



ENERGY STAR® Program Requirements for Data Center Storage

Partner Commitments

Following are the terms of the ENERGY STAR Partnership Agreement as it pertains to the manufacture and labeling of ENERGY STAR certified products. The ENERGY STAR Partner must adhere to the following partner commitments:

Certifying Products

1. Comply with current ENERGY STAR Eligibility Criteria, which define performance requirements and test procedures for Data Center Storage. A list of eligible products and their corresponding Eligibility Criteria can be found at www.energystar.gov/specifications.
2. **Prior to associating the ENERGY STAR name or mark with any product**, obtain written ENERGY STAR certification from a Certification Body recognized by EPA for Data Center Storage. As part of this certification process, products must be tested in a laboratory recognized by EPA to perform Data Center Storage testing. A list of EPA-recognized laboratories and certification bodies can be found at www.energystar.gov/testingandverification.

Using the ENERGY STAR Name and Marks

3. Comply with current ENERGY STAR Identity Guidelines, which define how the ENERGY STAR name and marks may be used. Partner is responsible for adhering to these guidelines and ensuring that its authorized representatives, such as advertising agencies, dealers, and distributors, are also in compliance. The ENERGY STAR Identity Guidelines are available at www.energystar.gov/logouse.
4. Use the ENERGY STAR name and marks only in association with certified products. Partner may not refer to itself as an ENERGY STAR Partner unless at least one product is certified and offered for sale in the U.S and/or ENERGY STAR partner countries.
5. Provide clear and consistent labeling of ENERGY STAR certified Data Center Storage.

Partner shall adhere to the following product-specific commitments regarding use of the ENERGY STAR certification mark on certified products:

5.1. Partner must use the ENERGY STAR mark in all of the following ways:

5.1.1. The ENERGY STAR mark shall be included on the product specification sheet on the Partner's Web site where product information is displayed. This mark shall serve as a hyperlink from the manufacturer's specification sheet to the ENERGY STAR product website for Data Center Storage;

5.1.2. The ENERGY STAR mark shall be used to identify certified storage products and storage product families in electronic and printed marketing collateral materials, including but not limited to user manuals, product guides, and marketing brochures.

5.2. If additional information about the ENERGY STAR program(s) or other products provided by the Partner on its Web site, Partner must comply with the *ENERGY STAR Web Linking Policy*, which can be found at www.energystar.gov/partners.

Providing Information to EPA

6. Provide unit shipment data or other market indicators to EPA annually to assist with creation of ENERGY STAR market penetration estimates, as follows:
 - 6.1. Partner must submit the total number of ENERGY STAR certified Data Center Storage shipped in the calendar year or an equivalent measurement as agreed to in advance by EPA and Partner. Partner shall exclude shipments to organizations that rebrand and resell the shipments (unaffiliated private labelers).
 - 6.2. Partner must provide unit shipment data segmented by meaningful product characteristics (e.g., type, capacity, presence of additional functions) as prescribed by EPA.
 - 6.3. Partner must submit unit shipment data for each calendar year to EPA or an EPA-authorized third party, preferably in electronic format, no later than March 1 of the following year.Submitted unit shipment data will be used by EPA only for program evaluation purposes and will be closely controlled. If requested under the Freedom of Information Act (FOIA), EPA will argue that the data is exempt. Any information used will be masked by EPA so as to protect the confidentiality of the Partner;
7. Report to EPA any attempts by recognized laboratories or Certification Bodies (CBs) to influence testing or certification results or to engage in discriminatory practices.
8. Notify EPA of a change in the designated responsible party or contacts within 30 days using the My ENERGY STAR Account tool (MESA) available at www.energystar.gov/mesa.

Performance for Special Distinction

In order to receive additional recognition and/or support from EPA for its efforts within the Partnership, the ENERGY STAR Partner may consider the following voluntary measures, and should keep EPA informed on the progress of these efforts:

- Provide quarterly, written updates to EPA as to the efforts undertaken by Partner to increase availability of ENERGY STAR certified products, and to promote awareness of ENERGY STAR and its message.
- Consider energy efficiency improvements in company facilities and pursue benchmarking buildings through the ENERGY STAR Buildings program.
- Purchase ENERGY STAR certified products. Revise the company purchasing or procurement specifications to include ENERGY STAR. Provide procurement officials' contact information to EPA for periodic updates and coordination. Circulate general ENERGY STAR certified product information to employees for use when purchasing products for their homes.
- Feature the ENERGY STAR mark(s) on Partner website and other promotional materials. If information concerning ENERGY STAR is provided on the Partner website as specified by the ENERGY STAR Web Linking Policy (available in the Partner Resources section of the ENERGY STAR website), EPA may provide links where appropriate to the Partner website.
- Ensure the power management feature is enabled on all ENERGY STAR certified displays and computers in use in company facilities, particularly upon installation and after service is performed.
- Provide general information about the ENERGY STAR program to employees whose jobs are relevant to the development, marketing, sales, and service of current ENERGY STAR certified products.
- Provide a simple plan to EPA outlining specific measures Partner plans to undertake beyond the program requirements listed above. By doing so, EPA may be able to coordinate, and communicate Partner's activities, provide an EPA representative, or include news about the event in the ENERGY STAR newsletter, on the ENERGY STAR website, etc. The plan may be as simple as providing a list

of planned activities or milestones of which Partner would like EPA to be aware. For example, activities may include: (1) increasing the availability of ENERGY STAR certified products by converting the entire product line within two years to meet ENERGY STAR guidelines; (2) demonstrating the economic and environmental benefits of energy efficiency through special in-store displays twice a year; (3) providing information to users (via the website and user's manual) about energy-saving features and operating characteristics of ENERGY STAR certified products; and (4) building awareness of the ENERGY STAR Partnership and brand identity by collaborating with EPA on one print advertorial and one live press event.

- Join EPA's SmartWay Transport Partnership to improve the environmental performance of the company's shipping operations. The SmartWay Transport Partnership works with freight carriers, shippers, and other stakeholders in the goods movement industry to reduce fuel consumption, greenhouse gases, and air pollution. For more information on SmartWay, visit www.epa.gov/smartway.
- Join EPA's Green Power Partnership. EPA's Green Power Partnership encourages organizations to buy green power as a way to reduce the environmental impacts associated with traditional fossil fuel-based electricity use. The partnership includes a diverse set of organizations including Fortune 500 companies, small and medium businesses, government institutions as well as a growing number of colleges and universities. For more information on Green Power, visit www.epa.gov/greenpower.



ENERGY STAR® Program Requirements Product Specification for Data Center Storage

Eligibility Criteria Version 1.1

Following is the Version 1.1 ENERGY STAR Product Specification for Data Center Storage. A product shall meet all of the identified criteria if it is to earn the ENERGY STAR.

