ENERGY STAR® Program Requirements
Product Specification for
Data Center Storage

Eligibility Criteria
Draft 2, Version 2.0

Following is the Draft 2, Version 2.0 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 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) Disk Set 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 Disk Set Online storage must be accessible MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. Disk set Online storage is typically comprised of one or more HDDs and a storage controller, and provides primary data storage to supplement a Computer Server's internal memory.

2) Disk Set 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. Disk Set 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) Removable and Virtual Media Library (RVML) Set 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) RVML Set 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

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

5) Non-volatile Solid State (NVSS) Set Disk Access Storage: Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short response time. All data stored in NVSS Set Disk Access Online storage must be accessible MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. NVSS Set Disk Access Online storage is typically comprised of one or more SSDs and a storage controller, and provides primary data storage to supplement a Computer Server's internal memory.

6) NVSS Set Memory Access Storage: Storage products that are intended to service a mixture of Random and Sequential I/O requests with a short response time. All data stored in NVSS Set Memory Access Online storage must be accessible MaxTTFD ≤ 80 ms, unless the storage product is in a Deep Idle state. NVSS Set Memory Access Online storage is typically comprised of one or more banks of Solid State Storage devices and a storage controller, and provides primary data storage to supplement a Computer Server's internal memory.

Note: EPA is proposing to adopt the revised SNIA storage taxonomy definitions recently finalized through the SNIA Emerald Version 4.0 specification development process. Maintaining alignment with these definitions ensures industry and purchasers continue to define these products in the same way based on clear technical characteristics.

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) 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.

4) 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 which is representative of a product's maximum peak energy efficiency performance (performance/watt) for a given workload type. This configuration represents all products certified within the family under the associated workload type specified. This configuration is provided by the manufacturer and may be optimized for the following workload types:

i) Transaction (Block I/O products only): A workload optimized for random I/O usage measured in I/O per second per watt;

ii) Streaming (Block I/O products only): 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.

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) 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.

4) 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.

5) 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.

6) 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.

7) 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.

8) 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.

9) Response Time: The time required for the UUT to complete an I/O request.

10) 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 Disk Set Online categories 2, 3, or 4 and NVSS Set Disk Access categories Online 2, 4 or 4 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

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: Disk Set Near-Online, RVML Set Removable Media Library, RNML Set Virtual Media Library and NVSS Set Memory Access.

Note: EPA has updated Section 2.1.1.iii and Section 2.2.2.vi to harmonize with the updated SNIA taxonomy terminology. The effective scope of Draft 2 remains the same as proposed in Draft 1.

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. 6.7.1* (available at https://www.plugloadsolutions.com/docs/collatrl/print/Generalized_Internal_Power_Supply_Efficiency_Test_Protocol_R6.7.1.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 **Error! Reference source not found.**.

Table 1: Efficiency Requirements for PSUs

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

Note: Stakeholders commented that the relevant 80Plus equivalent level for 230V redundant power supplies should apply to each single and multi-output power supplies. In Draft 1, the multi-output requirement references the 80Plus Gold 230V non-redundant equivalent level.

EPA has confirmed the frequency of multi-output IPSs with redundancy features in the storage market and therefore supports maintaining consistency between the two types of IPS output. As a result, the multi-output requirements in Table 1 have been revised to align with the 80Plus equivalent 230V redundant requirements.

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

Note: EPA has engaged in further discussion with stakeholders about the relevancy of power modeling tools that generate energy use estimates based on real world usage rather than maximum power draw. The group determined that it is not appropriate to require real world energy modeling at this time , as modeling is still being refined and most do not have full confidence in the results yet. As such, EPA is proposing to remove the power modeling requirements in Draft 2. However, the Agency would like to continue engaging with stakeholders regarding other potential uses for power modeling tools at the datacenter level and how the ENERGY STAR program and manufacturers can help educate customers on how to use these tools to save energy.

3.4 Energy Efficiency Active State Requirements for Block I/O Systems

3.4.1 To certify for ENERGY STAR, each Optimal Configuration point submitted for a block I/O storage product or storage product family must meet the following applicable active state requirements in Table 3 for each workload type for which it is certified.

Table 3: Active State Requirements for Block I/O Storage Products

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

3.4.2 An Optimal Configuration point submitted for a streaming workload must meet either the sequential read or sequential write requirement in Table 3 above, but is not required to meet that value for both workload tests. Both test values will be reported and displayed publicly regardless of whether they meet the criteria in Table 3.

Note: EPA received stakeholder feedback on both the proposed transaction and streaming requirements in Draft 1.

A first concern was that the Draft 1 transaction requirements did not provide a path to certification for transaction optimized products that use a mixture of HDD and SSD technology unless there was a 7.2k HDD variation of the product that met the criteria. This is problematic as for transaction workloads, combined products with 10k and 15k HDDs and SDDs are an attractive choice for efficiency and cost.

EPA reviewed the data set and agrees with the concern expressed by stakeholders. As a result, EPA has proposed in Section 3.5.3.ii below that configurations may be tested with a mixture of HDD and SDD storage devices, often referred to as hybrid storage products. By allowing hybrid storage products to certify as ENERGY STAR, EPA's analysis shows that the data now supports a more challenging transaction requirement of 28 IOPS/watt which still allows a small portion of lower cost 10k HDD only transaction products to continue to earn the ENERGY STAR under Version 2.0 but the majority of certified products will be more efficiently designed hybrid SSD/HDD and all SSD based products.. This aligns with EPA's desire to highlight for purchasers higher efficiency SSDs while allowing the continued use of lower cost HDDs in configurations that are still relatively efficient for transaction workloads, typically through a hybrid approach.

