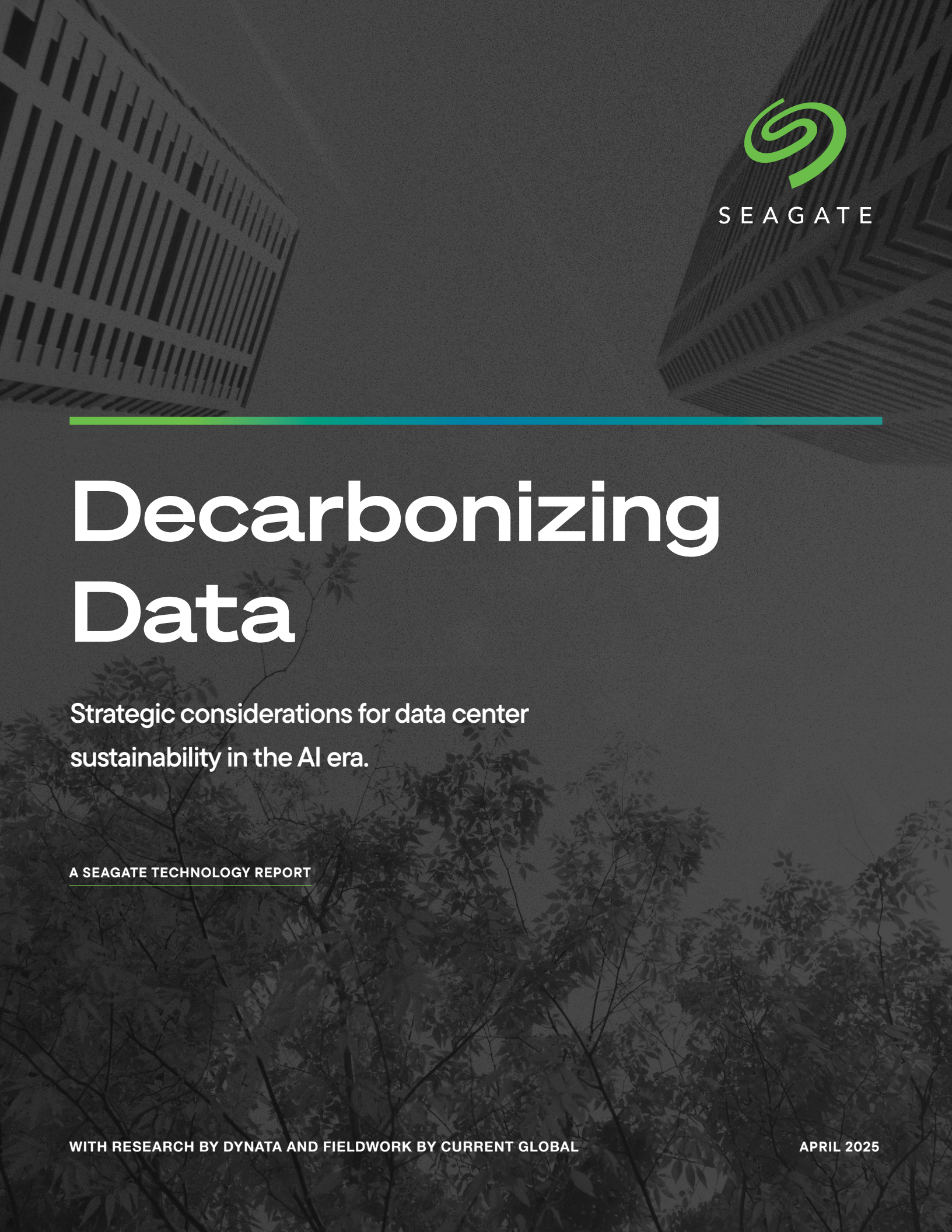

SEAGATE

Decarbonizing Data

Strategic considerations for data center sustainability in the AI era.

A SEAGATE TECHNOLOGY REPORT

WITH RESEARCH BY DYNATA AND FIELDWORK BY CURRENT GLOBAL

APRIL 2025

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Introduction

As widespread adoption of data-intensive artificial intelligence (AI) technologies speeds up worldwide, data center operations are facing unprecedented energy demands and a growing carbon footprint. They are grappling with escalating environmental concerns while also striving to scale compute power and storage capacity and to meet their total cost of ownership (TCO) goals.

According to McKinsey[1], the power needs of data centers are expected to triple by the end of 2030. "Skyrocketing compute and data demands are being further accelerated by gains in computing capabilities alongside reductions in chip efficiency relative to power consumption," the analyst firm noted.

