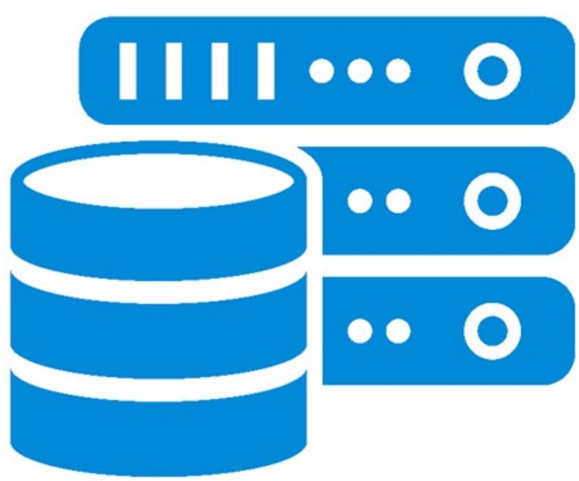
ENTERPRISE DATA STORAGE

EPEAT® Product Category Proposal

FINAL

April 2, 2025



GLOBAL ELECTRONICS COUNCIL®

Sustainabilty for a Connected Future

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1. Introduction

1.1 Overview

The rise of the internet of things (IoT) and cloud computing has resulted in significant increases in the global volume of data generated and managed, which in turn has led to a growing need for data storage and an accelerated evolution of storage technology [1]. Data centers store a wide range of data for organizations and services, including web content, business data, communication records, application and user information, and "big data" and analytics [2]. ENERGY STAR® reports that 28% of data center managers identified storage growth as the trend having the greatest impact on their data operations. In a data center, data storage products are responsible for 11% of energy consumption [3]. Data storage products are composed of many components such as SSDs (solid state drives), processors and printed circuit boards, known to have a high production environmental footprint. They are also part of the international electronics supply chain which requires due diligence to address potential adverse human rights impacts, especially in high-risk regions and countries.

GEC welcomes stakeholder comments on all aspects of this Product Category Proposal (PCP), which analyzes the market, presents State of Sustainability Research and establishes the business case for moving forward with an EPEAT product category. Details on how GEC selects technology categories for EPEAT are also publicly available in GEC Selection of Product Categories.

1.2 State of Sustainability Research

This Product Category Proposal (PCP) includes GEC State of Sustainability Research (SOSR), which assesses the environmental and social impacts of enterprise data storage products, across the product life cycle, including production (which involves raw material extraction, manufacturing and transportation), use phase and end of life management. The SOSR also identifies how sustainability impacts can be reduced through measures such as product design, and supply chain engagement to improve manufacturing and labor practices. GEC recently published SOSR reports for ICT products, covering four sustainability impact categories: climate, sustainable use of resources, chemicals of concern and responsible supply chains. While these SOSR reports are directly applicable to data storage products, this document elaborates on how past research applies to and provides further data specific to data storage.

The data and analyses in this document serve as the scientific basis for the development of sustainability performance criteria for an EPEAT enterprise data storage product category.

2. Product Overview

Data centers, which are physical storage facilities for enterprise-level data and applications, use their IT infrastructure to run applications and provide data services to business customers. Data storage products are a key part of the data center IT infrastructure which also includes IT equipment such as servers, network connectivity equipment, cables and backup power supplies (Figure 1). While servers support data center functionality by hosting applications and executing computing tasks, data storage products store and protect applications and business data [4].

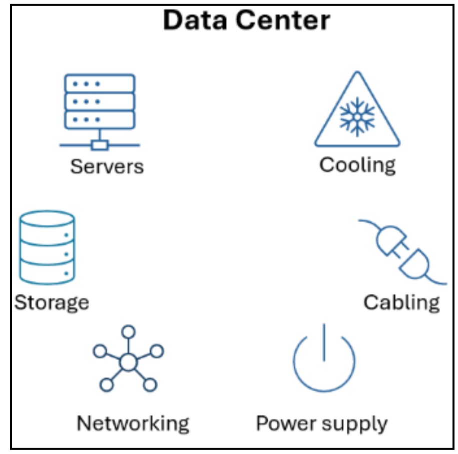

Figure 1: Data center components

2.1 Definition according to the U.S. EPA ENERGY STAR Program and the Commission Regulation (EU) for ecodesign of servers and data storage products

The ENERGY STAR® program and the EU Commission Regulation for ecodesign of servers and data storage products define a data storage product as 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 are considered to be part of the storage product [5].

Figure 2: Sample image of data storage product.[6]

ENERGY STAR differentiates data storage products based on connectivity as: Direct Attached Storage (DAS), Network Attached Storage (NAS) and Storage Area Network (SAN). In

Direct Attached Storage, one or more dedicated storage devices physically connect to one or more servers. In Network Attached Storage, one or more dedicated storage devices connect to a network and provide file access services (File I/O) to remote computer systems. Storage Area Network consists of a communication infrastructure, which provides physical connections, a management layer, storage controllers / devices, and computer systems.

ENERGY STAR excludes the following list of products from their data storage product certification:

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;

vi. 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.

The EU Commission Regulation excludes 'small data storage products' and 'large data storage products' from the eco-design requirement directive for servers and data storage products. The Commission defines 'small data storage product' as a data storage product containing a maximum of three data storage devices and 'large data storage product' as a high end or mainframe data storage product that supports more than 400 data storage devices in its maximum configuration and with the following required attributes: no single point of failure, non-disruptive serviceability and integrated storage controller. Both ENERGY STAR and the EU regulation have defined data storage products based on the Storage Networking Industry Association (SNIA) Green Storage Initiative, as defined in the SNIA Emerald taxonomy [39]. The small data storage products definition in the EU regulation corresponds to the Online 1 equipment as set out in the SNIA Emerald taxonomy, and the large data storage products definition corresponds to the Online 5 and 6 equipment as set out in the SNIA Emerald taxonomy. The EU regulation revision proposal document notes that the enterprise sector storage products are mainly found in the Online 2, Online 3, and Online 4 (low-end to mid-range) categories in the SNIA taxonomy. ENERGY STAR data center storage specification

(Version 2.1) also includes only the Online 2, 3, and 4 storage products from the SNIA taxonomy and excludes Online 1, 5 and 6 categories.

2.2 Overview of product components, functionality, and composition

A data storage product may be composed of integrated storage controllers, storage devices, embedded network elements, software, and other devices (Figure 3). "Storage device" is a collective term for the various technologies providing data storage function, such as disk drives (HDDs), solid state drives (SSDs), tapes, cartridges, and any other mechanisms providing non-volatile data storage. Both ENERGY STAR and the EU Commission Regulation 2019/424 on ecodesign requirements for servers and data storage products exclude aggregating storage elements such as RAID array subsystems, robotic tape libraries, filers, file servers and storage devices not directly accessible by end-user application programs, in their definition of data storage devices [5].

A storage controller is a device for handling storage requests via a processor or sequencer programmed to autonomously process a substantial portion of I/O requests directed to storage devices, e.g., Redundant Array of Independent Disks (RAID) controllers, filers. [5]. The detailed component list generally considered in the data storage product environmental analysis includes SSDs, HDDs, RAM, CPU, main board, PSU (power supply unit) and fans [7].

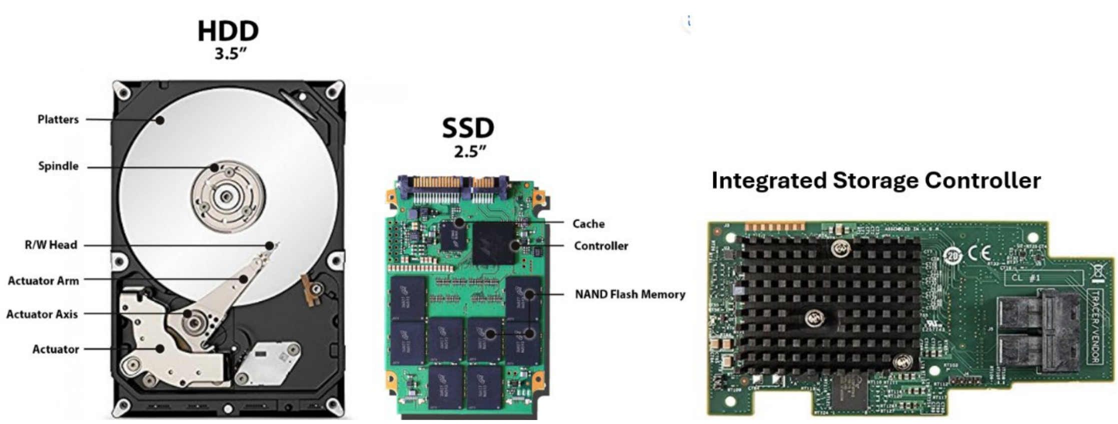

Figure 3: Sample images of key components in a data storage product. [8] [9]

3. Market Analysis

3.1 Global Market Overview

The global revenue of the data center storage market was estimated to be 58.59 billion USD in 2023 (Figure 4). Storage segment revenue is projected to grow to over 100 billion USD by 2029 with a growth rate of over 10% (Figure 5).

