration that is chosen. There are several factors which impact performance and efficiency these include the application of software-based functionality including compression, de-duplication, software defined storage management systems, and workload tiering. Utilising these software functions enables data storage products to significantly reduce the number of storage systems required to manage specific workloads. At product level it may increase the energy consumption, resulting in in a lower efficiency as measured by SNIA Emerald. However, it will reduce the overall energy consumption required to perform a workload as a less storage devices and systems are required to service a given workload.

Storage controllers are either installed internally or externally as an extra controller enclosure (CE) with attached disk enclosures (DE) which can provide extra scalability. These systems are capable of organising hundreds to thousands of attached HDDs and SDDs.

The configuration that determines the type and number of attached drives can differ depending on the requirements of the customers. Typically, systems are sold with various basic configurations which differentiating the number of controllers and drive size (2.5 and 3.5 inch) while modern systems usually support all of the common interfaces like SAS, iSCSI, FCoE or FC. Common supported RAID levels are 0, 1, 3, 5 and 6. An entry-level example system is the FUJITSU Eternus AF150, the technical specification for this product are displayed below in Table 4.3.

Table 4.3 Fujitsu AF150 technical specifications[188]

Technical specifications	
Type	All-Flash Array
Latency	140µsec (Read), 60µsec (Write)
Sequential access performance	10,000 MB/s (128KB Read) 5,000 MB/s (128KB Write)
Random access performance	390,000 IOPS (8KB Read) 270,000 IOPS (8KB Write)
Host interfaces	Fibre Channel (16 Gbit/s, 32Gbit/s) iSCSI (10Gbit/s [10GBASE-SR, 10GBASE-CR, 10GBASE-T])
Maximum disk drives	24
Support Pack Options	Available in major metropolitan areas: 9x5, Next Business Day Onsite Response Time 9x5, 4h Onsite Response Time (depending on country) 24x7, 4h Onsite Response Time (depending on country)
Maximum Storage Capacity	92 TB
No. of host interfaces	4/8 ports
Max. no. of hosts	1,024
Supported RAID levels	0, 1, 1+0, 5, 5+0, 6
Drive interface	Serial Attached SCSI (12 Gbit/s)
Automated Storage Tiering	Yes
Remote Copy functionality	Synchronous and asynchronous
Recommended Service	24x7, Onsite Response Time: 4h

Modern data storage system designs are becoming increasingly case-specific and require products that can adapt to optimisation in performance or capacity, or even a hybrid of both. Advancing technologies such as IoT and IIoT (e.g., edge computing, machine to machine communication), along with faster communication protocols and increasingly robust interfaces (5G, WiFi, and GPON) has meant that storage media based on 2.5 inch drive formats are becoming increasingly limited[189]. Data storage products with these hard drive formats are not able keep pace with the increased demands of modern servers such as servers based on PCIe® 5.0 and 6.0 technologies. This is because the 2.5 inch drive is not optimal for flash memory packaging or optimised for flash memory channels[190]. Since performance is expected to continue to increase, so too will the flash memory and all of the dies, therefore, the energy consumption of the flash memory and interface will increase alongside this technology advancement. Therefore, in the near future a form factor

[188] https://www.fujitsu.com/global/products/computing/storage/all-flash-arrays/eternus-af150-s3/index.html#specs

[189] Introducing the EDSFF E3 Family of Form Factors (kioxia.com)

[190] Introducing the EDSFF E3 Family of Form Factors (kioxia.com)

will be required which can scale power, PCIe speed increases, and wider PCIe link widths to enable full-throttle input/output operations per second (IOPS) performance per terabyte (TB) capacity[191].

Hard disk drives (HDD)

Hard disk drives are a non-volatile data storage device. HDDs are a mature technology that is the most commonly uses volume storage media for high capacity block storage devices. HHDs are more cost efficient than SSDs. Within the HDD the data is stored on fast rotating disks by magnetic remanence. The most common form factors for HDDs in servers are the following:

- Large form factor - 3.5-Inch HDD for very high capacity;
- Small form factor - 2.5-Inch HDDs for faster access but smaller capacity

The HDD form factor refers to the physical size or geometry of the data storage device[192]. These follow industry standards that govern their length, width and height as well as their position and orientation of the host interface connector.

The performance requirements for HDDs are storage capacity, average latency, type of connectivity or interface, the maximum sustained transfer rate, spin speed, aerial density, cache, encryption, format, maximum operating shock, form factors, average failure rate, operating temperature, and average operating power[193]. The operating temperature for HDD is typically 5°C to 40°C. however, current product data sheets indicate even higher operating temperatures of up to 60°C.

HDDs are often differentiated for various applications using the mean time between failures ratings. These failures often occur due to vibration and thermal cycling which causes the spindle's swivel to gall. Workload is determined by the amount of time the HDD is in active mode. Input output per second (IOPS) is one of the main performance indicators for HDDs. It represents the average rotational latency and read/write seek latency. It can be defined by the following equation:

- IOPS = 1000/ (seek latency + rotational latency).

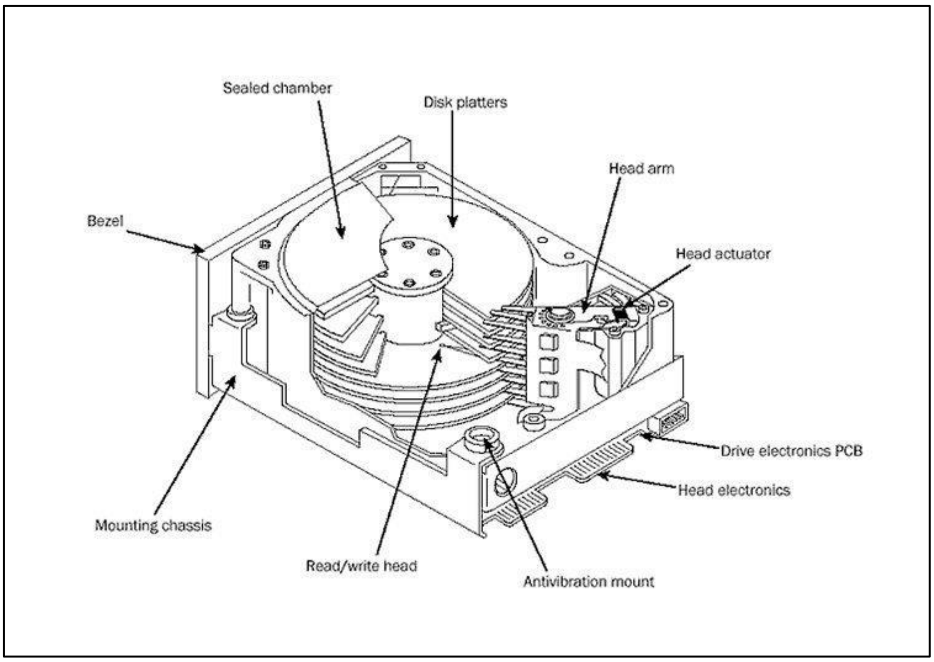
As demonstrated in Figure 4.9 basic HDDs contain several disk platters, which are made from either aluminium, glass, or ceramic. These platters spin with a motor which is connected to the spindle. The read and write heads magnetically record the information to and from tracks on the platters using the magnetic head.

[191] Introducing the EDSFF E3 Family of Form Factors (kioxia.com)

[192] https://www.techtarget.com/searchstorage/definition/hard-disk-drive

[193] https://www.seagate.com/gb/en/products/enterprise-drives/

Figure 4.9 Internal components of a HDD[194]



The general hardware elements that are shown in 0 are shown below:

- Platters – these are the storage media
- Electromechanical read and write systems
- Network and power connectors
- Aluminium cast housing (90% of the total weight)

Solid state drives (SSD)

Solid state drives (SSD) are another type of storage device used by servers. They are non-volatile storage medias storing persistent data on solid-state NAND flash memory chips. They are packaged as single-chip or multi-chip modules on a printed circuit board. Since SSDs are not defined as drives, they do not have to meet specific industry requirements which HDDs do. SSD are controlled by a firmware, an I/O interface controller and respective connector (bus). SSDs are offered in different form factors including PCIe cards and HDD standard housing.

An SSD reads and writes the data it collects on underlying NAND flash memory chips made from silicon. These chips can be stacked in a grid in order to achieve different densities. The flash memory chips use floating gate transistors, allowing it to hold an electric charge. Even after the device is disconnected from the power supply. Each FGT has a single bit of data, these are defined by a 1 for a charged cell or a 0 if the cell has no electrical charge. Every block of data is accessible at a constant speed. However, it should be noted SSDs are fastest when they write onto empty blocks, writing onto blocks with data already on will reduce the performance.

There are several types of SSDs, these include the following[195]:

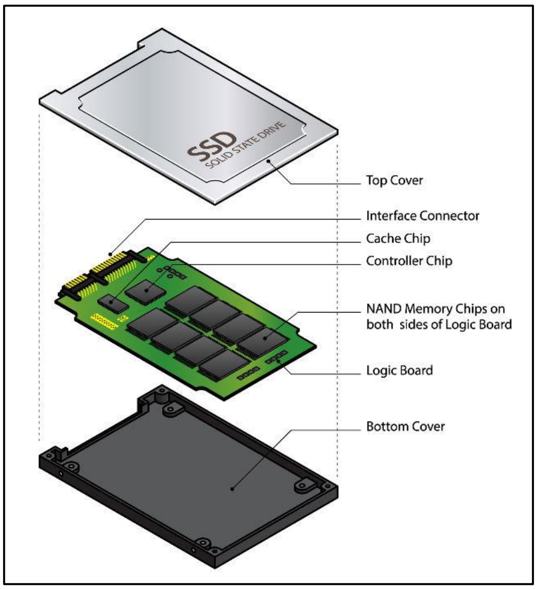
[194] https://www.techtarget.com/searchstorage/definition/hard-disk-drive

[195] https://www.techtarget.com/searchstorage/definition/SSD-solid-state-drive#:~:text=An%20SSD%2C%20or%20solid%2Dstate,functions%20as%20a%20hard%20drive

- Single-level cells (SLC) – hold one bit of data per cell. They are the most expensive but are the fastest and most durable.
- Multi-level cells (MLC) – hold two bits of data per cell and have a larger amount of storage space for the same amount of physical space as a SLC.
- Triple-level cells (TLC) – hold three bits of data per cell. They are the cheapest and deliver more flash capacity. However, they are write at slower speeds and are less durable than SLC and MLC.
- Enterprise multi-level cell (eMLC) – this is a MLC flash with a controller and software that helps remedy the faults for MLC.

SSDs have an I/O interface which contains the I/O controller and I/O connector. The I/O controller is a microprocessor that creates the link between the storage devices (SSD) and the server (host). There are many interfaces available on the market, the most common are SSDs that support Serial ATA (SATA), Serial Attached SCSI (SAS) and non-volatile memory express (NVMe). Figure 4.10 below illustrates where in the SSD these interfaces are found and demonstrates simply the internal structure of an SDD.

Figure 4.10 Internal components of an SSD[196].



SSD are often used to replace small form factor 2.5 inch HDDs because they are significantly faster. The main difference is that HDDs contain a spinning disk with read/write head on a magnetic arm, HDDs read the data magnetically. However, this can lead to mechanical breakdowns. SSD on the other hand have no moving parts, therefore, are less susceptible to breakdowns. Although SSDs have no moving parts they do have a wear-out mechanism which can be caused by too many writes on the SSD, this not an issue for HDDs. Nevertheless, having no moving parts is the reason why the access time is much faster for SSDs. Additionally, this means that the power consumption is also lower, and they can operate under slightly higher temperatures. The operating temperature of SSD is between 0°C to 70°C and therefore considerably wider in comparison to HDDs. Although standard SSDs may have a lower power consumption than comparable 10k RPM HDDs, a NVMe (non-

196 https://uwaterloo.ca/arts-computing-newsletter/winter-2018/feature/everything-you-need-know-about-solid-state-drives-ssd

volatile memory host controller) SSDs will consume higher amounts of power than the equivalent HDD.

However, SSDs are significantly more expensive than HDDs, HDDs also have much larger capacities than SSDs. With SSDs technology continuing to advance it is expected that they will soon be similarly priced. This has even started to happen in some instances. For example, SSDs are replacing the 10k RPM disk drives due to their better performance and cost. SSDs are cost competitive with HDDs for high performance systems[197]. Nonetheless, for some products the price of a HDD remains the more competitive. For example, a high capacity 7.2K RPM HDDs cost and power efficiency are competitive with the comparable SSDs and continue to be used in applications that do not require the higher performance of SSDs[198].

Direct attached storage (DAS)

DAS is a low cost, short distance storage solution which includes a fixed wired, direct connection between the server and the data storage product. DAS can be connected to one, two or four servers depending on the users needs. There are also options to create a DAS-system that is based upon Fibre Channel which can allow for the servers and data storage product to be separated by a larger distance. However, these are not common and are often more expensive than other wireless options.

Storage area network (SAN)

Storage area network (SAN) is a network (fabric) attached storage product, which provides fast, secure and lossless communication between the server and data storage product. SAN have a significant advantage over DAS storage units because they can connect to much larger number of servers via the fabric (network). This storage architecture will support the mutual administration of all storage elements, which improves the utilisation storage capacity. Which can then be accessed by the servers like a local storage device through the servers operating system. The architecture SAN consists of the Host Bus Adapter (HBA) situated in the case of Fibre Channel (FC), a network element such as switch or router, and arrays of storage devices including the RAID systems.

Typically, SANs are used for block I/O services rather than file access services. However, they are very sensitive to packet drops. SAN utilises high latency, lossless protocols and network interfaces such as fibre channels and InfiniBands. Development of SANs have included Fibre Channel over Ethernet (FCoE) and internet Small Computer System Interface (iSCSI) which both allow communication through TCP/IP.

Network attached storage (NAS)

Network attached storage is a more economical solution to increase the storage capacity and performance of a server than SAN. NAS are specialised systems that are attached via a local area network (LAN), which makes it far more cost efficient than SANs. As a result, NAS is very popular among smaller business networks, whereas SAN is usually preferred by larger businesses. This is because the user can install more storage capacity to a NAS system simply by installing more

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[197] Stakeholder feedback

[198] Stakeholder feedback

devices, even though each NAS system will operate independently. Contrastingly, SANs are utilised to handle high speed file transfers or many terabytes of centralised file storage. As SANs have a high-performance disk array but they do require their own hardware and interfaces.

The NAS architecture consists of an engine that implements the file services to one or more devices, on which the data is stored. Typically, a NAS product will contain its own operating system. NAS use distinctive remote file access protocols such as network file service (NFS) in Linux/Unix environments or Common Internet File Services (CIFS) in Windows environments. The NAS data storage product can be tested by the SNIA Emerald test standard, as it fits within the Near Online category.

Content addressed storage (CAS)

Content addressed storage (CAS) stores data by assigning a content address to each object, this means that the data can be retrieved based on its contents, rather than its name or location. This high-speed storage device ensures that the retrieval of data is extremely fast. This is because CAS minimises the storage space consumed by data backups and archives by assigning a retention period to each object and avoiding duplicates. Since, there is only one copy of each object, data retrieval is much faster than SAN, DAS or NAS[199].

CAS systems function by passing data within a file through a cryptographic hash function, which generates a unique key, known as the content address. The CAS will not store duplicate files because the duplicate file will create the same key, which will not be stored as it is already in the device. Today CAS systems continue to be utilised across numerous emerging technologies such as cryptocurrencies[200]. CAS have suited these technologies because every time an item is accessed it must be verified with a hash value to prove that it is the same item that was stored[200]. Feedback has suggested that their current market share is expected to be maintained moving forward[201].

4.1.1.4 Firmware

Firmware is defined within the current Regulation 2019/424 as system, hardware, component, or peripheral programming provided with the product to provide basic instructions for hardware to function inclusive of all applicable programming and hardware updates.

Firmware is installed permanently into a device's read only memory and dictates how the device (hardware) should operate. It enables the servers/storage systems to function.

Throughout the life of a component, there is a need for firmware updates which would enable better functionality, cybersecurity and improve compatibility. It is however a potentially risky maintenance operation which needs to be carried out carefully by the Administrators of those products. This is because often the new versions have increased performance requirements, which make the hardware unable to keep up and run. This can lead to limitations in product life expectancy.

[199] What is content-addressed storage (CAS) and how does it work? (techtarget.com)

[200] Design-And-Implementation-Of-Msha256-On-Blockchain-Using-Content-Addressable-Storage-Patterns.pdf (ijstr.org)

[201] Stakeholder feedback.

The current Regulation already ensures that products have access to latest firmware updates for eight years after the last product was placed on the market. However, the availability of previous versions could be helpful for refurbishers to extend life expectancy. The impacts of making these previous versions available shall be investigated, without lessening cybersecurity norms.

There is also a barrier on releasing firmware as open-source data, which is likely to be a breach of manufacturer Intellectual Property and is therefore difficult to implement.

4.1.1.5 Network Protocols

Small computer system interfaces (SCSI)

SCSI is the industry standard that specifies the physical connection and data transport between the host (servers) and storage devices. It is a buffered peer-to-peer interface, and a parallel bus-system that comes with a 68-pin (single) with large connectors which outlines the limitations of this SCSI. Of particular importance is the fact that SCSI works independently from the hosts operating systems.

Table 4.44 provides the technical specifications of some of the latest generations of SCSI.

Table 4.4 SCSI specifications[202]

Technology Name	Maximum cable length (metres)	Maximum speed (MBps)	Maximum number of devices
SCSI-1	6 Single Ended	5	8
Fast SCSI	3 Single Ended	10	8
Fast Wide SCSI	3 Single Ended	20	16
Ultra SCSI	1.5 Single Ended	20	16
Ultra SCSI	3 Single Ended	20	4
Wide Ultra SCSI	-	40	16
Wide Ultra SCSI	1.5 Single Ended	40	8
Wide Ultra SCSI	3 Single Ended	40	4
Ultra2 SCSI	12 LVD/ 25 HVD	40	8
Wide Ultra2 SCSI	12 LVD/ 25 HVD	80	16
Ultra3 SCSI (Ultra160 SCSI)	12 LVD	160	16
Ultra320 SCSI	12 LVD	320	16
Ultra640 SCSI	10 LVD	640	16

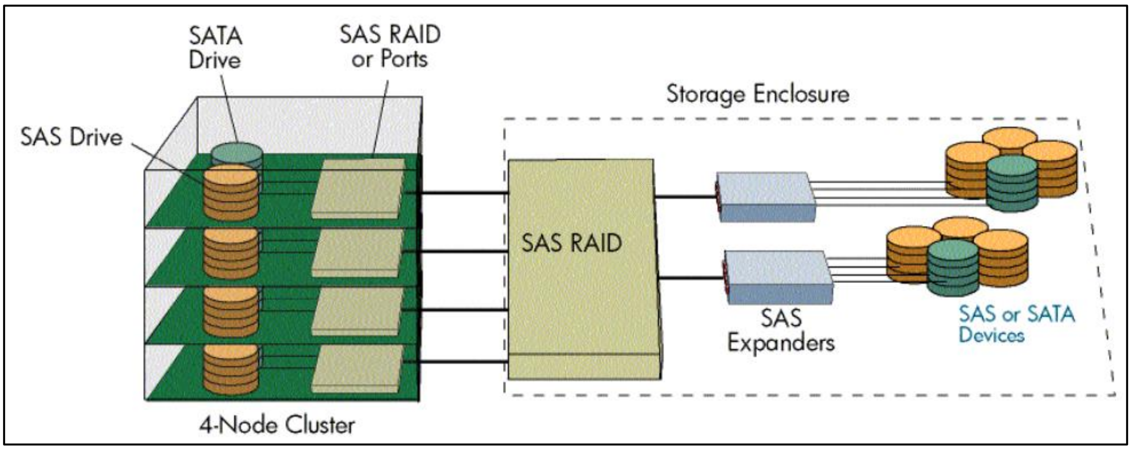
However, it's worth noting that SCSI technology, including Ultra 640 SCSI, has largely been replaced by newer interface standards such as Serial Attached SCSI (SAS) and Serial ATA (SATA) for most mainstream applications. These newer interfaces offer comparable or higher speeds while being more cost-effective and easier to implement.

[202] What is SCSI (Small Computer System Interface)? | Definition from TechTarget

Serial attached SCSI (SAS)

SAS are serial protocol that create a point-to-point connection instead of the bus-topology that is used by SCSI. It specifies all aspects from the physical layer up to the link, transport and application layer. With each generation of SAS the data throughput improves. SAS-1, the first version of the SAS standard released in 2003, supported data bandwidth of 3 gigabits per second (Gbps). SAS-2 supports 6 Gbps, SAS-3 supports 12 Gbps and the current version, SAS-4, supports 24 Gbps. SAS-5 is under development and will support bandwidth greater than 24 Gbps. Within an SAS device there is one transceiver with multiple transmitter and receiver for duplexing. For example, a HDD consists of two transceivers and a host bus adapter 4 or 8. Please see Figure 4.11 for an illustration of this multi-node cluster application.

Figure 4.11 SAS multi-node cluster applications[203]



The standard also specifies the various transport protocols for command-level communication with SATA devices (STP), SCSI devices (SSP), and for managing the SAS network (SMP). SAS expanders are an additionally element that links many SAS devices to a switch. Expanders contain eight or more external expander ports. SAS supports both point-to-point and daisy-chain configurations, providing flexibility in connecting multiple devices to a single SAS controller. It allows for the connection of up to 65,536 devices in a SAS domain, providing extensive scalability.

There are various small form factor (SFF) connector types available for SAS devices. One should distinguish between the internal and external connectors of a SFF. External connectors facilitate the interpolation with multiple SAS devices (SSF 8484) and with other standards including InfiniBand (SFF 8470) and SATA (SFF 8482). A small form factor allows the use of smaller storage devices such as the 2.5 inch HDD but also increase the possible number of connectors on the server side.

Serial Advanced Technology Attachment (SATA)

SATA is most recent version of the parallel ATA interface (bus) that features a bit-serial, point-to-point connection for storage devices with the server. SATA is available only via short distance connection. It provides a quick, simple, economical, small form factor, and hot-pluggable technology. The external SATA interface competes with USB and Firmware. The physical SATA is made of a 7 line flat band,

[203] http://h10032.www1.hp.com/ctg/Manual/c00256909.pdf

8mm cable, which is up to 1 metre long. In addition, SATA utilises low voltage differential signalling (LVSD) similar to SCSI to avoid signal interference.

The following bullet points cover all the revisions of SATA that have occurred. These have been extracted from the webpage TechTarget[204]:

- SATA Revision 1. These devices were widely used in personal desktop and office computers, configured from PATA drives daisy chained together in a primary/secondary configuration. SATA Revision 1 devices reached a top transfer rate of 1.5 Gbps.
- SATA Revision 2. These devices doubled the transfer speed to 3.2 Gbps with the inclusion of port multipliers, port selectors and improved queue depth.
- SATA Revision 3. These interfaces supported drive transfer rates up to 6 Gbps. Revision 3 drives are backward-compatible with SATA Revision 1 and Revision 2 devices, though with lower transfer speeds.
- SATA Revision 3.1. This intermediate revision added final design requirements for SATA Universal Storage Module for consumer-based portable storage applications.
- SATA Revision 3.2. This update added the SATA Express specification. It supports the simultaneous use of SATA ports and PCI Express (PCIe) lanes.
- SATA Revision 3.3. This revision addressed the use of shingled magnetic recording
- SATA Revision 3.5. This change promoted greater integration and interoperability with PCIe flash and other I/O protocols.

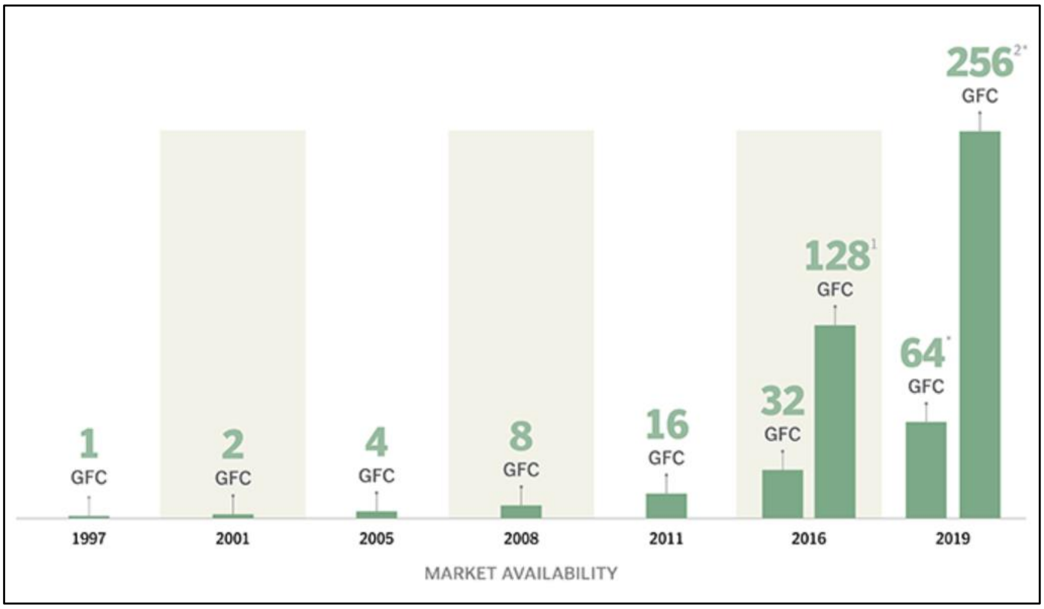
Fibre Channel (FC)

Fibre channel (FC) protocol is a standard interface for fast and lossless storage area networks. The FC standard defines the connection architecture, physical components including the connectors and cables (not only glass fibre but also copper), data throughput, distances, coding, management, and services. One of the main characteristics of FC is its high availability. It is able to avoid frame drops through link flow control mechanism based on credits that are called buffer to buffer credits. FC contain their own hardware element, the Host Bus Adapter (HBA), and the workload for the central processor unit of the server.

There are three topologies with respective port types these include point-to-point (P2P), arbitrary loop, and switched fabric. FC are comparable to SCSI hot-pluggable devices. The specifications for FC's are shown below in Figure 4.12.

[204] https://www.techtarget.com/searchstorage/definition/Serial-ATA

Figure 4.12 Fibre Channel Development[205]



Fibre Channel over Ethernet (FCoE)

FCoE is an extension of FC it covers fibre channel frames that use an Ethernet networks that are 10 Gigabit or faster. It is usually used in high performance applications with a lot tolerance for latency, packet loss and high throughput demands. FCoE is usually chosen by larger enterprises because it runs on FC hardware that is typically already implemented in high performance data centres. In comparison to iSCSI, FCoE has a significantly lower package overhead which allows for greater data transfer rates.

FC usually uses a stack with five layers (FC-0 to FC-4) and the Ethernet uses Open Systems Interconnection Model (OSI-model) with seven layers. Whereas, FCoE transfers the FC layer to FC-2 to Ethernet which enables higher FC-layers (FC-3 and FC-4) to be implemented in Ethernet infrastructures as well. This does however, limit the FCoE to layer 2 domains within the data centre infrastructure. Since, it is often very expensive to change system to contain an FCoE, because it requires a lot of hardware. Therefore, FCoE are usually installed in existing FC infrastructure or considered in the design of a new data centre.

Internet small computer interface (iSCSI)

The iSCSI standard is an IP-based SCSI network which operates over TCP. As servers utilise the same interface for both LAN and SAN, this allows iSCSI to merge the parallel network infrastructures to a convergent network, thus reducing cabling and the need for adapters. Since no new hardware is required for iSCSI it is relatively inexpensive, however, the performance is far lower than that of the more expensive FCoE. Nevertheless, the lower price of iSCSI makes it a popular choice amongst small and medium size enterprises. Table 4.5 describes the similarities and difference between iSCSI and FCoE, demonstrating which standard has the upper hand for reliability, performance, cost and flexibility.

[205] https://www.techtarget.com/searchstorage/definition/Fibre-Channel?Offer=abMeterCharCount_var3

Table 4.5 Fibre channel (FC) SAN vs. iSCSI SAN[206]

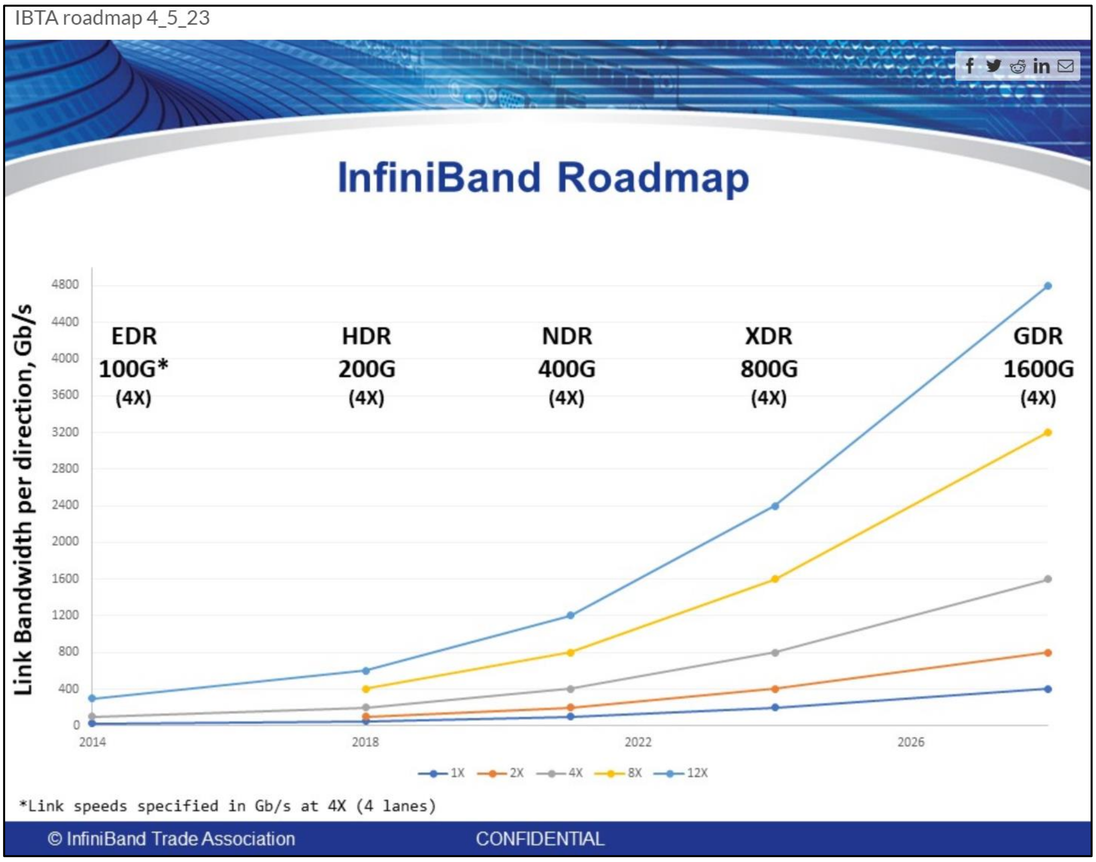
	FC SAN	iSCSI SAN	Supporting points
Reliability	Yes	No	▪ FC has been a ratified standard for 9 years longer than iSCSI (1994 vs. 2003). ▪ FC SANs are isolated from non-storage traffic, thus, creating a safe haven for critical data. ▪ FC SANs are much simpler than iSCSI SANs. Simple = reliable
Performance	Yes	No	▪ FC requires host bus adapter initiators. ▪ FC can offer line rate, non-blocking speeds for every device. ▪ FC ensures storage traffic have 100% of available network resources.
Cost	No	Yes	▪ iSCSI doesn't require host bus adapter or storage specific network devices ▪ iSCSI leverages IP network knowledge base reducing manpower. ▪ iSCSI storage arrays are cheaper than FC and aimed at SMEs.
Flexibility	No	Yes	▪ iSCSI doesn't limit initiator to target distance like FC does, as it runs on IP. ▪ iSCSI initiators, networks and targets have less interoperability challenges than FC. ▪ iSCSI are well suited for production, development, disaster recover and virtual environments.

Infiniband (IB)

Infiniband is a high speed, low latency technology use to interconnect servers, storage and networks in a datacentre. It has a low latency networking with delays around 20 microseconds. The InfiniBand roadmap details 1x, 2x, 4x, and 12x port widths with bandwidths reaching 600Gb/s data rate HDR in the middle of 2018 and 1.2Tb/s data rate NDR in 2020. The roadmap is intended to keep the rate of InfiniBand performance increase in line with systems-level performance gains.

[206] https://www.techtarget.com/searchstorage/definition/iSCSI

Figure 4.13 InfiniBand specifications[207]



IB is usually more expensive and complex than comparable solutions such as FCoE or iSCSI. This is because it often requires new hardware. Therefore, it is primarily used in applications where other solutions cannot match performance requirements.

4.1.1.6 Material efficiency- disassemblability and repair

Material efficiency requirements for disassembly are included in the current Ecodesign regulation for servers and data storage products in Annex II, 1.2.1. This requirement sets out that: *joining, fastening or sealing techniques do not prevent the disassembly for repair or reuse purposes of the following components, when present: data storage devices, memory, CPU, motherboard, expansion card/graphic card, PSU, Chassis, Batteries.*

The following section discusses the requirements in the scope of the following components (if included): data storage devices, memory, CPU, motherboard, graphic card, PSUs, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

According to EN 45554, there are four classifications related to disassembly requirements: the fastener types, the necessary tools, the working environment, and the skill level of the disassembler. These are described below.

Skill level:

[207] https://www.infinibandta.org/infiniband-roadmap/#iLightbox[01ab527150f12ce7d56]/0

- ***Layman (Class A):*** *person without any specific repair, reuse or upgrade experience or related qualifications.*
- ***Generalist (Class B)****: repair, reuse or upgrade process cannot be carried out by layman (class A) but can be carried out by a person with a general knowledge of basic repair, reuse or upgrade techniques and safety precautions.*
- ***Expert (Class C):*** *person with specific training and/or experience related to the product category concerned.*

Most disassembly can be done with generalist skills of **class B**. However, there is feedback that specific tasks currently require **class C** skills. For example when completing a refurbishment, there are server reconfigurations that need to be done. These require technical expertise to deliver but these are software based.

Working environment:

- ***Use environment (Class A):*** *If a repair, reuse or upgrade process can be carried out in the environment where the product is in use without any working environment requirements.*
- ***Workshop environment (Class B):*** *If a repair, reuse or upgrade process cannot be carried out in the environment where the product is in use (class A) but does not require a production-equivalent environment.*
- ***Production-equivalent environment (Class C):*** *If a repair, reuse or upgrade process can only be carried out in an environment that is comparable with the environment in which the product was manufactured.*

Class B workshop environment is likely to be the most apt description of working environment requirements. Many repairs are performed on data centre premises, **Class A** is also relevant.

Necessary tools:

- ***Class A:*** *feasible with no tool; a tool supplied with the product or spare part; or with basic tools (screwdriver, hex key, pliers, spanner)*
- ***Class B:*** *product group specific tools*
- ***Class C:*** *other commercially available tools*
- ***Class D:*** *proprietary tools*
- ***Class E:*** *not feasible with any existing tool*

The Intel study[208] revealed that the PSU, motherboard and drives are the components which are most likely to fail. Class A requirement of "tools supplied with the product or spare part" should be avoided, as many maintenance and repair activities use harvested parts that will not have the tools supplied.

Fastener types:

- ***Reusable (class A):*** *An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process.*
- ***Removable (class B):*** *An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes*

[208] IT@Intel: Green Computing at Scale, August 2021

reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for the repair, reuse or upgrade process.

There is currently a mix of reusable and non reusable fasteners used. It is understood that

- fasteners should be reusable or removable. Feedback is provided that
- the number of different types of screws should be reduced and that
- no proprietary fastening systems be used in order to facilitate disassembly.

Easy separation of the product facilitates increased reuse and recycling. Not only does the disassemblability allow for access to parts for reuse, but also ensures material is not lost during recycling, as making it easier to access circuit boards will ensure precious metal connections are not lost through shredding.

4.1.1.7 Power over Ethernet (PoE)

Power over Ethernet (PoE) is a technology that enables both data and electrical power to be transmitted over a single Ethernet cable. This technology simplifies the installation and deployment of devices like IP phones, wireless access points, security cameras, and other networked devices by eliminating the need for separate power cables. PoE offers convenience, cost savings, and flexibility in network design. PoE involves injecting direct current (DC) electrical power onto the unused pairs of wires in an Ethernet cable while still transmitting data over the other pairs. Power Sourcing Equipment (PSE), such as PoE-enabled switches or injectors, provides the power, while Powered Devices (PDs) receive power from the Ethernet cable.

1. POE Standards:

There are different PoE standards that define the power levels and requirements:

- IEEE 802.3af: Provides up to 15.4 watts of power per port.
- IEEE 802.3at (PoE+): Provides up to 30 watts of power per port.
- IEEE 802.3bt (Type 3 and Type 4): Provides up to 60 watts or 100 watts of power per port.

Each new standard provides for backward compatibility with all previous standards and notes the minimum power per port to be supplied to the powered devices. This minimum requirement accounts for power loss over the length of the cable, with a maximum length set at 100m.

With each power increase, cabling requirements also increased, with Cat 5 cabling being the minimum requirement for Type 3 (60W) and Type 4 (90W) PoE.

2. Benefits of POE

The use of PoE can provide several advantages during its installation that make it an attractive investment. These benefits are displayed below in Figure 4.14.

Figure 4.14 List of advantages of POE during installation[209]

Time and cost savings	PoE can reduce the time and expense of having electrical power cabling installed. Network cables do not require a qualified electrician to install. Reduction of power outlets required per installed device saves money. It also reduces energy costs by allowing for centralized control over lighting, window shades, and heating and cooling.
Flexibility	Without being tethered to electrical outlets, devices such as monitors, security cameras, and wireless access points can be positioned in ideal locations and be easily repositioned if moved.
Safety	Power delivery using PoE is designed to intelligently protect network equipment from overload, underpowering, and incorrect installation. It also eliminates the danger of working with or around dangerous high-voltage power sources.
Reliability	PoE power comes from a central and universally compatible source and not from a collection of distributed wall adapters. It can be backed up by an uninterruptible power supply (UPS), allowing for continuous operation even during power failures. PoE also allows for devices to be easily disabled or reset from a centralized controller.
Scalability	Having power available on the network means that the installation and distribution of network connections are simple and effective.

4.1.2 Standard improvement options

This section will discuss the current state of servers in the market today and where the technology currently is. At present the servers and data storage market is still a very fast paced industry demonstrating constant progress in a number of simultaneous areas such as new component development, product configuration, system architecture and all in short time intervals within months. Therefore, the baseline for products with standards improvement options is challenging to identify. Below is a list of areas of potential improvement:

- New component development
- Storage and utilisation
- Power management
- Data processing
- Virtualisation
- Modularity in the design
- Efficiency in power supply
- Thermal management

4.1.2.1 New component development

New and improved components provide much better performance compared to their predecessors. There is also significant energy consumption reduction.

