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Good practices Guide

Sustainable Infrastructure

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1. Sustainable energy supply

1.1. Key Factors in Green Energy Procurement

Green energy procurement is one of the essential elements for reducing the environmental impact of data centers that support artificial intelligence infrastructures. Beyond a reputational decision, it represents a critical factor in ensuring alignment with the European Union's decarbonization objectives and with the goals set out in the Paris Agreement.

When selecting a sustainable energy supply, the following key factors should be considered:

- **Guarantees of origin (GO):** It is essential that the contracted energy is backed by official certificates that prove its renewable origin. Directive (EU) 2018/2001 establishes the reference framework for the use of guarantees of origin for renewable electricity in the European Union.
- **Additionality:** It is not enough to acquire certificates of energy already produced. It is recommended to prioritize Power Purchase Agreements (PPAs) that encourage investment in new renewable installations, thus contributing to the expansion of clean capacity.
- **Stability and resilience of supply**: The reliability of supply must be evaluated in terms of energy security. Contracting energy from suppliers that integrate renewable storage (batteries, green hydrogen) **provides resilience by ensuring a firm and continuous supply even when renewable generation is intermittent**. This resilience is enhanced in the critical operation of data centers when combined with local storage (BESS, UPS, fuel cells) and redundancy at distribution network connection points.
- **Integration with the local energy mix:** The location of the DPC influences the availability of local renewable energies (solar, wind, hydroelectric) and the efficiency of their integration into the grid. The ITU-T L.1300 standard emphasizes the importance of assessing location in relation to the available renewable mix.
- **Levelized cost of energy (LCOE):** It is necessary to balance sustainability and economic viability. Contracts should value the total cost of energy based on its origin, stability and long-term predictability.
- **Transparency and additional certifications:** In addition to guarantees of origin, it is advisable to prioritize suppliers with certifications such as **ISO 50001 (Energy**

Management) or adherence to global initiatives (e.g. RE100), which demonstrate a sustained commitment to energy sustainability.

Overall, green energy procurement must move from a merely formal approach (purchase of certificates) to a strategic model based on long-term contracts, additionality and resilience, aligned with Europe's climate neutrality objectives by 2050.

1.2. Relevance of the DPC's geographical location

The geographical location of a data processing center (DPC) is a determining factor in both the environmental impact of the facility and the economic and operational viability of the infrastructure. This aspect is directly linked to the principle of *Green by Design*, since an adequate site selection allows the carbon footprint and dependence on external resources to be structurally reduced.

The main factors to consider are:

- **Energy mix of the region:**
  The percentage of renewable energy present in the local electricity grid is a key criterion. A DPC located in a country or region with a high penetration of renewable sources (wind, hydroelectric, solar) will have a significantly lower carbon impact than one located in areas with a high dependence on fossil fuels.

- **Availability of on-site renewable energy:**
  The possibility of integrating local renewable generation (e.g. adjacent solar parks, access to hydropower) provides greater control over sustainability and reduces *greenwashing risks* associated with the simple use of certificates of origin.

- **Climatic conditions and natural cooling:**
  The local climate directly influences the energy needs for cooling. Sites in cold climates allow you to take advantage of *free cooling strategies*, reducing the dependence on active air conditioning systems and, therefore, the total energy consumption of the DPC.

- **Access to network infrastructure and sustainable logistics:**
  Efficiency should not be evaluated only in terms of energy, but also considering hardware transport, access to low-latency connectivity, and proximity to large consumption nodes. A location that minimizes the transport footprint and optimizes connectivity contributes to the overall sustainability of the facility.

- **Geopolitical and energy supply risks:**
  Regulatory stability and the resilience of the local grid are critical elements. A data center in an environment with political uncertainty or reliance on imported fossil sources can compromise business continuity and increase its indirect carbon footprint.

In short, the location of the DPC must be evaluated not only in terms of operating costs or latency, but as a strategic decision that conditions the ability to meet the objectives of climate neutrality and energy resilience.