1 DEFINITIONS

A. Product Types:

- 1) Storage Product: A fully-functional storage system that supplies data storage services to clients and devices attached directly or through a network. Components and subsystems that are an integral part of the storage product architecture (e.g., to provide internal communications between controllers and disks) are considered to be part of the storage product. In contrast, components that are normally associated with a storage environment at the data center level (e.g., devices required for operation of an external SAN) are not considered to be part of the storage product. A storage product may be composed of integrated storage controllers, storage devices, embedded network elements, software, and other devices. For purposes of this specification, a storage product is a unique configuration of one or more SKUs, sold and marketed to the end user as a Storage Product.
- 2) Storage Device: A collective term for disk drives (HDDs), solid state drives (SSDs), tapes cartridges, and any other mechanisms providing non-volatile data storage. This definition is specifically intended to exclude aggregating storage elements such as RAID array subsystems, robotic tape libraries, filers, and file servers. Also excluded are storage devices which are not directly accessible by end-user application programs, and are instead employed as a form of internal cache.
- 3) Storage Controller: A device for handling storage request via a processor or sequencer programmed to autonomously process a substantial portion of I/O requests directed to storage devices (e.g., RAID controllers, filers).

B. Storage Product Connectivity:

- 1) Direct-attached Storage (DAS): One or more dedicated storage devices that are physically connected to one or more servers.
- 2) Network Attached Storage (NAS): One or more dedicated storage devices that connect to a network and provide file access services (File I/O) to remote computer systems.
- 3) Storage Area Network (SAN): A network whose primary purpose is the transfer of data between computer systems and storage products. A SAN consists of a communication infrastructure, which provides physical connections, and a management layer, which organizes the connections, storage controllers / devices, and computer systems so that data transfer is secure and robust. The term SAN is usually (but not necessarily) identified with block I/O services rather than file access services.

- C. Capacity Optimizing Methods (COMs)¹: The reduction of actual data stored on storage devices through a combination of hardware and / or software. Common COMs include:
- 1) Thin Provisioning: A technology that allocates the physical capacity of a volume or file system as applications write data, rather than allocating all the physical capacity at the time of provisioning.
 - 2) Data Deduplication: The replacement of multiple copies of data – at variable levels of granularity – with references to a shared copy in order to save storage space and/or bandwidth.
 - 3) Compression: The process of encoding data to reduce its size. For the purpose of this specification, only lossless compression (i.e., compression using a technique that preserves the entire content of the original data, and from which the original data can be reconstructed exactly) is recognized.
 - 4) Delta Snapshots: A type of point-in-time copy that preserves the state of data at an instant in time by storing only those blocks that are different from an already existing full copy of the data.
- D. Storage Taxonomy¹: A categorization scheme for use in segmenting the data center storage market by end-use application and key product characteristics. The major categories of the taxonomy that are referenced in this document are as follows:
- 1) Online Storage: Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short response time. All data stored in Online storage must be accessible $\text{MaxTTFD} \leq 80$ ms, unless the storage product is in a Deep Idle state. Online storage is typically comprised of one or more HDDs or SSDs and a storage controller, and provides primary data storage to supplement a Computer Server's internal memory.
 - 2) Near-online Storage: Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short to moderate response time. Near-online storage products offer an asymmetrical response; a portion of data may be accessible $\text{MaxTTFD} \leq 80$ milliseconds, while other data may be accessible $\text{MaxTTFD} > 80$ milliseconds.
 - 3) Virtual Media Library: Storage products that are intended to service primarily Sequential I/O, with a short response time. The media in a Virtual Media Library (e.g., HDD, optical disk) is not designed to be physically removed from the system. All data stored in the Virtual Media Library must be assessable $\text{MaxTTFD} \leq 80$ ms, unless the storage product is in a Deep Idle state. Virtual Media Libraries are intended primarily for moderate and long term data storage.
 - 4) Removable Media Library: Storage products that are intended to service primarily Sequential I/O, with a moderate to long response time. The media (e.g., tape cartridge, optical disk) in a Removable Media Library is designed to be physically removed from the storage product. Removable Media Libraries are intended primarily for long term data archiving.
- E. Other Data Center Equipment:
- 1) Computer Server: A computer that provides services and manages networked resources for client devices (e.g., desktop computers, notebook computers, thin clients, wireless devices, PDAs, IP telephones, other computer servers and other network devices). A computer server is sold through enterprise channels for use in data centers and office/corporate environments. A computer server is primarily accessed via network connections, versus directly-connected user input devices such as a keyboard or mouse. For purposes of this specification, a product must meet all of the following criteria to be considered a computer server:

¹ The ENERGY STAR storage taxonomy and COM references in this document are consistent with the terminology developed by the Storage Networking Industry Association Green Storage Initiative as defined in "SNIA Emerald™ Power Efficiency Measurement Specification" Version 3.0.2. Further detail may be found at www.snia.org/green.

- i) is marketed and sold as a Computer Server;
 - ii) is designed for and listed as supporting computer server operating systems (OS) and/or hypervisors;
 - iii) is targeted to run user-installed applications typically, but not exclusively, enterprise in nature;
 - iv) provides support for error-correcting code (ECC) and/or buffered memory (including both buffered DIMMs and buffered on board (BOB) configurations)
 - v) is packaged and sold with one or more ac-dc or dc-dc power supplies; and
 - vi) is designed such that all processors have access to shared system memory and are visible to a single OS or hypervisor.
- 2) Network Equipment: A device whose primary function is to provide data connectivity among an arbitrary combination of devices connected to its several ports. Data connectivity is achieved via the routing of data packets encapsulated according to Internet Protocol, Fibre Channel, InfiniBand or other standard protocol. Examples of network equipment commonly found in data centers are routers and switches.
 - 3) Power Distribution Unit (PDU): A single- or three-phase power strip designed for data center use. A PDU may include instrumentation for metering power input and output, switched outlets for control of individual receptacles, or other advanced features.
 - i) Intelligent Power Distribution Unit (iPDU): A PDU with additional functionality to provide operational measurements of power consumption and environmental temperature.
 - 4) Blade Storage: A storage product that is designed for use in a blade chassis. A blade storage product is dependent upon shared blade chassis resources (e.g., power supplies, cooling) for operation.
 - 5) Cache: Temporary storage used to transparently store transitory data and which is not directly addressable by end-user applications. Primarily used for expediting access to or from (typically) slower devices.
- F. Capacity: Capacity is reported in units of either binary bytes (1 MiB = 1,048,576 Byte) or decimal bytes (1 MB = 1,000,000 Byte).
- 1) Assigned Capacity: The amount of space on a system or data container which has been allotted to be written by an end user or application. (Note: For thin provisioning systems, an assigned capacity number represents a promise that that amount of space will be provided on demand; usable capacity is allocated as the container is written too. For fully-provisioned systems, usable capacity must be committed at the same time the container is allocated.)
 - 2) Effective Capacity: The amount of data stored on a storage product, plus the amount of unused formatted capacity in the system.
 - 3) Formatted (Usable) Capacity: The total amount of bytes available to be written after a storage product or storage device has been formatted for use (e.g., by an object store, file system or block services manager). Formatted capacity is less than or equal to raw capacity. It does not include areas set aside for system use, spares, RAID parity areas, checksum space, host- or file system-level remapping, "right sizing" of disks, disk labeling and so on. However, formatted capacity may include areas that are normally reserved – such as snapshot set-asides – if these areas may be configured for ordinary data storage.
 - 4) Free Space: The amount of unused, formatted capacity as reported by the storage product.

- 5) Raw (Addressable) Capacity: The sum total amount of addressable capacity of the storage devices in a storage product. The raw capacity of a storage device is commonly understood to be the number of bytes available to be written via SCSI or equivalent protocol. It does not include unaddressable space, ECC (error correcting code) data, remap areas, inter-sector gaps, etc.

