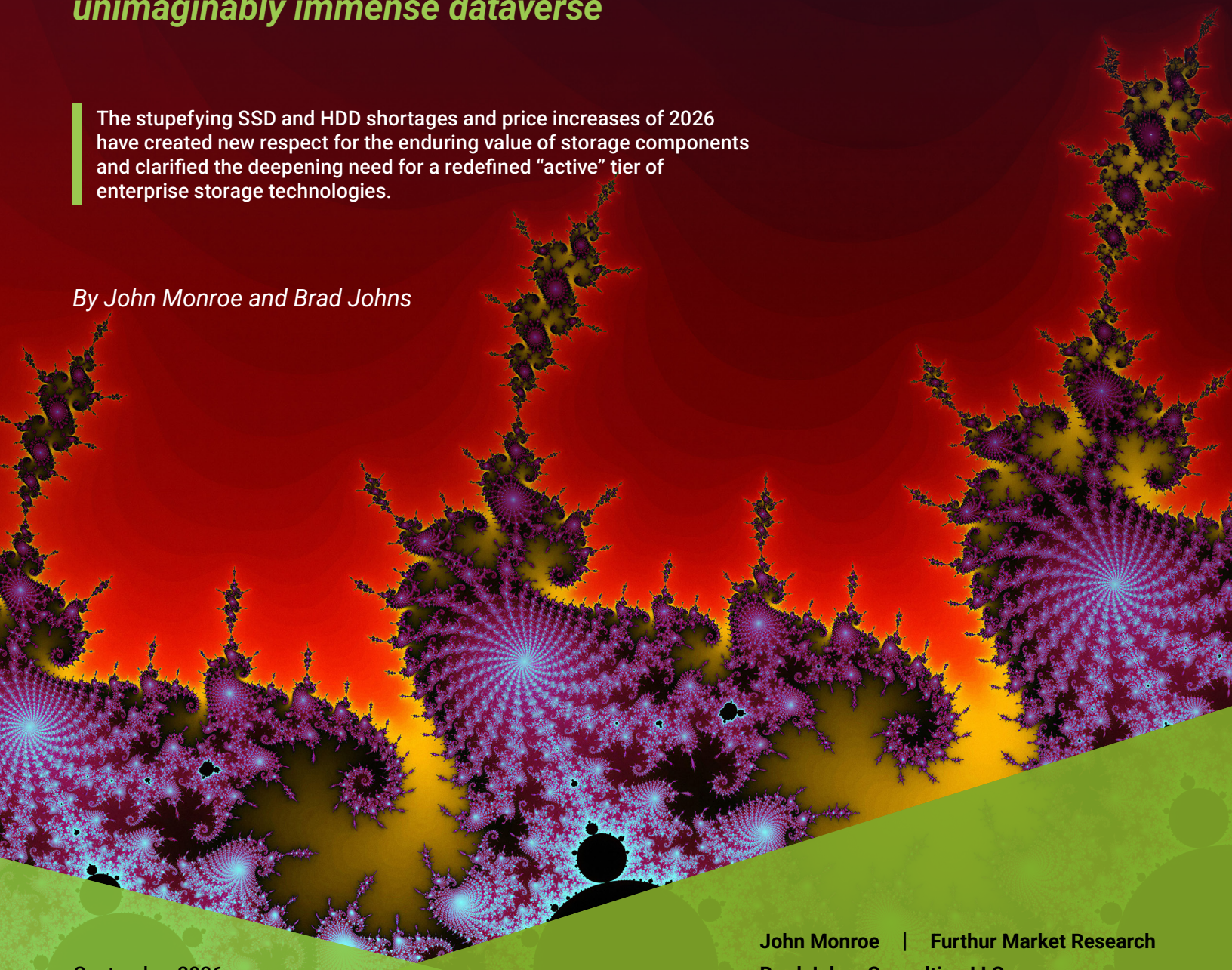
Furthur
Market Research

MITIGATING UNTENABLE STORAGE COSTS

— An examination of how tape and emerging technologies will sustain the management of an unimaginably immense dataverse

The stupefying SSD and HDD shortages and price increases of 2026 have created new respect for the enduring value of storage components and clarified the deepening need for a redefined “active” tier of enterprise storage technologies.

By John Monroe and Brad Johns



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Table of Contents



Preliminary Expectoration:
A Deepening Exabyte Crisis 4

I A New Enterprise Storage
"Pyramid" 5

II Recent History and Revised
Forecasts 7

III Key Forecast Assumptions 12

IV Essential Features for Emerging
Storage Technology (EST) 18

V EST Players on the Verge of
Production: Company and
Technology Profiles 20

VI Inconclusive Conclusions 24

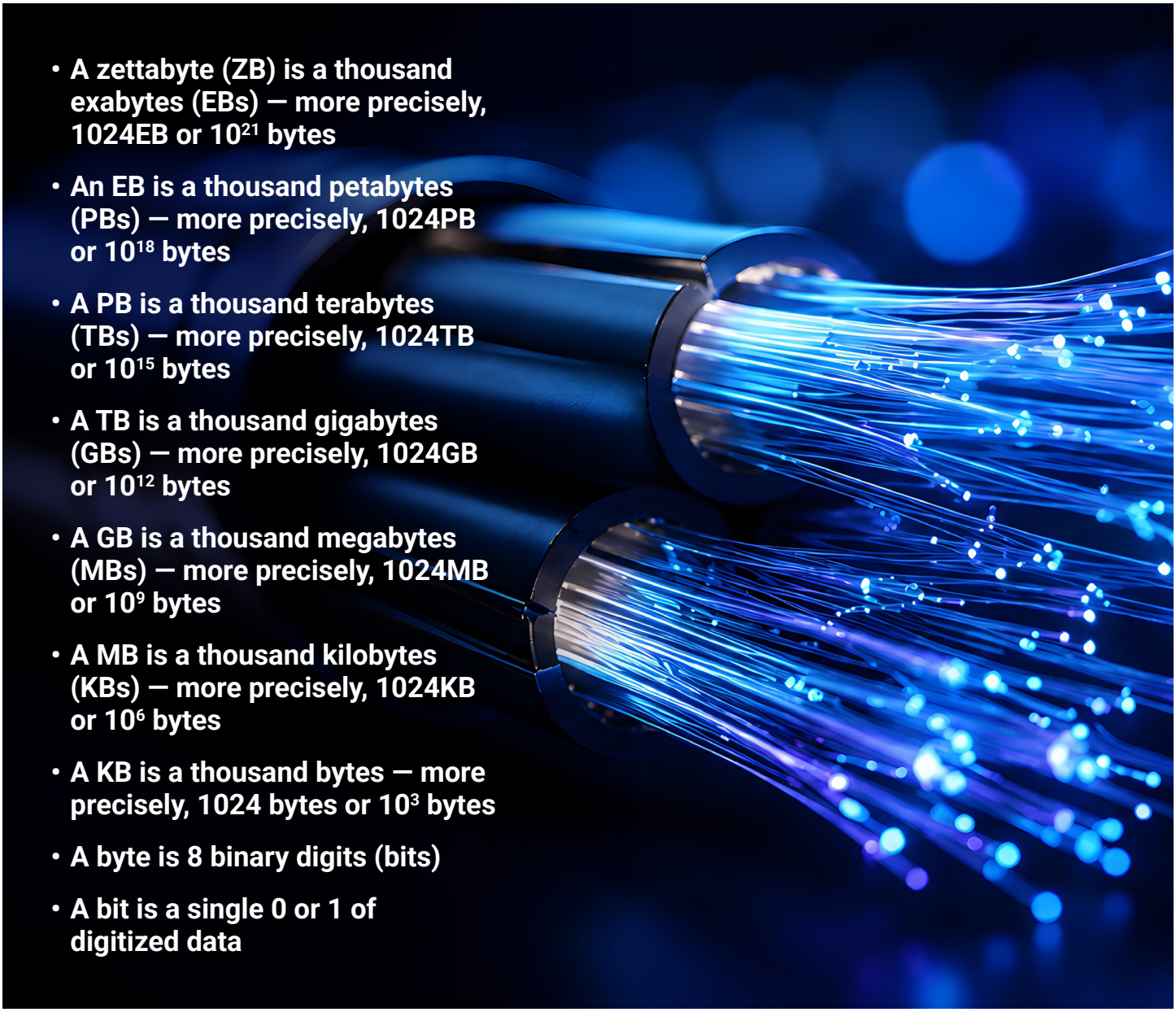
Appendix 1: Notes and Definitions 26

Appendix 2 27

Appendix 3 28

In the wake of the freakish pricing we've seen during 2026, in this paper we will re-assess the changing 2026-2050 revenue opportunities in enterprise storage markets by predicting the approximate number of exabytes (EB) delivered, estimating the evolving vendor average selling prices (ASPs) per terabyte (TB), and determining initial user average acquisition costs per TB on enterprise-grade solid-state-drive (SSD), hard-disk-drive (HDD), tape and emerging-storage-technology (EST) media, with a concerted emphasis on EST markets and vendors.

Digital Data Capacity Definitions:



CAGR Definition:

Compound Annual Growth Rate (CAGR) delineates expansions or contractions over designated time periods.

Preliminary Expectoration: A Deepening Exabyte Crisis

–AI demands data, data demands enterprise storage, and enterprise storage demands new ways to manage data…

The complex global needs of zettabyte-scale archival storage have been poorly served with expensive solutions that consume an inordinate share of the world's available energy.

The storage industry is ripe for transformative disruption. New Emerging Storage Technologies (ESTs) will be required to provide viable and cost-effective solutions to enterprise customers' crucial challenges with the security, immutability, and sustainability of their vital data.

For more than a decade we have predicted that the combined might of the SSD and HDD makers would be insufficient to meet evolving storage needs.

The precipitous 3Q22-4Q23 downward spiral in demand and prices made this prediction seem grossly exaggerated (and generated scoffing derision from some of our learned analyst colleagues), but we now find ourselves mired in an unprecedented "exabyte crisis"—wherein core memory, flash modules, SSDs and HDDs are in simultaneous and severe shortage—that has already lasted more than a year and currently seems destined to last at least through 4Q28. Even enterprise tape is now "sold out" through 4Q27.

Freakish pricing dynamics have become the norm and profits have soared for the drive makers, but this runaway freight train of AI-generated data will soon collide with increasing ROI demands and more-sophisticated assessments of the ***real*** requirements of short-term and long-term digital preservation.

The deepening need for high-capacity, low-cost, low-power technologies that can be deployed at massive scale for extended periods of time has become more and more blindingly blatant.



A New Enterprise Storage "Pyramid"

At the outset, and despite the desperate need for speed in AI infrastructures, we reiterate our firm convictions that:

- More than 70% of enterprise data has not had and will never have any enduring need for the performance of SSDs and HDDs, but will have greatly expanding needs for low-cost Sustainability, Immutability, and Security (SIS), attributes the active-archive technologies have been designed to deliver.
- Huge numbers of HDDs and a significant number of SSDs are managing and, during the near term, will continue to manage far too many of the active-archive workloads at far too great a cost per terabyte while consuming an inordinate share of the world's available energy.
- **You don't need to plow a field with a Ferrari. In most cases, oxen will suffice.**

In pursuit of more-sophisticated assessments of evolving data needs, we decided to devise a new model for the enterprise storage tiers.

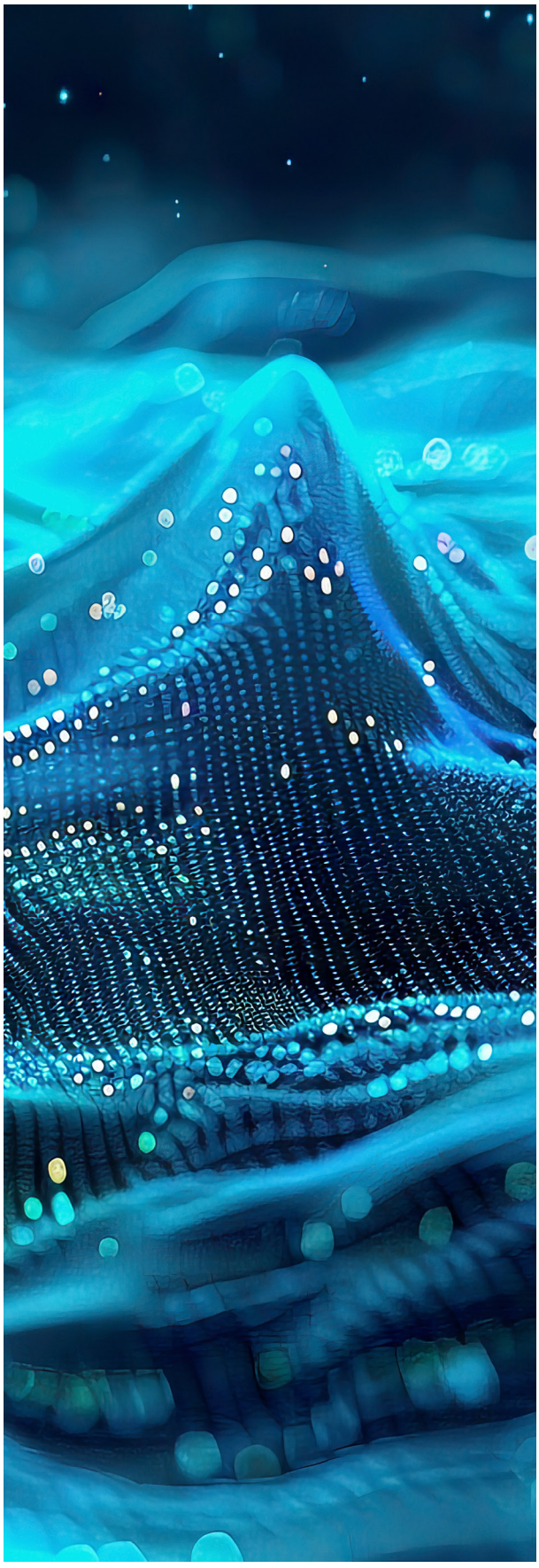
Our 2023 fivefold version of the pyramid with percentage of data distributions based on frequency of access and data "temperature"—to wit: ***Hot*** 7% (nanoseconds to microseconds), ***Warm*** 13% (microseconds to milliseconds), ***Cool*** 20% (milliseconds to seconds), ***Cold*** 25% (minutes to days), ***Frozen*** 35% (weeks to years), with neatly scaling top-to-bottom and bottom-to-top sizes and costs and performance metrics—requires a complete re-thinking for the AI era.

We thought that the growing immensity of data in the "frostbitten" (cold and frozen) tiers will be JIC (Just in Case) or WORN (Write Once Read Never) records which may never be accessed at all—nor, in most cases, will they ever be deleted.

However, in the AI era, any file in the "cold" data archive might become "hot" at any time depending on unpredictable and increasingly refined and intelligent data access requests digging for unforeseen value. As we move through a paradigm shift from a "cold" to a seamlessly accessible "active" archive with acceptable (<30-second, preferably <10-second) data-access metrics, our assumption is that ***all*** data will be accessed eventually but may ***never require*** the 25-to-100 microsecond or 5-10 millisecond access speeds of SSDs or HDDs.

Last year we initially compressed our old fivefold model to only two tiers (see images in Appendix 2). We thought that with the advent of more strictly enforced corporate archive and access rules, and the growing need to conduct AI business at the speed of flash, in most data centers ~30% of the data will be classified as hot, while distinctions between the warm and cool and cold and frozen data tiers diminish to insignificance in a huge new tier that grows to ~70% of the total—there will be no fine delineations, either the data is hot, or it's not.

This rhymed and was enticingly simple, but we decided that model did not accurately reflect actual use cases and was oversimplified.



Our new version of the storage tiers is based on application needs and technologies (not on "data temperature" and "access frequency") with the following fourfold breakdowns of data distribution:

GENERATIVE:

Most of the AI inference work is done here. This tier will process fresh incoming data and frequently tap into the Iterative, Active and Archive tiers to sustain and improve its modeling activities and will account for an enduring ~25% of the EB.

ITERATIVE[1]:

Cost-effectively offloads contextual AI redundancies in the Generative tier while providing fast access to data. Currently ~30% of the EB but will devolve to ~5% of the EB because most of the current Iterative HDD applications will be handled in the future by low-cost SSDs in the Generative tier and Fast Emerging technologies (with much lower acquisition and energy costs and "good enough" access speeds) in the Active tier.

ACTIVE:

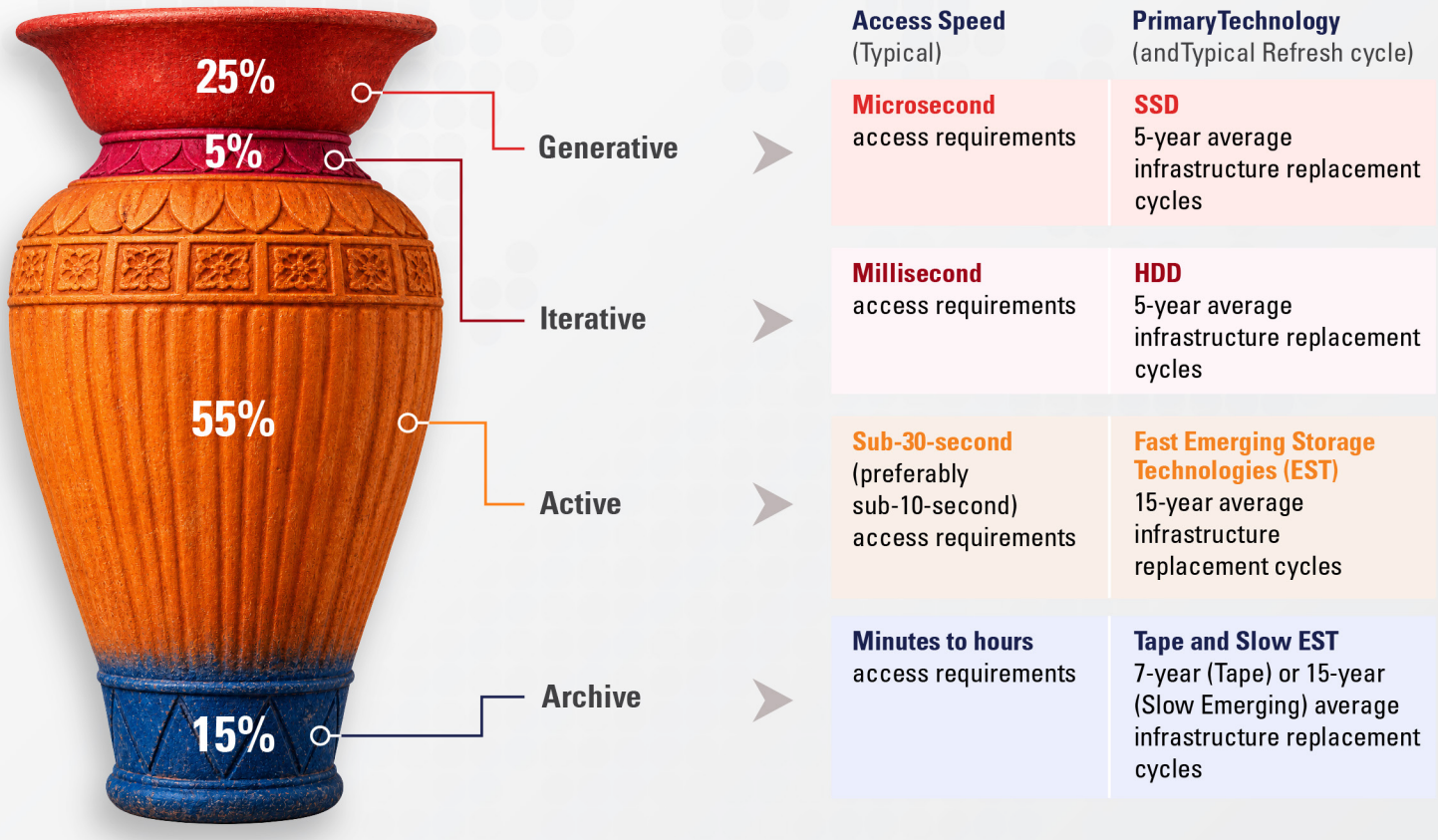
The most accessible and largest of the tiers will evolve to ~55% of the EB, sustaining enormous data oceans into which the Generative tier will continuously tap. The vast majority of the data in this tier has been handled by HDDs but in the future will be handled by Fast Emerging technologies.