1.3. Selection of energy-efficient suppliers and services

The selection of energy suppliers and services associated with the operation of the DPC must be based on criteria that guarantee a real impact on sustainability and not only on formal compliance with certifications or guarantees of origin. The right choice contributes to the reduction of the carbon footprint, operational efficiency and long-term resilience of the infrastructure.

The key aspects to consider are:

- **Use of renewable energies:**
  It is a priority to select suppliers that use a high percentage of renewable energies in their generation mix (solar, wind, hydroelectric, sustainable biomass). In addition to the contracting of certified electricity, it is advisable to favour long-term agreements (*Power Purchase Agreements*) that ensure **additionality**, i.e. the creation of new renewable capacity. This criterion guarantees a tangible impact on the decarbonization of the energy system.

- **Environmental and energy management certifications:**
  The existence of certified management systems provides transparency and reliability. It is recommended to prioritize suppliers with certifications such as **ISO 50001 (energy management), ISO 14001 (environmental management)** or the European **EMAS regulation**, as they ensure standardized processes of efficiency and continuous improvement.

- **Operational efficiency and verifiable metrics:**
  Suppliers must be able to demonstrate optimal values in key indicators such as **PUE (Power Usage Effectiveness)** or **WUE (Water Usage Effectiveness).** These parameters, recognized in international standards, allow you to evaluate the real efficiency in the use of energy and water in your facilities.

- **Transparency and continuous reporting:**
  The publication of independently audited sustainability reports is essential. Such reports should include clear metrics on energy consumption, greenhouse gas emissions and evolution towards reduction targets aligned with the European Union's climate targets.

In conclusion, the selection of suppliers must respond to a renewable energy framework, robust certification and effective transparency, ensuring that the DPC's energy supply is consistent with the principles of sustainability and long-term resilience.

In practice, the evaluation of energy-efficient suppliers can be structured based on objective criteria, such as:

- **Origin of energy:** guaranteed contractual percentage of renewable electricity (EU-recognized guarantees of origin).
- **Certification and reporting:** availability of certifications such as ISO 50001 or external sustainability audits, and publication of verified emissions reports.
- **Contracting models:** existence of long-term PPAs (*Power Purchase Agreements*) linked to new renewable generation (*additionality*).
- **Associated storage:** integration of renewable storage (batteries, hydrogen) that guarantees firm supply.
- **Resilience conditions:** redundancy in interconnection points and audited energy continuity plans.

1.4. Data Center Efficiency

Efficiency in data centers should be understood as a **cross-cutting criterion in the installation and deployment of hardware infrastructures** rather than as an isolated objective.

The key elements to consider are:

- **Physical design and distribution of hardware:**
  The location of racks, hot and cold aisles, as well as accessibility for maintenance, have a direct impact on energy efficiency. Proper distribution can reduce cooling consumption and optimize airflow without the need for additional systems.

- **Selection of efficient components:**
  The choice of processors, memory, and storage should be based on energy efficiency criteria and life cycle analysis (LCA). Equipment with higher compute density per unit of energy consumed offers substantial advantages in terms of PUE (*Power Usage Effectiveness*).

- **Sustainable cooling systems:**
  The efficiency of the DPC is closely linked to the choice of cooling system. Strategies such as *free cooling* (use of outside air in cold climates), closed-loop liquid cooling or waste heat reuse should be evaluated based on their impact on total energy consumption.

- **Integrated energy management:**
  The implementation of real-time monitoring systems allows inefficiencies to be detected and consumption to be dynamically adjusted. This includes intelligent workload management, so that the hardware operates in optimal conditions and with the minimum energy required.

In summary, data center efficiency should be approached as a **criterion for hardware design and deployment**, combining decisions in physical distribution, equipment selection, cooling, and operational control. In this way, the *Green by Design* principle is complied with and it is ensured that energy efficiency is an inherent result of the infrastructure, and not a subsequent correction.

2. Energy sustainability

2.1. Energy cogeneration

Energy cogeneration in data centers consists of **taking advantage of the waste heat** generated by IT equipment during operation to produce useful energy or cover external thermal needs. This strategy not only improves the overall efficiency of the system, but also contributes directly to the reduction of emissions by avoiding the use of additional fossil sources for heating or industrial processes.

