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Power Management in Storage Systems

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Outline

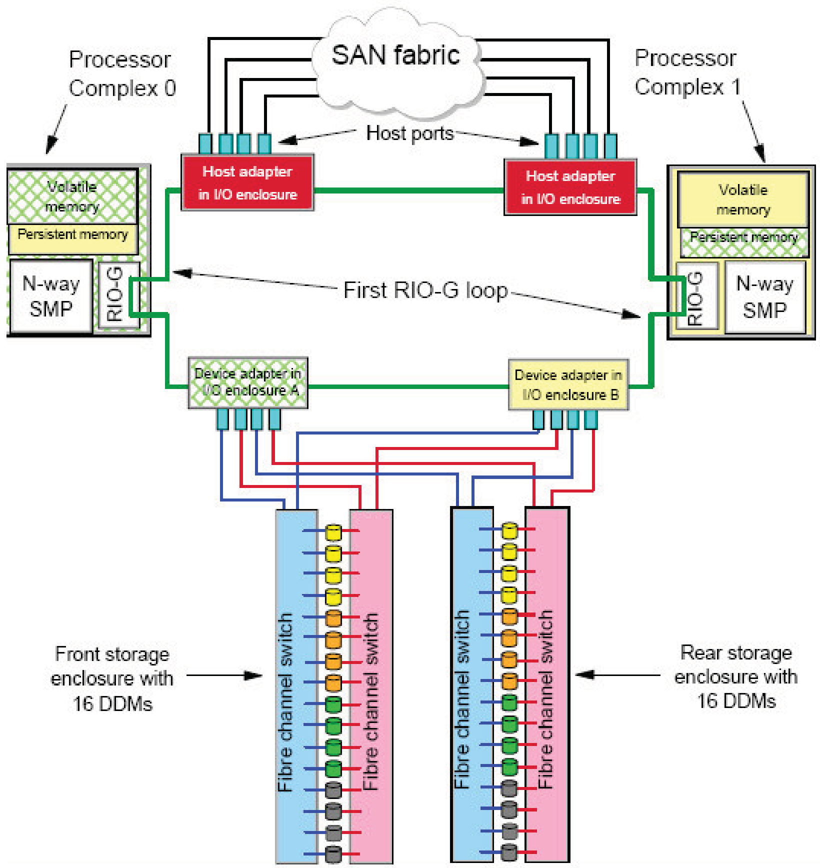
- Power Consumption Background in Data Centers and Storage Systems
- Power Management Strategies for Storage Systems
- Power Management Metrics
- Impact of Server Power Management Strategies on Storage Systems

Storage Consumption Constantly Increasing

- More types of information are being digitized and stored persistently (emergence of newer types of applications)
- Data is being stored persistently for longer periods of time (for legal and sentimental reasons)
- More people are persistently storing their information (computer usage globally is increasing)

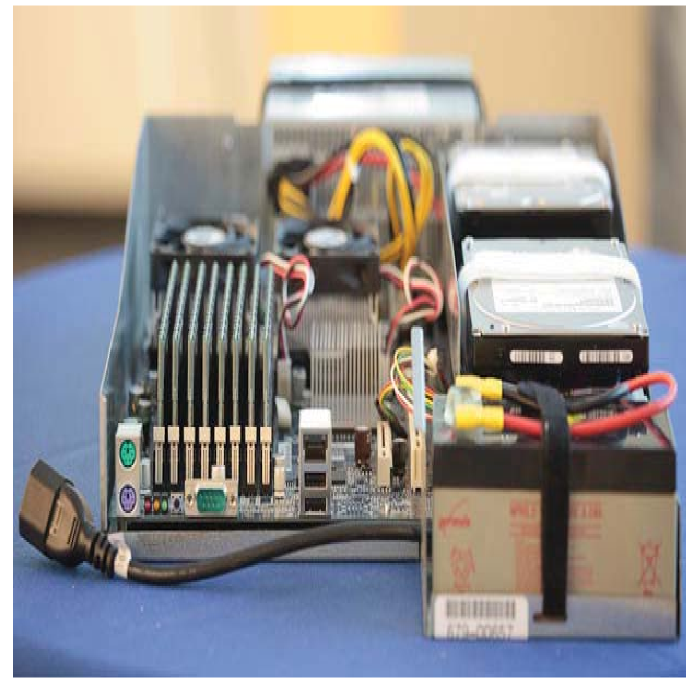
What is a Storage Controller?

