SPC-1/E and SPC-1C/E

Storage Performance Benchmark

with Energy Use Extensions

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EPA Stakeholders Meeting
15 October 2009

EPA Stakeholders Meeting

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SPC Overview

The Storage Performance Council (SPC) is a vendor-neutral standards body focused on the storage industry. The SPC has created a suite of benchmarks and benchmark energy extensions targeted at the needs and concerns of the storage industry.

SPC benchmark results provide a source of comparative storage performance and energy use information that is objective, relevant, and verifiable.

That information provides value through the storage product lifecycle, which includes development of product requirements, product implementation, performance characterization, capacity planning, market positioning and purchase evaluations.

SPC Overview

SPC benchmarks are designed to be vendor and platform independent and are applicable across a broad range of storage configurations and topologies.

Any SPC member can sponsor and publish an SPC benchmark result, provided the tested configuration satisfies the requirements of the appropriate SPC benchmark specification or energy extension.

SPC Value Proposition

- SPC benchmark results provide in-depth quantitative performance and energy use information across a broad spectrum of storage configurations.
- SPC benchmark results are used by end-users, industry analysts and vendors.
  - Product development
  - Product positioning and competitive comparisons
  - Purchase decisions

SPC Benchmarks and Extensions

- To date, the SPC has released four benchmark specifications and two benchmark energy extensions with 140+ results.
  - SPC-1, SPC-2 *(OLTP and sequential)*
  - SPC-1C, SPC-2C *(component-level versions)*
  - SPC-1C/E, SPC-1/E *(energy extensions to SPC-1 and SPC-1C)*
  - SPC-3 *(in development)*
  - See http://www.storageperformance.org/results for more information on each benchmark specification/extension

SPC Member Companies

SPC Member Companies

SPC Benchmark Development

- SPC Specification
  - Define the benchmark context based on real world workloads and valid end-user assumptions.
  - Define configuration constraints to ensure realistic configurations and prohibit “benchmark specials”
  - Define the workload(s) for the benchmark
  - Specify benchmark execution, measurement, data collection, and reporting requirements
  - Develop an SPC Toolkit to implement the above
  - Final testing and validation of workload and toolkit
  - Specify audit, disclosure, and peer-review requirements

SPC Result Production

- SPC Required Audit
  - Test Sponsor *(SPC member company)* preparation:
    - Pre-Audit and Audit checklists
    - Pre-Audit measurements and review
  - Audit ensures compliance with the benchmark specification for consistency and comparability
    - Valid configuration
    - Correct execution, measurement, data collection, and reporting
    - Full disclosure of all components in the benchmark configuration and the entire set of benchmark activities
      - » The Full Disclosure Report (FDR) contains sufficient detail to duplicate the complete tested configuration and reproduce the SPC Result.

SPC Result Production

- SPC Full Disclosure Report (FDR) and Public Use Requirements
  - Transparency
  - Consistency
  - Completeness
  - Comparability

SPC Energy Extensions

- SPC-1/E and SPC-1C/E Goals
  - Address the need for energy use measurement and reporting in addition to storage performance measurement and reporting.
  - Develop each extension using existing benchmark specifications: SPC-1 and SPC-1C.
  - Use identical measurement, data collection and reporting requirements for each extension.
  - Quantify storage performance and energy use without constraining technologies/implementations.

SPC-1/E and SPC-1C/E Details

- Common elements:
  - SPC approved power meter/analyzer
  - SPC developed tools for data collection, synchronization, post-processing, and reporting
  - Execution profile
    - Single/multiple application idle states
    - Active/performance state *(SPC-1, SPC-1C measurements)*
  - Reporting and disclosure