ARCHIVE:

The deep but accessible repository of infrequently accessed but crucial cultural, corporate and scientific data will evolve to ~15% of the EB. A majority of the Archive data is replicated in the Active tier.

Figure 1 depicts our new version of the "pyramid," with a swollen generative brain larger than the base operating at the speed of flash perched on a slender neck of iterative functions and a bulging wildly active torso sustaining the majority of all EB supported by a mostly inactive but solid and immutable archive base, comprising an ultimate and enduring record of what we've left behind, in all its garishness and grandeur, during our ephemeral lives.

Figure 1: New Enterprise Storage Tiers: An Ancient Pithos Storage Jar Reimagined

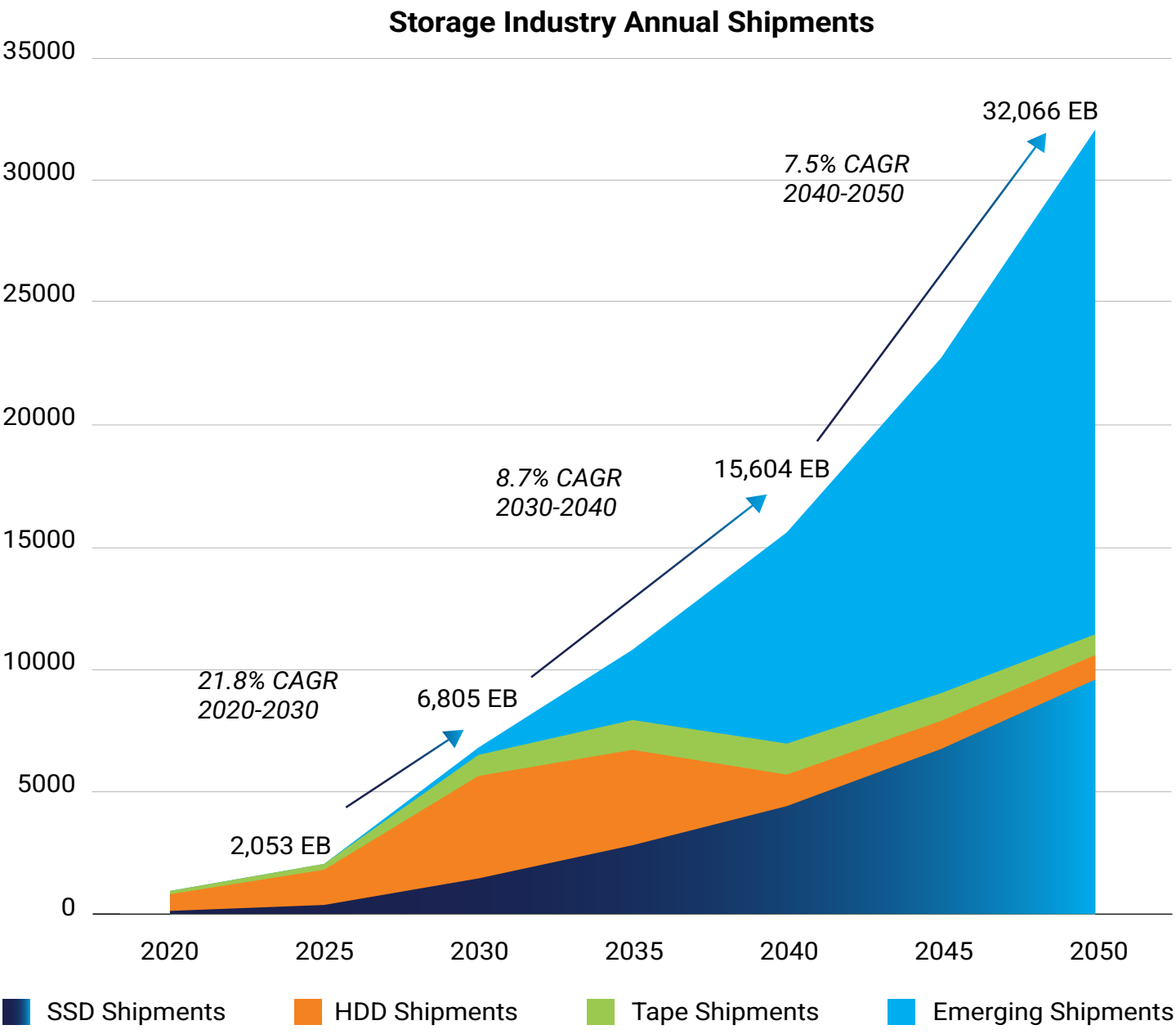


[1] *We also considered "operative" as an appropriate name for this tier, since non-AI-related CRM and ERP and other traditional high-bandwidth enterprise applications will likely be using ~50EB/year of HDD storage through 2050, but decided "iterative" more accurately captured this application tier in the future, because the cost-effective offload of contextual redundancies in the Generative tier will remain its primary ~1ZB/year use case (after HDDs cease to be used for active and archive workloads), and low-cost SSDs in the Generative tier will be performing many more of the historic Iterative-tier tasks.*

Recent History and Revised Forecasts

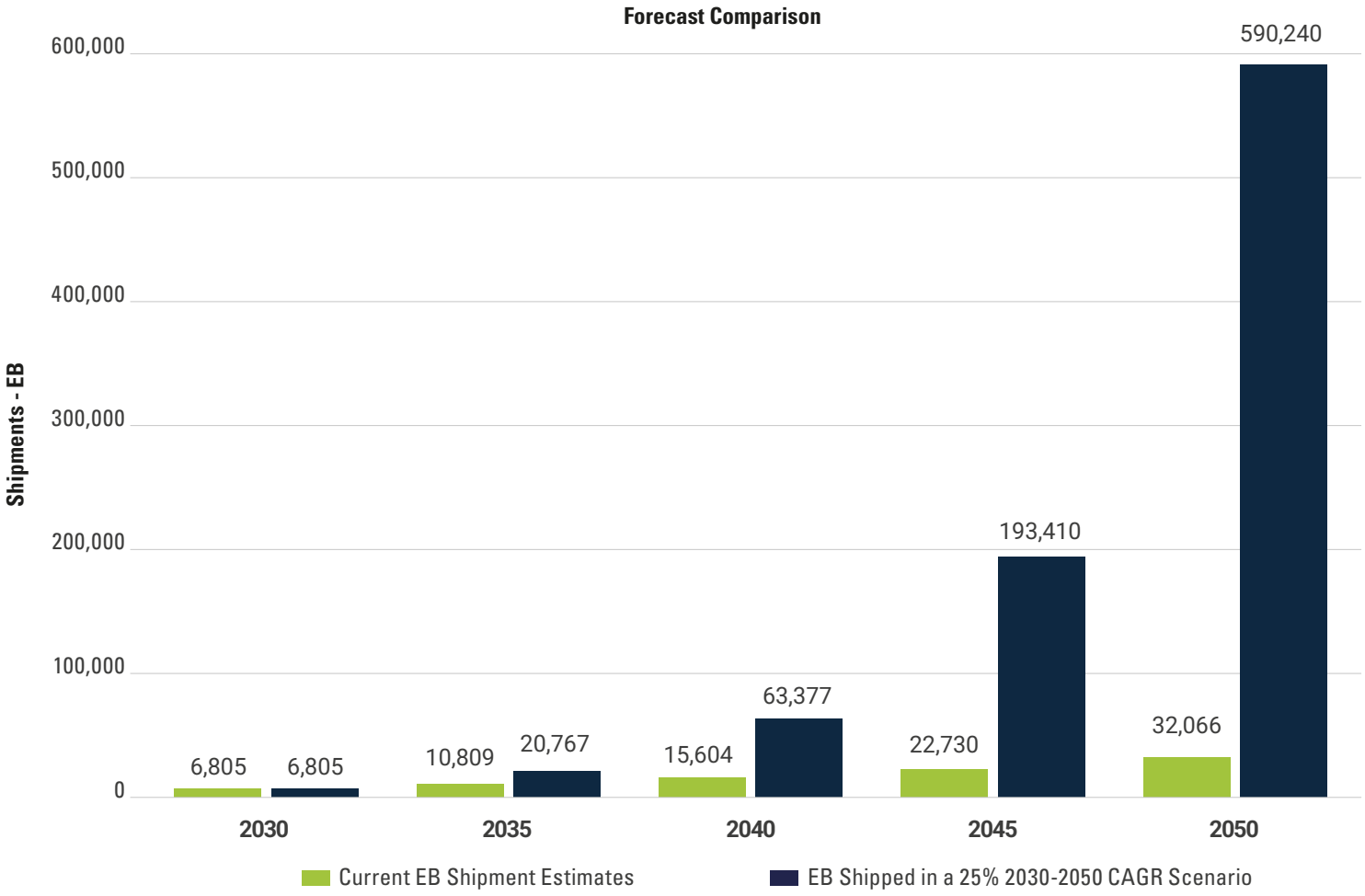
Figure 2 depicts 2020-2050 shipments of all enterprise storage technologies in five-year increments as detailed in Table 3. Figure 3 compares our base EB forecast as detailed in Table 3 with an alternate 25%/year growth scenario 2030-2050. Figure 4 compares our base User Spend forecast as detailed in Table 3 with an alternate 25%/year growth scenario 2030-2050.

Figure 2: New 2020–2050 Forecasts



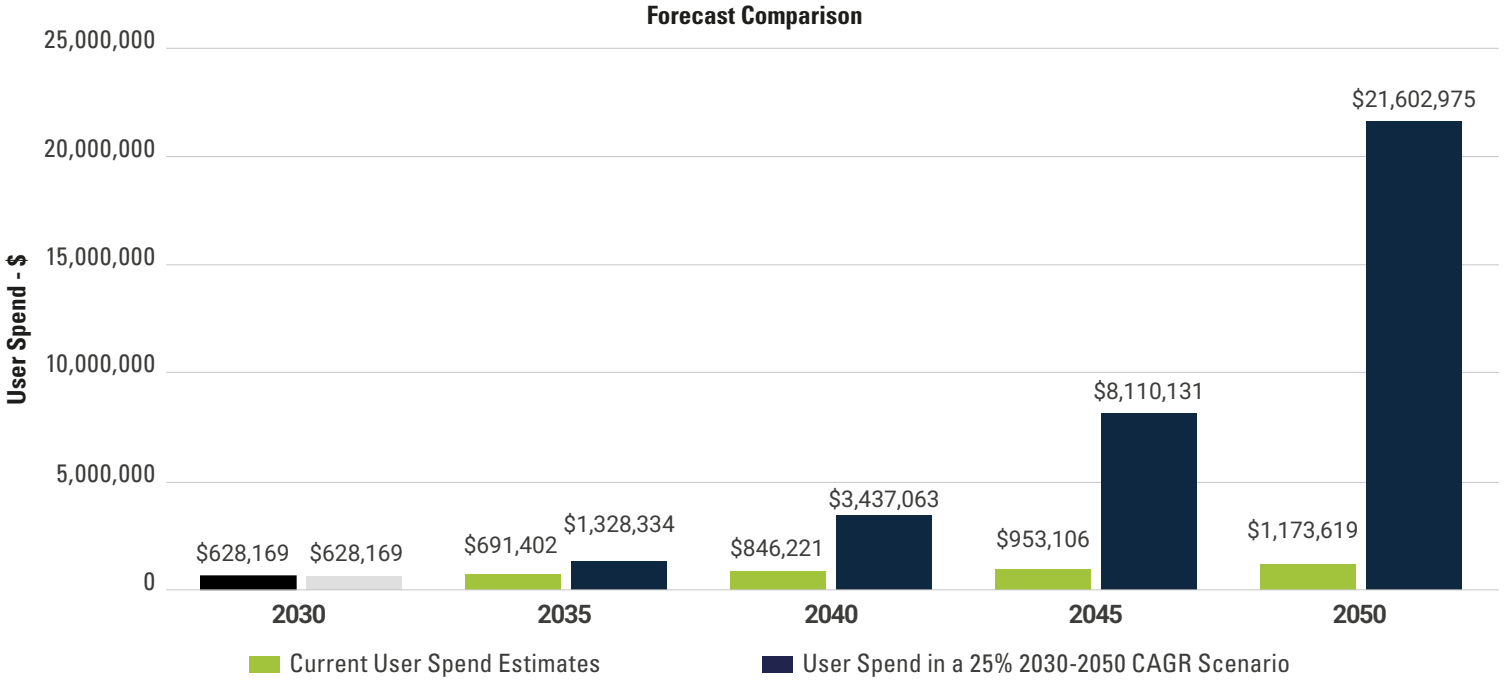
Source: Furthur Market Research and Brad Johns Consulting, September 2026

Figure 3: Current EB Shipment Estimates Compared with a 25% 2030-2050 CAGR



Source: Furthur Market Research and Brad Johns Consulting, September 2026

Figure 4: Current User Spend Estimates Compared with a 25% 2030-2050 CAGR



Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 1 details a ten-year snapshot, 2017-2026. Table 2 depicts 2022-2026 freakish pricing trends. Table 3 details 2020-2050 shipments of all enterprise storage technologies in five-year increments as well as an alternate 25%/year growth scenario (see numbers in ***bold green italic***). Table 4 details 5-year and 10-year changes in compound annual growth rates (CAGRs). See Tables 5-8 in Appendix 3 for granular annual details of 2010-2050 shipments.

Table 1: A Ten-Year Snapshot, Depicting a Nine-Year History and One-Year Forecast of Enterprise Storage Vendor Shipments and Revenue, 2017-2026

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
SSD										
Vendor Enterprise SSD Uncompressed Shipment Estimates (EB)	**29**	**52**	**66**	**109**	**149**	**173**	**120**	**251**	**312**	**519**
YoY Change %	*61.1*	*77.9*	*28.7*	*64.0*	*36.9*	*16.0*	*(30.5)*	*108.7*	*24.4*	*66.3*
Vendor Enterprise Uncompressed SSD Direct Revenue Estimates ($M)	$12,973	$14,861	$9,424	$16,601	$20,353	$20,741	$8,173	$26,891	$30,390	$201,680
YoY Change %	*55.2*	*14.5*	*(36.6)*	*76.2*	*22.6*	*1.9*	*(60.6)*	*229.0*	*13.0*	*563.6*
Vendor Uncompressed Enterprise SSD Direct Blended ASP/TB ($)	$447.36	$288.00	$141.92	$152.45	$136.51	$119.96	$68.00	$107.22	$97.40	$388.59
YoY Change %	*(3.7)*	*(35.6)*	*(50.7)*	*7.4*	*(10.5)*	*(12.1)*	*(43.3)*	*57.7*	*(9.2)*	*299.0*
HDD										
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	**267**	**394**	**490**	**680**	**959**	**942**	**1,039**	**1,085**	**1,439**	**1,815**
YoY Change %	*22.5*	*47.6*	*24.2*	*38.9*	*41.0*	*(1.8)*	*10.3*	*4.4*	*32.7*	*26.1*
Vendor Enterprise Uncompressed HDD Direct Revenue Estimates ($M)	$8,935	$10,915	$10,737	$11,326	$13,035	$12,887	$13,755	$14,077	$20,598	$28,180
YoY Change %	*(0.6)*	*22.2*	*(1.6)*	*5.5*	*15.1*	*(1.1)*	*6.7*	*2.3*	*46.3*	*36.8*
Vendor Uncompressed Enterprise HDD Direct Blended ASP/TB ($)	$33.46	$27.70	$21.93	$16.66	$13.59	$13.68	$13.24	$12.98	$14.31	$15.53
YoY Change %	*(18.8)*	*(17.2)*	*(20.8)*	*(24.1)*	*(18.4)*	*0.6*	*(3.2)*	*(2.0)*	*10.3*	*8.5*
TAPE										
Enterprise Tape Compressed Shipment Estimates (EB)	**136**	**125**	**134**	**136**	**190**	**207**	**228**	**265**	**240**	**376**
YoY Change %	*9.7*	*(8.1)*	*7.2*	*1.5*	*39.7*	*8.9*	*10.1*	*16.2*	*(9.4)*	*56.7*
Enterprise Tape User Spend Estimates ($M)	*	$1,646	$1,524	$1,518	$1,746	$1,712	$1,889	$2,208	$1,961	$3,184
YoY Change %		–	*(7.4)*	*(0.4)*	*15.0*	*(2.0)*	*10.4*	*16.9*	*(11.2)*	*62.3*
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)		$13.17	$11.38	$11.16	$9.19	$8.27	$8.28	$8.33	$8.17	$8.47
YoY Change %		–	*(13.6)*	*(1.9)*	*(17.7)*	*(10.0)*	*0.2*	*0.6*	*(1.9)*	*3.6*
	*Tracking of Tape user revenue begins 2018.									
Total Compressed Enterprise EB Shipped	**438**	**581**	**703**	**947**	**1,328**	**1,356**	**1,411**	**1,650**	**2,053**	**2,814**
YoY Change %	*20.4*	*32.7*	*21.0*	*34.6*	*40.3*	*2.2*	*4.0*	*17.0*	*24.4*	*37.0*
Uncompressed SSD % of Total EB Shipped	7.9	10.7	11.3	13.8	13.5	15.3	10.2	18.2	18.2	22.1
Uncompressed HDD % of Total EB Shipped	61.0	67.8	69.6	71.8	72.2	69.4	73.6	65.7	70.1	64.5
Compressed Tape % of Total EB Shipped	31.1	21.5	19.1	14.4	14.3	15.3	16.2	16.1	11.7	13.4

SSD and HDD vendors sell directly to hyperscalers (such as AWS), OEMs (such as Dell), and distributors (such as TD SYNNEX).
Users purchase cloud services from hyperscalers or smaller Internet Service Providers (ISPs) and integrated products from OEMs or distributors.