G. Operational States:

- 1) Active State: The state in which a storage product is processing external I/O requests.
- 2) Idle State: An operational state in which the storage product is capable of completing I/O transactions, but no active I/Os are requested or pending. The system may, however, be servicing self-initiated I/Os from background data protection and cleansing, and other operations not initiated by the user.
 - i) Ready Idle: The state in which a storage product is able to respond to arbitrary I/O requests within the MaxTTFD limits for its taxonomy category, but is not receiving external I/O requests. The storage product may perform routine housekeeping tasks during Ready Idle, provided such operations do not compromise the product's ability to meet MaxTTFD requirements.
 - ii) Deep Idle: A state in which one or more storage product components or subsystems have been placed into a low-power state for purpose of conserving energy. A storage product in Deep Idle may not be able to respond to I/O requests within the MaxTTFD limits for its taxonomy category, and may need to perform a managed 'wake-up' function in order to return to a Ready Idle or Active State. Deep Idle capability must be a user-selected, optional feature of the storage product.

H. Power Supply Unit (PSU): A device that converts ac or dc input power to one or more dc power outputs for the purpose of powering a storage product. A storage PSU must be self-contained and physically separable from the system and must connect to the system via a removable or hard-wired electrical connection. Note: Storage PSUs may be Field Replaceable Units (FRUs), but in some cases may be further integrated with the storage product.

- 1) Ac-dc Power Supply: A PSU that converts line-voltage ac input power into one or more dc power outputs.
- 2) Dc-dc Power Supply: A PSU that converts line-voltage dc input power to one or more dc power outputs. For purposes of this specification, a dc-dc converter (also known as a voltage regulator) that is internal to a storage product and is used to convert a low voltage dc (e.g., 12 V dc) into other dc power outputs for use by storage product components is not considered a dc-dc power supply.
- 3) Single-output Power Supply: A PSU that is designed to deliver the majority of its rated output power to one primary dc output. Single-output PSUs may offer one or more standby outputs that remain active whenever connected to an input power source. For purposes of this specification, the total rated power output from all additional PSU outputs that are not primary or standby outputs shall be less than or equal to 20 watts. PSUs that offer multiple outputs at the same voltage as the primary output are considered single-output PSUs unless those outputs (1) are generated from separate converters or have separate output rectification stages, or (2) have independent current limits.
- 4) Multi-output Power Supply: A PSU that is designed to deliver the majority of its rated output power to more than one primary dc output for the purpose of powering a storage product. Multi-output PSUs may offer one or more standby outputs that remain active whenever connected to an input power source. For purposes of this specification, the total rated power output from all additional PSU outputs that are not primary and standby outputs must be greater than or equal to 20 watts.

- 5) Redundant Power Supplies: Two or more PSUs that are configured to maintain uninterrupted output load in the event of failure of one PSU.
- I. Product Family: A group of models/configurations that share a set of common attributes that are variations on a basic design.
 - 1) Common Product Family Attributes: A set of features common to all models/configurations within a product family that constitute a common basic design. All models/configurations within a product family must share the following:
 - i) made by the same manufacturer;
 - ii) be from the same model line or machine type;
 - iii) utilize the same model of storage controller;
 - iv) fall under the same taxonomy category; and
 - v) contain equal or greater amount of cache than the corresponding certified configuration.
 - 2) Optimal Configuration: A product configuration that lies between the minimum and maximum certified configurations and is representative of a product with maximum peak energy efficiency performance (performance/watt) for a given workload. This configuration is provided by the manufacturer and may be optimized for the following workload types:
 - i) Transaction: A workload optimized for random I/O usage measured in I/O per second per watt;
 - ii) Streaming: A workload optimized primarily for sequential I/O usage, measured in MiB per second per watt;
 - iii) Composite (File I/O products only): A workload optimized for mixed I/O usage, measured in MiB per second per watt.
 - iv) Capacity (Block I/O products only): A workload optimized for maximum storage as measured by GB (Raw Capacity) per watt.
 - 3) Fixed Certification Range: Defined by testing product configurations at the Optimal Configuration and at points that are 40% smaller and 15% larger in storage device count than the Optimal Configuration. This certification range is fixed at 20% smaller and 5% larger than the Optimal Configuration. Product configurations which are unable to be configured for either the Fixed Maximum or Fixed Minimum Certified Configuration are not required to perform that respective test. In such a case, the certification range is limited to the region between the Optimal Configuration and whichever one of the Fixed Configurations is tested.
 - i) Fixed Maximum Certified Configuration: A product configuration that includes the combination of base components that generates a system which is 5% larger in storage device count than the Optimal Configuration.
 - (a) The resulting storage device count may be rounded up to the nearest drawer boundary.
 - ii) Fixed Minimum Certified Configuration: A product configuration that includes the combination of base components that generates a system which is 20% smaller in storage device count compared to the Optimal Configuration.
 - (a) The resulting storage device count may be rounded down to the nearest drawer boundary.

- 4) Flexible Certification Range: Defined by testing product configurations at the Optimal Configuration and at two manufacturer chosen points, one smaller than the Fixed Minimum Certified Configuration and one larger than the Fixed Maximum Certified Configuration. This certified range is extended out to the smaller and larger points, provided they are within 15% of the Optimal Configuration's performance/watt value.
 - i) Flexible Maximum Certified Configuration: A product configuration that includes a combination of base components that generate a system which is larger in storage device count than the Fixed Maximum Certified Configuration and which is within 15% of the Optimal Configuration performance/watt, validated through the testing data requirements in Section 3.5 below.
 - (a) Performance will be measured using the appropriate relative weighting of workloads defined in Table 6 or Table 7.
 - (b) Modeled data may not be used for Expanded Maximum Certified Configuration submissions.
 - (c) The resulting storage device count may be rounded up to the nearest drawer boundary.
 - ii) Flexible Minimum Certified Configuration: A product configuration that includes a combination of base components that generate a system which is smaller in storage device count than the Fixed Minimum Certified Storage Configuration and which is within 15% of the Optimal Configuration performance/watt, validated through the testing data requirements in Section 3.5 below.
 - (a) Performance will be measured using the appropriate relative weighting of workloads defined in Table 7 or Table 8.
 - (b) Modeled data may not be used for Expanded Minimum Certified Configuration submissions.
 - (c) The resulting storage device count may be rounded down to the nearest drawer boundary.
- 5) Mixed Certification Range: Defined by testing one of the fixed points in 1.1.3 and one of the flexible points in 1.1.4, provided they are on opposite sides of the Optimal Configuration. On the side with the Flexible Configuration, the certification range is extended from the Optimal Configuration out to the chosen flexible point. If the Fixed Minimum Certified Configuration was chosen, the range is kept to 20% smaller than the Optimal Configuration. If the Fixed Maximum Certified Configuration was chosen, the range is kept to 5% larger. A fixed testing point described in 1.1.3 can be used in place of a flexible testing point described in 1.1.4 to extend a range of certification so long as that point in storage device count is within 15% of the Optimal Configuration performance/watt, validated through the testing data requirements in Section 3.5 below.
- 6) Systems Composed of Combinations of Single Device Optimal Configurations: A product family which has demonstrated more than one Single Device Optimal Configuration may be sold as ENERGY STAR certified using a combination of those Single Device Optimal Configurations, provided all of the following apply:
 - i) Combined systems are configured using only those storage devices, or validated replacement storage devices (Section 3.6), and configuration options which were used in the individual certified Optimal Configurations.
 - ii) The combined system consists of percentage allocation of storage devices, or validated replacement storage devices (Section 3.6), from one or more Optimal Configurations.
 - iii) The total sum of all percent allocations of storage devices drawn from the Optimal Configurations must equal 100%.

