SNIA Emerald™
SNIA Emerald Power Efficiency Measurement Specification
SNIA Emerald Program

Leah Schoeb, VMware
SNIA Green Storage Initiative, Chair
PASIG 2012
Agenda

- SNIA GSI Overview
- SNIA Emerald™ Power Efficiency Measurement Specification
- SNIA Emerald™ Program
The GSI’s Mission

- To conduct research on power and cooling issues confronting storage administrators
- Educate the vendor and user community about the importance of power conservation in shared storage environments
- Leverage SNW and other SNIA and partner conferences to focus attention on energy efficiency for networked storage infrastructures
- Provide input to the SNIA Green Storage TWG on requirements for green storage metrics and standards
- Provide external advocacy and support of the technical work of the SNIA Green Storage Technical Working Group

Current GSI Members

EMC, HP, Hitachi, IBM, LSI, Oracle, QLogic, NetApp, Seagate, VMware

Members as of 10.1.11
Agenda

- SNIA GSI Overview
- SNIA Emerald™ Power Efficiency Measurement Specification
- SNIA Emerald™ Program
Challenge: Measuring Energy and Efficiency
System, sub-system, and various configurations

- System design, complexity and redundancy vary depending on applications & usage
- Component designs, software features, and workload affect power consumption and efficiency

- Switches
- Appliances
- Disk Arrays
- PDUs
  Power Distribution Unit
- UPSs
  Uninterruptible Power Supply
- Apps
- Software
- Power Supplies
- Fans
- Controllers
- Hard drives
SNIA Combined Work Effort
An industry effort, still ongoing

- 25 companies in SNIA Green Storage Tech. Work Group
- 11 companies in SNIA GSI
- Decomposing the storage system challenge
- Observed industry efforts for servers: SPEC, EPA, etc
- 3 years significant technical work,
  - many iterations of system testing, data analysis and methodology review
- Power supply efficiency work
  - ClimateSavers, EPRI, ECOS
- Power measurement tools
  - Reference SPEC
SNIA Emerald™ Power Efficiency Measurement Specification

This document has been released and approved by the SNIA. The SNIA believes that the ideas, methodologies, and technologies described in this document accurately represent the SNIA goals and are appropriate for widespread distribution. Suggestions for revision should be directed to http://www.snia.org/feedback.

SNIA Technical Position

23 August 2011

- **Taxonomy:** An industry-wide means of segmenting storage systems for products that span the range from consumer solutions to enterprise configurations which will be used to categorize the test results.

- **Test Methodology:** A detailed and consistent means of testing various types of storage systems with load generators and power measurement instruments.

- **Test Metrics - Idle Measurement Test:** The idle test applies to storage systems and components which are configured, powered up, connected to one or more hosts and capable of satisfying externally initiated, application-level initiated IO requests within normal response time constraints, but no such IO requests are being submitted.

- **Test Metrics - Active Measurement Test:** Testing of storage products and components are said to be in an “active” state when they are processing externally initiated, application-level requests for data transfer between host(s) and the storage product(s).

- **Capacity Optimization:** The specification and program test report do address disclosing configuration information for the system under test about energy-saving storage capacity optimizations that the system may have including features such as deduplication and thin provisioning.

http://snia.org/tech_activities/standards/curr_standards/emerald

SNIA Green Storage Initiative www.snia.org/green

SNIA Emerald™ Program www.sniaemerald.com
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
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Online</td>
</tr>
<tr>
<td>Access Pattern</td>
<td>Random/ Sequential</td>
</tr>
<tr>
<td>MaxTTFD (t)</td>
<td>t &lt; 80 ms</td>
</tr>
<tr>
<td>User Accessible Data</td>
<td>Required</td>
</tr>
<tr>
<td>Level</td>
<td>Category</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Consumer/Component</td>
<td>Online 1</td>
</tr>
<tr>
<td>Low-end</td>
<td>Online 2</td>
</tr>
<tr>
<td>Mid-range</td>
<td>Online 3</td>
</tr>
<tr>
<td></td>
<td>Online 4</td>
</tr>
<tr>
<td>High-end</td>
<td>Online 5</td>
</tr>
<tr>
<td>Mainframe</td>
<td>Online 6</td>
</tr>
</tbody>
</table>
How to, step by step guidance and recommendations

