Education

GREEN STORAGE PRODUCTS: Efficiency with ENERGY STAR & Beyond

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Abstract

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- **GREEN STORAGE PRODUCTS: Efficiency with ENERGY STAR & Beyond**
  - This tutorial will cover storage-specific topics related to energy-efficiency and outline the current state of the industry. We will discuss a range of technologies that are currently considered "green storage" and the components of modern storage systems that impact energy consumption. We will discuss potential metrics for measuring, managing and designing for power in storage systems. We will also outline ongoing efforts by the EPA ENERGY STAR® program and in the SNIA Green Storage Technical Work Group (TWG) to standardize metrics for measuring storage systems.

Tutorial Overview

- Storage-specific topics related to energy consumption and efficiency
  - current state of the industry
- Comparing the components of "green storage"
  - metrics for measuring, managing & designing for power
- Ongoing efforts in the SNIA
  - SNIA Green Storage Power Measurement Specification
  - Green Storage Technical Work Group (TWG)
  - collaboration with EPA on ENERGY STAR for Storage
  - partnerships with The Green Grid, the DMTF and others

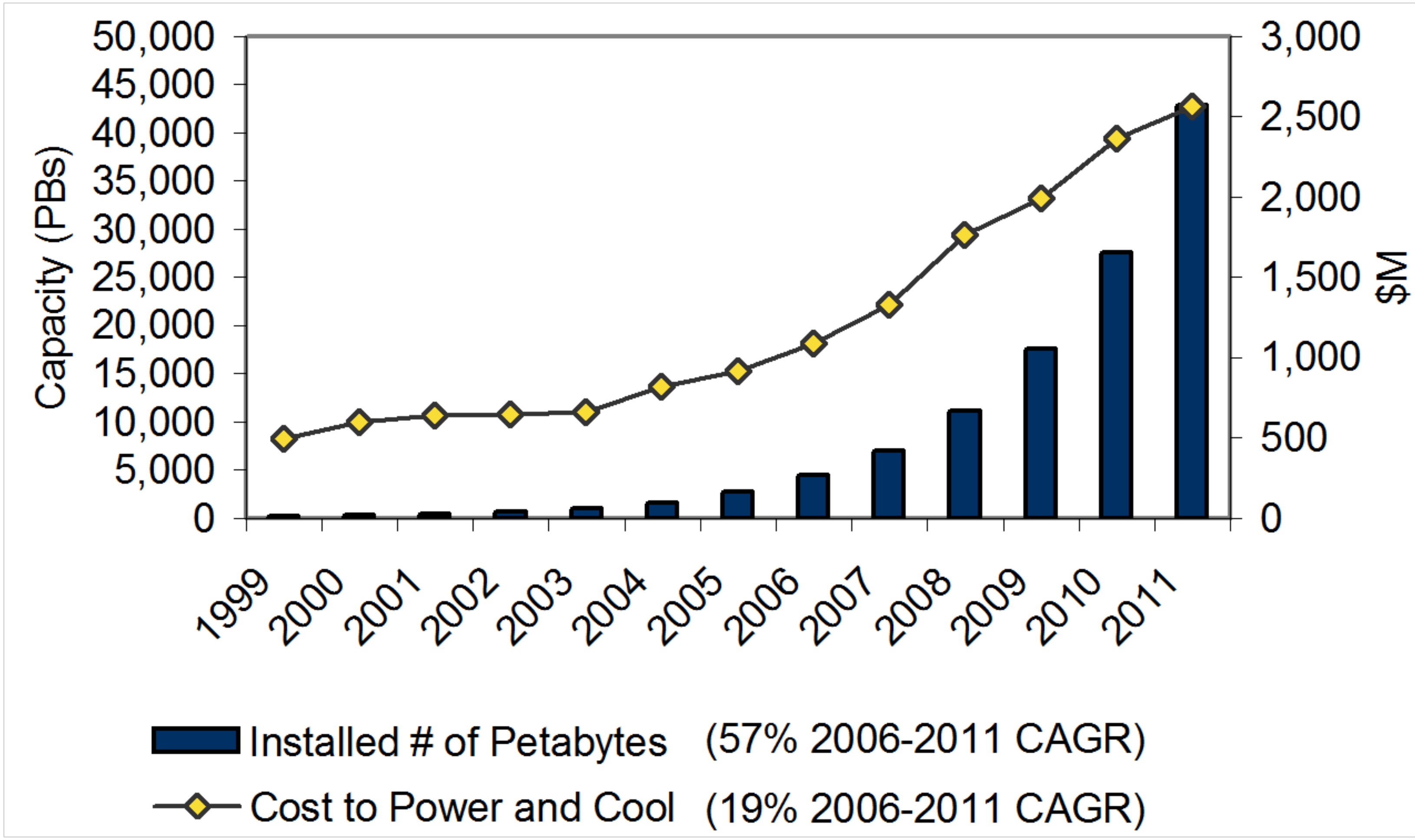
Background and Objectives

- Background
  - basic storage concepts; energy & engineering topics covered in the tutortial “Green Storage – The Big Picture”
- Objectives
  - understand the storage-specific aspects of “green” (especially energy and power) for storage components and aggregated products (e.g. arrays, controllers, appliances)
  - outline considerations in how to measure and model storage energy and power
  - identify technologies that might reduce the ongoing energy costs of reliably maintaining data
  - overview ongoing industry efforts to establish metrics and standards for more energy efficient storage

Outline

- Current state of affairs and industry trends
- Power measurement
  - storage subsystems
  - idle and active modes
  - power supply loading / efficiencies
  - power measurement & monitoring equipment
- Green metrics and taxonomy
  - measuring green-ness
  - storage product categories
- ENERGY STAR for Data Center Storage
  - update and overview
- SNIA green storage efforts
  - unplugged fests, green standards, workshops, alliances

Cost of Data Storage



IDC #212714, “The Real Costs to Power and Cool All the World's External Storage” – June 2008 Dave Reinsel
Chart used by permission of IDC

What impacts power consumption

- Storage capacity / usage efficiency
  - increasing data → larger capacity → more disks
  - redundant copies → magnify capacity needs
  - variability in usage and utilization → inefficient allocation of space
  - What is valuable data? What is the retention policy?
- Data transfer rate / access speed
  - high I/O bandwidth → higher rotational speed; striping across many drives
  - low access times → faster actuators; higher rotational speeds; caches
  - How fast and immediate must data be available? (time-to-data)
- Data integrity
  - 25% of “digital universe” is unique, but 75% are replicas / duplicates
  - partly to ensure data integrity and survivability; partly wasteful
- Data availability / system reliability
  - RAID uses extra drives, plus redundant power supplies, fans, controllers,
  - How valuable is data? How likely are failures? How fast must data be available?