As the global data storage leader supplying the world's leading data centers, Seagate has a front-row seat to the conversations around data center sustainability and growing demand for cost-efficient data storage. Among other things, working with our customers has taught us that TCO and sustainability goals are not mutually exclusive—often they are one and the same.

To better understand the link between TCO and sustainability, we decided to survey data center professionals. This report, informed by their insights, reveals a critical gap in understanding data centers' sustainability challenges, and the ways these challenges affect the entire supply chain. These insights can inform decisions that support both business growth and environmental goals.

It need not be either or.

1 *Data centers and AI: How data centers and the energy sector can sate AI's hunger for power*, McKinsey, 2024.

About the Report

This Seagate Technology report is based on a commissioned global study conducted by independent research firm Dynata, with fieldwork by global communications consultancy Current Global, part of The Weber Shandwick Collective.

The study included both qualitative and quantitative research to examine the AI-intensified strain on data center sustainability and opportunities for increasing the efficiency of operations.

The research began with in-depth qualitative interviews with five senior experts in data storage and infrastructure from the United States, Germany, China, and Japan. Each expert has over a decade of experience in data center planning, operations, and sustainability, which enabled robust insights into industry challenges and emerging trends. These insights informed the design of a global quantitative survey.

The survey gathered responses from 330 data center professionals across 11 markets: Australia, China, France, Germany, India, Japan, North America, Singapore, South Korea, Taiwan, and the United Kingdom. All respondents work for companies that manage at least 50 terabytes of storage, with most overseeing up to five petabytes. Participants included CIOs, CTOs, IT VPs, directors, executives, COOs, line-of-business leaders, storage architects, and solution architects in data storage companies and organizations that supply or provide data storage solutions.

The study explored the current landscape of data center efficiency and sustainability. It aims to provide industry leaders with data-driven insights to guide business-boosting, sustainable decision-making.

Seagate Technology is a global leader in scalable mass-capacity data storage, delivering more than four and a half billion terabytes of capacity over the past 45 years.

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Key Takeaways

Data centers are the backbone of today's AI economy. Modern-day rapid adoption of AI technologies has resulted in data centers facing unprecedented energy demands and a growing carbon footprint. The survey's results make two things abundantly clear:

- 94.5% of the survey respondents reported that their companies face increasing data storage needs.
- 97% anticipate AI's growth to further impact storage demand.

This corresponds to a growing energy demand. According to data from IEEE: by 2030, data center energy demand is projected to grow significantly, potentially accounting for 8% of global carbon emissions, up from 0.3% in 2022[2].

To keep pace with AI innovation, organizations must scale their data infrastructure while aligning with corporate sustainability mandates. Increasingly, businesses face expectations—and sometimes regulatory requirements—to operate data centers both cost-efficiently and sustainably. It can be challenging to reconcile these two expectations because the more energy data centers use, the trickier it is to reduce their carbon footprints.

For this reason, total cost of ownership (TCO) is sometimes seen as at odds with sustainability goals. The survey on which this report is based found that:

- Environmental impact is a concern for nearly 95% of respondents.
- But only 3.3% of the surveyed data center professionals said their companies prioritize low environmental impact in data center purchasing decisions.

Still, other findings from this survey clarify that TCO and sustainability are far from competing priorities. The TCO and sustainability considerations can and do often align, offering opportunities for operational efficiencies and environmental impact reduction.

The study found that data center operations are strongly affected by five factors that embody both TCO and sustainability goals.

1. **Energy consumption.** High energy usage drives both operational costs and carbon emissions, with 53.5% of respondents identifying this as a significant concern.
2. **Raw material requirements.** Nearly 49.5% of the surveyed data center professionals cited the large amounts of raw materials needed for infrastructure as a key issue.
3. **Physical space constraints.** Close to 45.5% of respondents highlighted the financial and logistical burden of limited space.
4. **Infrastructure costs.** High construction costs for sustainable infrastructure (identified by 28.5% survey takers) and acquisition costs for data center components (27% of respondents) significantly impact capital expenditure (CapEx).
5. **Life cycle extension.** Over 92% of respondents agreed that extending the life cycle of storage equipment is important, emphasizing durability to reduce replacement and maintenance costs. (In contrast, only 15% of the respondents considered life cycle extension a top purchasing factor for data storage infrastructure or equipment, and 12% chose durability as an important factor.)

2 *Toward a Systematic Survey for Carbon Neutral Data Centers*, IEEE Communications Surveys & Tutorials, Vol. 24, No. 2, Second Quarter, 2022.

These concerns underscore the multifaceted nature of TCO, integrating both CapEx and operational costs. They also directly bear on sustainability. Improving energy efficiency reduces both emissions and operational costs—and extending equipment life cycles minimizes e-waste and raw material demand.