How to submit test results to the SNIA Emerald™ Program

Develop a product family definition beyond the SNIA Emerald Measurement Specification taxonomy

Arriving at appropriate system configurations to test

Set-up system under test and complete the measurement sequence

Sample workload scripts for tools to generate IO workload

How to avoid test and measurement mistakes and problems
Storage System Testing for Power Efficiency

System Under Test SUT

- Benchmark Driver System
  - e.g. IOMETER or Vdbench

- Environmental Meter for Temp. and Hum.

- Power Meter
  - e.g. Yokogawa or others....

- System Under Test pre-test measurement conditioning
- Active workload generation and measurements
- Idle workload and measurements
- Capacity optimization method (COM) verification.
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?
Opportunities to make storage green(er)

✿ Environment
- Higher system tolerance to high/low temperatures and humidity
- In line with cold and hot aisles designs on new data centers

✿ Improve usage efficiency
- De-duplication and compression
- Thin provisioning

✿ Minimize energy consumption
- Improved component designs – high-efficiency power supplies, advanced & flexible storage devices
- Variants of MAID – idle and spin-down

✿ New technologies
- Solid state storage
- Alternative + hybrid system designs (opportunity to rethink)

must be driven by metrics / standards / guidelines
SNIA recommended metrics

- **Capacity metric (ready-idle)**
  - Relates the power of the system to its total storage raw capacity. It is reported as GB/watt (or TB/watt)
  - Power required to store and protect the data

- **Workload metric (Active)**
  - Relates the power of the system to the maximum possible IOPS generated by a specific random stress load. It is reported as IOPS/watt
  - Power required to randomly supply data to and from a host

- **Bandwidth metric (Active)**
  - Relates the power drawn by the system to the maximum possible MBPS generated by a specific sequential stress load. It is reported as MBPS/watt
  - Power required to stream data to and from a host
Storage Power – Idle

Average Power

Where:

\[ PA_i(T) = \frac{\sum W_s}{n} \]

• \( PA_i(T) \) is the AVERAGE POWER during test or test phase \( i \), taken over a time interval of \( T \) seconds;
• \( W_s \) is power in watts measured at each sampling interval \( s \) taken during the time interval \( T \);
• \( n \) is the number of samples gathered by the power meter during the time interval \( T \);
• \( T = n \times s \).

Idle Metric

Power Efficiency, Ready Idle

Where:

\[ EP_{RI} = \frac{C_R}{PA_{RI}(7200)} \]

\( EP_{RI} \) is the POWER EFFICIENCY metric for the READY IDLE TEST;
\( C_R \) is the RAW CAPACITY of the SUT (see 4.2.20);
\( PA_{RI}(7200) \) is the AVERAGE POWER over the 2-hour MEASUREMENT INTERVAL for the READY IDLE TEST.
### Storage Power – Active Online

<table>
<thead>
<tr>
<th>IO Profile</th>
<th>IO Size (KiB)</th>
<th>Read/Write Percentage</th>
<th>IO Intensity</th>
<th>Transfer Alignment (KiB)</th>
<th>Access Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Workload 1 (i=MW1)</td>
<td>8</td>
<td>70/30</td>
<td>100</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Mixed Workload 2 (i=MW2)</td>
<td>8</td>
<td>70/30</td>
<td>25</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Random Write (i=RW)</td>
<td>8</td>
<td>0/100</td>
<td>100</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Random Read (i=RR)</td>
<td>8</td>
<td>100/0</td>
<td>100</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Sequential Write (i=SW)</td>
<td>256</td>
<td>0/100</td>
<td>100</td>
<td>256</td>
<td>Sequential</td>
</tr>
<tr>
<td>Sequential Read (i=SR)</td>
<td>256</td>
<td>100/0</td>
<td>100</td>
<td>256</td>
<td>Sequential</td>
</tr>
</tbody>
</table>

