SEAGATE

The Evolution of Storage Media in Data Centers: Assessing the Future of Flash/SSD, Hard Drives, and Tape Storage

HUGO BERGMANN

SENIOR PRODUCT MARKETING MANAGER

Different Storage Technologies, with fundamentally different approaches to reading and writing data

SSD/Flash

- Electric recording
- Printed circuit board
- Data retention varies by use-case
- Performance for realtime data processing

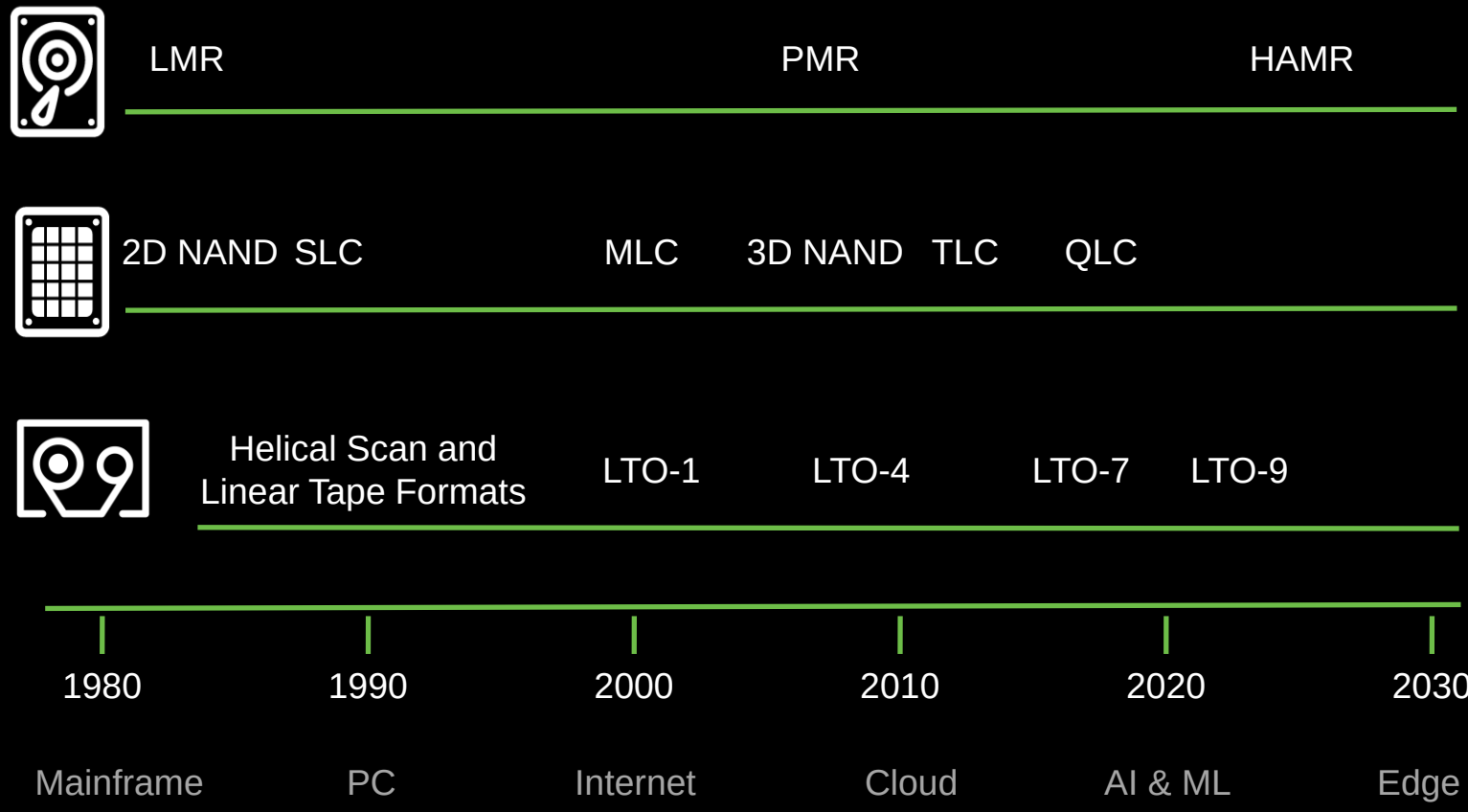
Hard Drive

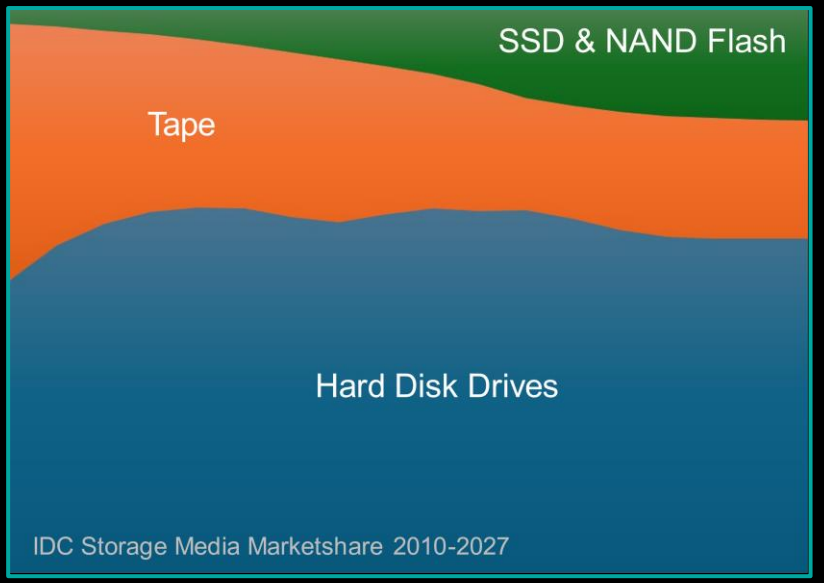
- Magnetic recording
- Mechanical device
- High data retention
- Performance for general purpose workloads