This is not to say that sustainability does not complicate TCO calculations—it can.

- For example, power consumption is an inherent part of the TCO equation, but green energy sources may be more costly up front. In this instance, the focus on the nature of energy procured adds cost and efficiency constraints to an already challenging cost efficiency problem.

From Cost to Carbon

At today's data centers, TCO and sustainability goals can be two sides of the same coin.

LIFE CYCLE EXTENSION	INFRASTRUCTURE COSTS	ENERGY CONSUMPTION	RAW MATERIAL REQUIREMENTS	PHYSICAL SPACE CONSTRAINTS
Longer hardware life lowers replacement costs and e-waste.	Smarter infrastructure spend cuts CapEx and waste.	Less power usage reduces operational costs and emissions.	Efficient design requires fewer raw materials, reduces cost, and waste.	Smarter and advanced storage optimizes space and logistics costs.
$ Better long-term ROI	Reduced CapEx	Reduced OpEx	Predictable economics	Efficient space use
Reduced e-waste	Less resources	Lower carbon emissions	Less rare minerals used	More green space kept

The proliferation of AI applications is driving up data creation and increasing demand for data processing and storage. This demand, in turn, amplifies both the costs and carbon footprint of data centers. The data center professionals that we surveyed identified key concerns that have an impact on both TCO and sustainability. Each of these factors–optimizing hardware lifespan, infrastructure costs, energy use, material efficiency, and space utilization–can be fine-tuned to both improve cost efficiency and reduce environmental impact. When solving for cost efficiency, it is possible to achieve greener data center operations at the same time.

$ TCO benefits
Sustainability gains

A Threefold Choice

As the increasing use of AI drives up data creation, organizations need more room for ever-expanding data volumes, and many struggle with space limitations. Spatial constraints affect their ability to expand and implement more sustainable storage solutions. In addition, high up-front costs associated with sustainable infrastructure remain a significant barrier to progress.

- About 82.5% of respondents said they lack the physical space to build sustainable data storage infrastructure.

When asked about top three barriers to sustainable data center operations, respondents pointed to lack of physical space (45.5% of respondents); cost of constructing storage infrastructure (28.5%); and cost of acquiring data center components (27%).

Because of these barriers, organizations often face a threefold choice. To accommodate skyrocketing volumes of data, they must choose one of the three:

1. **scale up** (add more storage within existing center footprint)
2. **scale out** (add a building or expand the data center footprint)
3. **migrate data to the cloud**

Each of these options comes with TCO and sustainability trade-offs.

Sustainability strategies. The survey revealed that businesses are increasingly adopting a number of strategies that align sustainability with TCO goals.

Renewable energy sources. Nearly 62% of respondents reported using renewable energy sources to power their data infrastructure.

Renewable energy infrastructure. Close to 58% of survey takers said their organizations are investing in renewable energy infrastructure.

AI-enabled storage and sustainability operations. Additionally, 55.5% of represented organizations are implementing AI-based systems to optimize storage operations and enhance sustainability monitoring.

Despite these efforts, challenges remain. Many companies struggle with high infrastructure and component costs, as well as space limitations.

KEY TAKEAWAYS

The Path Forward

Addressing these challenges requires a shift in how the industry approaches TCO and sustainability. Increasingly, they go together. When sustainability goals do complicate TCO plans, attention needs to be paid across the entire ecosystem to:

Scope 1: Greenhouse gases (GHG) that an organization emits from sources it owns or controls directly.

Scope 2: GHG deriving from an organization's purchase of electricity, steam, heat, or cooling.

Scope 3: GHG emissions originating from business operations by sources that are not directly owned or controlled by an organization.

The AI-amplified impact on data center sustainability calls for innovative and holistic thinking about data center practices. Among other things, this means looking beyond operational carbon emissions (Scope 2 and Scope 3) to include evaluation of embodied carbon—or, carbon emitted during upstream extraction, production, transport, bill of material, manufacturing, packaging, and distribution stages of a product's life cycle (Scope 3).

As the boom of AI applications stimulates the growth of data centers, collaboration and innovation across the supply chain will be key to achieving a sustainable and more efficient datasphere.

Section 1

Challenges to Decarbonizing Data Centers

In today's AI economy, the rapid adoption of smart technologies is driving a sharp increase in data storage demand. Nearly all survey respondents (over 97%) expected AI to have a substantial impact on storage needs.

But data always leaves a footprint: data centers consume energy and generate emissions.

The AI-driven rising demand for data storage directly increases the carbon footprint of data centers. As data volumes grow, so does the energy required to maintain them. Of course, AI's energy demands extend beyond data storage. The most energy-hungry areas include compute, networking, and data processing.

