Energy Efficiency Metrics for Storage

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Outline

- Energy Efficiency Basics
  - Tutorial; (work done/ power consumed)
- Storage Performance Council
  - Summary & sample HP data
- SNIA EMERALD™
  - Summary, predictions, and sample HP data
- EPA Energy Star™ for Data Center Storage
  - Expected requirements for V1.0
- TGG – DCsE (operational metrics)
  - Summarize TGG white paper
  - Use case: tiered storage COM
- Summary compare and key benefits of Metrics
Energy Efficiency Basics

- Energy efficiency
  (Useful work done / Power consumed)
- Storage useful work
  - Ready idle: Capacity
  - Active: IOs/sec, Throughput
- Storage energy efficiency metrics
  - GB/watt
  - IOPs/watt
  - MBPS/watt
SPC-1/E™

SPC Benchmark 1/Energy™ (SPC-1/E™) is an extension of the first industry standard storage benchmark, SPC Benchmark 1™. SPC-1™ is based on an exchange workload.

SPC-2/E™

SPC-2/E™ incorporates the SPC Energy Extensions into the sequential workloads of SPC-2™. The SPC-2™ Workload is comprised of large block reads, writes and combinations thereof in addition to a Video on Demand Workload.
Sample SPC data

HP EVA P6400 Power/Performance Profile

Power, watts

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5 5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9 6 6.1 6.2 6.3 6.4

0:00 0:10 0:20 0:30 0:40 0:50 1:00 1:10 1:20 1:30 1:40 1:50 2:00 2:10 2:20 2:30 2:40 2:50 3:00 3:10 3:20 3:30 3:40 3:50 4:00 4:10 4:20 4:30 4:40 4:50 5:00 5:10 5:20 5:30 5:40 5:50 6:00 6:10 6:20 6:30 6:40

Power, W
cndtn - 475.24 w, 16751.02 IOPS
Idle-L - 463.09 w
rcvry - 463.54 w, 1701.72 IOPS
sustain - 475.05 w, 16751.87 IOPS
r100 - 475.04 w, 16741.16 IOPS
r95 - 474.38 w, 15907.01 IOPS
r90 - 473.91 w, 15060.81 IOPS
r80 - 472.87 w, 13402.02 IOPS
r50 - 468.83 w, 8351.11 IOPS
r10 - 463.85 w, 1651.13 IOPS
rp1-10 - 463.89 w, 1649.38 IOPS
rp1-100 - 475.03 w, 16767.28 IOPS
rp2-10 - 463.86 w, 1651.02 IOPS
rp2-100 - 474.94 w, 16739.73 IOPS

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Sample SPC data (continued)

HP EVA P6400 Power/Performance Table

SPC-1/E Reported Data
The initial SPC-1/E energy extension temperature, recorded during the first one minute of the Idle Test was 81.50F. The final SPC-1/E energy extension temperature, recorded during the last one minute of the Primary Metrics Test was 82.64F.

<table>
<thead>
<tr>
<th>Usage Profile</th>
<th>Hours of Use per Day</th>
<th>Nominal Power, W</th>
<th>Nominal Traffic, IOPS</th>
<th>Nominal IOPS/W</th>
<th>Nominal Heat, BTU/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy</td>
<td>Moderate</td>
<td>Idle</td>
<td>227.85</td>
<td>3333.14</td>
</tr>
<tr>
<td>Low Daily Usage</td>
<td>0</td>
<td>8</td>
<td>16</td>
<td>231.49</td>
<td>8499.58</td>
</tr>
<tr>
<td>Medium Daily Usage</td>
<td>4</td>
<td>14</td>
<td>6</td>
<td>235.84</td>
<td>14499.49</td>
</tr>
<tr>
<td>High Daily Usage</td>
<td>18</td>
<td>6</td>
<td>0</td>
<td>231.73</td>
<td>8777.40</td>
</tr>
</tbody>
</table>

Composite Metrics:
- Annual Energy Use, kWh: 2029.93
- Energy Cost, $/kWh: 0.12
- Annual Energy Cost, $: 243.59

The above usage profile describes conditions in environments that respectively impose light (“low”), moderate (“medium”), and extensive (“high”) demands on the Tested Storage Configuration (TSC).
The SNIA EMERALD™ Program

- Provides a well-defined storage taxonomy and testing procedure, and public access to power efficiency data submissions