Traditional Storage Controller



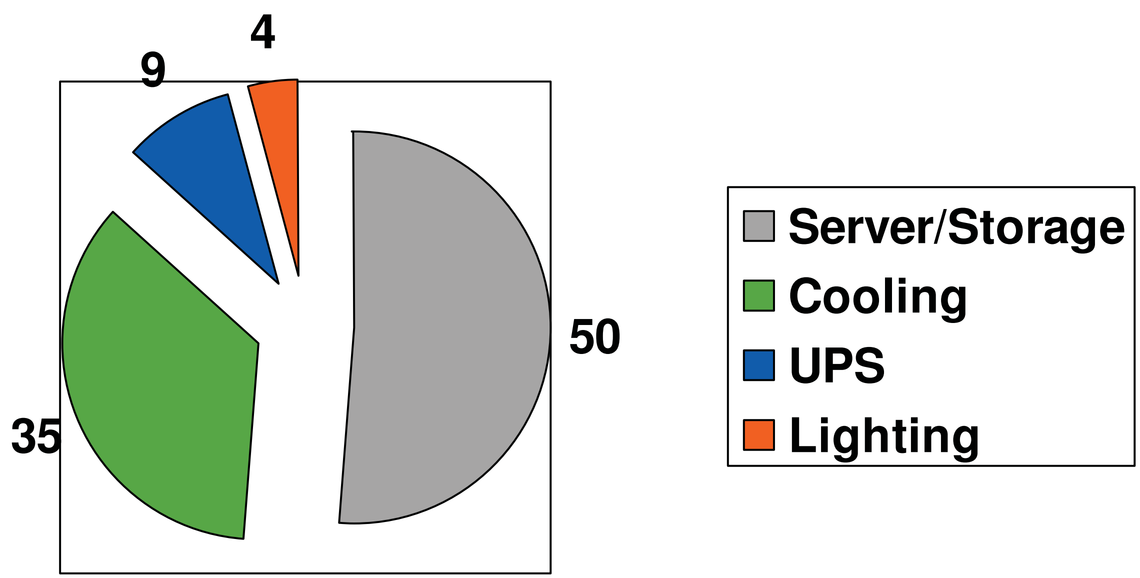
Source: IBM Redbook DS8000

Cluster of thousands of Google Servers



Source: CNET News April/2009

Where Does the Power Go in a Data Center?

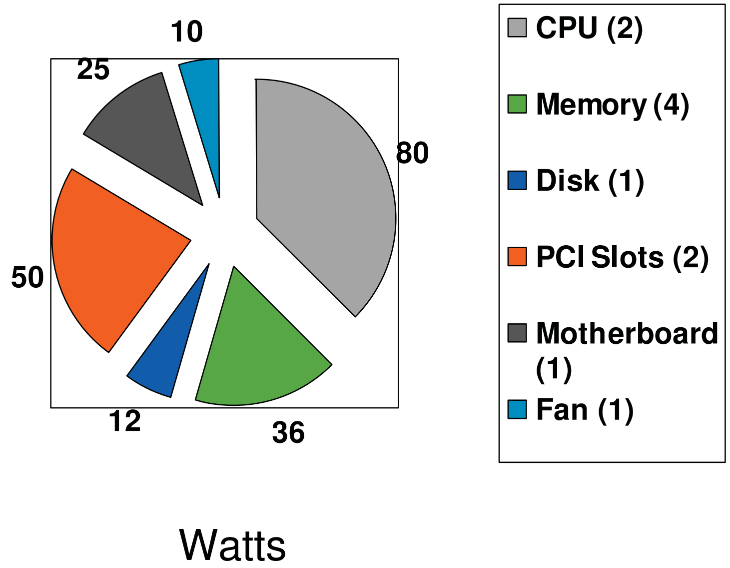


Percentages

Source: IDC Report 2008

Where Does the Power Go in a Storage Controller?