The whole supply chain matters, too. Component manufacturing for AI—such as specialized processors and hardware—is highly energy- and resource-intensive, which increases the embodied carbon of these components. (Embodied carbon refers to the quantity of GHG emissions related to the upstream extraction, production, transport, bill of material, manufacturing, packaging, and distribution stages of a product's life cycle.) Consequently, both the production and operation of AI systems contribute to a larger carbon footprint, intensifying the environmental challenges faced by data centers.

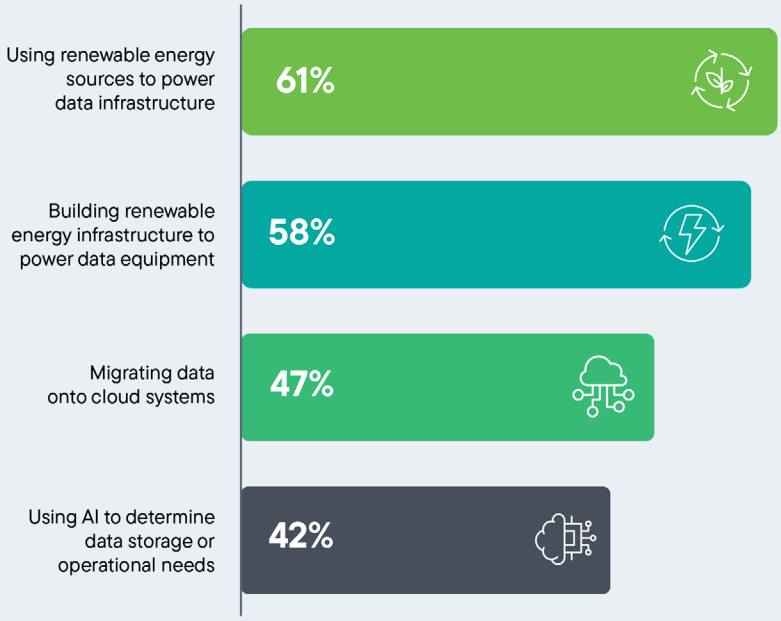
In response to this new demand, data centers have begun to prioritize sustainability and decarbonization. Nearly all survey respondents (close to 94.5%) reported that their companies are working to lower the carbon footprint of their data storage operations.

The survey found that to reduce their environmental footprint, companies are primarily adopting renewable energy ***(see Figure 1)***:

- 61% of respondents reported that their companies use renewable energy sources to power data infrastructure.
- Nearly 58% of respondents said their companies were building new renewable energy infrastructure to power data equipment.
- Close to 42% of the data center professionals surveyed reported implementing AI-driven solutions to better determine their data storage or operational needs.

FIGURE 1

What current methods are your company implementing to reduce the environmental impact of its data operations?



Source: *The Decarbonizing Data Survey*, Dynata, commissioned by Seagate, 2025.

Another strategy is cloud migration. Nearly half of respondents (over 47%) believed migrating data to cloud systems helps reduce their company's carbon footprint. Cloud service providers, with their best-in-class practices and infrastructure, have an advantage in lowering the environmental impact of data operations.

However, enterprises looking to deploy this strategy need to keep in mind that cloud migration can also be seen as shifting responsibility rather than eliminating impact. While cloud providers may operate more efficiently, the environmental burden remains. It is merely transferred from individual companies to the cloud providers, who must manage energy and resource demands. This underscores the need for a holistic approach to sustainability, where both cloud providers and their clients work together to minimize the carbon footprint of data.

In transitioning to more sustainable data storage operations, companies face significant challenges. They include physical space constraints, costs, high energy consumption, and effective assessment. Let us take a closer look at each of these factors.

Challenge: Space and Cost

The top three barriers to sustainable data center operations are the lack of physical space (45.5%), the cost of constructing storage infrastructure (28.5%), and the cost of acquiring data center components (27%) ***(see Figure 2)***.