On the chip-level this is achieved by techniques such as voltage scaling, multi-core designs, new materials, and single core power management as well as power gating.

On the board-level energy consumption this is achieved by integrating passive component functionality into semiconductor ICs. This reduces the number of actual components that need to be powered and generating thermal energy loss.

209 https://www.cisco.com/c/en/us/solutions/enterprise-networks/what-is-power-over-ethernet.html

An example is the latest DDR5 memory generation. It debuted in 2021 and already featured a 50% increase in bandwidth, and ~20% less energy consumption compared to DDR4[210].

Configuration of the system is another aspect that helps on the energy and resource efficiency: The use of the appropriate configuration for the intended application can contribute significantly to savings.

4.1.2.2 Storage and utilisation

The available SSD and HDD options in the market, offer different advantages depending on the application and therefore storage device selection is important. Performance improvements are seen in storage worklets in SPEC SERT as well as in the comparison of maximum and idle power measurements on otherwise identical systems (all SSDs or all HDDs).

There are also software based options that enable optimisation of the storage capacity. This is achieved through managing redundant data.

4.1.2.3 Power management

There are a number of power management options available and some main examples of those are:

- Dynamic voltage and frequency scaling (also known as CPU Throttling). This function automatically reduces the processor's frequency (or clock speed) and voltage when idle.
- Core Parking. This feature dynamically disables CPU cores in an effort to conserve power when idle.
- Power profiles. These are a number of pre-defined groups of power management settings. Although varying from brand to brand, they offer three basic options of balanced, maximum performance and maximum energy efficiency.
- Power metering & budgeting. This function offers the setting of power limits, or caps, for individual servers based on monitoring of power use of the server[211].

ICF has created reference material for the U.S. EPA on how users can take full advantage of power management in servers titled "How to Save Idle Energy in Computer Servers"[212]

As discussed in the above section Processor and memory, Dynamic Voltage and Frequency Scaling (DVFS) is a technique used to reduce energy consumption in electronic devices by adjusting the operating voltage and frequency. DVFS allows for the dynamic adjustment of the supply voltage and clock frequency of a device based on its workload or performance requirements. By lowering the voltage and frequency during periods of low activity or idle states, energy consumption can be significantly reduced. This approach helps to optimise the power-performance trade-off and minimise unnecessary energy usage. There are currently no processor power management function requirements in Ecodesign. However, there is interest

[210] DDR5 Memory Standard: An introduction to the next generation of DRAM module technology - Kingston Technology

[211] https://www.energystar.gov/products/utilize_built_in_server_power_management_features

[212] ENERGY STAR Ask the Experts | Products | ENERGY STAR

to review this technique as by reducing voltage and frequency, the energy consumption and associated carbon footprint of electronic devices can be lowered.

Implementation of DVFS and activating reduced power states for idle cores or sockets, has already proven effective in the ENERGY STAR program.

Another example of power management is the latest DDR5 modules for example which feature on-board Power Management Integrate Circuits (PMIC), which help regulate the power required by the various components of the memory module (DRAM, register, SPD hub, etc)[213] .

4.1.2.4 Data processing

There are a number of methods utilised that have enabled effective data processing. These include having multiple cores to the CPU which allow multiple single threaded activities on the same machine. Others include muti-threading and parallel computing. These are both software activities that help accelerate processing for larger complex problems sets.

The latest processors are designed to accelerate performance across the fastest-growing workloads in artificial intelligence (AI), data analytics, networking, storage, and high-performance computing (HPC).

These processors incorporate the highest number of built-in accelerators. Built-in acceleration is an alternative, more efficient way to achieve higher performance than growing the CPU core count. With built-in accelerators and software optimizations, processors have been shown to deliver leading performance per watt on targeted real-world workloads. This can result in more efficient CPU utilization, lower electricity consumption[214]. However, it should be noted that built-in accelerators are not yet included in the SERT methodology. They are a side processor that performs more work, which is offloaded to it, which the CPU core cannot handle.

4.1.2.5 Virtualisation

Virtualisation allows multiple virtual machines to run on a single physical server, enabling better utilisation of hardware resources. Cloud computing services offer scalable infrastructure, allowing organisations to dynamically provision and deprovision resources as needed. Both virtualisation and cloud computing help reduce the likelihood of having idle or underutilised servers.

Over the last decade or so, a significant number of hypervisor vendors, solution developers, and users have been equipped with Virtualisation technology, which is now serving a broad range of users in the consumer, enterprise, cloud, communication, technical computing sectors.

Virtualisation is used in[215]:

- CPU virtualisation
- Memory virtualisation
- I/O virtualisation
- Graphics Virtualisation
- Virtualisation of Security and Network functions

213 DDR5 Memory Standard: An introduction to the next generation of DRAM module technology - Kingston Technology

214 4th Gen Intel® Xeon® Scalable Processors

215 Intel® VT: Intel® Virtualization Technology - What is Intel® VT? |...

It is worth noting however, that as discussed in Task 2, section 2.2, it was expected virtualisation to increase utilisation rates (and therefore lower sales). However, stakeholder feedback indicates that utilisation rates have not increased as much as expected, primarily due to end-user behaviour.

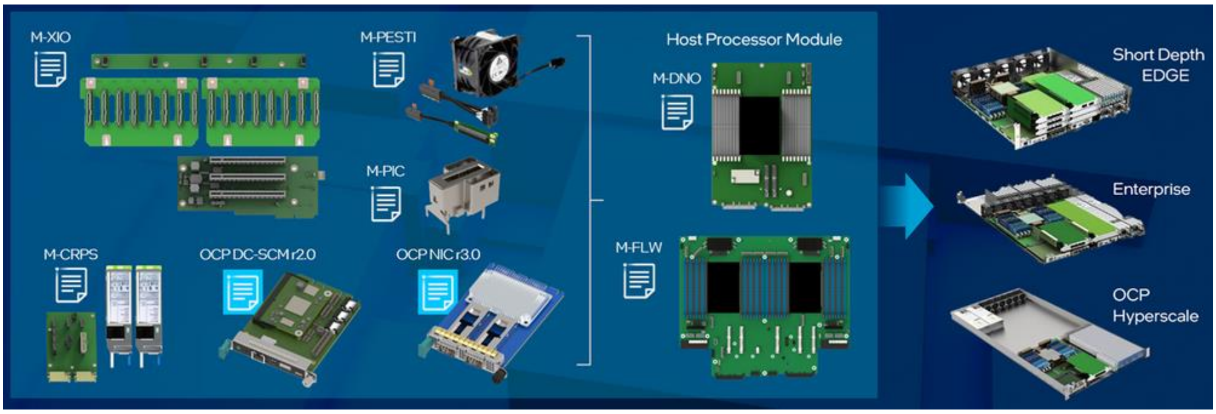
4.1.2.6 Modularity in the design

Modular server architecture comes as an answer to the search for more compute choices which can be provided faster. This is a result of rapid digital transformation which has ignited an eruption of intelligent devices and cloud-based services. Modular server architectures let suppliers use standard building blocks, flexibly configure systems and deliver innovative solutions.

In early 2022, six companies, Intel, Dell, HPE, Google, Meta, and Microsoft (and recent addition AMD) started a collaboration in the Open Compute Project (OCP) called Data Center Modular Hardware System (DC-MHS).

DC-MHS documents (through six base specifications) several types of Host Processor Modules (HPMs) and how they interface with building blocks needed to configure a full server. Host Processor Modules (with CPU and memory) and other modular, standardized elements allow a wider range of systems for Enterprise, Hyperscale, Cloud, Telecom and Edge sooner and with reduced engineering investment. The same module is deployed in multiple configurations at higher scale[216]. The benefits are deemed to be multiple and include reduced costs, reduced custom designs, reusable building blocks across multiple designs and markets, faster time to market, module replacement, easier reuse or recycling.

Figure 4.15 Demonstrating DC-MHS Modularity[217]



4.1.2.7 Efficiency in power supply

As discussed in section Power supply unit above, there are continuous discussions on how to best increase its efficiency.

80 PLUS® PSU certification scheme[218] continues to be sought after and a good practice to demonstrate meeting the current regulation requirements uplifted from 1 January 2023 on PSU as indicated in Figure 4.7.

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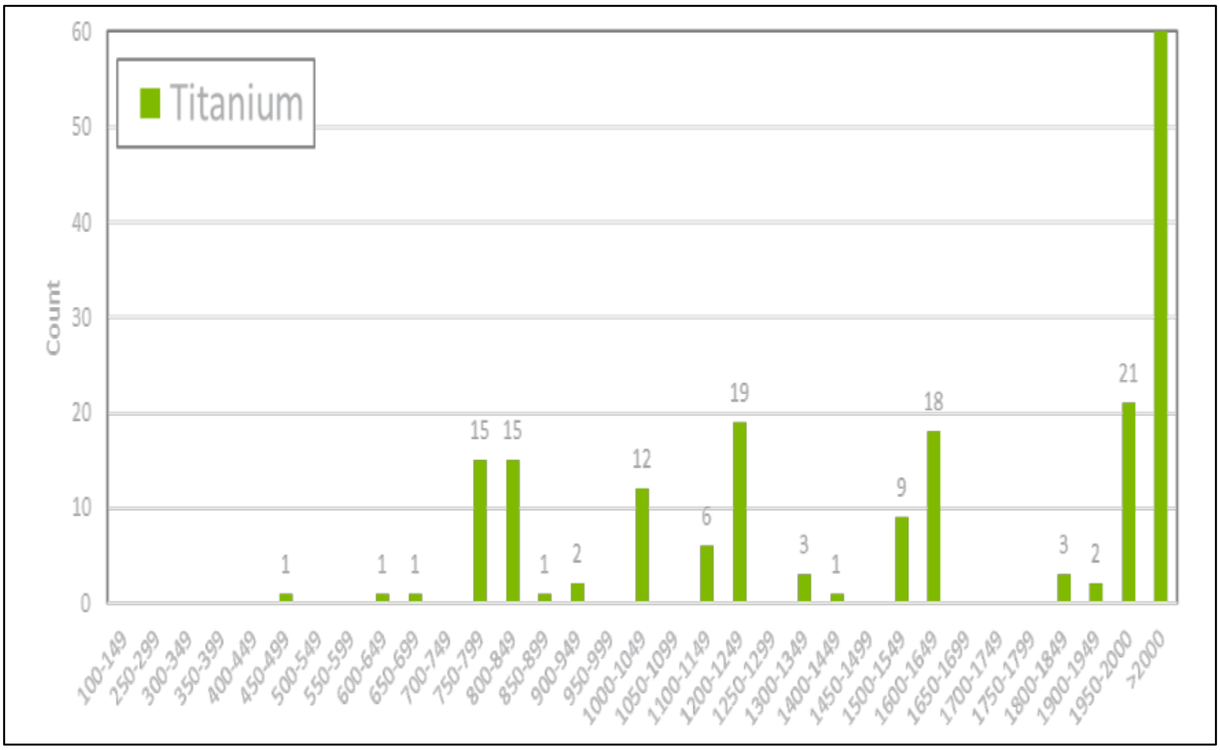
216 Modularity and Standardization Transforming Server Architecture (intel.com)

217 As above

218 80 Plus Overview | CLEAResult

A white paper from ITI's The Green Grid published in 2021[219] studied the 230V Enterprise PSU market-ready efficiency and identifies barriers and solutions to the uplifted current Regulation's requirements from January 2023. It is worth noting that the required efficiency baseline requires 96% efficiency of the PSU, power supply, at 50% of rated power. This is equivalent to the 80 PLUS® 230V Data Center Titanium Certification, the highest Certification currently offered. It is claimed that currently there are very limited products that can offer this as shown in the graph below with a recommendation being on having PSU under 750W to use a baseline of 94% efficiency at 50% load (equivalent to the 80 PLUS Platinum Certification), while working with the power supply manufacturers to meet the current level.

Figure 4.16 Chart showing quantity of power supply units that meet Titanium Certification for wattages up to 2000 watts, in increments of 50 watts



4.1.2.8 Thermal management

Thermal Management has two aspects and relates to the server level and the data centre level.

On this section it is taken to be the transport of the heat away from the active components of the server to the warm aisle of the data centre. Design of the Server board must determine how the unit will be cooled and how that will affect the overall board.

Latest technology enables monitoring of equipment and components to improve performance, monitor temperature and predict failures. The sensors also help load the server more efficiently, such that workloads from one server rack can be transmitted to the other sever racks that may be idle (and therefore cool).

219 230V ENTERPRISE PSU MARKET-READY EFFICIENCY STUDY_1.pdf (clearesult.com)

Ensuring that thermal properties are carefully monitored will help to reduce downtime and integrating modern solutions like artificial intelligence into thermal management systems is the likely next step forward for this field[220].

4.1.3 Best Available Technology (BAT)

This section will discuss where the servers and data storage market is progressing towards and how it is expected to develop. A lot of the innovations are happening at the component level. Architecture of the servers and storage products are not evolving as rapidly.

4.1.3.1 Microprocessors and memory

The most advanced microprocessors being mass produced on the market currently employ TMSC's 4N feature size, which is a modified version of TMSC's 5nm node process[221]. These smaller features allow for additional transistor density, generating additional performance and improved efficiency over previous generations of CPUs and GPUs. This latest technology is available on the market in certain high end GPU applications.

While DDR5 is relatively new on the market and is currently the most advanced form of server memory available, additional iterations on the technology will cause its CAS latency ratings to fall over time. This will unlock additional performance and access the full potential of DDR5's upgraded speed and bandwidth over previous generations of DDR.

4.1.3.2 Hard disk drives and storage

The item will be finalised in the second iteration of this report once further insight has been obtained.

4.1.3.3 Modular Servers and Microservers

Modular servers have continued to evolve and incorporate newer CPU, GPU and advanced SSD components that can be configured to service a specific workload type more effectively. They now employ more advanced features including improved fabric and bus technologies such as CXL, higher speed connectors such as silicon photonics, and support higher maximum power limits[222].

Innovation in the microserver space has lagged since the last preparatory study was finalized as the market for these products did not materialize to the degree initially expected. There are a handful of microservers still available on the market, but they are largely a niche application.

4.1.3.4 Advanced cooling

As discussed in Phase 1, the best available advanced cooling technologies for ICT equipment are currently CPU cold plate and immersion.

220 Circuit Protection – Server Thermal Management | Arrow.com

221 https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_5nm

222 https://www.cisco.com/c/en/us/solutions/computing/what-is-modular-computing.html

- CPU cold plates are attached directly to the CPU, replacing traditional fan technology and runs circulating cooling water directly to the plate to cool the CPU.
- Immersion cooling involves submerging the entire ICT product in a dielectric fluid which allowing for efficient cooling of very high-density electronics. Two-phase immersion cooling in particular allows for high efficiency heat removal as it uses a dielectric liquid with low boiling point in a sealed system that generates vapor when boiling that then phase changes back into liquid and removing heat when interacting with the chilled water condenser coil within the system.[223]

These are highly efficient and allow for higher outlet temperatures, 60 – 75 degrees C, which allows for more efficient waste heat recovery applications and the use of additional free cooling. These have low maintenance and low total cost of ownership. There are some installation concerns, but the main drawbacks are in the design of the specialised server to accommodate for the liquid heat exchange. Internal analysis from Asetek shows that the electrical consumption for a per-node cooling system can be reduced by 40%. Examples of such technologies and companies are Denmark based Asetek, and Canada based CoolIT.

These technologies are currently employed in HPC applications, but their use may increase in high rack density enterprise applications in the future.

4.1.4 Best Not yet Available Technology (BNAT)

4.1.4.1 Standby-Readiness for Servers

As discussed in the Phase 1 report, section 2.5, there has been interest in servers to gaining the ability to enter deep sleep state and recover from them in a rapid fashion to give data centre operators the option to power down groups of servers in a behaviour similar to “core parking” at the CPU level. This functionality is not yet available on the market.

There is little demand for it currently and concerns were raised that this type of behaviour can negatively impact reliability and increase jitter and latency which can negatively impact certain workload types within the data centre more broadly.

4.2 Production, Distribution and End-of-Life

4.2.1 Bill of Materials

4.2.1.1 Rack- mounted server

The following Bill of Materials is maintained based on the previous preparatory study[224] and reiterated here for discussion and further input on materials and quantities involved.

[223] https://datacenters.lbl.gov/liquid-cooling

[224] Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 4: Technologies, July 2015 – Final report, Produced by bio by Deloitte and Fraunhofer IZM

Figure 4.17 Bill of materials of an average rack server

Component	Material	Weight (g)	Component	Material	Weight (g)
Chassis	Metal Body	12 265	PSUs (2*400W)	Low-alloyed steel	1 027
	Plastics	348		Chromium steel	66
	Plastics	282		Brass	42
	Aluminium	249		Copper	9
	Copper	179		Zinc	7
	Electronic components	131		Aluminium	491
Fans (4)	Steel	386		High Density Polyethylene	184
	Copper	78		Polyvinylchloride (PVC)	92
	Iron based	55		Paper	50
	Plastic (PBT-GF30)	206		Electronic components	1 101
	Plastic (PCABSFR40)	21		Solder	31
	Plastic (undefined)	200		PCB	326
HDDs (4)	Steel	12	CPU Heat Sink	Copper	442
	Low alloyed steel	222		Steel	140
	Aluminium	1 335	Mainboard	Controller board	1 667
	PCB	179	Memory	PCB	97
				IC	38
ODD	Low alloyed steel	115	Expansion Card	PCB	349
	Copper	7	Cables	Brass	7
	Aluminium	1		Copper	81
	High Density Polyethylene (HDPE)	28		Zinc 0.166 kg	96
	Acrylonitrile-Butadiene-Styrene	12		High Density Polyethylene	104
	Polycarbonate (PC)	7		Polyvinylchloride (PVC)	145
	Electronic components (capacitors,	8		Polyurethane (PUR)	2
	Solder	2		Synthetic rubber	35
	PCB	9	Packaging	Cartons	3629
CPUs (2)	Copper	31		HDPE/ unspecified plastics	78
	Gold	0,4		GPPS/ Styrofoam	1 026
	PCB	21			
	IC	2			
Total weight of BC-1: 27 748 g					

The mainboard does not include memory and CPUs, which are listed and evaluated as separate items.

4.2.1.2 Rack-blade server

The following Bill of Materials is again maintained based on the previous preparatory study[225] and reiterated here for discussion and further input on materials and quantities involved by the stakeholders.

225 Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 4: Technologies, July 2015 – Final report, Produced by bio by Deloitte and Fraunhofer IZM

Figure 4.18 Bill of materials of a blade system with 8 servers

Enclosure		
Component	**Material**	**Weight (g)**
Chassis	Steel	87 000
Fans (6)	Steel	964
	Copper	194
	Iron based	137
	Plastic (PBT-GF30)	515
	Plastic (PCABSFR40)	52
	Plastic (undefined)	499
PSUs (4)	Low-alloyed steel	4 981
	Chromium steel	319
	Brass	202
	Copper	43
	Zinc	32
	Aluminium	2 384
	High Density Polyethylene (HDPE)	894
	Polyvinylchloride (PVC)	447
	Paper	245
	Electronic components	5 343
	Solder	149
	PCB	1 581
Total weight of enclosure		**105 981 g**

Figure 16: Illustration of a blade system

8 Blade Servers					
Component	**Material**	**Weight (g)**	**Component**	**Material**	**Weight (g)**
Chassis	Steel	33 600	HDDs (16)	Steel	47
CPUs (16)	Copper	244		Low alloyed Steel	888
	Gold	3		Aluminium	5 341
	PCB	170		PCB	717
	IC	15	Packaging	Cartons	14 969
CPU Heat Sinks	Copper	1 688		HDPE/ unspecified plastics	321
	Steel	560		GPPS/ Styrofoam	4 233
Memory	PCB	773	Mainboards	Controller Board	6 451
	IC	307			
Total weight of 8 Blade Servers: 70 327g					
Total weight of BC-2: 176 308 g					

4.2.1.3 Resource considerations for rack and blade mounted systems

As discussed in Task 3, Section 3.3.6. Most hardware manufacturers have end-of-life mechanisms to recuperate products when customers no longer require these (whether due to failure or upgrade). These mechanisms will aim to reuse (or resell) the product, repair (or refurbish), recuperate functioning components and recycle remaining materials.

Table 3.6 below shows the breakdown of material usage, recycling, energy recovery and landfill for enterprise servers provided by a European waste disposal stakeholder in 2023. This data shows how 81% of collected server mass is either re-used or materially recycled. Including waste heat recovery, up to 99% of server materials value is recovered. Only 0.16% of material by mass is incinerated or sent to landfill.

Table 4.6 Inputs in the end-of-life phase of collected enterprise servers[226]

	Plastics	Metals	Electronics	Misc.
Mass ratio within server	0,97%	67,88%	30,88%	0,28%
Re-use	0%	0%	1%	0%
Material recycling	98%	98%	43%	50%
Heat recovery	0%	2%	56%	0%
Non-recovery incineration	0%	0%	0%	50%
Landfill	2%	0%	0%	0%
Total	100%	100%	100%	100%

4.2.1.4 Storage system

The following Bill of Materials is based on the previous preparatory study[227] and put forward for discussion and further input on materials and quantities involved by the stakeholders.

Figure 4.19 Bill of materials of a controller

Material	Weight (g)	Material	Weight (g)
Controller		**PSU Controller**	
steel	14900	Mainboard	1650
stainelss stell	3360	Cables	40
sluminum sheet	574	Chassis andbulk material	1778
copper	1040		
ABS	1020	**PSU Fans**	
PET	78	Steel	220
HDPE	174	Copper	130
PP	36	iron based	26
PC	62	Nylon 6	18
Nylon 6	10	PC	70
PVC	170	ABS	38
Other plastics	24		
Printed circuit board	1154	**Packaging**	
		Cartons	7258
		HDPE/unspecified plastics	156
		GPPS/ Styrofoam	2052

Total weight: 36038g

[226] Feedback from European electronics waste disposal stakeholder 2023

[227] Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 4: Technologies, July 2015 – Final report, Produced by bio by Deloitte and Fraunhofer IZM

Figure 4.20 Bill of materials for a Disc Array Enclosure (DAE)

Material	Weight (g)
Chassis	
PC	203
ABS	46
Steel sheet part	7687
Zinc Part	149
Steel Machined Part	1.5
PSUs in DAE (2)	
mainborad	2108.5
cables	52
chassis and bulk	2273
Fans in PSU (4)	
Steel	281.5
Copper	166
iro based	33
Nyylon 6	23.5
PC	88.5
ABS	47.5
Controller cards (2)	1154
Mid plane board	460

Total weight: 14774g

Figure 4.21 Bill of materials for an average storage media mix

Storage Media Mix (40.1 TB)					
3.5 HDD (19.35)	Steel	58	2.5 HDD (14.01)	Steel	278
	Low Alloyed Steel	1 103		Low Alloyed Steel	211
	Aluminium	6 637		Aluminium	2 562
	PCB	890		PCB	123
				ABS	7
SSDs (2.86)	Electronic components	172			
	IC	5			

Total weight: 12050g

4.2.1.5 Resource considerations for storage systems

Table 4.7 shows the inputs in the end-of-life phase of the storage systems assumptions from the 2015 Preparatory study for further discussion and considerations and input from stakeholders.

Table 4.7 Inputs in the end-of-life phase of storage systems[228]

	Plastics	Metals	Electronics	Misc.
Re-use	25%			
Material recycling	5%	70%	50%	68%
Heat recovery	69%	0%	24%	1%

[228] Source: Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC, DG ENTR Lot 9 - Enterprise servers and data equipment, Task 3: User, July 2015: Final report, bio by Deloitte & Fraunhofer IZM

	Plastics	Metals	Electronics	Misc.
Non-recovery incineration	0.5%	0%	0.5%	5%
Landfill	0.5%	5%	0.5%	1%
Total	100%	100%	100%	100%

4.2.2 Packaging

As discussed in Task 3, Product packaging has been categorised into three main elements:

- The cardboard packaging.
- Foam protection of the product (including bubble wrap), these are usually plastics based.
- Other plastics (films, wrappings)

The main packaging quantities for rack and blade servers are outlined in Figure 4.17 and Figure 4.18 above. Stakeholder feedback has suggested that these categories are appropriate. Additionally, it was mentioned that there is a trend to use greater amounts of cardboard for product production, replacing the use of foam.

5 Introduction to Task 5 Environment and Economics

5.1 Overview of Base cases

This section aims to define and elaborate on base-cases derived from prior tasks, stakeholder inputs, and a thorough literature review. These base-cases, intentional abstractions of reality, are crucial in encompassing the diverse range of servers and storage systems across the European market. They aim to strike a balance: being few enough for streamlined analysis yet comprehensive enough to represent the technological breadth of servers and storage systems. Guided by the MEErP methodology, the objective is to define two base-cases for servers and one base case for storage system that effectively encapsulate the study's scope. Each base-case's characteristics allow for the multiplication of its impacts during the use phase, production and distribution, and end-of-life stages with the respective total number of products in use, sold, and discarded, thereby providing a holistic representation of the environmental impact of this equipment.

Table 5.1 below serves as the key and shows the number of models in the SERT dataset segregated by product type. This includes models from 2016-2021.

Table 5.1 SERT dataset overview

Entire Data set				
Server Type	# installed Processors	Count in data set	# Families	# of families with Typical Configs
Rack	1	152	57	37
Rack	2	247	90	70
Rack	4	58	19	17
Tower	1	30	10	7
Tower	2	23	7	6
Blade	2	77	25	24
Blade	4	22	8	7
	Total	609	216	168

The equipment under scrutiny in the Lot 9 preparatory study relies heavily on its configuration. To ensure a comprehensive yet manageable approach, a selected subset of base-cases has been curated to represent this diversity. Rack servers represent 75% and Blade 16% count in the SERT dataset. Notably, the utilisation of a 2-socket server with only one socket populated falls short of optimal usage, and market data lacks clarity on the prevalence of underpopulated 2-socket servers. Given that 2-socket servers constitute over 50% of the SERT dataset, the analysis focuses on this dominant market segment. Within this segment, the study distinguishes between rack and blade servers, as outlined in the conclusion of Task 4. Tower servers represent about 8.7% of the SERT dataset and therefore are not eligible to considered as a base case. BC-1 and BC-2 in the table below are developed using the average technical characteristics of the most popular configurations in the SERT dataset and identifying the closest representative model.

The selection of the storage system hinges significantly on the dataset characteristics, which play a pivotal role in determining its suitability. The base case BC-3 was constructed using Online 3 systems where multiple drive type configurations are commonly deployed. Online 2 systems typically deploy a single drive type and are not an ideal base case candidate. Primarily, the choice is rationalised based on the predominant connectivity model, where Block I/O constitutes a substantial 73% of the dataset. Aligning with workload optimisation, the decision leans towards a Transaction-oriented approach, mirroring the dataset's composition, where Transactions account for 47%, with Streaming at 28% and Composite at 25%. Furthermore, the configuration of the storage controller heavily leans towards Scale Up, representing a dominant 70% of the dataset. Considering these vital characteristics, the proposed storage system configuration emerges as the optimal choice. It not only encapsulates these crucial traits but also integrates a hybrid storage model—incorporating both HDD and SSD components, aligning seamlessly with prevalent applications in the field. This hybrid configuration is a common and versatile solution, addressing the diverse demands present within the dataset while ensuring comprehensive adaptability and performance. Internal shipment data was used to ensure that models identified were representative of commonly installed configurations. Table 5.2 below summarises the retained technical specificities of the different base cases.

Table 5.2 Technical specifications of BC-1, BC-2, and BC-3.

Base Case	Description
BC-1 2 socket Rack Server	• Silver level Intel processor • 2021 model • 2U volume • 16 memory DIIMMs • 2 storage devices • 800-Watt nameplate power • 136 idle watt measurement • 27.1 efficiency score
BC-2 2 socket Blade Server	• 2 storage devices • 3000-Watt nameplate power • Memory capacity: 3TB • Number of blade slots: 8 • SERT Score (typical config): 31.2 • Idle measurement (typical config): 166 watts
BC-3 Storage (virtual product, hybrid system)	• Taxonomy: Online 3 • Workload optimization: Transaction • Storage model connectivity: Block I/O • Storage controller config: Scale-up • 1100-Watt nameplate power • 22 storage devices in optimal configuration (6 SSD + 16 HDDs)

5.2 Product specific inputs

It should be noted that the Task 5 methodology, modelling inputs and outcomes should not be directly compared to the outputs from the prior preparatory study which underpinned regulation 2019/424. This is because a newer version of the EcoReport tool has been utilised for this review study, with the prior version (2013) being withdrawn. In addition, since the last preparatory study, the servers and data storage industry has seen a dramatic increase in the performance rate of their products.

5.2.1 Servers

5.2.1.1 Inputs and Assumptions common to all BCs

5.2.1.2 Discount Rate and Escalation Rate

The discount and escalation rates used for BCs were provided in the MEErP and are presented in Table 5.3.

Table 5.3 Discount rate and Escalation Rate

Input / Assumption	Value	Unit	Source
Escalation rate (annual growth of running costs)	3%	per year	MEErP, 2024
Discount Rate	3%	per year	MEErP, 2024

5.2.1.3 Electricity Rate

The electricity rate used for all BCs was calculated based on the values and methodology provided in the MEErP[229] and are presented in Table 5.4.

Table 5.4 Electricity rates

Input / Assumption	Value	Unit	Source
Electricity prices	0.6	Euro/kWh	MEErP 2024

5.2.1.4 Water rate

The water rate used for all BCs were provided in the MEErP are presented in Table 5.5.

Table 5.5 Water rates

Input / Assumption	Value	Unit	Source
Water rate	1	Euro/m3	MEErP, 2024

[229] Section 2.3 of the MEErP 2011 Methodology Part 1 - Final provides guidance for estimating the electricity prices. Because Servers are not a household appliance, the electricity prices used were those presented in Section 2.4 for the Industry.

5.2.1.5 Critical raw materials

CRM as per the EcoReport tool are: Antimony, Baryte, Bauxite, Beryllium, Bismuth, Borates, Cobalt, Coking coal, Fluorspar, Gallium, Germanium, Hafnium, Indium, Lithium, Magnesium, Natural graphite, Natural rubber, Niobium, Phosphate rock, Phosphorus, Scandium, Silicon metal, Strontium, Tantalum, Titanium, Tungsten, Vanadium, Platinum Group Metals, Heavy Rare Earth Elements, Light Rare Earth Elements.

Hazardous materials as per RoHS Directive are: Lead, Mercury, Cadmium, Hexavalent chromium, Polybrominated biphenyls (PBB), Polybrominated diphenyl ethers (PBDE)

5.2.1.6 Inputs in the production phase of BC1 – Rack Server

The bill of materials for the BC-1, a rack server is presented below in Table 5.6.

Table 5.6 Bill of Materials of BC1 (Rack Server)

Input / Assumption	Value	Unit
Ag - Silver	0.0013	kg
Al - Aluminum	1.42	kg
Au - Gold	0.0012	kg
Ba - Barium	0.04	kg
Ca - Calcium	0.07	kg
Co - Cobalt	0.01	kg
Cr - Chromium	0.01	kg
Cu - Copper	1.00	kg
Dy - Dysprosium	0.0001	kg
Fe - Iron	12.14	kg
In - Indium	0.0001	kg
Mg - Magnesium	0.01	kg
Mn - Manganese	0.03	kg
Mo - Molybdenum	0.00001	kg
Nd - Neodymium	0.0005	kg
Ni - Nickel	0.07	kg
Pb - Lead	0.0019	kg
Pr - Praseodymium	0.0001	kg
Sb - Antimony	0.0004	kg
Sn - Tin	0.06	kg
Sr - Strontium	0.0006	kg
Ta - Tantalum	0.0003	kg

Input / Assumption	Value	Unit
Ti - Titanium	0.01	kg
W - Tungsten	0.01	kg
Zn - Zinc	0.03	kg
Zr - Zirconium	0.0001	kg
Silicon	0.01312	kg
Plastic	0.91	kg

The above data have been obtained from and aggregated from several industry stakeholders[230] and internet research. The total weight of BC-1 amounts to around 15.82 kg.

The BC-1 values for packaging, distribution, the direct and in-direct use-phase values, maintenance and repair, and input values for EU totals and economic life cycle costs, are presented in Table 5.7 to Table 5.12, respectively.

Table 5.7 Packaging of BC-1

Input / Assumption	Value	Unit	Source
HDPE	0.078	kg	CEDaCI data
GPPS/Styrofoam	1.026	kg	CEDaCI data

Table 5.8 Distribution of BC1

Input / Assumption	Value	Unit	Source
Transport mean 1	Ship		ICF, assumption
Weight of the transported product	0.02	t	CEDaCI data
Distance 1	16000	km	ICF, assumption. Servers are mostly shipped from Hong Kong & San Francisco. Taken the average of “shipping distance” from these 2 cities to Rotterdam port
Transport mean 2	Lorry		ICF, assumption
Weight of the transported product	0.02	t	CEDaCI data
Distance 2	450	km	ICF, assumption Average distance by road from Rotterdam to Frankfurt

230 The Bill of Materials was provided by CEDaCI Project

Table 5.9 Use Phase Direct ErP of BC1

Input / Assumption	Value	Unit	Source
ErP Product service Life in years (see comment)	4	years	Task 2
		Electricity	
Electricity mix (Click & select)	243-Electricity grid mix 1kV-60kV technology mix consumption mix, to consumer 1kV - 60kV		ICF assumption
On-mode: Consumption per hour, cycle, setting, etc.	0.27		Calculated
On-mode: No. of hours, cycles, settings, etc. / year	6077.25	#	Calculated
Standby-mode: Consumption per hour	0.14		Calculated
Standby-mode: No. of hours / year	2682.75	#	Calculated
Off-mode: Consumption per hour	0		Calculated
Off-mode: No. of hours / year	0	#	Calculated
TOTAL over ErP Product Life	8.03	MWh (=000 kWh)	Calculated
		Heat	
Type (click & select)			
Avg. Heat Power Output	0	kW	
No. of hours / year	0	hrs.	
Efficiency (insert the value manually)			
TOTAL over ErP Product Life	0	GJ	

Table 5.10 Use Phase Indirect ErP of BC1

Input / Assumption	Value	Unit	Source
ErP Product (service) Life in years	4	Years	Task 2

Input / Assumption	Value	Unit	Source
	Electricity		
Electricity mix (Click & select)	243-Electricity grid mix 1kV-60kV technology mix consumption mix, to consumer 1kV - 60kV		Calculated
On-mode: Consumption per hour, cycle, setting, etc.	0.27		Calculated
On-mode: No. of hours, cycles, settings, etc. / year	6077.25	#	Calculated
Standby-mode: Consumption per hour	0.14		Calculated
Standby-mode: No. of hours / year	2682.75	#	Calculated
Off-mode: Consumption per hour	0		Calculated
Off-mode: No. of hours / year	0	#	Calculated
TOTAL over ErP Product Life	8.032	MWh (=000 kWh)	Calculated
	Heat		
Boiler dataset (click & select)			
Avg. Heat Power Output (when saving use a negative value)	0	kW	
No. of hours / year	0	hrs.	
Efficiency (insert the value manually)			
TOTAL over ErP Product Life	0	GJ	

Table 5.11 Maintenance & Repair of BC1

Input / Assumption	Value	Unit	Source
Spare parts % of product materials	158.0964243	G	ICF assumption

Table 5.12 Inputs for EU-Totals & economic Life Cycle Costs of BC1

Input / Assumption	Value	Unit	Source
Product expected lifetime	4	Years	Task 2
Latest Annual sales	1.38	mln. Units/year	Calculated
EU Stock	5.52	mln. Units	Calculated
Product price	23420	Euro/unit	Task 2
Installation/acquisition costs (if any)	340	Euro/ unit	Task 2
Fuel rate (gas, oil, wood)	0	Euro/MJ	
Electricity rate	0.6	Euro/kWh	MEErP 2024
Water rate	1	Euro/m3	MEErP 2024
Auxiliary material 1	0	Euro/kg	
Auxiliary material 2	0	Euro/kg	
Auxiliary material 3	0	Euro/kg	
Auxiliary material 4	0	Euro/kg	
Auxiliary material 5	0	Euro/kg	
Repair & maintenance costs	400	Euro/ unit	Task 2
Discount rate (interest minus inflation)	0.03	%	MEErP 2024
Escalation rate (project annual growth of running costs)	0.03	%	MEErP 2024
Present Worth Factor (PWF) (calculated automatically)	4	(years)	MEErP 2024
Ratio efficiency STOCK: efficiency NEW, in Use Phase	0.9		MEErP 2024

5.2.1.7 BC2 – Blade Server

The bill of materials for the BC2 blade server is presented below in Table 5.13.

Table 5.13 Bill of Materials of BC2 (Blade Server)

Input / Assumption	Value	Unit
	Chassis	
Steel	65.25	kg
	Fans (6)	
Steel	0.964	kg

Input / Assumption	Value	Unit
Copper	0.194	kg
Iron base	0.137	kg
Plastic (PBT-GF30)	0.515	kg
Plastic (PCABSFR40)	0.052	kg
Plastic (undefined)	0.499	kg
PSUs (3 x 3000W)		
Low-alloyed steel	7.004	kg
Chromium steel	0.448	kg
Brass	0.284	kg
Copper	0.06	kg
Zinc	0.045	kg
Aluminum	3.35	kg
High Density Polyethylene (HDPE)	1.25	kg
Polyvinylchloride (PVC)	0.62	kg
Paper	0.344	kg
Electronic components	2.44	m2
Solder	0.21	kg
PCB	0.73	m2
Chassis		
Steel	16.8	kg
CPUs (8)		
Copper	0.122	kg
Gold	0.0015	kg
PCB	0.028	m2
IC	0.0024	m2
CPU heat sinks		
Copper	0.844	kg
Steel	0.28	kg
Memory		
PCB	0.125	m2
IC	0.049	m2

Input / Assumption	Value	Unit
	CPU heat sinks	
Copper	0.844	kg
Steel	0.28	kg
	Memory	
PCB	0.125	m2
IC	0.049	m2
	HDDs (8)	
Steel	0.0235	kg
Low Alloyed Steel	0.444	kg
Aluminium	2.67	kg
PCB	0.116	m2
	Mainboards	
Controller Board	1.047	m2

The above data have been obtained from and aggregated from several industry stakeholders and internet research. The total weight of BC-2 amounts to around 116.4 kg.

The BC2 values for packaging, distribution, the direct and in-direct use-phase values, maintenance and repair, and input values for EU totals and economic life cycle costs, are presented in the Table 5.14 to Table 5.19, respectively.