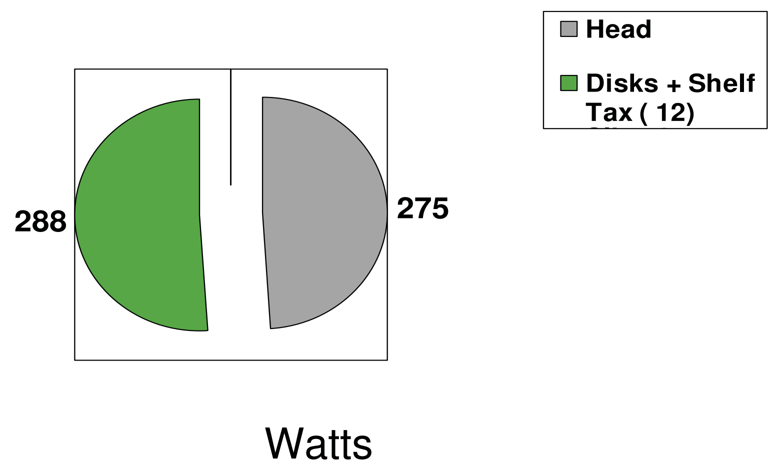
Google Box Power Consumption



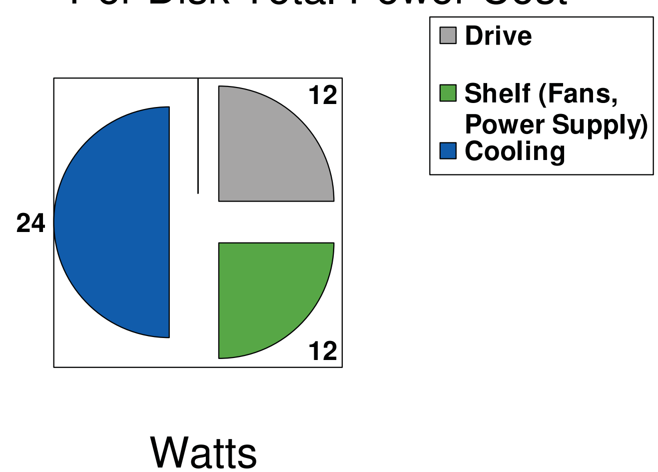
Source: Google Paper, ISCA 2007

Source:NetApp Internal Study

Storage Controller Box Consumption



Per Disk Total Power Cost



Storage Power Management Strategies

- Hardware
  - Can select the appropriate storage architecture
  - Can select the appropriate storage system
  - Can select the appropriate hardware features
- Software
  - Storage Efficiency
  - Migration and Spinning/Shutting Disks Down

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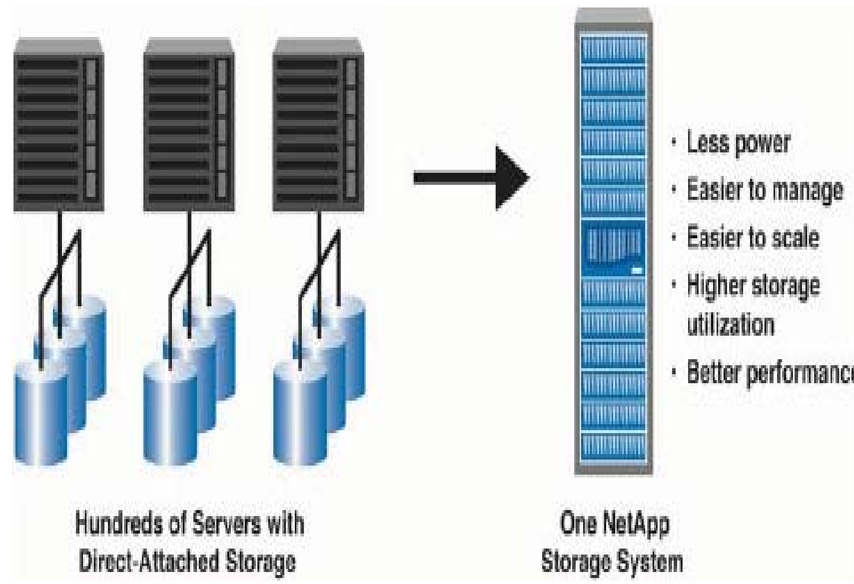
Power Management Strategies (Hardware)

- Hardware Techniques
  - Architectural Level
    - DAS versus Storage Controllers
    - Single Node Battery versus UPS Technology
  - Storage Box Level
    - Disks versus SSDs
    - Efficient Power Sources
    - Use of higher capacity disks
    - Use of lower RPM disks

DAS versus Storage Controllers

- DAS Storage
  - Application and storage are co-located
  - Power consumption is efficient if box is used tc run applications (e.g. m reduce applications)
  - Power consumption is r efficient if the cluster nodes are only used to serve storage
  - Low powered shared-nothing nodes are being proposed for archival storage (Pergamum work from UC Santa Cruz)