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 2: Freakish Pricing Trends, 2022-2026

	2022	2023	2024	2025	2026
Vendor Direct Customer Bare-Bones Enterprise SSD Uncompressed ASP/TB ($)	$119.96	$68.00	$107.22	$97.40	$388.59
YoY Change %	*(12.5)*	*(43.3)*	*57.7*	*(9.2)*	*299.0*
Vendor Direct Customer Bare Bones Enterprise HDD Uncompressed ASP/TB ($)	$13.68	$13.24	$12.98	$14.31	$15.53
YoY Change %	*0.6*	*(3.2)*	*(2.0)*	*10.2*	*8.5*
Enterprise Tape Enduser Fully Integrated Compressed Average Acquisition Cost/TB ($)	$8.27	$8.28	$8.33	$8.17	$8.47
YoY Change %	*(16.3)*	*0.2*	*0.6*	*(1.9)*	*3.6*

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 3: Quick-Reference Summary, Enterprise Storage Histories and Forecasts, 2010-2050

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Vendor Enterprise SSD Compressed Shipment Estimates (EB)	0.2	13	131	374	1,458	2,816	4,414	6,748	9,587
Estimated SSD User Spend, 85% Markup Over Vendor Revenue ($M)	$1,839	$11,624	$30,713	$56,222	$543,878	$622,007	$801,215	$904,672	$1,119,892
Estimated SSD User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$7,662.15	$880.57	$235.02	$150.16	$373.03	$220.85	$181.53	$134.07	$116.82
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	46	157	680	1,439	4,188	3,897	1,286	1,147	998
Estimated HDD User Spend, 50% Markup Over Vendor Revenue ($M)	$10,047	$14,285	$16,988	$30,897	$76,404	$54,864	$16,652	$13,457	$11,099
Estimated HDD User Initial Integrated Uncompressed Average Acquisition Cost/TB ($)	$218.41	$90.98	$24.99	$21.47	$18.24	$14.08	$12.95	$11.73	$11.12
Enterprise Tape Compressed Shipment Estimates (EB)	30	98	136	240	861	1,221	1,270	1,137	851
Estimated Tape User Spend ($M)	Tracking begins 2018		$1,518	$1,961	$5,524	$4,193	$2,397	$1,314	$795
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)			$11.16	$8.17	$6.42	$3.43	$1.89	$1.16	$0.93
Vendor Enterprise Emerging Shipment Estimates (EB)	Tracking begins 2026				298	2,875	8,634	13,698	20,630
Estimated Emerging User Spend ($M)					$2,363	$10,338	$25,958	$33,664	$41,834
Estimated Emerging User Initial Integrated Average Acquisition Cost/TB ($)					$7.93	$3.60	$3.01	$2.46	$2.03
Total Compressed Enterprise Shipment Estimates (EB)	**76**	**269**	**947**	**2,053**	**6,805**	**10,809**	**15,604**	**22,730**	**32,066**
SSD % of Total Shipments	0.3	4.9	13.8	18.2	21.4	26.1	28.3	29.7	29.9
HDD % of Total Shipments	60.3	58.5	71.8	70.1	61.5	36.1	8.2	5.0	3.1
Tape + Emerging (Active Archive) % of Total Shipments	39.3	36.6	14.4	11.7	17.0	37.9	63.5	65.3	67.0
Total Compressed Enterprise Active Installed Base Estimates (EB)	**252**	**851**	**3,215**	**8,068**	**23,748**	**49,758**	**77,032**	**138,467**	**231,134**
Total Enterprise User Spend Estimates ($M)	Tracking begins 2018		**$49,219**	**$89,080**	**$628,169**	**$691,402**	**$846,221**	**$953,106**	**$1,173,619**
Total Estimated User Initial Integrated Compressed Average Acquisition Cost/TB ($)			**$52.00**	**$43.38**	**$92.31**	**$63.96**	**$54.23**	**$41.93**	**$36.60**
SSD % of Total Spend			62.4	63.1	86.6	90.0	94.7	94.9	95.4
HDD % of Total Spend			34.5	34.7	12.2	7.9	2.0	1.4	0.9
Tape + Emerging (Active Archive) % of Total Spend			3.1	2.2	1.3	2.1	3.4	3.7	3.6
Alternate 2030-2050 Shipment Scenario at 25% Annual Expansion, Mimicing the 2025-2030 Forecast CAGR (EB)						20,767	63,377	193,410	590,240
					EB Delta to Current Forecast	***9,958***	***47,773***	***170,680***	***558,174***
Even at 1/2 the Acquisition Costs Detailed Above, Alternate 2030-2050 Scenarios Are Clearly Unsustainable…					Alternate 2030-2050 User Spend Scenario ($M)	$1,328,334	$3,437,063	$8,110,131	$21,602,975
					$ Delta to Current Forecast	***$636,932***	***$2,590,841***	***$7,157,025***	***$20,429,356***
Alternate 2030-2050 Active Installed Base Scenario at 25% Annual Expansion, Mimicing the 2025-2030 Forecast CAGR (EB)						70,449	213,684	650,804	1,984,787
					EB Delta to Current Forecast	***20,691***	***136,653***	***512,337***	***1,753,654***

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 4: Five-Year and Ten-Year Compound Annual Growth Rate (CAGR) Trends, 2010-2050

	CAGR 2010-2015	CAGR 2015-2020	CAGR 2010-2020	CAGR 2020-2025	CAGR 2025-2030	CAGR 2020-2030	CAGR 2030-2035	CAGR 2035-2040	CAGR 2030-2040	CAGR 2040-2045	CAGR 2045-2050	CAGR 2040-2050
Vendor Enterprise SSD Compressed EB Shipment Estimates	122.9	58.2	>1000	23.4	31.2	27.3	14.1	9.4	11.7	8.9	7.3	8.1
Vendor Enterprise HDD Uncompressed EB Shipment Estimates	27.8	34.1	30.9	16.2	23.8	19.9	(1.4)	(19.9)	(11.1)	(2.3)	(2.7)	(2.5)
Enterprise Tape Compressed EB Shipment Estimates	26.8	6.7	16.3	12.0	29.1	20.3	7.2	0.8	4.0	(2.2)	(5.6)	(3.9)
Vendor Enterprise Emerging EB Shipment Estimates			Tracking begins 2026		>1000	NA	57.4	24.6	40.0	9.7	8.5	9.1
Total Compressed Enterprise EB Shipment Estimates	28.6	28.7	28.6	16.8	27.1	21.8	9.7	7.6	8.7	7.8	7.1	7.5

An overarching assumption in our forecasts is that shipment growth rates must decline after 2030.

Source: Furthur Market Research and Brad Johns Consulting, September 2026



Key Forecast Assumptions

He who foretells the future lies, even if he tells the truth. – Arab Proverb

Forecasting the data storage industry through 2050 requires diverse assumptions about data growth, infrastructure investment, technology development, energy consumption, and storage economics. The further the forecast extends, the greater the uncertainty surrounding individual technologies and growth rates. Accordingly, the following assumptions form a framework for our long-term forecast, and are not predictions that any individual technology or growth rate will develop precisely as projected.

An overarching assumption in our new forecasts is that EST companies will deliver low-cost, power-efficient products—capable of <30-second-to-<10-second access metrics (for Fast Emerging systems) or minutes-to-hours access metrics (for Slow Emerging systems)—in massive commercial scale beginning in 2028. With adequate infrastructure support for seamless integration and extended >15-year product refresh cycles, ESTs will grow to account for more than 50% of the EB delivered in 2039 and more than 60% of the EB delivered in 2045.

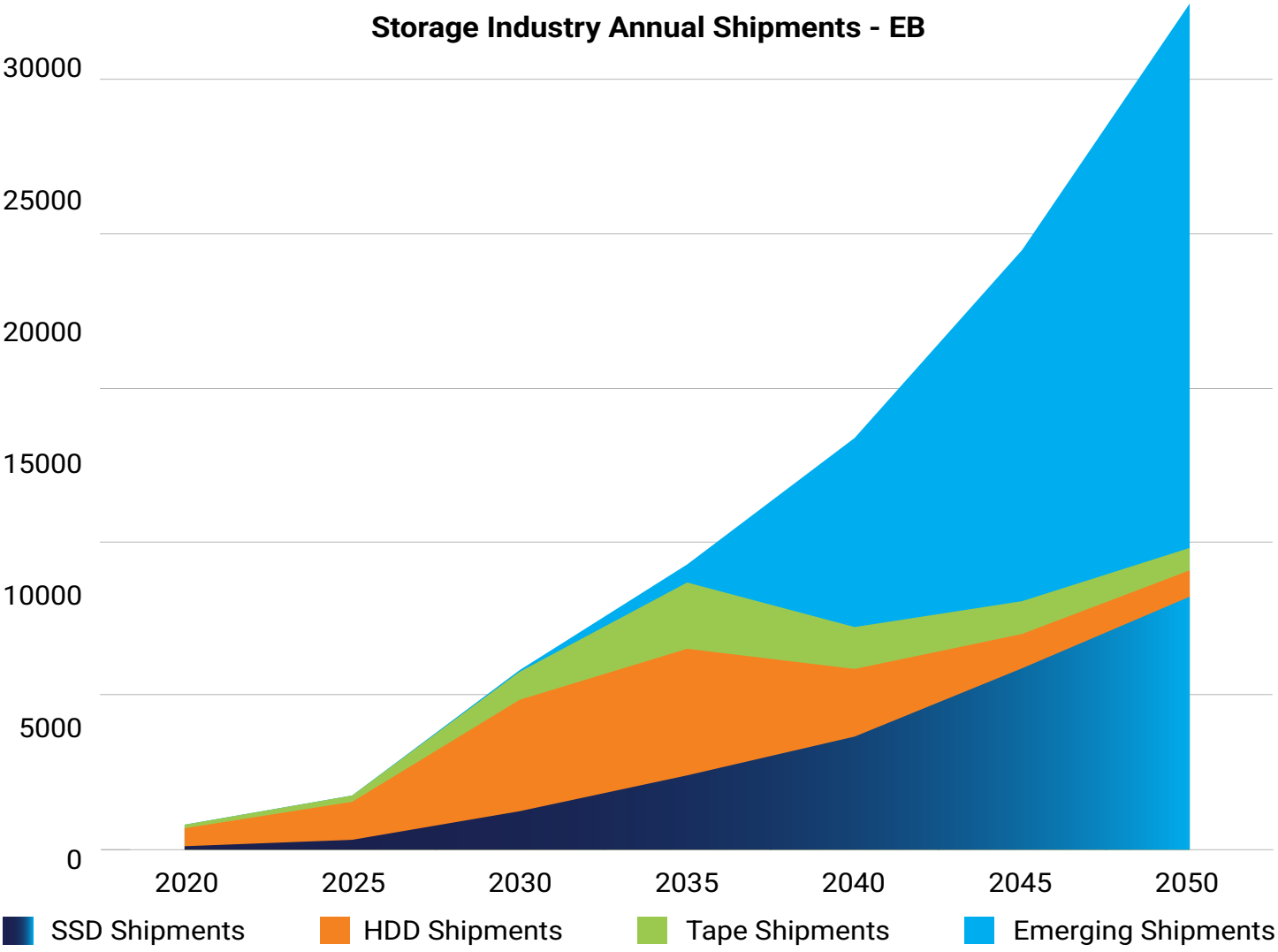
If ESTs do not deliver in these ways, then the HDD and tape markets will be far larger for far longer.

Let us consider that decisive "if." Figure 5 depicts a different scenario from our base forecast as detailed in Figure 2. In this scenario, ESTs have minimal impact 2030-2035, and the HDD and tape markets account for much greater portions of the EB shipments.

However, we believe it is more likely that ESTs will have multi-zettabyte impacts prior to 2035. Even in this less-likely scenario, ESTs still account for the largest share of the EB in 2040, more than 50% of the EB in 2045, and more than 60% of the EB in 2050.

The growth of ESTs will be inevitable and inescapable.

Figure 5: Alternate Shipment Scenario If the Impact of ESTs is Delayed



Source: Furthur Market Research and Brad Johns Consulting, September 2026

IT Infrastructure and Data Center Expansion

AI will remain the principal driver of IT infrastructure investment for at least the next five years. Continued expansion of AI training, inference, retrieval-augmented generation, and other data-intensive applications will drive demand for servers, networking, and storage infrastructures. This demand will also support continued construction and expansion of hyperscale and enterprise data centers.

At the same time, power availability, water consumption, and community impacts will increasingly constrain data center development. Hyperscalers and other operators will therefore place greater emphasis on energy efficiency, water-efficient or water-free cooling, and infrastructure designs that reduce their impact on local power grids and costs to communities.

Energy consumption will become the most critical storage-selection criterion. As storage infrastructures expand into the zettabyte era, acquisition cost and performance will no longer be sufficient measures of storage efficiency. Power consumption, cooling requirements, carbon emissions, equipment longevity, and total cost of ownership (TCO) will increasingly influence technology selection. This will create an enormous opportunity for tape and new storage technologies capable of retaining vast quantities of data while consuming little or no energy when data is inactive.

New enterprise data infrastructures must not only cost less but must also consume less power to be in crucial and resilient alignment with the total availability of energy. There are already a multitude of CO^2 emission compliance regulations in place throughout the world (with much stricter regulations in Europe) and growing scarcities of total available energy in myriad locales. There is also growing citizen outrage and organized protest[2] against data center development in many communities.

Healthy ecosystems have become more crucial considerations in all IT purchasing decisions, and many data center managers will soon be ***forced***—by upper-level management edict, by compliance regulations, or by community protest—to use tape and various ESTs as ultra-low-cost, sustainable alternatives.

In the Active and Archive enterprise data tiers, the most cost-effective and power-efficient technologies will inevitably prevail, because they make the greatest fiscal ***and*** ecological sense.

A Dataverse of Staggering Dimension

Enterprise EB shipments are projected to grow at a 27% CAGR from 2025 through 2030, driven primarily by AI and the enormous quantities of data created, retained, processed, and reused by AI applications. But this growth rate cannot continue indefinitely. As the installed base becomes increasingly immense, the economics of storing everything will become increasingly challenging. We therefore project industry EB shipment growth will moderate to an 8.7% CAGR during the 2030–2040 period and a 7.5% CAGR 2040-2050. Organizations will increasingly use AI itself—along with improved data management, classification, compression, deduplication, and deletion policies—to determine which data have sufficient value to retain.

Despite slowing 2030-2050 growth rates and longer refresh cycles for ESTs, we still foresee an active installed base of enterprise data that expands from 8 zettabytes in 2025 to 50 zettabytes in 2035, 77 zettabytes in 2040, and 231 zettabytes in 2050—with respective increases of 27,304x, 262,799x and 788,386x over 2010.

We will surely have to devise new ways to manage an active dataverse of staggering dimension.

In an alternate scenario, in which growth rates do not modulate and retained data expands in concert with a 25%/year growth rate (which merely mimics actual 2010-2030 growth rates), the active installed base expands to 71 zettabytes in 2035, 214 zettabytes in 2040, and 1,985 zettabytes in 2050. This scenario also foresees that User Spend will grow from $1.3 trillion in 2035 to $21.6 trillion in 2050 (see ***green bold italic*** numbers in Table 3).

We do not consider this to be a feasible scenario.



[2] *For example, see www.medinastandstogether.org (various Medina county Texas protests). Also, see www.brockovichdatacenter.com, activist Erin Brokovich's new crusade, for "town by town" reports of community efforts to accept, modify or derail data center development. Her constantly evolving map details hundreds of data center projects in the United States that are operational, under construction, permitted, proposed or cancelled.*

SSD

AI's insatiable demand for large amounts of data to be stored and processed at microsecond speeds has generated a market need for enormous and growing quantities of SSDs which far exceeds the NAND industry's current abilities to produce and deliver.

Our estimated SSD 2025-2030 CAGR of 31.2% in EB shipped, largely driven by AI data center requirements, is hardly unprecedented (for example, we saw a 58.2% CAGR 2015-2020 despite a severe downturn in 2019).

However, the recent pricing dynamics are unlike anything we've ever seen in any storage market.

A surplus of SSDs lasted from 2Q22 through 4Q23. There was a great demand uptick in 2024 and a 57.7% vendor-direct ASP/TB uptick to $107.22 from the historic low of $68 in 2023, but there were some aggressive prices in 1H25 which led to a vendor-direct ASP/TB of $97.40 for all of 2025 (down 9.2% YoY).

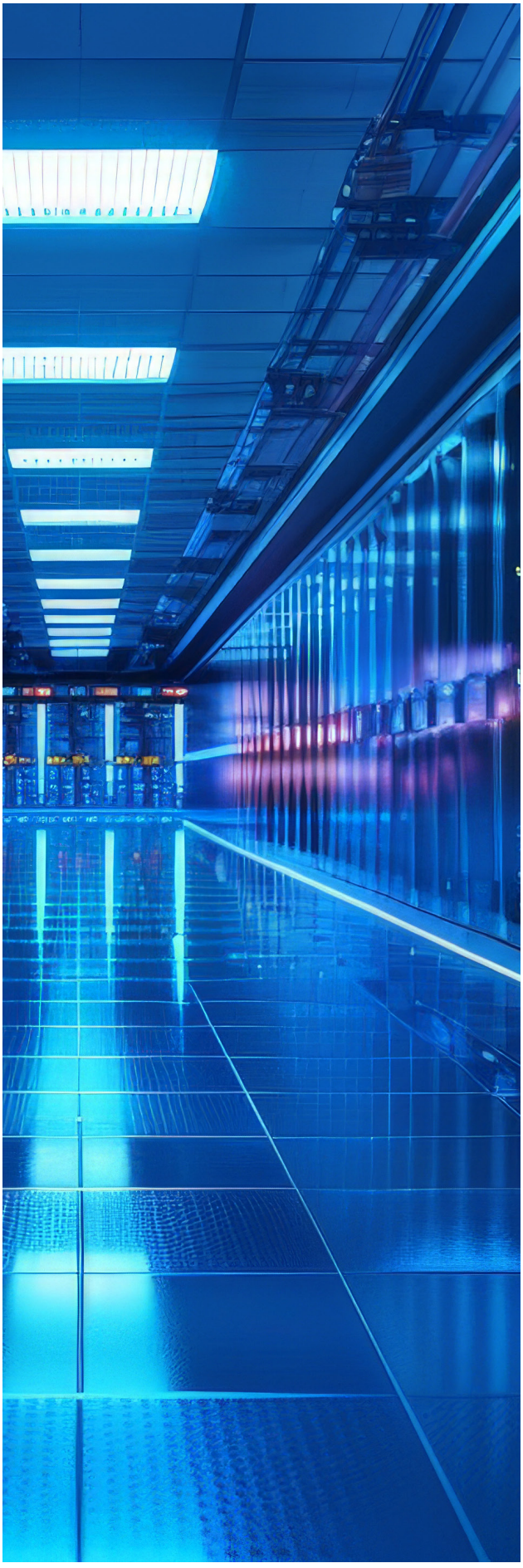
Then SSD price increases of unprecedented global scope and scale began to occur in late 4Q25 and 1Q26. We are currently forecasting SSD direct vendor revenue to climb to $201.7 billion in 2026 (up 563.6% over 2025) based on an increase of vendor-direct ASP/TB to $388.59 (up 299% over 2025) and shipments of 519EB (up 66.3% over 2025). Vendor-direct ASP/TB will increase again in 2027, up 3.6% to an astounding $402.77, but will decline thereafter.