Potential paths to “green”

must be driven by metrics / standards / guidelines

- Improve usage efficiency
  - De-duplication
  - Thin provisioning
- Minimize energy consumption
  - Improved component designs – high-efficiency power supplies, advanced & flexible drives
  - Variants of MAID – idle and spin-down
- New technologies
  - Solid state storage
  - Alternative + hybrid system designs (opportunity to rethink)

Anatomy of a Storage System

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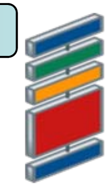
- System design, complexity and redundancy vary depending on applications & usage

Apps

- Component designs, software features, and workload affect power consumption and efficiency

Software



Switches

Appliances

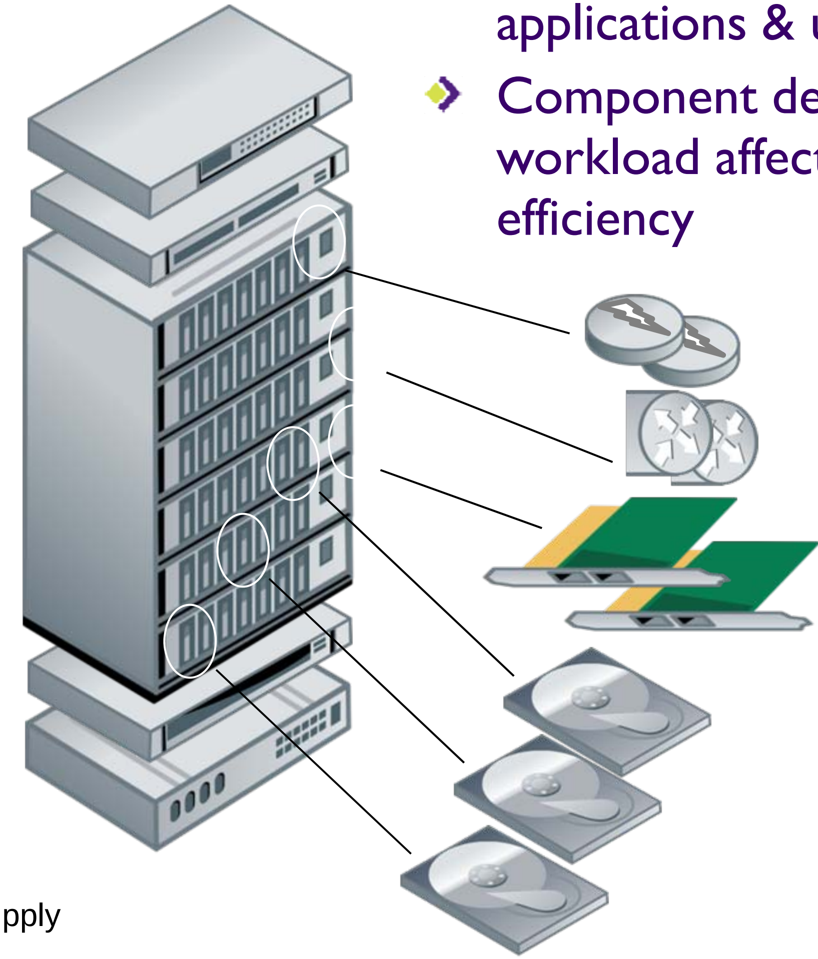
Disk Arrays

PDUs

Power Distribution Unit

UPSs

Uninterruptible Power Supply



Power Supplies

Fans

Controllers

Hard drives

Storage – Power Supply Efficiency

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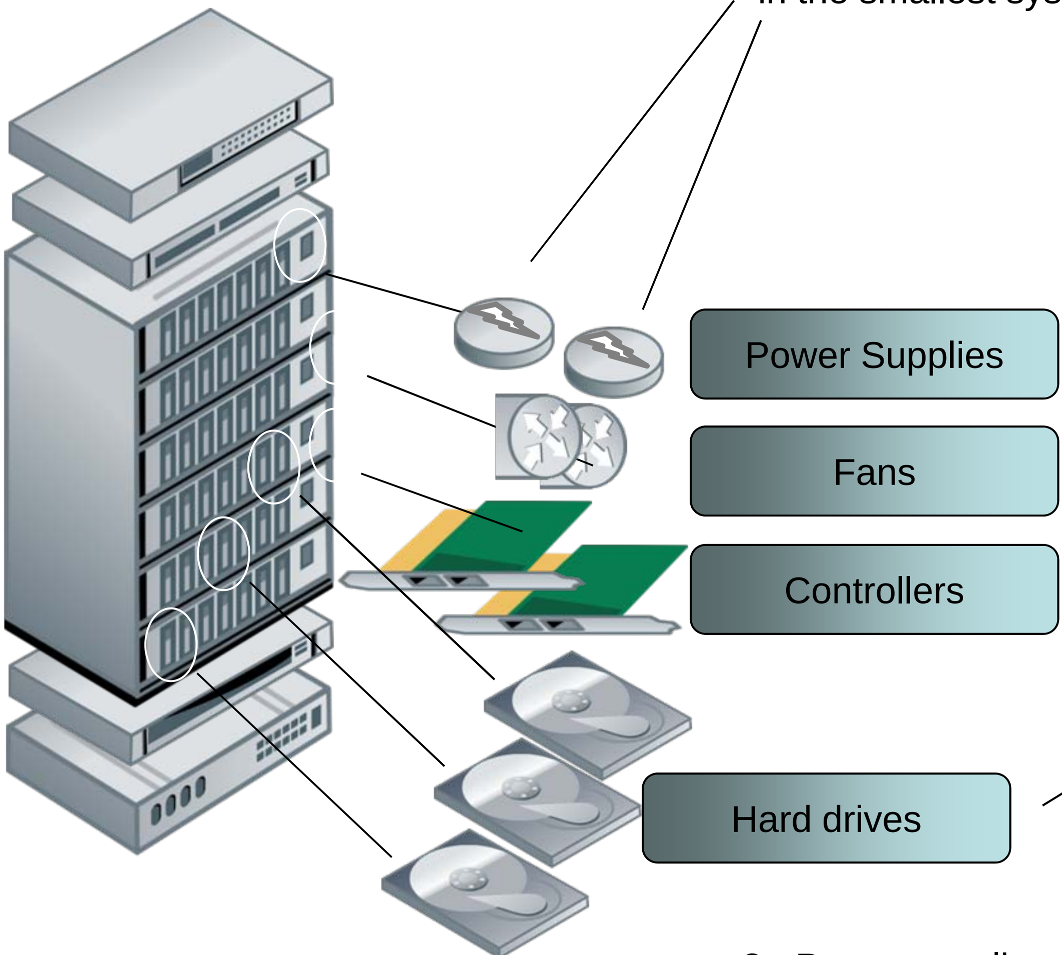
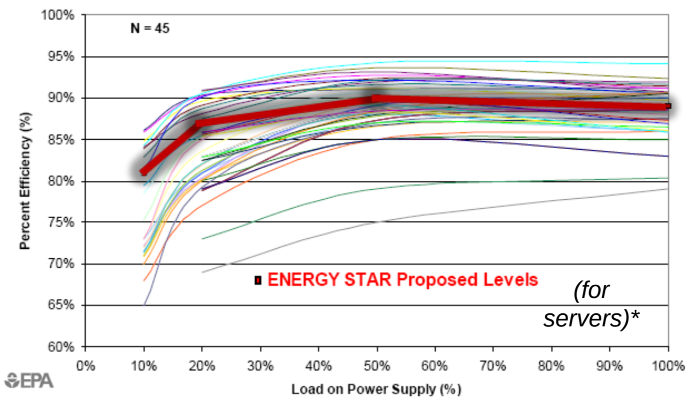
1 - Redundant power supplies are standard, except in the smallest systems