Tape

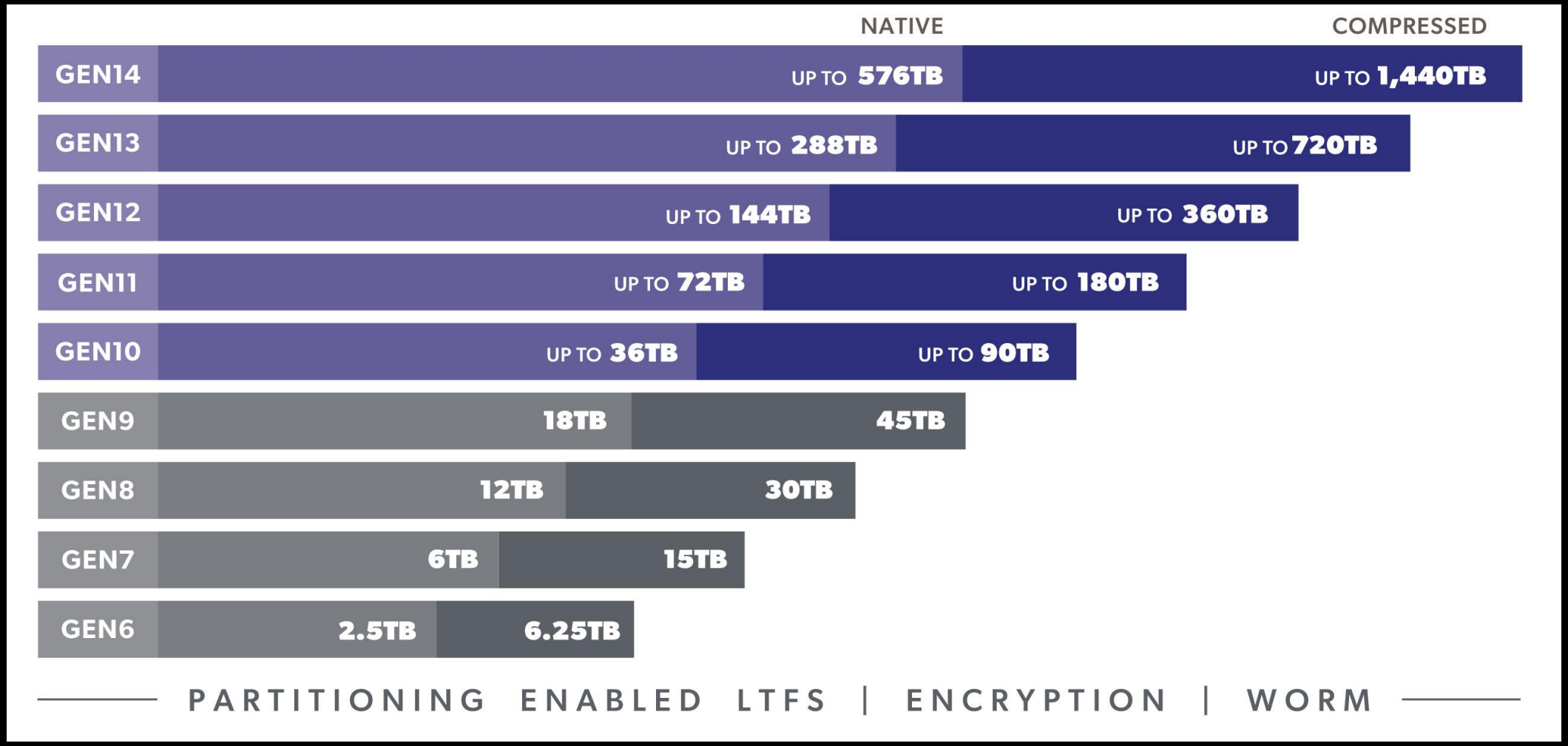
- Magnetic recording
- LTO technology by IBM
- Mechanical device with Drive + Removable Media
- Cold archive storage
- Sequential Data Access
- Data retention 30 Years
- Media migration required