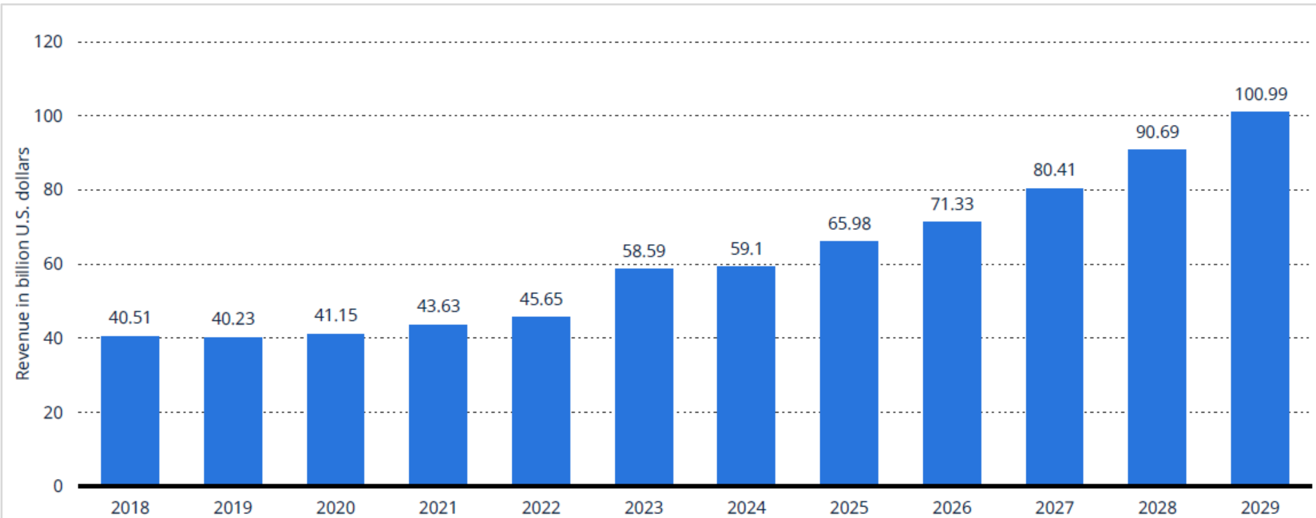

Figure 4: Revenue of the storage market worldwide from 2018 to 2029 in billion U.S. dollars. [10]

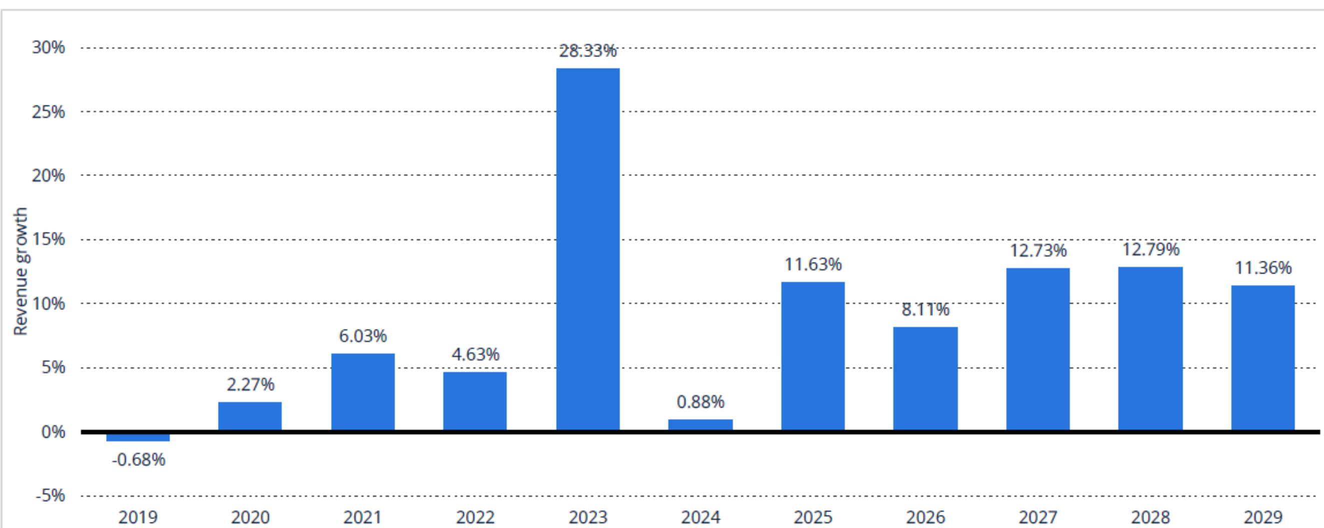

Figure 5: Revenue growth of the storage market worldwide from 2019 to 2029. [10]

Market reports suggest that the COVID-19 pandemic significantly impacted the market growth, leading to a surge in demand for cloud storage and data center services. The development of generative AI which can autonomously generate huge amounts of diverse and complex data is also estimated to increase the demand for storage infrastructure [11].

Figure 6 provides a breakdown of the data storage market by industry. The banking, financial services and insurance (BFSI) sector is projected to hold the highest market share (34%) due to the increasing need for safe and secure storage mediums that enable banking companies to store and process the huge volumes of data generated in the sector. The IT and telecommunication and retail and consumer goods sectors are not far behind in terms of market share. Data storage is critical for managing huge amounts of network and system data in IT and telecom while in retail, storage capacity is key in managing inventory, customer information, and transaction records. Sectors such as manufacturing, healthcare and life sciences and governments and public sector also hold significant share in the data storage market. For efficient healthcare delivery, data storage capacity is essential for allowing the secure storing, retrieving, and sharing of patient records and research data.

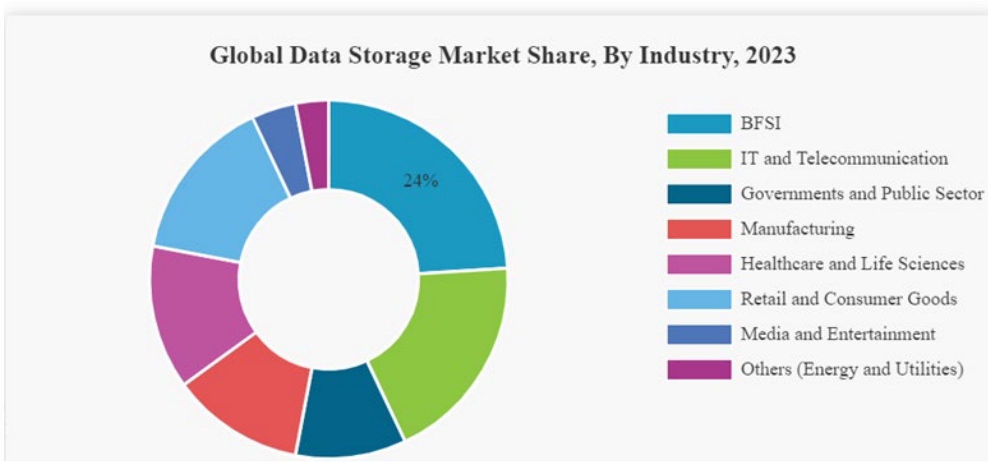

Figure 6: Global data storage market share. [11]

Based on enterprise type, the data storage market can be categorized as small office/home office (SoHo), mid-size, and large enterprise, among which the large enterprise segment is estimated to hold the highest market share [11]. Data center storage plays a key role in the IT infrastructure of today's enterprises, with demand for storage growing rapidly and continuously [2]. Figure 7 shows revenue projections for the three data center IT equipment market segments -- servers, network infrastructure and storage, as reported by Statista. The storage market revenue accounts for 14.2% of the data center market. It is to be noted that the products considered in this storage market analysis include storage intensive servers, such as Dell EMC PowerVault Series and HPE StoreEasy Storage and cloud storage solutions, such as integration with Amazon AWS S3, and Microsoft Azure Blob Storage, in addition to enterprise storage devices, such as HPE 3PAR StoreServ Storage and IBM FlashSystem.

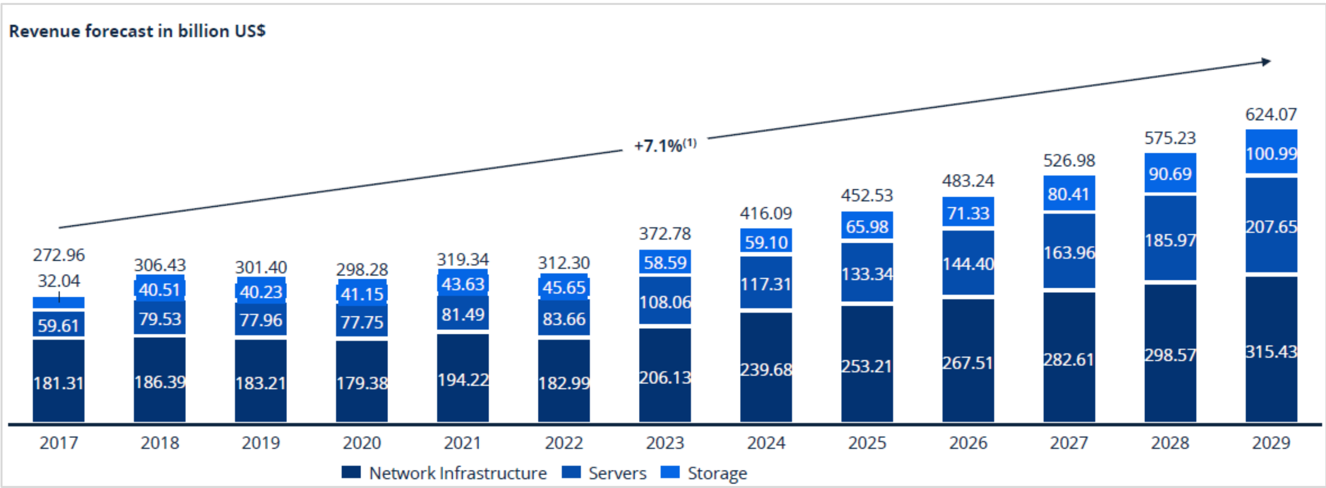

Figure 7: Global revenue forecast for storage, servers and network infrastructure revenue forecast in billion USD. [12]

3.2. Key Players in Data Center Storage Market

The main enterprise storage hardware vendors in the world are Dell EMC, Hewlett Packard Enterprise (HPE), NetApp, Hitachi, Pure Storage, IBM, and Huawei (Figure 8). As per IDC's Worldwide Quarterly Enterprise Storage Systems Tracker, Dell Technologies was the largest external enterprise data storage systems supplier, accounting for 28.8% of worldwide revenue. HPE/New H3C group was second with a 10.8% share. NetApp (9.9%) and Huawei (8.9%) tied for third place in the market. Hitachi (4.9%) and IBM (4.7%) were fifth and sixth with market shares. Other manufacturers of data storage equipment include Lenovo, Viking, Seagate, and Veritas.