SPC-1/E and SPC-1C/E Details

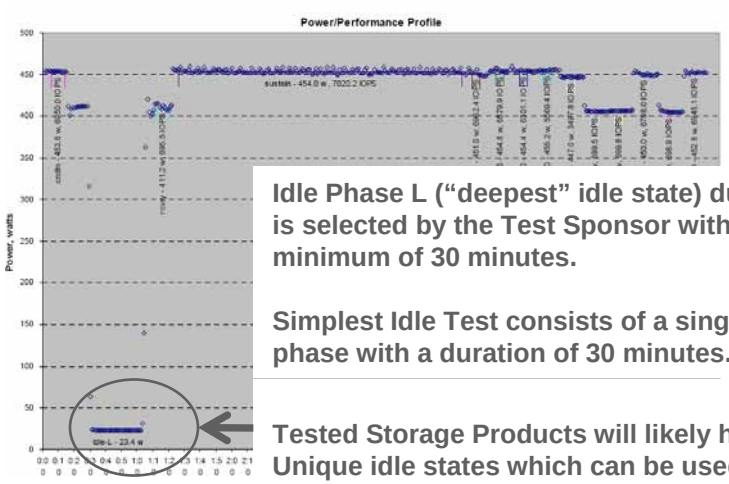
- SPC-1/E, SPC-1C/E execution profile:
  - A 10 minute “precondition” phase at 100% of the specified performance offered load.
  - An application idle phase lasting at least 30 minutes with one or more distinct phases.
  - Each application idle phase may be preceded by an optional transition period not to exceed 3 minutes.
  - A second 10 minute “precondition” phase at 10% of the specified performance offered load.
  - Execution of the current SPC-1, SPC-1C Tests: Metrics *(Sustainability, IOPS, Response Time Ramp),* Repeatability, and Persistence *(energy use measurements are not taken during the Persistence Test*

SPC-1/E and SPC-1C/E Details

- SPC-1/E, SPC-1C/E application idle phases:
  - More than one idle phase is allowed as long as transitions between idle phases do not require manual intervention. *Idle Phase 0, Idle Phase 1…Idle Phase L-1, Idle Phase L*
  - Idle Phase 0 thru Idle Phase L-1 must have the same duration, selected by the Test Sponsor, up to a maximum of 10 minutes.
  - Idle Phase L ("deepest" idle state) duration is selected by the Test Sponsor with a minimum of 30 minutes.
  - The simplest Idle Test consists of a single idle phase with a duration of 30 minutes.

SPC-1/E and SPC-1C/E Details

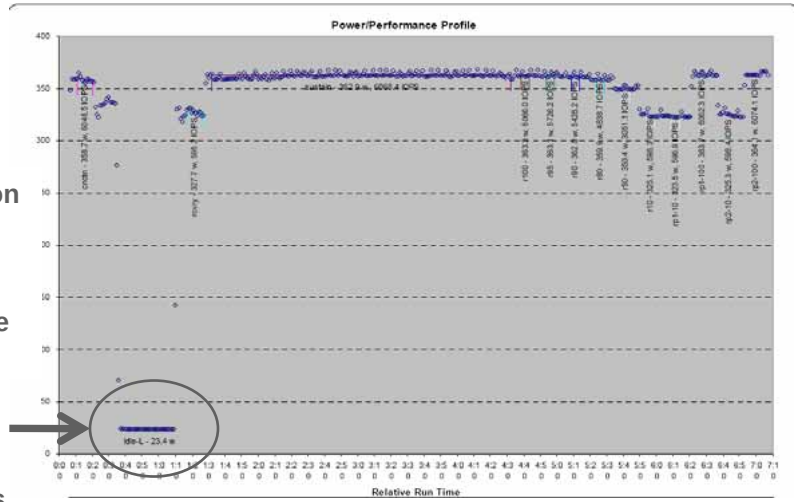
SPC-1/E, SPC-1C/E application idle examples:

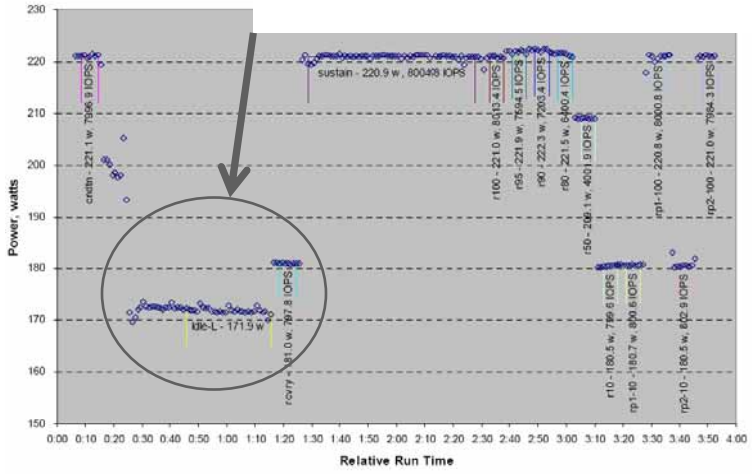


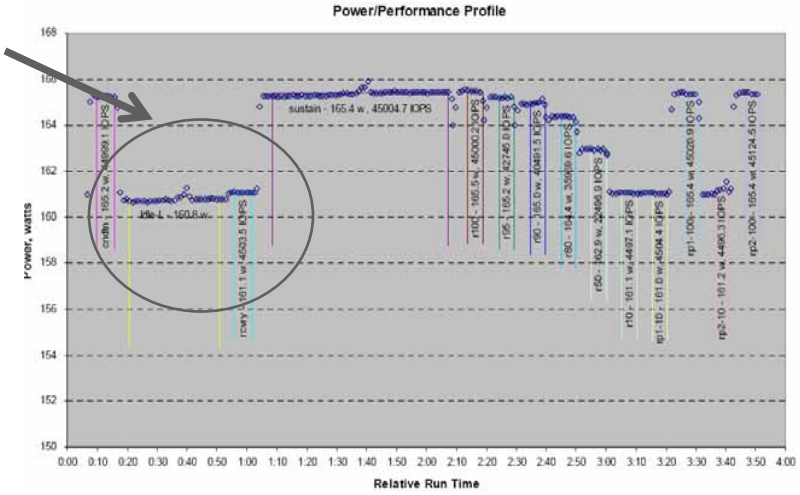
Idle Phase L ("deepest" idle state) duration is selected by the Test Sponsor with a minimum of 30 minutes.

Simplest Idle Test consists of a single idle phase with a duration of 30 minutes.

Tested Storage Products will likely have Unique idle states which can be used to highlight new energy saving technologies & techniques