#### Periodic Power Efficiency

Where:

\[
EPP_i(T) = \frac{O_i(T)}{PA_i(T)}
\]

- \(EPP_i(T)\) is the **PERIODIC POWER EFFICIENCY** during test or test phase \(i\), taken over a time interval of \(T\) seconds;
- \(O_i(T)\) is the **OPERATIONS RATE** during test or test phase \(i\), taken over the same time interval of \(T\) seconds;
- \(PA_i(T)\) is the **AVERAGE POWER** during test or test phase \(i\), taken over the same time interval of \(T\) seconds.
### C.1 Data Collection Requirements

A summary of the data collection requirements for the benchmark driver is provided in Table C-1.

<table>
<thead>
<tr>
<th>Test</th>
<th>Collection Interval (seconds)</th>
<th>Minimum Benchmark Driver Data Collection</th>
<th>Minimum Test Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power Meter</td>
<td>Temp Meter</td>
<td>Online/ Near Online</td>
</tr>
<tr>
<td>Conditioning</td>
<td>5</td>
<td>60</td>
<td>Response Time (per 1m Interval)</td>
</tr>
<tr>
<td>Active</td>
<td>5</td>
<td>60</td>
<td>Response Time (per 1m Interval)</td>
</tr>
<tr>
<td>Idle</td>
<td>5</td>
<td>60</td>
<td>N/A</td>
</tr>
</tbody>
</table>
8.2 Primary Metrics
This revision of the specification defines the following primary metrics:

- **POWER EFFICIENCY for each test phase for Online and Near Online systems (see 8.3):**
  - $E_{MW1}$ for Mixed Workload 1
  - $E_{MW2}$ for Mixed Workload 2
  - $E_{RR}$ for Random Read
  - $E_{RW}$ for Random Write
  - $E_{SR}$ for Sequential Read
  - $E_{SW}$ for Sequential Write
  - $E_{RI}$ for Ready Idle

- **POWER EFFICIENCY for each test phase for Removable Media Library systems (see 8.4):**
  - $E_{SW}$ for Sequential Write
  - $E_{SR}$ for Sequential Read
  - $E_{RI}$ for Ready Idle

- **POWER EFFICIENCY for each test phase for Virtual Media Library systems (see 8.5):**
  - $E_{SW}$ for Sequential Write
  - $E_{SR}$ for Sequential Read
  - $E_{RI}$ for Ready Idle

- **Online Storage**
  - **Active Metrics ("work")**
    - IOs/Watt (R/W)
    - MBs/Watt (Sequential)
  - **Idle Metric ("capacity")**
    - GB/Watt
What to measure and evaluate

- 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 itself is only one part of the story it must be reflected as a metric as indicated on the previous charts.
- Power consumed is not linearly proportional to workload (indicates potential room for improvement)
What to measure and evaluate –
What to consider

- **Recommended Analysis tools**
  - Power meters recommended on the Emerald Specification
  - Temperature recording tools recommended on the Emerald Specification
  - SNIA will also recognize the SPEC recommended measurement devices as indicated on their web site:
    [www.spec.org/power/docs/SPECpower-Device_List.html](http://www.spec.org/power/docs/SPECpower-Device_List.html)

- If the storage system reports power and temperature consider logging it to compare with the analyzers for accuracy comparison.

- Both total and sub-system power consumed are valuable info

- **capacity metric (GB/Watt)** may be your best indicator on how energy efficient your system is. (The larger this number is the less watts are used to energize the total storage of your system)
Depending on the systems and their usage their energy usage may be evaluated according to:

- For systems running more than 12 hours a day
  - You should be interested in the Power to move the data onto and off the storage system
  - Is your load predominantly sequential?
    - Bandwidth metric (MBS/Watt) will help you to determine how effective is your power use. The larger this number is, the more data the system is pushing per watt
  - Is your load predominantly random?
    - Workload metric (IOPS/Watt) will help you determine how effective is your power use. The larger this number is the system is provides more operations per watt.
  - Independently on how long the system is idle it is always good to know what is your capacity per watt ratio
Many industry wide efforts can help you become more green

❖ Emerald
  ❖ A complete set of tests intended to measure power use ratios based on all previously mentioned metrics.