Main cogeneration strategies in DPCs

- **Reuse of waste heat in district heating:**
  The heat captured in cooling systems can be injected into neighbourhood heating networks, hospitals, universities or public buildings, replacing fossil fuels. This model is already applied in Nordic countries such as Denmark or Sweden.

- **Integration with local industrial processes:**
 Data centers located near facilities that require low or medium temperature heat (water treatment plants, greenhouses, food processes) can provide waste heat, reducing costs and the carbon footprint of the value chain.

- **Generation of domestic hot water (DHW):**
The integration of surplus heat into DHW systems for adjacent buildings is a measure that can be implemented quickly, especially in urban environments.

- **Conversion of heat into electricity through thermodynamic cycles (ORC – Organic Rankine Cycle):**
 Emerging technologies allow part of the waste heat to be transformed into electricity, although with moderate yields, being more viable in large-scale installations.

Success factors in implementation

1. **Integrated design from planning:** Heat recovery must be considered in the design phase of the DPC, ensuring physical proximity to potential thermal consumers.
2. **Joint economic-environmental analysis:** The viability of cogeneration projects depends on the stable thermal demand in the environment and a favourable regulatory framework.
3. **Efficiency in capture systems:** Liquid cooling or closed-loop technologies facilitate greater use of waste heat compared to air systems.
4. **Collaboration with local entities:** Cooperation with municipalities, energy service companies (ESCOs) or district heating networks is key to materializing projects at scale.

In conclusion, cogeneration in data centers represents a **practical strategy with an immediate impact** on energy sustainability. It allows a waste (heat) to be transformed into a useful resource, aligning with the principles of the circular economy and with the European objective of reducing dependence on fossil fuels.

Practical example of cogeneration in data centers

In **Stockholm, Sweden**, data centers connected to the district heating network managed by **Fortum Värme** reuse waste heat to heat thousands of homes. Thanks to this system, it is estimated that for every **10 MW of heat recovered, approximately** 20,000 apartments **can be supplied**, reducing in parallel the emissions associated with the use of gas or coal for heating. This model has become a European reference for the integration of data centers in urban sustainability strategies.

2.2. Sustainable energy resilience

Energy resilience in data centers is key to ensuring continuity of service in the face of outages, power failures, or extreme weather events. However, protection and recovery measures must be aligned with sustainability principles, avoiding resorting to highly polluting or inefficient backup systems.

2.2.1. Sustainable recovery and protection

- **Backup systems with low environmental impact:**
  Replace traditional diesel generators with less polluting alternatives, such as lithium-ion or green hydrogen battery systems. These can provide immediate support in the event of a power outage, reducing the carbon footprint.
- **Integration of renewable energy storage:**
  The use of batteries associated with renewable sources (solar, wind) makes it possible to cover peaks in demand and maintain critical operations during periods of interruption.
- **Protection against network peaks and fluctuations:**
  Implement highly energy-efficient uninterruptible power supply systems (UPSs), with European eco-design certifications, which limit energy losses under normal conditions and guarantee continuity in emergencies.
- **Strategic location of the DPC:**
  Assess risks of natural disasters (floods, heat waves, forest fires) when selecting the location, integrating climate risk maps from the **European Environment Agency (EEA).**

2.2.2. Practices for energy resilience

- **Diversification of energy supply:**
  Contracting electricity from different suppliers or resorting to PPAs (Power Purchase Agreements) with renewable sources, guaranteeing security of supply and less exposure to price volatility.
- **Microgrids and distributed generation:**
  Integrate the DPC into local microgrid ecosystems powered by renewable energy, facilitating resilience in the event of a main grid failure.
- **Modular design of the infrastructure:**
  Implement an architecture that allows isolating specific load modules or racks in the event of an incident, keeping the rest of the DPC operational without total interruption.
- **Sustainable recovery plans:**
  Develop contingency plans that not only prioritize service continuity, but also include sustainability criteria in the choice of emergency technologies and resources.