HDD, SSD AND TAPE HAVE UPHELD THE WORLD'S DIGITAL INFRASTRUCTURE FOR DECADES





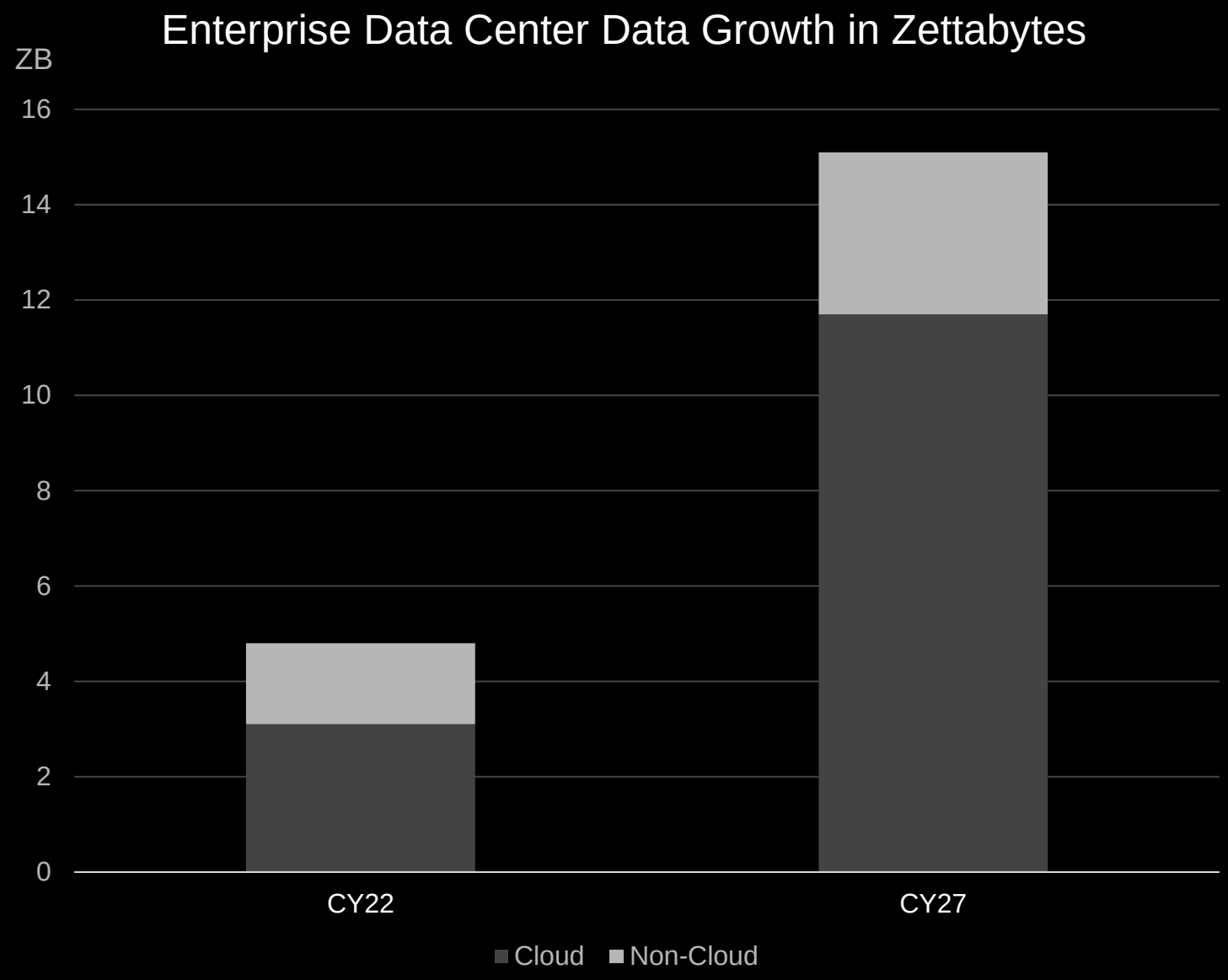
LTO the Tape Storage Standard



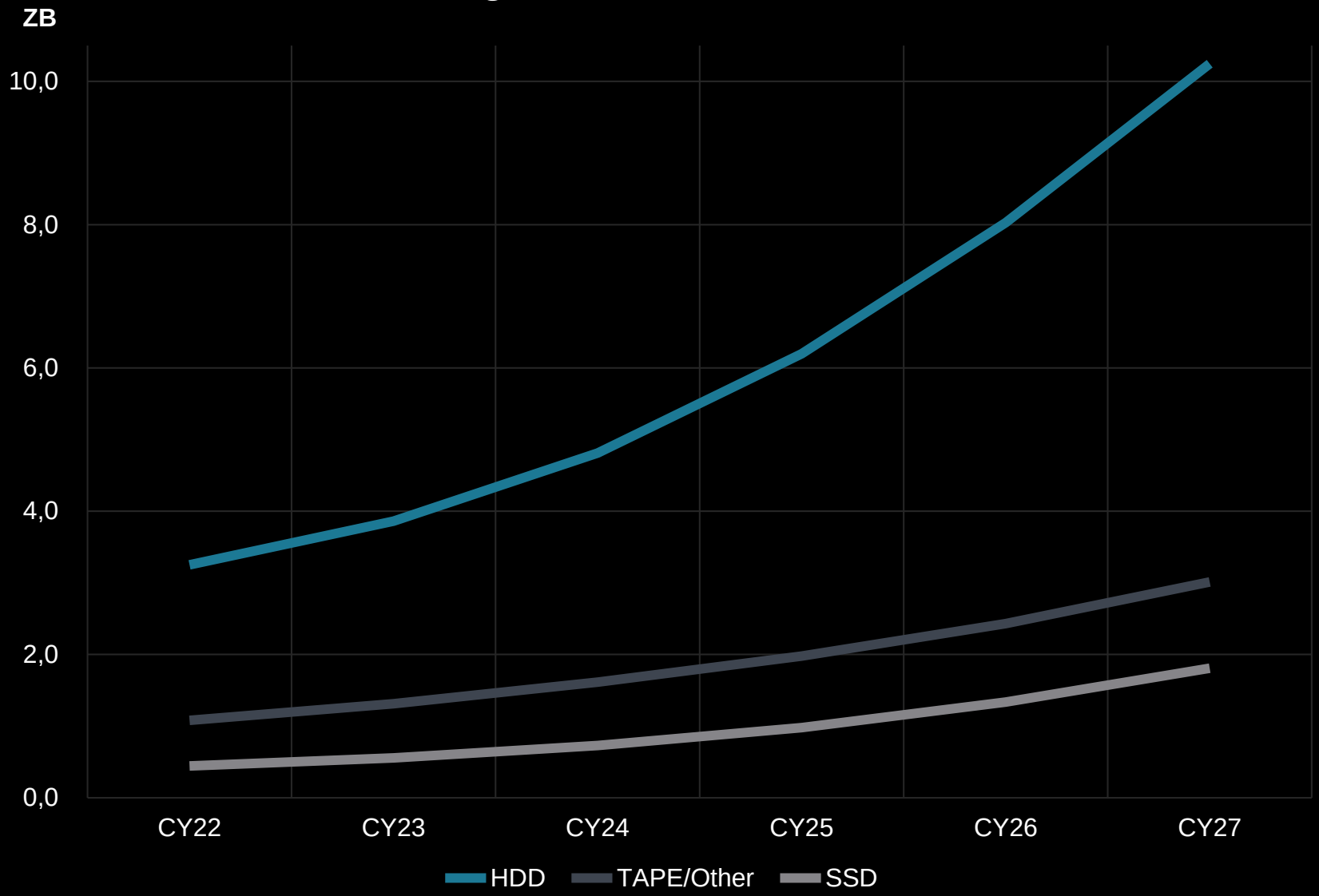
The cloud will be the primary beneficiary of accelerated exabyte growth.

IDC estimates a five-year CAGR of 29% for hard drive storage in the cloud.

Source: Seagate analysis based on IDC Global StorageSphere Forecast, 2023-2027 Doc. #US50851423, June 2023.Lighter colors represent enterprises' non-cloud exabytes and darker colors represents their cloud exabytes.



Growing Demand for Hard Drives

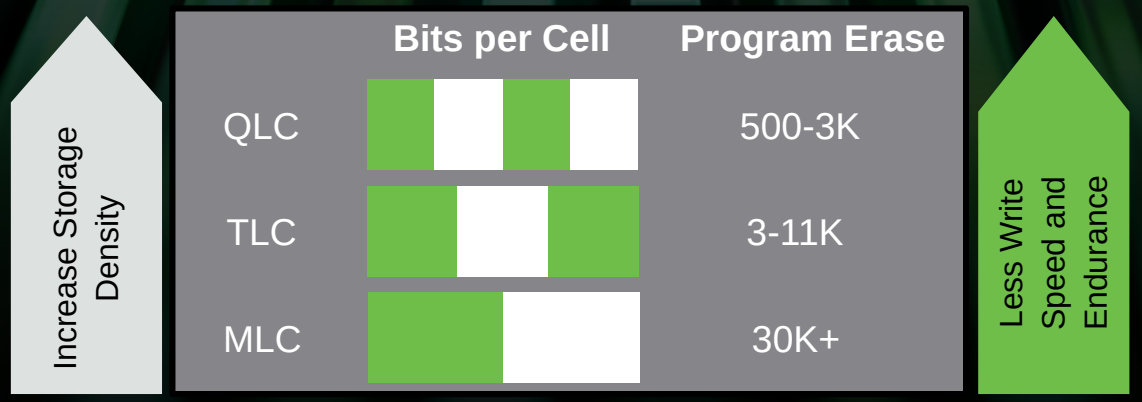


FOR HARD DRIVES

Exabyte strorage growth continues to climb exponentially in enterprise data centers.

Source: Seagate analysis based on IDC Global StorageSphere Forecast, 2023-2027 Doc. #US50851423, June 2023.

Is QLC Flash Storage a Hard Drive Displacement Technology in Data Centers?



QLC will displace TLC-Flash primarily, like TLC displaced MLC

The world's largest data centers **choose hard drives** to store most of their exabytes.

Why?