Single Node Battery Versus Centralized UPS

- Large UPSs can reach 92 to 95 percent efficiency at full load
  - Operating at lower load results in inefficiency which results in the generation of heat
  - Need cooling to remove the heat from the data center
- By having 12 volt battery at each of the storage nodes, Google is able to get 99.9 percent efficiency

Source: CNET.com Article on Google, April, 2009

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Efficient Power Supply

Source: NetApp Internal Study

- Want Power Supplies that are Efficient for a wider range of load
  - These cost more
  - But offer savings in power consumption due to less heat generation (less cooling required)
- If there are multiple Power Supplies usually each one is run at lesser load, and thus, has higher inefficiency

Load	Less Efficient Power Supply (Efficiency)	More Efficient Power Supply (Efficiency)
10 % Load	50 % Eff	80% Eff
50 % Load	75% Eff	80% Eff
100 % Load	75% Eff	90% Eff

Higher Capacity Disks

Source: NetApp White Paper: WP 7010-0207

	Old Systems	New Systems	Improvement
# of systems	11 Old Systems: 4 F880 3 F810 2 F820 1 F825 1 F840	1 FAS 3020 with 3 disk shelves	11:1
Power* (kW HRs) * Does not include power for cooling.	113,651	20,915	81% Decrease
Space (Cubic Feet)	63.0	4.3	93% Decrease
Capacity (GBs)	9,776	14,000	16% Increase

Power Management Strategies (Software)

- Software Techniques
  - Storage Efficiency
    - Reduce overhead per amount of usable storage
    - Efficient Copies
    - Data De-duplication/Compression
    - Thin Provisioning
    - Number of copies
    - Protection Mechanism
  - Migration and disk shutdown/spin-down

Storage Efficiency Techniques

Source: Oliver Wyman Article, Dec 2007
"Making Green IT a Reality"

- Reducing Storage Overhead
- Thin Provisioning
- Efficient Protection Mechanisms
- Consolidation of Protocols
- Efficient Copies
- De-duplication/Compression

Capability	Benefits
Snapshot	20% storage overhead compared to 100% for full copies or BCV
Thin Provisioning (FlexVol)	20% - 33% savings by growing and shrinking volume sizes on demand
RAID 6 Implementation (RAID-DP™)	14% - 17% overhead compared to 100% for RAID 1

Capability	Benefits
Multi-protocol (Unified Storage) & FC/SATA Drives	2-3x savings if running multiple protocols with low util rates; up to 50% savings with SATA instead of FC
Multiple Writeable Snapshot Copies (FlexClone®)	Up to 66% savings if creating five copies of original data compared to BCV or full copies
Deduplication	10% - 80% space savings depending on data set