- iv) After allocation, storage devices and drawers are rounded per the Maximum and Minimum Certified Configuration rules above.
 - v) When rounding to a drawer, storage devices are added or removed (as appropriate) to maintain storage device percentages in a proportion as close as possible to the proportion used in the combined system configuration prior to drawer rounding.
 - vi) Allocation of Optimal Configurations is also used when a storage product provides Block I/O capability in addition to NAS capabilities. In this usage, the system wide percentage of defined allocations will include the portion of the system providing NAS functionality.
 - vii) Multiple transaction or streaming optimizations may be submitted to incorporate different storage device technologies and customer usage needs.
- 7) Systems Composed of Multiple Device Types in an Optimal Configuration: An Optimal Configuration that contains more than one type of addressable storage device may be certified as part of an ENERGY STAR product family provided **all** of the following apply:
- i) System features used during certification of Multiple Device Configurations must include automated storage tiering for those portions of the Multiple Device Configurations containing mixed storage devices.
 - ii) If SSD storage devices are used as part of the certified Multiple Device Configuration, they must be included in all certification testing and modeling.
 - iii) The ratio of the different storage devices in the certified Multiple Device Configuration must be maintained as closely as possible during testing of the required Minimum and Maximum Certified Configurations, as well as in all configurations sold as ENERGY STAR certified.
 - iv) Multiple Device Configurations may be combined with Single Device Configurations under the same product family, and combinations of Multiple and Single Device Configurations from that family may be sold as ENERGY STAR certified.
 - v) End-user selectable automated storage tiering functionality must be included with all Multiple Device Configurations sold as ENERGY STAR certified,
 - vi) All other conditions in Section 1.1.6 above for both Single Device Optimized Configurations and Multiple Device Optimized Configurations must be met.
- 8) Capacity Optimization Family Restriction: Since the scope in 2.1.1 only encompasses Online systems, a product family may not be based solely on Capacity Optimized Configurations. Every storage device submitted for certification under Capacity Optimized Configurations must also include one or more Transaction Optimized Configuration(s) and/or Streaming Optimized Configuration(s) using the same storage device. A Capacity Optimized Configuration may only be submitted as an addition to one (or more) of the other optimizations and cannot be submitted for a File I/O certification as it is not a testable workload for that configuration.

J. Other Definitions:

- 1) Scale-Up Storage: A storage product comprised of a discreet storage controller (with or without redundancy), which has a full view of all the storage devices in the storage product. Incremental storage capacity is added by the addition of storage devices under the control of the existing storage controller.

- 2) Scale-Out Storage: A storage product capable of being comprised of two or more discreet storage controllers (with or without redundancy), combined with an overall integration or aggregation function resulting in a single storage product view for attached servers. Each discreet storage controller often has a partial view to a partition of the overall system's storage devices, but this is not a fixed requirement. Incremental storage capacity is added by the addition of storage devices under the control of the existing storage controller(s) and/or addition of additional storage devices along with additional controller(s).
- 3) Automated Storage Tiering: Automatic movement of data between different types of storage devices. Tiering may occur within a single storage product or may span multiple storage products. For the purposes of this specification, only tiering within a single storage product is applicable. If automated storage tiering is enabled during testing, then the multi-storage device groups necessary for tiering may be represented as a single storage device when determining testing and certification ranges and when calculating storage device allocations. While doing so, the ratio of each discrete storage device within the multi-storage device group must remain as constant as the system architecture and configuration options allow.
- 4) Field-replaceable Unit (FRU): A unit, or component of a system that is designed to be replaced "in the field;" i.e., without returning the system to a factory or repair depot. Field replaceable units may either be customer-replaceable, or their replacement may require trained service personnel.
- 5) High-availability (HA): The ability of a system to perform its function continuously (without interruption) for a significantly longer period of time than the reliabilities of its individual components would suggest. High availability is most often achieved through failure tolerance.
- 6) Maximum Time to First Data (MaxTTFD): The maximum time required to start receiving data from a storage product to satisfy a read request for arbitrary data.
- 7) RAS Features: An acronym for reliability, availability, and serviceability features. RAS is sometimes also expanded to RASM, which adds "Manageability" criteria. The three primary components of RAS as related to storage products are defined as follows:
 - i) Reliability Features: Features supporting a storage product's ability to perform its intended function without interruption due to component failures. Technologies applied to increase reliability include: component selection (MTBF), redundancy (both at a micro and macro levels), temperature and/or voltage de-rating, error detection and correction technologies.
 - ii) Availability Features: Features that support a storage product's ability to maximize normal operating time and minimize planned and unplanned down time.
 - iii) Serviceability Features: Features that support a storage product's ability to be serviced (e.g., hot-plugging).
 - iv) Advanced Data Recovery Capability: A collective term used in this specification to refer to error detection and correction features such as RAID, mirroring / grid technology, or other comparable advanced error detection and recovery systems
 - v) Non-disruptive Serviceability: Support for continued availability of data and response times during all FRU and service operations; including break/fix, code patches, software/firmware upgrades, configuration changes, data migrations, and system expansion.
- 8) Physical Data: Data generated by testing a storage product using the ENERGY STAR Test Method for Data Center Storage.

- 9) Modeled Data: Data generated from an algorithmic tool, designed either by the ENERGY STAR Partner or a third party, which generates estimated test results (e.g., power, performance) for a set of storage product configuration inputs.
- 10) Block I/O Loads:
- i) Random Read: Any I/O load in which consecutively issued read requests do not specify adjacently addressed data. The term random I/O is commonly used to denote any I/O load that is not sequential, whether or not the distribution of data locations is indeed random.
 - ii) Random Write: Any I/O load whose consecutively issued write requests do not specify adjacently addressed data. The term random I/O is commonly used to denote any I/O load that is not sequential, whether or not the distribution of data locations is indeed random.
 - iii) Sequential Read: An I/O load consisting of consecutively issued read requests to adjacently addressed data.
 - iv) Sequential Write: An I/O load consisting of consecutively issued write requests to adjacently addressed data.
 - v) Hot Band: An I/O load consisting of a collection of read and write requests that models areas of higher frequency I/O activity over the addressed data.
- 11) File I/O Loads:
- i) DATABASE: An I/O load that simulates an OLTP database Table and Log file scenario.
 - ii) Software (SW) Build: An I/O load that simulates a large software project compilation or build phase of an EDA workflow.
 - iii) Video Data Acquisition (VDA): An I/O load that simulates acquisition of data from a temporarily volatile source such as surveillance or big data ingestion.
 - iv) Virtual Desktop Infrastructure (VDI): An I/O load that simulates the workload generated by a hypervisor to support a heavy steady-state knowledge worker workload.
- 12) Response Time: The time required for the UUT to complete an I/O request.
- 13) Unit Under Test (UUT): The storage product being tested.