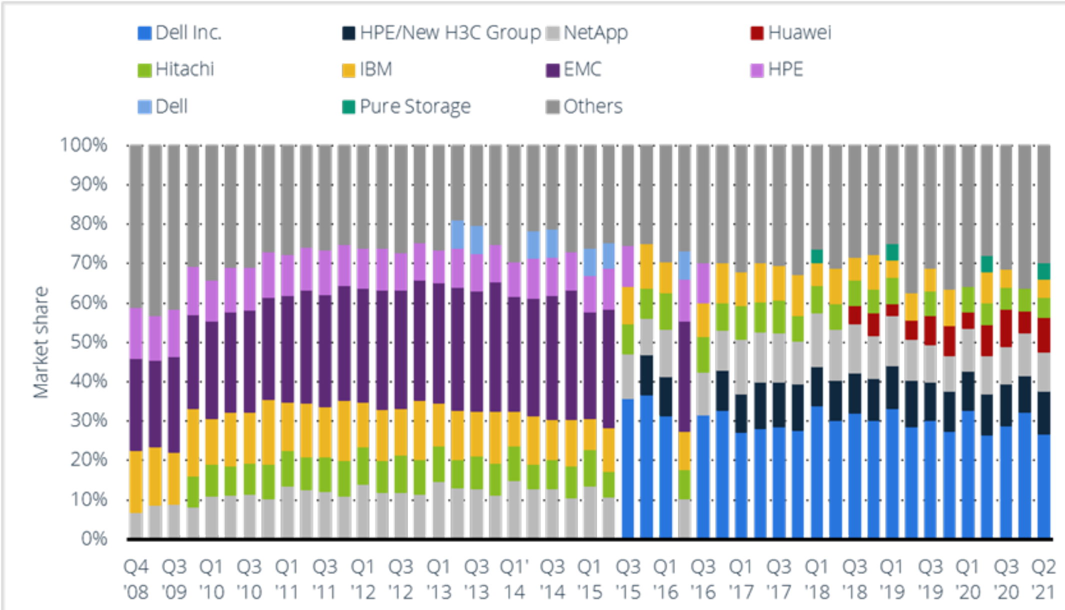

Figure 8: Enterprise external storage systems vendor market share [13]

Other key players in the data storage market include data storage device component manufacturers and enterprise data storage product purchasers such as data center owners and operators, a significant portion of which could be cloud service providers, referred to as hyper scalers. The global hyperscale cloud market size was valued at USD 172.26 billion in 2022, and the market is projected to grow to USD 2,185.39 billion by 2030 with a CAGR of 37.8% [14]. The number of hyperscale data centers has increased from 259 in the year 2015 to 992 in the year 2023 [10]. The growth rate projected for hyperscale cloud market can be taken as an indication of data storage product purchaser demand. Microsoft, Amazon Web Services (AWS), Salesforce, and Google Cloud are all among the top cloud vendors with Microsoft as the leader among cloud vendors in terms of revenue (Figure 9). Additional hyperscalers include Meta, Akamai, and Oracle. Other key players in this market that procure data storage equipment for use in data centers include those servicing the finance, hospital, retail, academia, and other sectors as noted in the previous section.

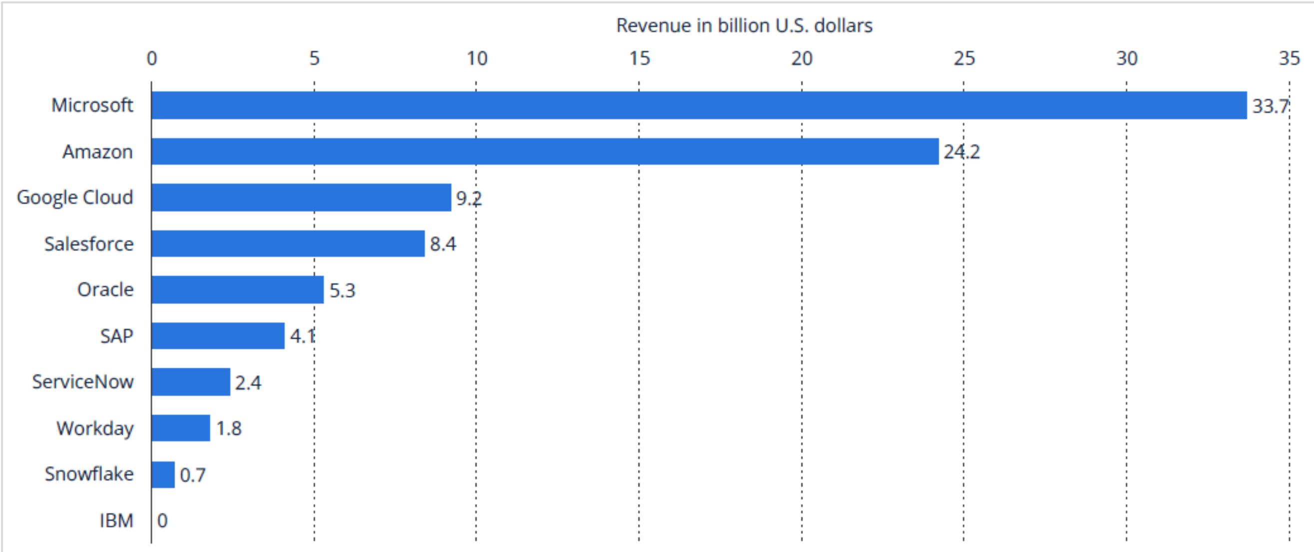

Figure 9: Top cloud vendors in the world by revenue. [10]

The leading storage device component original equipment manufacturers are Seagate, Western Digital, and Toshiba. The OEMs design, manufacture, and supply data center storage devices such as hard disk drives (HDDs) and solid-state drives (SSDs) for data storage product manufacturers.

3.3. Stakeholder Interest

As part of building the business case for adding a new EPEAT product category, GEC investigates stakeholder interest. To identify stakeholder interest in data storage products, GEC conducted a purchaser survey on EPEAT products category expansion. 65% of the purchaser survey respondents selected data storage product as one of the top five product categories of interest. Of these respondents, 12% ranked data storage as their top priority for EPEAT product category expansion. The survey results demonstrated the demand for sustainable data storage products among large scale institutional purchasers, including national governments who represented 42% of the purchaser survey participants. Figure. 10 shows the breakdown of purchaser survey participants.

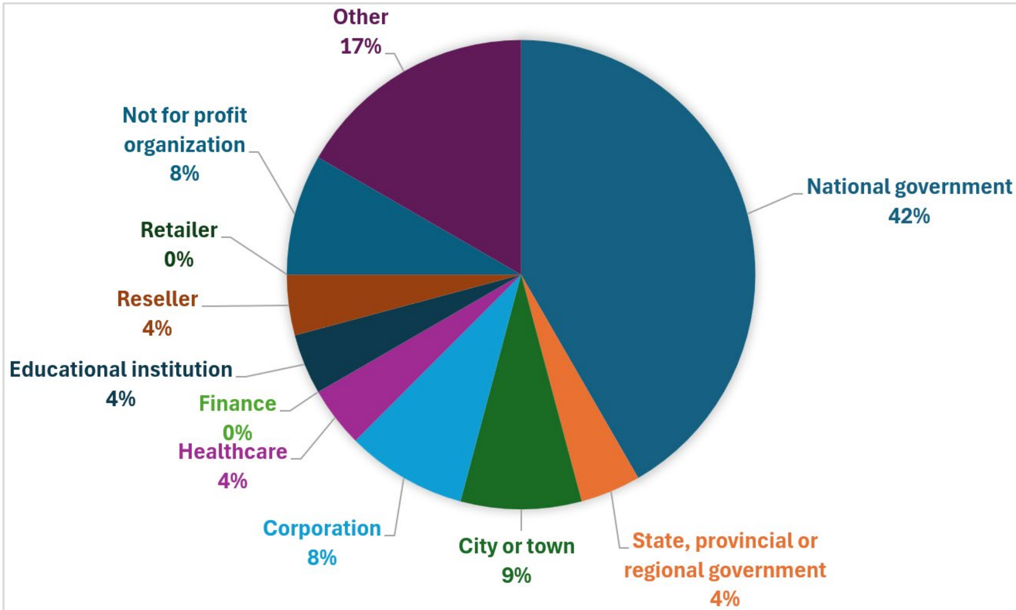

Figure 10: GEC purchaser survey participants' organizational breakdown.

GEC also surveyed 2024 EPEAT Purchaser Award winners regarding their interest in procuring more sustainable enterprise data storage products. In 2024, the following organizations indicated support for an EPEAT data storage product category:

- Bowdoin College
- Canadian Government
- City of Fort Collins, Colorado
- City of La Crosse
- Commonwealth of Pennsylvania
- Kaiser Permanente
- Klöckner Pentaplast
- Los Angeles Department of Water and Power
- Maryland Department of Transportation
- Memorial Sloan Kettering Cancer Center
- New York State Office of General Services
- OhioHealth
- Seattle Children's
- Silicon Ranch Corporation
- Stanford Medicine
- State of California
- State of Maryland
- Swift Current Energy
- Texas Department of Information Resources
- The American College of Greece
- U.S. Government
- UMass Chan Medical School
- University of South Florida
- Upper Merion Township
- Voya Financial
- Wipro Limited
- Yale University

In addition to stakeholder interest, GEC also assesses the product manufacturers' ability to address the sustainability impacts as part of the business case. In the case of enterprise data storage products, major manufacturers such as Dell and HPE, who collectively make up more than one-third of the storage market, already have EPEAT registered products for similar products such as servers and are demonstrating their commitment to reducing sustainability impacts.

4. Sustainability Impacts

GEC organizes its analysis of sustainability impacts, and the criteria aimed at reducing these impacts, into four priority impact areas of importance to large-scale purchasers and producers of electronic products: climate change mitigation, sustainable use of resources, chemicals of concern and responsible supply chains, as described in the box below. Focusing on sustainability impacts allows for a systematic analysis of data based on a unifying theme or metric to identify "hot spots" in the life cycle of the product or service, followed by a targeted examination of strategies that offer opportunities to reduce the identified life cycle impacts. While this sustainability impact focus provides a practical approach for analysis, criteria development, and communication, it is also generally recognized that these sustainability impacts are not mutually exclusive; for example, sustainable use of resources will also contribute to climate change mitigation.

