ENERGY STAR® Program Requirements
Product Specification for
Data Center Storage

Eligibility Criteria
Version 1.0

Following is the Final Draft ENERGY STAR Version 1.0 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 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.

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 Taxonomy[1]: 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 MaxTTFD ≤ 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 MaxTTFD ≤ 80 milliseconds, while other data may be accessible 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 MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. Virtual Medial 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.

5) Adjunct Storage Products: Products which closely support storage devices by adding in real time value or additional control capabilities not present in the storage device(s) itself. Examples include SAN based virtualization controllers, NAS gateways, or other storage services. A key feature of these products is that no end user data is primarily stored on Adjunct Storage products, though data may be held in cache or other working buffers.

6) Interconnect Element: Devices which provide for interconnection functionality within a storage area network. Examples include SAN Switches, etc.

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[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 2.0.2. Further detail may be found at www.snia.org/green.

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:

   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) <u>Formatted (Usable) Capacity</u>: 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) <u>Free Space</u>: The amount of unused, formatted capacity as reported by the storage product.

5) <u>Raw (Addressable) Capacity</u>: 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. <u>Operational States</u>:

1) <u>Active State</u>: The state in which a storage product is processing external I/O requests.

2) <u>Idle State</u>: 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) <u>Ready Idle</u>: 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) <u>Deep Idle</u>: 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. <u>Power Supply Unit (PSU)</u>: 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) <u>Ac-dc Power Supply</u>: A PSU that converts line-voltage ac input power into one or more dc power outputs.

2) <u>Dc-dc Power Supply</u>: 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) <u>Single-output Power Supply</u>: 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) <u>Multi-output Power Supply</u>: 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) <u>Redundant Power Supplies</u>: Two or more PSUs that are configured to maintain uninterrupted output load in the event of failure of one PSU.

I. <u>Product Family</u>: A group of models/configurations that share a set of common attributes that are variations on a basic design.

1) <u>Common Product Family Attributes</u>: 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 qualified configuration.

2) <u>Optimal Configuration</u>: A product configuration that lies between the minimum and maximum qualified 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) Capacity: A workload optimized for maximum storage as measured by GB (Raw Capacity) per watt.

3) <u>Fixed Qualification Range</u>: 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 qualification 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 Qualified Configuration are not required to perform that respective test. In such a case, the qualification range is limited to the region between the Optimal Configuration and whichever one of the Fixed Configurations is tested.

   i) <u>Fixed Maximum Qualified Configuration</u>: 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) <u>Fixed Minimum Qualified Configuration</u>: 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) <u>Flexible Qualification Range</u>: Defined by testing product configurations at the Optimal Configuration and at two manufacturer chosen points, one smaller than the Fixed Minimum Qualified Configuration and one larger than the Fixed Maximum Qualified Configuration. This qualified range is extended out to the smaller and larger points, provided they are within 15% of the Optimal Configuration's performance/watt.

    i) <u>Flexible Maximum Qualified Configuration</u>: 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 Qualified 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.

> (b) Modeled data may not be used for Expanded Maximum Qualified Configuration submissions.

> (c) The resulting storage device count may be rounded up to the nearest drawer boundary.

    ii) <u>Flexible Minimum Qualified Configuration</u>: 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 Qualified Storage Configuration and which is within 15% of the Optimal Configuration performance/watt, validated though 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.

> (b) Modeled data may not be used for Expanded Minimum Qualified Configuration submissions.

> (c) The resulting storage device count may be rounded down to the nearest drawer boundary.

5) <u>Mixed Qualification Range</u>: Defined by testing one of the fixed points in 1.I.3 and one of the flexible points in 1.I.4, provided they are on opposite sides of the Optimal Configuration. On the side with the Flexible Configuration, the qualification range is extended from the Optimal Configuration out to the chosen flexible point. If the Fixed Minimum Qualified Configuration was chosen, the range is kept to 20% smaller than the Optimal Configuration. If the Fixed Maximum Qualified Configuration was chosen, the range is kept to 5% larger. A fixed testing point described in 1.I.3 can be used in place of a flexible testing point described in 1.I.4 to extend a range of qualification 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) <u>Systems Composed of Combinations of Single Device Optimal Configurations</u>: A product family which has demonstrated more than one Single Device Optimal Configuration may be sold as ENERGY STAR qualified 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 qualified 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 Qualified 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) <u>Systems Composed of Multiple Device Types in an Optimal Configuration</u>: An Optimal Configuration that contains more than one type of addressable storage device may be qualified as part of an ENERGY STAR product family provided **all** of the following apply:

     i)   System features used during qualification 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 qualified Multiple Device Configuration, they must be included in all qualification testing and modeling.

     iii) The ratio of the different storage devices in the qualified Multiple Device Configuration must be maintained as closely as possible during testing of the required Minimum and Maximum Qualified Configurations, as well as in all configurations sold as ENERGY STAR qualified.

     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 qualified.

     v)   End-user selectable automated storage tiering functionality must be included with all Multiple Device Configurations sold as ENERGY STAR qualified,

     vi) All other conditions in Section 1.I.6 above for both Single Device Optimized Configurations and Multiple Device Optimized Configurations must be met.

8) <u>Capacity Optimization Family Restriction</u>: 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 qualification 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.

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 qualification 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)   <u>Non-disruptive Serviceability</u>: 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) <u>Physical Data</u>: Data generated by testing a storage product using the ENERGY STAR Test Method for Data Center Storage.