Disk Spin-down/Shut-down Techniques

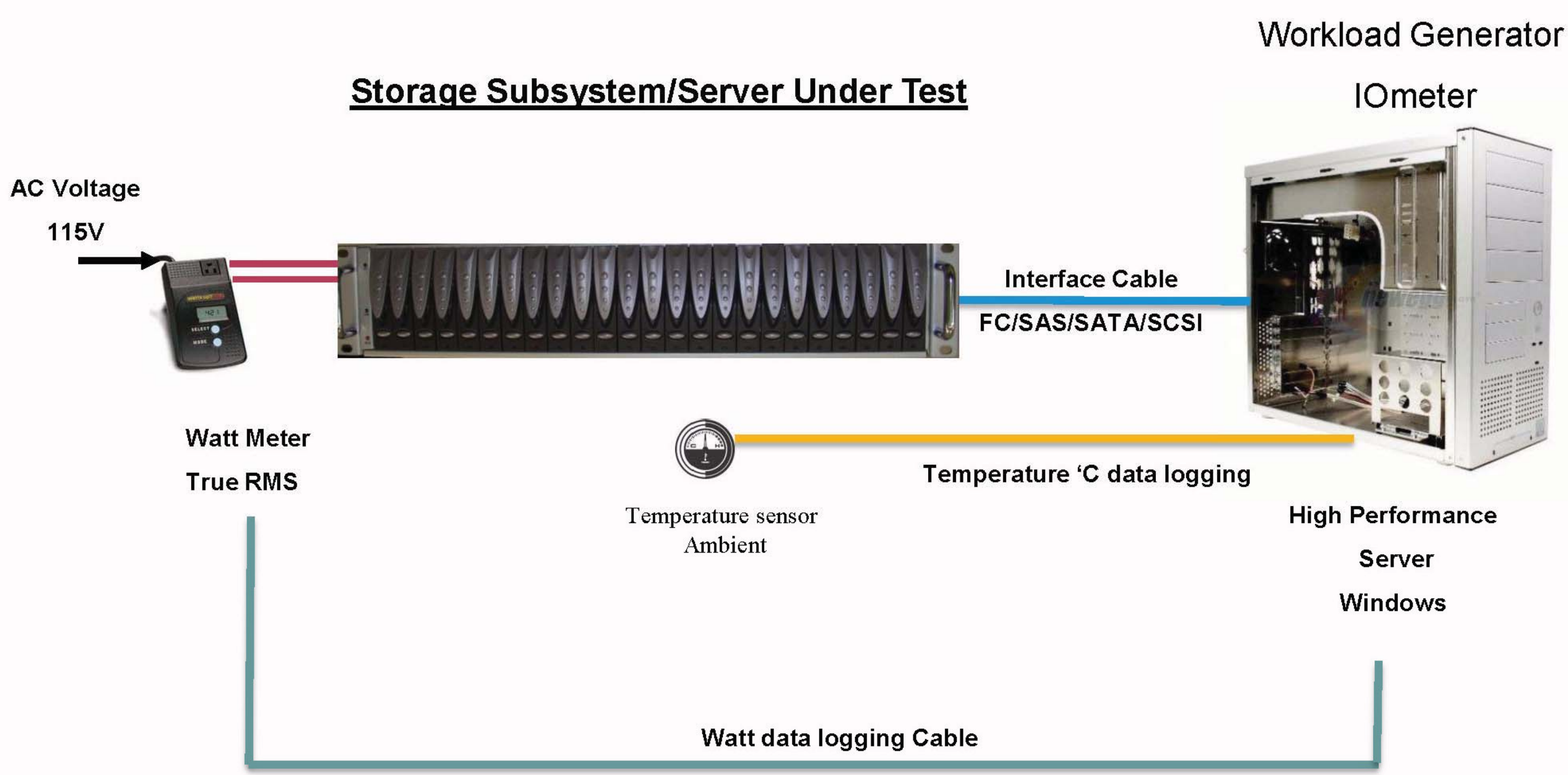
- Migrate less accessed data to lower tiers of storage and shut-down disks
- Archival data can be stored on disks that are shut down because of write-once and read-maybe properties
- Difficult to shut-down disks for those applications that have strict latency requirements and have long-tailed distribution access patterns
- Spinning things down to lower RPM and then spinning them up is difficult because constant spinning up disks can actually result in higher power consumption
- COPAN has shown roughly 5x times power savings compared to normal storage controllers in cases where things can be shut down.
  - Very dense packaging than traditional storage controllers
  - Keeps application meta-data in cache
  - Spins disks down but keeps the electronics up