*presented by EPA at ENERGY STAR Computer Server Stakeholder Meetings; July 2008

2 - Significant mechanical components, require dual-output power supplies (12V, 5V)

3 - Power supplies often custom-designed for reliability

Idle Power vs. Active Power

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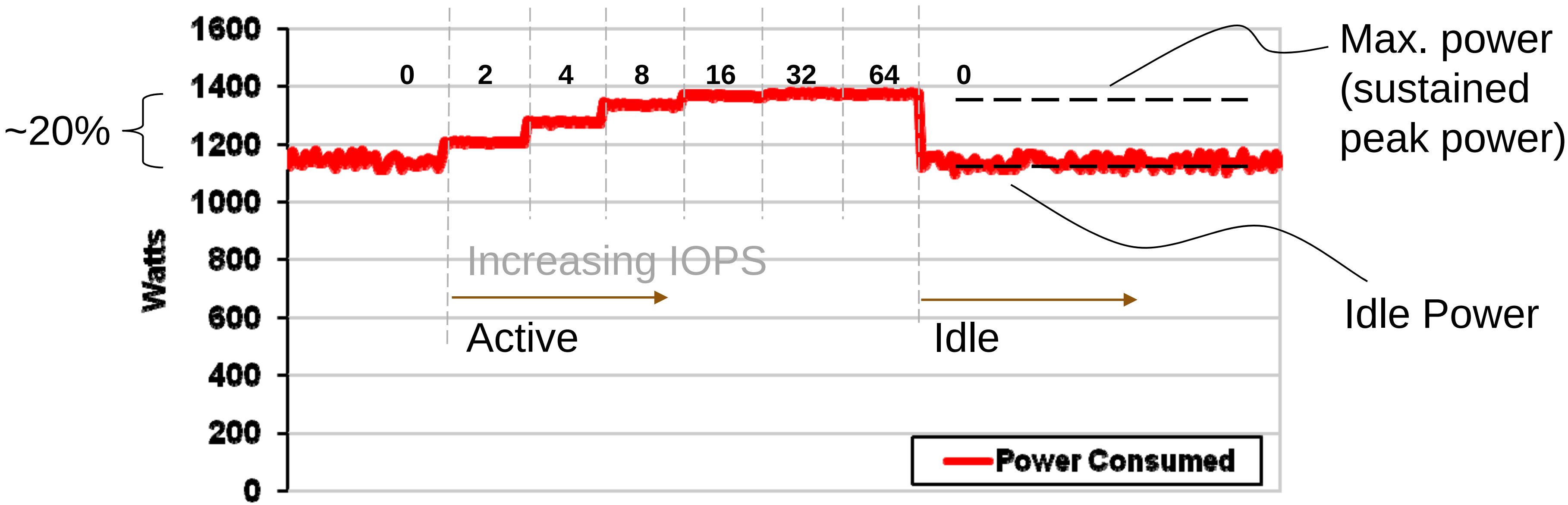
- **Idle Mode**
  - storage system is protecting data, ready to process IOs
  - background maintenance & optimization tasks on-going
  - factors: time-to-data, overhead electronics, fan, maintenance
  - systems are idle large fractions of the time
- **Active Mode**
  - storage system is carrying out IOs
  - background tasks continue in parallel
  - factors: workload (seq/random), response time, throughput
  - evaluate a variety of workloads, plus sustained peak power

Example of Power Measurement



- Ideally, systems consume minimum power in all modes
  - Example system consumes **significant power in idle (80% of max)**
- % of time in Idle versus Active depends on storage type, application and workloads; available optimizations will vary
- Power consumed is not linearly proportional to workload (indicates potential room for improvement)

Measurement Tools

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- Variety of power monitoring & measurement tools available
  - rack-mounted, networked PDUs for continuous operational monitoring
  - more accurate power meters w/ data logging capabilities are preferred for system characterization and benchmarking
  - select a tool based on accuracy, features, ampere/volt/watt levels
  - refer to SPEC website for recommended measurement devices and settings www.spec.org/power_ssj2008/docs/device-list.html
- Measure operating conditions (temp, humidity, altitude) w/ power to establish baselines and understand system behaviors
- Both total and sub-system power consumed are valuable info.

