PERFORMANCE/ POWER EFFICIENCY (PPE)

SANDISK™

A New Metric for SSDs in AI-Driven Data Centers

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PERFORMANCE/POWER EFFICIENCY (PPE):
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Executive Summary

The rapid emergence of artificial intelligence (AI) as a primary workload in modern data centers is driving a paradigm shift in power and performance requirements. Accelerated compute resources, such as GPUs, are exponentially increasing power demands, pushing data center architects to deliver higher performance while adhering to stringent power budgets. Traditionally, storage performance has been benchmarked using conventional I/O metrics. However, these metrics do not account for the rising importance of power efficiency.

This white paper introduces Performance/Power Efficiency (PPE) as a critical new benchmark for solid-state drives (SSDs). PPE combines performance and power consumption into a single metric, enabling data center architects to make informed decisions about storage infrastructure to meet Service Level Agreements (SLAs) within power-constrained environments. Using PPE, we evaluate the Sandisk DC SN861 PCIe® Gen5 SSD and demonstrate its efficiency and performance across key workloads encountered in a datacenter environment.

The Power Paradigm Shift in Data Center Design

Power is the New Unit of Measure for Data Center Capacity

Historically, data center capacity was defined by physical floor space. However, AI workloads with their substantial power requirements have shifted the focus to power availability. Compared to traditional workloads:

- The power intensity for AI Servers is climbing much higher than that of traditional servers without accelerators, often more than 5x the rated power per server.[1]
- GPUs, despite being more power-efficient than CPUs, require significant power for model training and inference.

The introduction of NVIDIA® Blackwell GPUs has accelerated this trend. Blackwell-based AI server designs are transitioning from air-cooled, rack-level configurations (8 GPUs per 4U rack) to liquid-cooled racks housing up to 76 GPUs, requiring power densities of up to 140kW per rack. This represents a 9x increase over traditional 15–17kW racks.

According to IDC (September 2024), electricity is the largest ongoing expense for operating a data center, already accounting for 60% of operational expenses, and power costs are projected to escalate further. By 2028, with even conservative estimates of AI server adoption, overall power requirements for data centers are expected to double.[2] This prediction cannot be taken lightly.

Data Is the Oxygen of AI Engines

AI compute engines live and breathe data. That is, they depend on the continuous, efficient movement of massive datasets. Storage infrastructure plays a pivotal role in maximizing GPU utilization. Traditional performance benchmarks, such as 4-corner testing (sequential reads, sequential writes, random reads, random writes), remain relevant but fail to consider power constraints.

To address this gap, we propose Performance/Power Efficiency (PPE) as a more relevant benchmark for evaluating modern SSDs. PPE measures the performance output relative to power consumed, providing a holistic view of efficiency for data center workloads.

Measuring PPE: Methodology and Observations

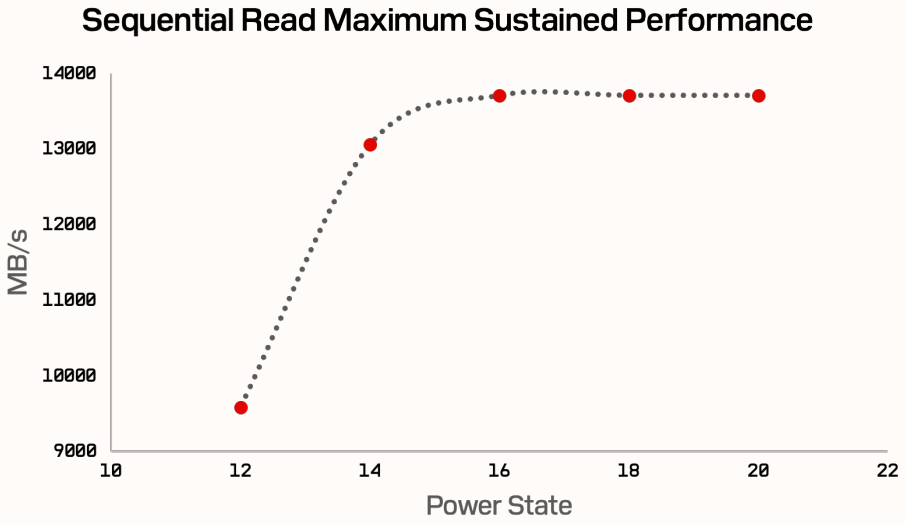
Sandisk DC SN861 PCIe® Gen5 SSD: Designed for Efficient Performance

To measure PPE, the Sandisk® DC SN861 SSD will undergo a series of datacenter specific workloads and industry standard benchmarks while monitoring key performance and power consumption metrics. The Sandisk DC SN861 SSD's architecture maintained performance and efficiency as its key points of improvement from the beginning of its design and incorporates:

- Configurable power states ranging from 12W to 20W in 2W increments.
- Optimized design to achieve peak performance at 20W power consumption, eliminating the 25W power state, which is no longer required to achieve peak performance.