Table 5.14 Packaging of BC2

Input / Assumption	Value	Unit	Source
HDPE	0.16	kg	CEDaCI data
GPPS/Styrofoam	2.116	kg	CEDaCI data
Cartons	7.484	kg	CEDaCI data

Table 5.15 Distribution of BC2

Input / Assumption	Value	Unit	Source
Transport mean 1	Ship		ICF, assumption
Weight of the transported product	0.126	T	CEDaCI data
Distance 1	16000	km	ICF, assumption. Servers are mostly shipped from Hong Kong & San Francisco. Taken the average of “shipping distance” from these

Input / Assumption	Value	Unit	Source
			2 cities to Rotterdam port
Transport mean 2	Lorry		ICF, assumption
Weight of the transported product	0.126	T	CEDaCI data
Distance 2	450	km	ICF, assumption Average distance by road from Rotterdam to Frankfurt

Table 5.16 Use Phase Direct ErP of BC2

Input / Assumption	Value	Unit	Source
ErP Product service Life in years (see comment)	4	years	Task 2
	Electricity		
Electricity mix (Click & select)	243-Electricity grid mix 1kV-60kV technology mix consumption mix, to consumer 1kV - 60kV		ICF assumption
On-mode: Consumption per hour, cycle, setting, etc.	0.527	kWh	Calculated
On-mode: No. of hours, cycles, settings, etc. / year	6077.25	#	Calculated
Standby-mode: Consumption per hour	0.17	kWh	Calculated
Standby-mode: No. of hours / year	2682.75	#	Calculated
Off-mode: Consumption per hour			Calculated
Off-mode: No. of hours / year		#	Calculated
TOTAL over ErP Product Life	14.59	MWh (=000 kWh)	
	Heat		
Type (click & select)			
Avg. Heat Power Output		kW	
No. of hours / year		hrs.	
Efficiency (insert the value manually)			

Input / Assumption	Value	Unit	Source
TOTAL over ErP Product Life	0	GJ	

Table 5.17 Use Phase Indirect ErP of BC2

Input / Assumption	Value	Unit	Source
ErP Product (service) Life in years	4	years	Task 2
	Electricity		
Electricity mix (Click & select)	243-Electricity grid mix 1kV-60kV technology mix consumption mix, to consumer 1kV - 60kV		Calculated
On-mode: Consumption per hour, cycle, setting, etc.	0.527	kWh	Calculated
On-mode: No. of hours, cycles, settings, etc. / year	6077.25	#	Calculated
Standby-mode: Consumption per hour	0.17	kWh	Calculated
Standby-mode: No. of hours / year	2682.75	#	Calculated
Off-mode: Consumption per hour			
Off-mode: No. of hours / year		#	
TOTAL over ErP Product Life	14.59	MWh (=000 kWh)	
	Heat		
Boiler dataset (click & select)			
Avg. Heat Power Output (when saving use a negative value)		kW	
No. of hours / year		hrs.	
Efficiency (insert the value manually)			
TOTAL over ErP Product Life	0	GJ	

Table 5.18 Maintenance & Repair of BC2

Input / Assumption	Value	Unit	Source
Spare parts % of product materials	1164	g	ICF assumption

Table 5.19 Inputs for EU-Totals & economic Life Cycle Costs of BC2

Input / Assumption	Value	Unit	Source
Product expected lifetime	4	years	Task 2
Latest Annual sales	0.35	mln. Units/year	Calculated
EU Stock	1.4	mln. Units	Calculated
Product price	8435	Euro/unit	Task 2
Installation/acquisition costs (if any)	340	Euro/ unit	Task 2
Fuel rate (gas, oil, wood)	0	Euro/MJ	
Electricity rate	0.6	Euro/kWh	MEErP 2024
Water rate	1	Euro/m3	MEErP 2024
Auxiliary material 1	0	Euro/kg	
Auxiliary material 2	0	Euro/kg	
Auxiliary material 3	0	Euro/kg	
Auxiliary material 4	0	Euro/kg	
Auxiliary material 5	0	Euro/kg	
Repair & maintenance costs	400	Euro/ unit	Task 2
Discount rate (interest minus inflation)	3%	%	MEErP 2024
Escalation rate (project annual growth of running costs)	3%	%	MEErP 2024
Present Worth Factor (PWF) (calculated automatically)	4	(years)	MEErP 2024
Ratio efficiency STOCK: efficiency NEW, in Use Phase	0.9		MEErP 2024

5.2.2 Data Storage

5.2.2.1 BC3 – Storage system

Please note the modelled BC3 which has been developed by the study team is only representative of data storage products in 2023. However, with the advancement of data storage products, by 2025 it is expected that SSDs will be the predominant product across EU market. Thus, by 2025, the modelled BC3 may no longer be representative of the market, which is when the Regulation is expected to be updated by.

The bill of materials for BC3 data storage is presented below in Table 5.20.

Table 5.20 Bill of Materials of BC3 (Data Storage: SSDs)

Material/ component	Weight	Unit
3,5 HDD (9)		
Steel	0.03	kg
Low alloyed steel	0.51	kg
Aluminum	3.09	kg
PCB	0.13	m2
SSDs (6)		
Electronic components	0.12	m2
IC	0.003	m2
2.5 HDD (7)		
Steel	0.14	kg
Low alloyed steel	0.11	kg
Aluminum	1.28	kg
PCB	0.02	m2
ABS	0.003	kg
Disc Array Enclosures (2)		
Chassis		
PC	0.20	kg
ABS	0.05	kg
Steel Sheet part	7.69	kg
Zinc Part	0.15	kg
Steel Machined Part	0.002	kg
PSUs in DAEs (2)		
Mainboard	0.7	m2
Cables	4.0	m
Chassis and bulk materials	2.3	kg
Fans in PSUs (4)		

Material/ component	Weight	Unit
Steel	0.3	kg
Copper	0.2	kg
Iron based	0.033	kg
Nylon 6	0.024	kg
PC	0.1	kg
ABS	0.048	kg
	Controller cards (2)	
Electronics	0.4	m2
	Mid plane boards (1)	
Electronics	0.1	m2
	Controller (1/2)	
	Controller	
Steel	7.5	kg
Stainless Steel	1.7	kg
Aluminum Sheet	0.3	kg
Copper	0.5	kg
ABS	0.5	kg
PET	0.039	kg
HDPE	0.1	kg
PP	0.018	kg
PC	0.031	kg
Nylon 6	0.005	kg
PVC	0.1	kg
Other Plastics	0.012	kg
Printed Circuit Board	0.2	m2
	PSU Controller	
Mainboard	0.3	m2
Cables	1.5	m
Chassis and bulk material	0.9	kg
	PSU Fans	

Material/ component	Weight	Unit
Steel	0.1	kg
Copper	0.1	kg
Iron based	0.013	kg
Nylon 6	0.009	kg
PC	0.035	kg
ABS	0.019	kg

The BC3 values for packaging, distribution, the direct and in-direct use-phase values, maintenance and repair, and input values for EU totals and economic life cycle costs, are presented in the Table 5.21 to Table 5.26, respectively.

Table 5.21 Packaging of BC3

Input / Assumption	Value	Unit	Source
HDPE	3.629	kg	CEDaCI data
GPPS/Styrofoam	0.078	kg	CEDaCI data
Cartons	1.026	kg	CEDaCI data

Table 5.22 Distribution of BC3

Input / Assumption	Value	Unit	Source
Transport mean 1	Ship		ICF, assumption
Weight of the transported product	0.126	t	CEDaCI data
Distance 1	16000	km	ICF, assumption. Servers are mostly shipped from Hong Kong & San Francisco. Taken the average of "shipping distance" from these 2 cities to Rotterdam port
Transport mean 2	Lorry		ICF, assumption
Weight of the transported product	0.126	t	CEDaCI data
Distance 2	450	km	ICF, assumption Average distance by road from Rotterdam to Frankfurt

Table 5.23 Use Phase Direct ErP of BC3

Input / Assumption	Value	Unit	Source
ErP Product service Life in years (see comment)	6	years	Task 2
	Electricity		

Input / Assumption	Value	Unit	Source
Electricity mix (Click & select)	243-Electricity grid mix 1kV-60kV technology mix consumption mix, to consumer 1kV - 60kV		ICF assumption
On-mode: Consumption per hour, cycle, setting, etc.	0.278	kWh	Calculated
On-mode: No. of hours, cycles, settings, etc. / year	8760	#	Calculated
Standby-mode: Consumption per hour	0	kWh	Calculated
Standby-mode: No. of hours / year		#	Calculated
Off-mode: Consumption per hour	0	kWh	Calculated
Off-mode: No. of hours / year		#	Calculated
TOTAL over ErP Product Life	14.61168	MWh (=000 kWh)	Calculated
	Heat		
Type (click & select)			
Avg. Heat Power Output		kW	
No. of hours / year		hrs.	
Efficiency (insert the value manually)		please choose your item in cell D284	
TOTAL over ErP Product Life	0	GJ	

Table 5.24 Use Phase Indirect ErP of BC3

Input / Assumption	Value	Unit	Source
ErP Product (service) Life in years	6	years	Task 2
	Electricity		
Electricity mix (Click & select)			
On-mode: Consumption per hour, cycle, setting, etc.	0.278	kWh	Calculated

Input / Assumption	Value	Unit	Source
On-mode: No. of hours, cycles, settings, etc. / year	8760	#	Calculated
Standby-mode: Consumption per hour		kWh	
Standby-mode: No. of hours / year		#	
Off-mode: Consumption per hour		kWh	
Off-mode: No. of hours / year		#	
TOTAL over ErP Product Life	14.61168	MWh (=000 kWh)	Calculated
	Heat		
Boiler dataset (click & select)			
Avg. Heat Power Output (when saving use a negative value)		kW	
No. of hours / year		hrs.	
Efficiency (insert the value manually)			
TOTAL over ErP Product Life	0	GJ	

Table 5.25 Maintenance & Repair of BC3

Input / Assumption	Value	Unit	Source
Spare parts % of product materials	340.6162364	G	ICF assumption

Table 5.26 Inputs for EU-Totals & economic Life Cycle Costs of BC3

Input / Assumption	Value	Unit	Source
Product expected lifetime	6	years	Task 2
Latest Annual sales	32.10	mln. Units/year	Calculated
EU Stock	192.6	mln. Units	Calculated
Product price	24400	Euro/unit	Task 2
Installation/acquisition costs (if any)	425	Euro/ unit	Task 2
Fuel rate (gas, oil, wood)	0	Euro/MJ	
Electricity rate	0.6	Euro/kWh	MEErP 2024
Water rate	1	Euro/m3	MEErP 2024

Input / Assumption	Value	Unit	Source
Auxiliary material 1	0	Euro/kg	
Auxiliary material 2	0	Euro/kg	
Auxiliary material 3	0	Euro/kg	
Auxiliary material 4	0	Euro/kg	
Auxiliary material 5	0	Euro/kg	
Repair & maintenance costs	220	Euro/ unit	Task 2
Discount rate (interest minus inflation)	0.03	%	MEErP 2024
Escalation rate (project annual growth of running costs)	0.03	%	MEErP 2024
Present Worth Factor (PWF) (calculated automatically)	6	(years)	MEErP 2024
Ratio efficiency STOCK: efficiency NEW, in Use Phase	0.9		MEErP 2024

5.3 BASE CASE ENVIRONMENTAL IMPACT ASSESSMENT

5.3.1 Scope

Using the EcoReport tool and the above inputs, it is possible to calculate environmental impacts for the following phases of a product life cycle:

- Raw Materials Use and Manufacturing;
- Distribution;
- Use phase;
- End-of-Life Phase.

This chapter provides the environmental impacts of the Base-Cases throughout all the life cycle stages. The results were calculated using the EcoReport tool of the MEErP, based on the inputs presented in the previous section. The MEErP tracks 16 impact categories used in the EF method by using the Circular Footprint Formula (CFF).

Circular Footprint Formula (CFF) parameters

The simplified version of the CFF (material part only):

$$(1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V\right)$$

Where:

- R1 (recycled content): it is the proportion of material in the input to the production that has been recycled from a previous system.

- R2 (recycling output rate): it is the proportion of the material in the product that will be recycled (or a component to be reused) in a subsequent system. R2 shall therefore consider the inefficiencies in the collection and recycling processes. R2 shall be measured at the output of the recycling plant.
- A (allocation factor): allocation factor of burdens and credits between supplier and user of recycled materials.
- Ev: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.
- Ev*: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials. It will be set by default equal to Ev.
- Erecycled: specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled material (or reused component), including collection, sorting and transportation process.

5.3.2 Servers

BC-1 Rack Server

Figure 5.1 below presents the results of the environmental analysis of BC-1 (rack server). According to this, the energy consumption during the use phase is by far the predominant aspect contributing to the environmental impacts from the product's entire life cycle.

Figure 5.1 Distribution of BC-1 environmental impacts by life cycle phase

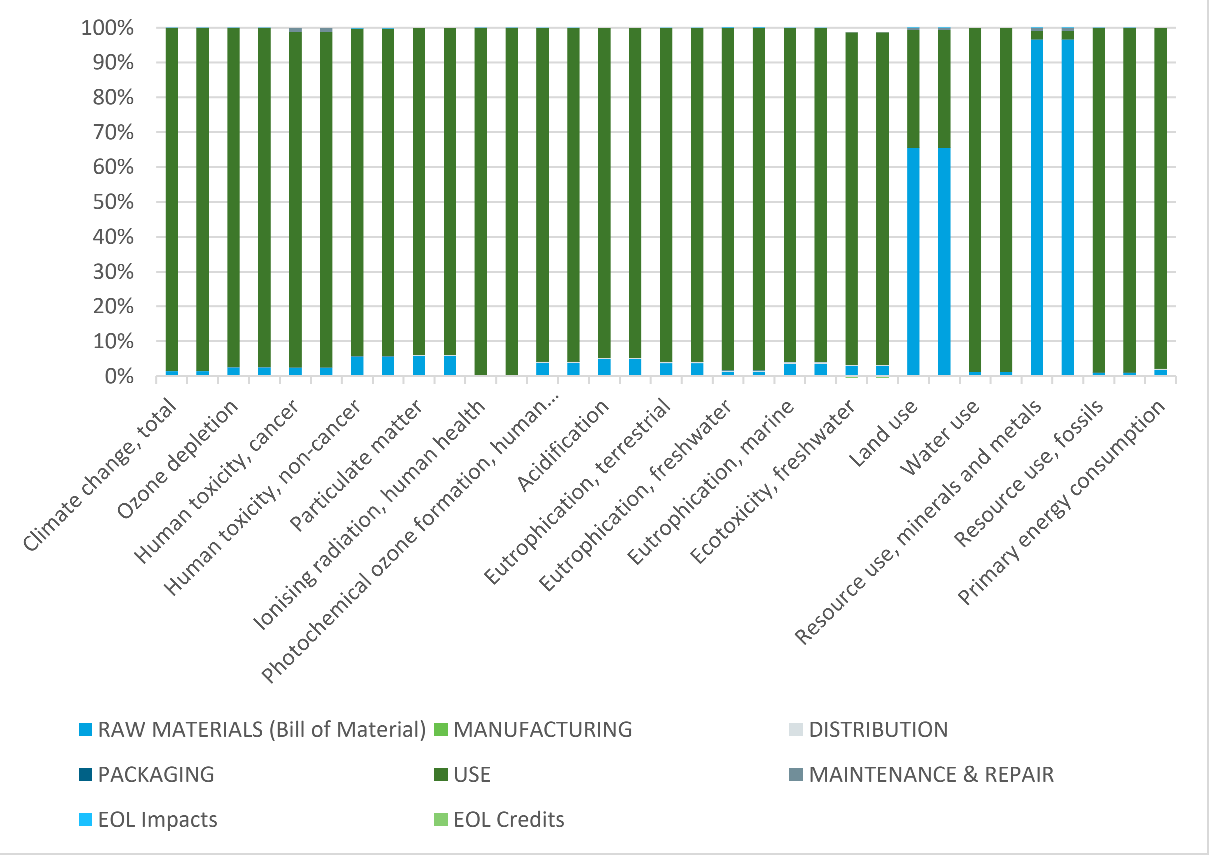


Table 5.27 below presents the Life Cycle Impacts (per unit) of BC-1.

Table 5.27 Life Cycle Impacts (per unit) of BC-1: Rack Server

Life Cycle phases --> Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL Impacts	EOL Credits	Total
PEF Impact categories										
Climate change, total	kg CO2 eq	9.4E+01	0.0E+00	6.6E+00	2.4E+00	6.7E+03	9.4E-01	1.6E-01	-6.4E+00	6.8E+03
Ozone depletion	kg CFC-11 eq	6.5E-08	0.0E+00	4.3E-12	4.3E-11	2.5E-06	6.5E-10	1.3E-11	-1.6E-09	2.6E-06
Human toxicity, cancer	CTUh	2.6E-08	0.0E+00	1.6E-09	1.1E-09	1.1E-06	1.3E-08	2.6E-11	-1.5E-09	1.1E-06
Human toxicity, non-cancer	CTUh	1.3E-06	0.0E+00	4.0E-08	4.1E-08	2.3E-05	1.3E-08	3.7E-10	-5.1E-08	2.4E-05
Particulate matter	disease incidence	1.3E-05	0.0E+00	6.7E-07	3.1E-08	2.1E-04	1.3E-07	4.2E-09	-2.8E-07	2.3E-04
Ionising radiation, human health	kBq U235 eq	3.7E+00	0.0E+00	3.1E-02	7.9E-02	2.9E+03	3.7E-02	1.6E-02	-1.7E+00	2.9E+03
Photochemical ozone formation, human health	kg NMVOC eq	4.4E-01	0.0E+00	4.2E-02	4.4E-03	1.1E+01	4.4E-03	4.2E-04	-1.2E-02	1.1E+01
Acidification	mol H+ eq	1.1E+00	0.0E+00	5.4E-02	4.2E-03	2.0E+01	1.1E-02	4.8E-04	-2.7E-02	2.2E+01
Eutrophication, terrestrial	mol N eq	1.6E+00	0.0E+00	2.0E-01	1.2E-02	4.1E+01	1.6E-02	1.7E-03	-4.3E-02	4.3E+01

Life Cycle phases -->								EOL		
Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	Impacts	Credits	Total
Eutrophication, freshwater	kg P eq	1.9E-04	0.0E+00	3.6E-05	6.5E-06	1.4E-02	1.9E-06	2.0E-07	-2.0E-06	1.4E-02
Eutrophication, marine	kg N eq	1.4E-01	0.0E+00	1.8E-02	1.1E-03	3.9E+00	1.4E-03	1.5E-04	-3.9E-03	4.0E+00
Ecotoxicity, freshwater	CTUe	9.5E+02	0.0E+00	6.4E+01	4.3E+01	3.1E+04	9.5E+00	3.3E+00	-4.1E+02	3.1E+04
Land use	pt	5.6E+04	0.0E+00	4.5E+01	1.8E+00	2.9E+04	5.6E+02	4.6E-01	-3.3E+00	8.6E+04
Water use	m3 water eq. of deprived water	2.6E+01	0.0E+00	5.1E-01	4.2E-01	2.3E+03	2.6E-01	3.2E-02	-3.3E+00	2.3E+03
Resource use, minerals and metals	kg Sb eq	6.8E-02	0.0E+00	3.1E-06	6.8E-07	1.7E-03	6.8E-04	4.0E-08	-7.7E-07	7.0E-02
Resource use, fossils	MJ	1.1E+03	0.0E+00	9.0E+01	8.3E+01	1.2E+05	1.1E+01	2.7E+00	-9.1E+01	1.2E+05
Primary energy consumption	MJ	1.1E+03	0.0E+00	9.0E+01	8.3E+01	5.8E+04	1.1E+01	2.7E+00	-9.1E+01	5.9E+04

BC-2 Blade System

Figure 5.2 below presents the results of the environmental analysis of BC-2 (blade server[231]). According to this, the energy consumption during the use phase is by far the predominant aspect contributing to the environmental impacts from the product's entire life cycle.

Figure 5.2 Distribution of BC-2 environmental impacts by life cycle phase

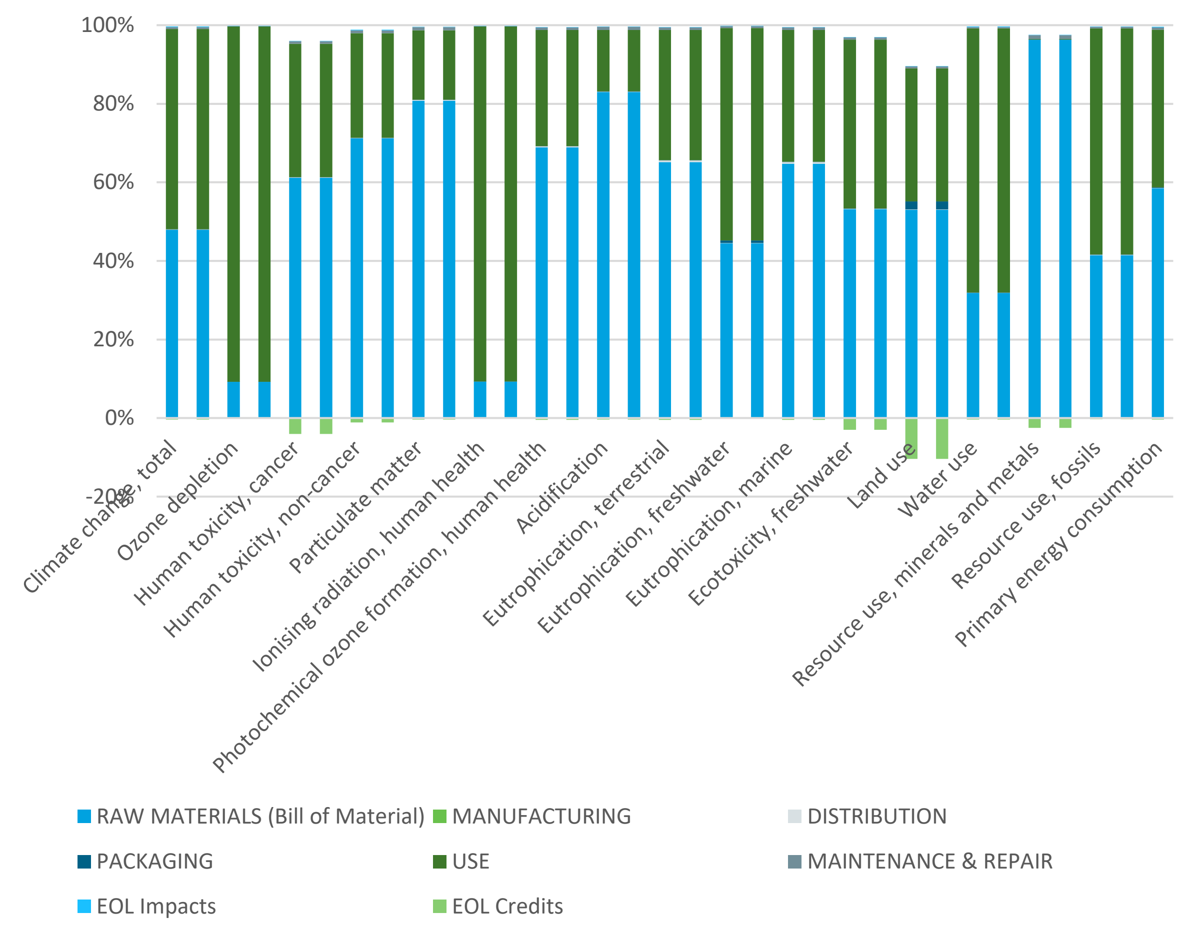


Table 5.28 below presents the Life Cycle Impacts (per unit) of BC -2

Table 5.28 Life Cycle Impact (per unit) of BC2: Blade Server

Life Cycle phases -->	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL		Total
Resources Use and Emissions								Impacts	Credits	
PEF Impact categories										

231 The Environmental Impacts including energy consumption are calculated per Blade

Life Cycle phases -->								EOL		
Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	Impacts	Credits	Total
Climate change, total	kg CO2 eq	1.1E+04	0.0E+00	1.3E+01	1.4E+01	1.2E+04	1.1E+02	2.9E+01	-8.3E+01	2.4E+04
Ozone depletion	kg CFC-11 eq	4.6E-07	0.0E+00	4.8E-12	5.3E-10	4.5E-06	4.6E-09	5.2E-09	-7.8E-09	5.0E-06
Human toxicity, cancer	CTUh	3.7E-06	0.0E+00	3.3E-09	4.6E-09	2.0E-06	3.7E-08	5.1E-09	-2.4E-07	5.5E-06
Human toxicity, non-cancer	CTUh	1.1E-04	0.0E+00	5.9E-08	1.4E-07	4.1E-05	1.1E-06	3.2E-07	-1.7E-06	1.5E-04
Particulate matter	disease incidence	1.8E-03	0.0E+00	4.3E-06	4.6E-07	3.9E-04	1.8E-05	1.0E-06	-9.0E-06	2.2E-03
Ionising radiation, human health	kBq U235 eq	5.4E+02	0.0E+00	4.6E-02	6.8E-01	5.2E+03	5.4E+00	6.4E+00	-8.6E+00	5.7E+03
Photochemical ozone formation, human health	kg NMVOC eq	4.7E+01	0.0E+00	2.0E-01	6.2E-02	2.0E+01	4.7E-01	5.9E-02	-3.1E-01	6.7E+01
Acidification	mol H+ eq	2.0E+02	0.0E+00	2.7E-01	4.9E-02	3.7E+01	2.0E+00	8.4E-02	-9.4E-01	2.4E+02
Eutrophication, terrestrial	mol N eq	1.5E+02	0.0E+00	8.1E-01	1.6E-01	7.5E+01	1.5E+00	2.1E-01	-1.0E+00	2.2E+02
Eutrophicatio	kg N eq	1.4E+01	0.0E+00	7.4E-02	1.7E-02	7.1E+00	1.4E-01	1.9E-02	-9.6E-02	2.1E+01

Life Cycle phases -->	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL		Total
Resources Use and Emissions								Impacts	Credits	
n, marine										
Ecotoxicity, freshwater	CTUe	6.9E+04	0.0E+00	1.4E+02	1.3E+02	5.6E+04	6.9E+02	1.1E+02	-3.9E+03	1.2E+05
Land use	pt	8.3E+04	0.0E+00	4.7E+01	3.2E+03	5.3E+04	8.3E+02	1.0E+02	-1.6E+04	1.2E+05
Water use	m3 water eq. of deprived water	2.0E+03	0.0E+00	5.2E-01	2.6E+00	4.2E+03	2.0E+01	9.0E+00	-2.2E+01	6.2E+03
Resource use, minerals and metals	kg Sb eq	1.5E+00	0.0E+00	4.4E-06	5.4E-06	3.1E-03	1.5E-02	7.3E-06	-3.8E-02	1.5E+00
Eutrophication, marine	kg N eq	1.4E+01	0.0E+00	7.4E-02	1.7E-02	7.1E+00	1.4E-01	1.9E-02	-9.6E-02	2.1E+01
Ecotoxicity, freshwater	CTUe	6.9E+04	0.0E+00	1.4E+02	1.3E+02	5.6E+04	6.9E+02	1.1E+02	-3.9E+03	1.2E+05
Land use	pt	8.3E+04	0.0E+00	4.7E+01	3.2E+03	5.3E+04	8.3E+02	1.0E+02	-1.6E+04	1.2E+05
Water use	m3 water eq. of deprived water	2.0E+03	0.0E+00	5.2E-01	2.6E+00	4.2E+03	2.0E+01	9.0E+00	-2.2E+01	6.2E+03
Resource use, minerals and metals	kg Sb eq	1.5E+00	0.0E+00	4.4E-06	5.4E-06	3.1E-03	1.5E-02	7.3E-06	-3.8E-02	1.5E+00

Life Cycle phases -->								EOL		
Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	Impacts	Credits	Total
Resource use, fossils	MJ	1.5E+05	0.0E+00	1.7E+02	2.7E+02	2.1E+05	1.5E+03	4.7E+02	-1.1E+03	3.7E+05
Primary energy consumption	MJ	1.5E+05	0.0E+00	1.7E+02	2.7E+02	1.1E+05	1.5E+03	4.7E+02	-1.1E+03	2.6E+05

5.3.3 Data storage

BC-3 Storage Unit

Figure 5.3 below presents the results of the environmental analysis of BC-3 (data storage). According to this, the energy consumption during the use phase is by far the predominant aspect contributing to the environmental impacts from the product's entire life.

Figure 5.3 Distribution of BC-3 environmental impacts by life cycle phase

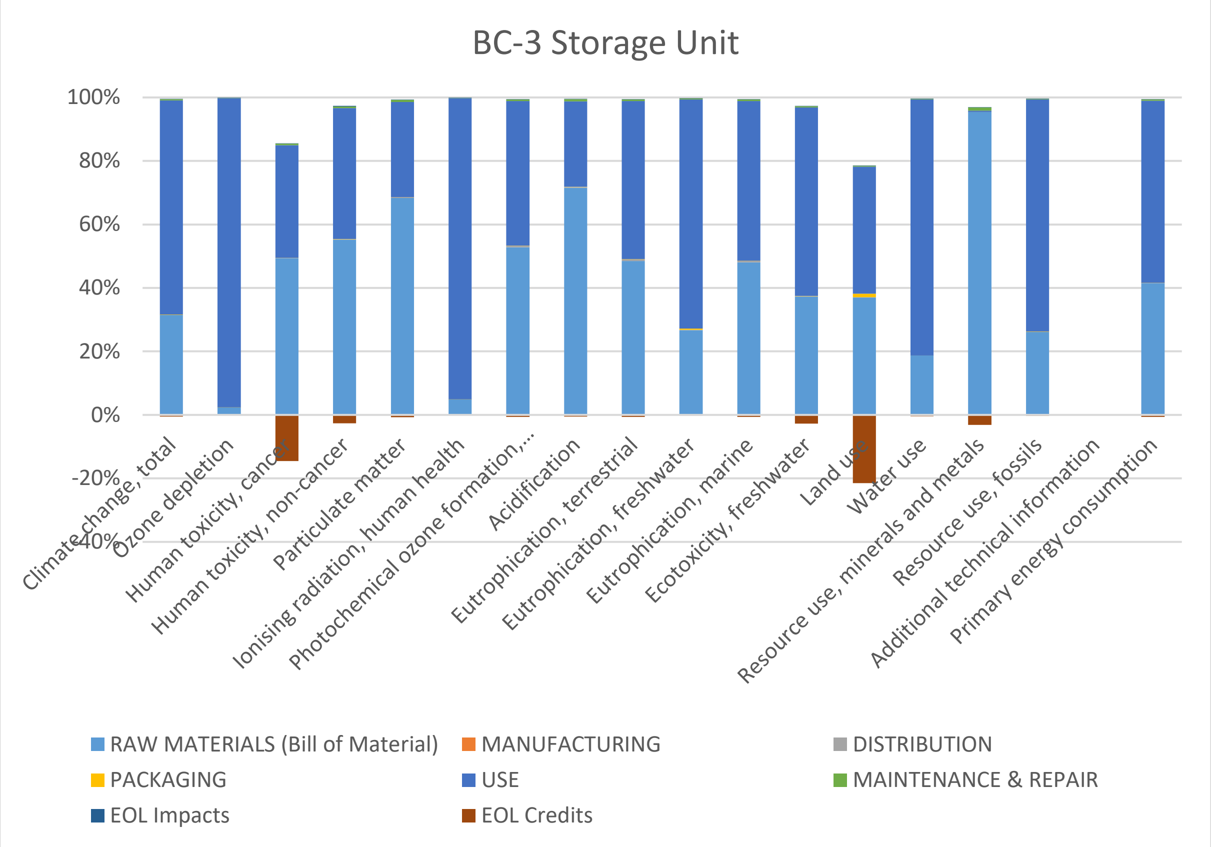


Table 5.29 below presents the Life Cycle Impacts (per unit) of BC-3

Table 5.29 Life Cycle Impact (per unit) of BC3: Data Storage

Life Cycle phases --> / Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL Impacts	EOL Credits	Total
					PEF Impact categories					
Climate change, total	kg CO2 eq	5.7E+03	0.0E+00	1.3E+01	6.6E+00	1.2E+04	5.7E+01	9.1E+00	-9.5E+01	**1.8E+04**
Ozone depletion	kg CFC-11 eq	1.1E-07	0.0E+00	4.8E-12	2.6E-10	4.5E-06	1.1E-09	1.2E-09	-6.4E-09	**4.7E-06**
Human toxicity, cancer	CTUh	2.8E-06	0.0E+00	3.3E-09	2.2E-09	2.0E-06	2.8E-08	1.7E-09	-8.3E-07	**4.1E-06**

Life Cycle phases --> Resources Use and Emissions	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL Impacts	EOL Credits	Total
Human toxicity, non-cancer	CTUh	5.5E-05	0.0E+00	5.9E-08	6.6E-08	4.1E-05	5.5E-07	1.4E-07	-2.7E-06	**9.4E-05**
Particulate matter	disease incidence	8.9E-04	0.0E+00	4.3E-06	2.2E-07	3.9E-04	8.9E-06	2.7E-07	-9.5E-06	**1.3E-03**
Ionising radiation, human health	kBq U235 eq	2.7E+02	0.0E+00	4.6E-02	3.3E-01	5.2E+03	2.7E+00	1.6E+00	-7.3E+00	**5.5E+03**
Photochemical ozone formation, human health	kg NMVOC eq	2.3E+01	0.0E+00	2.0E-01	3.0E-02	2.0E+01	2.3E-01	1.7E-02	-2.7E-01	**4.3E+01**
Acidification	mol H+ eq	9.9E+01	0.0E+00	2.7E-01	2.4E-02	3.7E+01	9.9E-01	2.3E-02	-7.2E-01	**1.4E+02**
Eutrophication, terrestrial	mol N eq	7.3E+01	0.0E+00	8.1E-01	7.8E-02	7.5E+01	7.3E-01	6.2E-02	-9.0E-01	**1.5E+02**
Eutrophication, freshwater	kg P eq	9.2E-03	0.0E+00	3.8E-05	1.4E-04	2.5E-02	9.2E-05	1.4E-05	-9.4E-05	**3.4E-02**
Eutrophication, marine	kg N eq	6.7E+00	0.0E+00	7.4E-02	8.4E-03	7.1E+00	6.7E-02	5.6E-03	-8.3E-02	**1.4E+01**
Ecotoxicity, freshwater	CTUe	3.5E+04	0.0E+00	1.4E+02	6.5E+01	5.6E+04	3.5E+02	3.8E+01	-2.6E+03	**8.9E+04**

Life Cycle phases -->	Unit	RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL		Total
Resources Use and Emissions								Impacts	Credits	
Land use	pt	4.9E+04	0.0E+00	4.7E+01	1.6E+03	5.3E+04	4.9E+02	2.8E+01	-2.8E+04	**7.5E+04**
Water use	m3 water eq. of deprived water	9.7E+02	0.0E+00	5.2E-01	1.3E+00	4.2E+03	9.7E+00	2.6E+00	-2.1E+01	**5.1E+03**
Resource use, minerals and metals	kg Sb eq	7.0E-01	0.0E+00	4.4E-06	2.6E-06	3.1E-03	7.0E-03	2.0E-06	-2.3E-02	**6.9E-01**
Resource use, fossils	MJ	7.6E+04	0.0E+00	1.7E+02	1.3E+02	2.1E+05	7.6E+02	1.5E+02	-1.1E+03	**2.9E+05**
Primary energy consumption	MJ	7.6E+04	0.0E+00	1.7E+02	1.3E+02	1.1E+05	7.6E+02	1.5E+02	-1.1E+03	**1.8E+05**

5.4 BASE CASE LIFE CYCLE COST FOR CONSUMERS

This section presents the results of the Life Cycle Cost (LCC) analysis of the Base-Cases using the Ecoreport tool. In the analysis, all the consumer expenditures throughout the life span of the product are considered, which include:

- Average sales prices of the Base-Cases (in Euro);
- Average installation costs (in Euro);
- Average repair and maintenance costs (in Euro);
- Average electricity rates (in Euro Cent/kWh);
- Average lifetime of the Base-Case (in years);
- Average annual energy consumption (in kWh).

A typical consumer of the server/data storage products will be the owner of the equipment (e.g. data centre / server room). Table 5.30 below presents the Ecoreport outcomes of the LCC calculations for all base-cases per product per year.

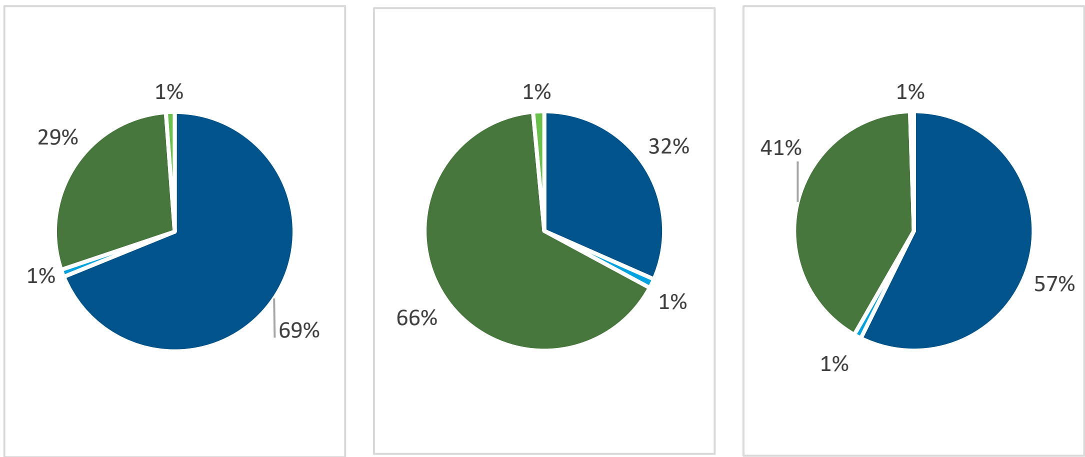
Table 5.30 Life Cycle Costs for all Base Cases per product per year

	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit
Product price, EUR	23,420	8,435	24,400
Installation/ acquisition costs (if any), EUR	340	340	425
Electricity, EUR/year	2,464	4,378	2,922
Repair & maintenance costs, EUR	400	400	220
Total, EUR/year	**8,504**	**6,672**	**7,097**

Figure 5.4 below visually presents the distributions of the values represented in Table 5.30 for all three base cases. It is clear for all base cases the largest costs in each comes from the product prices and electricity costs per year to operate the product. However, each base case cost breakdowns varies dramatically. For example, BC1 has the highest initial product price whereas BC2 requires a significantly lower capital expenditure however, its running costs are dramatically higher, close to seven times BC1 electrical costs. There are similarities across all three base cases with the installation costs, BC3 is slightly more expensive to install than the server products. Meanwhile, BC1 and BC2 have the same repair & maintenance costs, although for BC3 this cost is close to 50% less.

Figure 5.4 Life Cycle Costs for all Base Cases presented as pie charts.

BC-1 Rack Server	BC-2 Blade System	BC-3 Storage unit



Legend: Product price, EUR; Installation/ acquisition costs (if any), EUR; Electricity, EUR/year; Repair & maintenance costs, EUR

5.5 BASE CASE LIFE CYCLE COSTS FOR SOCIETY

The societal life cycle costs are a sum of direct environmental costs, externalities and other indirect costs. The calculations are based on MEErP 2024 tool using the following formula:

Societal LCC = LCC consumer + LCC external.damages

Where:

LCC external.damages = PP damages + Lifetime operating expense (N* OEdamages) + End of Life (EoLdamages)

And

- PPdamages = Impacts (GWP in kg CO2 eq., AP in kg SO2 eq., etc.) in Production and Distribution phase x Damage unit value (in €/kg)
- OEdamages = Impacts in Use Phase x Damage unit value
- EoLdamages = Impacts in End-of-Life Phase x Damage unit value

Table 5.31 below presents the life cycle costs per product per year for society calculated by the factors given in MEErP 2024 tool.