Low-current / voltage power meter

Networked, instrumented rack-mounted PDU

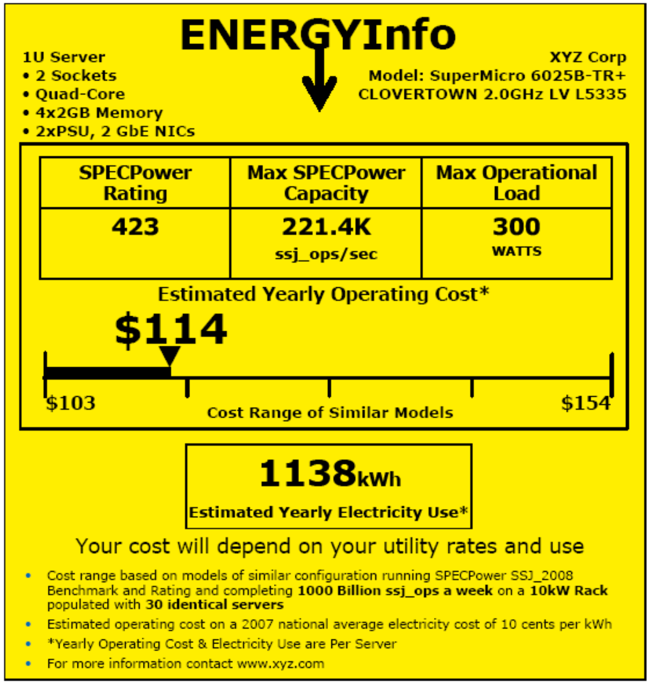
Power meter with data logging and 0.1% accuracy

Green Metrics – purpose / challenge

- Need scientific measures and common vocabulary to assess "green" performance
  - assist in data center design, operational monitoring/tuning and regulatory compliance
- Storage systems have many modes and outputs
  - a single metric (such as GB/Watt) may not reflect the characteristics or capability of the whole system
  - some system "outputs" are not all easily quantifiable
- Multiple metrics may be weighed and combined to form a single metric (e.g. annual energy bill)
  - will vary with usage and system; your mileage will vary

Metrics motivation

Department of Energy labeling program



Computer Server example

Workload considerations

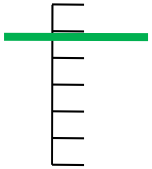
- **Data at rest – Idle power (GB/Watt)**
- Data on the move – Throughput (MB/s)
- Data at work – Performance (IOPS)

Potentially useful metrics

- **GB per Watt;** MB/s per Watt; IOPS per Watt
- Power supply efficiency; CO_2 footprint
- Total annual energy bill (ultimately determined by usage)

Reliability / availability / serviceability considerations

- Latency (time-to-date)
- Redundancy level (RAID efficiency, resilience to failures)



ENERGY STAR

EPA ENERGY STAR certification program

Storage taxonomy

- Need a taxonomy (product classification) to enable fair comparisons among similar storage products
  - e.g. for motor vehicles – motorcycles, cars, trucks
- Similar green metrics may apply to all product categories, but different values establish best-in-class
- Unique considerations apply to special categories
  - e.g. amphibious cars, skid steer loaders, tanks
- Clear taxonomy will simplify comparisons and aid regulatory efforts

Measurement Standard

- Storage taxonomy
- Measurement conditions
- Idle metric
- Reporting results

- See document at www.snia.org/tech_activities/publicreview

SNIA
Advancing storage & information technology

SNIA Green Storage Power Measurement Technical Specification

WORKING DRAFT

Version 0.0.18

20 January 2009

Publication of this Working Draft for review and comment has been approved by the Green TWG. This draft represents a "best effort" attempt by the Green TWG to reach preliminary consensus, and it may be updated, replaced, or made obsolete at any time. This document should not be used as reference material or cited as other than a "work in progress."

Taxonomy – Categories

Attribute	Category					
	Online	**Near online**	**Removable Media**	**Virtual Media Library**	**Appliance**	**Interconnect**
Access Pattern	Random	Random	Sequential write	Sequential write		
MaxTTD (t)1	t < 80 ms	t > 80 ms	t > 80 ms t < 5 min	t < 80 ms	t < 80 ms	t < 80 ms
User accessible data	Required	Required	Required	Required	Prohibited	Prohibited

- Six categories, covering most storage industry products

Taxonomy – Categories

Attribute	Category					
	Online	Near online	Removable Media	Virtual Media Library	Appliance	Interconnect
Access Pattern	Online 1	Near Online 1	Removable 1	Virtual 1	Appliance 1	Interconnect 1
MaxTTD (t)1	Online 2	Near Online 2	Removable 2	Virtual 2	Appliance 2	Interconnect 2
User accessible data	Online 3	Near Online 3	Removable 3	Virtual 3	Appliance 3	Interconnect 3
	Online 4		Removable 4			
	Online 5		Removable 5			

- 22 total "buckets" covering the breadth of the industry

Taxonomy – Online

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- Most common storage systems

Attribute	Classification				
	Online 1	Online 2	Online 3	Online 4	Online 5
Access Pattern	Random	Random	Random	Random	Random
Connectivity	Not specified	Connected to single or multiple hosts, but not shared	Network-connected	Network-connected	Network-connected
Storage Protection	Optional	Optional	Required	Required	Required
FBA/CKD Support	Optional	Optional	Optional	Optional	Required
Maximum Configuration 1	4	> 4	> 20	> 100	> 1000
MaxTTD (t)	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Optional	Optional	Required	Required
Integrated PDU and UPS	Optional	Optional	Optional	Optional	Required
Rackmount	No	Yes	Yes	Yes	Yes
Non-Disruptive Serviceability	Optional	Optional	Optional	Optional	Required
User-Accessible Data	Required	Required	Required	Required	Required

Taxonomy – Near Online

Attribute	Classification		
	Near Online 1	Near Online 2	Near Online 3
Access Pattern	Random	Random	Random
Connectivity	Network connected	Network connected	Network connected
Maximum Configuration 2	4	> 4	> 100
MaxTTD (t)	t > 80 ms	t > 80 ms	t > 80 ms
No SPOF	Optional	Optional	Required
Non-Disruptive Serviceability	Optional	Optional	Required
User-accessible Data	Required	Required	Required