TOTAL COST OF OWNERSHIP

WORKLOADS

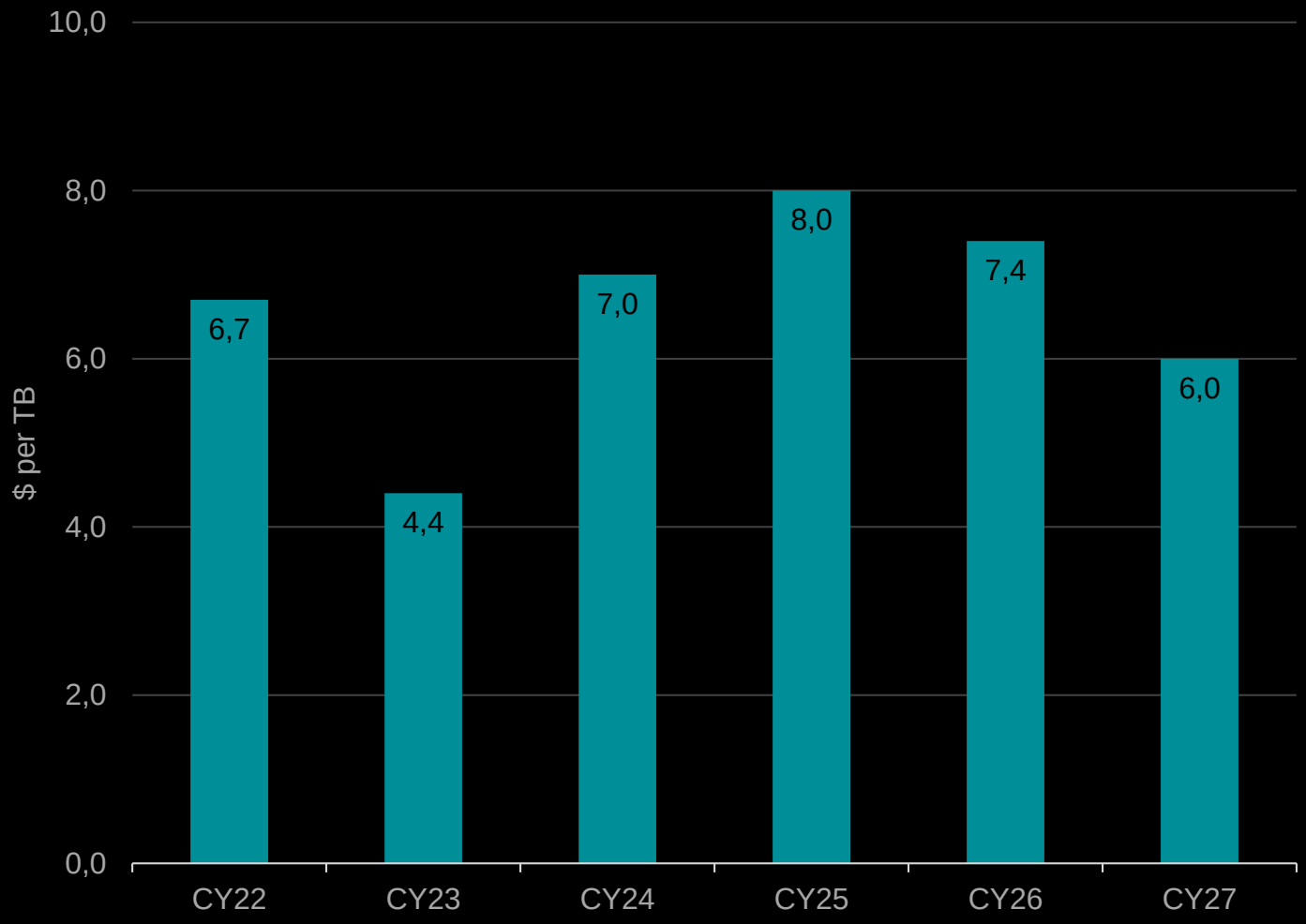
SCALE

SUSTAINABILITY

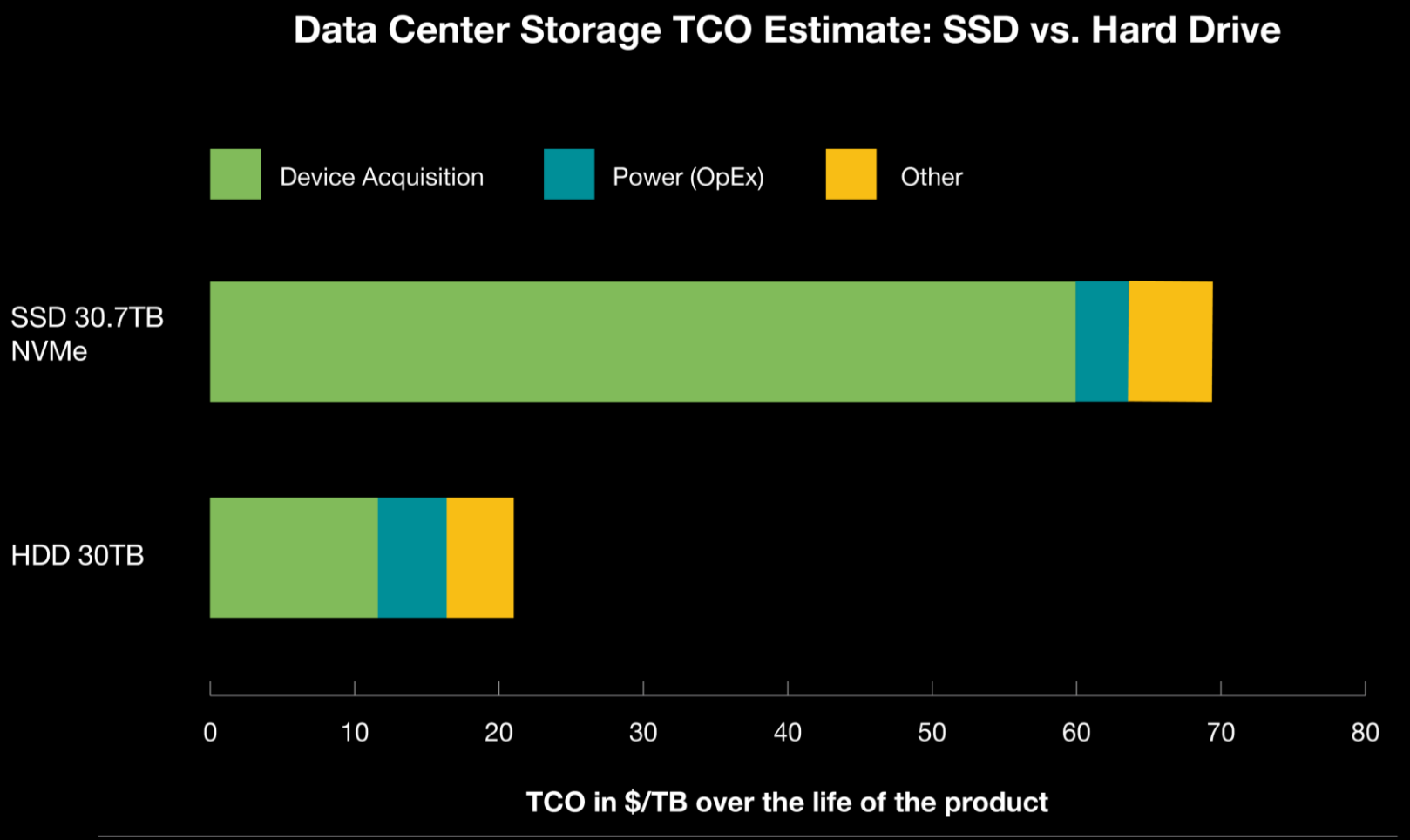
Hard drives will maintain a >6:1 $/TB advantage over SSDs.