9) <u>Modeled Data</u>: 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) <u>Read/Write</u>:

   i)   <u>Random Read</u>: 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) <u>Random Write</u>: 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) <u>Sequential Read</u>: An I/O load consisting of consecutively issued read requests to adjacently addressed data.

   iv) <u>Sequential Write</u>: An I/O load consisting of consecutively issued write requests to adjacently addressed data.

11) <u>Response Time</u>: The time required for the UUT to complete an I/O request.

12) <u>Unit Under Test (UUT):</u> The storage product being tested.

2   QUALIFYING 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 categories[2] with the following additional criteria;

     a) contain a controller with advanced data recovery capability

     b) support Block I/O storage functions either entirely or as an additional capability; and

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

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[2] As defined in the "SNIA Emerald™ Power Efficiency Measurement Specification", Version 2.0.2.

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.   Network Attached Storage Products that cannot perform block I/O;

    vi.   Storage Products capable of object based storage;

    vii.   Storage devices in the following categories of the taxonomy: Near-online, Removable Media Library, Virtual Media Library, Adjunct Storage Products, and Interconnect Elements;

3   QUALIFICATION 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. <u>Power Factor</u>: 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 <u>Power Modeling Presale tool</u>: For systems that qualify using modeled data, EPA expects that a power modeling tool characterizing the storage product will be made available to manufacturer qualified 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 qualified using modeled data are expected to make performance/watt data available to manufacturer qualified purchasers of the product.

3.4 Energy Efficiency Feature Requirements

3.4.1 To qualify 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   <u>Active and Idle State Efficiency Disclosure</u>: To qualify for ENERGY STAR, all active and idle state test results based on workload tests listed in Table 5 shall be reported:

Table 5: Required Workload Tests for all Configurations

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

3.5.2   <u>Workload Weighting Requirements</u>: The weighted percentages shown in Table 6 shall be used to calculate the appropriate Optimal Configuration point for a given storage product.

Table 6: Workload Weighting Requirements

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%

Note: 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 qualification. The same weighting of the sums should also be used for subsequent qualification measurements (e.g. determining optional flexible or mixed qualification ranges).

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[3] SNIA defined workload tests in Table 5 and through the rest of this document can be found in the "SNIA Emerald™ Power Efficiency Measurement Specification" Version 2.0.2. Further detail may be found at www.snia.org/green.

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 qualification 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 Qualification Range, a Flexible Size Qualification Range, or a Mixed Qualification Range.

iv. For the chosen workload type, highest predicted deployed volume storage device, and qualification range, physical data for all 6 measurements listed in Table 5 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 6 measurements listed in Table 5 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 qualified under 3.5.3.v will assume the qualification range of the configuration qualified under 3.5.3.iv.

vi. To qualify 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 qualification) 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 vender'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 qualification 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 qualification 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 <u>Testing Data Requirements for Scale-up Storage Products using Physical and Modeled Data</u>: The following test data is required for each configuration submitted for qualification 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 Qualification Range, a Flexible Size Qualification Range, or a Mixed Qualification Range.

iv. For the chosen workload type, highest predicted deployed volume storage device, and qualification range, physical data for all 6 measurements listed in Table 5 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 ±5%, modeled data shall be submitted for all of the following system sizes;
   (a) Manufacturer determined Optimal Configuration points for all other storage devices qualified 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 small 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 large physical point tested in 3.5.4.iv

vi. To qualify 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 <u>Testing Data Requirements for all Scale-out Storage Products</u>: The following test data is required for each configuration submitted for qualification 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 qualified 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;

        (b)　Storage controller details (e.g. model name and number);

        (c)　Software configuration;

        (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 qualified system configurations, including maximum, minimum and optimal configurations of qualified 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 qualified storage products within the family; and

    vii.　Energy Efficiency Performance data (performance/watt) for required active and idle state test reporting specified in Table 7 below:

Table 7: Active and Idle State Efficiency Test Results Displayed on the ENERGY STAR Website

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

3.5.8 The following test information shall be submitted as part of the qualification 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 <u>Storage Product Performance Improvement Cap</u>: 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 6 (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 <u>Replacement Storage Devices in As-Shipped Configurations</u>: In order to reduce testing burden, manufacturers may replace storage devices that were used during qualification with storage devices that have similar energy efficiency (performance/watt) compared to the device being replaced after qualification. Storage product manufacturers must submit specification sheets for the original and replacement devices to validate the following:

i. No change in the following categories:

(a) Interface type, quantity, or transfer speed

(i) A Replacement Storage Device *may* contain new transfer speeds providing the new speeds are not able to be utilized in the storage system due to architectural / design limitations (e.g., new transfer speeds not supported by the host bus adapter).

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 ± 10% for **all** of the following categories:

(a) Average seek time;

(b) Average latency;

(c) Reported average power consumption in like modes of operation;

(d) 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.

iv. Reported values within -5%/+15% for the following category:

(e) Sustained transfer rate.

v. Equal or greater reported values for the following categories:

(c) Capacity;

(b) Cache size in the storage device.

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 ±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 ± 2°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 8 shall be used for purposes of evaluating active and idle state storage product energy efficiency.

Table 8: Test Methods for ENERGY STAR Certification

Product Type	Test Method
All	ENERGY STAR Test Method for Data Center Storage Equipment, Rev. Aug- 2013.

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 Qualified Configuration, Minimum Qualified 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   <u>Effective Date</u>: 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   <u>Future Specification Revisions</u>: 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, Virtual Media Libraries, and NAS only products. 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.