Taxonomy – Removable

Attribute	Classification				
	Removable 1	**Removable 2**	**Removable 3**	**Removable 4**	**Removable 5**
Access Pattern	Sequential write	Sequential write	Sequential write	Sequential write	Sequential write
MaxTTD (t)	80 ms < t < 5 m	80 ms < t < 5 m	80 ms < t < 5 m	80 ms < t < 5 m	80 ms < t < 5 m
No SPOF	Optional	Optional	Optional	Optional	Required
Robotics	Prohibited	Required	Required	Required	Required
Maximum Drive Count	Not specified	≤ 4	≥ 5	≥ 25	≥ 12
User-accessible Data	Required	Required	Required	Required	Required

Taxonomy – Virtual

Attribute	Classification		
	Virtual 1	Virtual 2	Virtual 3
Access Pattern	Sequential write	Sequential write	Sequential write
Connectivity	Network connected	Network connected	Network connected
FICON Support	Optional	Optional	Required
Maximum Configuration [1]	100	> 100	> 100
MaxTTD (t)	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Required	Required
Non-Disruptive Serviceability	Optional	Optional	Required
User-accessible Data	Required	Required	Required

Taxonomy – Appliance & Interconnect

Attribute	Classification		
	Appliance 1	Appliance 2	Appliance 3
Connectivity	Direct or Network connected	Direct or Network connected	Network connected
Maximum Configuration [1]	20	> 20	≥ 100
MaxTTD (t)	t < 80 ms	t < 80 ms	t < 80 ms
No SPOF	Optional	Optional	Required
Non-Disruptive Serviceability	Optional	Optional	Required
User-accessible Data	Prohibited		

Attribute	Classification		
	Interconnect 1	Interconnect 2	Interconnect 3
Maximum Port Count (n)	Switch: n ≤ 32	Router: n ≤ 4 Switch: 32 ≤ n ≤ 128 Extender: ≤ 4	Router: > 4 Switch: > 128
No SPOF	Optional	Optional	Required
User-accessible Data	Prohibited	Prohibited	Prohibited

Storage Power – Idle

Equation 6-1: Average Idle Power

$$P_i = \frac{\sum W_i}{n}$$

Where:

- *P_i is average idle power*
- *W_i is power in watts measured in each sampling interval i*
- *n is the number of samples gathered by the power meter during the measurement interval.*

- Idle Metric

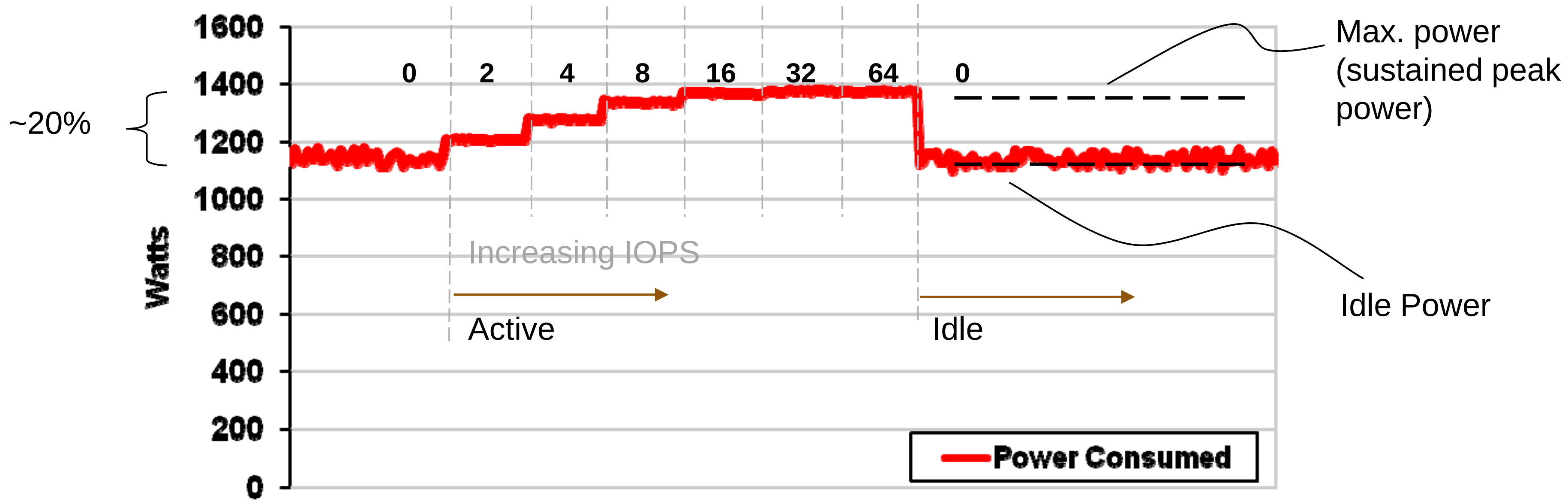
Equation 7-1 SNIA Idle Power Metric

$$P = \frac{C}{P_i}$$

Where:

- *P is the SNIA Idle Power Metric*
- *C is the total capacity of the SUT*
- *P_i is the average idle power*

What's Next – Active Power



- Many variations in workloads
- Many variations in system configuration
- Takes us into the realm of benchmarking

Desired Metric – "Productivity"

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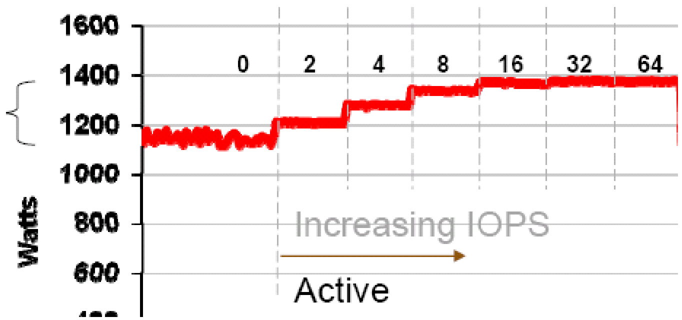
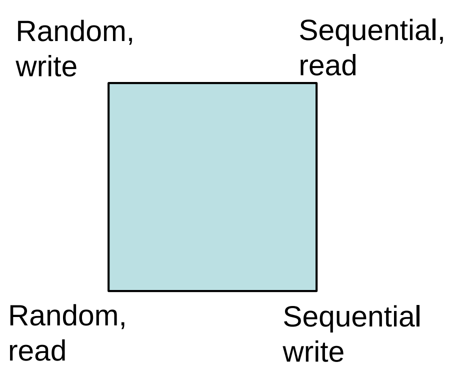
Many possible definitions – must balance simplicity against applicability