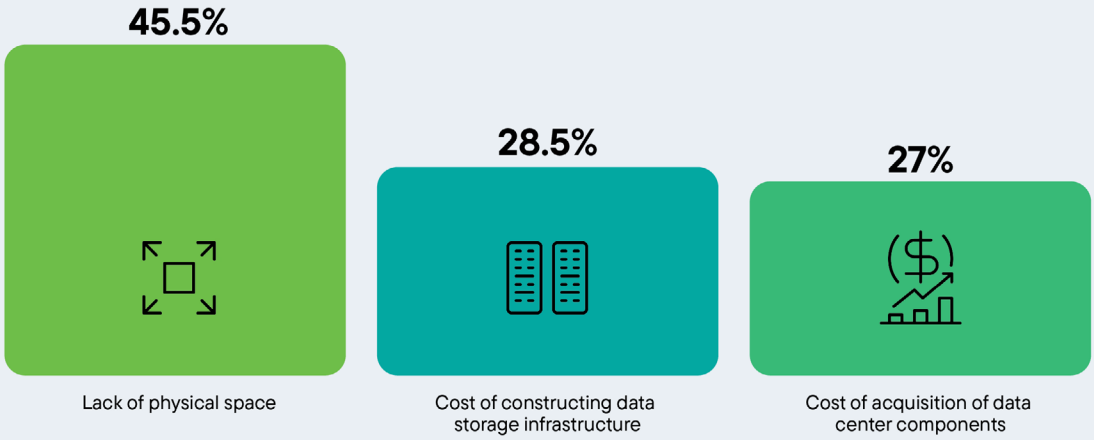
Not surprisingly, physical constraints—such as space limitations for new infrastructure—ranked as the biggest challenge, with 45.5% of all respondents citing a "lack of physical space" as the top obstacle. This barrier was particularly pronounced in Japan (60%) as well as Taiwan and France (both close to 57%), where it was the top concern.

Building additional physical spaces for data centers can significantly increase direct (Scope 1) GHG emissions, as it involves extensive construction activities that consume resources and rare earth minerals, and release GHG.

Given the dilemma of having to choose between a) increasing costs of expansion within the same space, b) building a new addition (also costly, often more so than the first choice), or c) migrating data to the cloud (which passes the sustainability burden to cloud's supply chain), the survey pointed to a need for innovative solutions to optimize existing space.

FIGURE 2

What are some barriers that you think are preventing your company from building or implementing sustainable data storage solutions?



Source: *The Decarbonizing Data Survey*, Dynata, commissioned by Seagate, 2025.

In response to a different survey question, 82.5% of respondents agree or strongly agree with the statement, "My company does not have the physical space to build sustainable storage infrastructure."

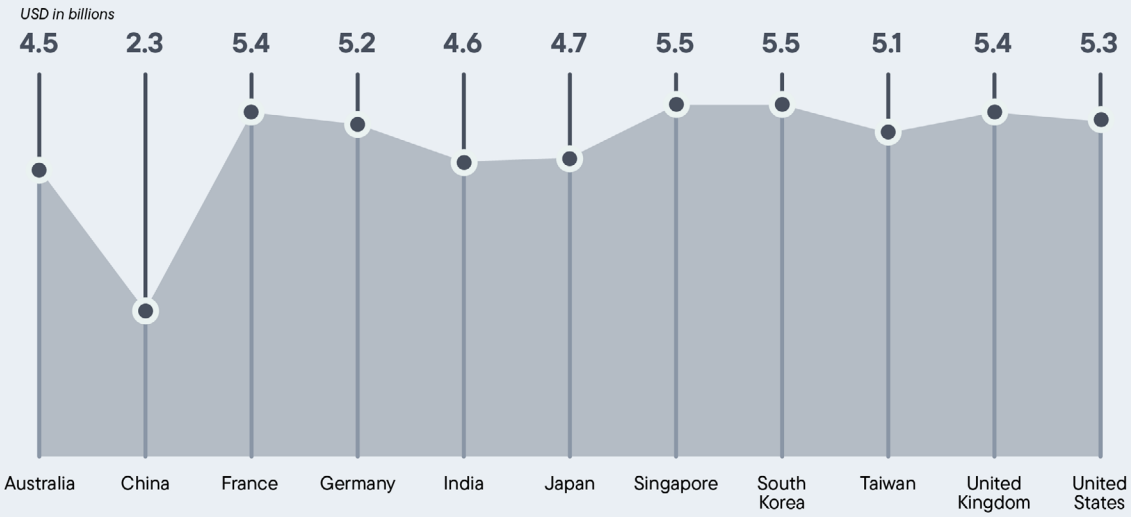
The need to accommodate more servers, storage devices, and networking equipment intensifies this challenge of limited space. In urban areas, where space is already scarce, finding suitable locations for new data centers is especially difficult. Several countries, including Singapore, Japan, Taiwan, France, and Germany, have imposed restrictions on the number of and locations where data centers can be built. These regulations aim to balance the benefits of increased data center resources with environmental protection and efficient land use, underscoring the need for innovative solutions to meet rising data storage demand.

The high costs of constructing and maintaining green infrastructure remain a major barrier to implementing sustainable solutions. These expenditures include the upfront investment in renewable energy and the ongoing expenses of sustainable IT infrastructure.