- Advocates using the Best Foot Forward (BFF) approach to identify and test optimized configurations that produce a set of peak power efficiency metrics for the test sequence
  - Random workloads [IOP/S/Watt]
  - Sequential throughput [MiB/S/Watt]
  - Idle Capacity [GB/Watt]

- Pending enhancements
  - Cache friendly / hotband workloads to replace uniform workloads
  - NAS filer workloads
Example Predictions: 128K Sequential Read, Write

SFF 15K rpm, RAID 5

Sequential Read

Peak Metric: 1.63 MB/S/Watt and 25 drives

Sequential Write

Peak Metric: 1.0 MB/S/Watt and 50 drives
Example Predictions:
Mixed workload 8K Random 70/30 R/W

SFF 15K rpm, RAID 5

Peak metric = 12.7 IOPS/Watt at 125 drives

Changing the read/write mix changed the metric but not the drive count
60/40 r/w = 11.5 IOPS/W; 80/20 r/w = 14.9 IOPS/W
Example Predictions: Ready-Idle

LFF 2TB 7.2K rpm and SFF 500GB 7.2K rpm drives at Ready-Idle
Sample Emerald data submission (Online 3: HP P6500)

Key Point: This data submittal represents a configuration tuned for producing the best Sequential metrics.
Emerald Enhancements: Data for cache friendly performance

HP Low & High End Array Products Comparison Chart

<table>
<thead>
<tr>
<th></th>
<th>Hot IOPS</th>
<th>Hot RT</th>
<th>Rnd IOPS</th>
<th>Rnd RT</th>
<th>C/WS ratio</th>
<th>Cache Hit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Array</td>
<td>4330</td>
<td>32.8 ms</td>
<td>4130</td>
<td>33.4 ms</td>
<td>&lt;&lt;</td>
<td>N/A</td>
</tr>
<tr>
<td>Large Array</td>
<td>1679</td>
<td>4.755 ms</td>
<td>844</td>
<td>9.47 ms</td>
<td>~26%</td>
<td>60%/24%</td>
</tr>
<tr>
<td>Large Array</td>
<td>16680</td>
<td>4.245 ms</td>
<td>7831</td>
<td>9.13 ms</td>
<td>~3%</td>
<td>60%/24%</td>
</tr>
</tbody>
</table>
ENERGY STAR™ Timeline for IT products

- **Enterprise Servers 1.0**, May 2009
- **Enterprise Servers 2.0***, July 2013
- **Data Center Storage 1.0**, Spec Oct 2012, Effective Jan 2013
- **UPS 1.0**, June 2012
- **Blade Servers****, Sept 2012
- **Displays 6.0***, Jan 2013
- **PCs 6.0***, Feb 2013
- **Imaging Equipment 2.0***, March 2013
- **3rd party Cert Testing**, Dec 30, 2010
- **Testing by Accredited Labs**, Nov 30, 2010
- **Process change**, Spec in
- **Process change**, Spec in
EPA Energy Star™ for Data Center Storage*

- Eligible product categories are low, mid, and high-end Online Arrays (Online 2, 3, 4)
- Requirements include checklist items (√) and data submissions
  - (√) Parity RAID, adaptive cooling, Silver-rated power supplies, power monitoring, x out of y Capacity Optimization Method (COM) features, online power modeler (optional)
  - Data for ready idle, sequential, and random “BFF” / optimal configuration. Eligible product SKU’s are within -20% to +5% size range (drive count) Rounding to nearest full draw is allowed for ≥ 150 drive count
  - Drive combinations are permissible, based on % allocation of multiple optimal configurations
  - Storage device replacement (upgrade) if similar energy efficiency performance
- V2.0 will use the data from V1.0 to establish the top 25% cut line
  - Will also include: cache-friendly active workloads for Online, NAS filers, expanded product categories

* Expectations, based on latest review of Draft 3, V1.0 Spec
In contrast to the other “Acquisition” metrics, the DCsE metrics are “Operational”

- The Capacity, Workload, and Throughput metrics are the same, but measurement and usage aspects differ.
- For DCsE, measurements are made in the data center under normal operation.
- For DCsE, each storage system must consider its taxonomy category and its use case.

These represent key performance indicators (KPI) that show storage system efficiency over time.