- "typical workload", with levels



- "four corners", maximum performance, maximum power



- detailed performance benchmarks – results/W

Storage Performance Council

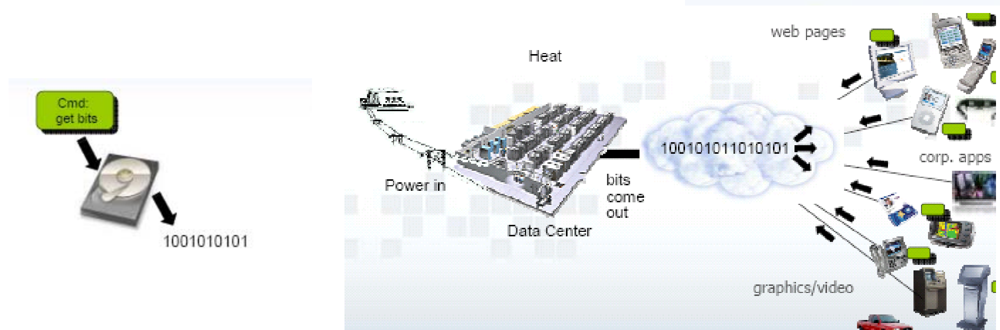
Defining, administering, and promoting industry-standard, vendor-neutral benchmarks to characterize the performance of storage products

spec

Standard Performance Evaluation Corporation

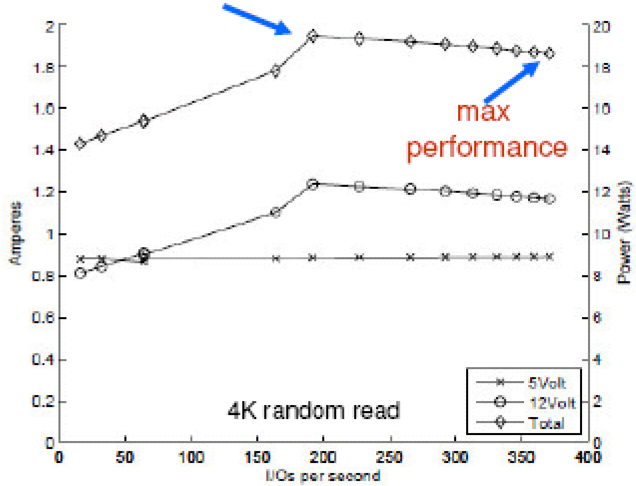
- The Green Grid Productivity Proxy Proposals example – Proxy #4 – bits/kilowatt-hour

the green grid SM get connected to efficient IT

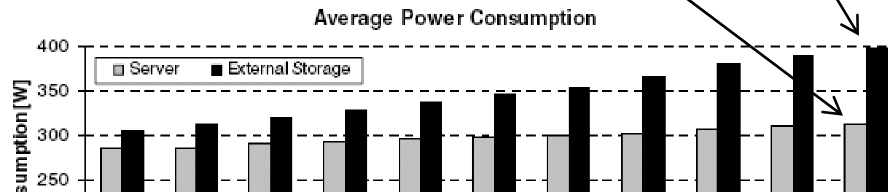


Complications

- Max power =/= Max performance



Single disk drive power profile



SPECweb 2005 (banking) + storage

- Significant whole-system considerations

Storage Modeling for Power Estimation

Miriam Allalouf • Yuriy Arbitman • Michael Factor •
Ronen I. Kat • Kalman Meth • Dalit Naor •

IBM Haifa Research Labs

ABSTRACT

Power consumption is a major issue in today's datacenters. Storage typically comprises a significant percentage of datacenter power. Thus, understanding, managing, and reducing storage power consumption is an essential aspect of any efforts that address the total power consumption of datacen-

decade. We observe that the power consumption of disks is composed of fixed and dynamic portions. The fixed portion is consumed in the idle state and includes items such as the power consumed by the spindle motor. The dynamic factors are affected by the I/O workload and include items such as the power for data transfers

"Storage Modeling for Power Estimation", Miriam Allalouf , Yuriy Arbitman, Michael Factor, Ronen I. Kat, Kalman Meth, and Dalit Naor; IBM Haifa Research Labs; manuscript; March 2009

The Next Frontier for Power/Performance Benchmarking: Energy Efficiency of Storage Subsystems

Klaus-Dieter Lange

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Klaus.Lange@hp.com

Abstract. The increasing concern of energy usage in datacenters has drastically changed how the IT industry evaluates servers. The energy conscious selection of storage subsystems is the next logical step. This paper first quantifies the possible energy savings of utilizing modern storage subsystems by identifying inherent energy characteristics of next generation disk IO subsystems. Additionally, the power consumptions of a variety of workload patterns is demonstrated.

Keywords: SPEC, Benchmark, Power, Energy, Performance, Server, Storage, Datacenter.

1 Introduction

Today's challenge for datacenters is their high energy consumption [1]. The demand for efficient real estate in datacenters has moved to more power efficient datacenters. This increasing concern of energy usage in datacenters has drastically changed how

"The Next Frontier for Power/Performance Benchmarking: Energy Efficiency of Storage Subsystems" Klaus-Dieter Lange; SPEC Benchmark Workshop 2009; January 2009