Sustainability Impact Categories

Climate Change Mitigation

This impact category addresses life cycle greenhouse gas emissions associated with the production, transport, use and end of life management of electronic products. The production phase impacts cover emissions from raw materials mining, product assembly and manufacturing.

Sustainable Use of Resources

This impact category identifies priority sustainability impacts with respect to material selection and use, product design, end-of-life management, water management and packaging for electronic products.

Chemicals of Concern

This impact category seeks to reduce the use of chemicals of concerns in products, packaging and manufacturing through effective management of the supply chain, chemical substance restrictions and alternatives assessment to prevent regrettable substitutions.

Responsible Supply Chains

Electronic product manufacturers leverage complex, global supply chains for material sourcing and production of electronics, which often have negative labor, human rights, and environmental consequences. This impact category covers such social risks in the supply chain and promotes best practices for labor, and responsible sourcing of raw materials in the electronics sector.

4.1 Climate Impact

Product carbon footprint reports for data storage products have been published by manufacturers such as IBM, Pure Storage and Dell. Dell Technologies estimated a mean of 9,639 kg CO2e (+/- 4,908 kg of CO2e) life cycle emissions for its Power Store 500T product over 4-year use period while IBM estimated 11,000 kgCO2e (+/- 7000 kgCO2e) lifecycle emissions for its *Flash System 5200* IBM data storage product over 5-year

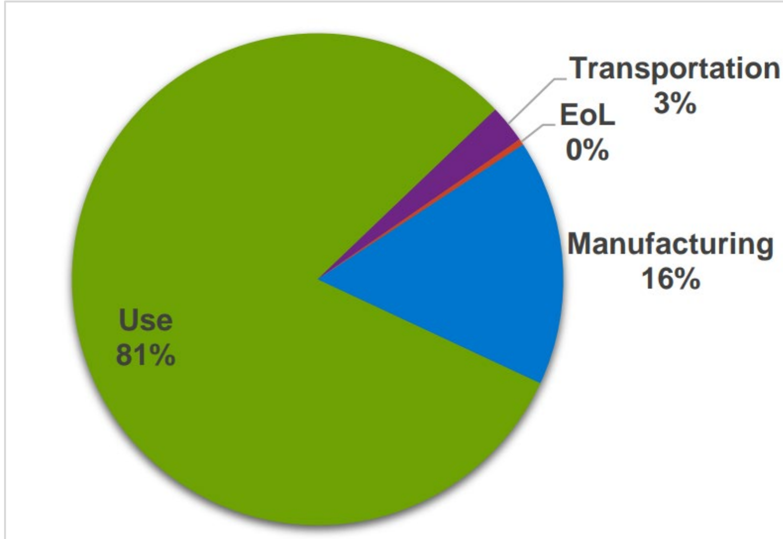

Figure 11: Product Carbon Footprint of Dell Technologies Power Store 500T Storage product estimated using PAIA - a streamlined LCA tool. [7]

use period. Pure Storage has reported the estimated carbon footprint of manufacturing their Flash Array storage product family to be between 3895 kgCO2e and 6109 kgCO2e. As shown in Figures 11, 12 and 13, the carbon footprint analyses of Dell, IBM and Pure Storage products report that the use phase contributes the most to the total life cycle climate impact of data storage products. For the Dell and IBM data storage products in Figure 11 and Figure 12, the use phase contribution to total life cycle carbon footprint is 81% while the Pure Storage product in Figure 13 shows the use phase contribution to vary from 75% to 93% of the products' carbon footprint depending on the install country. For Pure Storage, the remaining portion of CO2 emissions is due to manufacturing activities which make up 7% to 25%. The manufacturing emissions considered in the Pure Storage analysis include emissions from raw materials, assembly and testing, packaging, transportation and end of life management (recycling).

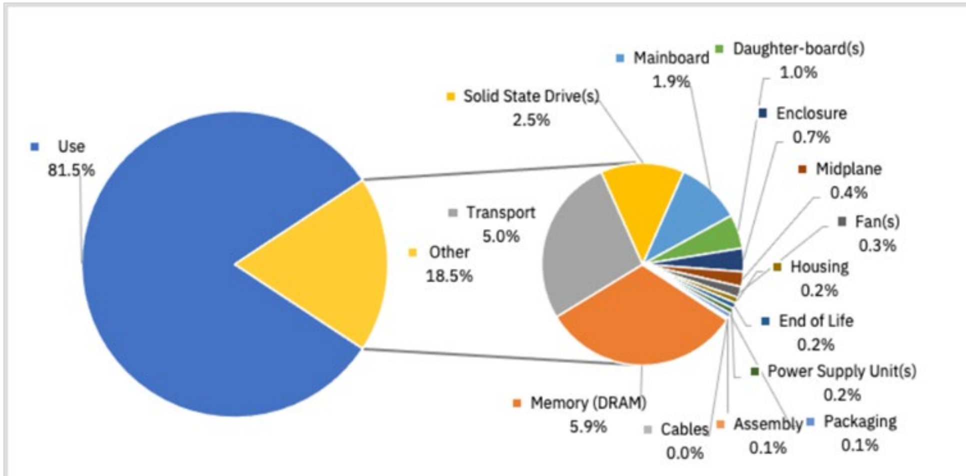

Figure 11: Carbon footprint impact by phase for the IBM Storage FlashSystem 5200 product configuration based on the PAIA model; 81.5% occurs in the use phase and the remaining 18.5% is broken out.[15]

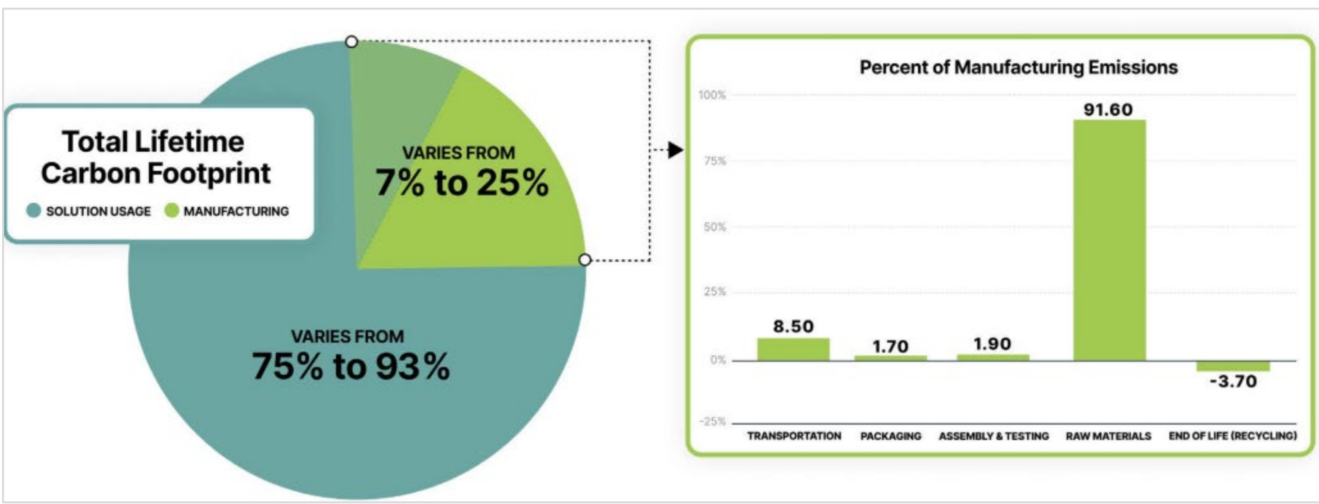

Figure 12: Pure Storage Flash Array solution use and manufacturing emissions. The percentage of manufacturing emissions due to specific activities is shown in the graph on the right. [16]

The carbon footprint of data storage product production is reported to represent around 15% of its total life cycle carbon footprint by Dell Technologies and IBM. Carbon emissions associated with the production of storage (SSD, HDD) and memory (RAM) device components as well as the main board are shown to dominate the production climate impact (Figure 12). This high impact component list is relatively similar to that of a server (Table 1). Table 1 shows the device component level impact contribution to product carbon footprint of a Dell server and an IBM storage product.

Key Components	Server (Dell R740)	Storage (IBM Flash System 5200)
Chassis/Midplane/Housing	1%	10%
Fan	0%	2%
PWB Mixed/ Daughter Boards	14%	8%
Mainboard	4%	14%
PSU	1%	2%
Packaging	0%	1%
SSD & Memory DRAM	80%	64%

Table 1: CO_2e production impact contributions of components in servers (Dell R740) [17]and data storage products (IBM Flash System 5200). [15]

It is to be noted that assumptions regarding product configurations and location of product manufacturing and use significantly affect product carbon footprint estimations. For example, the relative contribution of the chassis can vary based on the chassis material used in a specific product configuration and the chassis production location. However, the comparison table helps identify device components such as SSDs and RAM as the main impact contributors to the production carbon footprint of both servers and data storage products. PCBs are also significant contributors to climate impact. Therefore, EPEAT ICT priority components such as PCBs, CPUs and integrated circuits in SSDs, HDDs and RAM, are relevant for data storage products as well.

4.2 Sustainable Use of Resources

When product material composition is analyzed, data storage products are found to have a lot of commonalities with servers both at component and material level. Table 2 presents a high-level summary of the bill of materials (BOM) of a rack server, blade server and a data storage unit estimated from the detailed BOM presented by the European Commission in the Eco design Preparatory Study on Enterprise Servers and Data Equipment. The detailed BOM as adopted from the study is presented in Appendix Table 1, 2 and 3.

At material level (chassis), for both servers and data storage, we see predominantly steel with significantly lower and variable amounts of plastics. Aluminum also constitutes a significant share of total weight in servers and data storage products. At the device component level (HDD), aluminum constitutes the largest share (76%) of the total weight mix. See Appendix Table 1, 2 and 3 for material contribution at component level for servers and data storage products. It is to be noted that the blade server system data presented is a server with 8 blades which has more capacity than one rack server.