Table 5.31 Total Societal Life Cycle Costs per product per year

	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit
PP damages, EUR	33	2,748	1,376
N*OE damages, EUR	921	1,637	1,639
EoL damages, EUR	-1	-17	-24
Total External Damages, EUR	933	4,369	2,992
LCC (excl. ext. damages), EUR/year)	8,504	6,672	7,097
Total Societal LCC, EUR/year	8,743	7,764	**7,595**
Total External damages as % of Total Societal LCC	10.67%	56.27%	39.3%

5.6 EU TOTALS

5.6.1 Lifecycle Environmental Impact at EU-27 Level

In this section, the environmental impact data is aggregated at the EU-27 level using stock and market data from Task 2. The aggregated results of the life cycle environmental impacts per year corresponding to the EU stock of products are presented in Table 5.32.

Table 5.32 EU Total Annual Impact of Stock of Products

Main life cycle indicators / PEF Impact categories	unit	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit	Total
Climate change, total	kg CO2 eq	37,706	33,341	3,456,785	3,527,832
Ozone depletion	kg CFC-11 eq	1.42E-05	7.0E-06	9.0E-04	9.2E-04
Human toxicity, cancer	CTUh	6.33E-06	7.7E-06	7.8E-04	8.0E-04
Human toxicity, non-cancer	CTUh	1.32E-04	2.1E-04	1.8E-02	1.8E-02
Particulate matter	disease incidence	1.26E-03	3.1E-03	2.5E-01	2.5E-01
Ionising radiation, human health	kBq U235 eq	1.58E+04	8.0E+03	1.1E+06	1.1E+06
Photochemical ozone formation, human health	kg NMVOC eq	6.35E+01	9.4E+01	8.4E+03	8.5E+03
Acidification	mol H+ eq	1.19E+02	3.3E+02	2.6E+04	2.7E+04
Eutrophication, terrestrial	mol N eq	2.37E+02	3.1E+02	2.9E+04	2.9E+04
Eutrophication, freshwater	kg P eq	7.70E-02	6.4E-02	6.6E+00	6.8E+00
Eutrophication, marine	kg N eq	2.23E+01	2.9E+01	2.7E+03	2.7E+03
Ecotoxicity, freshwater	CTUe	1.73E+05	1.7E+05	1.7E+07	1.7E+07
Land use	pt	4.73E+05	1.7E+05	1.5E+07	1.5E+07
Water use	m3 water eq. of deprived water	1.28E+04	8.6E+03	9.9E+05	1.0E+06
Resource use, minerals and metals	kg Sb eq	3.89E-01	2.0E+00	1.3E+02	1.4E+02
Resource use, fossils	MJ	6.53E+05	5.1E+05	5.6E+07	5.7E+07
Primary energy consumption	MJ	326,485.14	364,554.37	**35,149,544.43**	35,840,583.94

Table 5.33 below presents the life cycle environmental impacts of new products.

Table 5.33 EU Total Impact of New Products over their lifetime

Life Cycle phases -->	Unit	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit	Total
		PEF Impact categories			
Climate change, total	kg CO2 eq	9.4E+03	8.3E+03	5.8E+05	5.9E+05
Ozone depletion	kg CFC-11 eq	3.5E-06	1.8E-06	1.5E-04	1.5E-04
Human toxicity, cancer	CTUh	1.6E-06	1.9E-06	1.3E-04	1.3E-04
Human toxicity, non-cancer	CTUh	3.3E-05	5.3E-05	3.0E-03	3.1E-03
Particulate matter	disease incidence	3.2E-04	7.6E-04	4.1E-02	4.2E-02
Ionising radiation, human health	kBq U235 eq	3.9E+03	2.0E+03	1.8E+05	1.8E+05
Photochemical ozone formation, human health	kg NMVOC eq	1.6E+01	2.4E+01	1.4E+03	1.4E+03
Acidification	mol H+ eq	3.0E+01	8.3E+01	4.4E+03	4.5E+03
Eutrophication, terrestrial	mol N eq	5.9E+01	7.8E+01	4.8E+03	4.9E+03
Eutrophication, freshwater	kg P eq	1.9E-02	1.6E-02	1.1E+00	1.1E+00
Eutrophication, marine	kg N eq	5.6E+00	7.3E+00	4.5E+02	4.6E+02
Ecotoxicity, freshwater	CTUe	4.3E+04	4.3E+04	2.8E+06	2.9E+06
Land use	pt	1.2E+05	4.3E+04	2.4E+06	2.6E+06
Water use	m3 water eq. of deprived water	3.2E+03	2.2E+03	1.7E+05	1.7E+05
Resource use, minerals and metals	kg Sb eq	9.7E-02	5.1E-01	2.2E+01	2.3E+01
Resource use, fossils	MJ	1.6E+05	1.3E+05	9.3E+06	9.6E+06
Primary energy consumption	MJ	8.1E+04	9.1E+04	5.8E+06	6.0E+06

5.6.2 Life Cycle Costs for Consumers at EU-27 Level

Table 5.34 below presents the aggregated results of the annual consumer expenditure per Base-Case in the EU-27. This represents the total expenditure at

EU level per year, assuming that the Base-Cases represent the entire installed stock in the EU-27.

Table 5.34 Total Annual Consumer Expenditure in the EU-27 million €

	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit
Product price, EUR/year	32,320	2,952	783,240
Installation/ acquisition costs (if any), EUR/year	469	119	13,643
Electricity, EUR/year	13,612	6,133	562,973
Repair & maintenance costs, EUR/year	552	140	7,064
Total, EUR/year	**48,270**	**10,874**	**1,462,966**

5.6.3 Life Cycle Costs for Society at EU-27 Level

Table 5.35 below presents the total annual social life-cycle costs at EU-27 level. Adding the external costs to society to the LCC gives the total annual social life cycle costs.

Table 5.35 Total annual social life-cycle costs in the EU-27

	BC-1 Rack Server	BC-2 Blade System	BC-3 Storage Unit
PP damages (m €/year)	45.93	961.97	44,176.35
N*OE damages (m €/year)	1244.37	573.44	52,634.45
EoL damages (m €/year)	-1.29	-5.78	-763.28
Total External Damages (m €/year)	1289.01	1,529.64	96,047.52
LCC (excl. ext. damages) (m €/year)	46,953	9,345	1,366,919
Total Societal LCC (m €/year)	48,270	10,874	1,462,966

6 Introduction to Task 6 Design Options

6.1 Identification of design options and assessment of their impacts

This section outlines various design options that have been identified for consideration. These options are presented individually, each representing a distinct approach that may or may not be integrated into subsequent modelling. The purpose of delineating these design options is to facilitate a comprehensive evaluation of potential strategies and solutions. The decision on which options to carry forward will depend on their efficacy in addressing project objectives and constraints. Task 7 activities will amalgamate and synthesize a series of these design options, to form scenario modelling. The inclusion of specific options in Task 7 will be contingent upon their compatibility, feasibility, and alignment.

6.1.1 Server Energy Efficiency Design Options

The Ecodesign regulation currently sets minimum active efficiency values and maximum idle power consumption. This is set for all servers as they enter the market, or to a configuration family. For a configuration family to be compliant, their low-end and high-end performance configurations need to be complaint. These are defined as follows:

- ‘low-end performance configuration’ of a server product family means the combination of two data storage devices, processor with the lowest product of core count and frequency (in GHz) and memory capacity (in GB) that is at least equal to the product of the number of memory channels and the lowest capacity dual in-line memory module (DIMM) (in GB) offered on the server that represents the lowest performance product model within the server product family. All memory channels shall be populated with the same DIMM raw card design and capacity;
- ‘high-end performance configuration’ of a server product family means the combination of two data storage devices, processor with the highest product of core count and frequency and memory capacity (in GB) equal to or greater than 3 times the product of the number of CPUs, cores and hardware threads that represents the highest performance product model within the product family. All memory channels shall be populated with the same DIMM raw card design and capacity;

For the following design options, energy efficiency criteria for server configuration families will need to be met not only by the low-end and high-end performance configurations, but also on *the typical configuration*. This configuration is defined as: "*a product configuration that lies between the Low-end Performance and High-end Performance configurations and is representative of a deployed product with high volume sales."*

Ecodesign 2019/424 currently sets the active efficiency requirement for servers at:

Table 6.1 Active state efficiency requirements in 2019/424

Product type	Minimum active state efficiency
1-socket servers	9.0
2-socket servers	9.5
Blade or multi-node servers	8.0

The study team has used the SERT threshold tool dataset[232] to analyse the impacts of the current regulatory requirements and to estimate the impacts of Design Options. The SERT® Suite offers an initial estimate of server efficiency across a wide range of application environments. It has been implemented and tested on various 64-bit processors, operating systems, and JVMs, demonstrating scalability up to 8 processor sockets and 64 nodes. The server under test (SUT) can be either a single stand-alone server or a multi-node server set. Multi-node SUTs consist of server nodes that rely on shared infrastructure such as backplanes, power supplies, fans, or other components, commonly referred to as blade servers or multi-node servers. The dataset includes products with different form factors from 2016 to 2021, with rack servers making up 75% and blade servers 16% of the dataset. Since 2-socket servers account for over 50% of the SERT dataset, the analysis primarily focuses on this significant market segment. Tower servers represent about 8.7% of the dataset. The dataset encompasses products with low-end, high-end, and typical performance configurations within a server product family. It has been observed that product performance and efficiency significantly improves with the introduction of new chipsets with a relatively flat energy consumption and these trends will continue in the future. To better reflect the current market offerings and based on the typical product development cycles, only models certified from 2019 to 2021 are included in the analysis. This ensures that the models in the dataset are representative of the current models sold in the market. The server market is segmented into Original Equipment Manufacturers (OEMs) and Original Device Manufacturers (ODMs). AI accelerators are typically not used in commodity servers. Most of the ODM servers are inherently more efficient as they are typically designed to maximise that organisations workloads and infrastructure layout. The highly customised design of these products for very specific use cases makes it difficult to include the same in the scope of the regulation. It is for these reasons that a number of scope extensions are currently present in Regulation 2019/424, and that most of them are proposed to be kept. The table below presents the pass rate for the current requirements using the SERT tool dataset:

Table 6.2 Pass rate of SERT database under efficiency requirements in 2019/424

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	97	60
2	Rack	100	159
2	Blade or multi-node servers[233]	100	46
4	Rack	100	25
4	Blade or multi-node	100	7

6.1.1.2 Design Option 1: Active efficiency aligned with EU GPP

This design option proposes to increase this minimum active state efficiency. The first level proposed is to raise the efficiency levels to be in line with the EU Green Public Procurement minimum requirements, such that:

[232] The dataset used is The Green Grid SERT dataset from the 12th of January 2024.

[233] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

Table 6.3 Proposed active efficiency requirements from EU GPP

Number of sockets	Product type	Minimum Active efficiency
1	Rack	13.0
2	Rack	18.0
2	Blade or multi-node servers	20.0
4	Rack	16.0
4	Blade or multi-node	9.6

**Note that although tower servers are defined in the GPP, they are classified as small-scale servers and are covered in the Ecodesign 617/2013 regulation.*

According to the SERT threshold tool dataset, these settings incur the following pass rates:

Table 6.4 Pass rate of SERT database under EU GPP efficiency requirements

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	88	76
2	Rack	84	152
2	Blade or multi-node servers[234]	83	60
4	Rack	88	24
4	Blade or multi-node	100	10

According to this dataset, this measure will at most remove 17% of the server families in the SERT dataset. More recent servers registered have a higher pass rate.

6.1.1.3 Design Option 2: Higher-rate active efficiency

Considering how much of the dataset already pass the EU GPP efficiency requirements, the active efficiency requirement could be considered at a higher level.

Table 6.5 Proposed higher-rate active efficiency requirements

Number of sockets	Product type	Minimum Active efficiency
1	Rack	15.0
2	Rack	20.0
2	Blade or multi-node servers	20.0
4	Rack	16.0
4	Blade or multi-node	12.0

[234] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

According to the SERT threshold tool data set, these settings incur the following pass rates:

Table 6.6 Pass rate of SERT database under higher rate active efficiency limits

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	82	76
2	Rack	82	152
2	Blade or multi-node servers[235]	83	60
4	Rack	88	24
4	Blade or multi-node	100	10

According to this dataset, this measure will at most remove 18% of the server families in the SERT dataset.

6.1.1.4 Design Option 3: Stricter active efficiency

Considering a stricter active efficiency wherein 75% of the models from the SERT threshold tool meet the requirement.

Table 6.7 Proposed stricter-rate active efficiency requirements

Number of sockets	Product type	Minimum Active efficiency
1	Rack	15.33
2	Rack	23.36
2	Blade or multi-node servers	21.09
4	Rack	20.32
4	Blade or multi-node	22.44

According to the SERT threshold tool dataset, these settings incur the following pass rates:

Table 6.8 Pass rate of SERT database under stricter-rate active efficiency limits

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	75%	76
2	Rack	75%	152
2	Blade or multi-node servers[236]	75%	60
4	Rack	75%	24
4	Blade or multi-node	75%	10

[235] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

[236] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

According to this dataset, this measure will remove 25% of the server families from the SERT dataset.

6.1.1.5 DO1, DO2 and DO3 effects on base cases

For the Base cases modelling, this would change performance such that:

Table 6.9 Base case performance against a range of considered efficiency DOs

Product modelled	Active efficiency modelled	Idle consumption modelled (W)	Server weighted performance
Base Case 1	27.1	136	7945
Base Case 1 after DO1: EU GPP requirements	30.2	142	9196
Base Case 1 after DO2: high-rate active efficiency requirements	30.4	141	9269
Base Case 1 after DO3: Stricter active efficiency requirements	31.6	142.5	9784.8
Base Case 2	31.2	166	17934
Base Case 2 after DO1: EU GPP requirements	33.2	172	20015
Base Case 2 after DO2: high-rate active efficiency requirements	33.2	172	20015
Base Case 2 after DO3: Stricter active efficiency requirements	34.2	182.8	21716.8

For the base case modelling purposes, the following changes are made:

Table 6.10 Modelling changes for DO1, DO2 and DO3

DO	Base Case	Change made	Percentage difference
1	1	Cost increase	0%
1	1	Active consumption figures reduced by:	11%
1	1	Idle consumption changed by:	+4%
1	1	Performance figures increased by:	16%
1	2	Cost increase	0%
1	2	Active consumption figures reduced by:	7%
1	2	Idle consumption reduced by:	6%
1	2	Performance figures increased by:	15%
2	1	Cost increase	0%
2	1	Active consumption figures reduced by:	12%
2	1	Idle consumption reduced by:	3%
2	1	Performance figures increased by:	17%

DO	Base Case	Change made	Percentage difference
2	2	Cost increase	0%
2	2	Active consumption figures reduced by:	8%
2	2	Idle consumption changed by:	5%
2	2	Performance figures increased by:	16%
3	1	Cost increase	0%
3	1	Active consumption figures reduced by:	16%
3	1	Idle consumption reduced by:	5%
3	1	Performance figures increased by:	23%
3	2	Cost increase	0%
3	2	Active consumption figures reduced by:	10%
3	2	Idle consumption reduced by:	10%
3	2	Performance figures increased by:	21%

6.1.1.6 Server Idle efficiency

The Ecodesign 2019/424 regulation currently sets maximum idle power consumption values for servers with a base allowance and an additional power allowance due to additional components. These are defined as:

Table 6.11 Base idle state power allowances for Ecodesign 2019/424

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

Table 6.12 Additional idle power allowances for extra components under 2019/424

System characteristics	Applies to	Additional idle power allowance
CPU performance	All servers	1 socket: 10 x Perf CPU W 2 socket: 7 x Perf CPU W
Additional PSU	PSU installed explicitly for power redundancy	10 W per PSU
HDD or SSD	Per installed HDD or SSD	5.0 W per HDD or SSD
Additional memory	Installed memory greater than 4 GB	0.18 W per GB
Additional buffered DDR Channel	Installed buffered DDR channels greater than 8 channels	4.0 W per buffered DDR channel
Additional I/O devices		< 1 GB/s: No allowance
		= 1 GB/s: 2.0 W/Active Port

System characteristics	Applies to	Additional idle power allowance
	Installed devices greater than two ports of >1 Gbit, onboard Ethernet	> 1 GB/s and <10 Gb/s: 4.0 W/Active port
		> 10 GB/s and <25 Gb/s: 15.0 W/Active port
		> 25 GB/s and <50 Gb/s: 20.0 W/Active port
		>50 Gb/s 26.0 W/Active Port

Idle power kept as it is

For servers on the market since 2019 on the SERT database, the current idle maximum power consumption metric would allow for 13% of servers to pass without the adders metrics. However, including the adders metric regarding additional memory, this pass rate is increased to 28%. Furthermore, the CPU performance additional power allowance brings the total pass rate to 100%. Therefore, as the metric is currently operating it has limited effect at limiting idle power consumption. It is therefore suggested to consider a new metric to limit the consumption of idle energy.

6.1.1.7 Design Option 4: Idle consumption to workload ratio

A new idle efficiency metric is proposed here, to ensure that idle consumption is being optimised for use in the market, but also allow for servers with performance ratios to be included. This metric is as follows:

$$Idle\ to\ workload\ ratio = \frac{idle\ power\ (in\ Watts)}{100\%\ SSJ\ workload\ power\ (in\ Watts)}$$

This metric ensures that the smaller the ratio, the smaller the idle power contribution compared to the SSJ workload contribution. The SSJ worklet chosen represents a worklet with both CPU processing and memory activities. Therefore, a smaller ratio will mean that the idle power consumption is scaled to be more efficient versus an active workload parameter. This metric therefore serves as a method to remove products which are operating inefficiently in idle versus their maximum power consumption. As this metric is a ratio that includes the SSJ workload, this includes insight into the specificities and components of the server, such as CPU power and memory, and hence doesn't require additional allowances to be included.

Applying this idle to workload ratio to servers on the market since 2019 on the SERT database, if a pass rate of needing the idle to workload ratio to be smaller than 0.38 was set, then 75% of the BC1 servers would pass the metric. And for BC2 if idle to workload ratio was set to be smaller than 0.16, then 75% of the BC2 servers would pass the metric.

Manufacturers are already designing systems to maximise idle efficiency and power scaling to maximise their SERT scores, so there is no additional increase in cost factored into this DO.

The effect of this measure on the Base cases 1 and 2 has been estimated in Table 6.13.

Table 6.13 Modelling changes for DO4

DO	Base Case	Change made	Percentage difference
4	1	Cost increase	0%
4	1	Active consumption figures reduced by:	10%
4	1	Idle consumption reduced by:	7%
4	1	Performance figures increased by:	14%
4	2	Cost increase	0%
4	2	Active consumption figures reduced by:	1.3%
4	2	Idle consumption reduced by:	11%
4	2	Performance figures increased by:	2%

6.1.1.8 Design Option 5: Processor management functions to be mandated and shipped enabled.

The following Design option is considered:

Computer servers shipped onto the EU market must have the following power management functions and enabled by default, when shipped. All processors must be able to reduce power consumption in times of low utilisation by reducing voltage and/or frequency through Dynamic Voltage and Frequency Scaling (DVFS). Note whilst DVFS is commonly referred to across the industry there is no documented definition.

This measure is in two parts: the inclusion of the power management functions DVFS, and the enabling of these by default.

DVFS is a common metric which is required by the Energy Star programme. It allows for greater energy savings when switching to idle. As the feature is common, it is expected the cost on the base case to be minimal, and idle consumption to be lowered slightly.

The enabling of these by default is not expected to have any additional costs, as most servers are already equipped with this functionality. However, it is expected to lower consumption, as having the feature enabled by default will increase its use, and hence reduce idle consumption. This reduction is expected to reduce overall server energy consumption by 5%.[237,238] This reduction of 5% energy use can be applied to BC1 and BC2 modelling, with no changes to cost, materials or life expectancy.

[237] Power-performance tradeoffs in data center servers: DVFS, CPU pinning, horizontal, and vertical scaling - ScienceDirect {accessed 26/04/2024}

[238] Ecodesign preparatory study on Enterprise servers and data equipment, Bio Deloitte, 2015

6.1.2 Data storage product energy efficiency design options

6.1.2.1 Design option 6: Including energy efficiency requirements on data storage products

Set a SNIA performance level on storage systems

The following energy efficiency feature is set as a requirement for data storage devices. This setting aligns with the Energy Star criteria such that: each optimal configuration point submitted for a block I/O storage product or storage product family must meet the following applicable active state requirements in Table 6.14 for each workload type. For streaming workloads, the data storage product must meet either the sequential read or the sequential write requirement.

Table 6.14 Active state requirements for Block I/O Storage products

Workload Type Specific	Specific Workload Test	Minimum Performance/Watt Ratio	Applicable Units of Ratio
Transaction	Hot Band	28.0	IOPS/Watt
Streaming	Sequential Read	2.3	MiBS/Watt
Streaming	Sequential Write	1.5	MiBS/Watt

Where the optimal configuration is defined as the products maximum peak energy efficiency performance (performance/watt) for a given workload type. This configuration is provided by the manufacturer and may be optimized for the transaction, streaming and composite workload types.

The Hot Band workload test is an I/O load consisting of a collection of read and write requests that models areas of higher frequency I/O activity over the addressed data. This is measured in I/O per second per Watt (or IOPS/Watt).

The Sequential read workload test is an I/O load consisting of consecutively issued read requests to adjacently addressed data. This is measured in MiB (a binary megabyte, 1 MiB = 1,048,576 Byte) per second per Watt (or MiBS/Watt).

The Sequential write workload test an I/O load consisting of consecutively issued write requests to adjacently addressed data. This is measured in MiB (a binary megabyte, 1 MiB = 1,048,576 Byte) per second per Watt (or MiBS/Watt).

Power management functions: Capacity optimisation methods data be included for storage

The following energy efficiency feature is set as a requirement for data storage devices. A storage product shall make available to the end user configurable / selectable features listed in Table 6.15 in quantities greater than or equal to those listed in Table 6.16.

Table 6.15 Recognised COM features[239]

Feature	Verification Requirement
COM: Thin Provision	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Data Deduplication	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Compression	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Delta Snapshots	SNIA Verification test, following ISO/IEC 24091:2019 standard

Table 6.16 COM reqs for Disk Set & NVSS Disk Set Access Online 2, 3 & 4 Systems

Storage Product Category	Minimum number of COMs required to be made available
Online 2	1
Online 3	2
Online 4	3

COMs are defined as **Capacity Optimising Methods**, resulting in the reduction of actual data stored on storage devices through a combination of hardware and / or software. These include:

- **Thin Provisioning**: A technology that allocates the physical capacity of a volume or file system as applications write data, rather than allocating all the physical capacity at the time of provisioning.
- **Data Deduplication**: The replacement of multiple copies of data – at variable levels of granularity – with references to a shared copy in order to save storage space and/or bandwidth.
- **Compression**: The process of encoding data to reduce its size. For the purpose of this specification, only lossless compression (i.e., compression using a technique that preserves the entire content of the original data, and from which the original data can be reconstructed exactly) is recognized.
- **Delta Snapshots**: A type of point-in-time copy that preserves the state of data at an instant in time by storing only those blocks that are different from an already existing full copy of the data.

Where "online" is set for storage which is accessible MaxTTFD ≤ 80ms. Maximum Time to First Data is the time required to start receiving data from a storage product to satisfy a read request for arbitrary data.

Impacts on Base case 3 modelling

The measures considered here are taken from the Energy Star data storage product requirements. According to Energy Star: *Data storage products that qualify for the ENERGY STAR are made by leading OEMs. They usually cost and perform the same (or better) than standard products, but they are designed and/or constructed*

[239] ISO/IEC 24091:2019(en), Information technology — Power efficiency measurement specification for data center storage

to save energy.[240] We therefore assume that for our Base case 3 modelling, there are no additional costs for including these measures.

With regards to energy savings, according to Energy Star 2014 survey indicates that 60% of data centre administrators already use data compression, 55% use deduplication technology, and 62% use snapshot technology. 40% of IT administrators are also noted to use thin provisioning. The different techniques are estimated to make savings such that a snapshot copy would use 10 to 20% of the base volume and deduplication can save data stored from 30-95%. Therefore, it is a conservative estimation that 75% of data centres already have data storage capacity optimisation methods, and hence only 25% would benefit from the new regulatory measures. Assuming these measures would deliver 40% saving in data storage, the base case 3 modelling can assume that this Design option would provide an overall 10% saving to the average purchaser. This modelling method is conservative as it does consider potential effects of reduced number of data storage products required.

6.1.3 Material efficiency

6.1.3.1 Design Option 7: Improved disassembly, repairability and recycling on servers

This Design option is composed of multiple measures to improve the disassembly, the repairability and recycling of servers.

Disassemblability requirements by class B generalist, workshop environment class A, using tools from A, B or C nomenclature.

The following measure is considered to favour repairability, reuse, refurbishment and recycling of servers and data storage products.

Servers must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. The definition of "disassembly" is marked as "a process whereby a product is taken apart in such a way that is could subsequently be reassembled and made operational". This is the process for replacement of parts. The requirements follow the definitions from EN 45554, such that:

- **Generalist (Class B)**: repair, reuse or upgrade process cannot be carried out by layman (class A) but can be carried out by a person with a general knowledge of basic repair, reuse or upgrade techniques and safety precautions.
- **Workshop environment (Class B):** If a repair, reuse or upgrade process cannot be carried out in the environment where the product is in use (class A) but does not require a production-equivalent environment.
- With **tools** meeting the requirements of:
  - **Class A:** feasible with no tool; or with basic tools (screwdriver, hex key, pliers, spanner)
  - **Class B:** Product group specific tools
  - **Class C:** other commercially available tools

Furthermore, fasteners should all be reusable (class A) or removable (class B), following the definitions below:

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Fastener types:

- **Reusable (class A):** An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process.
- **Removable (class B):** An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for the repair, reuse or upgrade process.

This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

For the PSU and data storage drives, the tool requirement for removal for replacement/upgrade shall be only of class A.

This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As Motherboards are connected to all components, these cant be set at a higher stringency level. However, it is noted that PSUs and data storage drives are typically set aside from the rest of the server design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

This measure is expected to have some slight cost increases to redesign products for disassembly. However, these costs should be minimised once the disassemblability design features have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment, reuse of parts and recycling of server and data storage products.

Information provided to professionals on how to disassemble.

This measure follows from the previous one, to ensure that repair professionals have the required information to appropriately disassemble, and hence repair, servers and data storage products. This would take the form of:

- the unequivocal product identification;
- a disassembly map or exploded view;
- wiring and connection diagrams, as required for failure analysis;
- electronic board diagrams;
- a list of necessary repair and test equipment;
- technical manual of instructions for repair, including marking of the individual steps;
- diagnostic fault and error information (including manufacturer-specific codes, where applicable);
- component and diagnosis information (such as minimum and maximum theoretical values for measurements);
- instructions for software and firmware (including reset software);

- information on how to access professional repair, including the internet webpages, addresses and contact details of professional repairers registered in accordance with points 2 (a) and (b).

This information shall be made available on the manufacturers website, indicating the process for professional repairers to register for access to information.

This measure is estimated to have some additional costs to provide the administration for the information provision. The benefits are that this may improve the rate of repair of products (hence extend life expectancy), refurbishments, reuse of components and recycling.

Availability of spare parts

This measure is considered to ensure that repair can be done on servers.

Manufacturers, importers or authorised representatives of computer servers shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market:

- memory cards
- CPU
- Motherboard
- Graphic cards
- PSU
- Chassis
- Batteries
- Fans
- Integrated switch
- RAID controllers
- Network interface cards

This measure is expected to have a small additional cost in order for manufacturers to ensure that they have spare parts available as they ship. The benefits are that this may improve the rate of repair of products (hence extend life expectancy).

Preventing parts pairing

The following measure is considered to favour repairability, reuse and refurbishment of servers and their components.

For serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement;

Whereby a serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device;

This shall cover the following components: CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

These measures are expected to have an administrative cost to create and host websites to provide access to repairers to serialised software or firmware tools. However, these costs should be minimised once the processes have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment and reuse of parts for server and data storage products.

Provision of hardware component level performance and material content compatibility in information sheet.

This measure is considered for that recycling industry can better target their recycling efforts to recover these materials.

Servers should be sold with an Ecodesign information sheet which details the following components, along with their performance capabilities and compatibility metrics (including pins design and number).

Indicative weight ranges of bulk materials and specific targeted ranged for the following critical raw materials:

- - tantalum in all components (weight range: less than 0,01 g, between 0,01 g and 0,1 g, above 0,1 g);
- - gold in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- - Germanium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- - Dysprosium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- - Silicon in all components (weight range: less than 5 g, between 5 g and 25 g, above 25 g);

This should cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: Cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). This list will allow recyclers to identify which component streams will have the most concentrated CRM.

This measure is estimated to have not to have any additional cost as it is not a material impact but an administrative burden for manufacturers to track their components. The benefits are that this may improve the rate of recycling.

6.1.3.2 Design Option 8: Improved disassembly, repairability and recycling on data storage products

This Design option is composed of multiple measures to improve the disassembly, the repairability and recycling of data storage products.

Disassemblability requirements by class B generalist, workshop environment class A, using tools from A, B or C nomenclature.

The following measure is considered to favour repairability, reuse, refurbishment and recycling of servers and data storage products.

Data storage products must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. These definitions follow EN 45554, such that:

- **Generalist (Class B)**: repair, reuse or upgrade process cannot be carried out by layman (class A) but can be carried out by a person with a general knowledge of basic repair, reuse or upgrade techniques and safety precautions.
- **Workshop environment (Class B):** If a repair, reuse or upgrade process cannot be carried out in the environment where the product is in use (class A) but does not require a production-equivalent environment.
- With **tools** meeting the requirements of:
  - **Class A:** feasible with no tool; or with basic tools (screwdriver, hex key, pliers, spanner)
  - ***Class B:*** *Product group specific tools*
  - ***Class C:*** *other commercially available tools*

Furthermore, fasteners should all be reusable (class A) or removable (class B), following the definitions below:

Fastener types:

- **Reusable (class A):** An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process.
- **Removable (class B):** An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for the repair, reuse or upgrade process.

This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

For the PSU and storage drives, the tool requirement for disassembly shall be only of class A.

This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As Motherboards are connected to all components, these can't be set at a higher stringency level. However, it is noted that PSUs and storage drives are typically set aside from the rest of the device design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

This measure is expected to have some slight cost increases to redesign products for disassembly. However, these costs should be minimised once the disassemblability design features have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment, reuse of parts and recycling of server and data storage products.

Information provided to professionals on how to disassemble.

This measure follows from the previous one, to ensure that repair professionals have the required information to appropriately disassemble, and hence repair, servers and data storage products. This would take the form of:

- the unequivocal product identification;
- a disassembly map or exploded view;
- wiring and connection diagrams, as required for failure analysis;
- electronic board diagrams;
- a list of necessary repair and test equipment;
- technical manual of instructions for repair, including marking of the individual steps;
- diagnostic fault and error information (including manufacturer-specific codes, where applicable);
- component and diagnosis information (such as minimum and maximum theoretical values for measurements);
- instructions for software and firmware (including reset software);
- information on how to access professional repair, including the internet webpages, addresses and contact details of professional repairers registered in accordance with points 2 (a) and (b).

This information shall be made available on the manufacturers website, indicating the process for professional repairers to register for access to information.

This measure is estimated to have some additional costs to provide the administration for the information provision. The benefits are that this may improve the rate of repair of products (hence extend life expectancy), refurbishments, reuse of components and recycling.

Availability of spare parts

This measure is considered to ensure that repair can be done on servers.

Manufacturers, importers or authorised representatives of data storage products shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market:

- memory cards
- CPU
- Motherboard
- Graphic cards
- PSU
- Chassis
- Batteries
- Fans
- Integrated switch
- RAID controllers

- Network interface cards

This measure is expected to have a small additional cost in order for manufacturers to ensure that they have spare parts available as they ship. The benefits are that this may improve the rate of repair of products (hence extend life expectancy).

Preventing parts pairing

The following measure is considered to favour repairability, reuse and refurbishment of servers and their components.

For serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement;

Whereby a serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device;

This shall cover the following components: CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

These measures are expected to have an administrative cost to create and host websites to provide access to repairers to serialised software or firmware tools. However, these costs should be minimised once the processes have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment and reuse of parts for server and data storage products.

Provision of hardware component level performance and material content compatibility in information sheet.

This measure is considered for that recycling industry can better target their recycling efforts to recover these materials.

Data storage products should be sold with an Ecodesign information sheet which details the following components, along with their performance capabilities and compatibility metrics (including pins design and number).

Indicative weight ranges of bulk materials and specific targeted ranged for the following critical raw materials:

- tantalum in all components (weight range: less than 0,01 g, between 0,01 g and 0,1 g, above 0,1 g);
- gold in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- Germanium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- Dysprosium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);
- Silicon in all components (weight range: less than 5 g, between 5 g and 25 g, above 25 g);

This should cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: Cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). This list will allow recyclers to identify which component streams will have the most concentrated CRM.

This measure is estimated to have not to have any additional cost as it is not a material impact but an administrative burden for manufacturers to track their components. The benefits are that this may improve the rate of recycling.

6.1.3.3 Effects of DO7 and DO8 on the base cases

The principal effect of these measures together are:

- An increased cost to manufacturers of servers and data storage products, in order to facilitate a new design which is disassemblable, providing information to repairers on how to disassemble. This is estimated to cost an additional 5% to the product.
- An increase in manufacturer cost to have spare parts available in stock. This is estimated to cost an additional 5% to the product.
- The additional material impacts of spare parts used in the repair. For servers, it is noted in Task 3, section 3.3.4, that the most likely component failure is the PSU and the motherboard. We shall mark this as a 0.5% increase in the use of both of those parts. For data storage products, Task 3, section 3.3.4 noted that HDDs last for 1.5 million hours, versus 2 million hours for SSD. These hours estimate a rate of failure for SSDs after 228 years and 171 years for HDDs. We therefore estimate a replacement rate for HDDs of 0.5% per year, and 0.4% per year for SSDs, which will be used as increased materials requirements reference.
- The lifetime of a server or data storage product is estimated to increase by 50% when the product is repaired. We estimate that these measures will increase the rate of repair by 10%. Therefore, the average product life expectancy will increase by 5%.
- According to the Task 3, Table 3.6, the current reuse of electronic components in servers is only 1%, and 25% for data storage products. Assuming these measures double the reuse of electronic components, we model this in the model such that the R1 recycled content of electronic components in the inputs are doubled.
- The measures for improved disassemblability and information provision, is estimated to provide improved identification, and reduced effort for material recycling. Hence this increases the business case and reduce the costs for businesses to collect and recycle materials. Therefore, we assume that collection rates are increased from 40% to 50%, which increases the R2 recycling output rates in the Ecoreport tool.

6.1.4 Design Option 9: Combined measures servers, BC1 and BC2

For servers, BC1 and BC2, the following DOs have been combined:

- DO3 stricter-active efficiency server
- DO4 idle consumption to workload ratio
- DO5 processor management function
- DO7 material efficiency

This design option combines the DO3, DO4, DO5 and DO7.

For Base case modelling, DO3 and DO4 would change performance as given in Table 6.17 with additional 5% reduction in idle consumption due to DO5. DO7 will increase the cost by 10%.In this DO, the pass rate for BC1 will be 65% and for BC2 60%.

Table 6.17 Modelling changes for DO9

DO	Base Case	Change made	Percentage difference
9	1	Cost increase	10%
9	1	Active consumption figures reduced by:	19%
9	1	Idle consumption reduced by:	2%
9	1	Performance figures increased by:	27%
9	2	Cost increase	10%
9	2	Active consumption figures reduced by:	8.1%
9	2	Idle consumption reduced by:	7%
9	2	Performance figures increased by:	15%

6.1.5 Design Option 10: Combined measures data storage products, BC3

The data storage product combined DO should consider the measures of DO6 on energy efficiency, and DO8 on material efficiency. These measures do not directly clash, and hence the impacts on data storage products can be directly summed.

6.1.5.1 DO6 energy efficiency

The Base Case 3 modelling can assume that this Design option would provide an overall 10% saving to the average purchaser.

We therefore assume that for our Base Case 3 modelling, there are no additional costs for including these measures.

6.1.5.2 DO8 material efficiency

The principal effect of these measures together are:

- An increased cost to manufacturers of servers and data storage products, in order to facilitate a new design which is disassemblable, providing information to repairers on how to disassemble. This is estimated to cost an additional 5% to the product.
- An increase in manufacturer cost to have spare parts available in stock. This is estimated to cost This is estimated to cost an additional 5% to the product.

- The additional material impacts of spare parts used in the repair. For servers, it is noted in Task 3, Section 3.3.4, that the most likely component failure is the PSU and the motherboard. We shall mark this as a 0.5% increase in the use of both of those parts. For data storage products, Task 3, Section 3.3.4 noted that HDDs last for 1.5 million hours, versus 2 million hours for SSD. These hours estimate a rate of failure for SSDs after 228 years and 171 years for HDDs. We therefore estimate a replacement rate for HDDs of 0.5% per year, and 0.4% per year for SSDs, which will be used as increased materials requirements reference.
- The lifetime of a server or data storage product is estimated to increase by 50% when the product is repaired. We estimate that these measures will increase the rate of repair by 10%. Therefore, the average product life expectancy will increase by 5%.
- According to Task 3,Table 3.6, the current reuse of electronic components in servers is only 1%, and 25% for data storage products. Assuming these measures double the reuse of electronic components, we model this in the model such that the R1 recycled content of electronic components in the inputs are doubled.
- The measures for improved disassemblability and information provision, is estimated to provide improved identification, and reduced effort for material recycling. Hence this increases the business case and reduce the costs for businesses to collect and recycle materials. Therefore, we assume that collection rates are increased from 40% to 50%, which increases the R2 recycling output rates in the Ecoreport tool.

6.1.6 Information sharing

The following measures may have benefits at the level of the datacentre system, as they encourage better product utilisation, datacentre facilities management and improved purchasing practices. These are therefore not expected to have direct impacts on the Base Cases to be modelled in the Task 6. However, their impacts will be considered in the Task 7 system impacts.

6.1.6.1 Data Sharing

Server real time utilisation and power consumption reporting

The following design option is considered:

A computer server must provide real-time data on input power consumption (W) and average utilisation of all logical CPUs. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Processor utilization: Average utilization must be estimated for each logical CPU that is visible to the OS and must be reported to the operator or user of the computer server through the operating environment (OS or hypervisor); This should be reported under the ITEUSV ISO/IEC 30134-5:2017 metric.

Input power: Measurements must be reported with accuracy of at least ±5% of the actual value, with a maximum level of accuracy of ±10W for each installed PSU (i.e., *power reporting accuracy for each power supply is never required to be better than ± 10 watts) through the operating range from Idle to full power;*

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to increase product utilisation and therefore decrease the total need for hardware.