Outline

- Current state of affairs and industry trends
- Power measurement
  - storage subsystems
  - idle and active modes
  - power supply loading / efficiencies
  - power measurement & monitoring equipment
- Green metrics and taxonomy
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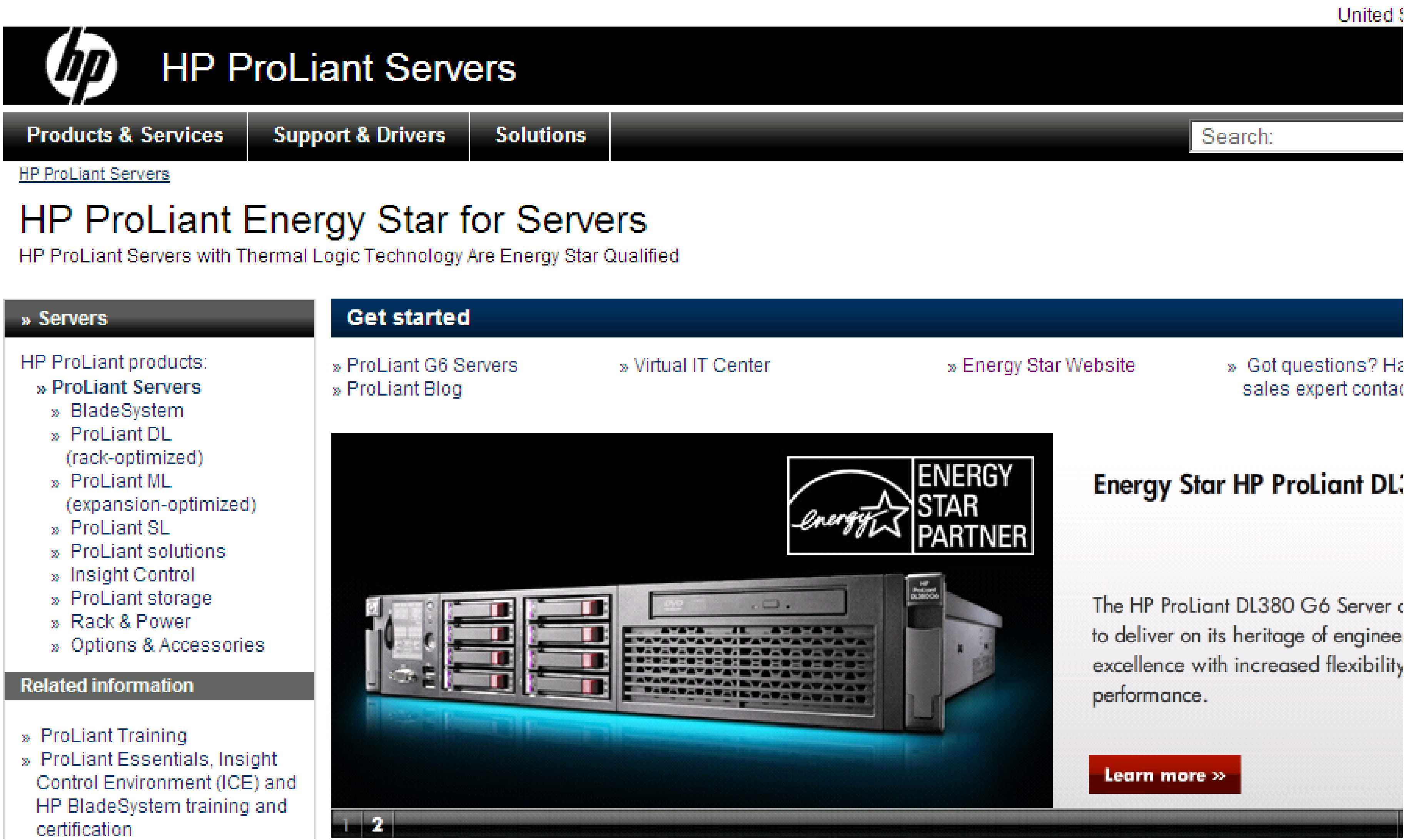
  - storage product categories
- ENERGY STAR for Data Center Storage
  - update and overview
- SNIA green storage efforts
  - unplugged fests, green standards, white papers / workshops, alliances

ENERGY STAR for Computer Servers

Date	Document	Effective Date (Tier 1)	Effective Date (Tier 2)	Pages
December 2006	Stakeholder Letter	TBD		3
July 2007	Framework Document	TBD	TBD	3
February 2008	Draft 1	TBD	TBD	10
	Draft 2	1 January 2009	TBD	13
November 2008	Draft 3	1 February 2009	1 October 2010	17
February 2009	Draft 4	1 May 2009	1 October 2010	28
May 2009	Final 1.0	15 May 2009	1 October 2010	20
July 2010	Final 2.0	--	1 October 2010	plan

29 months from letter to live

results for 13 servers & 32 server families posted as of 1 April 2010


United S
HP ProLiant Servers
Products & Services
Support & Drivers
Solutions
Search:
HP ProLiant Servers
HP ProLiant Energy Star for Servers
HP ProLiant Servers with Thermal Logic Technology Are Energy Star Qualified
» Servers
HP ProLiant products:
» ProLiant Servers
» BladeSystem
» ProLiant DL (rack-optimized)
» ProLiant ML (expansion-optimized)
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1 2

ENERGY STAR® Power and Performance Data Sheet

DL360 G6; 504633-xx1

System Characteristics

Form Factor	1U
Available Processor Sockets	2
Available DIMM Slots / Max Memory Capacity	18/144GB
ECC and/or Fully Buffered DIMMs	Yes, ECC and Registered DIMM (RDIMM) memory
Available Expansion Slots	Up to 2 PCI-E and up to 1 PCI-X, not to exceed 2 total
Minimum and Maximum # of Hard Drives	0 and 8
Redundant Power Supply Capable?	Yes
Power Supply Make and Model	460W High Efficiency 503296-B21
Power Supply Output Rating* (watts)	460
Minimum and Maximum # of Power Supplies	1 and 2
Input Power Range (AC or DC)	100-240VAC
Power Supply Efficiency at Specified Loadings*	85.5%@10%, 90.1%@20%, 92.2%@50%, 91.6%@100%
Power Supply Power Factor at Specified Loadings*	0.816@10%, 0.923@20%, 0.956@50%, 0.982@100%

PowerEdge Servers Engineered with Energy Smart Technologies

Dell and Energy Star
Dell is committed to maximizing IT productivity and saving energy. In order to provide our customers with lower overall power consumption in the data center, we engineer our products to rigorous standards to achieve industry-leading performance per watt. These products also qualify for the new ENERGY STAR® specifications sponsored by the U.S. Environmental Protection Agency and the Department of Defense.