Test Results and Observations

The following table summarizes the power states and their associated peak performance while testing the Sandisk DC SN861 SSD:

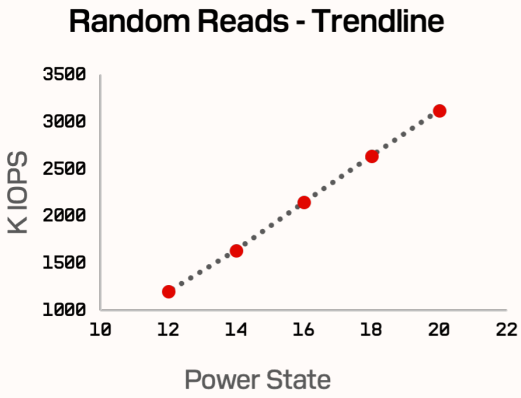


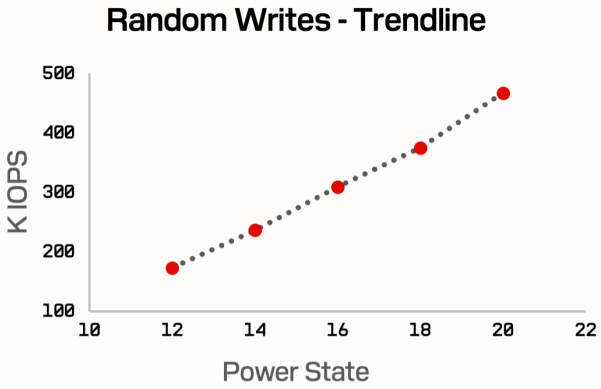
Key observations include:

1. **Consistent Power-Performance Trend:** The Sandisk DC SN861 SSD exhibits a near-linear performance trend across power states, except for sequential reads, where PCIe® bus saturation occurs sooner, at just **16W, which is only 80% of maximum power state**.
2. **Power State Compliance/Adherence:** The Sandisk DC SN861 SSD, with no additional tuning required, respects and maintains an appropriate draw of power under the prescribed Power State in all tests.
3. **Portfolio Leading Efficiency:** The Sandisk DC SN861 SSD is over 30% more efficient than previous generation[3] enterprise class drives from Sandisk.

Comparative PPE Analysis

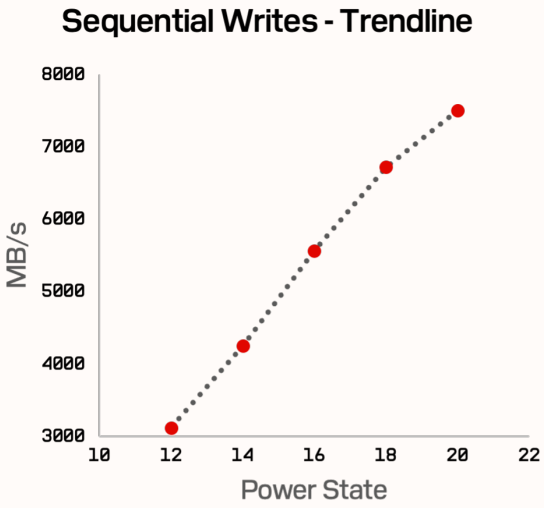
The graphs below illustrate how well the Sandisk DC SN861 SSD is architected. One can almost draw a straight trending line across the measured data points for three corners of I/O testing.





- **Random Reads:** The Sandisk DC SN861 SSD even in it's lowest power state can achieve over 1M IOPS and has linear performance through its maximum power state.
- **Random Writes:** Stellar write performance at the lowest power state can also be observed with the Sandisk DC SN861 SSD achieving higher write IOPS than previous PCIe® Gen4 drives.