Server thermal management and monitoring

The following design option is considered:

A computer server must provide real-time data on inlet air temperature (°C) monitoring and fan speed management capability that is enabled by default. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Inlet air temperature: Measurements must be reported with an accuracy of at least ±2°C.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

Data storage products performance reporting

The following design option is considered:

Data storage products with an Online 3 and Online 4 capability shall be capable of measuring and reporting the following;

- Input Power, in watts. Input power measurements must be reported with accuracy within ±5% of the actual value for measurements greater than 200 W, through the full range of operation. For measurements less than or equal to 200 W, the accuracy must be less than or equal to 10 W multiplied by the number of installed PSUs; and
- Inlet Air Temperature, in degrees Celsius, with accuracy of ± 2°C.

The data shall be made available in a published or user-accessible format that is readable by third-party, non-proprietary management systems. This data shall be available over a standard network for end users and third-party management systems.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with.

The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

6.1.6.2 Labelling for server products

The following design option is considered:

Servers should be sold with an energy label which includes the following information:

- Server form factor
- Server active efficiency
- Server active efficiency score
- Idle power consumption (in Watts)
- ASHRAE temperature range

For servers which are part of a server configuration family, the "typical server configuration" data should be reported.

This measure could also be considered to be run via a QR code set directly on the server which links to a webpage with the information.

This measure is estimated to have not to have any additional cost than that of the typical server configuration testing. However, that test is currently required under Energy star, and will be required under the above Ecodesign active efficiency and idle consumption design options.

This measure is expected to show benefits to encourage the purchase of more efficient servers over time. In this manner, the measure is expected to have a system improvement effect and not an effect on the Base case modelling.

6.1.7 Product exemptions and scope

Review from Phase 1 the exemptions and scope changes proposed to the regulation. These measures will not affect the Base case modelling, and hence will not be considered under the Task 6 modelling. However, they may have an effect under the total server and data storage impacts which will be modelled in Task 7.

Server appliances

Under this design option, the server appliances product will be brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Fully fault tolerant

Under this design option, the fully fault tolerant servers are brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Hyperconverged servers

Under this design option, the hyperconverged servers are brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

Hyperconverged Server will be defined under this design option as: *A highly integrated server which contains the additional features of large network equipment and storage products.*

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Large servers

Large servers are currently out of scope from SPEC SERT, EPEAT and IEC 21836:2020. They therefore do not have an energy measurement standard.

Under this design option, we propose to include large servers into the regulation, but kept out of scope of: the PSU requirements set out in Annex II point 1.1, the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424. Most large servers would also be exempt from the information requirements from Annex II 3.1 as they generally meet the exemption criteria of being "*custom made servers, made on a one-off basis"* as currently set in the regulation.

This will ensure that large server providers must provide firmware support for 6 years, allow for part harvesting, provide availability of spare parts, disassemblability and repair, along with information provision on materials used.

6.1.8 Other measures not taken forward

The scope of the review study had set out a number of aspects to consider in the Phase 1 of the study. These elements were complimented with the stakeholder engagement and research undergone in this study to determine what design options to consider. Below are noted the elements which were considered for design option, but not taken forward, along with the reasoning for it. For more details on these decisions, please refer to the Phase 1 report.

PSU energy efficiency metrics

This energy efficiency metric is not being proposed for increase, as Phase 1 research shows that the current regulation already requires best in class PSUs for servers and data storage products.

Standby readiness

Given this functionality is not currently available on the market and that consumer demand for this functionality appears low, this functionality will not be set as a design option.

DC power supply

The current evidence does not support the argument that DC servers systems are more efficient than AC server systems. Therefore, this functionality is not set as a design option in this study.

High Performance Computing and servers with integrated APA exclusions

The exclusion on energy efficiency metrics (annex II point 2.1 and point 2.2) for High Performance Computing (HPC) servers and servers with integrated APA. These products are currently out of scope of the testing standards SPECT SERT tool and the ISO/IEC 21836.2020. Therefore, no design option is set out for these products.

Ban of particular polymer combinations

Stakeholders indicated that recycling of plastics in servers can be a concern if particular polymer combinations which are difficult to separate (and hence recycle). This combination problem comes in two parts:

- bonded parts with multiple plastics - might not separate on shredding so can't be reliably sorted and may not be compatible if they're mechanically recycled together.
- plastic and plastic alloys that don't really work well with regular recycling processes.

Although these concerns for recycling exist, this measure was not taken forward as a design option. The concern here is that clear evidence is needed to determine which are the polymer combinations of concern and what problems are explicitly being caused. To mandate a removal of these, it would be preferable to have an industry-wide agreement on which of the polymers are the most problematic and what replacement options exist.

Liquid cooling

Liquid cooling of servers is becoming more common. It is done in multiple ways, the first is with indirect liquid cooling, where the liquid cooling pipes are applied to the rack, these are sold as separate equipment to the server and are therefore out of scope of the Ecodesign regulation. The second is immersion liquid cooling, where servers are immersed in a cooling fluid. This is irrespective of the server design, and hence is out of scope of Ecodesign regulation.

The third is liquid cooling to the chip itself. This can be done with setups where third parties will attach a device to the chip and allow for the liquid cooling. These are done irrespective of the product design. And lastly, there are products designed with liquid cooling done directly to the chip, which is largely limited to HPC systems, which are out of scope of the regulation. Furthermore, the regulated server products are currently tested under SERT in an air-cooled configuration.

Due to the limited scope of products currently designed for liquid cooling specifically, and tested under SERT as such, there is no recommendation to consider Design Option for this technology. However, as this is marked as a growing technology, these should be considered in the scope of the next regulatory review.

Waste heat recuperation

The recuperation of waste heat is beyond the scope of the Ecodesign product regulation as this relates to the system and not the product itself. However, waste heat recuperation could be enabled further by increasing the operating range of servers (hence higher temperatures to recuperate), or by enabling liquid to chip cooling system which would be more effective at recuperating heat. As indicated in Phase 1, setting higher operating temperatures may lead to higher overall energy consumption and is therefore not advised to be mandated. For liquid-to-chip, a test standard under SERT needs to be determined for measuring the active efficiency. Therefore, no Design option is suggested for waste heat recuperation.

Firmware provision

The Ecodesign regulation already has the Annex II article 1.2.3, which stipulates that manufacturers must provide the latest firmware for products at least 8 years after their placing on the market. This allows for products to be repaired. It was suggested that this measure was increased to cover not only the sharing of the latest firmware but also the previous firmware versions, in order to allow for the server repair industry to better integrate older components which would require the older firmware. However, this measure is not taken forward as it has the risk of exposing servers to cybersecurity risks, which are often what firmware updates are patching for.

Custom servers

Custom servers are defined in the current regulation as " Custom made server, made on a one-off basis". Under this regulation, these servers are exempt from providing information requirements. They are however, still required to meet the remaining regulatory requirements.

Resilient servers

There are few models of resilient servers, which are more expensive than other servers due to their redundancy requirements. These are maintained as being excluded from the energy efficiency requirements of the regulation. Their small number of models, make them difficult to benchmark and distinguish performance requirements for a regulation. Furthermore, their increased costs of manufacture ensure that they do not create a regulatory loophole.

Setting minimum operation range requirement to be ASHRAE A2. (or ban A1)

Under the Ecodesign regulation, servers must currently reveal in their information requirements if they meet the environment standards under ASHRAE of A1, A2, A3 or A4. These environment requirements extend the allowable range of operation for servers in terms of temperature and humidity. It was proposed that this range should be extended to allow for servers to operate at higher temperatures, which would therefore mean reduced cooling needs, and higher temperature heat recovery.

However, it should be noted, that although servers under an A3 ASHRAE condition class can be allowed to operate at a higher temperature, this is meant to be the allowable range, for temporary operation. For longer periods of time, all servers are still recommended to be operated within the recommended range 18 – 27 Degrees Celsius. If servers are operated for an extended period of time at higher temperatures than the recommended range, their internal fan consumption will increase. This has been shown to mean that although cooling costs would reduce, the energy consumption of the server itself would increase, which would overall increase the energy consumption of the datacentre. It is therefore not recommended to increase the ASHRAE range of server operation requirements.

6.2 Assessment of environmental impacts, life cycle costs and purchase price

6.2.1 BC1: Rack Server

Task 5 identified the Life Cycle cost and Environmental Impacts of BC1.Within Task 6, different design options applicable to Base Case 1 and their impact analysis was done.

Table 6.18 below shows the primary energy consumption and life cycle cost of all design options compared to the Base Case 1.

Table 6.18 Primary energy consumption & LCC of design options compared to BC1

	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Primary Energy Consumption (MJ)	6.0E+04	5.22E+04	5.13E+04	4.88E+04	5.20E+04	5.63E+04	5.62E+04	4.70E+04
% change with BC		-14	-15	-19	-14	-6.7	-7	-22
Life Cycle Cost (euro/yr)	8,504	8,164	8,127	8,024	8,157	8,335	8,918	8,532
% change with BC		-4	-4.43	-5.64	-4.08	-1.9	4.87	0.33

Figure 6.1 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 1.

Figure 6.1 Primary energy consumption for Design Options compared to BC1 (%)

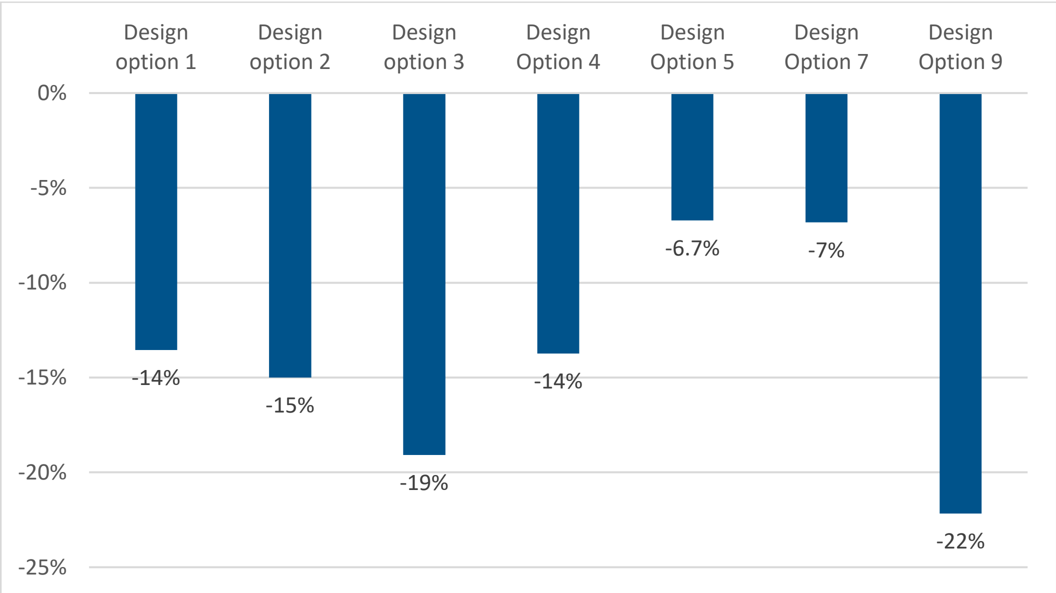
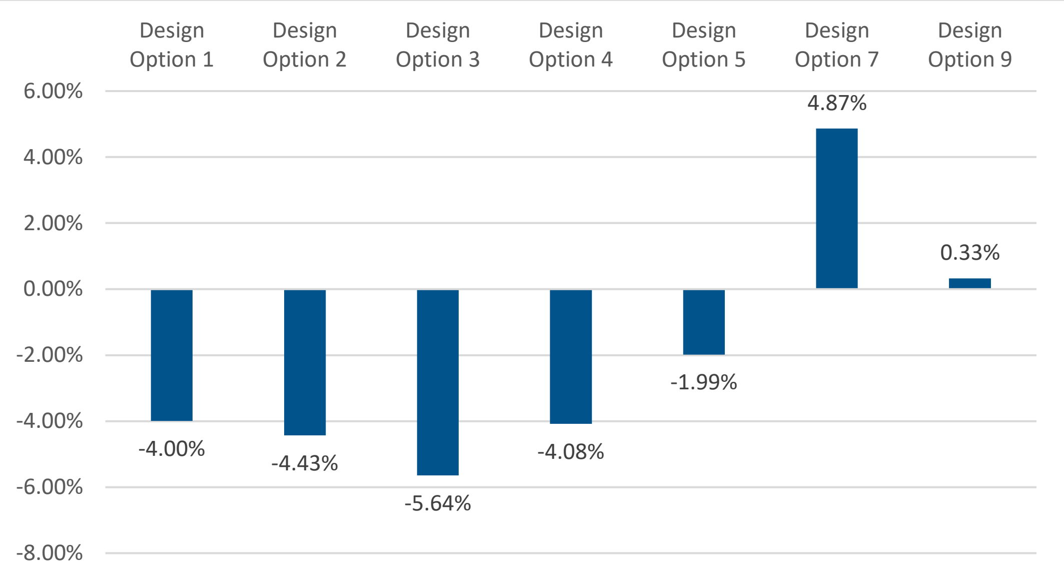


Figure 6.2 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 1.

Figure 6.2 Life Cycle Cost as compared with BC1 (%)



Each of the design options applicable to Base Case 1 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in Table 6.19.

Table 6.19 Impact on climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC1

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Climate change, total	kg CO2 eq	6.98E+03	6.03E+03	5.93E+03	5.64E+03	6.01E+03	6.51E+03	6.50E+03	5.42E+03
	% change with BC		-14	-15	-19	-14	-7	7	-22
Particulate Matter	disease incidence	2.33E-04	2.03E-04	2.00E-04	1.90E-04	2.02E-04	2.18E-04	2.18E-04	1.84E-04
	% change with BC		-13	-14	-18	-13	-6	-7	-21
Acidification	mol H+ eq	2.20E+01	1.91E+01	1.88E+01	1.80E+01	1.91E+01	2.06E+01	2.06E+01	1.73E+01
	% change with BC		-13	-15	-18	-13	-7	-7	-22
Resource use, minerals and metals	kg Sb eq	7.05E-02	7.02E-02	7.02E-02	7.01E-02	7.02E-02	7.04E-02	7.05E-02	7.01E-02
	% change with BC		-0.34	-0.38	-0.48	-0.35	-0.17	0	-1
Resource use, fossils	MJ	1.21E+05	1.04E+05	1.03E+05	9.76E+04	1.04E+05	1.13E+05	1.21E+05	9.38E+04

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
	% change with BC		-14	-15	-19	-14	-6.7	-7	-22

All the Life Cycle Indicators per unit of product for different design options of Base Case 1 are annexed in Table A3.1.

6.2.2 BC2: Blade Server

Task 5 identified the Life Cycle cost and Environmental Impacts of BC2.Within Task 6, different design options applicable to Base Case 2 and their impact analysis was done.

Table 6.20 below shows the primary energy consumption and life cycle cost of all design options compared to Base Case 2[241].

Table 6.20 Primary energy consumption & LCC of design options compared to BC2

	BC 2	DO1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Primary Energy Consumption (MJ)	2.60E+05	2.52E+05	2.51E+05	2.48E+05	2.57E+05	2.57E+05	2.59E+05	2.25E+05
% change with BC		-3.1	-3.5	-4.49	-1	-1	-0.29	-13.5
Life Cycle Cost (euro/yr)	6,672	6,334	6,292	6,186	6,557	6,562	6,883	5,427
% change with BC		-5	-6	-7	-1.7	-1.6	3.2	-18.7

Figure 6.3 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 2.

[241] The Environmental Impacts including energy consumption are calculated per Blade for BC2 and Design Options

Figure 6.3 Primary energy consumption for Design Options compared to BC2 (%)

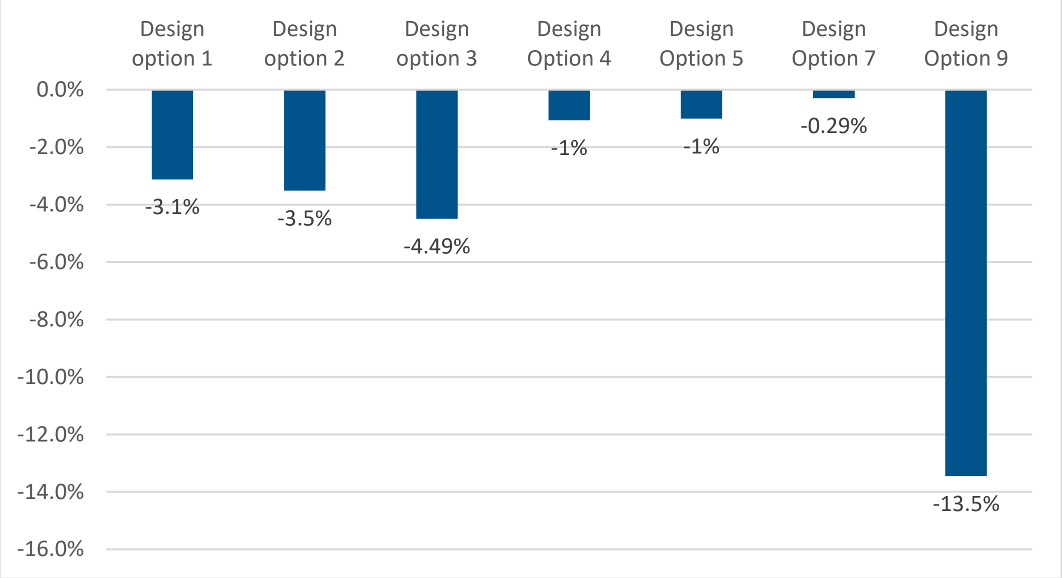
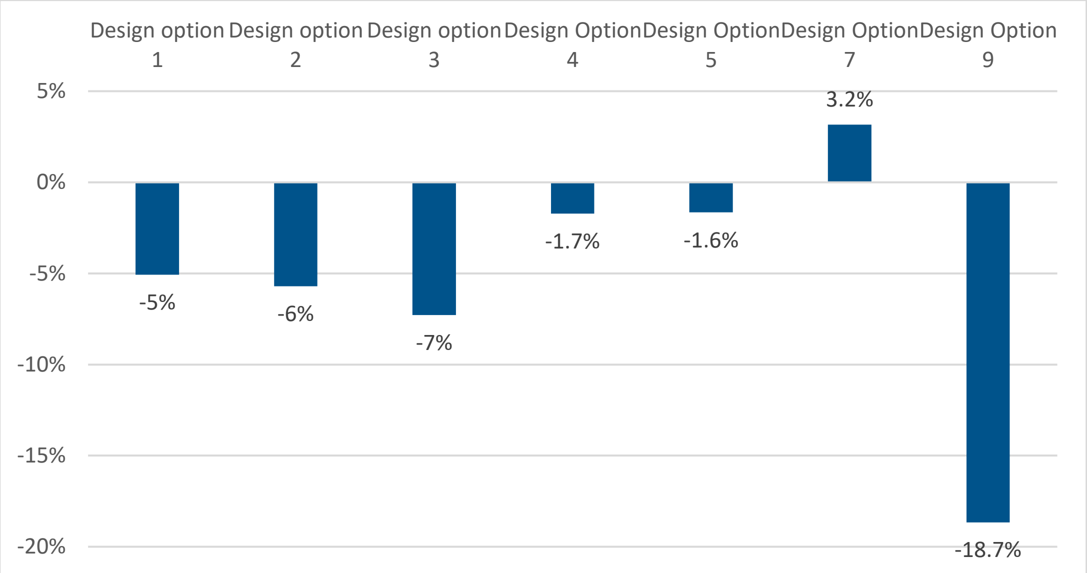


Figure 6.4 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 2.

Figure 6.4 Life Cycle Cost as compared to BC2 (%)



Each of the design options applicable to Base Case 2 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in Table 6.21.

Table 6.21 Impact on climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC2

Life-cycle indicators per unit	Unit	BC 2	DO 1	DO 2	DO 3	DO4	DO 5	DO 7	DO 9
Climate change, total	kg CO2 eq	2.38E +04	2.29E +04	2.27E +04	2.24E +04	2.35E +04	2.35E +04	2.37E +04	1.97E +04
	% change with BC		-4	-4	-6	-1	-1	-0.24	-17

Life-cycle indicators per unit	Unit	BC 2	DO 1	DO 2	DO 3	DO4	DO 5	DO 7	DO 9
Particulate Matter	disease incidence	2.18E-03	2.15E-03	2.15E-03	2.14E-03	2.17E-03	2.17E-03	2.17E-03	2.05E-03
	% change with BC		-1	-2	-2	0	0	-0.4	-6
Acidification	mol H+ eq	2.36E +02	2.33E +02	2.33E +02	2.32E +02	2.35E +02	2.35E +02	2.35E +02	2.24E +02
	% change with BC		-1.2	-1.4	-1.7	-0.4	-0.4	-0.4	-5
Resource use, minerals and metals	kg Sb eq	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.45E +00	1.46E +00
	% change with BC		-0.02	-0.02	-0.02	-0.01	-0.01	-0.48	-0.07
Resource use, fossils	MJ	3.67E +05	3.51E +05	3.49E +05	3.44E +05	3.62E +05	3.62E +05	3.66E +05	2.97E +05
	% change with BC		-4	-5	-6	-2	-1	0	-19

All the Life Cycle Indicators per unit of product for different design options of Base Case 2 are annexed in Table A3.2.

6.2.3 BC3: Storage Unit

Task 5 identified the Life Cycle cost and Environmental Impacts of BC3.Within Task 6, different design options applicable to Base Case 3 and their impact analysis was done.

Table 6.22 below shows the primary energy consumption and life cycle cost of all design options compared to the Base Case 3.

Table 6.22 Primary energy consumption & LCC of design options compared to BC3

	BC 3	DO 6	DO 8	DO 10
Primary Energy Consumption (MJ)	1.82E+05	1.71E+05	1.73E+05	1.66E+05
% change with BC		-6	-5	-8
Life Cycle Cost (euro/yr)	7,097	6,805	7,159	6,994
% change with BC		-4	1	-1

Figure 6.5 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 3.

Figure 6.5 Primary energy consumption for Design Options compared to BC3 (%)

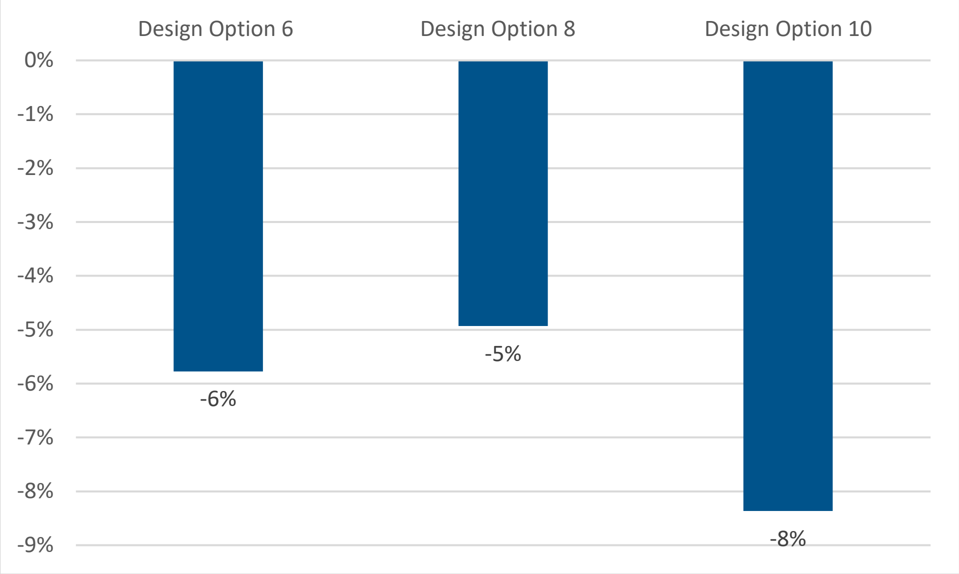
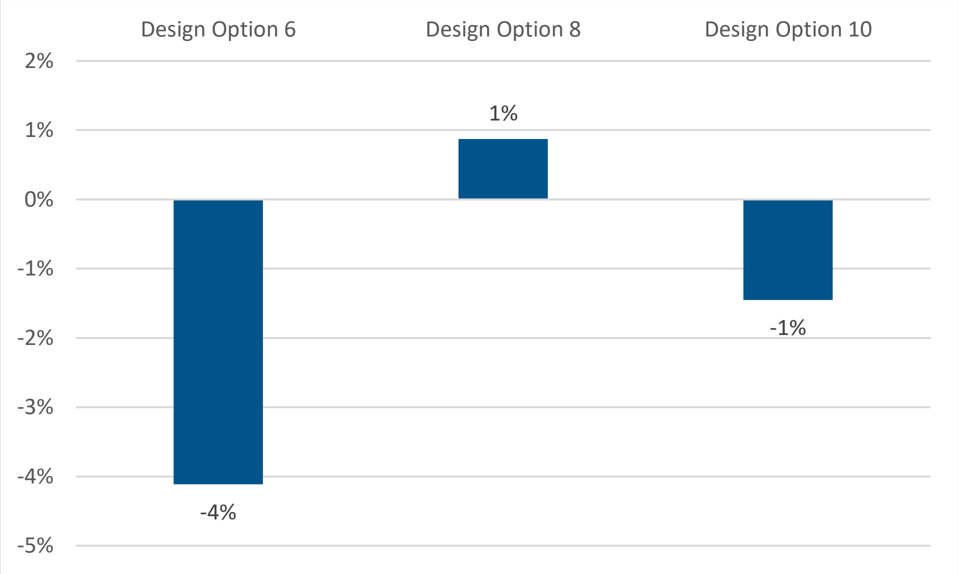


Figure 6.6 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 3.

Figure 6.6 Life Cycle Cost as compared to BC3 (%)



Each of the design options applicable to Base Case 3 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in Table 6.23.

Table 6.23 Impact of climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC3

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
Climate change, total	kg CO2 eq	1.79E+04	1.67E+04	1.73E+04	1.66E+04
	% change with BC		-7	-4	-8

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
Particulate Matter	disease incidence	1.28E-03	1.25E-03	1.18E-03	1.15E-03
	% change with BC		-3	-9	-10
Acidification	mol H+ eq	1.37E+02	1.33E+02	1.25E+02	1.22E+02
	% change with BC		-3	-9	-11
Resource use, minerals and metals	kg Sb eq	6.90E-01	6.90E-01	6.03E-01	6.02E-01
	% change with BC		0	-13	-13
Resource use, fossils	MJ	2.89E+05	2.68E+05	2.81E+05	2.68E+05
	% change with BC		-7	-3	-7

All the Life Cycle Indicators per unit of product for different design options of Base Case 3 are annexed in Table A3.3.

6.3 Analysis of BAT and Least Life Cycle Costs (LLCC)

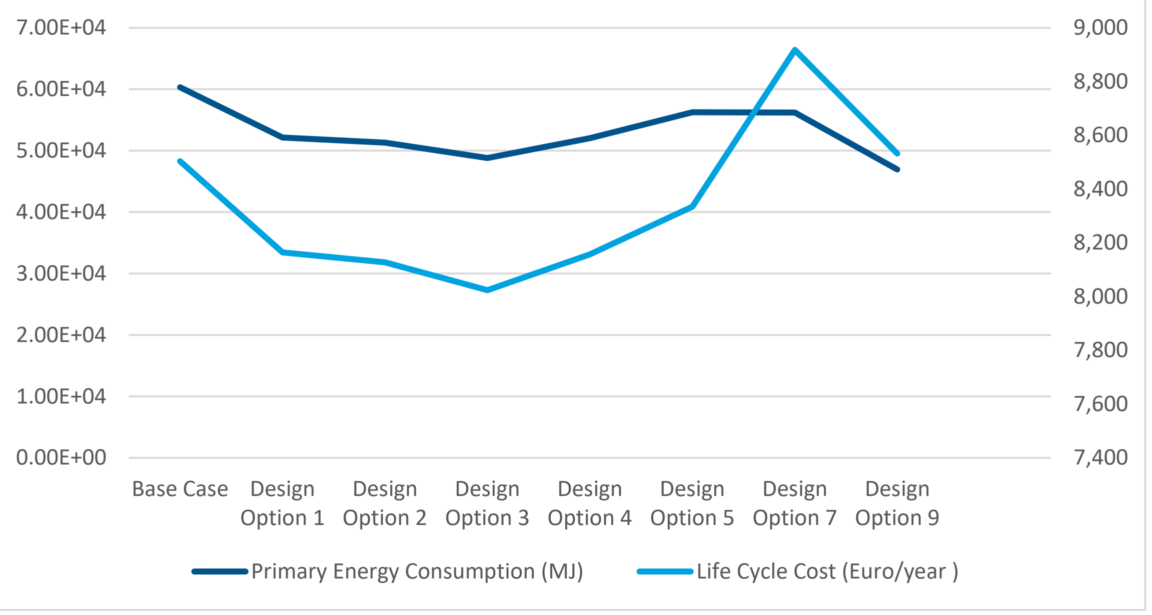
The design options are ranked to identify improvement options with the least cycle environmental impacts (BAT) and the Least Life Cycle Costs (LLCC). Energy-LCC curve (Y-axis = energy consumed and LCC, X-axis = options) allows the LLCC and BATs to be identified.

The performance of each Design Option is compared with the base case. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC) as described in Task 5.

6.3.1 Base Case 1

Figure 6.7 shows the LLCC curve for Base Case 1. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC)

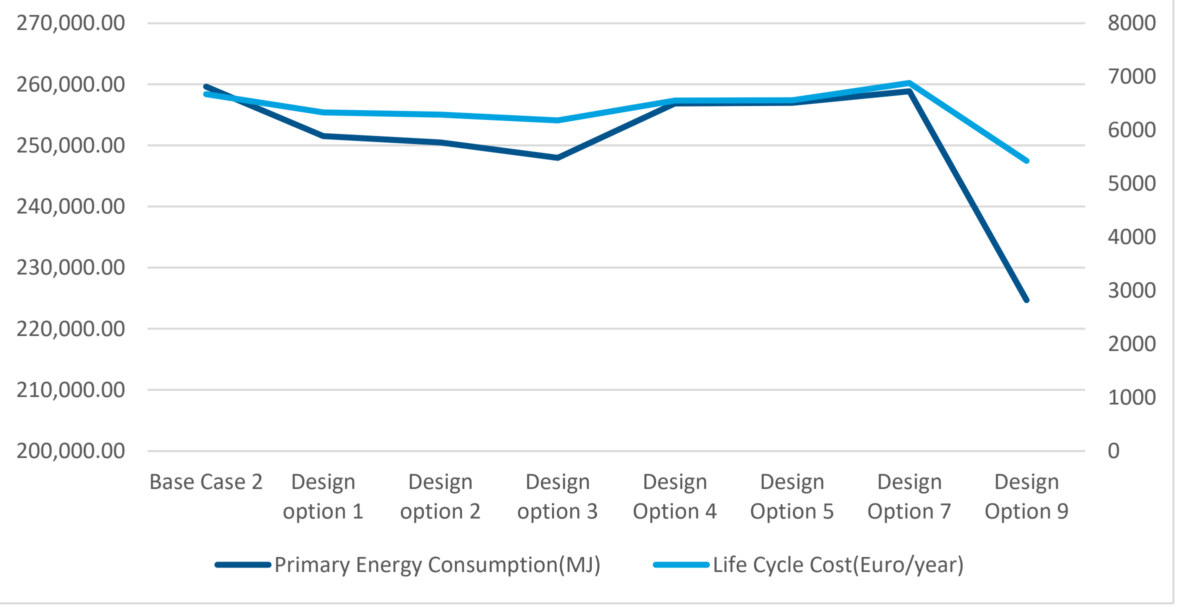
Figure 6.7 LLCC curve for Base Case 1



6.3.2 Base Case 2

Figure 6.8 shows the LLCC curve for Base Case 2. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC)

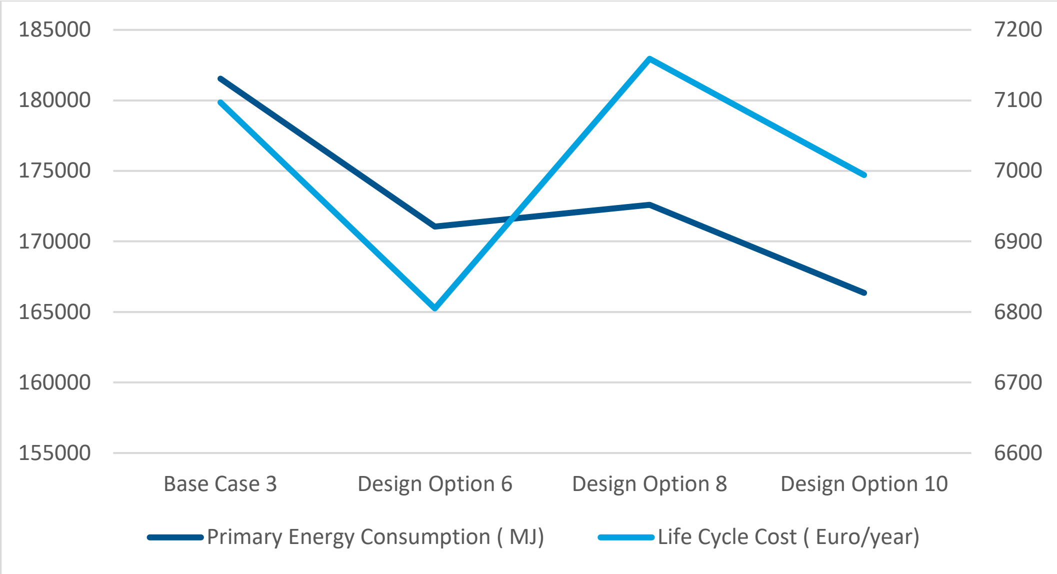
Figure 6.8 LLCC curve for Base Case 2



6.3.3 Base Case 3

Figure 6.9 shows the LLCC curve for Base Case 3. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC).

Figure 6.9 LLCC curve for Base Case 3



7 Introduction to Task 7 Scenarios

The aim of this task is to look at suitable policy means to achieve the potential improvement. For example, this could include implementing the Least Life Cycle Cost (LLCC) as a minimum requirement, using the environmental performance of the Best Available Technology (BAT) or Best Not Available Technology (BNAT) as a benchmark and using standards, labelling or incentives relating to public procurement.

This task also aims to draw together scenarios quantifying the improvements that can be achieved versus a Business-as-Usual (BaU) scenario and compares the outcomes with EU environmental targets and societal costs.

This task aims to estimate the impact on users and industry considering the typical design cycle in a product sector.

This task provides an analysis of which significant impacts may have to be measured under possible implementing measures and what measurement methods would need to be developed or adapted.

7.1 Policy Analysis

The objective of this sub-task is to identify policy options considering the outcomes of the previous tasks. The analysis will:

- Include a description of the main stakeholders' positions
- Discuss possible market and legislative barriers and opportunities for measures
- Be based on the exact definition of the products, according to subtask 1.1
- Provide Ecodesign requirements, such as minimum (or maximum) requirements
- Be complemented with (dynamic) labelling and benchmark categories
- Where appropriate, apply existing standards or propose needs/ generic requirements for harmonised standards to be developed
- Provide requirements on installation of the product or on user information

7.1.1 Stakeholders

Stakeholders have been engaged during this review and particularly at key junctures of the study. These have included the first stakeholder meeting, held on 29 March 2023; circulation of the Phase 1 Technical Analysis report; the second stakeholder meeting, held on 28 September 2023; and circulation of updated MEErP Tasks 1-4 reports and laterally Tasks 5-7. Comments have been collated and addressed during an ongoing iteration of the draft reports. Further direct engagement has been undertaken in order to strengthen the type and quality of information received, particularly in the Task 2 Markets report. Representatives from The Green Grid have supported the study with detailed feedback, quantitative data and sense checking of market estimates.

7.1.2 Barriers & Opportunities

As evidenced elsewhere within study, opportunities exist to strengthen the current energy efficiency requirements for servers. Opportunities also exist to expand the material efficiency requirements currently specified within Regulation 2019/424 in order to reflect the Commission's approach to improving the circular economy, using Ecodesign as a vehicle for that in line with its wider policy intentions.

7.1.3 Scope

The product scope for the proposed measures is in line with the categories and definitions for servers and data storage products presented within the Task 1 report.

7.1.3.1 Category definitions under existing scope

The following definitions apply to products in scope of the existing regulation 2019/424:

- '**server'** means a computing product that provides services and manages networked resources for client devices, such as desktop computers, notebook computers, desktop thin clients, internet protocol telephones, smartphones, tablets, tele-communication, automated systems or other servers, primarily accessed via network connections, and not through direct user input devices, such as a keyboard or a mouse and with the following characteristics:
  - it is designed to support server operating systems (OS) and/or hypervisors, and targeted to run user-installed enterprise applications;
  - it supports error-correcting code and/or buffered memory (including both buffered dual in-line memory modules and buffered on board configurations);
  - all processors have access to shared system memory and are independently visible to a single OS or hypervisor.
- **'resilient server'** means a server designed with extensive reliability, availability, serviceability and scalability features integrated in the micro architecture of the system, central processing unit (CPU) and chipset.
- '**multi-node server**' means a server that is designed with two or more independent server nodes that share a single enclosure and one or more power supply units. In a multi-node server, power is distributed to all nodes through shared power supply units. Server nodes in a multi-node server are not designed to be hot-swappable.
- **'network server'** means a network product which contains the same components as a server in addition to more than 11 network ports with a total line rate throughput of 12 Gb/s or more, the capability to dynamically reconfigure ports and speed and support for a virtualized network environment through a software defined network
- **'data storage product'** means a fully-functional storage system that supplies data storage services to clients and devices attached directly or through a network. Components and subsystems that are an integral part of the data storage product architecture (e.g., to provide internal communications between controllers and disks) are considered to be part of the data storage product. In contrast, components that are normally associated with a storage environment at the data centre level (e.g. devices required for operation of an external storage area network) are not considered to be part of the data storage product. A data storage product may be composed of integrated storage controllers, data storage devices, embedded network elements, software, and other devices.
- '**data storage device'** means a device providing non-volatile data storage, with the exception of aggregating storage elements such as subsystems of redundant arrays of independent disks, robotic tape libraries, filers, and file servers and

storage devices which are not directly accessible by end-user application programs, and are instead employed as a form of internal cache;

- **'online data storage product'** means a data storage product designed for online, random-access of data, accessible in a random or sequential pattern, with a maximum time to first data of less than 80 milliseconds;

To ensure clarity and harmonisation, it is recommended to align product definitions with Energy Star, EPEAT, ISO/IEC 21836:2020 and ETSO EN 303 470. In particular, an update should be considered for the definitions of resiliency under the resilient server definition and the High-Performance Computing (HPC) servers as these do not align with ENERGY STAR. We also recommend the inclusion of the following definition for storage heavy servers:

- Storage Heavy Server (SHS): A computer server with greater storage capacity than a standard computer server. As shipped, these computer servers support 30 or more internal storage devices. These servers differ from Storage Products in that they run computer server operating systems and software stacks.