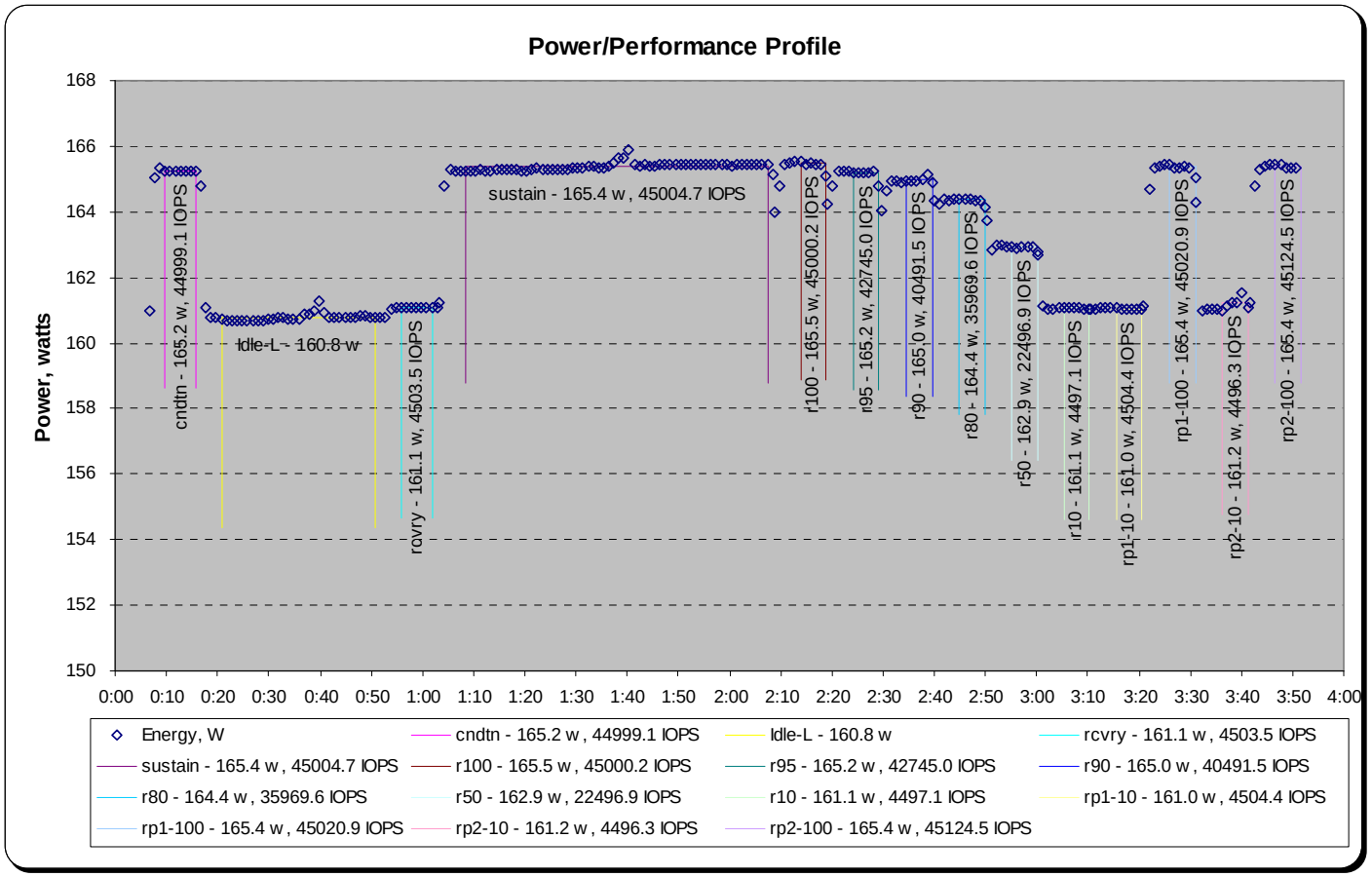


SPC Energy Data and Reporting

- Power and SPC-1 or SPC-1C IOPS are measured for each test segment
  - Application Idle Phase
    - Pre-condition 1, application idle, and pre-condition 2
  - Active/Performance Phase:
    - Each SPC-1 / SPC-1C Test Run
  - The measured data is presented in a graph that illustrates the entire measurement sequence.

SPC Energy Data and Reporting

- Example of SPC-1/E, SPC-1C/E required graph



SPC Energy Data and Reporting

- SPC Energy metrics calculated using measured data.
  - Daily use
  - Average annual use and cost
- Daily use metrics describe average I/O traffic (SPC IOPS) and related energy use.
  - Across three selected conditions: Low, Medium, and High daily usage
  - Taking into account hourly variations in application load: Heavy (80%), Moderate (50%), and Idle (0%)

SPC Energy Data and Reporting

- Daily Use Metrics
  - For each of the three daily usage patterns: *(Low/Medium/High Daily Usage)*
    - Nominal Power (W), Nominal Traffic (IOPS), Nominal IOPS/W, Nominal Heat (BTU/hr)
  - Same metrics reported as a composite of all three daily usage patterns.
- Average Annual Metrics:
  - Annual Energy Use in kWh
  - Annual Energy Cost
    - The $0.12/kWh was selected as a reasonable value for the U.S. and to provide consistency and comparability

SPC Energy Data and Reporting

- SPC-1/E, SPC-1C/E Reported Data :
  - Items highlighted in red have been added to the reporting requirements since the initial release of SPC-1C/E

Power Environment

Average RMS Voltage: 206.64 **Average Power Factor:** 0.832

Usage Profile

	Hours of Use per Day			Nominal	Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W	Heat, BTU/hr
Low Daily Usage:	0	8	16	**164.58**	**1165.93**	**7.08**	**561.56**
Medium Daily Usage:	4	14	6	**342.46**	**2968.61**	**8.67**	**1,168.51**
High Daily Usage:	18	6	0	**453.15**	**5051.52**	**11.15**	**1,546.18**
			Composite Metrics:	**320.06**	**3,062.02**	**9.57**	

Annual Energy Use, kWh: 2,803.75

Energy Cost, $/kWh: $ 0.12 **Annual Energy Cost, $:** $ 336.45

AVERAGE RMS VOLTAGE: The average supply voltage applied to the Tested Storage Product (TSP) as measured during the Measurement Intervals of the SPC-1/E Tests.