2 CERTIFYING PRODUCTS

2.1 Included Products

- 2.1.1 Products that meet all of the following conditions are eligible for ENERGY STAR certification, with the exception of products listed in Section 2.2:
- i. meet the definition of a Storage Product provided in Section 1 of this document;
 - ii. are comprised of one or more SKUs and be able to be purchased in a single order from a storage product vendor;
 - iii. are characterized within the Online 2, 3, or 4 Storage Taxonomy categories² with the following additional criteria;
 - a) contain a controller with advanced data recovery capability
 - b) support Block I/O and/or File I/O storage functions; and

² As defined in the “SNIA Emerald™ Power Efficiency Measurement Specification”, Version 3.0.2.

c) implement scale-up or scale-out storage.

2.2 Excluded Products

- 2.2.1 Products that are covered under other ENERGY STAR product specifications are not eligible for certification under the ENERGY STAR Data Center Storage specification. The full list of specifications currently in effect can be found at www.energystar.gov/specifications.
- 2.2.2 The following products are specifically excluded from certification under this specification:
- i. Personal / Portable Data Storage Products;
 - ii. Computer Servers;
 - iii. Blade Storage Products;
 - iv. Direct Attached Storage Products
 - v. Storage Products capable of only object based storage;
 - vi. Storage devices in the following categories of the taxonomy: Near-online, Removable Media Library, Virtual Media Library, Adjunct Storage Products, and Interconnect Elements;

3 CERTIFICATION CRITERIA

3.1 Significant Digits and Rounding

- 3.1.1 All calculations shall be carried out with directly measured (unrounded) values.
- 3.1.2 Unless otherwise specified, compliance with specification limits shall be evaluated using directly measured or calculated values without any benefit from rounding.
- 3.1.3 Directly measured or calculated values that are submitted for reporting on the ENERGY STAR website shall be rounded to the nearest significant digit as expressed in the corresponding specification limit.

3.2 Power Supply Requirements

- 3.2.1 Power Supply Units (PSUs): PSUs used in storage products eligible under this specification shall meet the following requirements when tested using the *EPRI Generalized Internal Power Supply Efficiency Test Protocol, Rev. 6.6* (available at http://www.plugloadsolutions.com/docs/collatrl/print/Generalized_Internal_Power_Supply_Efficiency_Test_Protocol_R6.6.pdf).
- 3.2.2 Efficiency and Power Factor in Primary Embedded Equipment: Embedded PSUs that power primary components of the storage product, including controllers and drawers, must meet the requirements in Table 1 and Table 2.
- i. Efficiency: A storage product PSU shall meet efficiency requirements as specified in Table 1.

Table 1: Efficiency Requirements for PSUs

PSU Type	Rated Output Power	20% Load	50% Load	100% Load
Redundant and Non-Redundant Capable PSU	All Output Levels	85%	89%	85%

- ii. Power Factor: A storage product PSU shall meet power factor requirements as specified in Table 2.

Table 2: Power Factor Requirements for PSUs

PSU Type	Rated Output Power	20% Load	50% Load	100% Load
Redundant and Non-Redundant Capable PSU	All Output Levels	0.80	0.90	0.95

- iii. Embedded PSUs that do not power primary components of the storage product are not subject to PSU requirements.

3.3 Power Modeling Requirements

- 3.3.1 Power Modeling Presale tool: For systems that certify using modeled data, EPA expects that a power modeling tool characterizing the storage product will be made available to manufacturer certified purchasers of the product. The power modeling tool must provide an estimated energy efficiency performance of a deployed configuration based on user-selected configuration characteristics. Systems that are certified using modeled data are expected to make performance/watt data available to manufacturer certified purchasers of the product.

3.4 Energy Efficiency Feature Requirements

- 3.4.1 To certify for ENERGY STAR, a storage product must contain the following feature, implemented as specified:
 - i. *Adaptive Active Cooling*: Primary components of a storage product must utilize adaptive cooling technologies that reduce the energy consumed by the cooling technology in proportion to the current cooling needs to the storage product. (e.g., reduction of variable speed fan or blower speeds at lower ambient air temperature). This requirement is not applicable to devices that employ passive cooling.
- 3.4.2 A storage product shall make available to the end user configurable / selectable features listed in Table 3 in quantities greater than or equal to those listed in Table 4.

Table 3: Recognized COM Features

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

Table 4: COM Requirements for Online 2, 3, and 4 Systems

Storage Product Category	Minimum number of COMs required to be made available
Online 2	0
Online 3	1
Online 4	1

3.5 Information Reporting Requirements

3.5.1 Active and Idle State Efficiency Disclosure: To certify for ENERGY STAR, all active and idle state test results based on workload tests listed in Table 5 or Table 6 shall be reported:

Table 5: Required Workload Tests for all Block I/O Configurations

Workload Test
Hot Band
Random Read
Random Write
Sequential Read
Sequential Write
Ready Idle ³

Table 6: Required Workload Tests for all File I/O Configurations

Workload Test
DATABASE
SW Build
VDA
VDI
Ready Idle ³

3.5.2 Workload Weighting Requirements: The weighted percentages shown in Table 7 or Table 8 shall be used to calculate the appropriate Optimal Configuration point for a given storage product.

³ SNIA defined workload tests in Table 5, Table 6, and through the rest of this document can be found in the “SNIA Emerald™ Power Efficiency Measurement Specification” Version 3.0.2. Further detail may be found at www.snia.org/green.

Table 7: Workload Weighting Requirements for all Block I/O Systems

Workload Test	Transaction Optimization	Streaming Optimization	Capacity Optimization
Hot Band	100%	0%	0%
Sequential Read	0%	50%	0%
Sequential Write	0%	50%	0%
Ready Idle	0%	0%	100%

Example: To optimize for a streaming workload, manufacturers should identify a system configuration and storage device count where the weighted sum (per Table 6) of the Sequential Read and Sequential Write results are maximized. The resulting storage device count should be used as the streaming optimization point for ENERGY STAR testing and certification. The same weighting of the sums should also be used for subsequent certification measurements (e.g. determining optional flexible or mixed certification ranges).

Table 8: Workload Weighting Requirements for all File I/O Systems

Workload Test	Transaction Optimization	Streaming Optimization	Composite Optimization
DATABASE	50%	0%	0%
SW Build	0%	0%	100%
VDA	0%	100%	0%
VDI	50%	0%	0%

3.5.3 Testing Data Requirements for Scale-up Storage Products using only Physical Data: The following test data is required for each configuration submitted for certification as ENERGY STAR:

- i. The manufacturer must choose a workload type for testing from 1.1.2.
- ii. The manufacturer must choose a storage device representative of its highest predicted deployed volume for the chosen workload.
- iii. The manufacturer may determine to test either a Fixed Size Certification Range, a Flexible Size Certification Range, or a Mixed Certification Range.
- iv. For the chosen workload type, highest predicted deployed volume storage device, and certification range, physical data for all measurements listed in Table 5 or Table 6 shall be submitted for a manufacturer determined Single or Multiple Device Optimal Configuration point. Additionally:
 - a) If a fixed range, two additional points must be tested, one 40% smaller and one 15% larger in storage device count compared to the Optimal Configuration.
 - b) If a flexible range, two additional points must be tested. The points are manufacturer determined. One must be at least 40% smaller and the other at least 15% larger in storage device count compared to the Optimal Configuration.
 - c) If a mixed range, test the smaller (larger) fixed point at 40% smaller (15% larger) in storage device count, and test the larger (smaller) manufacturer determined flexible point.
- v. To include any additional storage devices (not chosen in 3.5.3.ii) for the selected workload, physical data for all measurements listed in Table 5 or Table 6 shall be submitted for all of the following system sizes for each additional storage device:
 - (a) A manufacturer determined Single or Multiple Device Optimal Configuration point. No additional smaller or larger points are necessary.
 - (b) Configurations using additional storage devices certified under 3.5.3.v will assume the certification range of the configuration certified under 3.5.3.iv.