7.1.3.2 Category definitions under proposed expanded scope

This section presents product categories considered for inclusion within the scope of the regulation. Unless otherwise specified below, other product category exclusions from Regulation 2019/424 remain.

As set out in Task 6, the following amendments to scope are proposed. For all three categories, it is proposed that they will be brought into scope of the regulation but kept out of scope of the energy efficiency requirements, as set out currently in Annex II point 2.1 and point 2.2 of Regulation 2019/424. The definitions are repeated below from Task 1 and Task 6 respectively.

- **Server appliance** – means a server that is not intended to execute user-supplied software, delivers services through one or more networks, is typically managed through a web or command line interface and is bundled with a pre-installed OS and application software that is used to perform a dedicated function or set of tightly coupled functions.
- **Fully fault tolerant server –** means a server that is designed with complete hardware redundancy (to simultaneously and repetitively run a single workload for continuous availability in mission critical applications), in which every computing component is replicated between two nodes running identical and concurrent workloads (i.e., if one node fails or needs repair, the second node can run the workload alone to avoid downtime).
- **Hyperconverged servers** – means a highly integrated server which contains the additional features of large network equipment and storage products.

Task 6 also considered the inclusion of large servers in scope of the revised regulation, which are currently defined in 2019/424:

- **Large servers** – means a resilient server which is shipped as a pre-integrated/pre-tested system housed in one or more full frame racks and that includes a high connectivity input/output subsystem with a minimum of 32 dedicated input/output slots.

Large servers are currently out of scope from SPEC SERT, EPEAT and IEC 21836:2020. They therefore do not have an energy measurement standard. Under Task 6 it was proposed to include large servers in the regulation but kept out of scope from the PSU requirements currently set out in Annex II point 1.1, the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424. Most large servers would also be exempt from the information requirements from Annex II 3.1 as they generally meet the exemption criteria of being "*custom made servers, made on a one-off basis"* as currently set in the regulation. This addition however will ensure that large server providers must provide firmware support for 6 years, allow for part harvesting, provide availability of spare parts, disassemblability and repair, along with information provision on materials used.

7.1.4 Proposed Measures

The proposed measures for the servers and data storage product groups are presented and discussed below.

7.1.4.1 Stricter-active efficiency (servers)

Design Option 3 from Task 6, the stricter active efficiency measure for servers considers a scenario where 75% of the models from the SERT tool dataset from 2019 meet the requirement. The proposed limits are presented below in Table 7.1.

Table 7.1 Proposed server stricter-active efficiency thresholds

Number of sockets	Product type	Minimum Active efficiency
1	Rack	15.33
2	Rack	23.36
2	Blade or multi-node servers	21.09
4	Rack	20.32
4	Blade or multi-node	22.44

According to the SERT tool dataset which is comprised of models from 2019, the proposed thresholds presented in Table 7.1 would generate the following pass rates, as presented in Table 7.2.

Table 7.2 SERT 2019 dataset pass rate under stricter-active efficiency thresholds

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	75%	76
2	Rack	75%	152
2	Blade or multi-node servers[242]	75%	60
4	Rack	75%	24
4	Blade or multi-node	75%	10

7.1.4.2 Idle consumption to workload ratio (servers)

Design Option 4 from Task 6, the idle consumption to workload ratio for servers, considers a scenario where a new idle efficiency metric is proposed to ensure that

[242] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

idle consumption is being optimised for use in the market, but also to allow for servers with performance ratios to be included. The current ecodesign regulation 2019/424 sets maximum idle power consumption values for servers with a base allowance and an additional power allowance due to additional components. Under Task 6 it was determined that the current formulation of the requirement is having no effect, with a pass rate of 100% based upon the 2019 SERT Tool dataset.

$$Idle\ to\ workload\ ratio = \frac{idle\ power\ (in\ Watts)}{100\%\ SSJ\ workload\ power\ (in\ Watts)}$$

This metric ensures that the smaller the ratio, the smaller the idle power contribution compared to the SSJ workload contribution. The SSJ worklet chosen represents a worklet with both CPU processing and memory activities. Therefore, a smaller ratio will mean that the idle power consumption is scaled to be more efficient versus an active workload parameter. This metric therefore serves as a method to remove products which are operating inefficiently in idle versus their maximum power consumption. As this metric is a ratio that includes the SSJ workload, this includes insight into the specificities and components of the server, such as CPU power and memory, and hence doesn't require additional allowances to be included.

Applying this idle to workload ratio to servers on the market since 2019 within the SERT tool dataset, if a pass rate of needing the idle to workload ratio to be smaller than 0.38 was set, then 75% of the BC1 servers would pass the metric. And for BC2 if idle to workload ratio was set to be smaller than 0.16, then 75% of the BC2 servers would pass the metric.

7.1.4.3 Processor power management function (servers)

Design Option 5 from Task 6, mandating processor management functions, considers a scenario where servers shipped into the EU market shall have the following power management functions enabled by default: all processors must be able to reduce power consumption in times of low utilisation by reducing voltage and/or frequency through Dynamic Voltage and Frequency Scaling (DVFS). This feature allows for greater energy savings when switching to idle.

7.1.4.4 Improved disassembly, repairability and recycling for servers

Design Option 7 from Task 6, this measure considers multiple means to improve the overall disassembly, repairability and recycling of servers.

Firstly, the measure specifies disassemblability requirements by a class B generalist, workshop environment class A, using tools from A, B or C nomenclature, and favours the repairability, reuse, refurbishment and recycling of servers: *Servers must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. The definition of "disassembly" is marked as "a process whereby a product is taken apart in such a way that is could subsequently be reassembled and made operational". This is the process for replacement of parts.* Further details are presented in Task 6, section 6.1.3.1. Additionally, fasteners should all be reusable (class A) or removable (class B). This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards. For the PSU and storage drives, the tool requirement for removal and replacement/upgrade shall be only of class A. This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, Section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As motherboards are connected to all components, these cannot be set at a higher stringency level. However, it is noted that PSUs and storage drives are typically set aside from the rest of the server design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

Secondly, the measure specifies that information shall be provided to professionals on how to disassemble, and thus repair, servers. The suite of information presented in Task 6, Section 6.1.3.1 shall be made available on the manufacturer's website, indicating the process for professional repairers to register for access to information.

Thirdly, the measure specifies the availability of spare parts such that manufacturers, importers or authorised representatives of servers shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market: memory cards, CPU, motherboard, graphic cards, PSU, chassis, batteries, fans, integrated switch, RAID controllers and network interface cards.

Fourthly, the measure specifies that for serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement. This measure shall cover CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards. A serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device.

Finally, the measure specifies that hardware components, performance capabilities and compatibility metrics are published by manufacturers to support the recycling industry to better target their recycling efforts to recover the materials. This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). The requirements shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

7.1.4.5 Energy efficiency requirements for storage products

Design Option 6 from Task 6 considers a scenario where energy efficiency requirements are placed on data storage products, namely setting a SNIA performance level and capacity optimisation methods (COMs).

For SNIA, the measure aligns with the Energy Star criteria such that: each optimal configuration point submitted for a block I/O storage product or storage product family must meet the following applicable active state requirements in Table 6.14 for each workload type. For streaming workloads, the data storage product must meet either the sequential read or the sequential write requirement. The optimal configuration is defined as the products maximum peak energy efficiency performance (performance/watt) for a given workload type. This configuration is provided by the manufacturer and may be optimised for the transaction, streaming and composite workload types. Further information about specific workload test methods is provided in Task 6 Section 6.1.2.1.

Table 7.3 Active state requirements for Block I/O Storage products

Workload Type Specific	Specific Workload Test	Minimum Performance/Watt Ratio	Applicable Units of Ratio
Transaction	Hot Band	28.0	IOPS/Watt
Streaming	Sequential Read	2.3	MiBS/Watt
Streaming	Sequential Write	1.5	MiBS/Watt

For capacity optimisation methods (COMs), a storage product shall make available to the end user configurable / selectable features listed in Table 6.15 in quantities greater than or equal to those listed in Table 6.16. COMs result in the reduction of actual data stored on storage devices through a combination of hardware and / or software. Further details are provided in Task 6 Section 6.1.2.1.

Table 7.4 Recognised COM features[243]

Feature	Verification Requirement
COM: Thin Provision	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Data Deduplication	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Compression	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Delta Snapshots	SNIA Verification test, following ISO/IEC 24091:2019 standard

Table 7.5 COM reqs for Disk Set & NVSS Disk Set Access Online 2, 3 & 4 Systems

Storage Product Category	Minimum number of COMs required to be made available
Online 2	1
Online 3	2
Online 4	3

7.1.4.6 Improved disassembly, repairability and recycling for data storage products

Design Option 8 from Task 6, this measure considers multiple means to improve the overall disassembly, repairability and recycling of data storage products.

Firstly, the measure specifies disassemblability requirements by a class B generalist, workshop environment class A, using tools from A, B or C nomenclature, and favours the repairability, reuse, refurbishment and recycling of data storage products: *Data storage products must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. .* Further details are presented in Task 6, Section 6.1.3.2. Additionally, fasteners should all be reusable (class A) or removable (class B). This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards. For the PSU and storage drives, the tool requirement for

[243] ISO/IEC 24091:2019(en), Information technology — Power efficiency measurement specification for data center storage

disassembly shall be only of class A. This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As motherboards are connected to all components, these can't be set at a higher stringency level. However, it is noted that PSUs and storage drives are typically set aside from the rest of the device design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

Secondly, the measure specifies that information shall be provided to professionals on how to disassemble, and thus repair, data storage products. The suite of information presented in Task 6, Section 6.1.3.2 shall be made available on the manufacturer's website, indicating the process for professional repairers to register for access to information.

Thirdly, the measure specifies the availability of spare parts such that manufacturers, importers or authorised representatives of data storage products shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market: memory cards, CPU, motherboard, graphic cards, PSU, chassis, batteries, fans, integrated switch, RAID controllers and network interface cards.

Fourthly, the measure specifies that for serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement. This measure shall cover CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards. A serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device.

Finally, the measure specifies that hardware components, performance capabilities and compatibility metrics are published by manufacturers to support the recycling industry to better target their recycling efforts to recover the materials. This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). The requirements shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

7.1.5 Information sharing

7.1.5.1 Server real time utilisation and power consumption reporting

The following design option is considered:

A computer server must provide real-time data on input power consumption (W) and average utilisation of all logical CPUs. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Processor utilisation: Average utilisation must be estimated for each logical CPU that is visible to the OS and must be reported to the operator or user of the computer server through the operating environment (OS or hypervisor); This should be reported under the ITEUSV ISO/IEC 30134-5:2017 metric.

Input power: Measurements must be reported with accuracy of at least ±5% of the actual value, with a maximum level of accuracy of ±10W for each installed PSU (i.e., power reporting accuracy for each power supply is never required to be better than ± 10 watts) through the operating range from Idle to full power;

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to increase product utilisation and therefore decrease the total need for hardware.

7.1.5.2 Server thermal management and monitoring

The following design option is considered:

A computer server must provide real-time data on inlet air temperature (°C) monitoring and fan speed management capability that is enabled by default. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Inlet air temperature: Measurements must be reported with an accuracy of at least ±2°C.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

7.1.5.3 Data storage products performance reporting

The following design option is considered:

Data storage products with an Online 3 and Online 4 capabilities shall be capable of measuring and reporting the following;

- Input Power, in watts. Input power measurements must be reported with accuracy within ±5% of the actual value for measurements greater than 200 W, through the full range of operation. For measurements less than or equal to 200 W, the accuracy must be less than or equal to 10 W multiplied by the number of installed PSUs; and
- Inlet Air Temperature, in degrees Celsius, with accuracy of ± 2°C.

The data shall be made available in a published or user-accessible format that is readable by third-party, non-proprietary management systems. This data shall be available over a standard network for end users and third-party management systems.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used.

It is also a requirement for Energy Star, making it a common requirement for all products to align with.

The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

7.1.6 Labelling

7.1.6.1 Introduction

As initially presented in Task 6, a Design Option for a mandatory energy label for servers is a scenario being modelled under Task 7. The Design Option specifies that servers shall be sold with an energy label which includes the following information:

- Server form factor
- Server active efficiency
- Server active efficiency score
- Idle power consumption (in Watts)
- ASHRAE temperature range

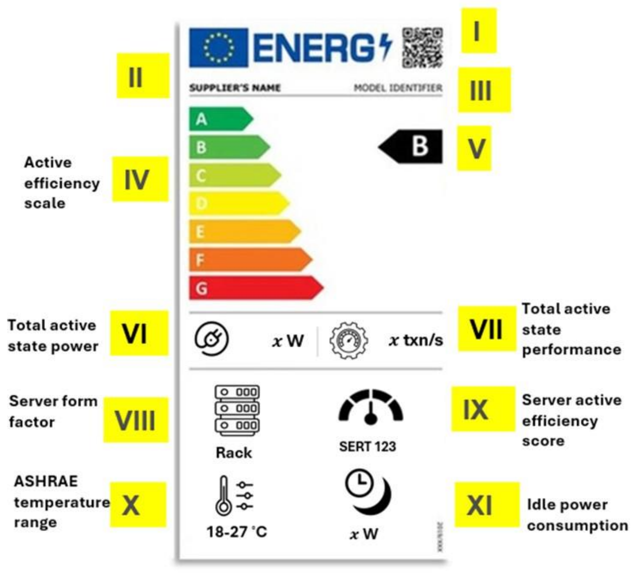
For servers which are part of a server configuration family, the "typical server configuration" data should be reported. As from the Energy Star scheme, the typical configuration 'lies between the Low-end performance and High-end performance configurations and is representative of a deployed product with high volume sales.'

This measure could also be considered to be run via a QR code set directly on the server which links to a webpage with the information.

This measure is expected to show benefits to encourage the purchase of more efficient servers over time.

An illustration of a possible energy label for servers is presented in Figure 7.1 along with an explanation of the content presented on the label.

Figure 7.1 Potential energy label for servers



A-G Scale:

Server active efficiency (determined directly from the different levels of the SERT score).

Pictograms:

Total active state power (Watts)

Total active state performance (transactions per second)

Server form factor

Server active efficiency score

ASHRAE temperature range

Idle power consumption (Watts)

For servers which are part of a server configuration family, the

	"typical server configuration" data should be reported.

Table 7.6 below reports the proposed levels for the energy efficiency classes of servers, based on the server active state efficiency (EEI).

Table 7.6 Illustrative energy label classes for a servers energy label

Energy Efficiency Class	Rack servers – 1 socket	Rack servers – 2 sockets	Rack servers – 4 sockets	Blade servers – 2 sockets	Blade servers – 4 sockets
A (most efficient)	EEI > 65.0	EEI > 75.0	EEI > 40.0	EEI > 35.0	EEI > 35.0
B	61.3< EEI ≤ 65.0	68.9< EEI ≤ 75.0	35.0< EEI ≤40.0	31.3< EEI ≤35.0	30.0< EEI ≤35.0
C	57.7< EEI ≤ 61.3	47.9< EEI ≤ 68.9	34.0< EEI ≤35.0	27.4< EEI ≤31.3	27.1< EEI ≤30.0
D	41.9< EEI ≤ 57.7	39.1< EEI ≤ 47.9	32.0< EEI ≤34.0	26.1< EEI ≤27,4	25.3< EEI ≤27.1
E	33.0< EEI ≤ 41.9	30.0< EEI ≤ 39.1	30.0< EEI ≤32.0	23.8< EEI ≤26.1	24.0< EEI ≤25.3
F	24.0 < EEI ≤ 33.0	26.6< EEI ≤ 30.0	25.0< EEI ≤30	22.5< EEI ≤23.8	23.0< EEI ≤24.0
G (least efficient)	EEI ≤ 24.0	EEI ≤ 26.6	EEI ≤ 25.0	EEI ≤ 22.5	EEI ≤ 23.0

7.1.6.2 Testing method, calculation method and tolerance

The same testing method, calculation method and tolerance for the active state efficiency foreseen under the Ecodesign Regulation for servers would be applicable for the energy label for servers.

7.1.6.3 Choice of configuration in the case of server product families

As stated in Figure 7.1, for servers which are part of a server configuration family, the "typical server configuration" data should be reported. The choice for the use of the (active state efficiency of the) "typical server configuration" for the energy label mainly lies on the consideration that it is on this configuration that the energy performance can be typically adjusted to, because of the significance in terms of sales. Choosing – for instance – to base the energy label of server product families on the active state efficiency of the low-end performance configuration seems not the preferred approach, as this would mean to represent, on the energy label, the energy efficiency of the worst-case for a certain product family. As shown below, attempts were made to find a systematic relation between the active state efficiency of the low-end performance configuration and the active state efficiency of the typical configuration. However, no pattern could be identified.

7.1.6.4 Comparative analysis of active state efficiency of the low-end, high-end performance configuration and of the typical configuration in server product families

In the following tables, the active state efficiency of the low-end, high-end performance configuration and of the typical configuration for a selection of server product families belonging to different subcategories is shown. Servers belonging to the following subcategories have been analysed:

- 2 tower servers
- 3 one socket rack servers
- 3 two socket rack servers
- 2 four socket rack servers
- 2 blade servers

The findings show that there is not a discernible pattern in highest efficiency score even within configurations in unique product families, which creates a significant hurdle when trying to compare product families against each other in a lettered ranking system. Often the high-end configuration has the highest efficiency score, but at times the typical configuration instead. The only consistency is that the low-end configurations are always the least efficient. However, no pattern can be identified for a systematic difference (see delta '∆' column) between the active state efficiency of the low-end performance configuration and the active state efficiency of the typical configuration as the deviation is relatively higher at times between the active state efficiency of high-end performance configuration and the active state efficiency of the typical configuration.

Table 7.7 Active state efficiency variation within tower server product families across different configurations

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Tower	2019	X1	High-End	29.17		
Tower	2019	X1	Typical	26.51	13.04	
Tower	2019	X1	Low-End	13.47		
Tower	2021	X2	High-End	32.31		
Tower	2021	X2	Typical	27.52	8.12	
Tower	2021	X2	Low-End	19.40		

Table 7.8 Active state efficiency variation within one socket rack server product families across different configurations

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Rack 1-socket	2019	X3	High-End	47.56		
Rack 1-socket	2019	X3	Typical	41.92	13.37	
Rack 1-socket	2019	X3	Low-End	28.55		
Rack 1-socket	2020	X4	High-End	11.57		

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Rack 1-socket	2020	X4	Typical	6.65	0.63	4.92
Rack 1-socket	2020	X4	Low-End	6.02		
Rack 1-socket	2021	X5	High-End	22.62		
Rack 1-socket	2021	X5	Typical	20.66	5.46	
Rack 1-socket	2021	X5	Low-End	15.20		

Table 7.9 Active state efficiency variation within two socket rack server product families across different configurations

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Rack 2-socket	2019	X6	High-End	32.31		
Rack 2-socket	2019	X6	Typical	30.13	16.26	
Rack 2-socket	2019	X6	Low-End	13.87		
Rack 2-socket	2020	X7	High-End	29.55		
Rack 2-socket	2020	X7	Typical	30.01	15.47	
Rack 2-socket	2020	X7	Low-End	14.54		
Rack 2-socket	2021	X8	High-End	42.87		
Rack 2-socket	2021	X8	High-End	40.01	2.31	15.8
Rack 2-socket	2021	X8	Typical	27.07		
Rack 2-socket	2021	X8	Low-End	24.76		

Table 7.10 Active state efficiency variation within four socket rack server product families across different configurations

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Rack 4-socket	2019	X9	High-End	34.72		
Rack 4-socket	2019	X9	Typical	32.38	7.95	
Rack 4-socket	2019	X9	Low-End	24.43		

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Rack 4-socket	2019	X10	High-End	28.66		
Rack 4-socket	2019	X10	Typical	28.66	10.95	
Rack 4-socket	2019	X10	Low-End	17.71		

Table 7.11 Active state efficiency variation within Blade server product families

Form Factor	Year	Family Identifier	Configuration	SERT Score	∆Typical-Low	∆High-Typical
Blade	2019	X11	High-End	21.37		
Blade	2019	X11	Typical	24.21	8.88	
Blade	2019	X11	Low-End	15.33		
Blade	2020	X12	High-End	27.84		
Blade	2020	X12	Typical	31.23	9.03	
Blade	2020	X12	Low-End	22.21		

7.2 Scenario Analysis – Resource Use & Environmental Impacts

The objective of this sub-task is to create a stock-model between 2010 and 2050 and calculate resources use and environmental impacts in the following scenarios:

- BaU – Business as usual. This scenario assumes no new policy measures on the European level. According to the market analysis in Task 2 and stock development till 2050, resource use and environmental impacts are modelled.
- MEPS – Implementation of Minimum Energy Performance Standard, as proposed in Section 7.1.4. This scenario assumes implementing Design Option 9 from Task 6, for BC1 and BC2 from year 2024 with no further changes. Labelling – Implementation of an Energy Label, as proposed in Section 7.1.5. The Energy Label is assumed to be implemented in 2024. Between 2010 and 2023, there is no difference between the BaU and the Labelling scenario. From 2024 onwards, the Labelling system is assumed to accelerate improvements in efficiency over time. In the Labelling scenario a reduction of 6% has been assumed for the year when the label is implemented (2024). Subsequently, a further 6% reduction is accounted for in year 2 (2025) as the competitive market for energy issues takes hold followed by further 7% (in 2026) and 4% (in 2027) reductions. From 2028 onwards, the annual improvement rate of electricity consumption is set at 1%.
- MEPS + Labelling – Implementation of both MEPS and an Energy Label. In this scenario, both the MEPs and the Labelling system are assumed to be implemented in 2024. Between 2010 and 2023, there is no difference between the BaU and the MEPS + Labelling scenario. In 2024 a reduction of 6% has been assumed along with MEPS. Subsequently, a further 6% reduction is accounted for in year 2 (2025) as the competitive market for energy issues takes hold followed by further 7% (in 2026) and 4% (in 2027) reductions. From 2028 onwards, the annual improvement rate of electricity consumption is set at 1%.

7.2.1 Inputs & Assumptions

7.2.1.1 Stock & Sales

The stock and sales assumptions from Tasks 2 and 5 are used for modelling the BaU, MEPS, Labelling and MEPS+Labelling scenarios. In the Labelling scenario, the implementation of the Energy Label is assumed not to affect sales or stock. This means that figures used in the Labelling scenario are the same as those in the BaU scenario. The rationale behind this assumption is that the label does not directly affect the price of products on the market nor the consumer's decision to procure a server. Instead, the effect of the label is to improve the performance of a market average product by shifting sales to more efficient products.

In the MEPS and MEPS + Labelling scenarios, the total stock and sales figures are the same as those in the BaU scenario.

There is further detail on the assumptions used to model stock and sales in the Task 2 and Task 5 reports.

Table 7.12 Estimated stock of BC1, BC2 and BC3 in the EU between 2010 and 2050.

	BC1	BC2	BC3
Year	Stock (In thousands)		
2010	4757	937	36197
2015	5526	1088	64793
2020	5666	1116	106455
2025	6583	1296	128228
2030	6750	1329	205092
2035	6923	1363	340150
2040	7100	1398	582438
2045	7282	1434	1023942
2050	7468	1471	1837672

7.2.1.2 BaU Scenario

In the BaU scenario, the energy consumption in the use phase and the consequent environmental impacts are calculated considering the technical inputs used to model the Base Cases in Task 5. Environmental impacts are also calculated using the EcoReport tool 2024, as per Task 5.

7.2.1.3 MEPS Scenario

In the MEPS scenario, the energy consumption in the use phase and the consequent environmental impacts are calculated considering the technical inputs used to model the Base Cases in Task 5 and Design Option 9 in Task 6 for BC1 & BC2. For BC3, Design Option 10 in Task 6 is used. Environmental impacts are also calculated using the EcoReport tool 2024, as per Task 5.

Between 2010 and 2023, there is no difference between the BaU and the MEPS scenario. The MEPS scenario comes into effect from 2024. The stocks and sales remain same as BaU scenario.

7.2.1.4 Labelling Scenario

The Energy Label is assumed to be implemented in 2024. Between 2010 and 2023, there is no difference between the BaU and the Labelling scenario. From 2024 onwards, the Labelling system is assumed to accelerate improvements in efficiency over time.

Table 7.13 compares the estimated yearly percentual reduction in the average electricity consumption used in the BaU and Labelling scenarios.

Table 7.13 Labelling-Estimated change in electricity consumption (%)

Year	BaU	Labelling
2010-2023	No change	Same as BaU
2024		6%
2025		6%
2026		7%
2027		4%
2028-2050		1%

Similar to the approach taken in BaU scenario, in the Labelling scenario the environmental impacts created have been calculated using the inputs for the Base Cases as per Task 5.

7.2.1.5 MEPS & Labelling Scenario

In this scenario, both the MEPs and the Labelling system are assumed to be implemented in 2024. Between 2010 and 2023, there is no difference between the BaU and the MEPS + Labelling scenario.

Table 7.14 compares the estimated yearly percentual reduction in the average electricity consumption used in the BaU and MEPS + Labelling scenarios.

Table 7.14 MEPS + Labelling – Estimated change in electricity consumption (%)

Year	BaU	Labelling
2010-2023	No change	Same as BaU
2024	MEPS	6%
2025		6%
2026		7%
2027		4%
2028-2050		1%

7.2.2 Results

The energy consumption of the stock of BC1 and BC2[244] in the EU for the four different scenarios were calculated.

[244] All results are calculated per Blade for BC2

7.2.2.1 Base Case 1

Figure 7.2 shows the Primary Energy Consumption for the four scenarios between 2010 and 2050 for EU27 for BC1.

Figure 7.2 BC1 Primary Energy Consumption, four scenarios, 2010-2050 (EU27)

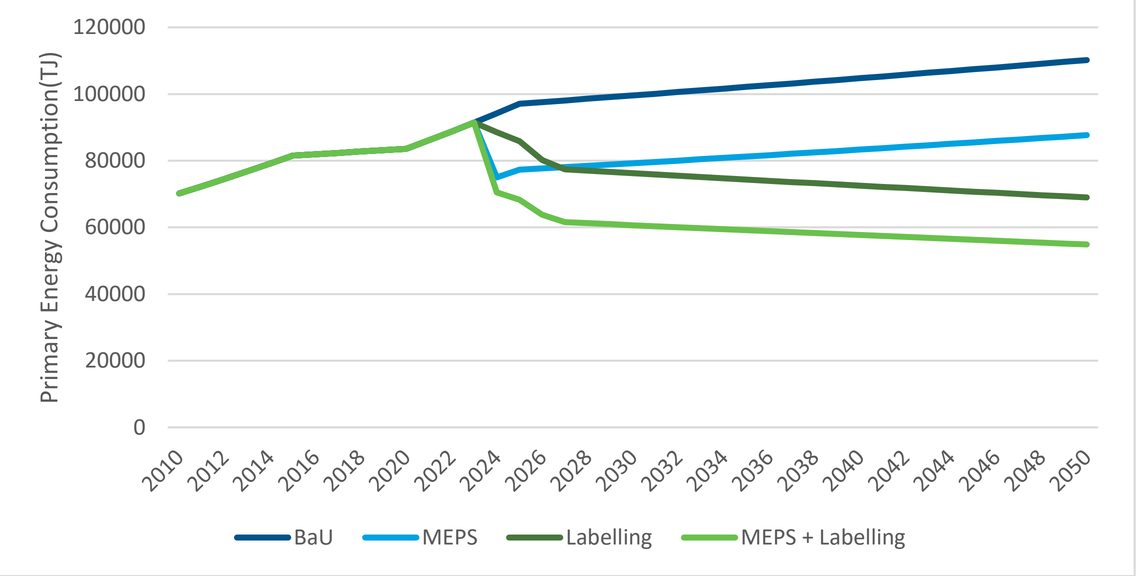


Figure 7.3 shows the Energy Cost for the four scenarios between 2010 and 2050 for EU27 for BC1.

Figure 7.3 BC1 Energy Cost for the four scenarios, 2010-2050 (EU27)

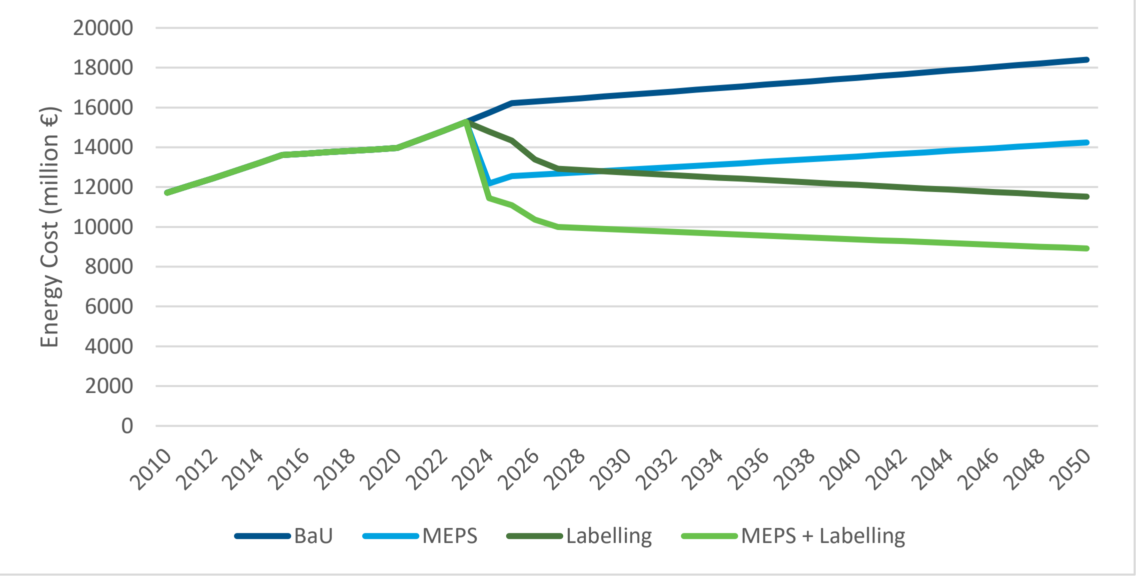
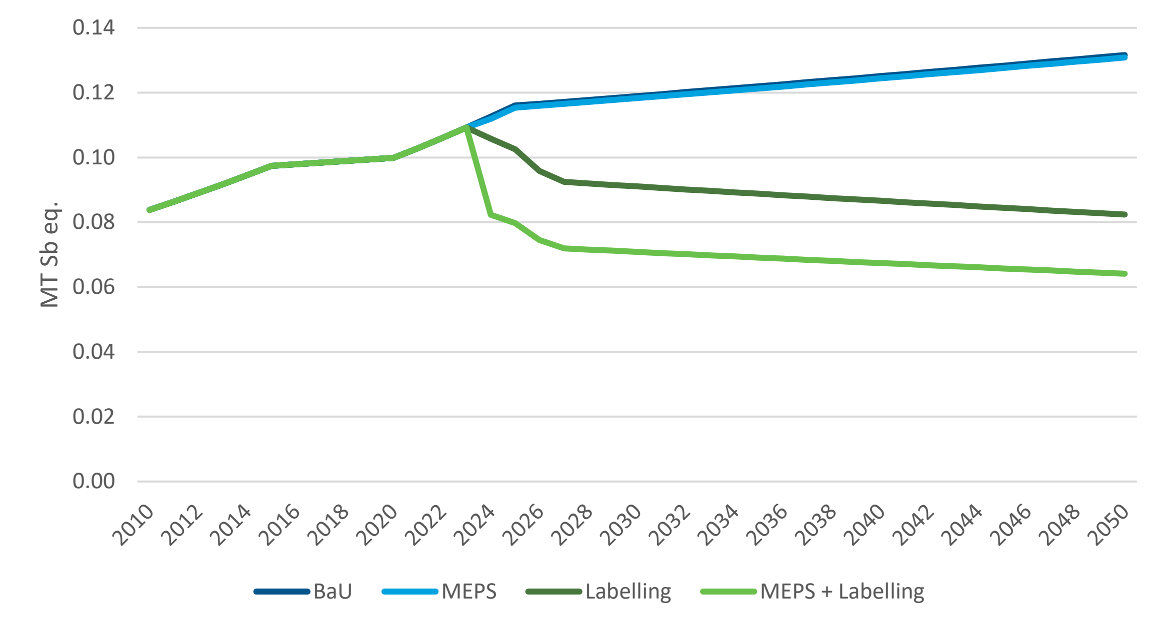


Figure 7.4 shows the Resource use (minerals & metals) for the four scenarios between 2010 and 2050 for EU27 for BC1.

Figure 7.4 BC1 Resource use, four scenarios, 2010-2050 (EU27)



7.2.2.2 Base Case 2

Figure 7.5 shows the Primary Energy Consumption for the four scenarios between 2010 and 2050 for EU27 for BC2.

Figure 7.5 BC2 Primary Energy Consumption, four scenarios, 2010-2050 (EU27)

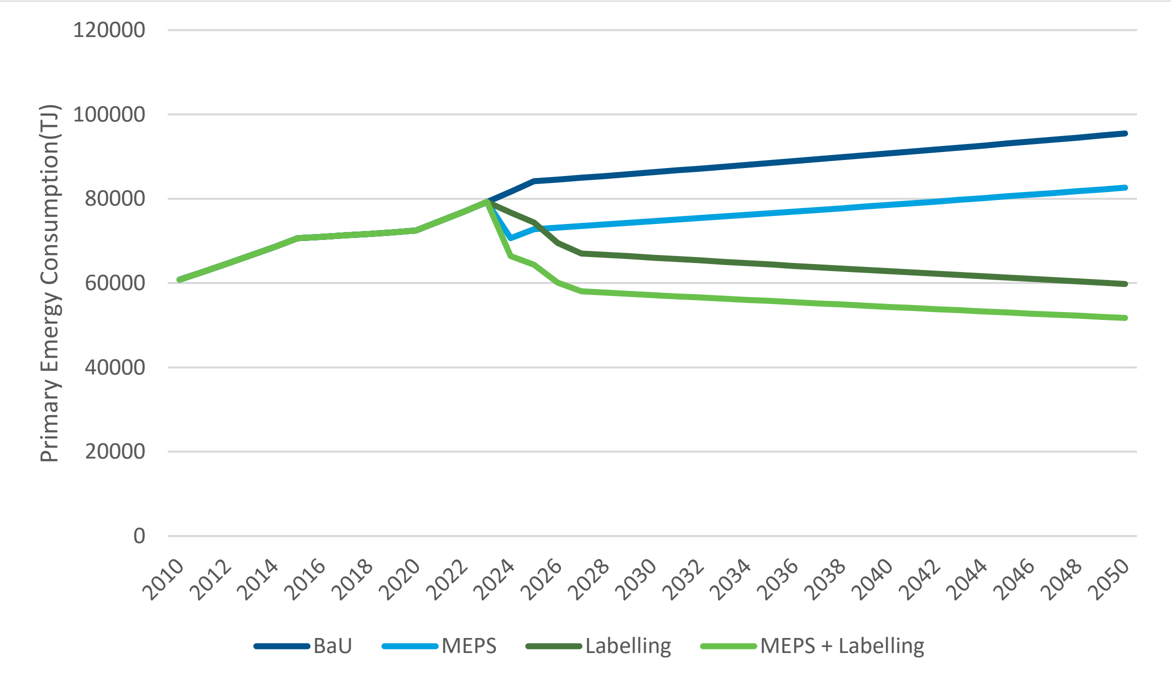


Figure 7.6 shows the Energy Cost for the four scenarios between 2010 and 2050 for EU27 for BC2.

Figure 7.6 BC2 Energy Cost, four scenarios, 2010-2050 (EU27)

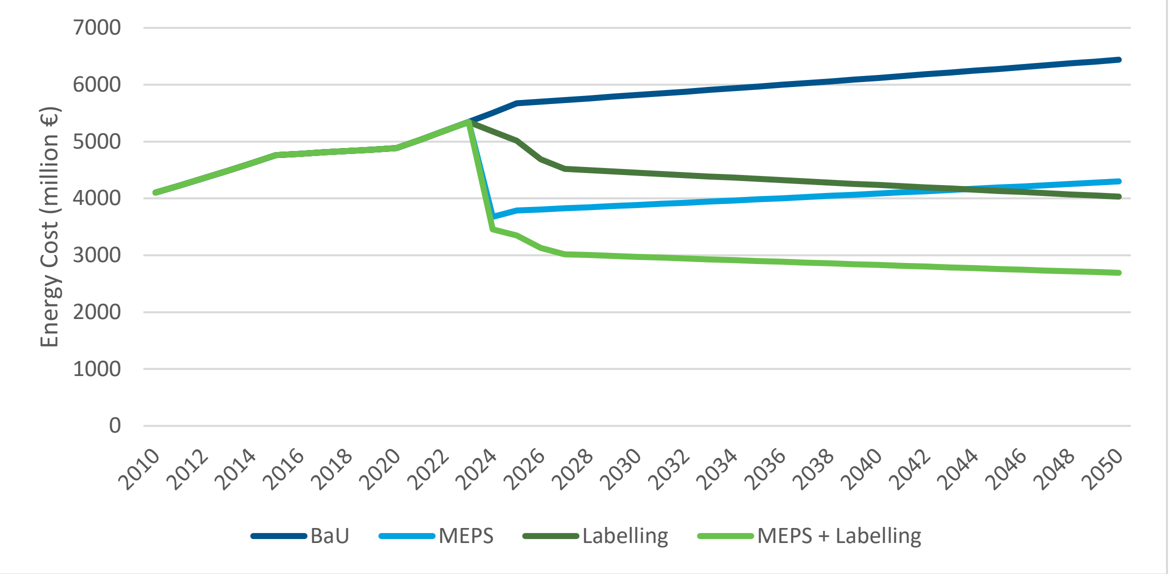
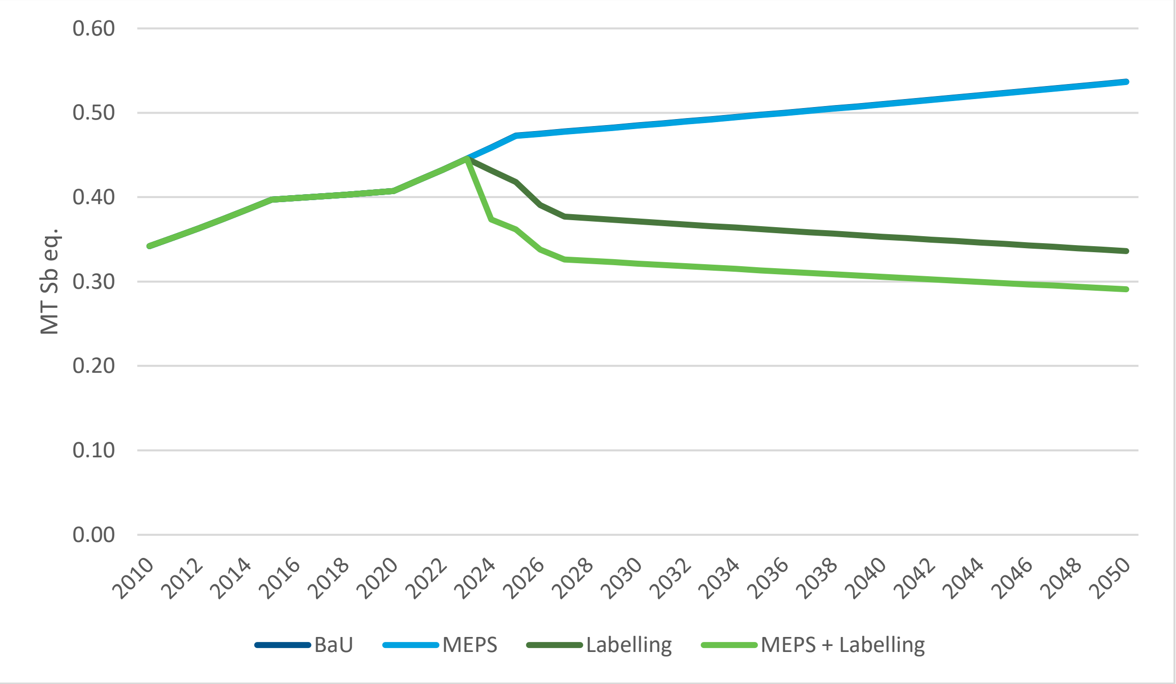


Figure 7.7 shows the Resource use (minerals & metals) for the four scenarios between 2010 and 2050 for EU27 for BC2

Figure 7.7 BC2 Resource use, four scenarios, 2010-2050 (EU27)



7.2.2.3 All Server Base Case (BC1 + BC2)

Figure 7.8 shows Primary Energy Consumption for all fours scenarios between 2010 and 2050 for EU27 for all servers BCs.