Large YoY SSD EB shipment increases are nothing new. We saw YoY expansions of 200%, 133.3%, 77.9% and 108.7% in 2013, 2014, 2018, and 2024, respectively. But we have never seen such swellings in vendor-direct ASP/TB and revenue, which have led to >80% and even >90% gross margins for the major SSD suppliers.

We believe these developments portend great changes in the SSD markets 2026-2050 which will also engender great changes and opportunities in the HDD, tape and EST markets. While SSD ASP/TB declines will be continuous after 2027, we will never again see the kind of drastic decline we saw in 2019 and 2023; SSD vendor-direct ASP/TB will remain above the $97.40 we saw in 2025 until 2043.

Direct customers of the SSD vendors and end-user clients have displayed an astonishing if grudging willingness to spend staggering sums on bare bones SSDs and integrated systems. Even with slowing growth rates, which reflect the immense costs and challenges of advancing NAND technology and bringing new fabs online to produce it, we believe SSD integrated system User Spend will swell from $544 billion in 2030 to $801 billion in 2040 and to $1.1 trillion in 2050. We also believe these are conservative estimates.

Capacity demand will be partially satisfied by advancing technology, which will enable lower manufacturing costs and, as production volumes increase, should engender lower vendor-direct ASP/TB from 2028 onward. Memory vendors are pushing NAND capacity beyond QLC (4 bits per cell) by adopting multi-bit-per-cell architectures alongside higher-layer 3D NAND (increasing current 162-238-layer designs to 500- and perhaps even 1,000-layer products by 2030) and new materials to balance density, speed, and reliability.



Although the recent precipitous ASP erosions—the price for raw NAND dropped by more than 80% during 3Q22-1Q23—delayed NAND capacity additions and temporarily idled new equipment ramps, the NAND producers certainly now plan to increase production.

Excluding YMTC in China, which has developed leading-edge technology (partially by alleged theft of IP from other NAND companies) but is currently shackled by semiconductor equipment import sanctions[3], there are only four companies which can create and manufacture the kind of advanced NAND-based products needed to satisfy evolving market demands: Kioxia/SanDisk, Micron, Samsung, and SK Hynix.

Micron has announced a 10-year, $24 billion investment to expand its production facilities in Singapore. Kioxia/SanDisk announced a $32 billion joint investment "through 2032" to expand production facilities in Iwate Prefecture Japan dedicated solely to enterprise-grade products. But these plans pale in comparison with SK Hynix's and Samsung's announcement of a joint-venture investment of $576-646 billion to build new high-bandwidth memory (HBM), DRAM and NAND production facilities in Southwest Korea. The companies' $600B+ plan is a "long-term, multi-facility, AI-driven semiconductor expansion aimed at securing South Korea's position in the global memory market and powering the next wave of AI infrastructure."

Given the fact that new fabs require at least two years to build and an additional six months to tune for cost-effective volume production, and that many major customers have committed to 3- and 5-year legally binding purchase agreements, and despite a forecast dip in 2028 shipment growth, we seriously doubt that supply will be sufficient to satisfy escalating demand for at least two more years, which will keep SSD vendor-direct ASP/TB well above $200.00 through 2031.

Because of the inordinate losses incurred during the 3Q22-4Q23 downturns in demand and ensuing precipitous price declines, the SSD makers are more excruciatingly aware that "the results of surplus production are always ruinous," and they are much more determined to increase manufacturing capacity with unprecedented reserve and caution in concert with actual increases in demand.

That demand will be huge. Profitably effective AI inferencing in the Generative tier will always require microsecond speed, and we believe that tier will consume ~25% of the enterprise EB delivered, growing from raw, uncompressed shipments of 312EB in 2025 to ~2.5ZB in 2035.

HDD

Demand for SSDs will obviously be great, but demand for HDDs will be greater, with shipments growing to peak at 4.9ZB in 2032 and surpassing SSD shipments through 2036. HDD deliveries in 2039 will still be greater than HDD deliveries in 2025 (1.6ZB vs 1.4ZB), and HDD vendor-direct revenue will still be greater in 2037 than it was in 2025 ($24.9B vs $20.6B).

HDDs have accounted for 60-70% of all enterprise EB delivered since 2016 and we do not see this trend abating until 2032, when multi-zettabyte incursions from tape and maturing ESTs begin to have largescale impacts. In 2025, HDDs comprised 70.1% of enterprise EB shipments. In 2035, HDDs will shrink to comprise only 36.1% of enterprise EB shipments but will still exceed HDD shipments in 2029 (3.9ZB in 2035 vs 3.5ZB in 2029).

Most of the applications and data historically handled by HDDs do not need constant sub-second access times but do need the much lower cost, much greater power-efficiency, and much more-extended refresh/replacement cycles that tape and ESTs offer. Initial tape and EST user acquisition cost/TB will continue to be 2-5 times less expensive than HDDs with >95% lower costs for long-term data retention and power consumption. TCO and power consumption will become increasingly crucial purchasing criteria for all chief financial officers (CFOs) and chief technology officers (CTOs). As previously stated, we believe many data center managers will soon be forced—by upper-level management edict, by compliance regulations, or by community protest—to use tape and ESTs as ultra-low-cost, sustainable alternatives to HDDs.

Like SSDs, HDDs are on severe allocation, with demand far exceeding current supply, and multiple legally binding long-term purchase agreements from major customers are in place. And like SSDs, it may be impossible for the HDD makers to overproduce relative to evolving demand for at least three more years.

Unlike the SSD vendors, some of whom have derogated the HDD makers for their lack of greed-given courage, the HDD vendors have held prices at more-moderate levels of increase, content to reap unprecedented ~50% profits with vendor-direct ASP/TB remaining above $10.00 through 2033.

Also unlike the SSD makers, the HDD suppliers have no intention of investing $ billions in new read/write head fabs (heads have become the most crucial gating components in limiting HDD production volumes), and will maintain supply discipline and meet exabyte growth through areal density advancements without increasing unit production volumes.

[3] *Yangtze Memory Technology Company (YMTC) has been blacklisted by the US government, along with 21 other Chinese AI and memory chip companies, citing national security concerns and the risk of technology diversion. These sanctions bar US suppliers from selling goods to YMTC without a difficult-to-obtain license and restrict access to technology made anywhere in the world using US equipment.*

This strategy, embraced by all the surviving HDD makers (Seagate, Toshiba, and Western Digital), should enable ~25% EB growth per year through 2030, with 30-33TB and 40-44TB heat-assisted-magnetic recording (HAMR) and enhanced perpendicular magnetic recording (ePMR) HDDs yielding to 50-55TB and perhaps even 100-110TB HAMR HDDs during the next 3-5 years.

Clearly HDDs have been managing far too many of the Active- and Archive-tier workloads at far too great a cost per terabyte while consuming an inordinate share of the world's available energy. But in recent years HDDs have also been more appropriately used to cost-effectively offload contextual AI redundancies in the Generative tier while providing fast access to data.

Non-AI-related Customer Relationship Management (CRM), Enterprise Resource Planning (ERP) and other traditional high-bandwidth enterprise applications will likely be using ~50EB/year of HDD storage through 2050. And after HDDs cease to be used for Active- and Archive-tier workloads that tape and ESTs will handle in the future, and after low-cost SSDs in the Generative tier perform many more of the historic Iterative-tier tasks currently handled by HDDs, high-capacity, relatively low-cost (compared to SSDs) and fast-access (compared to tape and ESTs) HDDs in the Iterative tier will still be used to offload and manage ~1ZB/year of contextual redundancies in the Generative tier.

Tape

Tape is expected to remain an important component of the storage hierarchy throughout the forecast period, although its role will evolve as emerging technologies mature.

We project tape EB shipments to grow at a 29.1% CAGR from 2025 through 2030. Massive AI-driven data creation will make it economically and environmentally difficult to keep all enterprise data on higher-cost, continuously powered storage. Tape's combination of low acquisition cost, extremely low energy consumption, high capacity, and established enterprise infrastructure should make it an attractive repository for the rapidly expanding volume of infrequently accessed data.

The forecast assumes that the LTO roadmap will continue to be executed on an approximate three-year generation cycle through LTO-14. After the current roadmap is complete, we assume tape technology will continue to advance, with a subsequent generation—potentially LTO-15—entering the market around 2040 with approximately 640TB of native capacity per cartridge, consistent with the long-term technology potential identified in the IEEE Mass Storage Roadmap.

Competition from ESTs becomes increasingly important after 2030. We therefore project tape EB shipment growth will moderate to an approximate 4% CAGR from 2030 through 2040, as emerging technologies achieve higher capacities, lower costs, improved access times, and broader software integration. Some workloads that otherwise would have migrated to tape will instead move to new ESTs.

During 2040–2050, tape EB shipments are projected to decline about 3.1% annually as mature ESTs address an increasing share of traditional tape applications. This does not mean tape will disappear. Its enormous installed base, mature ecosystem, removable-media characteristics, air-gap capabilities, and exceptionally low acquisition and operating costs should sustain demand well beyond 2040.



Most importantly, our forecast assumes that tape will retain a significant initial CapEx advantage through 2050. Even as ESTs mature, tape's combination of manufacturing scale, continually increasing cartridge capacity, established automation, and very low media cost per TB will remain difficult to displace completely. We therefore expect tape and ESTs to coexist for an extended period, with ESTs progressively capturing applications requiring faster access or exceptionally long media life while tape continues to provide a highly economical solution for storing massive quantities of inactive and archival data.

A key disadvantage of tape, compared with all EST roadmaps, is its lack of backward compatibility. This requires future media migrations of archived data, as new LTO tape drives will not be able to read older generations of LTO media.[4]

Emerging Storage Technologies

Our forecast assumes that several ESTs will ship in strategic volume during the next five years, with initial product deliveries beginning in late 4Q27 and commercial availability commencing in 2028. These technologies include new approaches to optical storage using new media, including ceramic, quartz, and thin film, in different shapes (discs, platters, and tape).

We expect the EST market to develop into two broadly differentiated categories. The first will emphasize relatively rapid access, initially providing access times of less than 30 seconds with modest IOPS performance (Fast Emerging). The second will emphasize extremely long media life, very low cost, high density, and long-term retention of inactive data, where access time is less important (Slow Emerging).

Performance should improve rapidly as these technologies mature. Our model assumes that one or more ESTs will consistently achieve access times below 10 seconds by 2030. Combined with falling costs and increasing storage-system integration, this should make EST capacity meaningful by the end of the decade. We project ESTs will account for >6% of total EB shipments by 2031.

Commercialization alone, however, will not be sufficient to drive widespread adoption. Considerable operating-system, file-system, object-storage, data-management, and storage-software development will be required during the 2027–2030 period to integrate these new media into mainstream enterprise environments. These investments will provide the foundation for rapid adoption during the following decade.

Consequently, we project EST capacity shipments to grow at an approximate 40% CAGR from 2030 through 2040 and comprise >50% of new EBs delivered beginning in 2039 as costs decline, performance improves, production capacity expands, and applications migrate to the new technologies. Growth is expected to moderate to approximately 9.1% annually from 2040 through 2050, compared with an approximate 7.5% growth for the overall storage market, as ESTs mature and penetrate most of their addressable use cases, expanding to >60% of new shipments.

A key advantage of all ESTs compared with tape is the promise of full backward compatibility, which minimizes the need for future data migration. This ability ensures future access to the data, regardless of the device that initially wrote it. But the EST vendors have yet to commercially achieve this promise.

Forecast Implications

The central assumption underlying this forecast is that new, innovative storage technologies will gain rapid market acceptance by offering low-cost, energy-efficient, high-capacity storage with acceptable access times and long media life. No single technology is likely to satisfy every requirement. SSDs and HDDs will remain important for performance-oriented applications, while tape and ESTs will increasingly address the immense volume of data that must be retained economically but does not require enduring nanosecond-to-millisecond access times.

By 2050, the result will likely be a four-tier storage hierarchy (as detailed in section I) consisting of a Generative high-performance tier primarily for varied AI applications that require very rapid response; an Iterative production tier for cost-effectively offloading contextual AI redundancies in the Generative tier while providing fast access to data, as well as for more traditional high-bandwidth applications such as online transaction processing, CRM or ERP systems; an Active tier for massive amounts of reference data to feed AI applications in the Generative tier; and an Archive tier for long-term digital preservation.

The economic and energy requirements of storing unprecedented quantities of data will make intelligent data placement increasingly important—and will create vast opportunities for both established technologies such as tape and new ESTs now moving toward commercialization.

We need to reiterate here that, if ESTs do not deliver on their promises, then the markets for HDDs in the Iterative and Active tiers and tape in the Active and Archive tiers will remain far larger for far longer, as depicted in Figure 5.

[4] LTO 1-7 could read two generations prior and write one generation prior. LTO 8 could read and write LTO 8 and LTO 7 tapes but could not read LTO 6 tapes. LTO 9 could read and write LTO 9 and LTO 8 tapes but could not read LTO 7 tapes. LTO 10 can read and write only LTO 10 tapes, with no backward compatibility with any prior generation, and this will be the case with all future LTO generations.

IV Essential Features for Long-Term Digital Preservation

The rapid growth of enterprise data is increasing the need for storage solutions designed specifically for long-term digital preservation, particularly for infrequently accessed information that does not require sub-second access or extremely high I/O performance. Effective long-term storage solutions require a balanced combination of capacity, economics, energy efficiency, performance, durability, reliability, and seamless long-term accessibility.



High Capacity

Long-term storage solutions must provide high media capacities and excellent rack-level density to accommodate rapidly growing data volumes. Storage density becomes increasingly important as archives grow from petabytes to exabytes and beyond.

Low Cost/TB

Cost should be evaluated using long-term TCO (TCO), not simply media acquisition cost. Hardware, media, software, maintenance, power, cooling, and technology refreshes should be considered over retention periods of 10, 20, or more years.

Low Power Consumption

Energy requirements should include power used to write, read, and preserve data. Technologies whose media consume little or no power while inactive can offer substantial energy and cooling advantages, particularly for very large archives.

Acceptable Access Times

Access time determines the applications a long-term storage solution can support. Consistent retrieval in less than approximately 30 seconds could enable active and iterative archive applications, while retrieval measured in minutes or hours will generally be more appropriate for deep archives.

Adequately Fast Read/Write Speeds

Transfer rates must be sufficient relative to media capacity and workload requirements. Very high-capacity media with slow transfer rates can tie up readers and writers for long periods, requiring additional devices and potentially diminishing economic advantages.

Media Robustness

Archival media should provide long life and tolerate reasonable ranges of temperature, humidity, and environmental threats. Long media life combined with extended infrastructure refresh cycles can reduce cost, eWaste, and operational disruption.

Reliability and Data Integrity

Long physical media life does not by itself ensure reliable preservation. Long-term storage solutions must provide acceptable bit-error rates, error correction, write verification, checksums, redundancy, data scrubbing, and effective recovery mechanisms.

Media Immutability

Write Once, Read Many (WORM) capability can protect scientific, regulatory, historical, and other permanent records from alteration, ransomware, or accidental deletion. However, immutable media may be less suitable for workloads requiring frequent modification or capacity reclamation.

IT Infrastructure Support

Long-term storage solutions should integrate easily with existing enterprise environments through familiar interfaces, protocols, file systems, object APIs, automation, and storage-management software. Open standards and minimal changes to existing workflows can significantly reduce adoption barriers.

Logical Preservation

Preserving the physical bits is not enough; organizations must retain the ability to locate, read, decode, and interpret them decades or centuries later. Readers, interfaces, software, metadata, file systems, and data formats must therefore remain accessible or reproducible throughout the archive's lifetime.

A new consortium (LAST) has been formed to help ensure perpetuation of the priceless artifacts of our personal, corporate, and cultural history[5].

Ultimately, no single characteristic determines the effectiveness of a long-term digital storage solution. Successful digital preservation requires that data remain economically sustainable, physically intact, reliably recoverable, and logically usable for as long as it has value.

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[5] *In September 2026, SNIA (Storage Networking Industry Association) launched the Long-term Access, Storage & Technology (LAST) Community, a provisional group to address the "digital dark age" risk of obsolete storage media.*

V EST Players on the Verge of Production: Company and Technology Profiles

From the many "startups" scattered in the world[6] we have chosen to profile five companies in this section based on the following criteria:

- The company must be "on the verge" in terms of demonstrable "technology readiness."
- The company's technology must meet the major capacity, cost, power, robustness and longevity features required for success in the Emerging markets.
- The company must have comparatively modest additional funding needs (<$50 million USD) to attain strategic volume production, with a realistic goal of achieving initial "commercial readiness" within two years, which means that 2028 will be a "crucible" year for the company's future.

The following five companies meet our criteria for profiled inclusion in this section.

We need to emphasize that being "on the verge" is vastly different from being actually ready for commercial production. On the final stages of the road to "technology readiness," all companies will have to make further compromises between performance and capacity. At this point in time, many targeted specifications are in a fluid state.

In addition to technical challenges, there will be enormous challenges for all of these companies to cost-effectively ramp manufacturing at scale.

We believe 2028 will indeed be a "crucible" year.

Our aim in these profiles is not to promote but to scrutinize and objectively report "from the field."

Cerabyte

Product Category: *Fast Emerging (<30-second-to-<10-second access times)*

www.cerabyte.com

Contact: *Steffen Hellmold, President, steffen.hellmold@cerabyte.com*



Cerabyte is a Munich-based startup founded in 2022 that is developing a high-capacity archival storage technology using laser-written ceramic media. Its approach combines the durability of ceramic materials with high-speed optical recording and reading, potentially providing an unusual combination of extremely long media life, high performance, random access, and very low energy consumption.