- vi. To certify additional workload types, repeat the above starting at 3.5.3.i for a different workload.
- vii. The following rules apply to all testing above:
 - (a) Test points with storage device counts smaller and larger than the Optimal Configuration may be rounded down and up, respectively, to the nearest drawer boundary.
 - (b) Configurations consisting *exclusively* of SSD storage devices (and that are also not part of a Multiple Device Configuration certification) are not required to submit physical test point results. Note this exclusion does not apply to configurations consisting of mixed storage devices where one of the devices is an SSD or when an SSD storage device is representative of the highest predicted deployed volume by the manufacturer.
 - (c) Verification testing of COM features (Table 3) specified by the storage product shall be executed at least once using storage devices of the vendor's choice. Once verified there is no requirement to re-execute the COM verification testing procedure with different storage devices.
 - (d) If the storage product is not marketed with storage device configurability or scalability needed to achieve either the smaller or larger test points above, then these points are not required.
 - (e) As noted in 1.I.8, a product family may not be based solely on Capacity workload Optimized Configurations. Every storage device submitted for certification under Capacity Optimized Configurations must also include one or more Transaction workload Optimized Configuration(s) and/or Streaming workload Optimized Configuration(s) using the same storage device. A Capacity workload Optimized Configuration may only be submitted as an addition to one (or more) of the other optimizations.
 - (f) As noted in 1.J.3, if automated storage tiering is enabled during testing, then the multi-storage device groups necessary for tiering may be counted as single storage devices when determining testing and certification ranges and when calculating storage device allocations. The ratio of each single storage device within the multi-storage device group must remain as constant as possible across different test points.

3.5.4 Testing Data Requirements for Scale-up Storage Products using Physical and Modeled Data:
The following test data is required for each configuration submitted for certification as ENERGY STAR:

- i. The manufacturer must choose a workload type for testing from 1.I.2.
- ii. The manufacturer must choose a storage device representative of its highest predicted deployed volume for the chosen workload.
- iii. The manufacturer may determine to test either a Fixed Size Certification Range, a Flexible Size Certification Range, or a Mixed Certification Range.
- iv. For the chosen workload type, highest predicted deployed volume storage device, and certification range, physical data for all measurements listed in Table 5 or Table 6 shall be submitted for a manufacturer determined Single or Multiple Device Optimal Configuration point. Additionally:
 - a) If a fixed range, two additional points must be tested, one 40% smaller and one 15% larger in storage device count compared to the Optimal Configuration.
 - b) If a flexible range, two additional points must be tested. The points are manufacturer determined. One must be at least 40% smaller and the other at least 15% larger in storage device count compared to the Optimal Configuration.
 - c) If a mixed range, test the smaller (larger) fixed point at 40% smaller (15% larger) in storage device count, and test the larger (smaller) manufacturer determined flexible point.

- v. If manufacturer generated modeled data for all physical measurements submitted in Section 3.5.4.iv above are within $\pm 10\%$, modeled data shall be submitted for all of the following system sizes;
 - (a) Manufacturer determined Optimal Configuration points for all other storage devices certified for the respective workload type that are not defined in Section 3.5.4.ii above;
 - (b) At least 6 manufacturer chosen points smaller in storage device count compared to the Optimal Configuration, with two of those points being at least 10% smaller than the smallest physical point tested in 3.5.4.iv
 - (c) At least 6 manufacturer chosen points larger in storage device count compared to the Optimal Configuration, with two of those points being at least 10% larger than the largest physical point tested in 3.5.4.iv
- vi. To certify additional workload types, repeat the above starting at 3.5.4.i for a different workload.
- vii. The following rules apply to all testing above: See Section 3.5.3.vii

3.5.5 Testing Data Requirements for all Scale-out Storage Products: The following test data is required for each configuration submitted for certification as ENERGY STAR:

- i. All testing and data requirements of Sections 3.5.3 and 3.5.4 shall be followed.
- ii. When testing, the smallest marketed quantity of storage controllers / nodes shall be tested.
- iii. Additional systems with a larger quantity of storage controllers may be optionally submitted.

3.5.6 Data for display on the ENERGY STAR website shall be submitted for each ENERGY STAR certified storage product or storage product family.

- i. Whenever possible, Partners should also provide a hyperlink to a more detailed power calculator on their website that purchasers can use to understand power and performance data for specific configurations within the product family.

3.5.7 The following information will be displayed on the ENERGY STAR website:

- i. Product model name, model number, and SKU or other configuration identification number;
- ii. A list of important product characteristics, including;
 - (a) System configuration and tested I/O type;
 - (b) Storage controller details (e.g. model name and number);
 - (c) Software configuration and transfer protocols used in testing;
 - (d) Storage controller power supply information;
 - (e) Storage device drawer power supply information;
 - (f) Storage devices used per optimization points;
 - (g) Input power and environmental characteristics during testing;
 - (h) System power optimization capabilities;
 - (i) Inlet air temperature and power consumption reporting capabilities.

- iii. A list of certified system configurations, including maximum, minimum and optimal configurations of certified product families; and disclosure of the time period used for data averaging.
- iv. A list of power management and other power saving features available and enabled by default;
- v. Specified thermal measurements conducted during testing;
- vi. For product families, a list of certified storage products within the family; and
- vii. Energy Efficiency Performance data (performance/watt) for required active and idle state test reporting specified in Table 9 or Table 10 below:

Table 9: Active and Idle State Efficiency Block I/O Test Results Displayed

Workload Test	Transaction Optimization	Streaming Optimization	Capacity Optimization
Hot Band	Yes	No	No
Random Read	Yes	No	No
Random Write	Yes	No	No
Sequential Read	No	Yes	No
Sequential Write	No	Yes	No
Ready Idle	Yes	Yes	Yes

Table 10: Active and Idle State Efficiency File I/O Test Results Displayed

Workload Test	Transaction Optimization	Streaming Optimization	Composite Optimization
DATABASE	Yes	No	No
SW Build	No	No	Yes
VDA	No	Yes	No
VDI	Yes	No	No
Ready Idle	Yes	Yes	Yes

3.5.8 The following test information shall be submitted as part of the certification process, but will not be displayed on the ENERGY STAR website:

- i. Discrete power and performance data for all tested configurations;
- ii. Response time measurement data for all tested configurations.