Bill of materials comparison at component level			
Component	**Rack Server**	**Blade Server**	**Storage Unit**
Fans	3%	1%	3%
HDDs	6%	4%	20%
ODD	1%		
Mainboard & other PCBs	7%	4%	5%
PSUs	12%	9%	18%
Cables	2%		
CPU	0.2%	0.2%	
CPU Heat Sinks	2%	1%	
Memory	0%	1%	
Packaging	17%	11%	8%
SSDs			0.3%
Controller			19%
Bill of materials comparison at material level			
Material	**Rack Server**	**Blade Server**	**Storage Unit**
Steel	52%	73%	54%
Plastics	6%	1%	3%
Aluminium	8%	4%	16%
Copper	3%	1%	2%
Zinc	0%	0%	1%
Packaging Materials	17%	11%	8%
Electronic components (capacitors, inductors, printed circuit boards, resistors,transformers, transistors)	14%	9%	17%

Table 2: Estimated high-level summary of the bill of materials (BOM) of a rack server, blade server and a data storage product. Data from European Commission Eco design Preparatory Study on Enterprise Servers and Data Equipment. [18]

Other common metals found in servers and data storage product components include REEs (Rare Earth Elements) and PGMs (Platinum Group Metals) (Figure 14). Many of the materials presented in Figure 14 as found in servers and storage products, are classified as strategic and critical raw materials in the U.S. [19] and the EU [20].

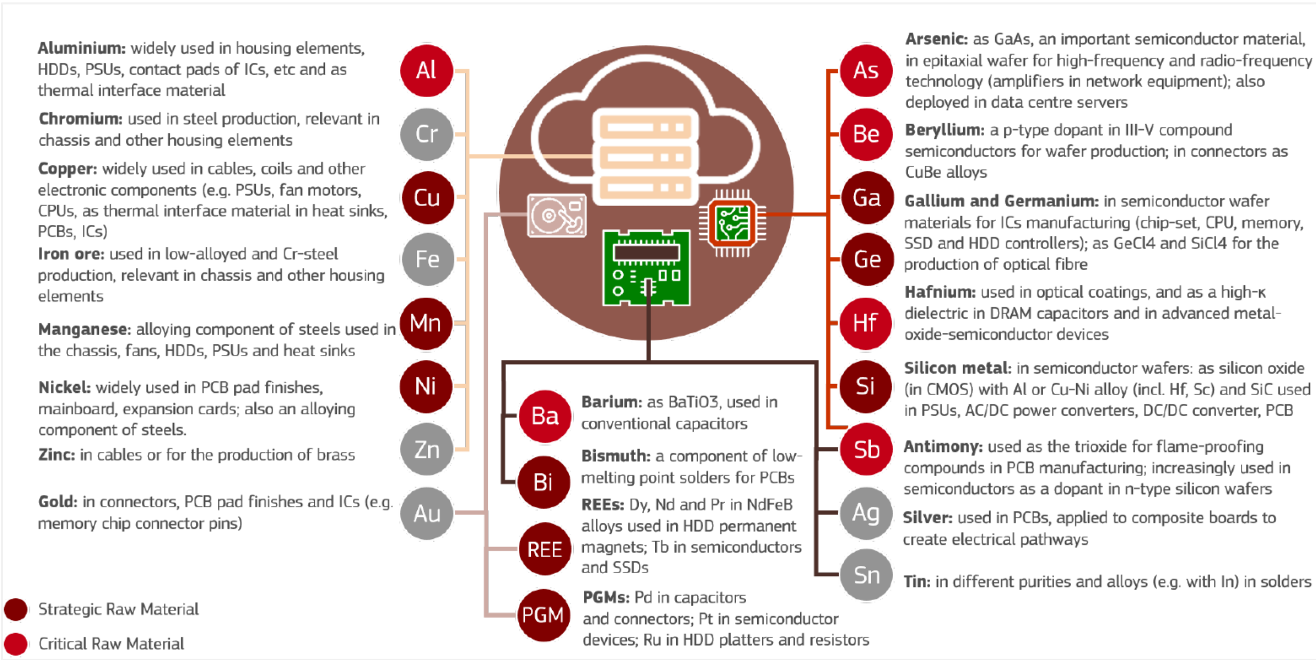

Figure 13: Selection of raw materials used in data storage and servers, and their function. Figure is adopted from 2023 JRC report on 'Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU'. [20]

The estimated weight of critical minerals in the PCBs and HDDs of a typical rack server, blade server system and data storage product are shown in Table 3. The largest CRM amounts found are Neodymium and Silicon for both servers and data storage products. Again, it is to be noted that the blade server system data presented is a server with 8 blades which has more capacity than one rack server.

Material	Rack Server(g)	Blade server system (g)	Data storage equipment (g)
Dysprosium	0.24	0.96	2.00
Neodymium	4.18	16.70	34.83
Praseodymium	0.58	2.32	4.84
Palladium	0.93	2.06	2.41
Platinum	0.09	0.20	0.24
Antimony	0.02	0.34	0.40
Silicon	11.01	24.40	28.53
Gallium	0.05	0.11	0.13
Germanium	0.06	0.14	0.16
Cobalt	0.05	0.10	0.12

Table 3: Estimated weight (in g) of diverse critical raw minerals contained in the PCBs and HDDs of a Rack server, Blade server system and Data storage equipment. Data from European Commission Eco design Preparatory Study on Enterprise Servers and Data Equipment [18].

4.3 Chemicals of Concern

Electronic components containing hazardous substances include batteries, ceramics, hardware plating, insulator resins, integrated circuits, paints or pigments, plasticizers, printed circuit board (PCB) finishes, solders, and plastic parts; most of which are found in data storage devices.

The following topics, discussed in depth in GEC State of Sustainability Research for Reducing Chemicals of Concern [21], are applicable to a range of electronic products, including data storage products and device components:

a) There are over 400 chemical substances used in semiconductor manufacturing, including substances classified as carcinogens, reproductive toxins, neurotoxins, skin or respiratory irritants and/or as persistent in the environment.
b) Clean Electronics Production Network (CEPN) and Responsible Business Alliance (RBA) have identified problematic types of chemicals to avoid when formulating solvents for cleaners and degreasers used in electronics manufacturing [35] [36].
c) Select phthalates, found in PVC used in coating cords and cables, are chemicals of concern due to reproductive system toxicity.
d) Select chlorinated, brominated and fluorinated substances used in polymers are classified as persistent, bio-accumulative and toxic and hence can accumulate in the food chain.

4.4. Responsible Supply Chains

Social risks have been identified in the global electronics supply chain. This includes worker rights related issues as well as local community risks associated with mining and production operations.

Social risks highlighted in GEC State of Sustainability Research on Corporate ESG Performance [22] include:

a) High risk of worker rights violations in some electronic manufacturing regions, as identified by independent third parties including civil society organizations. A recent review of RBA Validated Assessment Program (VAP) data from 2023 identifies top risk areas as freely chosen employment or forced labor, working hours and emergency preparedness [37].

b) Forced labor and excessive working hours are endemic in the electronics industry.

c) Discrimination in hiring where preference is given to women who are paid less than men.

d) The mining of the minerals used in electronics results in pollution of waterways, destruction of local habitats and adverse health and safety impacts on local populations. And mining in conflict affected and high-risk areas has been associated with armed conflict, violence and widespread human rights abuses.

5. Sustainability Impact Mitigation Strategies

This section presents potential strategies considering the latest research on ICT products with a focus on data storage products. Due to the similarity to servers in material composition or materiality, impact mitigation strategies for servers may apply to data storage products as well. It is to be noted that strategies below can help in alleviating more one impact category. For example, circularity strategies such as use of recycled content can not only reduce resource consumption but also result in avoiding climate impacts associated with extraction and use of virgin materials. Similarly, the reduction of toxic materials in products reduces chemical impacts while enabling circularity.

5.1. Product carbon footprint/ LCA Studies to mitigate hot spots

Most publicly available LCA data for data storage products is aggregated (e.g., production, use) which is not helpful for identifying the climate impact hotspots for different product configurations. Conducting LCA studies or product carbon footprint analyses for different product configurations can help gain insights into which materials, components, and activities contribute to carbon emissions for a specific product configuration. For example, LCA studies of SSDs which are high impact components in data storage products show that the production of integrated circuits in SSDs dominate the climate impact of the device component (Figure 15). This indicates that the SSD chip manufacturing facilities need consideration in climate mitigation efforts.

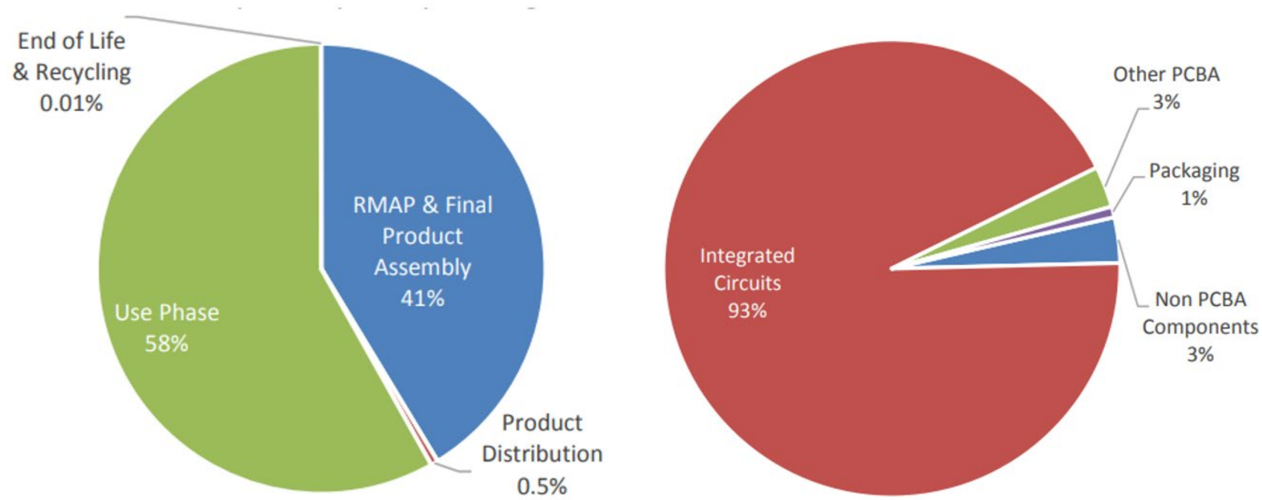

Figure 14: SSD climate impact by life cycle stage (left). RMAP climate impacts by subassembly (right). RMAP =Raw Material Acquisition and Pre-processing. [23]

Carbon footprints studies with more component data delineation would also enable the comparison of different climate mitigation strategies such as material substitution, low emission transportation modes and use of renewable energy in manufacturing.