- **Real-time monitoring:**
  Use of energy management platforms that integrate grid, consumption, storage and renewable data, to anticipate failures and redistribute loads automatically.

Hardware Installation and Deployment Procedure

1. Environmentally responsible transport

The transportation of data center equipment, both in the initial construction phase and in replacement and maintenance operations, accounts for a significant portion of indirect **emissions from the value chain (GHG Protocol Scope 3).** Reducing this impact requires establishing clear criteria in the logistics of procurement, installation and replacement of hardware.

Recommended Strategies

- **Supply chain optimisation:**
  Favouring suppliers that have distribution centers close to the location of the DPC, reducing transport distances and associated emissions.
- **Low-emission transport:**
  Prioritize the use of fleets of electric, hybrid or sustainable biofuel-powered vehicles for the transport of equipment. In international transport, select logistics companies adhering to energy efficiency and emissions reduction programs (e.g. Noriega Grupo Logístico in Spain and other companies adhering to the national *Lean & Green* program).
- **Cargo consolidation:**
  Reduce partial shipments through logistics planning that maximizes the occupancy of vehicles and containers, thus reducing the number of trips and the carbon footprint per unit transported.
- **Selection of sustainable packaging:**
  Use recyclable, reusable or low-carbon footprint packaging, with designs that facilitate its return or recycling at destination. This reduces waste generation and the need for virgin raw materials.
- **Logistics lifecycle planning:**
  Integrate reverse logistics for the return of obsolete equipment and recyclable materials, ensuring responsible treatment of electronic waste (WEEE) and packaging.

- **Procurement criteria for logistics providers:**
  Include in the procurement specifications environmental certification requirements (**ISO 14001** or **ISO 14083 for transport emissions**) and periodic reports of scope 3 emissions.

Benefits of the application

The application of these measures makes it possible to:

1. Reduce indirect greenhouse gas emissions linked to transport.
2. Ensure consistency with European decarbonization objectives and Green *Public Procurement policies*.
3. Improve supply chain emissions traceability.

Ultimately, environmentally responsible transportation not only minimizes the climate impact of hardware deployment but also strengthens the transparency and sustainability of the entire infrastructure value chain.

2. Wiring

Cabling in a data center is a critical element for both the reliability and sustainability of the infrastructure. Although traditionally considered a secondary aspect, its design, choice of materials and physical layout have a direct impact on energy consumption, cooling efficiency and the environmental footprint associated with the construction and maintenance of the DPC.

2.1. Principles of Sustainability in Cabling

- **Selection of materials with low environmental impact:** opt for cables with recyclable, halogen-free materials and low smoke emissions, which also improve safety in the event of fire.
- **Standardization and modularity:** use standardized solutions (e.g. ISO/IEC 11801) that allow interoperability and facilitate partial replacement rather than complete renewals.
- **Durability and life cycle:** choose high-quality, mechanically resistant cables that reduce the need for frequent replacement.

2.2. Sustainable design

- **Optimized routes:** reduce the total length of cabling through logical route design, minimizing signal losses and unnecessary materials.

- **Proper Segregation:** Keep power and data wiring separate to avoid interference and facilitate maintenance without duplicating resources.
- **Accessibility and scalability:** design pipelines and trays that allow future expansion without the need for complete replacement of the existing system.
- **Cooling Impact:** Avoiding wiring build-up that hinders airflow in hot and cold aisles, improving overall thermal efficiency.

2.3. Choice of connectors

- **Modular and reusable connectors:** the use of standard connectors (RJ45, LC, MPO/MTP) integrated into structured cabling systems and modular patch panels allow only the affected elements (patch cords, cassettes or modules) to be replaced, without the need to remove permanent wiring. This approach facilitates technological evolution, reduces e-waste and minimizes the environmental and operational impact associated with rewiring the DPC.
- **Efficiency and Safety Certification: Prioritize** connectors that conform to recognized standards such as ANSI/TIA-568, ANSI/TIA-942, and ISO/IEC 11801, which define maximum insertion and return loss limits, as well as durability and environmental resistance requirements. Compliance with these standards ensures stable performance over time, reduces premature degradation and extends the useful life of the cable, clearly differentiating these connectors from non-certified solutions that lack guarantees of performance and durability.
- **Reduction of critical metals:** prioritize the use of fibre optics in backbone and distribution links and limit the use of copper to short and strictly necessary sections. This approach, coupled with optimized network architectures and higher-density cables, allows for a significant reduction in the total amount of high-impact metals without compromising data center efficiency or performance.