3.6 Storage Product Family Variation Allowances

- 3.6.1 Storage Product Performance Improvement Cap: Any changes to a storage product after testing (replacement storage devices, storage controller firmware, etc.) shall not lead to a change of greater than 20% of the overall system performance/watt as defined by Table 7 or Table 8 (with the exception of the Ready Idle metric). Any combination of changes that cause the storage product's performance/watt value to cross this threshold will require testing of a new Optimal Configuration for inclusion in the product family definition.
- 3.6.2 Replacement Storage Devices in As-Shipped Configurations: In order to reduce testing burden, manufacturers may replace storage devices that were used during certification with storage devices that have similar energy efficiency (performance/watt) compared to the device being replaced after certification. Storage product manufacturers must submit specification sheets for the original and replacement devices to validate the following:
- i. No change in the following area:
 - (a) Interface type
 - ii. No reduction in the following features:
 - (a) Data capabilities (e.g. Self-encryption);
 - (b) Power management-related features and capabilities (e.g. Power Down Modes).
 - iii. Reported values within $\pm 10\%$ for the following categories:
 - (a) Reported average power consumption in like modes of operation;
 - (b) Rotational speed;
 - (i) Not applicable to Non-Rotational storage devices;
 - (ii) If the storage device is capable of multiple spindle speeds, the discreet speeds must be within 5%, and the criteria for entering each of those speeds must be the same.

3.7 Standard Performance Data Measurement and Output Requirements

- 3.7.1 Data Elements: Online 3 and Online 4 storage products shall be capable of measuring and reporting the following data elements at the storage product level:
- i. Input Power, in watts. Input power measurements must be reported with accuracy within $\pm 5\%$ of the actual value for measurements greater than 200 W, through the full range of operation. For measurements less than or equal to 200 W, the accuracy must be less than or equal to 10 W multiplied by the number of installed PSUs; and
 - ii. Inlet Air Temperature (optional), in degrees Celsius, with accuracy of $\pm 2^{\circ}\text{C}$.
- 3.7.2 Reporting Implementation:
- i. Data shall be made available in a published or user-accessible format that is readable by third-party, non-proprietary management systems;
 - ii. Data shall be made available to end users and third-party management systems over a standard network connection;
 - iii. Data shall be made available via embedded components or add-in devices that are packaged with the storage product (e.g., a service processor, embedded power or thermal meter or other out-of-band technology, iPDU, or pre-installed OS);

- iv. When an open and universally available data collection and reporting standard becomes available, manufacturers should incorporate the universal standard into their products.

3.7.3 Sampling Requirements:

- i. *Input power:* Input power measurements must be sampled internally to the storage product at a rate of greater than or equal to 1 measurement per contiguous 10 second period.
- ii. *Inlet air temperature (optional):* Inlet air temperature measurements must be sampled internally to the storage product at a rate of greater than or equal to 1 measurement every 10 seconds.
- iii. *Timestamping:* Systems that implement time stamping of environmental data shall sample internally to the storage product data at a rate of greater than or equal to 1 measurement every 30 seconds.
- iv. *Management Software:* All sampled measurements shall be made available to external management software either via an on-demand pull method, or via a coordinated push method. In either case the system’s management software is responsible for establishing the data delivery time scale while the storage product is responsible to assuring data delivered meets the above sampling and currency requirements.

3.7.4 Documentation Requirements: The following information shall be included in the data submission:

- i. Guaranteed accuracy levels for power and optional temperature measurements, and
- ii. The time period used for data averaging (if present).

3.7.5 Use of iPDUs: Section 3.7 may be satisfied using iPDUs. In order to satisfy the Data Elements requirement, an iPDU must:

- i. Meet all requirements for accuracy, sampling, and data reporting;
- ii. Be made available for sale and delivery with certified ENERGY STAR storage products by appearing on the manufacturer’s website and/or in marketing material where information on the storage product is displayed.

4 TESTING

4.1 Test Methods

- 4.1.1 Test methods identified in Table 11 shall be used for purposes of evaluating active and idle state storage product energy efficiency.

Table 11: Test Methods for ENERGY STAR Certification

Product Type	Test Method
All	ENERGY STAR Test Method for Data Center Storage Equipment, Rev. May 2018.

4.2 Number of Units Required for Testing

- 4.2.1 Representative Models shall be selected for testing per the following requirements:
- i. For certification of an individual product model, a product configuration equivalent to that which is intended to be marketed and labeled as ENERGY STAR is considered the Representative Model;
 - ii. For certification of a product family one or more Optimization Configurations shall be tested and submitted. Within the range defined by the Maximum Certified Configuration, Minimum Certified Configuration, and Optimal Configuration, manufacturers continue to be held accountable for any efficiency claims made about their products, including those not tested or for which data was not reported;

5 EFFECTIVE DATE

- 5.1.1 Effective Date: The Version 1.0 ENERGY STAR Data Center Storage specification shall take effect on **December 2, 2013**. To certify for ENERGY STAR, a product model shall meet the ENERGY STAR specification in effect on its date of manufacture. The date of manufacture is specific to each unit and is the date on which a unit is considered to be completely assembled.
- 5.1.2 Future Specification Revisions: EPA reserves the right to change this specification should technological and/or market changes affect its usefulness to consumers, industry, or the environment. In keeping with current policy, revisions to the specification are arrived at through stakeholder discussions. In the event of a specification revision, please note that the ENERGY STAR certification is not automatically granted for the life of a product model.

6 CONSIDERATIONS FOR FUTURE REVISIONS

- 6.1 Active and Idle State Efficiency Criteria:** EPA intends to set active and idle state efficiency criteria in Version 2.0 for all storage products in which it has enough data to adequately differentiate products.
- 6.2 Right Sizing of Power Supplies:** EPA will investigate opportunities for encouraging right-sizing of power supplies in Version 2.0.
- 6.3 Redundant Power Supply Standby:** EPA will investigate requiring redundant power supplies to switch to standby when not in use in Version 2.0. EPA is aware that this circuitry is already offered by some manufacturers in data center products.
- 6.4 Expansion of Scope:** EPA will investigate expanding the scope of Version 2.0 to potentially cover larger Online products, as well as Near-Online, Removable Media Libraries, and Virtual Media Libraries. EPA may also explore requirements for SAN equipment if it not covered in the Version 1.0 Large Network Equipment Program Requirements currently under development.
- 6.5 Improved Input Power Calculation::** EPA will investigate requiring improvements to the Input Power calculations, such as rolling average capability in Version 2.0.
- 6.6 Inlet Air Temperature Sensing:** EPA will investigate making the current option to provide air inlet temperature measurements in Section 3.7 a requirement in Version 2.0.



ENERGY STAR® Program Requirements Product Specification for Data Center Storage

Final Test Method Rev. May 2018

1 OVERVIEW

The following test method shall be used for determining compliance with requirements in the ENERGY STAR Product Specification for Data Center Storage.

2 APPLICABILITY

The following test method is applicable to all products eligible for certification under the ENERGY STAR Product Specification for Data Center Storage.

3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR Eligibility Criteria for Data Center Storage.

4 TEST SETUP

- A) Input Power: Input power shall be as specified in Table 1 and Table 2. The frequency for input power shall be as specified in Table 3.
- B) Ambient Temperature: Ambient temperature shall be no less than 18 °C and no greater than 28 °C over the duration of the test.
- C) Relative Humidity: Relative humidity shall be within 15% and 80%.