5.2 Product energy efficiency

It is estimated that 11% of annual energy consumption in a typical data center is related to powering storage devices (Figure 16). Since energy consumption is the key driver of use phase GHG emissions, reducing the energy consumption can drive a major reduction in life cycle carbon emissions of data storage products. Use phase energy consumption and related emissions depend on various factors including product efficiency, power rating, user behavior as well as grid mix of the energy used.

For data storage products with ENERGY STAR, an annual energy use reduction of approximately 350 kwh is reported [24]. In addition, ENERGY STAR reports that one watt-hour of energy savings at the storage level results in almost double (1.9 watt-hours) the facility-level energy savings. The additional savings are reported to stem from reducing energy waste in the power infrastructure such as the power distribution unit and uninterruptible power supply, and by reducing the energy needed to cool the waste heat produced by data storage [25]. This means that even a single data storage product with ENERGY STAR can yield 665 kwh of energy savings in a data center annually. With 10,331 centers across the globe [26], even a single data storage product per data center could result in 6,870,115 kwh savings annually, roughly 3 million kgCO2 emissions annually[1].

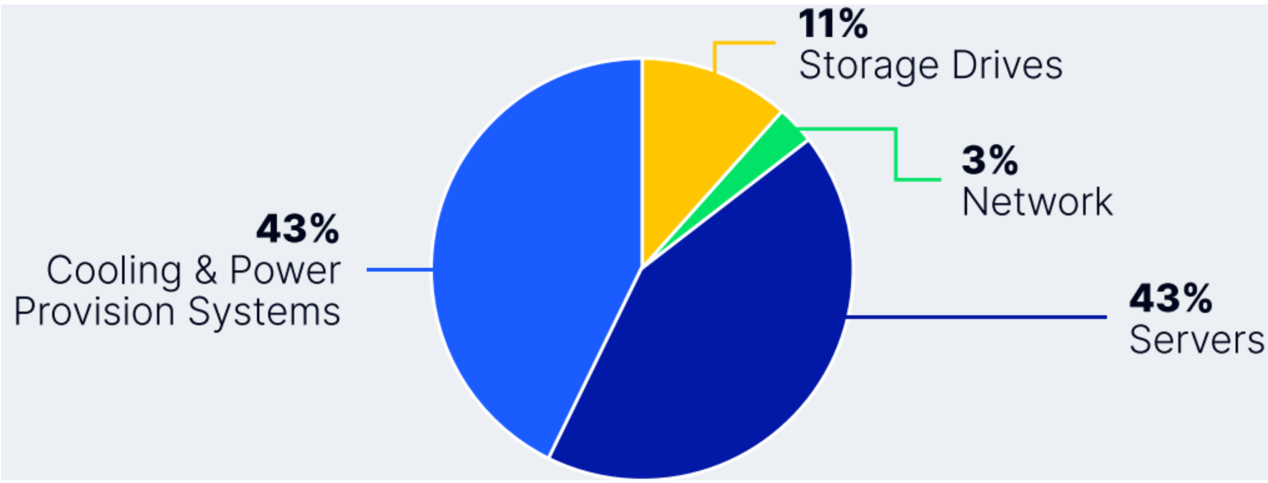

Figure 15: Fraction of U.S. data center electricity consumption by end use. [3]

The efficiency and power factor of Power Supply Units (PSUs) that power primary components in a data storage product are key factors that affect energy consumption or efficiency of a data storage product [5]. The different ways listed by ENERGY STAR [27] as ways for reducing data storage energy consumption include using:

a) ENERGY STAR certified storage equipment: ENERGY STAR certified products are constructed to save energy through more efficient power supplies and features such as compression, deduplication, and snapshot. ENERGY STAR certified data center storage products are required to use efficient power supplies and variable speed fans if using active cooling, make available storage management features and report on energy consumption under different operating conditions [28].

b) Lower-speed hard drive device components in data storage: Energy consumption is proportional to disk spin speed. Using slower HDDs for applications where slower read/write speeds won't adversely impact operations can boost product energy efficiency.

[1] A global-average-carbon-intensity of 436 gCO2/kwh is assumed for the emissions reduction calculations. https://www.iea.org/data-and-statistics/charts/global-average-carbon-intensity-of-electricity-generation-in-the-stated-policies-sustainable-development-and-net-zero-scenarios-2000-2040

c) Massive Array of Idle Disks (MAID): MAIDis is a storage technology which powers up individual hard disks only when an application needs to access the data stored on that disk thereby reducing power consumption and prolonging hard drive life span.

d) Scale-out storage: It is a data storage architecture in which the total amount of disk space can be expanded through the addition of new hardware. This avoids wastage of storage space.

e) Solid-state drives (SSDs) instead of HDDs: In SSDs data is stored in microchips. There are no moving parts and SSDs are so much faster delivering better performance per watt than a hard disk drive. SSDs also generate less heat, which can reduce data center cooling energy and costs.

Tiered storage is a data management strategy used to improve storage system performance by storing critical and frequently used data in high-speed SSDs and less critical bulk data in lower cost high-capacity storage devices like HDDs [38]. Storing rarely accessed data in slower drives which uses less electricity and using high-speed drives only where necessary can save energy and cost. Automated storage tiering (AST) is a storage software management feature that dynamically moves data between different disk types to meet capacity, performance and cost requirements [27].

5.3. Energy efficiency in manufacturing

Improving energy efficiency in component manufacturing and product assembly can provide a significant reduction in the upstream embodied carbon of products. In data storage products, facilities involved in the manufacturing of high impact components such as SSDs, RAM and the main board should be prioritized in efforts to improve energy efficiency, based on the LCA data presented earlier. Using customized supplier data in product LCAs may identify alternate or additional components to target. Further, detailed study of high impact components can facilitate identification of upstream facilities to prioritize for energy efficient manufacturing mitigation strategies. For example, studying SSDs can help identify where in the SSD supply chain (e.g., wafer manufacturing facilities supplying chips for SSDs), energy efficient manufacturing could be employed.

In addition to suggesting discrete energy efficiency projects as a strategy, GEC State of Sustainability Research for Climate Change also highlights the value of applying a systems-based continuous improvement approach to energy management, similar to ISO 9001 for quality management and ISO 14001 for environment management. As mentioned in the SOSR, U.S. DOE analysis has shown that the implementation of ISO 50001 energy management systems in manufacturing facilities can bring an average annual reduction of 4% to 5% in total energy consumption.

5.4. Use of renewable energy in manufacturing

In addition to implementing energy efficiency efforts in the upstream supply chain, the source of electricity (or grid energy mix) also plays a crucial role in increasing or decreasing GHG emissions from manufacturing facilities. Sourcing electricity generated from renewable energy sources, such as solar emits fewer greenhouse gases, which lowers the total carbon footprint of a product. Since electricity consumption is a key contributor to the climate impact of manufacturing integrated chips and printed wiring boards, which form key parts of ICT equipment, including data storage products and components, use of renewable energy in their manufacturing facilities can largely reduce the manufacturing emissions.

5.5. Reducing F-GHG emissions in manufacturing

ICT products, including data storage products contain integrated circuits (CPUs and ICs in device components such as SSDs, RAM etc.) the manufacturing of which involve silicon wafer fabrication, a process that generates high GHG emissions [29]. The lithography and dry etch processes in wafer fabrication rely on fluorinated compounds with high global warming impact (Figure 17). The direct emissions associated with those processes are also high [30].

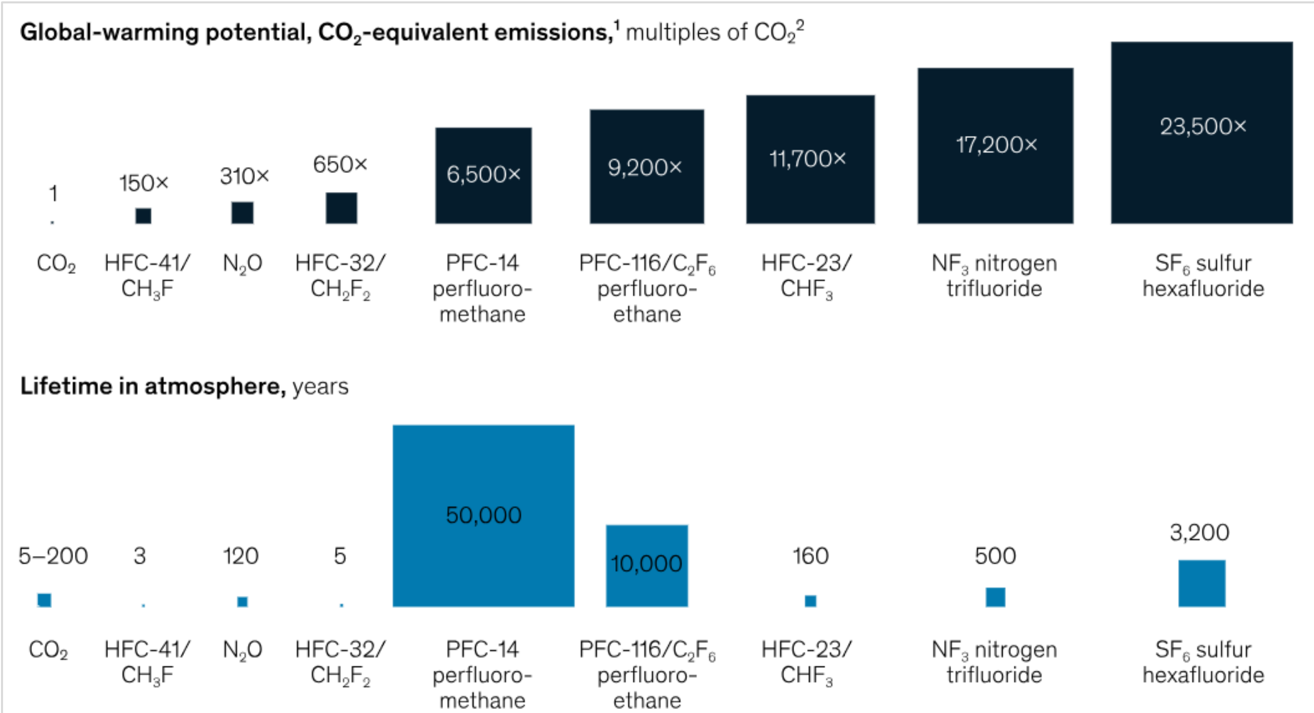

Figure 16: Environmental impact of semiconductor manufacturing process gases [31].