SSD price-per-TB multiple compared with nearline hard drive price-per-TB. Analysts project the price ratio to remain greater than 6 to 1 through 2027.The average for this period is 6.6 to 1. While dips happen, the pricing tends to rebound and equalize.

Sources: Seagate's analysis based on *Forward Insights Q323 SSD Insights, Aug. 2023; IDC Worldwide Hard Disk Drive Forecast 2022-2027, Apr. 2023*, Doc. #US50568323; TRENDFOCUS *SDAS Long-Term Forecast, Aug. 2023.*



This price advantage is magnified at scale, where device acquisition is by far the most signific ant element of TCO.



Even in 2023, when costs of NAND dropped temporarily, by far the weightiest element of TCO per purchased TB is device acquisition (in green). In contrast, power (OpEx, in teal) is a small factor. Other costs (CapEx of rack hardware per TB raw and OpEx of replacement servicing per TB raw, in orange) are also significantly smaller than device acquisition costs. Source: SNIA

NAND Exabytes Production

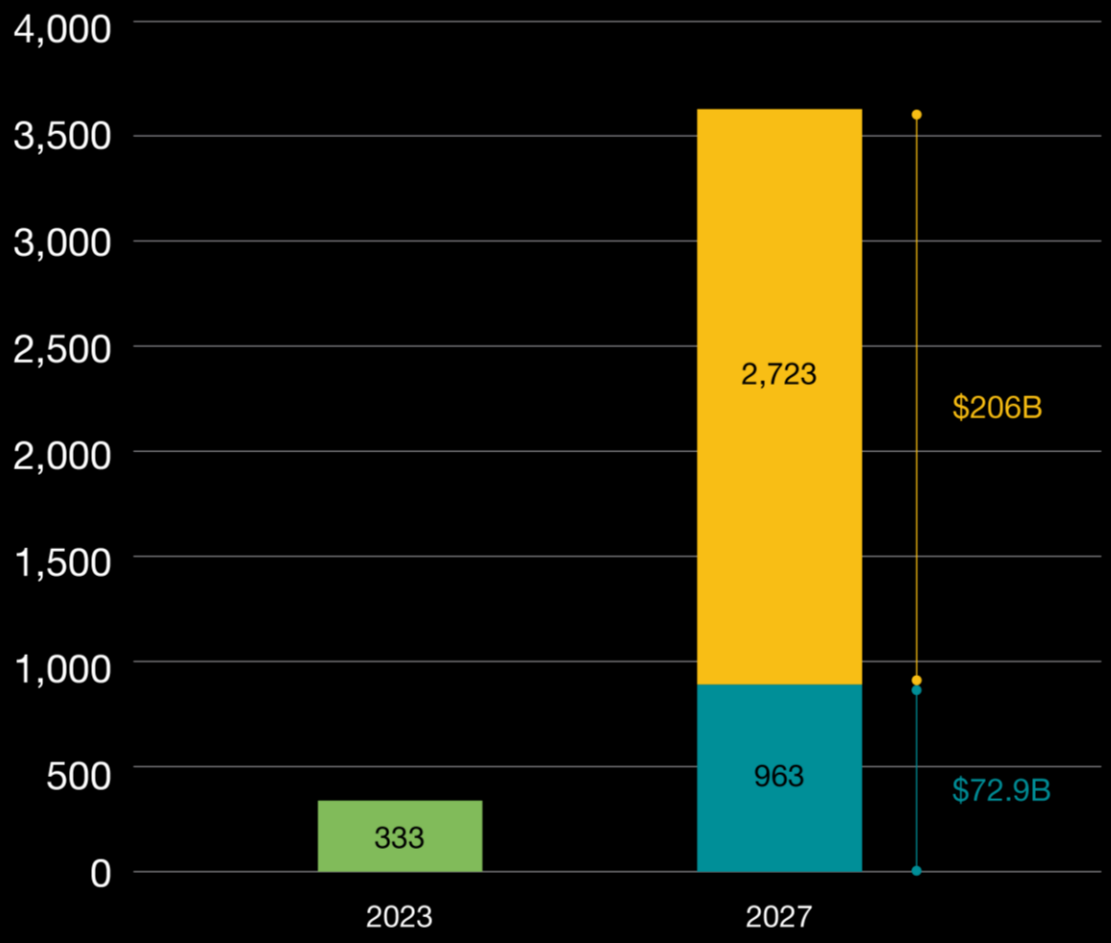


Image: Producing enough NAND EBs to fulfill hard drive demand would be cost-prohibitive.
Sources: Seagate analysis based on *NAND Flash Platinum Datasheet by TrendForce* and *IDC Global StorageSphere Forecast, 2023–2027* Doc. #US50851423, June 2023.

Producing enough NAND to replace all hard drive exabytes is cost-prohibitive.