❖ SPC
  ❖ Storage Performance Council mainly oriented to disk subsystems was the first industry association to add power to their benchmark

❖ The Green Grid
  ❖ Working on a usage metric.
Green Storage Technologies
Best Practices Available Today

- **Enabling technologies**
  - Storage virtualization
  - Storage capacity planning

- **Green software and technologies [capacity savings]**
  - Compression: depends on ratio/data types
  - Snapshots: vs Full clones
  - Thin provisioning: 40-60% savings, can be 80%
  - Non-mirrored RAID: 35%, e.g. RAID 6 vs RAID 10
  - De-duplication: 40-95% depending on data type
  - Re-sizeable volumes: 20-50%
  - SSD: 38% less heat, 90% less power; > if HDDs replaced
  - Tiered Storage, capacity drives vs performance drives
Agenda

- SNIA GSI Overview
- SNIA Emerald™ Power Efficiency Measurement Specification
- SNIA Emerald™ Program
SNIA Emerald™ Program
www.sniaemerald.com

Welcome to the SNIA Emerald Program website.

The purpose of the SNIA (Storage Networking Industry Association) Emerald Program is to provide public access to storage system power usage and efficiency through use of a well-defined testing procedure, and additional information related to system power. The measurement procedure, the SNIA Emerald™ Power Efficiency Measurement Specification, was developed and released, and is maintained by the Green Storage Technical Working Group (GS-TWG) under the guidance of the Green Storage Initiative (GSI) of the SNIA. Use of the specification with the intent of posting the results to the SNIA Emerald Program central repository and obtaining a SNIA Emerald Program trademark and logo requires the results to be used in accordance with the SNIA Emerald™ Program rules, which are available on the submission form.

The SNIA Emerald Program is sponsored, operated, and promoted by the SNIA GSI. The SNIA is a non-profit, international organization of manufacturers, systems integrators, developers, systems vendors, industry professionals, and end users. The GSI is responsible for managing the SNIA Emerald Program, providing input and guidance to the GS-TWG, and general marketing of energy efficiency activities within the SNIA and the storage networking industry.

Why use the Emerald Program? Read more here.
## View Test Data Results

You may sort on a particular column by clicking on the header. You may view the Full Disclosure Report by clicking on the "PDF" link.

<table>
<thead>
<tr>
<th>DATE</th>
<th>COMPANY</th>
<th>SYSTEM NAME</th>
<th>CATEGORY</th>
<th>CLASS</th>
<th>TDR-PDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/10/11</td>
<td>IBM</td>
<td>D53400</td>
<td>Online</td>
<td>3</td>
<td>PDF</td>
</tr>
<tr>
<td>10/10/11</td>
<td>Hewlett-Packard</td>
<td>EVA F6500</td>
<td>Online</td>
<td>3</td>
<td>PDF</td>
</tr>
<tr>
<td>12/19/11</td>
<td>Hewlett-Packard Company</td>
<td>MSL2224 (BLS42A)</td>
<td>Removable Media Library</td>
<td>2</td>
<td>PDF</td>
</tr>
<tr>
<td>12/19/11</td>
<td>Hewlett-Packard Company</td>
<td>MSL4048 (BLS32A)</td>
<td>Removable Media Library</td>
<td>2</td>
<td>PDF</td>
</tr>
<tr>
<td>12/20/11</td>
<td>Hewlett-Packard</td>
<td>MSL4048 (BLS43A)</td>
<td>Removable Media Library</td>
<td>2</td>
<td>PDF</td>
</tr>
</tbody>
</table>
The SNIA Emerald Test Data Report

Disclosure for sto

NOTICE: This document is published and non-commercial use only and subject to res of Use contained herein.