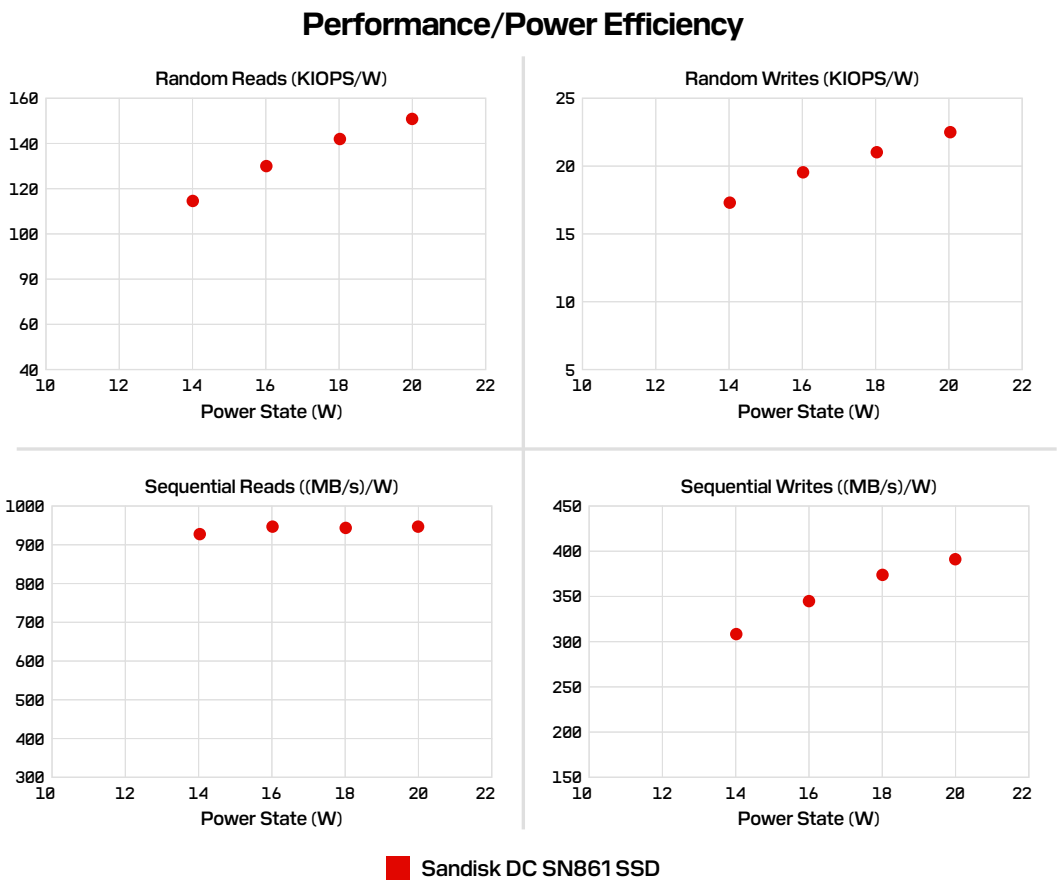
The Sequential Write graph below continues the nearly straight trendline as seen with Reads, yet the Sequential Read graph, where the DC SN861 SSD saturates the PCIe® bus at a much lower power state (16W), shows an interesting result: that higher power is NOT required to deliver higher performance.



- **Sequential Reads:** Sandisk DC SN861 SSD saturates performance at 16W, whereas the PCIe® specification allows for 25W or more of power draw. This is a 32% power savings from the allowed power budget, showing a truly optimized for efficiency architecture.
- **Sequential Writes:** Writes require more power overall due to the power required to program the NAND instead of just read its current state. Even with this limitation the Sandisk DC SN861 SSD achieves maximum performance at 20W, a savings of 25% from the allowed power budget, again showcasing it's optimized architecture.

Sandisk DC SN861 PPE Results

Sandisk benchmarked DC SN861 Performance/Power Efficiency (PPE), by dividing the performance metric by power consumed, achieving the results below.



Implications for AI-Driven Data Centers

To meet the growing demands of AI, next-generation AI models will be:

- 10x more compute-intensive
- Trained on larger datasets
- Deployed with faster GPUs requiring smarter, more efficient storage solutions

Storage infrastructure must evolve to meet these demands by:

1. Offering higher-density drives for greater capacity
2. Delivering faster performance to maximize GPU utilization
3. Supporting smarter power management to align with constrained power budgets

Why PPE Matters

PPE provides data center architects with a meaningful metric to evaluate SSDs based on their ability to balance performance and power consumption. By incorporating PPE into storage design, architects can:

- Optimize power usage across workloads
- Align storage infrastructure with SLA and cooling requirements
- Future-proof their infrastructure for AI-scale growth

Conclusion: The Future of Power-Efficient Storage

The Sandisk DC SN861 PCIe® Gen5 SSD sets a new industry benchmark for Performance/Power Efficiency (PPE). By offering configurable power profiles and delivering peak performance at lower power states, the Sandisk DC SN861 SSD empowers data center architects to design smarter, more efficient storage infrastructures.

As AI workloads continue to grow, scaling performance with power will be essential to overcoming power constraints. PPE will play a central role in enabling data centers to deliver on their AI-driven SLAs while maintaining cost efficiency.

Sandisk remains committed to driving innovation in power-efficient storage solutions, ensuring data centers can scale intelligently for the future of AI.

[1] https://www.iea.org/news/ai-is-set-to-drive-surging-electricity-demand-from-data-centres-while-offering-the-potential-to-transform-how-the-energy-sector-works
[2] IDC Report Reveals AI-Driven Growth in Datacenter Energy Consumption, Predicts Surge in Datacenter Facility Spending Amid Rising Electricity Costs, September 24, 2024, IDC, https://my.idc.com/getdoc.jsp?containerId=prUS52611224
[3] https://shop.sandisk.com/tools/documentRequestHandler?docPath=/content/dam/doc-library/en_us/assets/public/western-digital/product/data-center-drives/ultrastar-nvme-series/data-sheet-ultrastar-dc-sn655.pdf

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