2.4. Cable optimization

- **Use of high-density technologies (e.g. MPO/MTP):** reduce the amount of fibres required and the occupation of space.
- **Intelligent monitoring and management:** implement *intelligent cabling management* systems to control inventory, occupancy and status of the links.
- **Reuse and recycling at the end of life:** ensure a reverse logistics system for reuse of materials.
- **Future-proof:** Choose cabling categories and connectors that support emerging speeds (400G, 800G) that extend the life of the infrastructure.

3. Deploying the Hardware

3.1. Physical distribution of servers

The physical distribution of hardware within a data center is not merely a technical aspect: it has a direct impact on energy efficiency, operating costs, and the environmental sustainability of the entire infrastructure. A suitable design allows you to optimize the use of space, reduce the consumption associated with refrigeration and extend the useful life of the equipment.

3.1.1. Principles for efficient rack and server distribution

1. **Hot and cold aisles**: organize the racks so that the cold air inlets and hot air outlets are clearly separated, avoiding recirculation. This practice is recommended by the European Code of Conduct for Data Centers Energy Efficiency (European Commission). In practice, it is implemented by orienting all the racks in the same row in the same direction (facing fronts and facing rears), defining from the initial design which aisles are for delivery and which are for return, aligning the floor grilles or impulsion points exclusively with the cold aisles and validating the configuration through thermal measurements after installation.
2. **Physical isolation**: Use enclosures in the corridors to better control air flows and reduce the need for additional air conditioning. This is done through the installation of specific enclosures in hot or cold aisles (doors, ceilings and side panels), the systematic use of blind panels in free spaces of the racks and the integration of these elements with the air conditioning system to reduce flow rates and energy consumption.
3. **Balanced density**: distribute server load avoiding excessive concentrations that generate hot spots and demand more localized cooling. To this end, maximum power limits per rack are defined in the design phase, high-density loads are distributed homogeneously, and temperature and consumption are monitored to detect and correct operational imbalances.
4. **Modular scalability**: plan the room in scalable modules that allow capacity to be expanded without completely redesigning the infrastructure. This principle is applied by designing the room by repeatable blocks of racks, reserving electrical and cooling capacity for future growth and avoiding rigid layouts that force complete redistributions in each expansion.

3.1.2. Airflow optimization and accessibility for maintenance

- **Trays and tidy wiring**: A clean duct design prevents airflow obstructions and improves cooling efficiency. In practice, this is achieved by separating data and power wiring paths, using raised or side trays that do not interfere with the front-rear flow of air, and removing obsolete wiring during maintenance.

- **Free space around the racks**: maintaining aisles of sufficient width not only favors the movement of technicians but also allows a homogeneous distribution of temperature. This involves defining minimum aisle widths from the design, avoiding the storage of material in circulation areas and keeping the air supply and return areas clear.
- **Safe accessibility**: prioritizing designs that allow equipment to be intervened without interrupting airflow or electricity supply, reducing operational risks. It is applied by guaranteeing complete front and rear access to the racks, locating PDUs and critical elements outside the airflows and establishing maintenance procedures that do not require disassembly that alters ventilation.
- **Use of perforated raised floors and blind panels**: they channel cold air directly to the equipment and block unused areas to prevent leaks. In practice, perforated tiles are only placed in cold aisles and sized according to the required flow rate, unused openings in the raised floor are sealed and blind panels are installed in racks and areas without equipment.