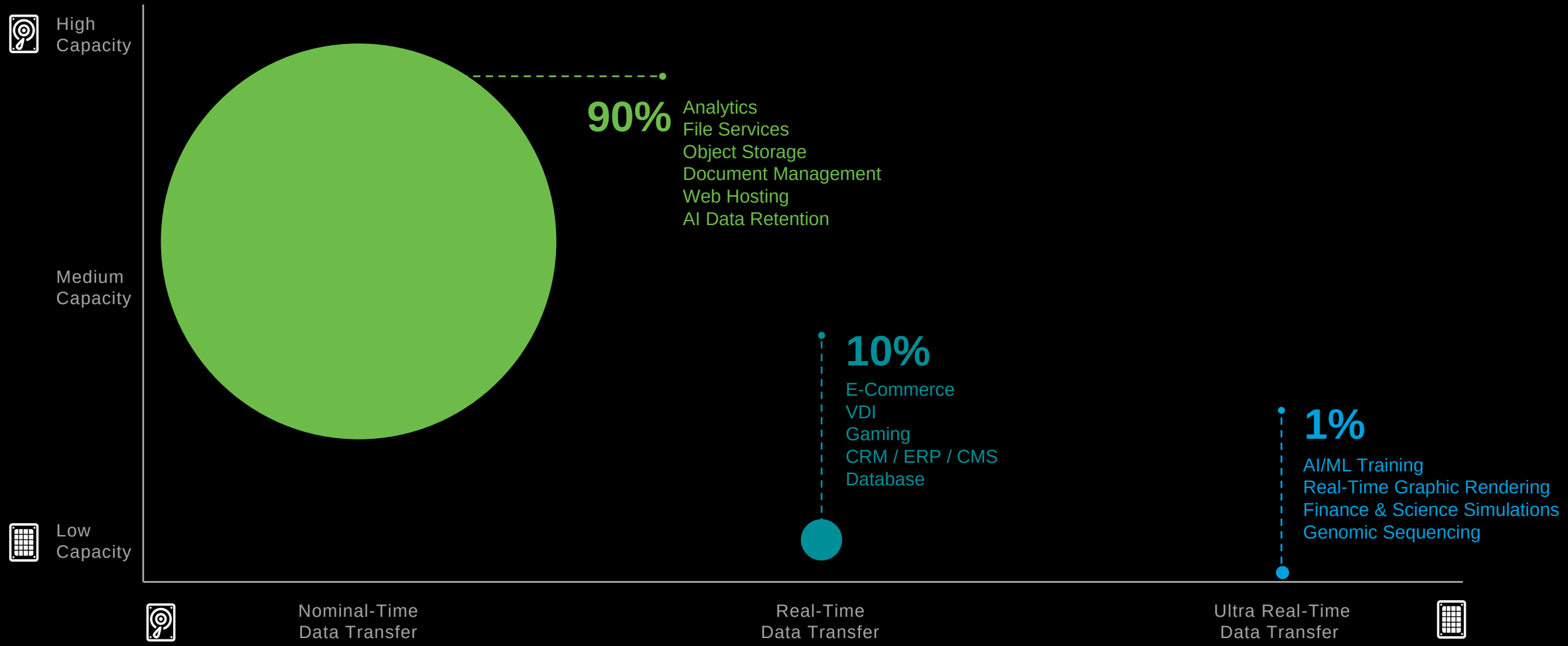
$10 investment required for a $1 return

- Exabytes the NAND industry produced
- Exabytes the NAND industry is projected to produce
- Exabytes the NAND industry would need to produce, if they were to replace all HDDs

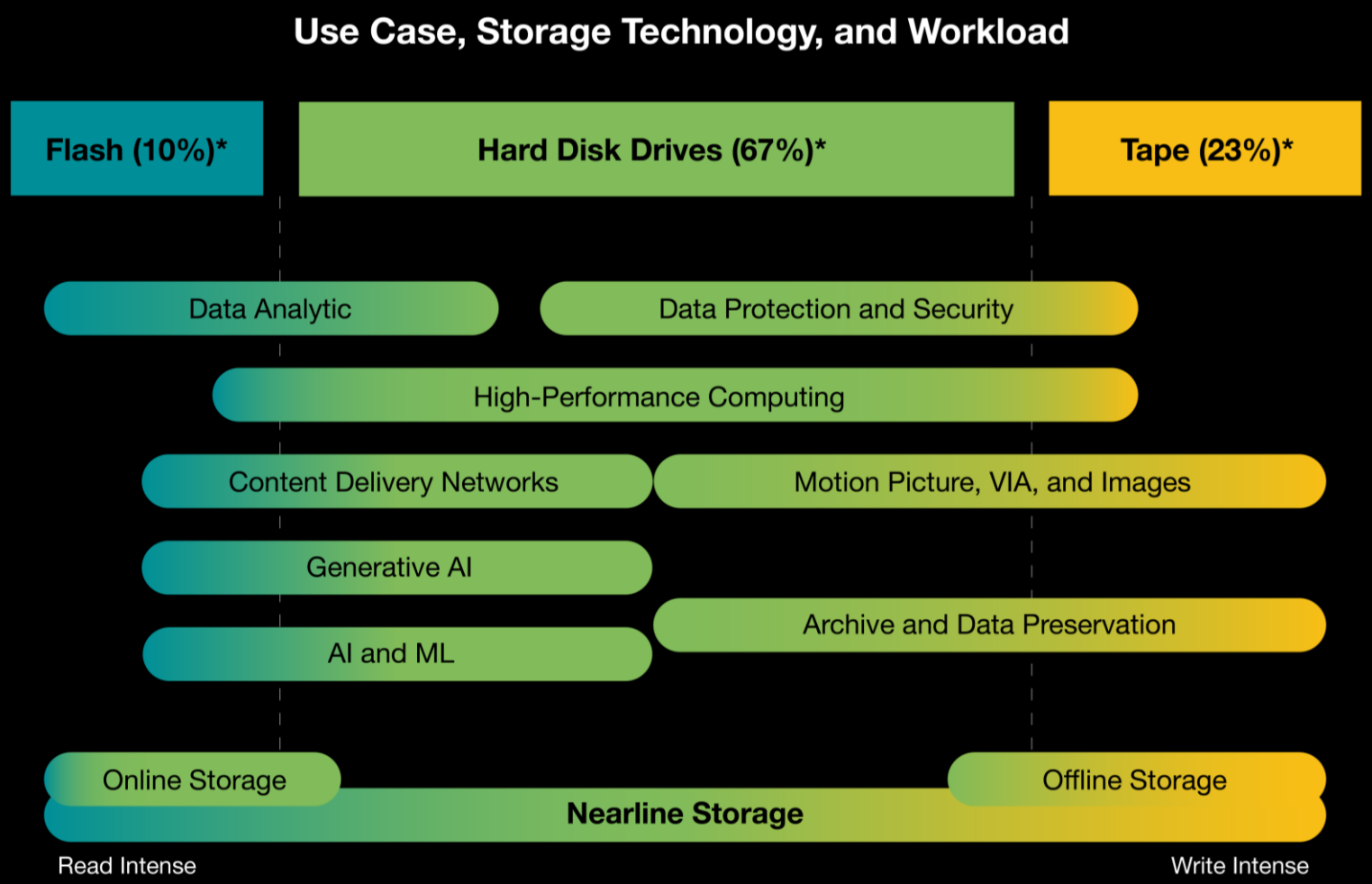
Most enterprise data is associated with general-purpose workloads.

Image: Mapping enterprise workloads to EBs stored.

Source: Seagate analysis of IDC, (May 2023). *Streaming and Real-Time Data Redefined and Superimposed on IDC's Global DataSphere*, 2022 (May 2023).