The survey projects that an average of $4.9 billion would be needed to invest in more sustainable data storage operations globally ***(see Figure 3)***. While this figure lacks definitive budget data, its scale highlights the magnitude of the challenge—one that requires significant attention, time, and resources.

FIGURE 3

How much budget do you think your company needs for more sustainable data storage operations?



Source: *The Decarbonizing Data Survey*, Dynata, commissioned by Seagate, 2025.

ADDITIONAL DATA POINTS

- Respondents in the United States (just under 47%), South Korea (40%), China, and Australia (both nearly 37%) identified "cost of constructing data storage infrastructure" as their most significant barrier preventing them from building or implementing sustainable data storage solutions.
- Breaking down some of the common data operating costs for companies, a German data center expert observed, "This includes expenses for the chief data officer, energy consumption, amortization, and annual infrastructure investments, totaling around €550,000 to €600,000. This estimate also covers security measures. If we were to transition to 100% green IT products, these costs would increase by about €60,000 to €65,000, which is approximately a 10% to 11% increase in our budget."

Device acquisition costs are the largest component of TCO at data centers. The initial CapEx required to purchase servers, storage systems, and networking equipment represents a significant share of the overall investment—especially at scale, where hardware purchases can reach tens of millions of dollars.

Acquiring state-of-the-art, energy-efficient hardware, renewable energy sources, and innovative technologies often comes at a premium. Despite the potential for long-term savings and environmental benefits, these higher costs can deter data center operators from making the switch. The need for continuous upgrades to keep pace with technological advancements further adds to the financial burden.

In the words of one interviewed data center expert, "shareholders are typically focused on minimizing costs, which can make it hard to justify the large expenditures required for initiatives like reducing energy usage or investing in renewable energy sources."

Challenge: High Energy Consumption

The continuous operation of data centers consumes large amounts of energy, contributing significantly to indirect GHG emissions from electricity, steam, heat, or cooling (Scope 2). The "always-on" nature of data center infrastructure, including servers and cloud systems, complicates energy reduction efforts and requires innovative solutions.

In this multi-market research, respondents identified their top three environmental concerns:

1. High energy consumption leading to carbon emissions (roughly 53.5% of respondents).
2. Large amounts of raw materials required for data center infrastructure (about 49.5%).
3. The substantial energy demands of data center operations (nearly 35%).

Experts warn that without immediate action, the environmental impact of data operations will continue to grow.

Compounding this issue, many companies reported that they search out renewable energy, but discover that they have no ability to choose sustainable energy sources.

- Almost 80% of respondents said their company had no option for a more sustainable electricity source because it was not available in their area.

The high costs associated with sourcing renewable energy can be a significant barrier.

- Over 61% of respondents indicated that they are using renewable energy sources as part of their mix to power their data infrastructure, and this has the most significant impact on reducing their indirect GHG emissions.
- However, renewable energy can be more costly due to the high initial investment in infrastructure, the need for reliable energy storage solutions, and the complex modifications required to integrate with existing systems.

Challenge: Measurement and Assessment

While data storage itself is a relatively small contributor to overall data center operations (with compute and processing workloads demanding much more energy), the survey asked about perceptions and measurement of the environmental impact of data storage.

- Most respondents (close to 61%) said their companies already measure the environmental impact of their data storage through "regular reports detailing the environmental footprints of data storage operations."
- Half of all respondents (over 50%) also said their companies are using "in-house software to monitor the environmental impact of data storage operations," while a third (nearly 33.5%) said their companies had outsourced measurement to external agencies.
- However, tracking remains inconsistent, as about 32.5% of respondents were unsure or unaware of whether their companies track these metrics.

There is also a notable lack of tools and procedures to assess the environmental impact of data storage practices. Without proper assessment methods, businesses struggle to evaluate the effectiveness of their sustainability efforts and make informed decisions about future investments in sustainable practices.