3.1.3. Impact of physical distribution on energy consumption and cooling

- Inefficient **distribution** can increase **energy consumption in air conditioning by up to 30%,** according to data from the *European Environment Agency (EEA).*
- **Optimized designs** reduce dependence on mechanical air conditioning systems, favoring *free cooling* strategies in cold regions.
- The correct arrangement of racks influences the **efficiency of PUE (Power Usage Effectiveness):** a low PUE (close to 1.2) is achievable when the physical distribution is well planned.
- Avoiding hot spots helps extend the life of servers, reducing the need for replacements and, with it, the carbon footprint associated with manufacturing new hardware.

3.1.4. Criteria for minimizing the environmental footprint in physical space

- **Efficient use of built space:** design compact data centers, avoid overbuilding and maximizing rack density within thermal efficiency limits.
- **Reuse flexibility:** planning infrastructures that can be converted for other technological uses when they become obsolete, reducing the need for new construction.
- **Sustainable materials in infrastructure:** integrate furniture and supports made from recycled materials or materials with low environmental impact.
- **Life cycle optimisation:** consider not only the use phase, but also the construction and decommissioning phase, applying circular economy principles.

3.2. Cooling systems

The design and operation of cooling systems in a data center represents one of the main determinants of its energy efficiency and environmental footprint. According to **the International Energy Agency (IEA, 2022),** up to **40% of a DPC's electricity consumption can be used for cooling**, making this a critical area for sustainable intervention.

The transition to **low-impact refrigeration systems** not only reduces operating costs but also contributes to meeting the European objectives of climate neutrality and efficient resource management.

3.2.1. Alternatives with low environmental impact

- **High-efficiency liquid cooling (direct-to-chip, immersion, or micro-channels):** Dissipates heat more effectively than air and enables higher compute densities with lower power consumption.
- **Free cooling and air economizers:** take advantage of cold ambient conditions to reduce or eliminate the need for mechanical air conditioning systems.
- **Hybrid systems (air + liquid):** allow progressively transitioning to more efficient cooling, reducing operational risks.
- **Use of low global warming potential (GWP) refrigerants:** aligned with **Regulation (EU) 517/2014 on fluorinated** gases, which seeks the progressive reduction of HFCs.

3.2.2. Efficient management of water use in refrigeration

- **Closed recirculation systems:** limit water consumption through continuous reuse, avoiding losses due to evaporation.
- **Use of recycled or non-potable water:** whenever possible, prioritize reclaimed water to minimize pressure on local water resources.
- **Water Usage Effectiveness (WUE):** integrate water use metrics into the CPD's sustainability reports.
- **Advanced monitoring:** apply sensors to measure leaks, water consumption and quality, guaranteeing efficiency and risk reduction.

3.2.3. Reduction of energy consumption in air conditioning

- **Intelligent and dynamic ventilation:** adjust the airflow according to the temperature and workload using automatic control systems.
- **Thermal distribution optimization:** use of closed hot and cold aisles, along with blind panels, to minimize recirculation.

- **Integration of renewable energies in the supply of cooling systems:** example: heat pumps powered by green electricity.
- **Predictive maintenance:** detect inefficiencies in fans, pumps and chillers using advanced analytics.

3.3. Maintenance and repair of components

Hardware maintenance and repair in data centers are key elements to extend the useful life of equipment, reduce the generation of electronic waste (*e-waste*) and optimize the use of resources. The European Commission estimates that **70% of the environmental impact of ICT equipment occurs in its manufacture**; therefore, prolonging its life cycle through preventive maintenance and repair strategies makes a decisive contribution to sustainability.

Principles of sustainable maintenance

- **Preventive and predictive maintenance:** through IoT sensors and advanced analytics, it is possible to anticipate failures and replace only the affected components, avoiding complete equipment replacements.
- **Document management and traceability:** implement digital maintenance records that guarantee compliance with environmental regulations and facilitate audits.
- **Sustainable service contracts:** requiring suppliers to provide clauses that prioritize repair over replacement and that include commitments to reuse parts.

Repair and Life Extension Strategies

- **Modular repair:** choose equipment with a modular design that allows you to replace cards, disks or memories independently.
- **Use of refurbished and certified parts:** promotes the circular economy and reduces the need to manufacture new components.
- **Standardization and compatibility:** opt for hardware that meets international interoperability standards, reducing premature obsolescence.