AVERAGE POWER FACTOR: The ratio of average real power, in watts, to the average apparent power, in volt-amps flowing into the Tested Storage Product (TSP) during the Measurement Intervals of the SPC-1/E Tests.

NOMINAL HEAT, BTU/HR: The average amount of heat required to be dissipated over the course of a day *(24 hours)*, taking into account hourly load variations. *(1 watt = 3.412 BTU/hr)*

SPC Energy Data and Reporting

- SPC-1/E, SPC-1C/E Reported Data *(continued)*:

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SPC-1/E Reported Data

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).

HEAVY SPC-1 Workload: 455.19W at 80% of maximum reported performance *(5,569.43 SPC-1 IOPS)*.

MODERATE SPC-1 Workload: 447.01W at 50% of maximum reported performance *(3,497.79 SPC-1 IOPS)*.

IDLE SPC-1 Workload: 23.37W at 0% of maximum reported performance *(0.00 SPC-1 IOPS)*.

LOW DAILY USAGE: Zero (0) hours of HEAVY SPC-1 Workload, eight (8) hours of MODERATE SPC-1 Workload, and sixteen (16) hours of IDLE SPC-1 Workload.

MEDIUM DAILY USAGE: Four (4) hours of HEAVY SPC-1 Workload, fourteen (14) hours of MODERATE SPC-1 Workload, and six (6) hours of IDLE SPC-1 Workload.

HIGH DAILY USAGE: Eighteen (18) hours of HEAVY SPC-1 Workload, six (6) hours of MODERATE SPC-1 Workload, and zero (0) hours of IDLE SPC-1 Workload.

SPC Energy Data and Reporting

- SPC-1/E, SPC-1C/E Reported Data*(continued)*:

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NOMINAL POWER, W: The average power consumption over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL TRAFFIC, IOPS: The average level of I/O requests over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL IOPS/W: The overall efficiency with which I/O requests can be supported, reflected by the ratio of **NOMINAL TRAFFIC** versus the **NOMINAL POWER**.

COMPOSITE METRICS: The aggregated **NOMINAL POWER**, **NOMINAL TRAFFIC**, and **NOMINAL IOPS/W** for all three environments: **LOW**, **MEDIUM**, and **HIGH DAILY USAGE**.

ANNUAL ENERGY USE, kWH: An estimate of the average energy use across the three environments over the course of a year and computed as (**NOMINAL POWER** * 24 *0.365).

ENERGY COST, $/kWH: A standardized energy cost per kilowatt hour.

ANNUAL ENERGY COST: An estimate of the annual energy use across the three environments over the course of a year and computed as (**ANNUAL ENERGY USE** * **ENERGY COST**).