STORAGE TECHNOLOGY SYNERGIES



67%*

Data Center Data stored on Hard Drives

Data center workloads and use cases ideal for NAND, hard drive, and tape storage.
Source: Seagate analysis of average workloads in *IDC Global StorageSphere Forecast, 2023–2027* Doc. #US50851423, June 2023.

Summary

Three truths about hard drives and SSDs

TRUTH #1

Pricing

SSD and hard drive pricing will not converge at any point in the next decade.

TRUTH #2

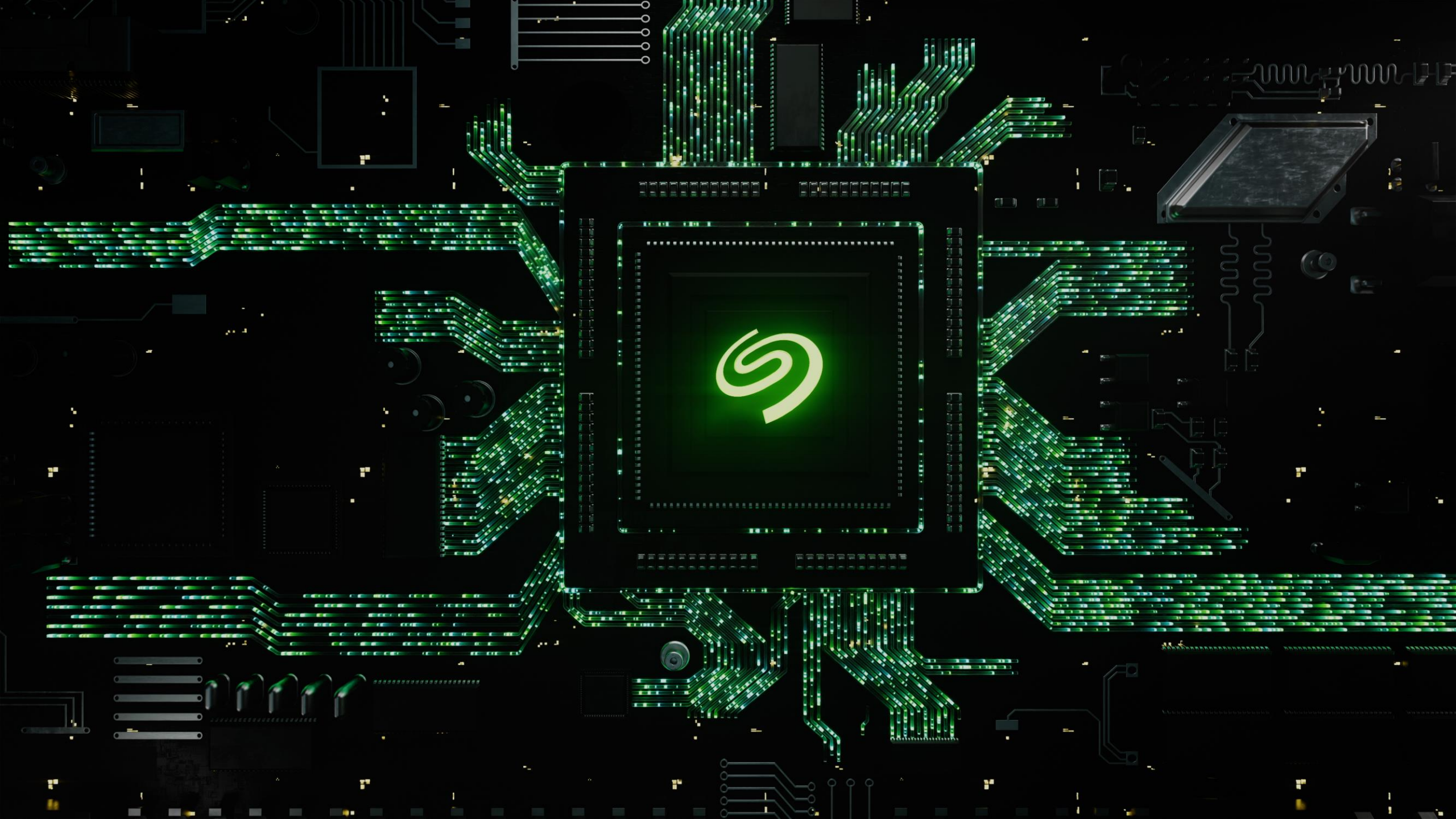
Supply

Entirely replacing hard drives with NAND would require untenable CapEx investments.

TRUTH #3

Workloads

Enterprise storage architecture mixes media types, using disk, flash, and tape to optimize for the cost, scale/capacity, and performance needs of specific workloads.



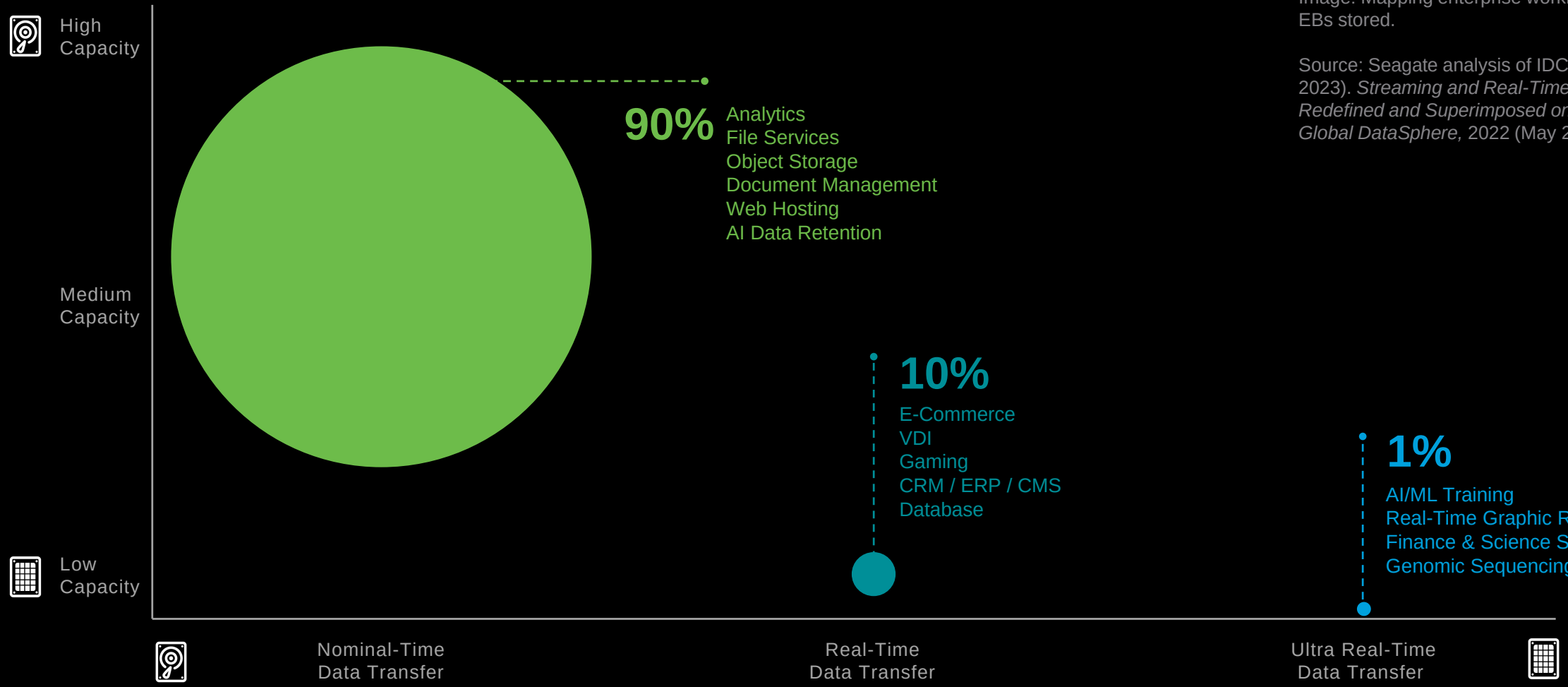
CAPEX EFFICIENCY: Hard disks outperform NAND