Sustainable management at the end of life

- **Reverse logistics:** establishing agreements with suppliers for the collection of obsolete equipment and its shipment to refurbishment or recycling plants.

- **Certified recycling:** comply with the **WEEE Directive (2012/19/EU)** for the management of waste electrical and electronic equipment, ensuring the recovery of critical metals such as copper, cobalt or rare earths.
- **Circularity reports:** incorporate metrics on repaired, refurbished and recycled equipment into the DPC's sustainability reports.

Benefits of the application

- Significant reduction in electronic waste.
- Reduction of emissions associated with the manufacture and transport of new equipment.
- Optimization of economic investment by extending the life cycle of the hardware.
- Compliance with the European Union's circular economy strategy.

3.4. Hardware Evaluation and Selection Criteria

Hardware selection is one of the most critical decisions in the life cycle of a data center, as it determines both its energy efficiency and its overall environmental impact. The evaluation must be carried out in a systematic manner, considering environmental indicators, efficiency criteria and specific aspects of each component.

3.4.1. Environmental Impact Assessment

- **Life Cycle Assessment (LCA):** apply standardized methodologies (ISO 14040/44, UNE-EN 45554 on repairability) to assess the environmental impact from the extraction of raw materials to the end of their useful life.
- **Key environmental indicators:**
    - Total energy consumption (direct and indirect).
    - CO_2 emissions associated with manufacturing and transportation.
    - Water consumption and use of critical mineral resources (cobalt, lithium, rare earths).
- **European Product Environmental Footprint (PEF):** a method recommended by the European Commission to ensure comparability in the evaluation of ICT products.

- **Regulatory compliance:** verification of WEEE (2012/19/EU) and RoHS (2011/65/EU) directives to ensure that equipment complies with restrictions on the use of hazardous substances and proper waste management.

3.4.2. Common selection procedure and criteria

- **Certified energy efficiency:** opt for equipment with certifications such as *Energy Star for Servers* or adhered to Regulation (EU) 2019/424.
- **Repairability and modularity: Prioritize** hardware that makes it easy to replace individual components (RAM, disks, power supplies) without replacing the entire system.
- **Durability and extended warranties:** Requiring manufacturers to make contractual commitments to ensure support and updates for longer cycles.
- **Compatibility and standardization:** It is recommended to favor equipment that complies with **open international standards** (e.g., Open Compute Project, NVMe, SATA, PCIe, SNIA SMI-S, IEEE 802.3) to improve interoperability between different manufacturers. This **reduces the risk of premature obsolescence** and facilitates the integration and updating of systems, although it does not completely eliminate obsolescence, as other technological and manufacturer factors also play a role.

3.4.3. Other criteria relating to the specificities of the different components

- **Processors:** select CPUs and GPUs optimized for AI (*performance per watt*) power efficiency, with support for modular scalability and advanced power management features.

- **RAM memory:** prefer modules with low power consumption (e.g. DDR5 with advanced power management) and prioritize densities that reduce the number of modules needed.

- **Storage:** Use HDDs for massive storage of infrequently accessed data (cold files, backups), and SSDs when high performance, low latency, and frequent read/write operations are needed, as well as hierarchical storage systems to optimize access.

- **Integrated cooling systems:** the use of efficient passive heatsinks, and racks prepared for low-impact liquid cooling technologies (such as rear-door heat exchanger or cold plates) is recommended. Compatibility is determined by reviewing the specifications of the refrigeration system and hardware, ensuring that temperatures, airflow and liquid pressure meet operational and energy efficiency requirements.

- **Other peripherals (power supplies, internal wiring, etc.):** require efficiency certifications (e.g. 80 PLUS Titanium in power supplies) and materials with low environmental impact.

This methodological framework ensures a hardware selection consistent with *Green by Design* principles, incorporating both general environmental impact criteria and specific technical aspects. In this way, it ensures that the AI infrastructure is deployed under a sustainable approach, aligned with European regulations and climate neutrality commitments.