Some of the strategies to reduce the process gas related emissions are [31]:

a) Gas abatement is a main lever when alternative gases with lower emissions are not available.

b) Process improvements that reduce emissions by adjusting process parameters such as temperature and pressure.

c) Use of process gas substitutes or alternative chemistry that have lower environmental impact.

d) Gas recycling where fabrication facilities capture unutilized process gases and by-products refine them into pure process gases that can be used again, potentially reducing process-gas emissions.

As referenced in GEC State of Sustainability Research for Climate Change, U.S EPA has estimated the technical effectiveness of different abatement options for etching and cleaning in flat panel display manufacturing and semiconductor fabs (Tables 1, 2 and 3 in Section 3.2 of GEC State of Sustainability Research for Climate Change Mitigation).

5.6. Use of Recycled Materials

One potential way of reducing material impact is by using materials with recycled content. For example, data storage product manufacturer Hitachi uses recycled content plastic (a blend of polycarbonate and ABS resin) in its data storage products. The recycled plastic (polycarbonate resin) made from materials recovered from CD and DVD disks, water bottles and automotive headlight covers is used in the cover bezel part of Hitachi's storage product. Hitachi reports that they evaluate the recycled plastic material to meet the strict safety standards for storage devices used in corporate and government organizations [32] [33].

5.7. Component device reuse, recycling and longevity

Circular strategies such as product life extension and component reuse and recycling are proven to reduce manufacturing impacts from raw material extraction to component and device manufacturing. For example, studies have quantified the environmental benefits of employing circular economy strategies at the end of life of HDDs, a key device component of data storage products. HDDs often contain neodymium-iron-boron (NdFeB) magnets made of rare earth elements, which are scarce and produced using emission intensive processes. The different circular economy strategies that could be employed for value recovery from HDDs include direct reuse of HDDs, reuse of magnet assemblies, magnet-to-magnet recycling and recovery of REEs (Figure 18). HDD life extension through reuse is the most environmentally preferable option (with approximately 5 to 18 kg CO2e reduction per drive life cycle) when compared to the virgin production and shredding for just base metal (aluminum) recovery. Reuse of magnet assembly is the next best option followed by magnet-to-magnet recycling and metal recycling (Figure 19].

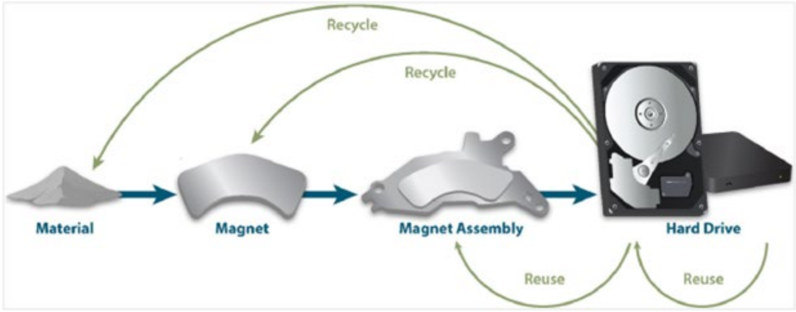

Figure 17: Potential for circularity in HDDs. [34]

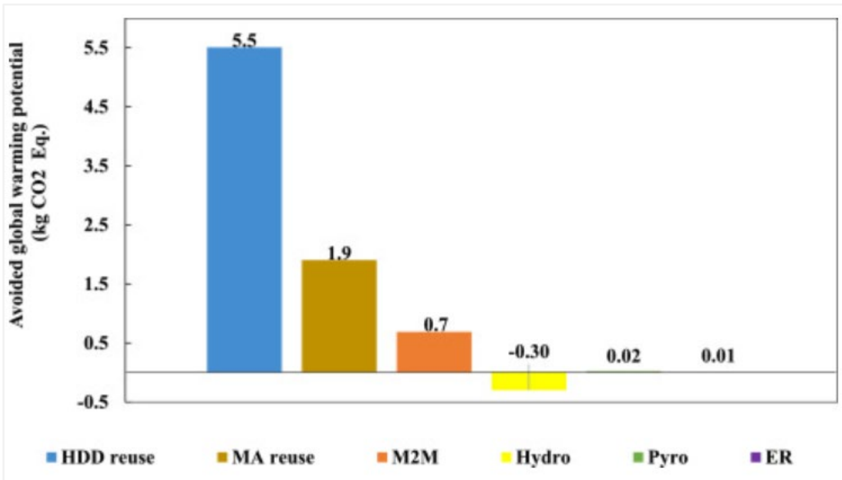

Figure 18: Avoided global warming potential of HDD value recovery pathways [34]. MA indicates magnet assembly, M2M indicates magnet-to-magnet recycling, Hydro stands for hydrometallurgical process, Pyro stands for pyrometallurgical process and ER stands for electrochemical recovery.

As per the European Commission's eco-design preparatory study for enterprise servers and data equipment published in 2015, the re-use rate is lower for storage equipment than for enterprise servers, ranging around 20-30%. Material recycling, heat recovery, incineration and landfill rate assumed in the study are indicated in Table 4.

EOL management	Plastics	Metals	Electronics	Misc.
Re-use	25%	25%	25%	25%
Material recycling	5%	70%	50%	68%
Heat recovery	69%	0%	24%	1%
Non-recovery incineration	0.50%	0%	0.50%	5%
Landfill	0.50%	5%	0.50%	1%

Table 4: The end-of-life phase of storage systems from European Commission's Eco design Preparatory Study on Enterprise Servers and Data Equipment [18].

Recently, there are reports of considerable amount of component/ material recovery from IT products in data centers. For example, Sims Lifecycle Services (SLS) reports that they see consistent repurposed unit growth in data center IT equipment. SLS receives and processes over a million cloud assets every year, within that over 7 million lbs. of SSD and HDD drives are repurposed or recycled for material recovery [1].

5.8. Chemicals Mitigation

Mitigation strategies, as described in GEC State of Sustainability Research for Reducing Chemicals of Concern [21] for ICT products are similarly applicable to data storage products and device components. These include identifying substances of concern used in manufacturing and remaining in products, assessing hazards and potential for exposure across the product life cycle, adopting safer alternatives, inclusive of substance elimination and/or adoption of safer alternatives, and driving transparency into chemicals used. Effective life cycle management of chemicals of concern is pivotal to protect human health and the environment.

5.9. Social Risk Mitigation

Approaches, as described in GEC State of Sustainability Research on Corporate ESG Performance [22] are similarly applicable to data storage products and device components. These include implementing human rights due diligence activities consistent with international standards, encouraging and improving meaningful supply chain mapping and risk assessment, increasing transparency through focused reporting on core issues, and driving meaningful remedy as appropriate.

6. Standardization

Table 5 summarizes relevant standards and voluntary programs that can provide a foundation for product definitions, best practices, and benchmarks. It is derived from existing resources in GEC State of Sustainability Research and criteria development for Climate Change Mitigation, Sustainable Use of Resources, Reducing Chemicals of Concern and ESG/Responsible Supply Chains. The standards and best practices most directly related to data storage products are listed here, however, the full breadth of resources available in the aforementioned State of Sustainability Research are also relevant.

Focus	Standard
Climate Change Mitigation	ISO 14040 and ISO 14044, Environmental management – Life cycle assessment – Principles, framework, requirements and guidelines; ISO 14067, Carbon footprint of products – Requirements and guidelines for quantification and communication
	U.S. EPA ENERGY STAR Specification for Data Center Storage
	ISO 50001 Energy Management
Sustainable Use of Resources	EN 45554:2020, General methods for the assessment of the ability to repair, reuse and upgrade energy-related products
	IEC 63333:2023, General method for assessing the proportion of reused components in products
	EN 45555:2019 General methods for assessing the recyclability and recoverability of ErP
	EN 45558:2019 General method to declare the use of critical raw materials in ErP; ISO 22444:2020 - Rare earth — Vocabulary — Part 1: Minerals, oxides and other compounds and Part 2: Metals and their alloys
	Commission Regulation (EU) Eco design for Servers and Data Storage products
	IEEE 2883 Standard for Sanitizing Storage; ISO/IEC 27040:2015, Information technology — Security techniques — Storage security
	The SERI R2 standard; The e-Stewards® Standard for Ethical and Responsible Reuse, Recycling, and Disposition of Electronic Equipment and Information Technology Version 4.0©; EN 50625 - Collection, logistics & treatment requirements for WEEE

Reducing Chemicals of Concern	EU Battery Directive; EU RoHS Directive; EU REACH Regulation
	IEC 62474 material declaration and IEC 63000 technical documentation for supply chain management of chemicals in products
Responsible Supply Chains	UN Guiding Principles on Business and Human Rights; OECD Guidelines for Multinational Enterprises and OECD Due Diligence Guidance for Responsible Business Conduct
	ILO Conventions for freedom of association and collective bargaining, forced labor, child labor, discrimination, equal remuneration and a safe and healthy work environment
	EU Corporate Sustainability Due Diligence Directive 2024/1760
	RBA Code of Conduct and Validated Assessment Program; Social Accountability International (SA) 8000 Certification Audits
	OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas; U.S. Dodd-Frank Wall Street Reform and Consumer Protection Act (2012), Section 1502; and EU Regulation 2017/821 on Conflict Minerals

Table 5: Overview of relevant sustainability standards for data storage and server products

7. Conclusions & Recommendations

Given the exploding importance of data storage products in data centers around the world and the corresponding sustainability impacts, the Global Electronics Council (GEC) proposes the addition of enterprise data storage products to its portfolio of products eligible for the EPEAT® ecolabel. An EPEAT category for enterprise data storage products would leverage existing GEC sustainability impact criteria, registry infrastructure and capacity and would enable purchasers worldwide to more easily identify devices that meet sustainability performance objectives and reduce their sustainability footprint. A conservative estimate of only 1 data storage product per data center results in roughly 3 million kgCO2 emissions avoided annually.