Year: 2015-2023	NAND Industry	Seagate
CAPEX Investment	$208 billion	$4.3 billion
Zettabytes Shipped	3.1 ZB	3.5 ZB
CAPEX Efficiency	47% of revenue	5% of revenue
Investment per Zettabyte	$ 67 billion	$ 1.2 billion
Financial Investment Projection to Replaces Hard Drive Storage with NAND		
Investment for projected NAND output	$ 72.9 billion ($75 per terabyte)	Hard Drive Storage cost is lower than NAND investment. $24.34 per TB**
Investment to replace projected hard drive storage	$ 202.5 billion; additional 30 new NAND Fabrications required	IDC projected revenue $ 25 billion*
Investment comparison	**NAND: For $1 investement you get $0.1 in return** **Seagate Hard Drive: $1 investment you get $20 in return**	
Double-Edged Sword	You can't have both: Enough Flash Memory and Cheaper Flash Storage	

* Projection is using IDC Longterm forecast, Nov. 2023
** Calculated based on Seagate total revenue and capacity shipment 2015–2023. Current hard drive cost per TB is lower, areal density increased and continues to do so with introduction of Mozaic technology

Are hard drive relevant for AI?

Data Created is 9.5 x Replicated and most data is stored on hard drives



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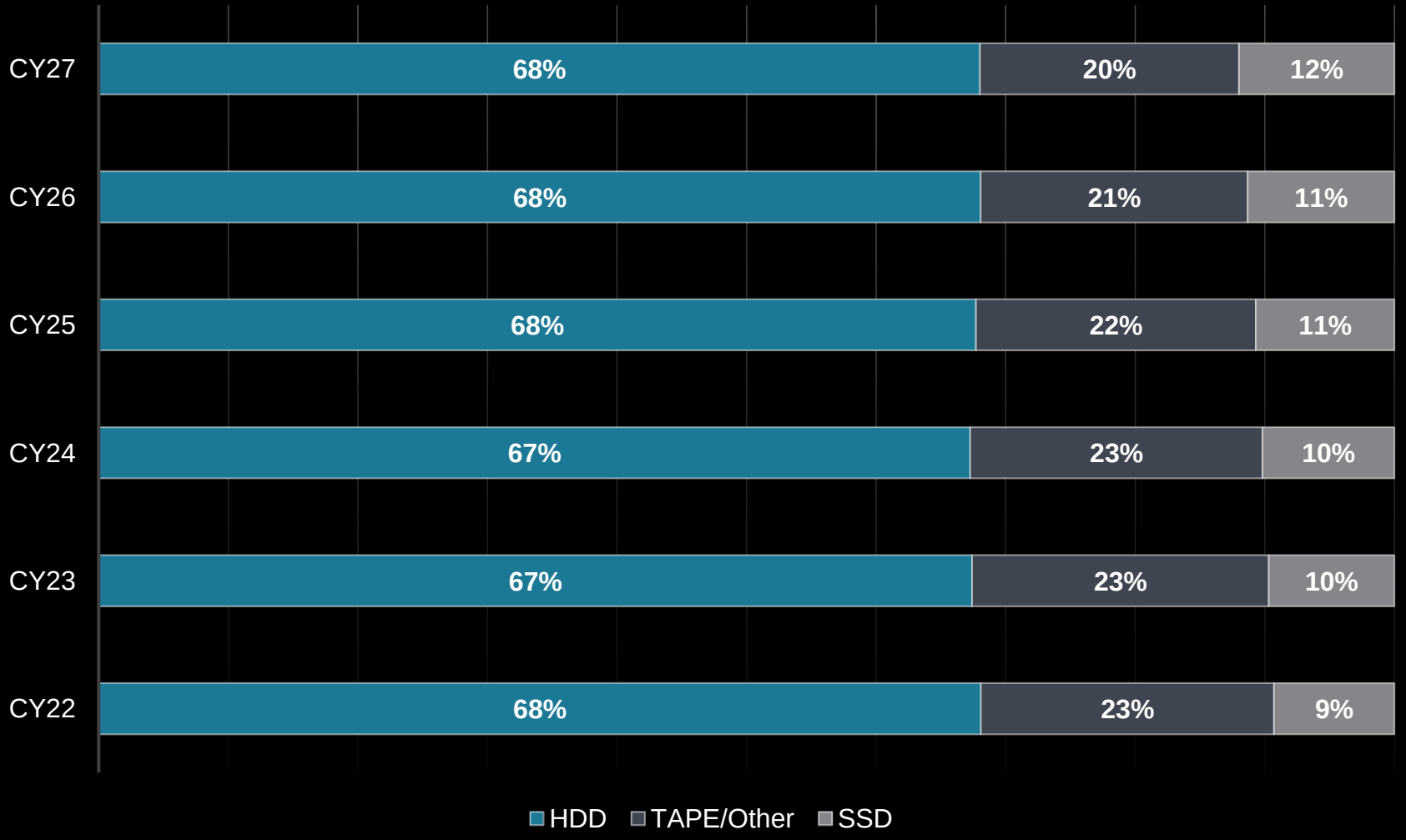
IDC Storage Media Share



FOR HARD DRIVES

The market share in enterprise data centers stays relatively consistent and will continue to be for years to come.

Source: Seagate analysis based on IDC Global StorageSphere Forecast, 2023-2027 Doc. #US50851423, June 2023.