Cerabyte's media consists of ultra-thin, 100-micron flexible glass sheets coated on both sides with a 15-nanometer dark ceramic nanolayer. Data is permanently recorded in the ceramic layer using laser pulses and Digital Micromirror Devices (DMDs), which allow large numbers of bits to be written in parallel. Cerabyte ultimately targets up to two million bits per laser pulse and read/write performance of 1–2 GB/s. Data is optically read using high-speed imaging and GPU-based processing.

The individual sheets are stacked in cartridges, providing high volumetric density while enabling random rather than sequential access to data. Cerabyte plans to integrate these cartridges into automated library systems, potentially providing substantially faster access than conventional tape archives. The company is also leveraging established display-glass manufacturing and coating technologies, which could provide a pathway toward high-volume, low-cost media production.

Durability is one of the technology's most compelling characteristics. Cerabyte projects media life measured in thousands of years, with resistance to water, electromagnetic pulses, UV and gamma radiation, and extreme temperatures. Once written, the media requires no power to retain data, potentially providing significant energy and cooling advantages for large-scale archives.

[6] *Other companies include but are not limited to Ewigbyte (www.ewigbyte.com), Optera (www.opteradata.com), Piql (www.piql.com), and of course there are many companies (see www.dnastoragealliance.org) exploring the possibilities for DNA data storage, which currently suffers from inordinately high costs and unacceptably slow access times, and is many years away from any technology or commercial readiness.*

Cerabyte's roadmap calls for pilot systems in 2026–2027 offering 1–5PB per rack, followed by 20–40PB/rack systems during 2028–2030 and ultimately 80–160PB/rack systems at cloud scale during the early-to-mid 2030s. If Cerabyte can achieve its ambitious density, performance, cost, and manufacturing objectives, the technology could address not only deep archive but also active archive applications. Its principal challenge will be translating a promising and highly differentiated technology into reliable, economically competitive systems manufactured and supported at enterprise scale.

Folio Photonics (FP)



Product Category: *Fast Emerging (<30-second-to-<10-second access times)*

www.foliophotonics.com

Contact: *Steve Santamaria, CEO, steven.santamaria@foliophotonics.com*

FP was built on more than a decade of materials-science research, developed in collaboration with Case Western Reserve University's Center for Layered Polymeric Systems, a National Science Foundation-funded Science and Technology Center. Based in Solon, Ohio, FP is poised to deliver a new optical technology, enabling 8 or 16 film layers per side per disc. Using next-generation materials, patented polymer co-extrusion and film-based disc construction processes (distinct from mere optical layering), in concert with customized optical pickup units (OPUs), FP is engendering far greater data densities and faster random-access speeds than was thought possible several years ago while remaining compatible with data center infrastructure already deployed at scale. The company plans to deliver up to 1-terabyte discs beginning in late 4Q27, with a roadmap that extends to 2-to-5-terabyte discs 2029-2030 and to 5-to-10-terabyte discs 2030-2035, with complete backward compatibility and consistent access times of <10 seconds.

In-library random access times are specified in milliseconds or seconds as opposed to 25 seconds to minutes for linear tape. The power budget is projected to be less than 100 watts per terabyte per year (significantly less than tape) and shelf life is expected to be greater than 100 years (a now standard optical claim; LTO tape is now specified at 50 years). The usual optical benefits of course will also obtain—indelible data with write once read many times (WORM) technology, encryption, and air gap security (a requirement of increasing dimension, due to increasing malware sophistication).

FP's required near-term future funding to attain initial volume production is modest, and the company's optical technology might actually begin to make some viable commercial impact in late 4Q27.

HoloMem



Product Category: *Slow Emerging (minutes to hours access times)*

https://holomem.co.uk

Contact: *Charlie Gale, CEO, charlie@holomem.co.uk*

HoloMem Ltd. is a UK-based startup founded in 2020 that is developing a holographic storage technology designed as a complement to conventional LTO tape. Its HoloDrive system uses low-cost lasers to write multiplexed holograms into a proprietary polymer ribbon, forming permanent volumetric structures called voxels, each of which stores multiple bits. The ribbon is packaged in an LTO form factor cartridge, allowing HoloMem to leverage much of the infrastructure already deployed for enterprise tape storage.

This compatibility is an important differentiator. In 2026, a prototype HoloDrive was successfully integrated into a data center using a BDT tape library, demonstrating that HoloMem and LTO drives and cartridges can coexist within the same library. By emulating conventional tape-drive behavior, HoloDrive is designed to integrate into existing archive environments with minimal software changes. BDT is also expected to act as HoloMem's scale-up and GTM partner. Pilot systems are planned for 2027, followed by initial commercial products in 2028. Early products are expected to offer capacities comparable to LTO-9 and transfer rates of approximately 100 MB/s, with longer-term targets of 200TB+ per cartridge.

The technology offers several attractive characteristics for archival storage: low media cost, WORM data protection, media life of at least 50 years, backward compatibility across media generations, low power consumption, and broad environmental tolerances. The polymer ribbon is designed to operate across temperatures from 0°C/32°F to 80°C/176°F and relative humidity from 10% to 90%.

HoloMem appears particularly well suited to deep archive environments requiring decades of economical data retention. Its ability to leverage existing tape libraries and archive software could significantly reduce barriers to enterprise adoption. Longer term, however, commercial success will depend on achieving higher capacities and transfer rates, demonstrating competitive economics at scale, and establishing a track record for reliability in production environments.

Indellium Storage

Product Category: *Slow Emerging (minutes to hours access times)*

www.indellium.com

Contact: *Rob Hummel, President, rob.hummel@indellium.com*



Indellium Storage, formerly Group 47, is developing a distinctive archival storage technology called the Digital Optical Technology System (DOTS). Its defining characteristic is simplicity: data is stored as microscopic visual patterns on tape that can ultimately be read optically. Indellium acquired the technology from Eastman Kodak, which had invested more than $120 million in its development. Indellium subsequently advanced the technology and has been awarded 5 additional patents to improve the hardware design, simplify manufacture of the writer and reader, and for the Bit Plane Image archive format.

DOTS uses a highly stable phase-change recording layer called Indellium, a proprietary three-metal alloy deposited on PET film. The WORM media is currently designed in two formats: a reel holding up to 20TB and an LTO-form-factor cartridge storing 2TB. Once recorded, the data cannot be altered. The media is resistant to electromagnetic pulses, water, and petrochemicals and can tolerate temperatures ranging from -6°C/21.2°F to 66°C/150.8°F.

Accelerated life testing performed by Carnegie Mellon University indicated a minimum media life of over 200 years. The company has also successfully developed a proof-of-concept DOTS writer and reader for the CIA. Perhaps DOTS's most compelling attribute is its potential to eliminate long-term dependence on any proprietary storage infrastructure.

Because information is stored visually, future recovery does not inherently depend on the original drive, operating system, device drivers, or storage application. Human-readable instructions can also be recorded on the media, providing future users with information needed to recover the digital content.

This combination of extremely durable WORM media and reduced technology dependency makes DOTS particularly intriguing for preservation periods measured in centuries rather than decades. Unlike the other technologies, the fundamental DOTS technology has been tested and proven by external entities (Carnegie Mellon University and the CIA); the remaining challenge is commercialization. Indellium must successfully transition from proven technology to manufacturable products, establish production capacity, and demonstrate competitive economics and reliability at enterprise scale.

SPhotonix

Product Category: *Fast Emerging (<30-second to <10-second access times)*

www.sphotonix.com

Contact: *Ilya Kazansky, CEO, ilya@sphotonix.com*



SPhotonix is a US startup with a Swiss-based R&D subsidiary founded in 2024 to commercialize an innovative optical storage technology developed over more than 20 years of research at the University of Southampton in the UK. The technology uses 5-inch fused-silica glass plates as the storage medium, with data written by a femtosecond laser that creates nanoscale structures encoded in five dimensions. At maturity, the technology could potentially store up to 250TB on a single piece of media with a targeted retail price of $35.

Glass provides some compelling advantages for long-term data preservation. The media is exceptionally durable, potentially retaining data for thousands of years without media migration or environmentally controlled storage. It is resistant to water and electromagnetic radiation and can withstand temperatures approaching 1,000°C/1,832°F.

Because the media is inherently WORM, it also provides strong protection against accidental or malicious alteration. SPhotonix is targeting approximately $30,000 for its laser writer and $6,000 for a reader.

In 2026, an SPhotonix laboratory prototype successfully stored 6TB on a 5-inch glass plate, achieving write speeds of 4MB/s and read speeds of 30MB/s. The company's roadmap calls for dramatically scaling both capacity and performance, targeting 250TB per plate and read/write speeds of 500MB/s by 2030.

If these objectives can be achieved economically, SPhotonix could offer an intriguing combination of high capacity, extremely long media life, low energy consumption, WORM protection, backward read compatibility, and relatively high data-transfer rates.

The technology appears particularly well suited to deep and active archive applications, where data immutability, longevity, energy efficiency, and low lifecycle cost are increasingly important. Its ultimate success, however, will depend on translating promising laboratory results into reliable, manufacturable systems and integrating them effectively into enterprise storage infrastructures.



VI Inconclusive Conclusions

If something cannot go on forever, it will stop.
– Herbert Stein, American Economist

Despite historical precedents—to wit, a 28.6% actual 2010-2020 CAGR—we reiterate our firm conviction that, after a projected near-term 2025-2030 27.1% CAGR and a 2020-2030 21.8% CAGR (which incorporates the 2022-2023 downturns in demand), annual growth rates must decline after 2030.

User Spend scenarios at 25% annual 2030-2050 EB growth rates (which are actually less than the 2010-2020 CAGR) generate absurd results, expanding from a feasible $628 billion in 2030 to ludicrous levels of $3.4 trillion in 2040 and $21.6 trillion in 2050. Even if we decrease initial User Spend per TB estimates by 50% or even 75%, the numbers are still farcical.

Of course, one could accurately describe the recent freakish pricing dynamics (especially for SSDs, but also for HDDs and tape) as "farcical," but they did in fact happen, and will continue to obtain for several more years. But they cannot go on forever.

We will surely be far closer to fulfilling actual storage demand during the next three years, and we may begin to see new iterations of Monroe's Law: *Just as soon as the drive makers manage to ramp production to meet an apparent increase in demand, the demand dissipates*—often with the kind of disastrous fiscal consequences the SSD vendors suffered in 2023. Why this happens is a matter of mystery and some debate (is it simply customer double-ordering and vendor miscalculation combined with blind competitive greed?), but it has happened in the past with disturbing frequency.

What will be different in the coming cycles?

Where do we come from? What are we? Where are we going?[7]

Let's take another look at what was different during the 2022-2023 surplus and re-examine what is happening now.

In the past, a surplus of supply relative to demand lasted one to three quarters. The recent surpluses lasted six quarters (from late 2Q22 through 4Q23), and led to unprecedentedly low 2.2% and 4% shipment increases in 2022 and 2033, after 34.6% and 40.3% expansions in enterprise EB deliveries in 2020 and 2021.

Enterprise SDD deliveries declined for the first time in history by 30.5% in 2023, causing a 43.3% decline in vendor ASP/TB and a 60.6% decline in vendor revenue. Enterprise HDD deliveries declined for the first time in history by 1.8% in 2022. (Enterprise SSD and HDD YoY growth rates had varied over the years but they had never declined.) Enterprise tape deliveries expanded by only 8.9% in 2022 and 10.1% in 2023 after a record 39.7% uptick in 2021.

To put this in historical perspective: During the 22-year period from 2000-2021, there were ***no*** years of sub-5% growth; in fact, there were ***no*** years of sub-10% growth, and—despite (among much else) the impacts of the 2008-2009 economic meltdown and the Q4/2011 effects of the Thai floods (which temporarily reduced HDD production capabilities by >60%)—there was a 25% CAGR in total enterprise EB delivered.

All NAND fab expansions were halted in 2022-2023 to prevent adding to surplus inventories and NAND fab utilization rates were allowed to fall below 100%. This had never happened before. If any semiconductor plant is designed to produce, say, 100,000 wafers per month (WPM), it must, once operational, produce 100K WPM, irrespective of evolving demand; anything less than 100% production is enormously costly to the fab owner.

As previously stated, new NAND fabs require at least two years to build and an additional six months to tune for cost-effective volume production. The 2022-2023 suspension of all fab-expansion activity meant that the production capacity that might have come online during 2024-2025 would not come online until at least 2026-2027.

Meanwhile, all HDD makers were already deeply involved in the process of aligning future production with diminishing unit-volume demand. OEM integration of HDDs in notebook and desk-based/workstation PCs were shrinking from 92.8 million units in 2019 (36% of the PC total) toward almost no units in 2024-2025 (the aftermarkets for PC-/consumer-grade HDDs were also diminishing), and the 2019 17.6-million-unit markets for mission-critical 10K- and 15K-rpm HDDs were also dwindling toward extinction.

The HDD makers focused almost exclusively on the design and production of high-capacity, business-critical/nearline 7.2K-rpm enterprise HDDs. Shipments of these drives grew to almost 70 million units in 2021 but declined in 2022 and displayed only a tepid recovery in 2023 and 2024.

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[7] *The title of Paul Gauguin's Post-Impressionist masterpiece,* ***D'ou venons-nous? Que sommes-nou? Ou allons-nous?***

Will the Past Be Prologue, or Will History Be Bunk?[8]

In the past, a dearth of supply relative to demand lasted one to three quarters. The current lack of supply relative to evolving demand has already lasted for more than four quarters and seems destined to last for at least another eight quarters, from late 2Q25 through 4Q28.

The 2024-2025 AI-generated surge in demand was hardly unprecedented but it was largely unanticipated, and was collectively regarded with skepticism by SSD and HDD industry executives: Is this uptick a "bubble"? Will it soon burst? These were reasonable questions to ask in the wake of the costly 2022-2023 downturns in demand.

Major customers were shocked to discover that the drive makers had no immediate inclination to increase production. By midyear 2025, the impossible had occurred: core memory (SRAM, DRAM), NAND flash modules, NAND SSDs, and HDDs were in severe, simultaneous and ongoing shortage. By midyear 2026, all major customers had engaged in long-term, legally-binding purchase agreements to secure supply through 2028. These agreements contain stringent penalties for failure to take delivery of allotted products at agreed-upon schedules.

And this too had never happened before.

In the last year, as demand has again risen to more-or-less historic norms and inventories shrank, prices have never risen so high and so fast, and gross margins have never risen to >90% for the SSD makers and to >50% for the HDD makers. The drive makers are of course loathe to relinquish these margins, and the net profits they produce.

One of the key differences between the past and what we are seeing in the present is the concertedly aligned strategies of the drive makers. We have never seen the SSD and HDD makers add capacity with such coordinated reserve and caution in the face of a burgeoning demand, and this will surely lessen the likelihood of supply exceeding demand for several more years.

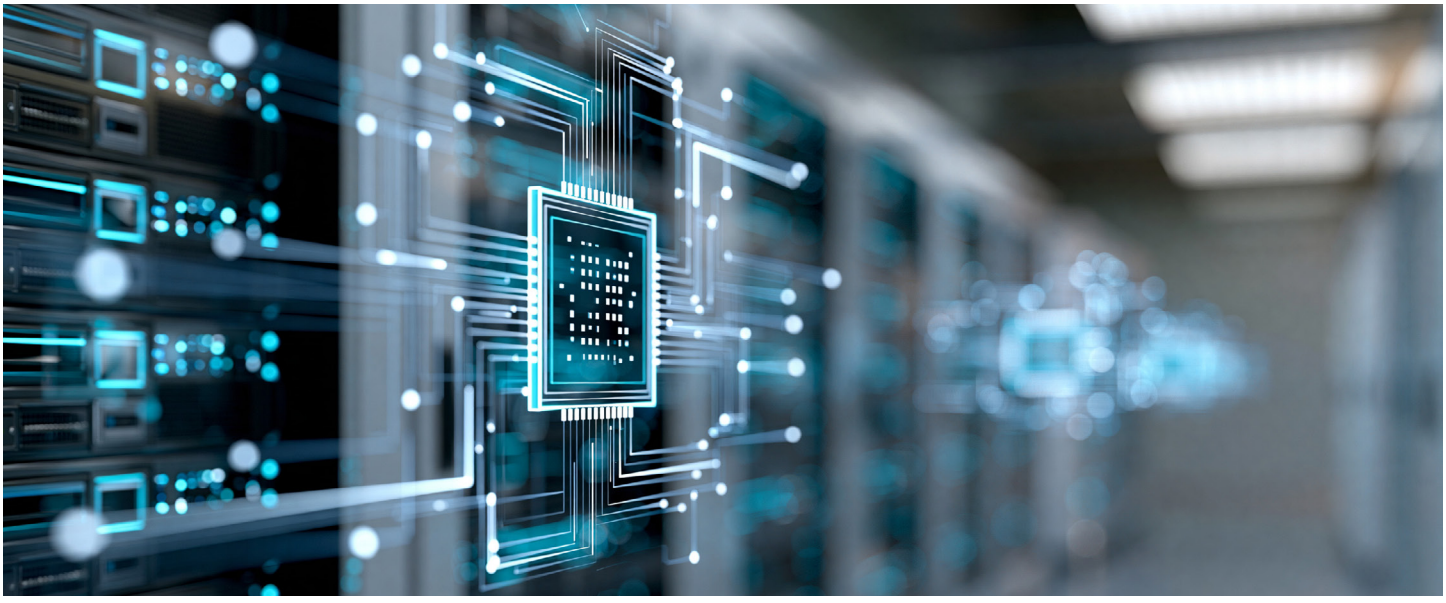
What began by accident and miscalculation will be prolonged by design. We may never again see the kind of reckless overproduction and senseless waste of profits we have seen during so much of the history of the SSD and HDD industries.

Another key difference between the past and what we are seeing in the present is the willingness and the ability of major customers to pay these absurdly inflated, unprecedented prices. The hyperscalers and traditional OEMs have never had so much cash at their disposal, and—driven by the conviction that in the AI era the company that has the greatest fast access to and control over the most zettabytes will prevail—are planning to spend hundreds of $ billions on their storage IT infrastructures.

But this cannot go on forever. The runaway freight train of enterprise data will soon collide with ROI restraints as limited budgets and enduring corporate profits become more-critical concerns of all CFOs.

All these developments will surely benefit the tape and EST suppliers, who can legitimately make great claims for immense cost savings and vast reductions in power requirements with sufficiently fast access to huge oceans of data.

We have already seen unprecedented new demand for tape and we expect demand for ESTs to surge soon.



[8] *"History is more or less bunk. It's tradition. We don't want tradition. We want to live in the present, and the only history that is worth a tinker's damn is the history that we make today."—Henry Ford, founder of the Ford Motor Company, pioneer of mass production.*

Appendix 1: Notes and Definitions

User Spend

We have depicted the reported and unreported 2010-2025 SSD and HDD vendor revenue with a great degree of accuracy, but because there are so many variables involved with so many different kinds of storage systems, it is impossible to know just what kind of average markups over bare-bones SSD and HDD vendor revenue to determine cost/TB User Spend, are truly realistic.