16 **Table 1: Input Power Requirements for Products with Nameplate Rated Power Less Than or Equal**
 17 **to 1500 W**

Product Type	Supply Voltage	Voltage Tolerance	Maximum Total Harmonic Distortion
Storage Products with Ac-Dc Single-Output PSUs	230 volts (V) ac or 115 V ac	+/- 1.0 %	2.0 %
Storage Products with Ac-Dc Multi-Output PSUs	230V ac or 115V ac		
Optional Testing Conditions For Ac-Dc Japanese Market	100V ac		
Three-phase Storage Products (North American Market)	208V ac		
Three-phase Storage Products (European Market)	400V ac		

18 **Table 2: Input Power Requirements for Products with Nameplate Rated Power Greater Than**
 19 **1500 W**

Product Type	Supply Voltage	Voltage Tolerance	Maximum Total Harmonic Distortion
Storage Products with Ac-Dc Single-Output PSUs	230 volts (V) ac or 115 V ac	+/- 5.0 %	5.0 %
Storage Products with Ac-Dc Multi-Output PSUs	230V ac or 115V ac		
Optional Testing Conditions For Ac-Dc Japanese Market	100V ac		
Three-phase Storage Products (North American Market)	208V ac		
Three-phase Storage Products (European Market)	400V ac		

20

Table 3: Input Frequency Requirements for All Products

Supply Voltage	Frequency	Frequency Tolerance
100 V ac	50 or 60 Hz	±1.0%
115 V ac	60 Hz	
230 V ac	50 Hz or 60 Hz	
Three-phase	50 Hz or 60 Hz	

21

22
23
24

D) **Power Meter:** Power Meter(s) shall report true Root Mean Square (RMS) power and at least two of the following measurement units: voltage, current and power factor. Power Meter(s) shall possess the following attributes:

25
26
27

1) **Calibration:** The meter shall be calibrated within the past one year of the test date, by a standard traceable to National Institute of Science and Technology (USA) or a counterpart national metrology institute in other countries.

28
29
30
31

2) **Crest Factor:** An available current crest factor of 3 or more at its rated range value. For analyzers that do not specify the current crest factor, the analyzer must be capable of measuring an amperage spike of at least 3 times the maximum amperage measured during any 1 second sample.

32

3) **Minimum Frequency Response:** 3.0 kHz

33

4) **Minimum Resolution:**

34

i. 0.01 W for measurement values less than 10 W;

35

ii. 0.1 W for measurement values from 10 W to 100 W; and

36

iii. 1.0 W for measurement values greater than 100 W.

37
38
39
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5) **Logging:** The reading rate supported by the meter shall be at least 1 set of measurements per second, where set is defined as watts. The data averaging interval of the analyzer shall equal the reading interval. Data averaging interval is defined as the time period over which all samples captured by the high-speed sampling electronics of the analyzer are averaged to provide the measurement set.

42
43

6) **Measurement Accuracy:** Measurement uncertainty as introduced by the instrument that measures the input power to the product under test, including any external shunts.

44
45

i. Power measurements with a value greater than or equal to 0.5 W shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level.

46
47

ii. Power measurements with a value less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level.

48

E) **Temperature Sensor:** The temperature sensor shall possess the following attributes:

49

1) **Logging:** The sensor shall have a minimum reading rate of 4 samples per minute.

- 50 2) Measurement Accuracy: Temperature must be measured no more than 50 mm in front of
51 (upwind of) the main airflow inlet of the UUT and reported by the sensor with an overall
52 accuracy of ± 0.5 °C or better.

53 **5 TEST CONDUCT**

54 **5.1 Guidance for Implementation of SNIA Emerald™ Power Efficiency Measurement** 55 **Specification Version 3.0.2**

- 56 A) Online 2 Data Center Storage products must include a RAID capable controller during all testing.
57
- 58 B) Storage products shipped with COMs must disable all COMs that are capable of being disabled
59 during the following tests:
- 60 1) SUT Pre-fill Test (7.3.2)
 - 61 2) SUT Conditioning Test (7.3.3)
 - 62 3) Block Access Active State Test (7.3.4, if applicable)
 - 63 4) File Access Active Test (7.4, if applicable)
 - 64 5) Ready State Idle Test (7.5)
 - 65 6) Following the completion of the Ready Idle State Test, COMs shipped with the storage
66 product shall be enabled and COM Validation Testing (7.6) shall be performed for all COMs
67 present in the product.
- 68
- 69 C) Products that are to be certified using Block I/O capability shall be tested using the Block I/O
70 Active State Test. Block I/O products with File I/O capability shall be tested under the following
71 additional requirements:
- 72 1) All usable Storage Devices shall be allocated to Block I/O for all testing with the exception of:
73 i. Storage Devices needed to enable a minimal File I/O capability in the system;
74 ii. Limitations imposed by the system for maximum allowable Block I/O capacity.
 - 75 2) File I/O functionality shall be enabled during all testing.
 - 76 3) No external File I/O storage requests shall be presented to a system during testing. (File I/O
77 functionality shall be in a Ready-Idle state).
- 78 D) Products that are to be certified using File I/O capability shall be tested using the File I/O Active
79 State Test.

80 **6 TEST PROCEDURES FOR ALL PRODUCTS**

81 **6.1 SUT Pre-fill Test**

82 The SUT pre-fill test shall be performed according to the SNIA Emerald™ Power Efficiency Measurement
83 Specification Version 3.0.2: Section 7.3.2: *Pre-fill Test*.

84 **6.2 SUT Conditioning Test**

85 The SUT conditioning shall be performed according to the SNIA Emerald™ Power Efficiency
86 Measurement Specification Version 3.0.2: *Section 7.3.3: Conditioning Test*.

87 **6.3 Block I/O Active State Test**

88 The Block I/O active state performance shall be measured according to the SNIA Emerald™ Power
89 Efficiency Measurement Specification Version 3.0.2: *Section 7.3.4: Block Access Online Active Test*; with
90 the additional guidance in Section 5 of this document.

91 **6.4 File I/O Active State Test**

92 The File I/O active state performance shall be measured according to the SNIA Emerald™ Power
93 Efficiency Measurement Specification Version 3.0.2: *Section 7.4: File Access Online and Near-Online*
94 *Active Test*; with the additional guidance in Section 5 of this document.

95 **6.5 Ready Idle State Test**

96 The Ready Idle state performance shall be measured according to the SNIA Emerald™ Power Efficiency
97 Measurement Specification Version 3.0.2: *Section 7.5: Block and File Access Ready Idle Test*; with the
98 additional guidance in Section 5 of this document.

99 **6.6 COM Validation Test**

100 The validation of COM functionality shall be recorded according to the SNIA Emerald™ Power Efficiency
101 Measurement Specification Version 3.0.2: *Section 7.6: Block and File Access Capacity Optimization Test*,
102 with the additional guidance in Section 5 of this document.

- 103
- 104 A) Verification testing of COM features specified by the storage product shall be executed at least
105 once using storage devices of the vender's choice. Once verified there is no requirement to re-
106 execute the verification testing procedure with different storage devices.

107