SNIA Green Storage Initiative Device Classification

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

SNIA Configuration & Workload Example

Configuration & Workload Example



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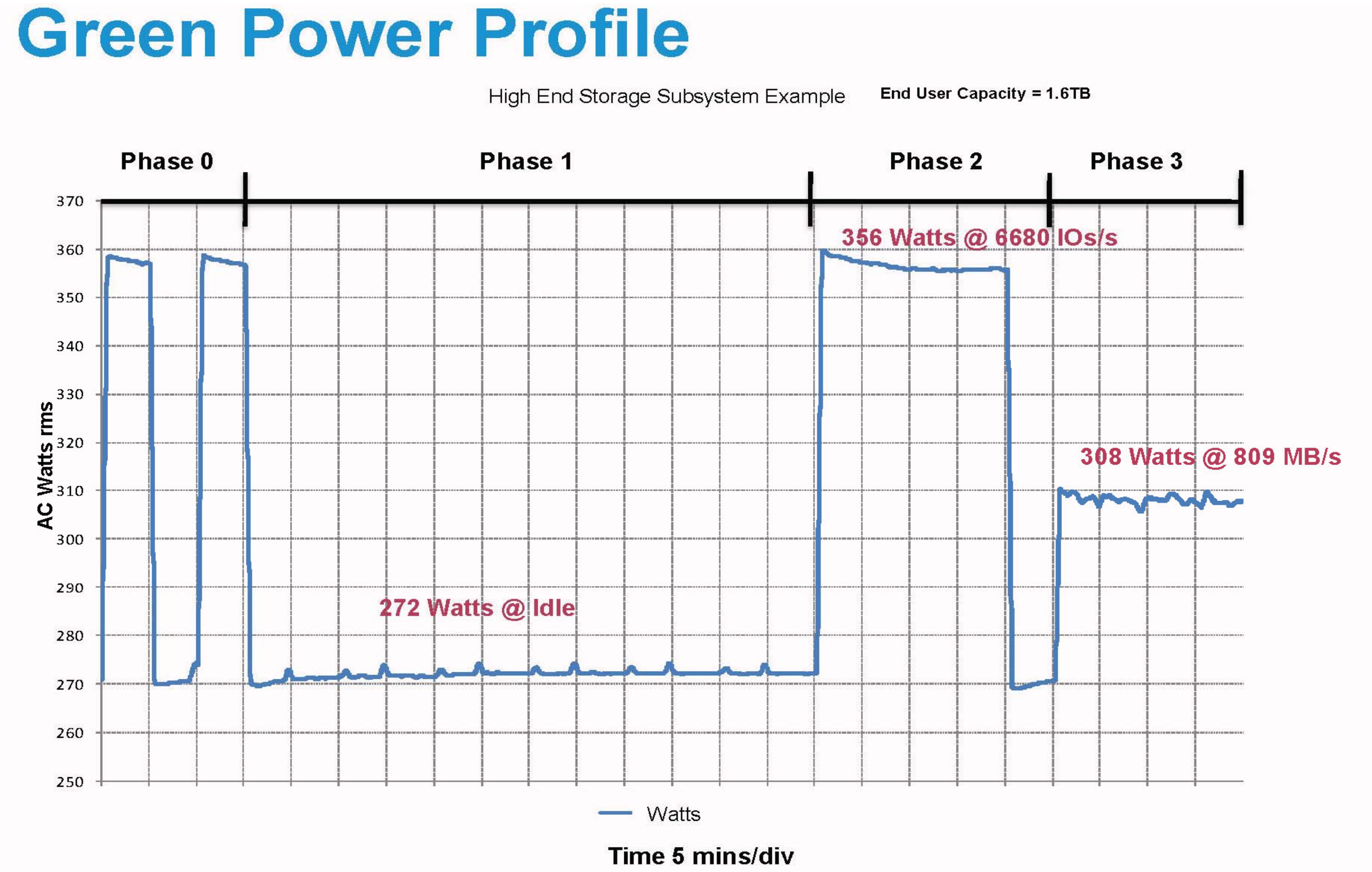
SNIA Green Power Profile Example

- **Green Power Profile**
  - Phase 0
    - Preconditioning phase no power or IO measurements are necessary
    - 5 minutes maximum OLTP workload
    - 5 minutes no workload (idle)
    - 5 minutes maximum OLTP workload
  - Phase 1
    - Idle measurement phase . No user initiated commands allowed
    - 60 minutes measurement period
  - Phase 2
    - OLTP workload
    - 20 minutes measurement period
    - 5 minutes rest no OLTP workload
  - Phase 3
    - Sequential Throughput 50% Read 50% Write 1MB transfer
    - 20 Minutes measurement period

SNIA Green Power Profile Example



Power Management Metrics

I/O Performance (OLTP Type Workloads)	IOPs/Watt
Capacity	GB/Watt
Usable Capacity	GB/Watt
Sequential I/O Throughput	MBps/Watt
Availability	RTO/Watt 9s/Watt

Impact of Server Virtualization on Storage

- Server Virtualization is being used to consolidate physical servers to obtain cost, space and power efficiencies

- Impact of Server Virtualization on Storage
  - Need for shared storage
  - Need for efficient storage with de-duplication
  - I/O interference due to Multi-tenancy
  - Mis-match of Hypervisor and Storage constructs
  - Block Mis-alignment due to layers of storage software

Conclusion

- Key takeaways
  - Storage Efficiency is the primary mechanism for saving power by having fewer number of disks
  - Flash is emerging as a power efficient alternative to disks (price is still an issue)
  - Shutting-down disks is only attractive for archival storage
- Need for:
  - Power Management Metrics Standards
  - Power aware storage management tools