Major IT analyst firms forego any scrupulous analysis and simply use a 30% markup over vendor revenue as a universal average for all manner of hardware and software technologies to determine "User Spend," but that indolent estimate cannot possibly reflect actual User Spend. We know the 2020 vendor ASP for solid-state arrays (SSAs) was $1,536/TB (uncompressed) and for Hybrid SSD/HDD arrays was $265/TB (uncompressed). These estimates were extracted from the vendor revenue derived from the sale of external controller-based (ECB)/ network fabric-attached storage systems to their direct customers. At a 30% markup for "User Spend," this would equate to $1,843.20/TB for SSAs and $318/TB for Hybrid SSD/HDD arrays. We estimate the server/direct-attached storage (DAS) ASPs were at least 50% lower but much harder to determine with any degree of accuracy, since the server vendors do not separately report their substantial storage revenue.

After careful further analysis in the wake of the 1Q26 pricing dynamics, we raised our estimates of SSD User Spend to an 85% markup over SSD vendor revenue (vs. a 50% markup in our prior forecast) and raised our estimates of HDD User Spend to a 50% markup over HDD vendor revenue (vs. a 35% markup in our prior forecast). Our revised 2020 estimates of a compressed $235.02/TB user-integrated SSD cost at 85% average markup over uncompressed SSD vendor revenue and of an uncompressed $24.99/TB user-integrated HDD cost at 50% average markup over uncompressed HDD revenue, are still probably far too conservative a reflection of actual User Spend, even considering that more than 60% of all the enterprise SSD and HDD EB go to the hyperscale customers at rock-bottom prices.

In any case, one can certainly argue that our SSD (85% markup) and HDD (50% markup) User Spend estimates are responsibly cautious and perhaps greatly understated, and yet they still portend unprecedented growth in User Spend.

Compressed tape User Spend is based on our estimates of the media, drives and libraries required to support our estimates of compressed tape EB shipments (at least 2.5x native capacities). Emerging storage User Spend is entirely speculative but is based on a competitive need to be >2 less than HDD initial acquisition Costs/TB with a 15-year as opposed to a 5-year replace/refresh cycle to achieve greater than 50% market penetration.

Enterprise Data Definitions

We define "enterprise exabytes" as the total capacities delivered on all enterprise-class SSDs, HDDs, tape, and—in the near future—enterprise emerging storage media. This definition specifically excludes exabyte shipments of consumer-grade SSDs, HDDs, and flash modules delivered to PCs, entertainment devices, cell phones, home video surveillance, and other consumer and industrial applications (such as aircraft and telecom installations), the vast majority of which are already backed up in, and therefore reflected by, the enterprise-grade exabytes serviced by corporate and cloud data centers.

Notes Relevant to All Tables

—SSD: Solid-state drive capacities reflect an approximate 5x compression ratio, but only for approximately 5% of all enterprise SSD EBs shipped, the vast majority of which (~95%) are configured in server/direct-attached storage (DAS) systems, with little or no data compression, not in fabric-attached solid-state arrays (SSAs), wherein sophisticated data compression software is the norm.

—HDD: Hard-disk drive capacities are raw/uncompressed, since so few enterprise HDDs are integrated with any form of data compression.

—Tape: Capacity estimates include both LTO and IBM TS1100 shipments and reflect a global average of at least 2.5x data compression.

—EST: There should be huge opportunities for what we refer to collectively as "enterprise emerging storage" technologies to play major roles in future markets, as indicated in our 2026-2050 growth estimates, from 0.3EB in 2027 to 20.6ZB in 2050. Emerging shipments begin to exceed tape shipments in 2033.

—Active Archive: The total active-archive storage markets are the sum of all LTO+IBM+EST shipments.

—Active Installed Base: This is an estimate of the total EBs of enterprise data which remain active, in use. We believe the active installed base was 94.6EB in 2006 and will likely grow to exceed 23ZB in 2030 and 230ZB in 2050. For the active installed base, we assume a 5-year SSD and HDD infrastructure refresh/ replacement cycle, retiring, for example, all 2010 shipments in 2015 while adding 2015 shipments to the installed base of the prior year, and we repeat this cycle through 2050. We have now refined our estimates of the active installed base with a 7-year tape and a 15-year EST infrastructure refresh/ replacement cycle.

—ASP/TB: This is the average price at which SSD and HDD vendors sell to hyperscalers (such as AWS), OEMs (such as Dell), and distributors (such as TD SYNNEX).

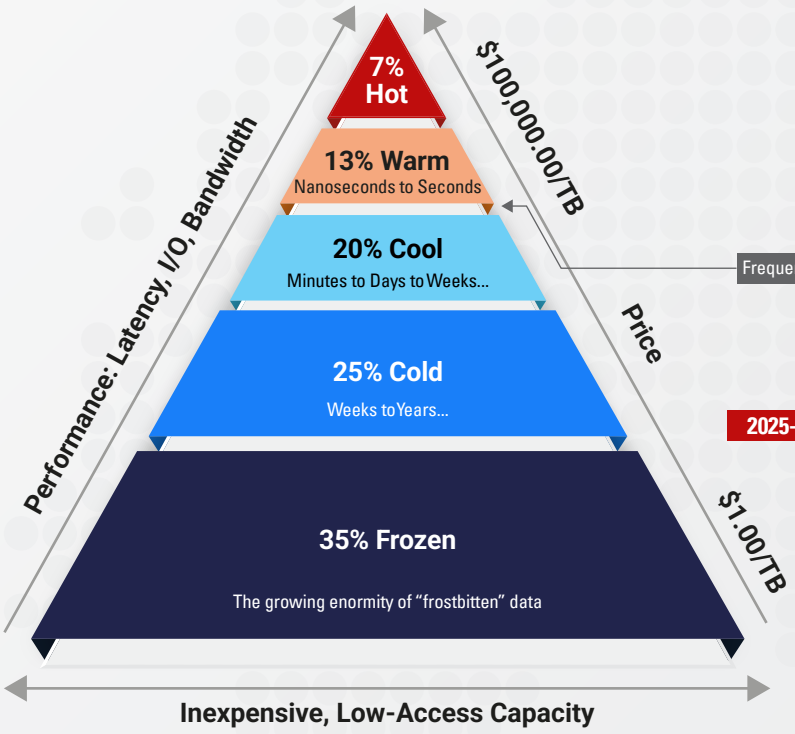
—Cost/TB and User Spend: This is the average cost which users pay for cloud services from hyperscalers or smaller Internet Service Providers (ISPs) and integrated products from OEMs or distributors. Average Cost/TB and total exabytes delivered for integration determine User Spend. We estimate an 85% markup over vendor ASP/TB for SSDs and a 50% markup over vendor ASP/TB for HDDs to determine User Spend.

Appendix 2

Below is a depiction of our initial 1Q26 reconsideration of the old storage pyramid model.

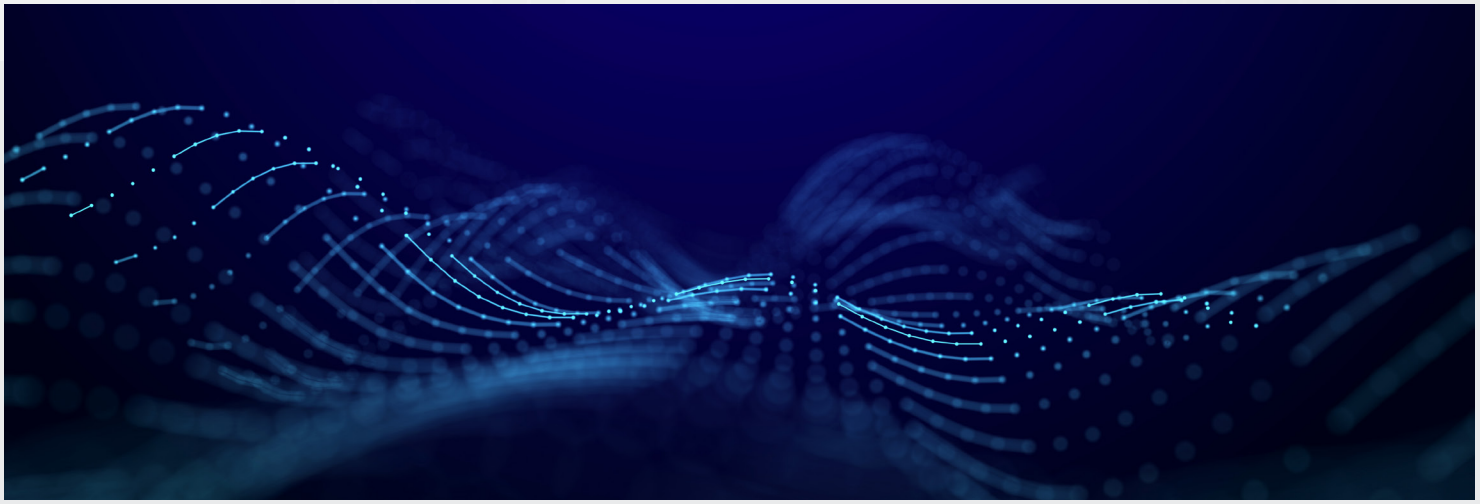
NEW WAYS OF TIERING: DECLINING OF DISTINCTIONS BETWEEN THE LAYERS... IT'S EITHER HOT, OR IT'S NOT...

Differing degrees of strong temperature, differing technologies in the layers...
With an ever-increasing base of cold/frozen data...



A majority of the cold/frozen layers may be JIC (Just in Case) or WORN (Write Once Read Never) data, which may never be accessed at all–nor, in most cases, will it ever be deleted.





Appendix 3

Annually detailed history and forecast tables, 2010-2050

Table 5: Granular Details of Enterprise Storage Shipment and Revenue Histories, 2010-2020

	2010	2011	2012	2013	2014	2015	CAGR 2010-2015	2016	2017	2018	2019	2020	CAGR 2015-2020
SSD													
Vendor Enterprise SSD Uncompressed Shipment Estimates (EB)	0.2	0.6	1.0	3.0	7.0	11.0	*122.9*	18.0	29.0	51.6	66.4	108.9	*58.2*
YoY Change %	-	*200.0*	*66.7*	*200.0*	*133.3*	*57.1*		*63.6*	*61.1*	*77.9*	*28.7*	*64.0*	
Vendor Enterprise SSD Uncompressed Direct Revenue Estimates ($M)	$994	$2,662	$3,022	$4,429	$5,630	$6,283	*44.6*	$8,359	$12,973	$14,861	$9,424	$16,601	*21.4*
YoY Change %	-	*167.8*	*13.5*	*46.6*	*27.1*	*11.6*		*33.0*	*55.2*	*14.5*	*(36.6)*	*76.2*	
Vendor Enterprise SSD Uncompressed Blended ASP/TB ($)	$4,970.04	$4,436.41	$3,021.87	$1,476.48	$804.34	$571.18	*(35.1)*	$464.39	$447.36	$288.00	$141.92	$152.45	*(23.2)*
YoY Change %	-	*(10.7)*	*(39.2)*	*(66.7)*	*(73.4)*	*(61.3)*		*(18.7)*	*(3.7)*	*(35.6)*	*(50.7)*	*7.4*	
Vendor Enterprise SSD Compressed Shipment Estimates (EB)	0.2	0.7	1	4	8	13	% Changes Same As Uncompressed	22	35	62	80	131	% Changes Same As Uncompressed
Estimated SSD System User Spend, 85% Markup Over Vendor Revenue ($M)	$1,839	$4,924	$5,590	$8,194	$10,416	$11,624		$15,464	$24,001	$27,492	$17,434	$30,713	
Estimated SSD User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$7,662.15	$6,839.47	$4,658.72	$2,276.23	$1,240.03	$880.57		$715.94	$689.68	$444.00	$218.80	$235.02	
HDD													
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	46	52	66	91	117	157	*27.8*	218	267	394	490	680	*34.1*
Vendor Enterprise HDD Uncompressed Direct Revenue Estimates ($M)	-	13.0	26.9	37.9	28.6	34.2	% Changes Same As User	38.9	22.5	47.6	24.2	38.9	% Changes Same As User
Vendor Enterprise HDD Uncompressed Blended ASP/TB ($)	$6,698	$7,831	$8,897	$8,917	$9,181	$9,523		$8,988	$8,935	$10,915	$10,737	$11,326	
Estimated HDD System User Spend, 50% Markup Over Vendor Revenue ($M)	$145.61	$150.60	$134.80	$97.98	$78.47	$60.66		$41.23	$33.46	$27.70	$21.93	$16.66	
Estimated HDD User Initial Integrated Uncompressed Average Acquisition Cost/EB ($)	$10,047	$11,747	$13,346	$13,375	$13,772	$14,285	*7.3*	$13,482	$13,403	$16,372	$16,106	$16,988	*3.5*
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	-	16.9	13.6	0.2	3.0	3.7		(5.6)	(0.6)	22.2	(1.6)	5.5	
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	$218.41	$225.89	$202.20	$146.98	$117.71	$90.98	*(16.1)*	$61.84	$50.20	$41.55	$32.90	$24.99	*(22.8)*
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	-	3.4	(10.5)	(27.3)	(19.9)	(22.7)		(32.0)	(18.8)	(17.2)	(20.8)	(24.1)	
TAPE													
Enterprise Tape Compressed Shipment Estimates (EB)	30	43	53	62	86	98	*26.8*	124	136	125	134	136	*6.7*
YoY Change %	-	*44.3*	*22.9*	*16.4*	*38.3*	*15.0*		*26.0*	*9.7*	*(8.1)*	*7.2*	*1.5*	
Enterprise Tape User Spend Estimates ($M)	*Tracking begins 2018*									$1,646	$1,524	$1,518	*(4.0)*
YoY Change %										-	*-7.4*	*-0.4*	
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)										$13.17	$11.38	$11.16	*(7.9)*
YoY Change %										-	*(13.6)*	*(1.9)*	
EMERGING													
Vendor Enterprise Emerging Shipment Estimates (EB)	*Tracking begins 2026*												
YoY Change %													
Vendor Enterprise Emerging Revenue Estimates ($M)													
YoY Change %													
Estimated Enterprise Emerging User Initial Integrated Average Acquisition Cost/TB ($)													
YoY Change %													
TOTAL ACTIVE ARCHIVE													
Active-Archive Storage, Vendor Tape+Emerging Shipment Estimates (EB)	30	43	53	62	86	98	*26.8*	124	136	125	134	136	*6.7*
YoY Change %	-	*44.3*	*22.9*	*16.4*	*38.3*	*15.0*		*26.0*	*9.7*	*(8.1)*	*7.2*	*1.5*	
Active-Archive Storage, Tape+Emerging Revenue Opportunity ($M)	*Tracking begins 2018*									$1,646	$1,524	$1,518	*(4.0)*
YoY Change %										-	*(7.4)*	*(0.4)*	
TOTAL SHIPMENTS FOR ALL TECHNOLOGIES													
Total Compressed Enterprise EB Shipped	**76**	**96**	**120**	**157**	**211**	**269**	*28.6*	**364**	**438**	**581**	**703**	**947**	*28.7*
YoY Change %	-	*25.9*	*25.4*	*30.0*	*34.8*	*27.3*		*35.4*	*20.4*	*32.7*	*21.0*	*34.6*	
Compressed SSD % of Total EB Shipped	0.3	0.7	1.0	2.3	4.0	4.9		5.9	7.9	10.7	11.3	13.8	
Uncompressed HDD % of Total EB Shipped	60.3	54.2	54.8	58.1	55.5	58.5		60.0	61.0	67.8	69.6	71.8	
Compressed Active Archive % of Total EB Shipped	39.3	45.1	44.2	39.6	40.6	36.6		34.1	31.1	21.5	19.1	14.4	
Total Compressed Active Installed Base of Enterprise EB	**293**	**321**	**402**	**505**	**659**	**881**	*24.6*	**1,192**	**1,533**	**1,976**	**2,501**	**3,215**	*29.5*
YoY Change %	-	*9.4*	*25.4*	*25.6*	*30.5*	*33.7*		*35.3*	*28.6*	*28.9*	*26.5*	*28.6*	
TOTAL USER SPEND FOR ALL TECHNOLOGIES													
Total User Acquisition Cost/TB ($)	*Tracking begins 2018*									**$78.33**	**$49.86**	**$52.00**	*(18.5)*
Total Enterprise Storage User Spend ($M)	*Tracking begins 2018*									**$45,511**	**$35,064**	**$49,219**	*4.0*
YoY Change %										-	*(23.0)*	*40.4*	
SSD % of Total Spend										60.4	49.7	62.4	
HDD % of Total Spend										36.0	45.9	34.5	
Active Archive % of Total Spend										3.6	4.3	3.1	
COMPREHENSIVE ASP AND COST RATIOS													
Vendor ASP Ratios													
SSD:HDD Vendor ASP/TB	34.1	29.5	22.4	15.1	10.3	9.4		11.3	13.4	10.4	6.5	9.2	
User Acquisition Cost Ratios	*Tracking begins 2018*												
SSD:Tape User Cost/TB										33.7	19.2	21.1	
HDD:Tape User Cost/TB										3.2	2.9	2.2	
SSD:Emerging User Cost/TB	*Tracking begins 2026*												
HDD:Emerging User Cost/TB													
Tape:Emerging User Cost/TB													

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 6: Granular Details of Enterprise Storage Shipment and Revenue Histories, 2020-2025, and Forecasts, 2026-2030