Figure 7.8 All servers BCs Primary Energy Consumption, four scenarios, 2010-2050 (EU27)

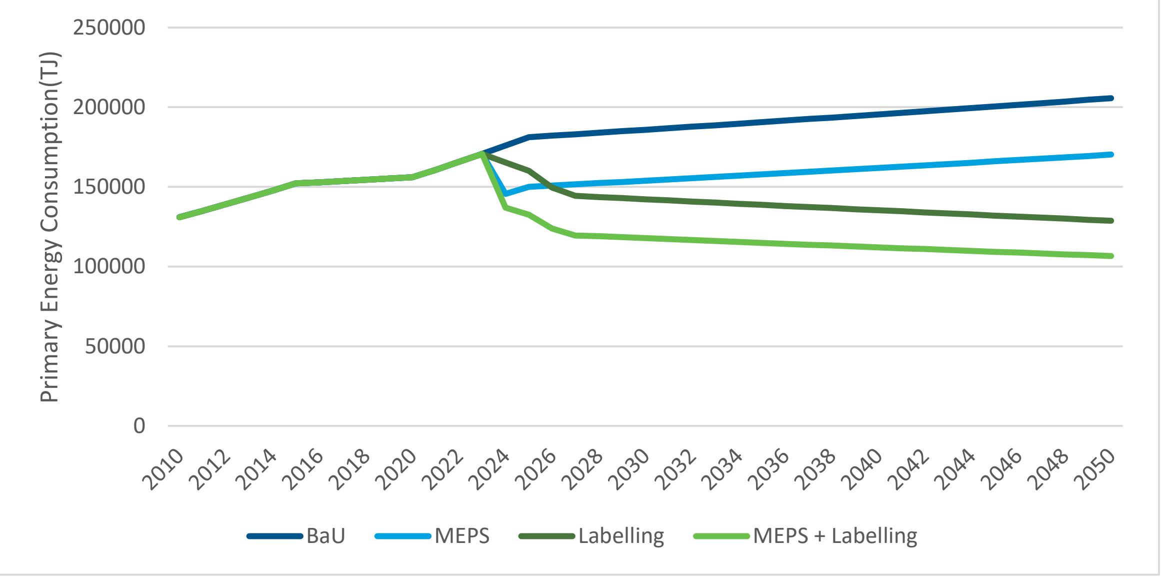


Figure 7.9 shows the Energy Cost for the four scenarios between 2010 and 2050 for EU27 for all servers BCs.

Figure 7.9 All servers BCs Energy Cost, four scenarios, 2010-2050 (EU27)

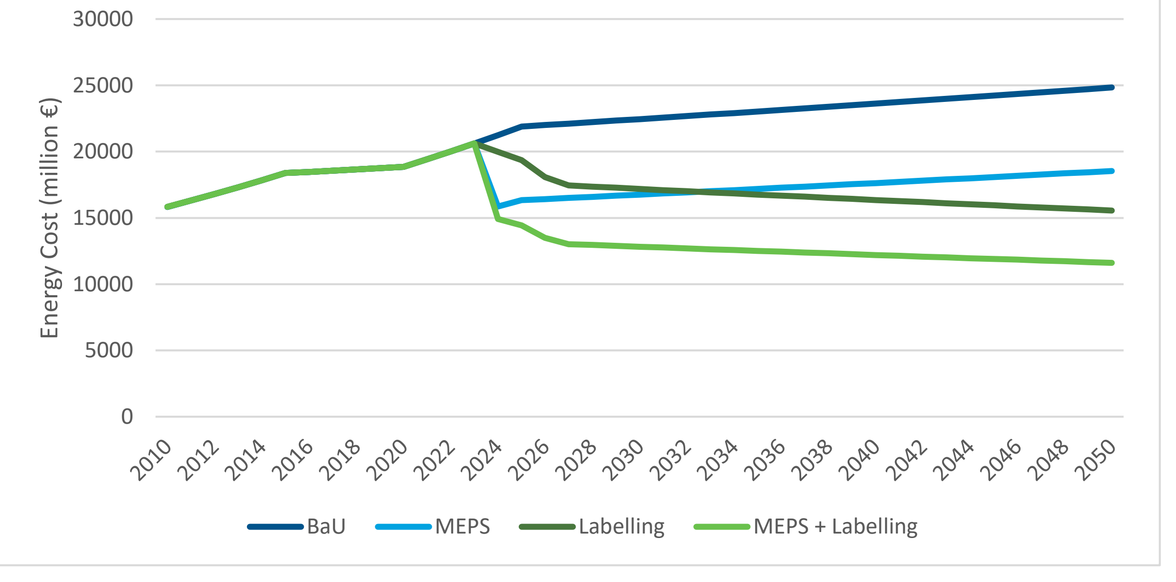
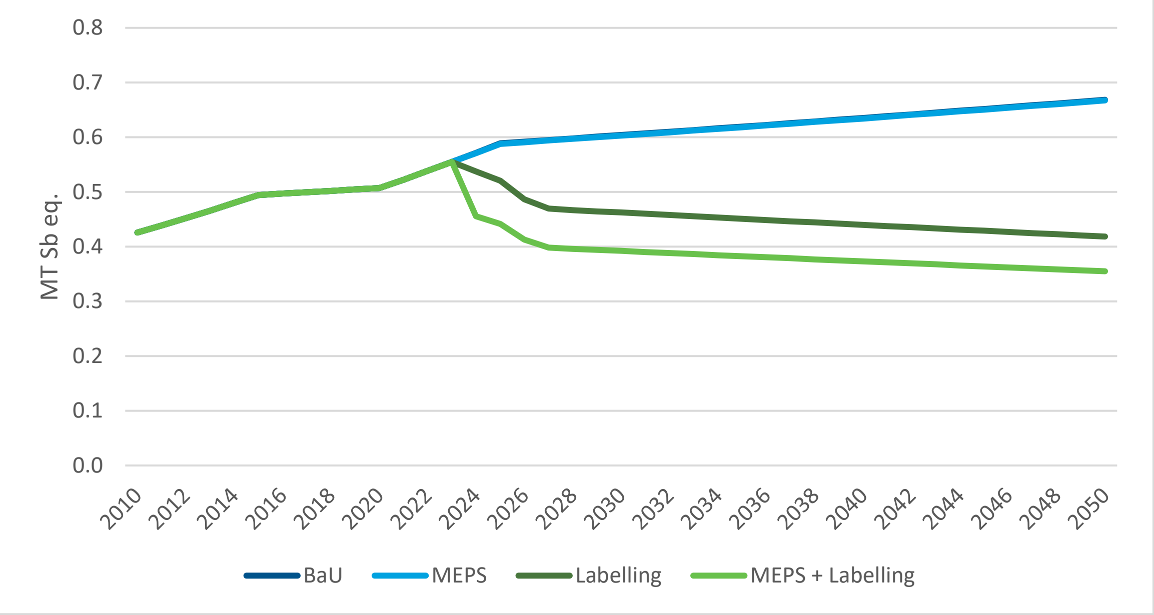


Figure 7.10 shows the Resource use (minerals & metals) for the four scenarios between 2010 and 2050 for EU27 for all BCs.

Figure 7.10 All servers BCs Resource use, four scenarios, 2010-2050 (EU27)



7.2.2.4 Base Case 3

Figure 7.11 shows Primary Energy Consumption for BaU and MEPS scenarios between 2010 and 2050 for EU27 for the Data Storage BC.

Figure 7.11 Data storage BC Primary Energy Consumption, BaU and MEPS scenarios, 2010-2050 (EU27)

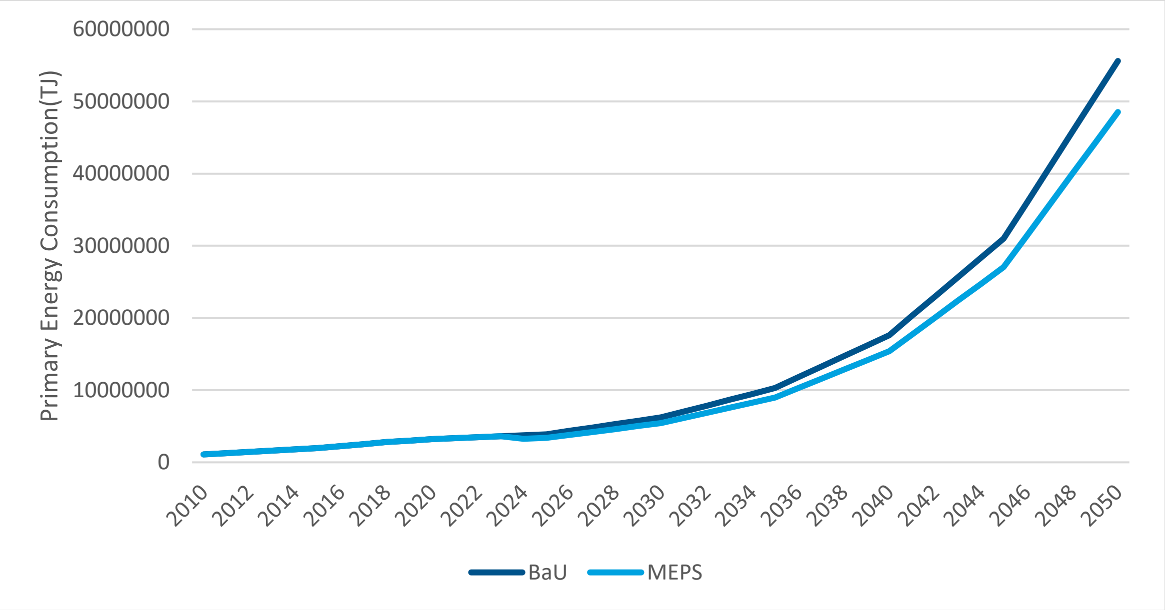


Figure 7.12 shows the Energy Cost for the BaU and MEPS scenarios between 2010 and 2050 for EU27 for the Data Storage BC.

Figure 7.12 Data storage BC Energy Cost, BaU and MEPS scenarios, 2010-2050 (EU27)

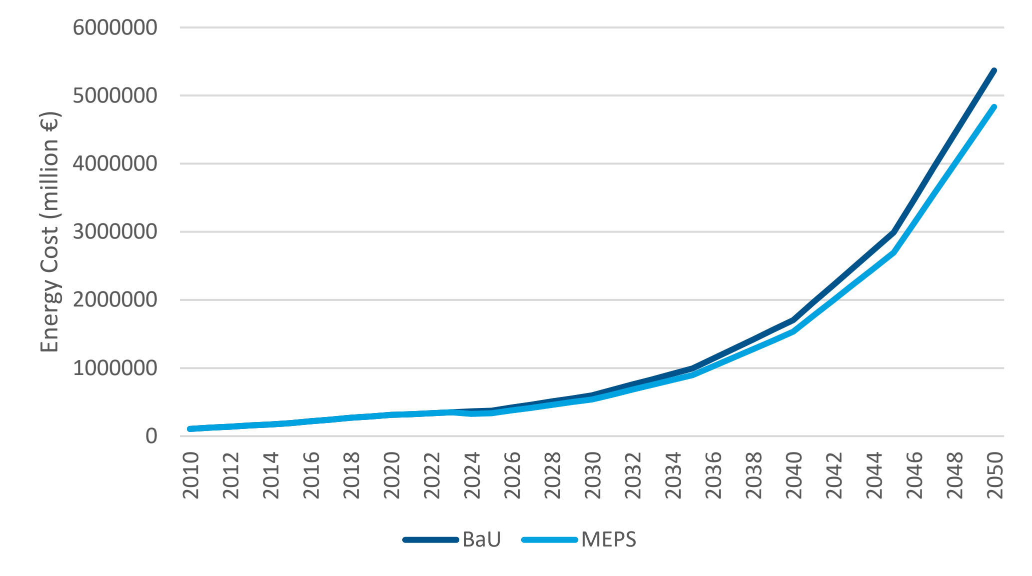
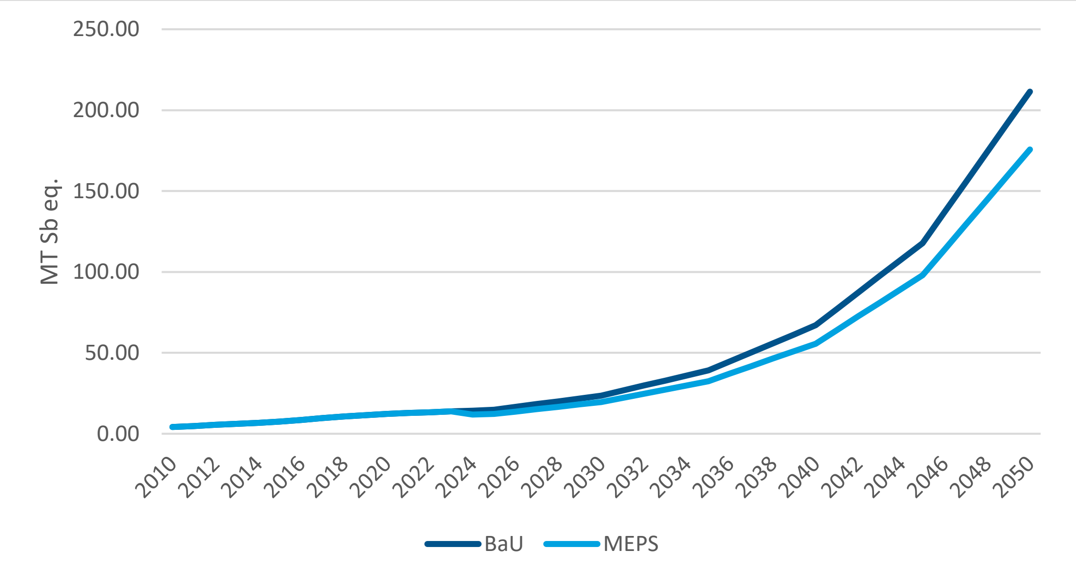


Figure 7.13 shows the Resource use (minerals & metals) for the BaU and MEPS scenarios between 2010 and 2050 for EU27 for the Data storage BC.

Figure 7.13 Data storage BC Resource use, BaU and MEPS scenarios, 2010-2050 (EU27)



7.3 Scenario Analysis – Socio-Economic Impacts

The objective of this sub-task is to discuss the socio-economics impacts created by the different policy scenarios proposed (i.e. BaU, MEPS, Labelling and MEPS + Labelling) for servers.

The same sales and stock model used previously to calculate resource use and environmental impacts is used to estimate the following outputs in all four scenarios:

- Consumer expenditure with purchase and installation.

- Running costs to the consumer, cost of electricity, cost of repair, and maintenance cost.
- Societal costs of the environmental impacts created.

The inputs and assumptions used in the modelling as well as the results are presented in the following sub-sections.

7.3.1 Inputs & Assumptions[245]

7.3.1.1 Purchase price

The purchase price inputs for the BaU scenario were used as per the Base Case models from Task 5 for the whole 2010-2050 period.

In the Labelling scenario, the purchase prices of units are similar to those in the BaU scenario. The rationale behind this assumption is that the label per se does not directly affect the price of products on the market.

In the MEPS and the MEPS + Labelling scenarios, the average price per unit is expected to increase in 2024 for all Categories due to the proposed measures as described in Task 6 for DO9 (BC1, BC2) and DO10 for BC3) .

The purchase price of units used in the scenarios are detailed in Table 7.15 below.

Table 7.15 Purchase price of units used in the four scenarios

Base Case	BaU and Labelling purchase price (€)	MEPS and MEPS + Labelling purchase price (€)
BC1	23,420	25,762
BC2	8,435	9,279
BC3	24,400	26,840

7.3.1.2 Installation cost

The installation cost inputs were used as per the Base Case models from Task 5 for the whole 2010-2050 period in all four scenarios.

The installation cost of units used in the scenarios are detailed in Table 7.16 below,

Table 7.16 Installation cost of units used in the four scenarios

Base Case	All 4 scenarios installation cost (€)
BC1	340
BC2	340
BC3	425

7.3.1.3 Maintenance & repair

The repair and maintenance cost inputs for the BaU scenario were used as per the Base Case models from Task 5.

[245] For BC3, only BaU and MEPS scenarios are considered and no Labelling and MEPS+Labelling is considered

The repair and maintenance cost of units used in the scenarios are detailed in Table 7.17 below.

Table 7.17 Repair and maintenance cost of units used in the four scenarios

Base Case	All 4 scenarios repair and maintenance cost (€)
BC1	400
BC2	400
BC3	220

7.3.1.4 Inflation

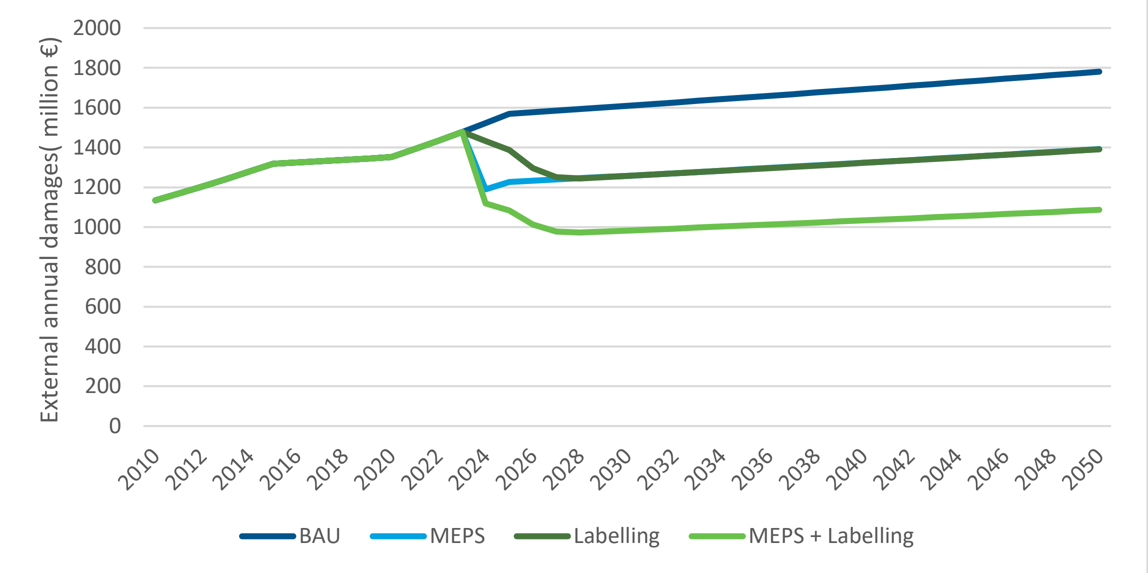
Socio-economic impacts were first calculated in terms of real value (i.e. current €) for an analysis of the effect of the assumptions and policies.

7.3.2 Results[246]

7.3.2.1 Base Case 1

Total annual external damages of the stock between 2010 and 2050 in the EU for the four different scenarios is presented in Figure 7.14 below.

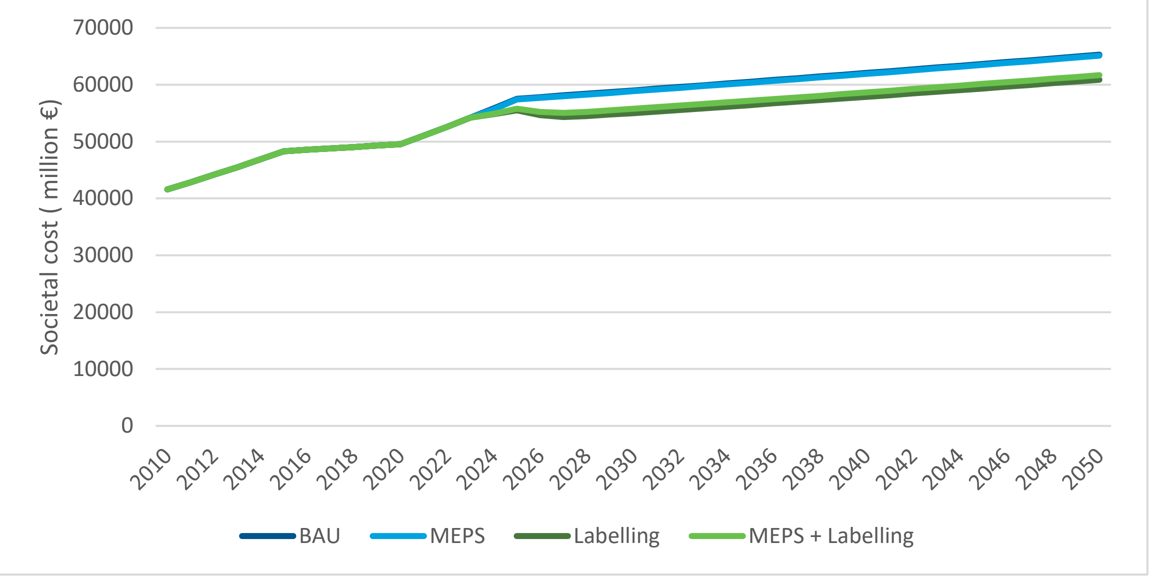
Figure 7.14 BC1 External annual damages, EU27



Total societal cost of the stock between 2010 and 2050 in the EU for the four different scenarios is presented below in Figure 7.15.

246 All results are calculated per Blade for BC2

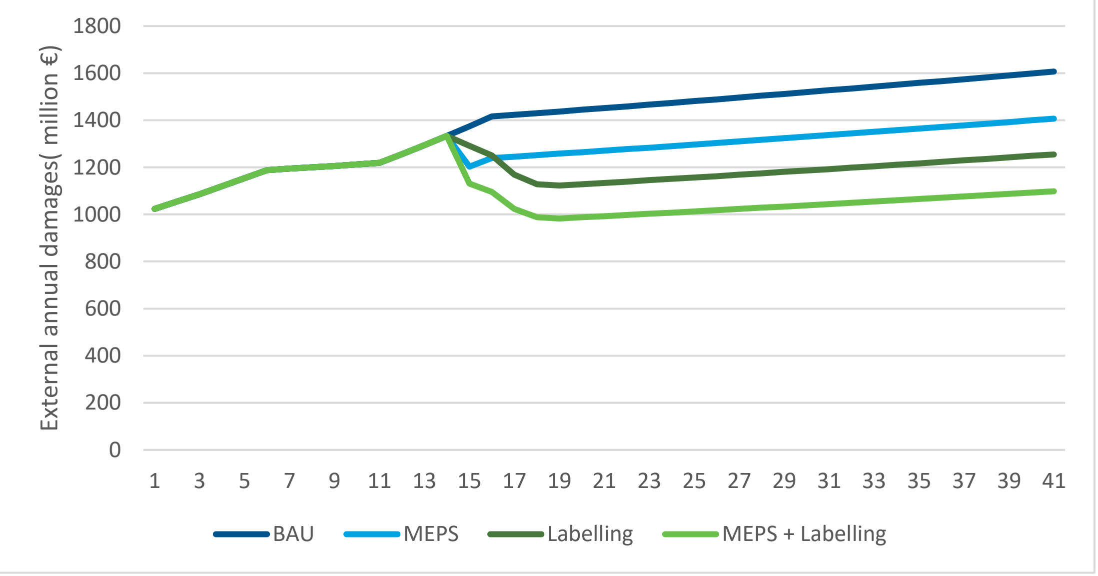
Figure 7.15 BC1 Total Societal cost, EU27



7.3.2.2 Base Case 2

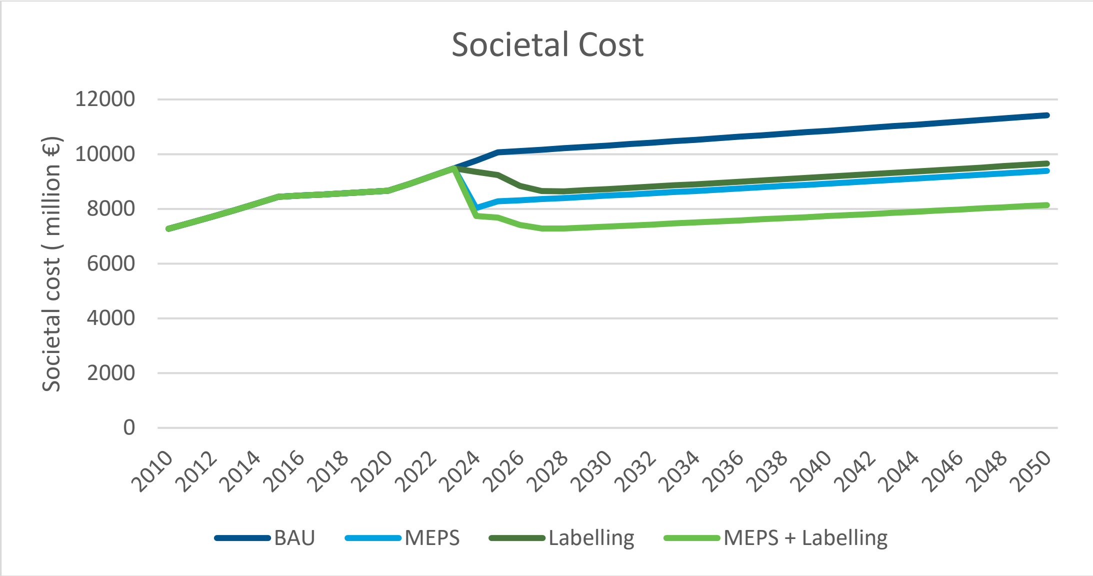
Total annual external damages of the stock between 2010 and 2050 in the EU for the four different scenarios is presented in Figure 7.16.

Figure 7.16 BC2 External annual damages, EU27



Total societal cost of the stock between 2010 and 2050 in the EU for the four different scenarios is presented below in Figure 7.17.

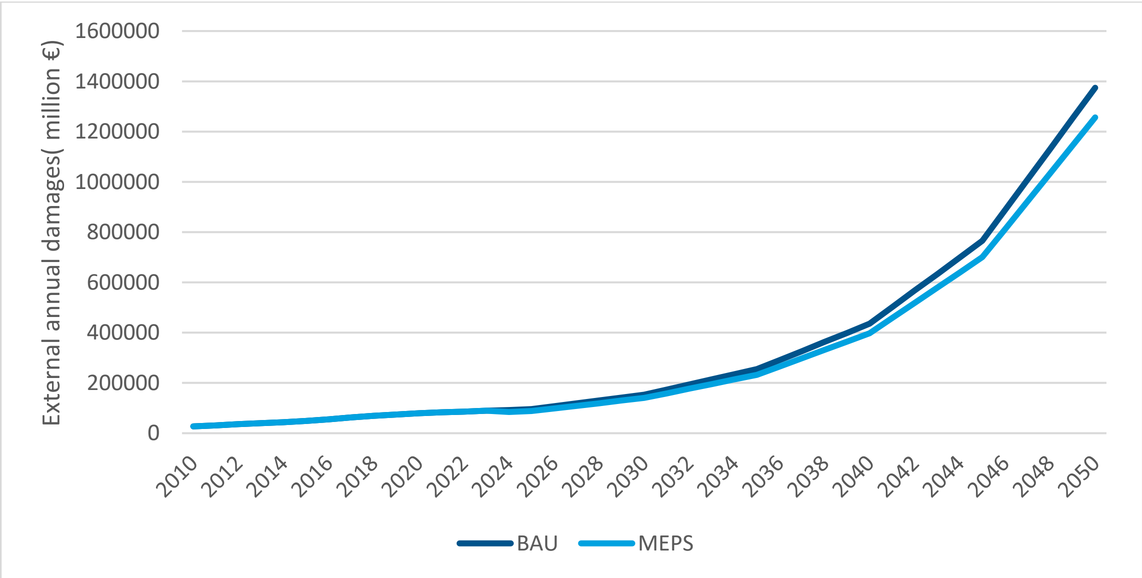
Figure 7.17 BC2 Total societal cost, EU27



7.3.2.3 Base Case 3

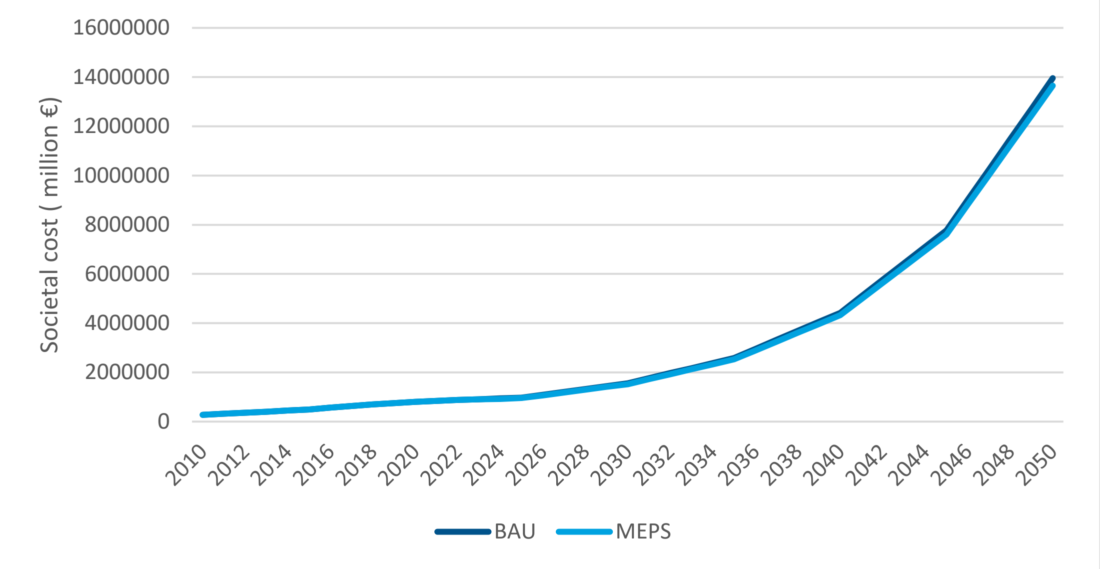
Total annual external damages of the stock between 2010 and 2050 in the EU for the BaU and MEPS scenarios is presented in Figure 7.18.

Figure 7.18 BC3 External annual damages, EU27



Total societal cost of the stock between 2010 and 2050 in the EU for the BaU and MEPS scenarios is presented below in Figure 7.19.

Figure 7.19 BC3 Total societal cost, EU27



7.4 Sensitivity Analysis

The objective of this sub-task is to conduct a sensitivity analysis of the four scenarios i.e. BaU, MEPS, Labelling and MEPS + Labelling with DO3 (for BC1 & BC2[247]) and only BaU and MEPS scenarios with DO6 for BC3 and present its outputs in comparison to the four scenarios. BaU is the existing regulation scenario, MEPS is the DO9 for BC1,BC2 and DO10 for BC3 . Labelling scenario is BaU with efficiency improvements as defined in 7.2.1.4. MEPS + Labelling scenario is DO9 with efficiency improvements as defined in 7.2.1.5.

7.4.1 Base Case 1

0 shows Primary Energy Consumption for all fours scenarios vs DO3 between 2010 and 2050 for EU27 for BC1.

[247] Sensitivity analysis is done per Blade for BC2

Figure 7.20 BC1 Primary Energy Consumption, four scenarios vs DO3, 2010-2050 (EU27)

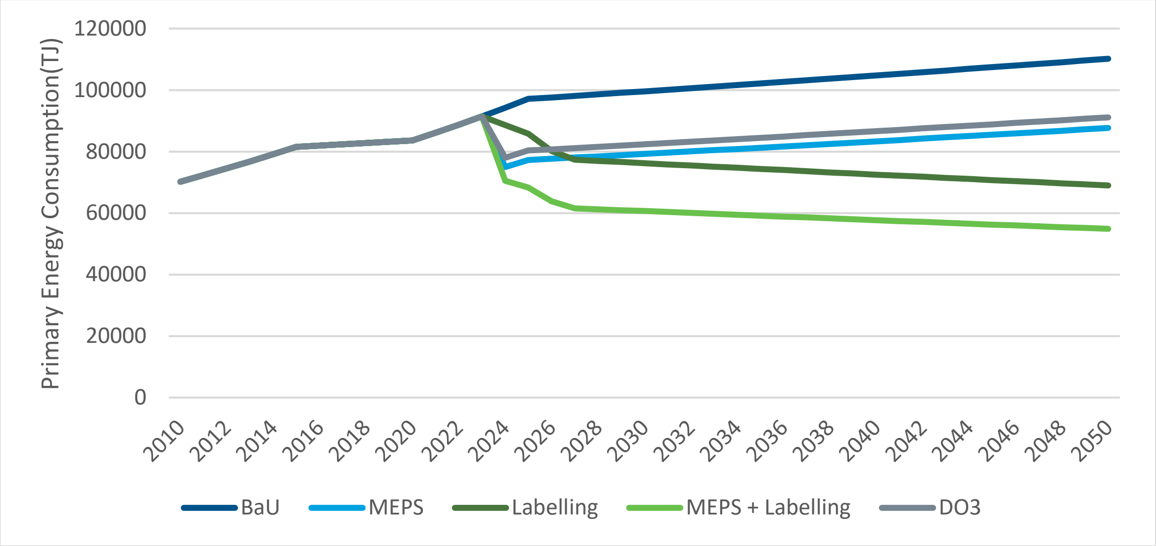


Figure 7.21 shows the Energy Cost for the four scenarios vs DO3 between 2010 and 2050 for EU27 for BC1.

Figure 7.21 BC1 Energy Cost, four scenarios vs DO3, 2010-2050 (EU27)

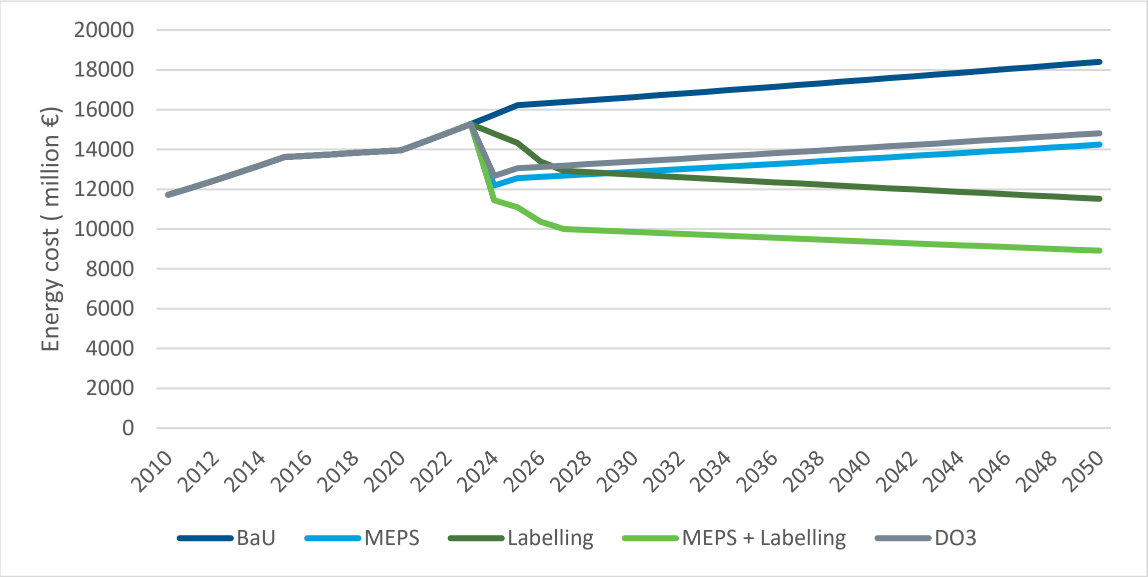
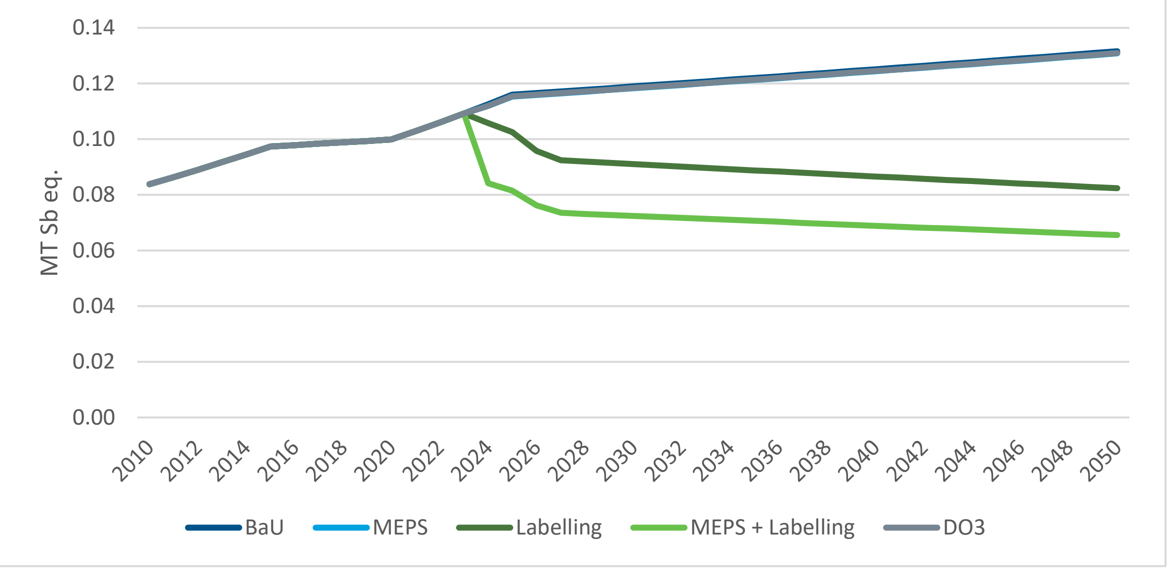


Figure 7.22 shows the Resource use (minerals & metals) for the four scenarios vs DO3 between 2010 and 2050 for EU27 for BC1.