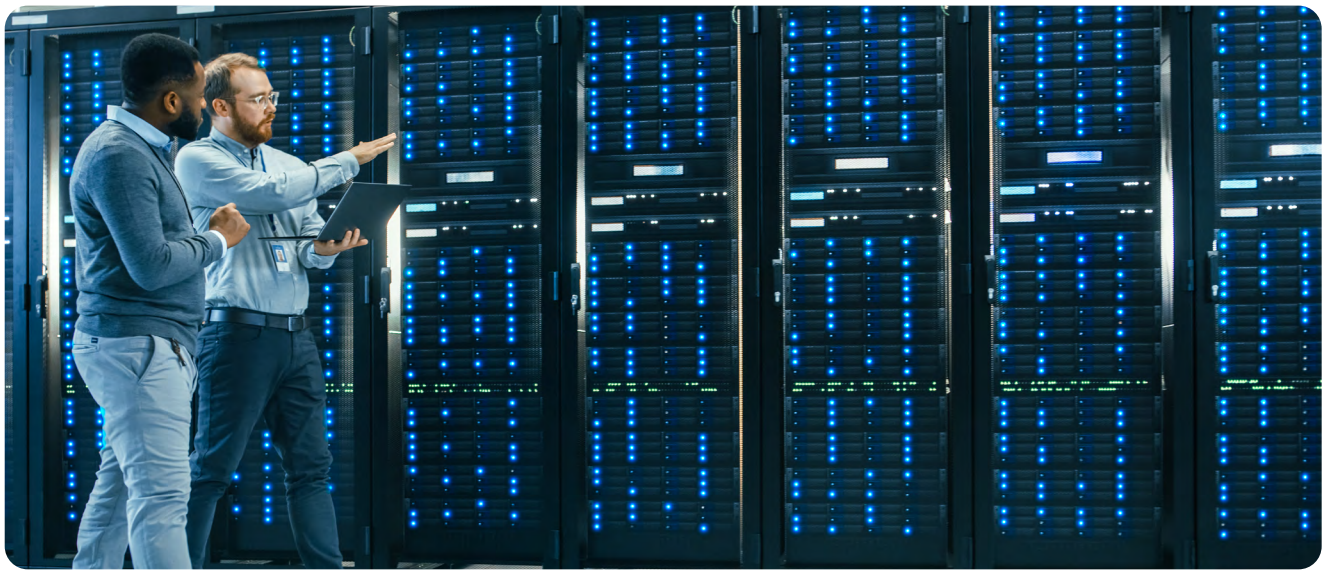
Calling for more real-time information, one of the interviewed US data center experts highlighted the need to know how much power we are using, the fluctuations, and any other relevant details: "This information should be logged so we can see what's happening over time. Data centers need to see the importance of providing this information, and companies need to demand it...real-time monitoring and reporting are essential for managing sustainability effectively."

A sustainability expert from the Asia-Pacific region reiterated the importance of transparency in reporting: "Transparent reporting can help a lot...such as comprehensive environmental impact reports, life cycle assessment, and case studies of successful implementation. Then there are tools for calculating the potential benefits and cost saving of sustainable solutions."

Section 2

Solutions That Reduce Data Centers' Carbon Footprint

The survey makes clear that most data centers could benefit from a reevaluation of traditional data management practices. While many organizations recognize sustainability's importance, they often take isolated measures instead of a holistic approach.



The Importance of Life Cycle Management, or Lack of It

Ironically, while at least 92% of respondents agreed that extending the life cycle of storage equipment and infrastructure significantly impacts data center sustainability, only 15.5% considered life cycle extension as a key factor in purchasing decisions.

Highlighting the short-term focus of such decisions, a data center expert from Germany observed:

> "Unfortunately, many consumers often choose the cheapest option without considering the long-term implications. They might buy a cheaper product only to find it fails after two or three years, necessitating a new purchase. This cycle of constant replacement isn't sustainable. Not enough people think about this cycle. When we purchase new products, it means more resources are needed—more components mined from places like Africa, more manufacturing processes, and more labor. This impacts the whole ecosystem. The current approach isn't as effective as I'd like it to be."

Extending the life cycle of data center solutions and infrastructure significantly reduces e-waste and carbon emissions. By maximizing the use of existing infrastructure, life cycle extensions help mitigate often-overlooked upstream and downstream emissions.

This highlights the benefits of considering equipment life cycle in purchasing decisions. Data center operators can evaluate the life cycle of all components—including power delivery, data processing, and storage density—to better understand their impact on overall carbon emissions. When possible, they should select equipment from providers with built-in circularity programs.

Circularity programs can provide significant sustainability benefits. They ensure that solutions such as hard drives are either refurbished, repurposed, or recycled in an environmentally responsible manner. By adopting circularity principles, data centers can reduce e-waste and the demand for new raw materials, while minimizing the environmental impact associated with the disposal of old devices.

This holistic approach not only advances sustainability goals, but also promotes the efficient use of resources.

Understanding the Role of Embodied Carbon

Another gap identified in the survey was how environmental impact factors into purchasing decisions:

- About 95% of respondents expressed concerns about the environmental impact of data center operations.
  - The top concerns were carbon emissions (nearly 53.5%), use of raw materials (close to 49.5%), and high energy consumption (just under 35%).
- However, only about 3% considered low environmental impact a key factor in purchasing decisions.