	2020	2021	2022	2023	2024	2025	CAGR 2020-2025	2026	2027	2028	2029	2030	CAGR 2026-2030
SSD													
Vendor Enterprise SSD Uncompressed Shipment Estimates (EB)	109	149	173	120	251	312	*23.4*	519	717	763	967	1,215	*31.2*
YoY Change %	*64.0*	*36.9*	*16.0*	*(30.5)*	*108.7*	*24.4*		*66.3*	*38.2*	*6.4*	*26.7*	*25.6*	
Vendor Enterprise SSD Uncompressed Direct Revenue Estimates ($M)	$16,601	$20,353	$20,741	$8,173	$26,891	$30,390	*12.9*	$201,680	$288,785	$257,677	$269,100	$293,988	*57.4*
YoY Change %	*76.2*	*22.6*	*1.9*	*(60.6)*	*229.0*	*13.0*		*563.6*	*43.2*	*(10.8)*	*4.4*	*9.2*	
Vendor Enterprise SSD Uncompressed Blended ASP/TB ($)	$152.45	$136.51	$119.96	$68.00	$107.22	$97.40	*(8.6)*	$388.59	$402.77	$337.72	$278.28	$241.97	*20.0*
YoY Change %	*7.4*	*(10.5)*	*(12.1)*	*(43.3)*	*57.7*	*(9.2)*		*299.0*	*3.6*	*(16.2)*	*(17.6)*	*(13.1)*	
Vendor Enterprise SSD Compressed Shipment Estimates (EB)	131	179	207	144	301	374	% Changes Same As Uncompressed	623	860	916	1,160	1,458	% Changes Same As Uncompressed
Estimated SSD System User Spend, 85% Markup Over Vendor Revenue ($M)	$30,712.55	$37,653	$38,371	$15,121	$49,749	$56,222		$373,108	$534,252	$476,702	$497,835	$543,878	
Estimated SSD User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$235.02	$210.45	$184.94	$104.83	$165.30	$150.16		$599.08	$620.93	$520.64	$429.02	$373.03	
HDD													
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	680	959	942	1,039	1,085	1,439	*16.2*	1,815	2,253	2,833	3,478	4,188	*23.8*
YoY Change %	*38.9*	*41.0*	*(1.8)*	*10.3*	*4.4*	*32.7*		*26.1*	*24.1*	*25.7*	*22.8*	*20.4*	
Vendor Enterprise HDD Uncompressed Direct Revenue Estimates ($M)	$11,326	$13,035	$12,887	$13,755	$14,077	$20,598	% Changes Same As User	$28,180	$33,976	$39,922	$45,611	$50,936	% Changes Same As User
Vendor Enterprise HDD Uncompressed Blended ASP/TB ($)	$16.66	$13.59	$13.68	$13.24	$12.98	$14.31		$15.53	$15.08	$14.09	$13.11	$12.16	
Estimated HDD System User Spend, 50% Markup Over Vendor Revenue ($M)	$16,988	$19,553	$19,330	$20,633	$21,116	$30,897	*12.7*	$42,270	$50,964	$59,883	$68,417	$76,404	*19.9*
YoY Change %	*5.5*	*15.1*	*(1.1)*	*6.7*	*2.3*	*46.3*		*36.8*	*20.6*	*17.5*	*14.3*	*11.7*	
Estimated HDD User Initial Integrated Uncompressed Average Acquisition Cost/EB ($)	$24.99	$20.39	$20.52	$19.86	$19.47	$21.47	*(3.0)*	$23.29	$22.62	$21.14	$19.67	$18.24	*(3.2)*
YoY Change %	*(24.1)*	*(18.4)*	*0.6*	*(3.2)*	*(2.0)*	*10.3*		*8.5*	*(2.9)*	*(6.6)*	*(6.9)*	*(7.3)*	
TAPE													
Enterprise Tape Compressed Shipment Estimates (EB)	136	190	207	228	265	240	*12.0*	376	485	617	745	861	*29.1*
YoY Change %	*1.5*	*39.7*	*8.9*	*10.1*	*16.2*	*(9.4)*		*56.7*	*29.0*	*27.2*	*20.7*	*15.6*	
Enterprise Tape User Spend Estimates ($M)	$1,518	$1,746	$1,712	$1,889	$2,208	$1,961	*5.3*	$3,184	$3,898	$4,701	$5,015	$5,524	*23.0*
YoY Change %	*(0.4)*	*15.0*	*(2.0)*	*10.4*	*16.9*	*(11.2)*		*62.3*	*22.4*	*20.6*	*6.7*	*10.1*	
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$11.16	$9.19	$8.27	$8.28	$8.33	$8.17	*(6.0)*	$8.47	$8.04	$7.62	$6.73	$6.42	*(4.7)*
YoY Change %	*(1.9)*	*(17.7)*	*(10.0)*	*0.2*	*0.6*	*(1.9)*		*3.6*	*(5.1)*	*(5.2)*	*(11.6)*	*(4.7)*	
EMERGING													
Vendor Enterprise Emerging Shipment Estimates (EB)	*Tracking begins 2026*							0.0	0.3	15.0	129.0	298.0	*>1000*
YoY Change %								*0*	-	*4,900.0*	*760.0*	*131.0*	
Vendor Enterprise Emerging Revenue Estimates ($M)								$0.00	$3.30	$151.00	$1,236.00	$2,363.00	*>1000*
YoY Change %								*0*	-	*4,475.8*	*718.5*	*91.2*	
Estimated Enterprise Emerging User Initial Integrated Average Acquisition Cost/TB ($)								$0.00	$11.00	$10.07	$9.58	$7.93	*(7.6)*
YoY Change %								-	-	*(8.5)*	*(4.8)*	*(17.2)*	
TOTAL ACTIVE ARCHIVE													
Active-Archive Storage, Vendor Tape+Emerging Shipment Estimates (EB)	136	190	207	228	265	240	*12.0*	376	485	632	874	1,159	*37.0*
YoY Change %	*1.5*	*39.7*	*8.9*	*10.1*	*16.2*	*(9.4)*		*56.7*	*29.1*	*30.2*	*38.3*	*32.6*	
Active-Archive Storage, Tape+Emerging Revenue Opportunity ($M)	$1,518	$1,746	$1,712	$1,889	$2,208	$1,961	*5.3*	$3,184	$3,901	$4,852	$6,251	$7,887	*32.1*
YoY Change %	*(0.4)*	*15.0*	*(2.0)*	*10.4*	*16.9*	*(11.2)*		*62.3*	*22.5*	*24.4*	*28.8*	*26.2*	
TOTAL SHIPMENTS FOR ALL TECHNOLOGIES													
Total Compressed Enterprise EB Shipped	**947**	**1,328**	**1,356**	**1,411**	**1,650**	**2,053**	*16.8*	**2,814**	**3,599**	**4,381**	**5,512**	**6,805**	*27.1*
YoY Change %	*34.6*	*40.3*	*2.2*	*4.0*	*17.0*	*24.4*		*37.0*	*27.9*	*21.7*	*25.8*	*23.4*	
Compressed SSD % of Total EB Shipped	13.8	13.5	15.3	10.2	18.2	18.2		22.1	23.9	20.9	21.1	21.4	
Uncompressed HDD % of Total EB Shipped	71.8	72.2	69.4	73.6	65.7	70.1		64.5	62.6	64.7	63.1	61.5	
Compressed Active Archive % of Total EB Shipped	14.4	14.3	15.3	16.2	16.1	11.7		13.4	13.5	14.4	15.9	17.0	
Total Compressed Active Installed Base of Enterprise EB	**3,215**	**4,218**	**5,174**	**6,005**	**6,951**	**8,068**	*20.2*	**9,610**	**11,923**	**15,065**	**18,985**	**23,748**	*24.1*
YoY Change %	*28.6*	*31.2*	*22.7*	*16.1*	*15.7*	*16.1*		*19.1*	*24.1*	*26.3*	*26.0*	*25.1*	
TOTAL USER SPEND FOR ALL TECHNOLOGIES													
Total User Acquisition Cost/TB	**$52.00**	**$44.39**	**$43.80**	**$26.68**	**$44.27**	**$43.38**	*(3.6)*	**$148.75**	**$163.70**	**$123.60**	**$103.86**	**$92.31**	*16.3*
Total User Enterprise Storage Spend	**$49,219**	**$58,952**	**$59,413**	**$37,642**	**$73,072**	**$89,080**	*12.6*	**$418,562**	**$589,117**	**$541,437**	**$572,503**	**$628,169**	*47.8*
YoY Change %	*40.4*	*19.8*	*0.8*	*(36.6)*	*94.1*	*21.9*		*369.9*	*40.7*	*(8.1)*	*5.7*	*9.7*	
SSD % of Total Spend	62.4	63.9	64.6	40.2	68.1	63.1		89.1	90.7	88.0	87.0	86.6	
HDD % of Total Spend	34.5	33.2	32.5	54.8	28.9	34.7		10.1	8.7	11.1	12.0	12.2	
Active Archive % of Total Spend	3.1	3.0	2.9	5.0	3.0	2.2		0.8	0.7	0.9	1.1	1.3	
COMPREHENSIVE ASP AND COST RATIOS													
Vendor ASP Ratios													
SSD:HDD Vendor ASP/TB	9.2	10.0	8.8	5.1	8.3	6.8		25.0	26.7	24.0	21.2	19.9	
User Acquisition Cost Ratios													
SSD:Tape User Cost/TB	21.1	22.9	22.4	12.7	19.8	18.4		70.7	77.3	68.3	63.7	58.1	
HDD:Tape User Cost/TB	2.2	2.2	2.5	2.4	2.3	2.6		2.8	2.8	2.8	2.9	2.8	
SSD:Emerging User Cost/TB	*Tracking begins 2026*							0.0	56.4	51.7	44.8	47.0	
HDD:Emerging User Cost/TB								0.0	2.1	2.1	2.1	2.3	
Tape:Emerging User Cost/TB								0.0	0.7	0.8	0.7	0.8	

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 7: Granular Details of Enterprise Storage Shipment and Revenue Forecasts, 2030-2040

	2030	2031	2032	2033	2034	2035	CAGR 2030-2035	2036	2037	2038	2039	2040	CAGR 2035-2040
SSD													
Vendor Enterprise SSD Uncompressed Shipment Estimates (EB)	1,215	1,401	1,799	1,953	2,198	2,347	*14.1*	2,545	2,881	2,994	3,390	3,678	*9.4*
YoY Change %	*25.6*	*15.3*	*28.4*	*8.6*	*12.5*	*6.8*		*8.4*	*13.2*	*3.9*	*13.2*	*8.5*	
Vendor Enterprise SSD Uncompressed Direct Revenue Estimates ($M)	$293,988	$301,304	$338,960	$320,167	$333,543	$336,220	*2.7*	$355,967	$387,654	$392,883	$419,865	$433,089	*5.2*
YoY Change %	*9.2*	*2.5*	*12.5*	*(5.5)*	*4.2*	*0.8*		*5.9*	*8.9*	*1.3*	*6.9*	*3.1*	
Vendor Enterprise SSD Uncompressed Blended ASP/ TB ($)	$241.97	$215.06	$188.42	$163.94	$151.75	$143.26	*(10.0)*	$139.87	$134.56	$131.22	$123.85	$117.75	*(3.8)*
YoY Change %	*(13.1)*	*(11.1)*	*(12.4)*	*(13.0)*	*(7.4)*	*(5.6)*		*(2.4)*	*(3.8)*	*(2.5)*	*(5.6)*	*(4.9)*	
Vendor Enterprise SSD Compressed Shipment Estimates (EB)	1,458	1,681	2,159	2,344	2,638	2,816	% Changes Same As Uncompressed	3,054	3,457	3,593	4,068	4,414	% Changes Same As Uncompressed
Estimated SSD System User Spend, 85% Markup Over Vendor Revenue ($M)	$543,878	$557,412	$627,076	$592,309	$617,055	$622,007		$658,539	$717,160	$726,834	$776,750	$801,215	
Estimated SSD User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$373.03	$331.56	$290.47	$252.73	$233.95	$220.85		$215.63	$207.44	$202.30	$190.94	$181.53	
HDD													
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	4,188	4,833	4,908	4,675	4,309	3,897	*(1.4)*	3,351	2,796	2,159	1,593	1,286	*(19.9)*
YoY Change %	*20.4*	*15.4*	*1.6*	*(4.7)*	*(7.8)*	*(9.6)*		*(14.0)*	*(16.6)*	*(22.8)*	*(26.2)*	*(19.3)*	
Vendor Enterprise HDD Uncompressed Direct Revenue Estimates ($M)	$50,936	$54,951	$52,909	$47,816	$43,004	$36,576	% Changes Same As User	$30,907	$24,993	$19,068	$14,006	$11,101	% Changes Same As User
Vendor Enterprise HDD Uncompressed Blended ASP/ TB ($)	$12.16	$11.37	$10.78	$10.23	$9.98	$9.39		$9.22	$8.94	$8.83	$8.79	$8.63	
Estimated HDD System User Spend, 50% Markup Over Vendor Revenue ($M)	$76,404	$82,427	$79,364	$71,724	$64,506	$54,864	*(6.4)*	$46,361	$37,490	$28,602	$21,009	$16,652	*(21.2)*
YoY Change %	*11.7*	*7.9*	*(3.7)*	*(9.6)*	*(10.1)*	*(14.9)*		*(15.5)*	*(19.1)*	*(23.7)*	*(26.5)*	*(20.7)*	
Estimated HDD User Initial Integrated Uncompressed Average Acquisition Cost/EB ($)	$18.24	$17.05	$16.17	$15.34	$14.97	$14.08	*(5.1)*	$13.83	$13.41	$13.25	$13.19	$12.95	*(1.7)*
YoY Change %	*(7.3)*	*(6.5)*	*(5.2)*	*(5.1)*	*(2.4)*	*(6.0)*		*(1.7)*	*(3.1)*	*(1.2)*	*(0.4)*	*(1.8)*	
TAPE													
Enterprise Tape Compressed Shipment Estimates (EB)	861	957	1,033	1,107	1,174	1,221	*7.2*	1,255	1,275	1,301	1,309	1,270	*0.8*
YoY Change %	*15.6*	*11.1*	*7.9*	*7.2*	*6.1*	*4.0*		*2.8*	*1.6*	*2.0*	*0.6*	*(3.0)*	
Enterprise Tape User Spend Estimates ($M)	$5,524	$5,370	$5,153	$4,994	$4,604	$4,193	*(5.4)*	$3,801	$3,431	$3,058	$2,802	$2,397	*(10.6)*
YoY Change %	*10.1*	*(2.8)*	*(4.0)*	*(3.1)*	*(7.8)*	*(8.9)*		*(9.3)*	*(9.8)*	*(10.9)*	*(8.4)*	*(14.4)*	
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$6.42	$5.61	$4.99	$4.51	$3.92	$3.43	*(11.7)*	$3.03	$2.69	$2.35	$2.14	$1.89	*(11.3)*
YoY Change %	*(4.7)*	*(12.5)*	*(11.1)*	*(9.6)*	*(13.1)*	*(12.4)*		*(11.8)*	*(11.2)*	*(12.6)*	*(8.9)*	*(11.8)*	
EMERGING													
Vendor Enterprise Emerging Shipment Estimates (EB)	298	535	909	1,451	2,055	2,875	*57.4*	3,656	4,532	5,915	7,319	8,634	*24.6*
YoY Change %	*131.0*	*79.5*	*69.9*	*59.6*	*41.6*	*39.9*		*27.2*	*24.0*	*30.5*	*23.7*	*18.0*	
Vendor Enterprise Emerging Revenue Estimates ($M)	$2,363	$3,535	$5,019	$7,788	$8,967	$10,338	*34.3*	$12,390	$14,889	$18,704	$22,765	$25,958	*20.2*
YoY Change %	*91.2*	*49.6*	*42.0*	*55.2*	*15.1*	*15.3*		*19.8*	*20.2*	*25.6*	*21.7*	*14.0*	
Estimated Enterprise Emerging User Initial Integrated Average Acquisition Cost/TB ($)	$7.93	$6.61	$5.52	$5.37	$4.36	$3.60	*(14.6)*	$3.39	$3.29	$3.16	$3.11	$3.01	*(3.5)*
YoY Change %	*(17.2)*	*(16.7)*	*(16.4)*	*(2.8)*	*(18.7)*	*(17.6)*		*(5.8)*	*(3.1)*	*(3.7)*	*(1.6)*	*(3.3)*	
TOTAL ACTIVE ARCHIVE													
Active-Archive Storage, Vendor Tape+Emerging Shipment Estimates (EB)	1,159	1,492	1,942	2,558	3,229	4,096	*28.7*	4,911	5,807	7,216	8,628	9,904	*19.3*
YoY Change %	*32.6*	*28.7*	*30.2*	*31.7*	*26.2*	*26.9*		*19.9*	*18.2*	*24.3*	*19.6*	*14.8*	
Active-Archive Storage, Tape+Emerging Revenue Opportunity ($M)	$7,887	$8,905	$10,172	$12,782	$13,571	$14,531	*13.0*	$16,191	$18,320	$21,762	$25,567	$28,355	*14.3*
YoY Change %	*26.2*	*12.9*	*14.2*	*25.7*	*6.2*	*7.1*		*11.4*	*13.1*	*18.8*	*17.5*	*10.9*	
TOTAL SHIPMENTS FOR ALL TECHNOLOGIES													
Total Compressed Enterprise EB Shipped	**6,805**	**8,006**	**9,009**	**9,577**	**10,176**	**10,809**	*9.7*	**11,316**	**12,060**	**12,968**	**14,289**	**15,604**	*7.6*
YoY Change %	*23.4*	*17.7*	*12.5*	*6.3*	*6.3*	*6.2*		*4.7*	*6.6*	*7.5*	*10.2*	*9.2*	
Compressed SSD % of Total EB Shipped	21.4	21.0	24.0	24.5	25.9	26.1		27.0	28.7	27.7	28.5	28.3	
Uncompressed HDD % of Total EB Shipped	61.5	60.4	54.5	48.8	42.3	36.1		29.6	23.2	16.6	11.1	8.2	
Compressed Active Archive % of Total EB Shipped	17.0	18.6	21.6	26.7	31.7	37.9		43.4	48.2	55.6	60.4	63.5	
Total Compressed Active Installed Base of Enterprise EB	**23,748**	**29,052**	**34,707**	**40,159**	**45,211**	**49,758**	*15.9*	**53,815**	**57,947**	**62,939**	**69,249**	**77,032**	*9.1*
YoY Change %	*25.1*	*22.3*	*19.5*	*15.7*	*12.6*	*10.1*		*8.2*	*7.7*	*8.6*	*10.0*	*11.2*	
TOTAL USER SPEND FOR ALL TECHNOLOGIES													
Total User Acquisition Cost/TB	$92.31	**$81.03**	**$79.55**	**$70.67**	**$68.31**	**$63.96**	*(7.1)*	**$63.72**	**$64.09**	**$59.93**	**$57.62**	**$54.23**	*(3.2)*
Total User Enterprise Storage Spend	**$628,169**	**$648,744**	**$716,612**	**$676,815**	**$695,132**	**$691,402**	*1.9*	**$721,091**	**$772,969**	**$777,198**	**$823,326**	**$846,221**	*4.1*
YoY Change %	*9.7*	*3.3*	*10.5*	*(5.6)*	*2.7*	*(0.5)*		*4.3*	*7.2*	*0.5*	*5.9*	*2.8*	
SSD % of Total Spend	86.6	85.9	87.5	87.5	88.8	90.0		91.3	92.8	93.5	94.3	94.7	
HDD % of Total Spend	12.2	12.7	11.1	10.6	9.3	7.9		6.4	4.9	3.7	2.6	2.0	
Active Archive % of Total Spend	1.3	1.4	1.4	1.9	2.0	2.1		2.2	2.4	2.8	3.1	3.4	
COMPREHENSIVE ASP AND COST RATIOS													
Vendor ASP Ratios													
SSD:HDD Vendor ASP/TB	19.9	18.9	17.5	16.0	15.2	15.3		15.2	15.1	14.9	14.1	13.6	
User Acquisition Cost Ratios													
SSD:Tape User Cost/TB	58.1	59.1	58.2	56.0	59.7	64.3		71.2	77.1	86.1	89.2	96.2	
HDD:Tape User Cost/TB	2.8	3.0	3.2	3.4	3.8	4.1		4.6	5.0	5.6	6.2	6.9	
SSD:Emerging User Cost/TB	47.0	50.2	52.6	47.1	53.6	61.4		63.6	63.1	64.0	61.4	60.4	
HDD:Emerging User Cost/TB	2.3	2.6	2.9	2.9	3.4	3.9		4.1	4.1	4.2	4.2	4.3	
Tape:Emerging User Cost/TB	0.8	0.8	0.9	0.8	0.9	1.0		0.9	0.8	0.7	0.7	0.6	
Alternate 2030-2040 Shipment Scenario at 25% Annual Expansion (EB)		**8,506**	**10,633**	**13,291**	**16,614**	**20,767**		**25,959**	**32,449**	**40,561**	**50,701**	**63,377**	
EB Delta to Current Forecast		***500***	***1,624***	***3,714***	***6,438***	***9,958***		***14,643***	***20,389***	***27,593***	***36,412***	***47,773***	
Alternate 2030-2040 User Spend Scenario at 25% Annual Expansion ($M)		**$689,263**	**$845,795**	**$939,327**	**$1,134,946**	**$1,328,334**		**$1,654,190**	**$2,079,725**	**$2,430,936**	**$2,921,382**	**$3,437,063**	
$ Delta to Current Forecast		***$40,519***	***$129,183***	***$262,512***	***$439,815***	***$636,932***		***$933,099***	***$1,306,755***	***$1,653,738***	***$2,098,056***	***$2,590,841***	
Alternate 2030-2040 Active Installed Base Scenario at 25% Annual Expansion (EB)		29,441	36,475	45,385	56,487	70,449		87,902	109,718	136,988	171,075	213,684	
EB Delta to Current Forecast		***389***	***1,768***	***5,226***	***11,275***	***20,691***		***34,087***	***51,771***	***74,048***	***101,826***	***136,653***	