Sustainable purchasing remains a powerful enabler of global policy agendas addressing challenges from net zero GHG emissions to national circular economy action plans, sustainable green chemistry and rapidly emerging global human rights due diligence requirements. With the addition of data storage products, GEC will offer sustainable choices for the major hardware products deployed in data centers and enterprises, further reducing the sustainability impact of ICT products.

7.1. Recommendations for criteria development

The State of Sustainability Research in this Product Category Proposal serves as the scientific foundation for criteria development for the EPEAT ecolabel. Material composition analysis found a high degree of commonality between sustainability impacts and mitigation strategies for servers and data storage products. Consequently, GEC proposes to apply published EPEAT criteria for Climate Change Mitigation, Sustainable Use of Resources, Reducing Chemicals of Concern and Responsible Supply Chains to data storage products in the same manner they are applied to servers. For example, while the criteria modules are largely applicable across ICT product categories, select criteria, such as those for portable products, are not applicable to servers. These same criteria are similarly not applicable to data storage products. Where select Sustainable Use of Resources criteria have product specific thresholds and/or functional performance requirements, such as for recycled content and availability of replacement components, GEC proposes to initiate a voluntary consensus process to evaluate the applicability of server requirements to data storage products.

8. Appendix A. Product Bill of Materials (BOM)

Appendix A. Table 1. Rack Server BOM. Data is adopted from the European Commission 2015 – Eco design preparatory study on enterprise servers and data equipment

Component	Material	Weight (g)
Chassis	Metal Body (steel)	12265
	Plastics	348
	Plastics	282
	Aluminium	249
	Copper	179
	Electronic components (capacitors, inductors, printed circuit, resistors,transformers, transistors)	131
Fans (4)	Steel	386
	Copper	78
	Iron based	55
	Plastic (PBT-GF30)	206
	Plastic (PCABSFR40)	21
	Plastic (undefined)	200
HDDs (4)	Steel	12
	Low alloyed steel	222
	Aluminium	1335
	PCB	179
ODD	Low alloyed steel	115
	Copper	7
	Aluminium	1
	High Density Polyethylene (HDPE)	28
	Acrylonitrile-Butadiene-Styrene (ABS)	12
	Polycarbonate (PC)	7
	Electronic components (capacitors, inductors, printed circuit, resistors,transformers, transistors)	8
	Solder	2
	PCB	9
Mainboard		1667
PSUs (2*400W)	Low-alloyed steel	1027
	Chromium steel	66
	Brass	42
	Copper	9
	Zinc	7
	Aluminium	491
	High Density Polyethylene (HDPE)	184
	Polyvinylchloride (PVC)	92
	Paper	50
	Electronic components (capacitors, inductors, printed circuit, resistors,transformers, transistors)	1101
	Solder	31
	PCB	326
PCB (expansion card/other)	PCB	349
Cables	Brass	7
	Copper	81
	Zinc	96
	High Density Polyethylene (HDPE)	104
	Polyvinylchloride (PVC)	145
	Polyurethane (PUR)	2
	Synthetic rubber	35
6869CPUs (2)	Copper	30.5
	Gold	0.4
	PCB	21.2
	IC	1.9
CPU Heat Sinks	Copper	442
	Steel	140
Memory	PCB	97
	IC	38
Packaging	Cartons	3629
	HDPE/ unspecified plastics	78
	GPPS/ Styrofoam	1026
	Total weight of rack server = 27.7 kg	

The chassis represents the major share (44%) of product weight. The mainboard does not include memory and CPUs, which are listed and evaluated as separate items. The packaging consists mainly of cardboard and different sorts of plastics [18].

Appendix A. Table 2. Blade Server System Bill of Materials. Table is adopted from the European Commission 2015 – Eco design preparatory study on enterprise servers and data equipment.

Component	Material	Weight (g)
Enclosure		
Chassis	Steel	87000
4 x PSU	Low-alloyed steel	4981
	Chromium steel	319
	Brass	202
	Copper	43
	Zinc	32
	Aluminium	2384
	High Density Polyethylene (HDPE)	894
	Polyvinylchloride (PVC)	447
	Paper	245
	Electronic components (capacitors, diodes, inductors, printed circuit, resistors, transformers, transistors, connectors)	5343
	Solder	149
	PCB	1581
6 x Fans	Steel	964
	Copper	194
	Iron based	137
	Plastic (PBT - GF30)	515
	Plastic (PCABSFR40)	52
	Plastic (undefined)	499
8 Blade Servers		
Top and bottom chassis, Drive cages, System board tray		33600
Mainboards	Controller board	6451
CPUs (16)	Copper	244.1
	Gold	3
	PCB	170
	IC	15
CPU Heat Sinks	Copper	1688
	Steel	560
Memory	PCB	773
	IC	307
HDDs (8 * 2 per server)	Steel	47
	Low alloyed steel	888
	Aluminium	5341
	PCB	717
Packaging	Cartons	14969
	HDPE/ unspecified plastics	321
	GPPS/ Styrofoam	4233
	Total weight of enclosure = 105981 g	
	Total weight of 8 blade servers = 70327 g	
	Total weight of blade system = 176 308 g	

The blade server system enclosure amounts to around 60% of overall weight, largely dominated by the chassis. An average blade server weighs around 6.3 kg [18].

Appendix A. Table 3. Storage Unit Bill of Materials. Table is adopted from the European Commission 2015 – Eco design preparatory study on enterprise servers and data equipment.

Component	Material	Weight (g)
0.5 x Controller		
	Steel	7450
	Stainless steel	1680
	Aluminium	287
	Copper	520
	ABS	510
	PET	39
	HDPE	87
	PP	18
	PC	31
	Nylon 6	5
	PVC	85
	Other Plastics	12
	Printed Circuit Board	577
PSU of Controller (1x in total)	Main board	825
	Cables	20
	Chassis and bulk material	889
PSU Fans (2x in total)	Steel	110
	Copper	65
	Iron based	13
	Nylon 6	9
	PC	35
	ABS	19
2x Disk Array Enclosures (DAE)		
Chassis	PC	406.4
	ABS	92.2
	Steel sheet part	15374
	Zinc part	298.6
	Steel Machined Part	3.4
PSUs in DAEs (4 in total)	Mainboard	4217.2
	Cables	104.4
	Chassis and bulk materials	4546.2
Fans in PSUs of DAEs (8 in total)	Steel	563.04
	Copper	332.928
	Iron based	66.912
	Nylon 6	47.328
	PC	177.888
	ABS	95.064
4 x Controller card		2308.2
2 x Mid plane board		920.36
Storage Media Mix (40.1 TB)		
3.5 HDD (19.35 in total)	Steel	58
	Low Alloyed Steel	1103
	Aluminium	6637
	PCB	890
2.5 HDD (14.01 in total)	Steel	278.41
	Low Alloyed Steel	211.2
	Aluminium	2562.57
	PCB	123.84
	ABS	7.15
SSDs (2.86 in total)	Electronic components (capacitors, inductors, printed circuit, resistors,transformers,	172.4
	IC	5.75
Packaging	Cartons	3629
	HDPE/ unspecified plastics	78
	GPPS/ Styrofoam	1026
Total weight of Controller (including packaging): 18 020 g		
Total weight of DAEs: 29 554 g		
Total weight of Storage Media Mix: 12 050 g		

The Appendix A. Table 3 presents the bill of materials of a storage system; a virtual storage unit with ½ controller, two disk array enclosures (DAEs) and a storage media mix consisting of 16.66 (+2.69 spare) 3.5-inch HDDs, 12.07 (+1.95 spare) 2.5-inch HDDs and 2.87 SSDs, representing a product belonging to the SNIA 2-3 taxonomy.

The 2 DAEs in the storage system together make up almost 50% of the total weight. The controller makes up 30% of the weight and the rest 20% can be attributed to storage media. Aluminum constitutes the largest share (76%) of the total weight of the storage media mix [18].

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The Global Electronics Council (GEC) accelerates systemic change to create a 100% sustainable electronics industry by 2050.

- This means net-zero emissions, zero waste, water neutrality and minimal adverse impact on the environment and human rights throughout the life cycle of products and services.
- As stewards of the EPEAT ecolabel, we set the global standard for sustainable electronics.
- We empower electronics manufacturers and buyers to meet their sustainability goals through our world-leading accreditation, advocacy and leadership.
- We are reshaping the world's relationship with technology and natural resources, and enabling the transformation of electronics from an escalating environmental and social challenge into an empowering, sustainable solution.

Our EPEAT® Ecolabel

We are stewards of the EPEAT ecolabel – the definitive global standard to drive change across the technology sector from extraction to end of life. EPEAT enables manufacturers to follow strict third party verified standards while providing transparency for buyers.

Drive Sustainable Technology Forward!

Discover products on the EPEAT Registry and explore how they can contribute to your sustainability goals. Visit epeat.net to learn more.