(*) Data Center storage Efficiency, per white paper by TGG and with SNIA collaboration
Case Study: Tiered Storage COM

- Description of the workload chosen for this case study
- Base-lining the performance using a single tier
- Re-running on the optimized tier structure
- Power/Performance benefit assessment
The SPC-1 workload was chosen for the case study as it satisfies 3 important criteria:

- The asymmetry of IO demand
  - Asymmetric IO Demand A.K.A. “hot spots” within subregions of the physical address space not application space
  - The location of these hot spots must persist long enough to monitor, move and most importantly, execute after migration
  - The relative demand of these regions must be sufficiently higher than that of the remainder of the space
- The benchmark configuration is precisely defined in terms of capacity requirements and the amount of physical space utilization (no short stroking)
- The stimulus is also precisely defined by the specification
Smart Tier Environment (HP P9500)

P9500 Single Tier Configuration
1 x DKC Module 0
2 x Processor Blade
2 x 16-port 8Gbps FC CHA
1 x SAS DKA
2 x Cache Memory Adapter
6 x 16GB Cache Memory Module
2 x Express Switch Adapter
128 x 146GB SAS 15K 2.5” HDD

P9500 Dual Tier Configuration
1 x DKC Module 0
2 x Processor Blade
2 x 16-port 8Gbps FC CHA
1 x SAS DKA
2 x Cache Memory Adapter
6 x 16GB Cache Memory Module
2 x Express Switch Adapter
104 x 146GB SAS 15K 2.5” HDD
8 x 400 GB SAS SSD
## Tiered Storage COM Benefit

### Power/Performance Comparison Points

<table>
<thead>
<tr>
<th></th>
<th>Single Tier</th>
<th>Dual Tier</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HDDs</strong></td>
<td>128 x 146GB SAS 15K rpm SFF (18688 GB total)</td>
<td>104 x 146GB SAS 15k rpm SFF + 8 x 400GB SSD (18384 GB total)</td>
<td>14 fewer drives (~ same)</td>
</tr>
<tr>
<td><strong>IOPS</strong></td>
<td>~35,000*</td>
<td>~61,000*</td>
<td>+74%</td>
</tr>
<tr>
<td><strong>Power Consumption (W)</strong></td>
<td>2453</td>
<td>2346</td>
<td>- 4.3%</td>
</tr>
<tr>
<td><strong>Power Efficiency (IOPS/W)</strong></td>
<td>14.27</td>
<td>26.0</td>
<td>+82%</td>
</tr>
</tbody>
</table>

*These are reference IOPS and may NOT be referred to as SPC-1 IOPS*
## Tiered Storage Impact on DCsE

<table>
<thead>
<tr>
<th></th>
<th>Single Tier</th>
<th>Dual Tier</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCsE, cap (idle capacity)</td>
<td>18688/1960* = 9.53 GB/W</td>
<td>18384/1870* = 9.83 GB/W</td>
</tr>
<tr>
<td>DCsE, io (active workload)</td>
<td>35000/2453 = 14.27 IOPS</td>
<td>61000/2346 = 26.0 IOPS</td>
</tr>
</tbody>
</table>

- The active workload metric is the relevant KPI for the tiered storage COM implementation

* Idle power derived from Power Calculator
## Summary Metrics Comparison

<table>
<thead>
<tr>
<th>Effective</th>
<th>Strengths – Key Benefits</th>
</tr>
</thead>
</table>
| SPC 1/E, 2/E  | **2010, 2012** Industry Standard - accepted workload & benchmark  
Precise, tightly controlled run rules (audited for accuracy)  
Benchmark produces both power/performance metrics & annual operating cost |
| Emerald       | **Oct 2011** Defined storage Taxonomy  
Documented test procedures/specification  
Database for energy-conscious Users  
Being leveraged by Energy Star |
| Energy Star   | **Jan 2013** World-wide recognized brand  
Will become a US government lockout on RFP’s  
The Europeans may require it more broadly, e.g., required as part of EPEAT |
| DCsE          | **Future** Potential for smart Data Center |
References

Storage Performance Council
http://www.storageperformance.org/home/

SNIA Emerald Program
http://sniaemerald.com/

EPA Energy Star Program
http://www.energystar.gov/index.cfm?c=new_spec_s.enterprise_storage

The Green Grid
http://www.thegreengrid.org/home
Thank You

Questions?

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