To learn more about our latest Energy Star certified servers, please review the following data sheets highlighting the qualifying platforms:

- Dell PowerEdge R710 Energy Star Datasheet
- Dell PowerEdge R610 Energy Star Datasheet

Dell PowerEdge Servers: Addressing Your Energy Needs
Limitations on space, power and cooling capacity combined with rising energy costs present enormous challenges for IT environments. Our newest Dell PowerEdge servers feature Energy Smart technologies designed to reduce power consumption while increasing performance and capacity based on Dell's five key technologies:

- **Dell Energy Smart Power Supplies**
  Energy Smart Power Supply Units (PSUs) are engineered and "right sized" to achieve some of the highest efficiencies in the industry by taking unneeded overhead out of the server power envelope.

Resources

C. Standard Information Reporting Requirements

Manufacturers must provide a standardized *Computer Server Version 1.0 Power and Performance Data Sheet* with each ENERGY STAR qualified Computer Server. This information must be posted on the Partner's Web site where information on the qualified model, or qualified configurations, is posted. Manufacturers are encouraged to provide one data sheet per qualified configuration, but may also provide one sheet per Product Family (as defined in Section 1.T above) with data on the Computer Server's power and performance for maximum, minimum and typical configurations (as defined in Sections 1.U – 1.W, above).

If one data sheet is used to represent many configurations under one Product Family, partners should, when available, also provide a link to a more detailed power calculator where information on the power use of specific system configurations can be found.

Templates for the *Server Version 1.0 Power and Performance Data Sheet* can be found on the ENERGY STAR Web page for Computer Servers at www.energystar.gov/products.

> **Note:** EPA has changed the Standard Information Reporting Requirements to harmonize with the new definition for Product Families in this specification.
>
> EPA has also included text that a template for the Power and Performance Data Sheet will be posted on the ENERGY STAR products page for Computer Servers. A revised draft of the Power and Performance Data Sheet has also been included with this Draft 4 specification. **EPA encourages all stakeholders to review this latest version and provide comments to EPA.**
>
> The revised data sheet includes a few key changes that EPA would like to make stakeholder aware of:
>
> - Since SPECpower is no longer being referenced for Idle power testing, manufacturers are not required to report SPECpower test results on the data sheet. However, EPA is still requiring testing and reporting of at least one benchmark, of the manufacturer's choosing, for inclusion on the data sheet.
> - EPA is requiring that Full Load (100%) power be tested and reported along with the method used to determine Full Load power indicated on the data sheet. EPA believes this will provide buyers the necessary information on the full power range of the Computer Server while also allowing EPA to collect valuable data which may be useful in the development of the Tier 2 specification.

ENERGY STAR for Data Center Storage

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Date	Document	Effective Date (Tier I)	Pages
April 2009	Stakeholder Letter	TBD	2
June 2009	Framework Document	March 2010	12
20 July 2009	1st Stakeholder Meeting	March 2010	--
15 October 2009	Test Procedure Meeting	TBD	--
2 February 2010	2nd Stakeholder Meeting	TBD	--
March 2010	Initial Test Period Ended	TBD	
April 2010*	Draft 1	TBD	

"this is one of the most complex areas we have tackled to date" – Andrew Fanara, Team Leader, EPA ENERGY STAR Product Specifications, July 2009 in San Jose

"we have learned a lot over the past year, and are grateful for the wide industry participation and support for this effort" – Andrew Fanara, February 2010 in San Jose

Observations from Stakeholder Meetings

- EPA ENERGY STAR
  - Open and willing to listen
  - Learning
  - Collaboration with industry is a key goal (while meeting the EPA needs and mission)
- Audience
  - Wide cross-industry participation – vendors & suppliers
  - The Green Grid, Wikibon, PG&E, Climate Savers
  - Some end-user participation (via phone and in person)

Goals for Data Center Storage

ENERGY STAR

- Encourage widespread adoption of energy efficient hardware and software strategies,
- Provide purchasers with the means to identify the most energy efficient enterprise storage solutions for their specific end-use application, and
- Provide tools and information to designers and mangers looking to improve the efficiency of data center operations

EPA

Litmus Test

- There are numerous product features, functions, and data management strategies that enable energy savings in data center storage.

- There is only one end result that matters: The ability to do more useful work, while consuming fewer resources, in a verifiable and quantifiable manner.

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  - storage product categories
- ENERGY STAR for Data Center Storage
  - update and overview
- SNIA green storage efforts
  - unplugged fests, green standards, white papers / workshops, alliances

SNIA Green Efforts

- SNIA Green Storage Initiative (GSI) and SNIA Green Storage Technical Work Group (TWG)
  - on-going efforts to develop data-driven green standards & metrics
  - power measurements at multi-vendor "unplugged" fests
  - alliances with other active green organizations
    - (The Green Grid, 80PLUS, Climate Savers, DMTF, SPEC, SPC)
  - collaboration with EPA on the ENERGY STAR program
- Whitepapers / workshops
  - three tutorials at SNW; online tutorials available (www.snia.org/education/tutorials)
  - white papers from GSI

towards energy-efficient storage networking solutions

Summary

- "Green is good" – for multiple reasons
  - a great engineering problem – doing more with less
  - saves money – great investment payback
  - helps save the planet – significant leverage
- Get involved with SNIA Green efforts
  - weekly discussions, regular face-to-face & data sharing (TWG)
    - Upcoming face-to-face meeting at SNIA Symposium on July 19 & 20 in San Jose
    - Get a power meter and try the measurement spec on your own systems (!)
  - education and promotion (GSI)
  - promote these industry-wide efforts within your company
- Learn about wider green technology and opportunities
  - online resources; workshops by SNIA, EPA, The Green Grid
- Share your experience / knowledge

References

- SNIA Green Storage Initiative – www.snia.org/green
- The Green Grid – www.greengrid.org
- EPA ENERGY STAR™ (Data Center Storage – www.energystar.gov/index.cfm?c=new_specs.enterprise_storage
- DOE Federal Energy Management Program – eere.energy.gov/femp
- Power calculators at various vendor sites
- SNIA Green Storage Outreach
  - www.snia.org/forums/green

Q&A / Feedback

- Thank you for your attention!
- Please send any questions or comments on this presentation to SNIA: trackstorage@snia.org and trackgreenstorage@snia.org

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