Source: Furthur Market Research and Brad Johns Consulting, September 2026

Table 8: Granular Details of Enterprise Storage Shipment and Revenue Forecasts, 2040-2050

	2040	2041	2042	2043	2044	2045	CAGR 2040-2045	2046	2047	2048	2049	2050	CAGR 2045-2050
SSD													
Vendor Enterprise SSD Uncompressed Shipment Estimates (EB)	3,678	3,988	4,567	4,699	5,171	5,623	*8.9*	5,885	6,606	6,760	7,334	7,989	*7.3*
YoY Change %	*8.5*	*8.4*	*14.5*	*2.9*	*10.0*	*8.7*		*4.7*	*12.3*	*2.3*	*8.5*	*8.9*	
Vendor Enterprise SSD Uncompressed Direct Revenue Estimates ($M)	$433,089	$435,694	$455,442	$433,784	$460,333	$489,012	*2.5*	$500,132	$550,144	$553,170	$580,145	$605,347	*4.4*
YoY Change %	*3.1*	*0.6*	*4.5*	*(4.8)*	*6.1*	*6.2*		*2.3*	*10.0*	*0.6*	*4.9*	*4.3*	
Vendor Enterprise SSD Uncompressed Blended ASP/ TB ($)	$117.75	$109.25	$99.72	$92.31	$89.02	$86.97	*(5.9)*	$84.98	$83.28	$81.83	$79.10	$75.77	*(2.7)*
YoY Change %	*(4.9)*	*(7.2)*	*(8.7)*	*(7.4)*	*(3.6)*	*(2.3)*		*(2.3)*	*(2.0)*	*(1.7)*	*(3.3)*	*(4.2)*	
Vendor Enterprise SSD Compressed Shipment Estimates (EB)	4,414	4,786	5,480	5,639	6,205	6,748	% Changes Same As Uncompressed	7,062	7,927	8,112	8,801	9,587	% Changes Same As Uncompressed
Estimated SSD System User Spend, 85% Markup Over Vendor Revenue ($M)	$801,215	$806,034	$842,568	$802,500	$851,616	$904,672		$925,244	$1,017,766	$1,023,365	$1,073,268	$1,119,892	
Estimated SSD User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$181.53	$168.43	$153.74	$142.32	$137.24	$134.07		$131.02	$128.39	$126.15	$121.95	$116.82	
HDD													
Vendor Enterprise HDD Uncompressed Shipment Estimates (EB)	1,286	1,258	1,250	1,193	1,189	1,147	*(2.3)*	1,109	1,075	1,051	1,015	998	*(2.7)*
YoY Change %	*(19.3)*	*(2.2)*	*(0.6)*	*(4.6)*	*(0.3)*	*(3.5)*		*(6.7)*	*(3.1)*	*(2.2)*	*(3.4)*	*(1.7)*	
Vendor Enterprise HDD Uncompressed Direct Revenue Estimates ($M)	$11,101	$10,755	$10,602	$9,870	$9,558	$8,971	% Changes Same As User	$8,502	$8,183	$7,930	$7,550	$7,399	% Changes Same As User
Vendor Enterprise HDD Uncompressed Blended ASP/ TB ($)	$8.63	$8.55	$8.48	$8.27	$8.04	$7.82		$7.67	$7.61	$7.55	$7.44	$7.41	
Estimated HDD System User Spend, 50% Markup Over Vendor Revenue ($M)	$16,652	$16,133	$15,903	$14,805	$14,337	$13,457	*(4.2)*	$12,753	$12,275	$11,895	$11,325	$11,099	*(3.8)*
YoY Change %	*(20.7)*	*(3.1)*	*(1.4)*	*(6.9)*	*(3.2)*	*(6.1)*		*(11.0)*	*(3.8)*	*(3.1)*	*(4.8)*	*(2.0)*	
Estimated HDD User Initial Integrated Uncompressed Average Acquisition Cost/EB ($)	$12.95	$12.82	$12.72	$12.41	$12.06	$11.73	*(2.0)*	$11.50	$11.42	$11.32	$11.16	$11.12	*(1.1)*
YoY Change %	*(1.8)*	*(1.0)*	*(0.8)*	*(2.5)*	*(2.8)*	*(2.7)*		*(2.0)*	*(0.7)*	*(0.9)*	*(1.4)*	*(0.3)*	
TAPE													
Enterprise Tape Compressed Shipment Estimates (EB)	1,270	1,246	1,225	1,208	1,193	1,137	*(2.2)*	1,089	997	973	917	851	*(5.6)*
YoY Change %	*(3.0)*	*(1.9)*	*(1.7)*	*(1.4)*	*(1.2)*	*(4.7)*		*(4.2)*	*(8.4)*	*(2.4)*	*(5.8)*	*(7.2)*	
Enterprise Tape User Spend Estimates ($M)	$2,397	$2,118	$1,754	$1,473	$1,360	$1,314	*(11.3)*	$1,207	$1,084	$1,011	$910	$795	*(9.6)*
YoY Change %	*(14.4)*	*(11.7)*	*(17.2)*	*(16.0)*	*(7.7)*	*(3.4)*		*(8.1)*	*(10.1)*	*(6.8)*	*(10.0)*	*(12.7)*	
Estimated Tape User Initial Integrated Compressed Average Acquisition Cost/TB ($)	$1.89	$1.70	$1.43	$1.22	$1.14	$1.16	*(9.4)*	$1.11	$1.09	$1.04	$0.99	$0.93	*(4.2)*
YoY Change %	*(11.8)*	*(10.0)*	*(15.8)*	*(14.9)*	*(6.5)*	*1.4*		*(4.1)*	*(1.8)*	*(4.5)*	*(4.5)*	*(5.9)*	
EMERGING													
Vendor Enterprise Emerging Shipment Estimates (EB)	8,634	9,505	10,244	12,137	13,077	13,698	*9.7*	14,988	16,786	17,995	19,681	20,630	*8.5*
YoY Change %	*18.0*	*10.1*	*7.8*	*18.5*	*7.7*	*4.7*		*9.4*	*12.0*	*7.2*	*9.4*	*4.8*	
Vendor Enterprise Emerging Revenue Estimates ($M)	$25,958	$27,035	$28,312	$32,031	$33,313	$33,664	*5.3*	$35,105	$37,499	$38,160	$40,580	$41,834	*4.4*
YoY Change %	*14.0*	*4.1*	*4.7*	*13.1*	*4.0*	*1.1*		*4.3*	*6.8*	*1.8*	*6.3*	*3.1*	
Estimated Enterprise Emerging User Initial Integrated Average Acquisition Cost/TB ($)	$3.01	$2.84	$2.76	$2.64	$2.55	$2.46	*(4.0)*	$2.34	$2.23	$2.12	$2.06	$2.03	*(3.8)*
YoY Change %	*(3.3)*	*(5.4)*	*(2.8)*	*(4.5)*	*(3.5)*	*(3.5)*		*(4.7)*	*(4.6)*	*(5.1)*	*(2.8)*	*(1.7)*	
TOTAL ACTIVE ARCHIVE													
Active-Archive Storage, Vendor Tape+Emerging Shipment Estimates (EB)	9,904	10,751	11,469	13,345	14,270	14,835	*8.4*	16,077	17,783	18,968	20,598	21,481	*7.7*
YoY Change %	*14.8*	*8.6*	*6.7*	*16.4*	*6.9*	*4.0*		*8.4*	*10.6*	*6.7*	*8.6*	*4.3*	
Active-Archive Storage, Tape+Emerging Revenue Opportunity ($M)	$28,355	$29,153	$30,066	$33,504	$34,673	$34,978	*4.3*	$36,312	$38,583	$39,171	$41,490	$42,629	*4.0*
YoY Change %	*10.9*	*2.8*	*3.1*	*11.4*	*3.5*	*0.9*		*3.8*	*6.3*	*1.5*	*5.9*	*2.7*	
TOTAL SHIPMENTS FOR ALL TECHNOLOGIES													
Total Compressed Enterprise EB Shipped	**15,604**	**16,795**	**18,199**	**20,177**	**21,664**	**22,730**	*7.8*	**24,248**	**26,785**	**28,131**	**30,414**	**32,066**	*7.1*
YoY Change %	*9.2*	*7.6*	*8.4*	*10.9*	*7.4*	*4.9*		*6.7*	*10.5*	*5.0*	*8.1*	*5.4*	
Compressed SSD % of Total EB Shipped	28.3	28.5	30.1	27.9	28.6	29.7		29.1	29.6	28.8	28.9	29.9	
Uncompressed HDD % of Total EB Shipped	8.2	7.5	6.9	5.9	5.5	5.0		4.6	4.0	3.7	3.3	3.1	
Compressed Active Archive % of Total EB Shipped	63.5	64.0	63.0	66.1	65.9	65.3		66.3	66.4	67.4	67.7	67.0	
Total Compressed Active Installed Base of Enterprise EB	**77,032**	**86,247**	**95,802**	**108,843**	**123,273**	**138,467**	*12.4*	**154,454**	**172,704**	**191,306**	**211,045**	**231,134**	*10.8*
YoY Change %	*11.2*	*12.0*	*11.1*	*13.6*	*13.3*	*12.3*		*11.5*	*11.8*	*10.8*	*10.3*	*9.5*	
TOTAL USER SPEND FOR ALL TECHNOLOGIES													
Total User Acquisition Cost/TB	**$54.23**	**$50.69**	**$48.82**	**$42.17**	**$41.57**	**$41.93**	*(5.0)*	**$40.18**	**$39.90**	**$38.19**	**$37.03**	**$36.60**	*(2.7)*
Total User Enterprise Storage Spend	**$846,221**	**$851,319**	**$888,537**	**$850,809**	**$900,626**	**$953,106**	*2.4*	**$974,309**	**$1,068,624**	**$1,074,431**	**$1,126,083**	**$1,173,619**	*4.3*
YoY Change %	*2.8*	*0.6*	*4.4*	*(4.2)*	*5.9*	*5.8*		*2.2*	*9.7*	*0.5*	*4.8*	*4.2*	
SSD % of Total Spend	94.7	94.7	94.8	94.3	94.6	94.9		95.0	95.2	95.2	95.3	95.4	
HDD % of Total Spend	2.0	1.9	1.8	1.7	1.6	1.4		1.3	1.1	1.1	1.0	0.9	
Active Archive % of Total Spend	3.4	3.4	3.4	3.9	3.8	3.7		3.7	3.6	3.6	3.7	3.6	
COMPREHENSIVE ASP AND COST RATIOS													
Vendor ASP Ratios													
SSD:HDD Vendor ASP/TB	13.6	12.8	11.8										
User Acquisition Cost Ratios													
SSD:Tape User Cost/TB	96.2	99.1	107.4	116.7	120.4	116.0		118.2	118.0	121.4	122.9	125.1	
HDD:Tape User Cost/TB	6.9	7.5	8.9	10.2	10.6	10.2		10.4	10.5	10.9	11.2	11.9	
SSD:Emerging User Cost/TB	60.4	59.2	55.6	53.9	53.9	54.6		55.9	57.5	59.5	59.1	57.6	
HDD:Emerging User Cost/TB	4.3	4.5	4.6	4.7	4.7	4.8		4.9	5.1	5.3	5.4	5.5	
Tape:Emerging User Cost/TB	0.6	0.6	0.5	0.5	0.4	0.5		0.5	0.5	0.5	0.5	0.5	
Alternate 2030-2040 Shipment Scenario at 25% Annual Expansion (EB)	**63,377**	**79,221**	**99,026**	**123,782**	**154,728**	**193,410**		**241,762**	**302,203**	**377,753**	**472,192**	**590,240**	
EB Delta to Current Forecast	***47,773***	***62,426***	***80,826***	***103,605***	***133,064***	***170,680***		***217,514***	***275,418***	***349,622***	***441,778***	***558,174***	
Alternate 2040-2050 User Spend Scenario at 25% Annual Expansion ($M)	**$3,437,063**	**$4,015,698**	**$4,834,668**	**$5,219,612**	**$6,432,356**	**$8,110,131**		**$9,714,245**	**$12,056,701**	**$14,427,847**	**$17,483,094**	**$21,602,975**	
$ Delta to Current Forecast	***$2,590,841***	***$3,164,379***	***$3,946,131***	***$4,368,803***	***$5,531,730***	***$7,157,025***		***$8,739,936***	***$10,988,077***	***$13,353,416***	***$16,357,010***	***$20,429,356***	
Alternate 2040-2050 Active Installed Base Scenario at 25% Annual Expansion (EB)	**213,684**	**266,946**	**333,523**	**416,744**	**520,771**	**650,804**		**813,346**	**1,016,522**	**1,270,494**	**1,587,958**	**1,984,787**	
EB Delta to Current Forecast	***136,653***	***180,699***	***237,721***	***307,901***	***397,497***	***512,337***		***658,892***	***843,819***	***1,079,188***	***1,376,912***	***1,753,654***	

Source: Furthur Market Research and Brad Johns Consulting, September 2026

This report was sponsored by Cerabyte, Folio Photonics and SPhotonix and was written by **John Monroe** and **Brad Johns.**

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cerabyte

Cerabyte is a deep-tech startup offering permanent, accessible, zero-retention-power ceramic-on-glass data storage designed for sustained long-term data retention without media management, replacement or data migration. Through standard S3 and gRPC interfaces, active pilot engagements are available to customers using their existing software stack. Backed by investor including storage leaders Western Digital and Everpure, Cerabyte provides an API-driven, low-cost tier for long-term data storage.

FOLIO PHOTONICS

Folio Photonics (FP) is a materials science company solving a storage problem with a disruptive, next-generation photonic storage system. FP's platform is aimed at the fast-growing tier of enterprise data that requires dependable, near-real-time access without the cost and energy overhead of legacy storage media. FP is nearing delivery of an affordable, energy-efficient, exabyte-scale storage that the AI era's expanding dataverse demands.

SPhotonix

SPhotonix is a U.S. technology company building a new storage tier for the AI era using 5D optical data storage in fused-silica glass, built on decades of peer-reviewed research and industrial validation. By encoding data volumetrically with femtosecond lasers, the platform enables multi-terabyte capacity on a single platter, fast random access, exceptionally high storage density and ultra-low media cost for active-archive and long-lived enterprise data.

Monroe Biography

John Monroe has been involved with the storage industry for more than 40 years, beginning in 1980.

- From 1997 to 2022, Monroe was a VP Analyst at Gartner, covering the history and forecasting the future of consumer and enterprise storage markets.
- From 1990 to 1997, he was the VP of all storage lines at SYNNEX Information Technologies (now TD SYNNEX), a global distribution and manufacturing services firm, responsible for the profitable resale and OEM integration of HDDs, controllers, subsystems, and tape.
- From 1988 to 1990 he was Director of North American Sales for Kalok Corporation (a startup HDD manufacturer).
- From 1983 to 1988 he was part owner and general manager of Media Winchester, Ltd., a storage products distributor and integrator which was one of Seagate's inaugural "SuperVARs."
- He began his career in 1980 at Electrolabs, selling ICs, power supplies, cables, monitors, printers, 8-inch floppy disk drives, and 8-inch HDDs ("oddments of all things" related to computing electronics).

Unlike most industry analysts, Monroe has had balance-sheet accountability for the stuff that he studies. Monroe earned a BA degree summa cum laude, Phi Beta Kappa from Amherst College in 1976 and a master's degree in fine arts (MFA) with a merit scholarship from Columbia University in 1980.

Johns Biography

Brad Johns is President of Brad Johns Consulting LLC, an Information Technology consulting firm specializing in storage technology economics, marketing, and strategy. He has over 40 years of experience in the IT industry.

- In 2010, he established and led Brad Johns Consulting LLC, which provides consulting and marketing strategy assistance for storage technology companies.
- From 1997 until his retirement in 2010, he held various IBM storage product marketing and management leadership positions for IBM's worldwide disk, storage virtualization, tape storage, and archive product portfolio.
- From 1978 to 1997, after starting with the Data Processing Division, he held a variety of enterprise sales, sales management, industry marketing, and consulting positions. He was a founding member of IBM's Innovation Workflow consulting team and engaged with leading-edge clients in the aerospace, automotive, and information technology industries.
- Johns earned a BA in Economics from the University of Arizona in 1976 and a master's in business administration (MBA) in 1977.

As in his analyses and forecasts of "infinitely-self-similar-but-never-the-same" storage market trends over many years, Monroe's aim at Furthur Market Research is to bring actionable business perspectives tempered by Chaos Science, knowing that, within the unpredictably turbulent flow of dynamically changing systems—which "mirror a universe that is rough, not rounded, scabrous, not smooth," which reflect a fractal "geometry of the pitted, pocked and broken up, the twisted, tangled, and intertwined"*—there lies a deeply mysterious order that, in some way, at some scale, will always repeat itself.

**Chaos, Making a New Science*
—James Gleick

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