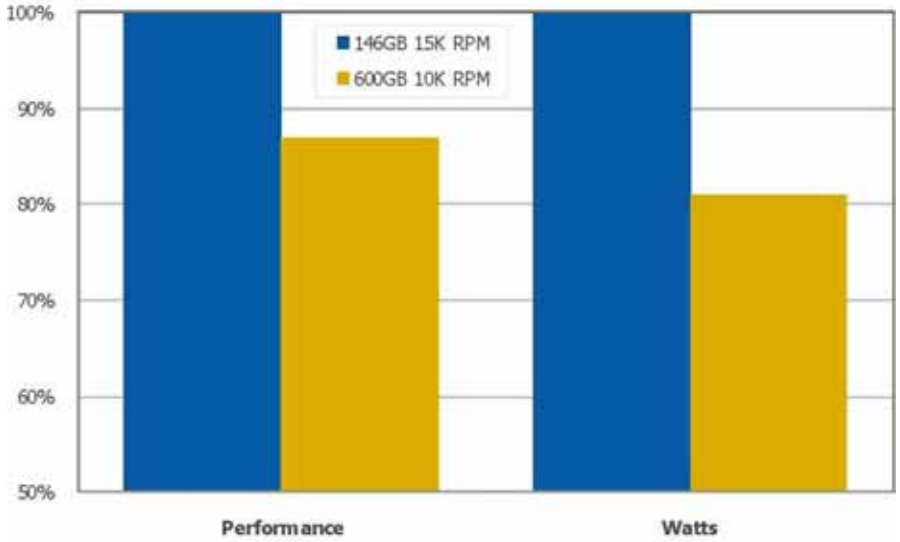
SPC Energy Data and Reporting

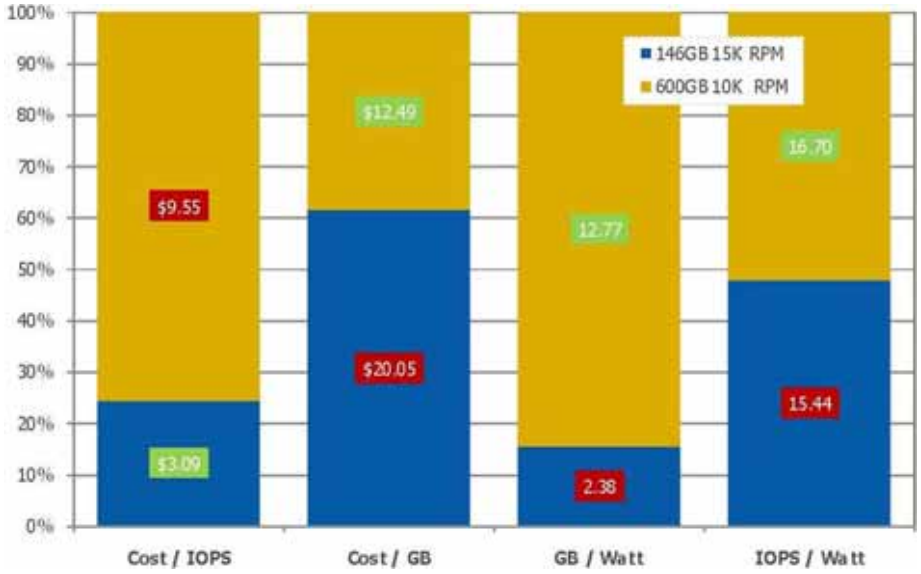
- IDEAS International has produced an in-depth analysis in a research paper and two blogs using SPC-1C/E and SPC-1E reported data.
  - SPC-1C/E *(blog)*:
    "Performance & Energy Shootout – SSDs vs. Traditional Disks"
    http://ideasint.blogs.com/ideasinsights/2009/06/performance-energy-shootout-ssds-vs-traditional-disks.html
  - SPC-1/E *(blog and research paper)*:
    "What are the Performance & Energy Tradeoffs of 15K vs. 10K RPM Disk Drives?"
    http://ideasint.blogs.com/ideasinsights/2009/10/what-are-the-performance-energy-tradeoffs-of-15k-vs10k-rpm-disk-drives.html

    "Energy and Performance Come Together with Storage Benchmarking"
    http://www.ideasinternational.com/misc/msc050.aspx?id=dc403bb8-d218-4204-88c2-25a514cefd71

SPC Energy Data and Reporting

- Comparison graphs from the IDEAS International's SPC-1/E research paper:





SPC-1/E and SPC-1C/E Details

- Differences
  - Storage configuration constraints
    - SPC-1C/E: *Small Storage Configuration only*
      - » *48 storage devices maximum, maximum total 4U enclosure*
    - SPC-1/E:
      - » *any SPC-1 configuration that can be measured with a single approved power meter/analyzer*
  - Offered load granularity
    - SPC-1/E: ~50 I/O Request increments
    - SPC-1C/E: ~5 I/O Request increments

SPC-1/E and SPC-1C/E Details

- Differences
  - Measurement Interval duration
    - SPC-1:
      - 3 hour Sustainability
      - 10 minutes for all other Tests
    - SPC-1C:
      - 1 hour Sustainability
      - 5 minutes for all other Tests