Figure 7.22 BC1 Resource use, four scenarios vs DO3, 2010-2050 (EU27)



7.4.2 Base Case 2

Figure 7.23 shows Primary Energy Consumption for all fours scenarios vs DO3 between 2010 and 2050 for EU27 for BC2.

Figure 7.23 BC2 Primary Energy Consumption, four scenarios vs DO3, 2010-2050 (EU27)

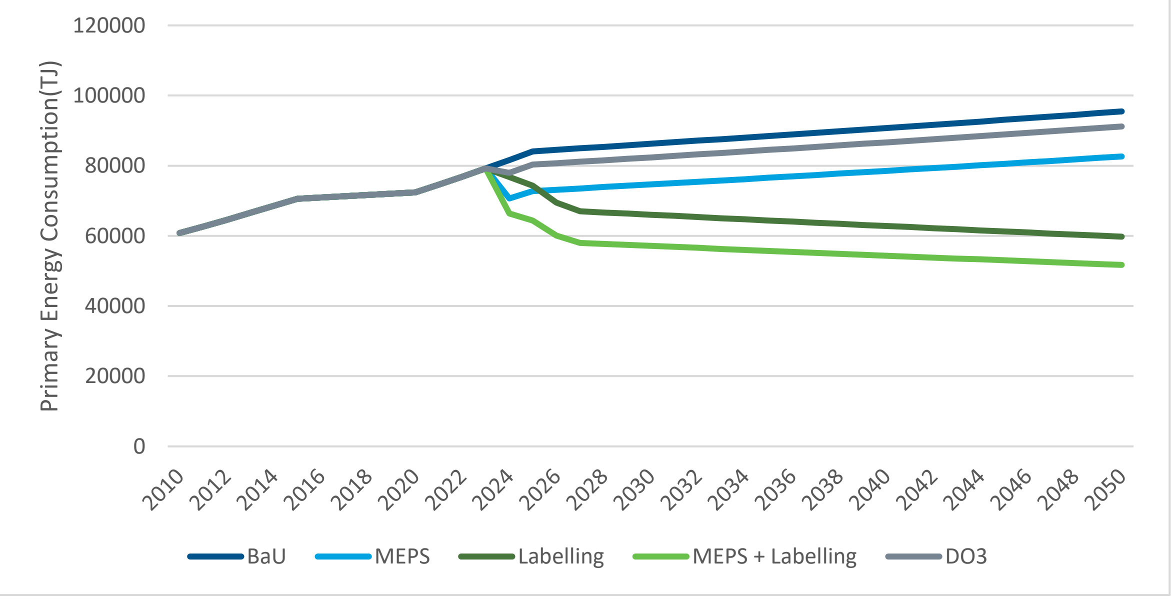


Figure 7.24 shows the Energy Cost for the four scenarios vs DO3 between 2010 and 2050 for EU27 for BC2.

Figure 7.24 BC2 Energy Cost, four scenarios vs DO3, 2010-2050 (EU27)

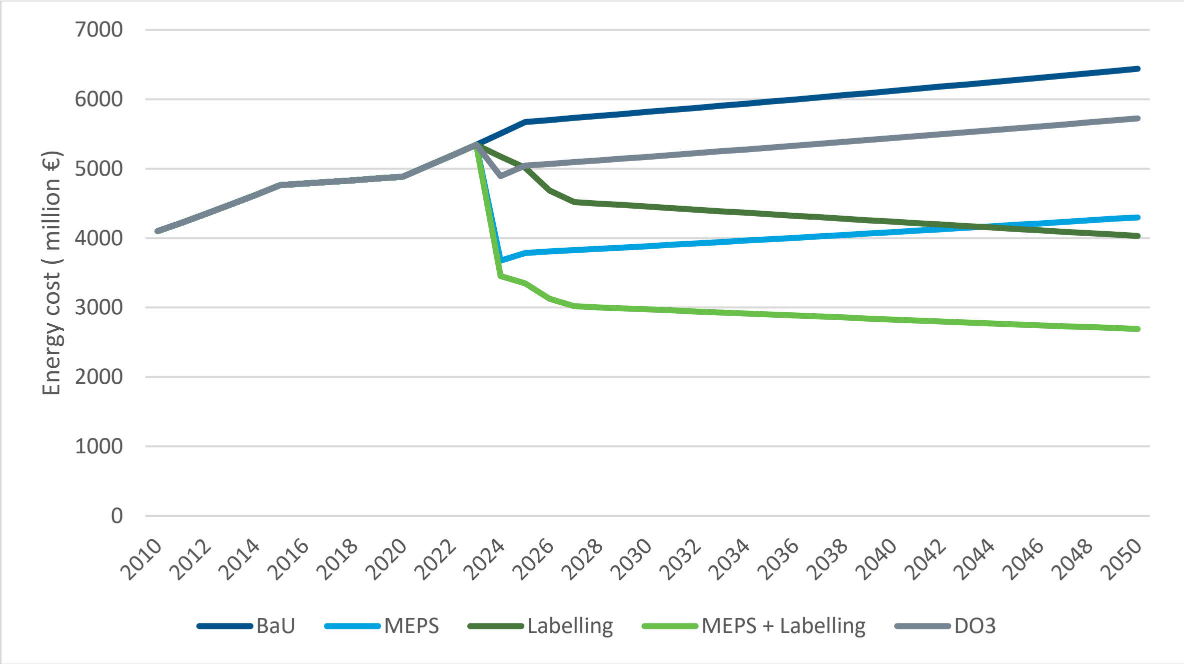
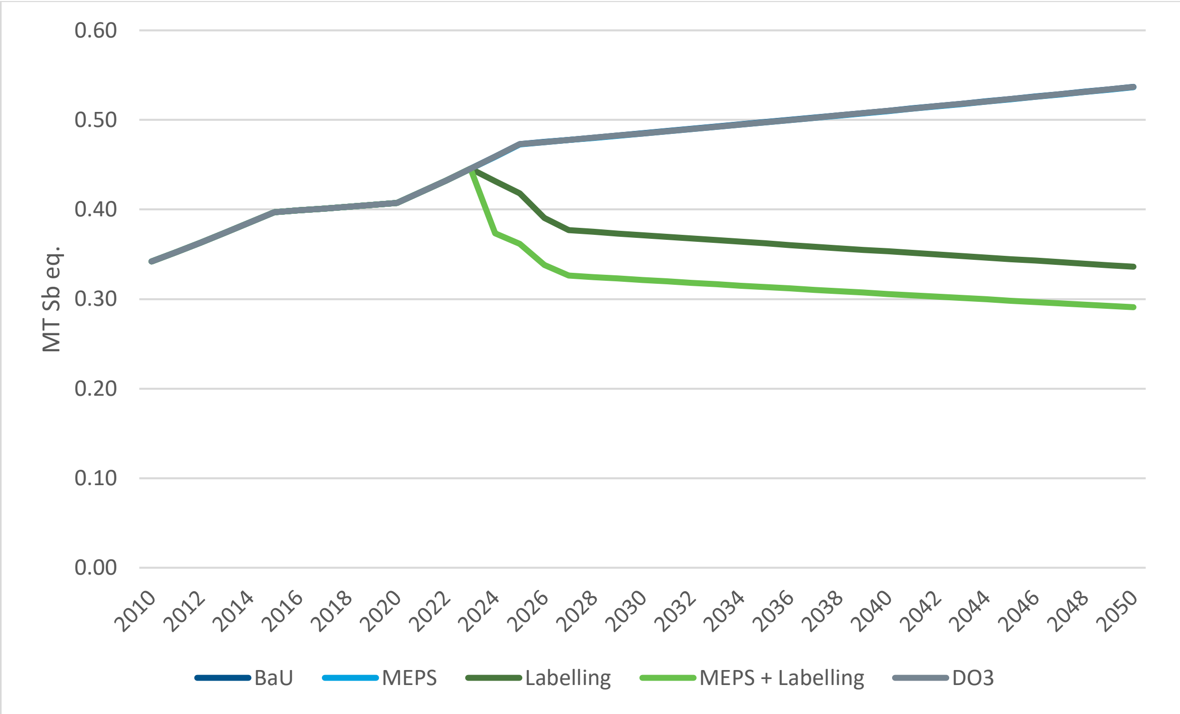


Figure 7.25 shows the Resource use (minerals & metals) for the four scenarios vs DO3 between 2010 and 2050 for EU27 for BC2

Figure 7.25 BC2 Resource use, four scenarios vs DO3, 2010-2050 (EU27)



7.4.3 Base Case 3

Figure 7.26 shows Primary Energy Consumption for BaU and MEPS scenarios vs DO6 between 2010 and 2050 for EU27 for BC3.

Figure 7.26 Primary Energy Consumption, BaU and MEPS scenarios vs DO6, 2010-2050 (EU27)

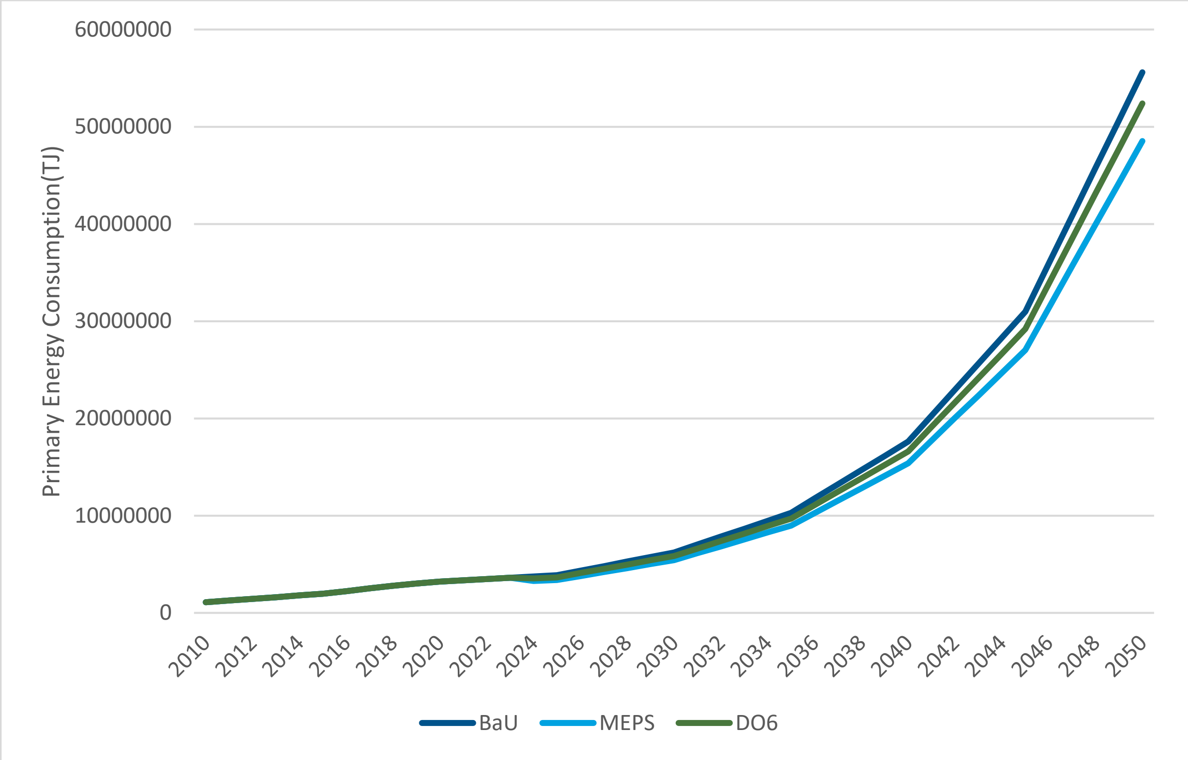


Figure 7.27 shows the Energy Cost for the BaU and MEPS scenarios vs DO6 between 2010 and 2050 for EU27 for BC2.

Figure 7.27 BC3 Energy Cost, BaU and MEPS scenarios vs DO6, 2010-2050 (EU27)

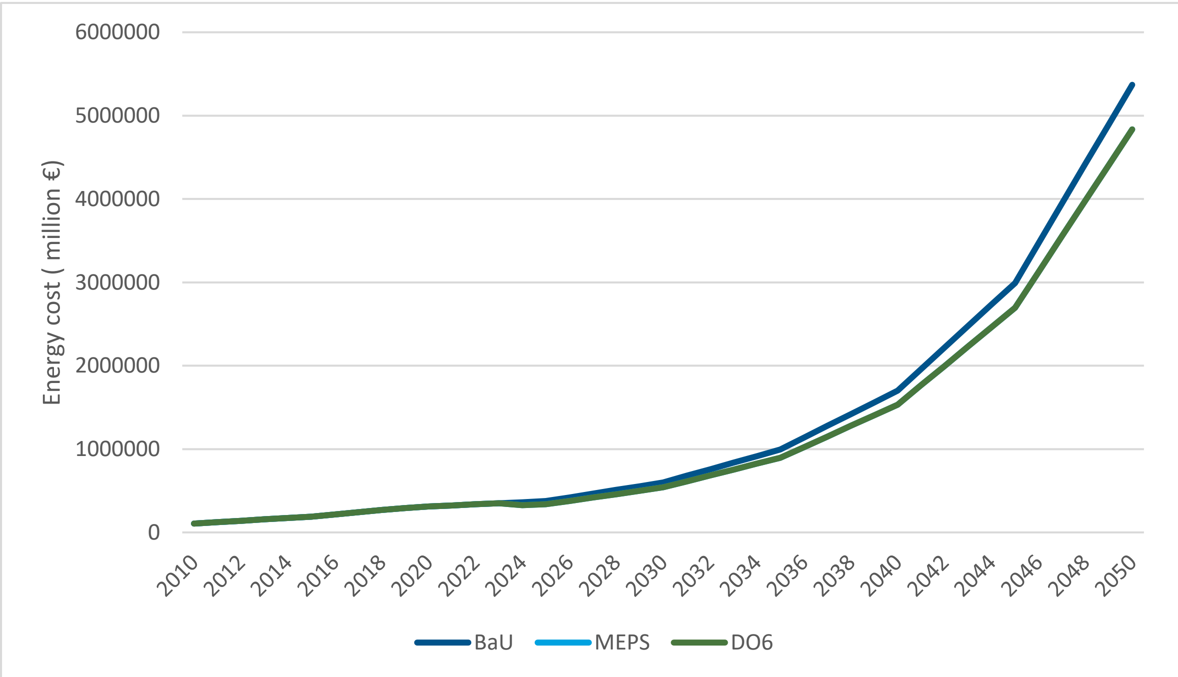
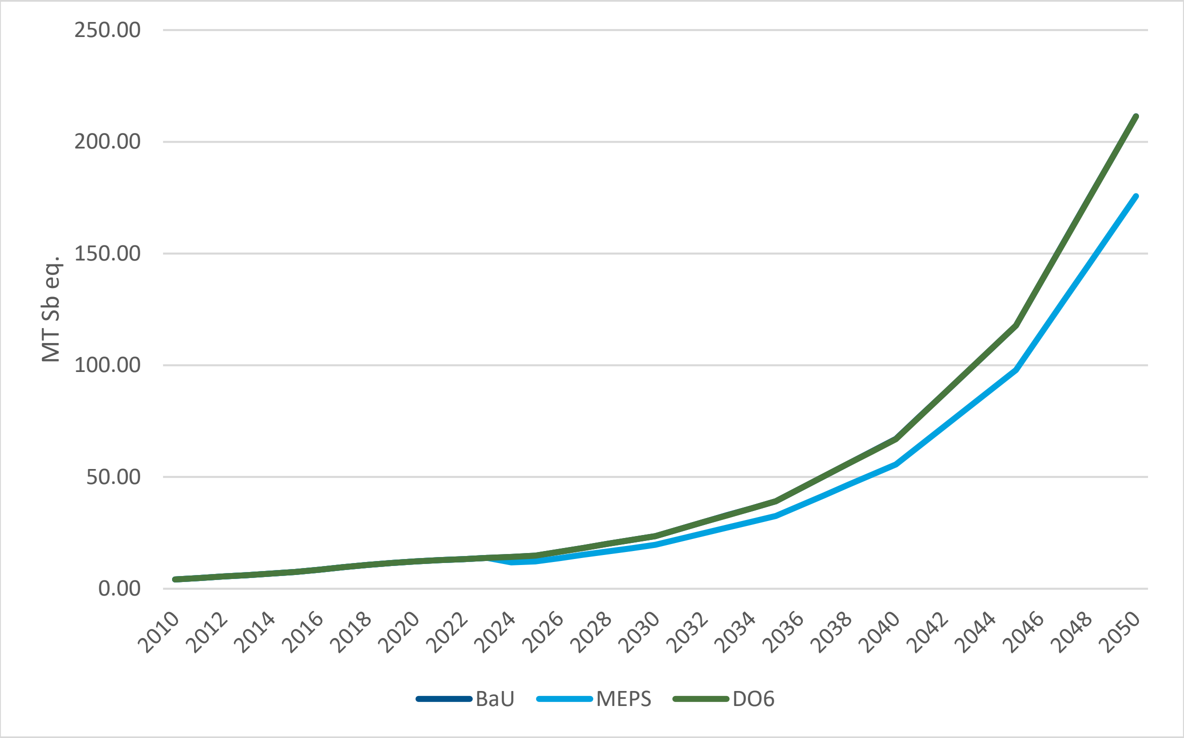


Figure 7.28 shows the Resource use (minerals & metals) for the BaU and MEPS scenarios vs DO6 between 2010 and 2050 for EU27 for BC3

Figure 7.28 BC3 Resource use, BaU and MEPS scenarios vs DO6, 2010-2050 (EU27)



Annex 1 Energy Star Definitions (Task 1)

A1.1 Version 4.0 ENERGY STAR® Specification for Computer Servers

Computer Server: A computer that provides services and manages networked resources for client devices (e.g., desktop computers, notebook computers, thin clients, wireless devices, PDAs, IP telephones, other computer servers, or other network devices). A computer server is sold through enterprise channels for use in data centers and office/corporate environments. A computer server is primarily accessed via network connections, versus directly-connected user input devices such as a keyboard or mouse. For purposes of this specification, a computer server must meet all of the following criteria:

- is marketed and sold as a Computer Server;
- is designed for and listed as supporting one or more computer server operating systems (OS) and/or hypervisors;
- is targeted to run user-installed applications typically, but not exclusively, enterprise in nature;
- provides support for error-correcting code (ECC) and/or buffered memory (including both buffered dual in-line memory modules (DIMMs) and buffered on board (BOB) configurations).
- is packaged and sold with one or more ac-dc or dc-dc power supplies; and
- is designed such that all processors have access to shared system memory and are visible to a single OS or hypervisor

Resilient Server: A computer server designed with extensive Reliability, Availability, Serviceability (RAS) and scalability features integrated in the micro architecture of the system, CPU and chipset. For purposes of ENERGY STAR certification under this specification, a Resilient Server shall have the following characteristics:

- Processor RAS: The processor must have capabilities to detect, correct, and contain data errors, as described by all of the following:
  - Error recovery by means of instruction retry for certain processor faults;
  - Error detection on L1 caches, directories, and address translation buffers using parity protection; and
  - Single bit error correction (or better) on caches that can contain modified data. Corrected data is delivered to the recipient as part of the request completion.
- System Recovery & Resiliency: No fewer than six of the following characteristics shall be present in the server:
  - Error recovery and containment by means of (a) data poison indication (tagging) and propagation which includes mechanism to notify the OS or hypervisor to contain the error, thereby reducing the need for system reboots and (b) containment of address/command errors by preventing possibly contaminated data from being committed to permanent storage;
  - The processor technology is designed to provide additional capability and functionality without additional chipsets, enabling it to be designed into systems with four or more processor sockets;
  - Memory Mirroring: A portion of available memory can be proactively partitioned such that a duplicate set may be utilized upon non-correctable memory errors. This can be implemented at the granularity of DIMMs or logical memory blocks;

- Memory Sparing: A portion of available memory may be pre-allocated or re-purposed to a spare function such that data may be migrated to the spare upon a perceived impending failure;
- Support for making additional resources available without the need for a system restart. This may be achieved either by processor (cores, memory, I/O) on-lining support, or by dynamic allocation/deallocation or processor cores, memory, and I/O to a partition;
- Support of redundant I/O devices (storage controllers, networking controllers);
- Has I/O adapters or storage devices that are hot-swappable;
- Can identify failing processor-to-processor lane(s) and dynamically reduce the width of the link in order to use only non-failing lanes or provide a spare lane for failover without disruption;
- Capability to partition the system such that it enables running instances of the OS or hypervisor in separate partitions. Partition isolation is enforced by the platform and/or hypervisor and each partition is capable of independently booting; or
- Uses memory buffers for connection of higher speed processor-memory links to DIMMs attached to lower speed DDR channels. Memory buffer can be a separate, standalone buffer chip which is integrated on the system board or integrated on custom-built memory cards.

- Power Supply RAS: All power supplies installed or shipped with the server shall be redundant and concurrently maintainable. The redundant and repairable components may also be housed within a single physical power supply, but must be repairable without requiring the system to be powered down. Support must be present to operate the system in a degraded mode.
- Thermal and Cooling RAS: All active cooling components shall be redundant and concurrently maintainable. The processor complex must have mechanisms to allow it to be throttled under thermal emergencies. Support must be present to operate the system in a degraded mode when thermal emergencies are detected in the system components.

A1.2 SPECpower Overview

Following on from Section 1.2.2.1, please see below the overview for SPECpower.

The Power committee developed SPECpower_ssj2008, the first benchmark for evaluating the power and performance characteristics of single server and multi-node servers[248]. With power efficiency becoming a high-priority issues for the IT industry, computer manufacturers and governments due to increasing energy consumption. The SPECpower benchmark was designed to address these rising concerns across industry and governments.

Based on the understanding that the power consumption profile of a server system is non-linear with respect to the workload (and respective performance), the SPECpower benchmark is varying the workload of the SPEC Java Business Benchmark (SPECjbb). According to SPEC, the benchmark provides a means to measure power (at the AC input) in conjunction with a performance metric[249]. It measures the energy efficiency of volume server class computers by evaluating both the power and performance characteristics of the System Under Test (SUT)[250]. This contributes to the increased efficiency of data centres by considering power characteristics and other selection criteria. It exercises the CPUs, caches, memory hierarchy and the scalability of shared memory processors (SMPs) as well as the

[248] https://www.spec.org/power_ssj2008/

[249] https://www.spec.org/power_ssj2008/

[250] Benchmark Overview SPECpower_ssj2008 (fujitsu.com)

implementations of the JVM (Java Virtual Machine), JIT (Just-In-Time) compiler, garbage collection, threads and some aspects of the operating system[251]. The benchmark runs on a wide variety of operating systems and hardware architectures and should not require extensive client or storage infrastructure.

The latest SPECpower_ssj2008 V1.12 was released on July 26th, 2012. This is a point release which includes several enhancements, including added reporter support for large numbers of JVMs, PTDaemon update to version 1.4.2, and support for a new analyser (Newtons4th PPA15x0).

[251] https://www.spec.org/power_ssj2008/

Annex 2 SNIA Taxonomy detail (Task 3)

Table A2.1 SNIA Taxonomy detail for Online storage[252]

Attribute	Classification					
	Online 1	Online 2	Online 3	Online 4	Online 5	Online 6
Access Pattern	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential
Connectivity	Not specified	Connected to single or multiple hosts	Network-connected	Network-connected	Network-connected	Network-connected
Consumer/ Component	Yes	No	No	No	No	No
FBA/CKD Support	Optional	Optional	Optional	Optional	Optional	Required
Integrated Storage Controller	Optional	Optional	Required	Required	Required	Required
Maximum Configuration[1]	≥1	≥ 4	≥ 12	> 100	>400	>400
MaxTTFD (t)	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Optional	Optional	Required	Required	Required
Non-Disruptive Serviceability	Optional	Optional	Optional	Optional	Required	Required
Storage Protection	Optional	Optional	Required	Required	Required	Required
User-Accessible Data	Required	Required	Required	Required	Required	Required

252 Taxonomy | SNIA

Table A2.2 SNIA Taxonomy detail for Near Online storage[253]

Attribute	Classification					
	Near Online 1	Near Online 2	Near Online 3	Near Online 4	Near Online 5	Near Online 6
Access Pattern	Random/ Sequential	Random/ Sequential	Random/ Sequential		Random/ Sequential	Random/ Sequential
Connectivity	Not specified	Network connected	Network connected		Network connected	Network connected
Consumer/ Component	Yes	No	No		No	No
FBA/CKD Support	Optional	Optional	Optional		Optional	Optional
Integrated Storage Controller	Optional	Optional	Required		Required	Required
Maximum Configuration[1]	≥ 1	≥ 4	≥ 12		> 100	> 1000
MaxTTFD (t)	t > 80 ms	t > 80 ms	t > 80 ms		t > 80 ms	t > 80 ms
No SPOF	Optional	Optional	Optional		Optional	Required
Non-Disruptive Serviceability	Optional	Optional	Optional		Optional	Required
Storage Protection	Optional	Optional	Required		Required	Required
User-accessible Data	Required	Required	Required		Required	Required

Table A2.3 SNIA Taxonomy detail for Removable Media Libraries[254]

Attribute	Classification					
	Removable 1	Removable 2	Removable 3	Removable 4	Removable 5	Removable 6
Access Pattern	Sequential	Sequential	Sequential		Sequential	Sequential
Maximum Drive Count	Not specified	4	≥ 5		≥ 25	≥ 25
MaxTTFD (t)	80ms < t < 5m	80ms < t < 5m	80ms < t < 5m		80ms < t < 5m	80ms < t < 5m
No SPOF	Optional	Optional	Optional		Optional	Required
Non-disruptive Serviceability	Optional	Optional	Optional		Optional	Required
Robotics	Prohibited	Required	Required		Required	Required
User-Accessible Data	Required	Required	Required		Required	Required

253 Taxonomy | SNIA

254 Taxonomy | SNIA

Table A2.4 SNIA Taxonomy detail for Virtual Media Libraries[255]

Attribute	Classification					
	Virtual 1	Virtual 2	Virtual 3	Virtual 4	Virtual 5	Virtual 6
Access Pattern	Sequential	Sequential	Sequential		Sequential	Sequential
User-accessible Data	Required	Required	Required		Required	Required
MaxTTFD (t)	t < 80 ms	t < 80 ms	t < 80 ms		t < 80 ms	t < 80 ms
Storage Protection	Optional	Optional	Required		Required	Required
No SPOF	Optional	Optional	Optional		Optional	Required
Non-Disruptive Serviceability	Optional	Optional	Optional		Optional	Required
Maximum Configuration[1]	12	>12	> 48		> 96	> 96

[255] Taxonomy | SNIA

Annex 3 All Life Cycle Indicators per unit for design options (Task 6)

This annex presents all Life cycle indicators per unit of different design options for the three Base Cases.

A3.1 Base Case 1

Table A3.1 All Life cycle indicators per unit of the different design options for BC 1

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Energy Consumption									
Electricity	kWh	16,428.0	14,157.9	13,914.8	13,229.8	14,115.0	15,303.2	15,285.3	12,712
	% change with BC		-13.82	-15.30	-19.47	-14.08	-6.85	-6.96	-22.62
Thermal Energy	MJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	% change with BC		0	0	0.00	0.00	0.00	0.00	0.00
PEF Impact Categories									
Climate change, total	kg CO2 eq	6.98E+03	6.03E+03	5.93E+03	5.64E+03	6.01E+03	6.51E+03	6.50E+03	5.42E+03
	% change with BC		-14	-15	-19	-14	-7	-7	-22
Ozone depletion	kg CFC-11 eq	2.62E-06	2.27E-06	2.23E-06	2.12E-06	2.33E-06	2.44E-06	2.44E-06	2.04E-06
	% change with BC		-13	-15	-19	-11	-7	-7	-22
Human toxicity, cancer	CTUh	1.17E-06	1.01E-06	9.96E-07	9.48E-07	1.01E-06	1.09E-06	1.09E-06	9.12E-07
	% change with BC		-13	-15	-19	-13	-7	-7	-22
Human toxicity, non-cancer	CTUh	2.44E-05	2.12E-05	2.09E-05	1.99E-05	2.11E-05	2.28E-05	2.28E-05	1.92E-05
	% change with BC		-13	-14	-18	-13	-6	-7	-21
Particulate Matter	disease incidence	2.33E-04	2.03E-04	2.00E-04	1.90E-04	2.02E-04	2.18E-04	2.18E-04	1.84E-04

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
	% change with BC		-13	-14	-18	-13	-6	-7	-21
Ionising radiation, human health	kBq U235 eq	2.93E +03	2.52E +03	2.48E +03	2.36E +03	2.51E +03	2.73E +03	2.72E +03	2.26E +03
	% change with BC		-14	-15	-19	-14	-7	-7	-23
Photochemical ozone formation, human health	kg NMVOC eq	1.17E +01	1.02E +01	1.00E +01	9.55E +00	1.02E +01	1.10E +01	1.10E +01	9.20E +00
	% change with BC		-13	-15	-19	-13	-7	-7	-22
Acidification	mol H+ eq	2.20E +01	1.91E +01	1.88E +01	1.80E +01	1.91E +01	2.06E +01	2.06E +01	1.73E +01
	% change with BC		-13	-15	-18	-13	-7	-7	-21
Eutrophication, terrestrial	mol N eq	4.39E +01	3.80E +01	3.74E +01	3.57E +01	3.80E +01	4.10E +01	4.09E +01	3.43E +01
	% change with BC		-13	-15	-19	-13	-7	-7	-22
Eutrophication, freshwater	kg P eq	1.43E-02	1.23E-02	1.21E-02	1.15E-02	1.23E-02	1.33E-02	1.33E-02	1.11E-02
	% change with BC		-14	-15	-19	-14	-7	-7	-22
Eutrophication, marine	kg N eq	4.13E +00	3.58E +00	3.52E +00	3.36E +00	3.57E +00	3.86E +00	3.86E +00	3.23E +00
	% change with BC		-13	-15	-19	-13	-7	-7	-22
Ecotoxicity, freshwater	CTUe	3.20E +04	2.77E +04	2.72E +04	2.59E +04	2.76E +04	2.98E +04	2.98E +04	2.49E +04
	% change with BC		-14	-15	-19	-14	-7	-7	-22
Land use	pt	8.63E +04	8.22E +04	8.17E +04	8.05E +04	8.21E +04	8.43E +04	8.63E +04	7.96E +04
	% change with BC		-5	-5	-7	-5	-2	0	-8
Water use	m3 water eq. of	2.37E +03	2.05E +03	2.01E +03	1.92E +03	2.05E +03	2.21E +03	2.37E +03	1.84E +03

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
	deprived water								
	% change with BC		-14	-15	-19	-14	-7	0	-22
Resource use, minerals and metals	kg Sb eq	7.05E-02	7.02E-02	7.02E-02	7.01E-02	7.02E-02	7.04E-02	7.05E-02	7.01E-02
	% change with BC		-0.34	-0.38	-0.48	-0.35	-0.17	0	-1
Resource use, fossils	MJ	1.21E+05	1.04E+05	1.03E+05	9.76E+04	1.04E+05	1.13E+05	1.21E+05	9.38E+04
	% change with BC		-14	-15	-19	-14	-7	0	-22
Primary energy consumption	MJ	6.03E+04	5.22E+04	5.13E+04	4.88E+04	5.20E+04	5.63E+04	5.62E+04	4.70E+04
	% change with BC		-14	-15	-19	-14	-6.7	-7	-22

A3.2 Base Case 2

Table A3.2 All Life cycle indicators per unit of the different design options for BC 2

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Energy Consumption									
Electricity	kWh	29,186.8	26,934.8	26,654.9	25,947.0	28,419.9	28,457.2	29,186.8	19,484
	% change with BC		-7.72	-8.67	-11.10	-2.63	-2.50	0.000	-33.24
Thermal Energy	MJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	% change with BC		0	0	0.00	0.00	0.00	0.00	0.00
PEF Impact Categories									
Climate change, total	kg CO2 eq	2.38E+04	2.29E+04	2.27E+04	2.24E+04	2.35E+04	2.35E+04	2.37E+04	1.97E+04
	% change with BC		-4	-4	-6	-1	-1	-0.24	-17
Ozone depletion	kg CFC-11 eq	5.00E-06	4.65E-06	4.61E-06	4.50E-06	4.89E-06	4.89E-06	5.00E-06	3.50E-06

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
	% change with BC		-7	-8	-10	-2	-2	-0.02	-30
Human toxicity, cancer	CTUh	5.49E-06	5.34E-06	5.32E-06	5.27E-06	5.44E-06	5.44E-06	5.48E-06	4.82E-06
	% change with BC		-3	-3	-4	-1	-1	-0.3	-12
Human toxicity, non-cancer	CTUh	1.50E-04	1.47E-04	1.47E-04	1.46E-04	1.49E-04	1.49E-04	1.50E-04	1.37E-04
	% change with BC		-2	-2	-3	-1	-1	-0.4	-9
Particulate Matter	disease incidence	2.18E-03	2.15E-03	2.15E-03	2.14E-03	2.17E-03	2.17E-03	2.17E-03	2.05E-03
	% change with BC		-1	-2	-2	0	0	-0.4	-6
Ionising radiation, human health	kBq U235 eq	5.73E+03	5.33E+03	5.28E+03	5.16E+03	5.60E+03	5.60E+03	5.73E+03	4.01E+03
	% change with BC		-7	-8	-10	-2	-2	0.0	-30
Photochemical ozone formation, human health	kg NMVOC eq	6.72E+01	6.57E+01	65.5	6.50E+01	6.67E+01	6.67E+01	6.70E+01	6.06E+01
	% change with BC		-2	-3	-3	-1	-1	-0.3	-10
Acidification	mol H+ eq	2.36E+02	2.33E+02	2.33E+02	2.32E+02	2.35E+02	2.35E+02	2.35E+02	2.24E+02
	% change with BC		-1.2	-1.4	-1.7	-0.4	-0.4	-0.4	-5
Eutrophication, terrestrial	mol N eq	2.23E+02	2.18E+02	2.17E+02	2.15E+02	2.21E+02	2.21E+02	2.23E+02	1.98E+02
	% change with BC		-3	-3	-4	-1	-1	0	-11
Eutrophication, freshwater	kg P eq	4.59E-02	4.40E-02	4.38E-02	4.32E-02	4.53E-02	4.53E-02	4.58E-02	3.77E-02
	% change with BC		-4	-5	-6	-1	-1	0	-18
Eutrophication, marine	kg N eq	2.08E+01	2.03E+01	2.02E+01	2.00E+01	2.06E+01	2.06E+01	2.07E+01	1.85E+01

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
	% change with BC		-3	-3	-4	-1	-1	0	-11
Ecotoxicity, freshwater	CTUe	1.22E +05	1.17E +05	1.17E +05	1.16E +05	1.20E +05	1.20E +05	1.21E +05	1.03E +05
	% change with BC		-4	-4	-5	-1	-1	0	-15
Land use	pt	1.23E +05	1.19E +05	1.19E +05	1.17E +05	1.22E +05	1.22E +05	1.23E +05	1.06E +05
	% change with BC		-3	-4	-5	-1	-1	0	-14
Water use	m3 water eq. of deprive d water	6.16E +03	5.84E +03	5.80E +03	5.70E +03	6.05E +03	6.06E +03	6.15E +03	4.77E +03
	% change with BC		-5	-6	-8	-2	-2	0	-23
Resource use, minerals and metals	kg Sb eq	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.46E +00	1.45E +00	1.46E +00
	% change with BC		-0.02	-0.02	-0.02	-0.01	-0.01	-0.48	-0.07
Resource use, fossils	MJ	3.67E +05	3.51E +05	3.49E +05	3.44E +05	3.62E +05	3.62E +05	3.66E +05	2.97E +05
	% change with BC		-4	-5	-6	-2	-1	0	-19
Primary energy consumption	MJ	2.60E +05	2.52E +05	2.51E +05	2.48E +05	2.57E +05	2.57E +05	2.59E +05	2.25E +05
	% change with BC		-3.1	-3.5	-4.49	-1	-1	-0.29	-13.5

A3.3 Base Case 3

Table A3.3 All Life cycle indicators per unit of the different design options for BC 3

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
		Energy Consumption			
Electricity	kWh	29223	26313	29360	27628
	% change with BC		-9.96	0.47	-5.46
Thermal Energy	MJ	0	0	0	0
	% change with BC		0.00	0.00	0.00
		PEF Impact Categories			
Climate change, total	kg CO2 eq	1.79E+04	1.67E+04	1.73E+04	1.66E+04
	% change with BC		-7	-4	-8
Ozone depletion	kg CFC-11 eq	4.65E-06	4.20E-06	4.66E-06	4.39E-06
	% change with BC		-10	0	-6
Human toxicity, cancer	CTUh	4.07E-06	3.87E-06	3.87E-06	3.75E-06
	% change with BC		-5	-5	-8
Human toxicity, non-cancer	CTUh	9.40E-05	8.99E-05	8.77E-05	8.53E-05
	% change with BC		-4	-7	-9
Particulate Matter	disease incidence	1.28E-03	1.25E-03	1.18E-03	1.15E-03
	% change with BC		-3	-9	-10
Ionising radiation, human health	kBq U235 eq	5.47E+03	4.95E+03	5.46E+03	5.15E+03
	% change with BC		-9	0	-6
Photochemical ozone formation, human health	kg NMVOC eq	4.35E+01	4.15E+01	4.07E+01	3.95E+01
	% change with BC		-5	-6	-9
Acidification	mol H+ eq	1.37E+02	1.33E+02	1.25E+02	1.22E+02
	% change with BC		-3	-9	-11
Eutrophication, terrestrial	mol N eq	1.49E+02	1.41E+02	1.40E+02	1.35E+02
	% change with BC		-5	-6	-9
	kg P eq	3.44E-02	3.19E-02	3.33E-02	3.19E-02

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
Eutrophication, freshwater	% change with BC		-7	-3	-7
Eutrophication, marine	kg N eq	1.39E+01	1.32E+01	1.31E+01	1.27E+01
	% change with BC		-5	-6	-9
Ecotoxicity, freshwater	CTUe	8.88E+04	8.32E+04	8.49E+04	8.16E+04
	% change with BC		-6	-4	-8
Land use	pt	7.54E+04	7.01E+04	7.48E+04	7.16E+04
	% change with BC		-7	-1	-5
Water use	m3 water eq. of deprived water	5.14E+03	4.73E+03	5.04E+03	4.80E+03
	% change with BC		-8	-2	-7
Resource use, minerals and metals	kg Sb eq	6.90E-01	6.90E-01	6.03E-01	6.02E-01
	% change with BC		0	-13	-13
Resource use, fossils	MJ	2.89E+05	2.68E+05	2.81E+05	2.68E+05
	% change with BC		-7	-3	-7
Primary energy consumption	MJ	1.82E+05	1.71E+05	1.73E+05	1.66E+05
	% change with BC		-6	-5	-8