A second concern was that Draft 1 streaming requirements do not allow 7.2k HDD based products to meet the requirements because 10k and 15k HDD data in the data set artificially raised the Draft 1 level

EPA has reviewed the data and proposed revised streaming requirements that specifically target the 7.2k HDD product offerings. EPA acknowledges that the 10k and 15k HDD data in the data set appears to have been submitted as superfluous data that was part of transaction optimized products, and that these data points do not represent real world steaming optimized products. EPA anticipates that the revised levels will allow roughly 31% of 7.2k HDD based products to meet the requirements.

3.5 Energy Efficiency Feature Requirements

3.5.1 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.

3.5.2 A storage product shall make available to the end user configurable / selectable features listed in Table 4 in quantities greater than or equal to those listed in Table 5.

Table 4: 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 5: COM Requirements for Disk Set and NVSS Disk Set Access Online 2, 3 and 4 Systems

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

Note: EPA has revised the title of Table 5 to cover both Disk Set and NVSS Disk Set Access storage products.

3.6 Information Reporting Requirements

3.6.1 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 6 or Table 7 shall be reported:

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

Workload Test
Hot Band
Random Read
Random Write
Sequential Read
Sequential Write
Ready Idle[2]

Table 7: Required Workload Tests for all File I/O Configurations

Workload Test
DATABASE
SW Build
VDA
VDI
Ready Idle[3]

3.6.2 Workload Weighting Requirements: The weighted percentages shown in Table 8 or Table 9 shall be used to calculate the appropriate Optimal Configuration point for a given storage product.

Table 8: 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 7) 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).

[2] SNIA defined workload tests in Table 6, Table 7, and through the rest of this document can be found in the "SNIA Emerald™ Power Efficiency Measurement Specification" Version 4.0. Further detail may be found at www.snia.org/green.

Table 9: 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%

3.6.3 Testing Data Requirements for all Scale-up Storage Products:: 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 single type of or combination of hard disk storage devices and solid state storage devices which result in the highest work/watt for that workload type. The amount of solid state storage devices in the tested configuration in a hybrid disk/solid state configuration cannot exceed 30% of the addressable storage being represented by solid state unless the product is testing with only solid state devices in which all devices in the configuration shall be solid state devices.

iii. For the chosen workload type, physical data for all measurements listed in Table 6 or Table 7 shall be submitted for a manufacturer determined Optimal Configuration point Additionally:

iv. To certify additional workload types, repeat the above starting at 3.5.3.i for a different workload.

v. The following rules apply to all testing above:

(a) Verification testing of COM features (Table 4) 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.

Note: EPA is proposing the following changes to the Test Data Requirement section above:

Specified in Section 3.5.3.ii that optimal configurations may contain a mixture of hard disk storage devices only, solid state storage devices only or a combination of hard disk storage and solid state storage devices where the maximum percentage of addressable space provided by solid state devices cannot exceed 30% of the product's total addressable space. This allows manufacturers to test hybrid HDD/SSD products which are efficient and prevalent on the market now while ensuring that the SSD portion of the product does not dominate the test results of the optimal configuration. In recent discussions with manufacturers, a 30% cap on SSD capacity in hybrid systems was agreed to be a reasonable proxy for commonly sold hybrid HDD/SSD configurations in the market today. Setting this cap will also enable EPA and stakeholders to create a dataset of comparable products that will support future evaluation of efficiency too. EPA welcomes stakeholder feedback on this approach as well as any supporting data that shows that a percentage different than 30% is more appropriate as a cap for the amount of SSD capacity permitted in a hybrid HDD/SSD optimal test point configuration.

In addition, EPA removed Section 3.5.3.v.b) as it pertained to products optimized to the capacity configuration which was removed in Draft 1

3.6.4 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 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.

3.6.5 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.

3.6.6 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 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 10 or Table 11 below:

Table 10: 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 11: 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

3.6.7 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;

3.7 Standard Performance Data Measurement and Output Requirements

3.7.1 Data Elements: Disk Set and NVSS Disk Set Access 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, 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, 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.

v. Inlet air temperature data shall be reported for the controller chassis only.

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*: 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 temperature measurements, and

ii. The time period used for data averaging (if present).

Note: EPA has proposed the following three changes in Section 3.8:

- Updated the Online 3 and Online 4 references to include both Disk Set and NVSS Disk Set Access storage product types, aligning with the new taxonomy proposed above.

- Removed any remaining references to "optional" in criteria relating to inlet air temperature reporting.

- Clarified that reporting inlet air temperature at the controller chassis location(s) only.

4 TESTING

4.1 Test Methods

4.1.1 Test methods identified in Table 12 shall be used for purposes of evaluating active and idle state storage product energy efficiency.

Table 12: Test Methods for ENERGY STAR Certification

Product Type	Test Method
All	ENERGY STAR Test Method for Data Center Storage Equipment, Rev. April 2019.

Note: EPA anticipates the full adoption of SNIA's new Emerald V4 test and measurement specification within an updated draft of the ENERGY STAR Test Method for Data Center Storage to be released with the Final Draft of this specification.

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 family covered by one or more Optimal Configurations, 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 2.0 ENERGY STAR Data Center Storage specification shall take

effect on **TBD**. 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.

Note: EPA anticipates completing this specification development effort in the spring of 2020.

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

TBD