Issues, Decisions, Rationale

- **Q: Do energy measurements require performance measurements**
  - Idle measurements alone will not meet the needs for product development, product positioning, and competitive comparison.
  - Idle measurements alone do not provide enough information for purchase decisions.
  - Successful benchmarks will drive design, features, and development resulting in benefits to customers
- **A: Energy measurements must be combined with a realistic performance workload to ensure applicability and adoption by the industry.**

Issues, Decisions, Rationale

- **Q: Developing an Energy Benchmark: Adopt, Extend, or Build?**
  - SPC development is historically evolutionary
  - Proven workloads and processes already in place and accepted
  - SPC benchmark architecture allowed new requirements to be added to match a new measurement need
- **A: Extending existing SPC benchmarks was most timely and resource-effective alternative.**

Issues, Decisions, Rationale

- **Q: Which SPC Benchmarks should be extended ?**
  - SPC-1, SPC-1C covers the broadest range of applications
    - OLTP, database applications, email server applications
  - SPC-1, SPC-1C are well understood, in significant use for development and purchase decisions.
  - SPC-1C would allow an incremental approach starting “small”
- **A: Start with SPC-1C to allow an incremental approach of “start small, learn, then scale” utilizing the broad applicability and significant use of the SPC-1C** *(SPC-1)* **workload.**

Issues, Decisions, Rationale

- **Q: How to collect and synchronize performance and energy data ?**
  - Consistent data collection across all approved power meters/analyzers is a required base for comparability
  - Energy data and performance data, which is collected separately, has to be synchronized to produce a unified report of the configuration's behavior.
- **A: Energy data collection uses required meter/analyzer settings. An SPC developed tool synchronizes performance and energy data, utilizing Host System timestamps present in both sets of collected data.**

Issues, Decisions, Rationale

- **Q: One reported metric, a few, or many?**
  - A more complete set of metrics will serve the largest set of consumers.
  - Consumers should be able to “pick and chose” metrics to meet their varying needs.
  - Simple, easy to state versus more detail, requiring careful consideration for appropriate use
- **A: Measure, calculate, and report a sufficient number of metrics to allow consumers to select those of interest to meet varying needs. Provide guidelines and descriptions to assist in appropriate use.**

Issues, Decisions, Rationale

- **Q: Energy Results:**
  Configuration or Product based?
  - There are significant energy use differences in the same product with different configuration options.
  - Referencing the SPC energy result to the product, rather than the configuration, will lead to inappropriate conclusions
  - The two Xiotech SPC-1/E Results offer a clear example.
- **A: SPC energy results are specific to the product's tested configuration. Public references must reference the key configuration components as well as the product.**

Configuration vs. Product

- Xiotech Emprise Performance 5000:
  - 146 GB, 15K RPM, 3.5” disk drives
- Xiotech Emprise Capacity 5000:
  - 600 GB, 10K RPM, 3.5” disk drives
- Identical products with the exception of the disk drives.
- 600 GB configuration used 20% less energy when compared to the 146 GB configuration and provided 88% of the performance.

SPC Future Development

- SPC-1/E future investigations/development:
  - Expanding SPC-1/E to use multiple power meters/analyzers.
    - Will begin testing later in the year with two power meters/analyzers with larger, more complex storage configurations.
    - Investigate the use of multiple power meters/analyzers to measure specific components as well the complete configuration.

SPC Future Development

- Energy use extension for SPC-2/SPC-2C
  - Will begin testing later this year or early 2010 to determine which of the three SPC-2/SPC-2C workloads (Large File Processing, Large Database Query, and Video on Demand) would be appropriate for inclusion in an energy use extension.

SPC Future Development

- An end-user tool for SPC-1/E and SPC-1C/E is under investigation, which would allow "customization/localization" of benchmark extension's Reported Data by:
  - Allowing the end-user to change values in the "Hours of Use per Day" matrix to reflect actual or projected values..
  - Use local energy cost for calculating "Annual Energy Use *(kWh)*.

SPC Future Development

- The end-user tool will allow changes to the values highlighted in **red**, which will reflect actual or projected usage values. All other values are either calculated by the tool or extracted by the tool from the SPC-1/E – SPC-1C/E Result of interest.

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