Product Description

Company: IBM
Address: 9000 S. Rita Rd
Tucson, AZ 85744
Municipality: Pima County
Product Name: DS4300
Taxonomy Category: online 3
Product Release Date: 11-Sep-05
Description: Entry level storage syste like dual controllers
Product Web Page: http://www-03.ibm.com
List Price (optional): US
Raw capacity: ~9,000 GB
Submission Date: 10-Oct-11
Document Status: Provisional

Operational Power

<table>
<thead>
<tr>
<th>Power Test</th>
<th>Power</th>
<th>Average latency</th>
<th>Average latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle power test</td>
<td>Average watts</td>
<td>1094.5 W</td>
<td>30.1 ms</td>
</tr>
<tr>
<td>EPt</td>
<td>Raw capacity tested</td>
<td>9,000 GB</td>
<td></td>
</tr>
<tr>
<td>EPw</td>
<td>Standard idle metric</td>
<td>8.2 GB/W</td>
<td></td>
</tr>
</tbody>
</table>

Active power tests

<table>
<thead>
<tr>
<th>Power Test</th>
<th>Power</th>
<th>Average latency</th>
<th>Average latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small random reads</td>
<td>run length</td>
<td>3.45 (minutes)</td>
<td>30.1 ms</td>
</tr>
<tr>
<td>Small random writes</td>
<td>run length</td>
<td>1.53 (minutes)</td>
<td>7.6 ms</td>
</tr>
<tr>
<td>Large sequential reads</td>
<td>run length</td>
<td>0.43 (minutes)</td>
<td>30.2 ms</td>
</tr>
<tr>
<td>Large sequential writes</td>
<td>run length</td>
<td>0.15 (minutes)</td>
<td>30.2 ms</td>
</tr>
<tr>
<td>Mixed workload 1</td>
<td>run length</td>
<td>2.78 (minutes)</td>
<td>20.1 ms</td>
</tr>
<tr>
<td>Mixed workload 2</td>
<td>run length</td>
<td>0.78 (minutes)</td>
<td>30.1 ms</td>
</tr>
</tbody>
</table>

Capacity Optimizations

<table>
<thead>
<tr>
<th>Optimization</th>
<th>On during test?</th>
<th>Available in SU?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduplication</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Compression</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Thin provisioning</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Parity RAID</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Read-only delta snapshots</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Writeable delta snapshots</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Product Configuration - Controller(s)

- Part number: 1726-42X
- Dual controller on rack mountable cabinet that includes
  - 2
  - 700 MB (base 2 arithmetic)
- RAID levels: 0, 1, 5, 10
- Other: RAID 5
- Supported I/Os/container: 8
- Supported I/Os/controller: 8
- Bing enabled: yes

Product Configuration - Cabinet(s)

- Part number: 1727-01X
- 2u fits on for 1u
- Cabinet W x D x H: 44.7 x 55.0 x 8.7 cm
- Cabinet maximum weight: ~27 kg
- Nominal voltage input: 208 Vac
- Phase: 60
- Number of UPS units: 0
- Remote power monitoring: no
- Remote temperature monitor: no
- Ventilation: Fan forced air (variable speed)
- Other detail (optional):
SNIA Emerald™ Program

- Open, public web-based repository location for SNIA Emerald™ Program Test Data Reports based on SNIA Measurements Specification
  - The report includes information related to system power including system configuration details such as storage device types, RAS features and their configuration, and power supply types.
- Easily identifiable program logo
- Voluntary, low cost program for manufacturers
  - Options to self-measure or third party measurement
  - No SNIA membership required
- Free to download the specifications, user guides, and test data report access
- The report data can help IT professionals make storage platform selections as part of an overall Green IT and Sustainability objective.
- Sign up for the mailing list: www.SNIAEmerald.com
Program Participants and Test Sponsors

- Manufacturers of Storage Systems
- Resellers/OEMs of Storage Systems
- Professional Services
  - Independent Testing Labs
  - Test Auditors

Consumers of SNIA Emerald Test Data Reports

- IT Decision Makers
- Manufacturers of Storage Systems
- National bodies focused on Green IT initiatives
Thank You

www.snia.org
www.snia.org/green
www.sniaemerald.com

VISIT SNIA in the SNW Event Foyer