Maintaining awareness of the embodied carbon of equipment and infrastructure (Scope 3) can help data centers identify opportunities to reduce their overall carbon footprint beyond just operational emissions (Scope 1 and Scope 2). Embodied carbon refers to the quantity of GHG emissions related to the upstream extraction, production, transport, bill of material, manufacturing, packaging, and distribution stages of a product's life cycle. Storage and infrastructure manufacturers as well as other data center suppliers ought to provide information on the embodied carbon of their products.

SEAGATE POV

Storage Media and Embodied Carbon

The table below compares the embodied carbon of solid-state drives (SSDs), hard drives, and tape-based storage, highlighting how storage media choices affect total data center emissions. Seagate Technology analyzed different capacities, usage patterns, and lifespans over a five-year period, measuring embodied carbon per device and per terabyte (TB) per year.

Storage media	Embodied carbon by product (Kg CO_2)	Embodied carbon per TB (CO_2/TB)	Embodied carbon per TB per year (CO_2/TB/year)
SSD[3]	4,915	160	32
Hard drive[4]	29.7	<1	<0.2
LTO (Tape)[5]	48	2.66	<0.6

These numbers reflect Seagate's analysis based on the following products:

- **Generic data center SSD:** 30.72TB
- **Hard drive:** Seagate 30TB Mozaic 3+™
- **Linear tape-open (LTO) 9 tape drive + 1 media:** LTO Ultrium

KEY INSIGHTS

- **SSDs** have the highest embodied carbon, both in total and per TB, making them the most carbon-intensive option among the three storage media.[6]
- **Hard drives** exhibit the least carbon footprint, both in total and on a per-TB basis, offering the most carbon-efficient sustainable storage solution.
- **LTO tapes** show moderate embodied carbon, but the technology's annual impact is higher than that of hard drives.

This analysis highlights the importance of selecting the appropriate storage media mix for both TCO and sustainability.

3 *The Dirty Secret of SSDs: Embodied Carbon*, HotCarbon Workshop on Sustainable Computer Systems, University of Wisconsin-Madison, University of British Columbia, 2022.

4 Embodied carbon prediction for Seagate 30TB Mozaic Hard Drive per TB for five-year life cycle

5 Seagate analysis of IBM's breakdown of the CO2 and other positive sustainability impacts of IBM physical tape and power consumption and cooling requirements; predictions for 1 LTO 9 drive + 1 LTO 9 Media using total embodied carbon with 5 Years life cycle for all technologies, LTO 9: 37 Watt operating and 18-watt idle power.

6 Since there is no publicly accessible life cycle assessment (LCA) data for any data center SSD product, we calculated the embodied carbon of the 30.72TB SSD using the available public data from the research "The Dirty Secret of SSDs: Embodied Carbon". We aim to provide accurate figures for data centers to make informed decisions; however, the NAND industry does not publish LCA data nor undergo third-party audits as Seagate does for hard drives.

Section 3

Rethinking Data Center Sustainability

The survey found that businesses are pursuing two key strategies to improve data center sustainability:

1. **Adoption of renewable energy.** Companies are increasingly integrating renewable energy sources to power their data infrastructure. About 62% said they are currently using renewable sources of energy to power their data infrastructure, and 58% said they are building renewable energy infrastructure to power data equipment.
2. **Deployment of technology-based solutions.** The implementation of tech-based solutions is gaining traction, from data migration to cloud systems (over 47% of respondents noted this solution) to adoption of a mix of storage media types (47%) and AI-based systems to streamline data storage operations (42%). As noted earlier, there are tradeoffs and costs (in both financial and sustainability realms) that need consideration, no matter the solution that is picked.

Integrating renewable energy sources to power data infrastructure can significantly reduce reliance on fossil fuels, thereby lowering the carbon footprint. But it also presents several challenges. The initial cost of infrastructure, such as solar panels and wind turbines, can be prohibitively high.

Additionally, the intermittent nature of renewable energy sources poses a challenge, as solar and wind power generation can be unpredictable and dependent on weather conditions. This necessitates reliable energy storage solutions to ensure a consistent power supply, further increasing costs. Moreover, integrating renewable energy with existing data center systems can require complex modifications and upgrades, making the transition time-consuming. Regulatory and logistical barriers add to the complexity, as policies and requirements vary across regions.

Beyond investing in renewable energy, data centers can focus on reducing power consumption at both the equipment and infrastructure levels. Lowering power usage not only cuts operational costs, but also enhances the effectiveness of renewable energy efforts by reducing overall demand.

SEAGATE POV

Storage Media and Power Consumption

Based on Seagate's analysis of power consumption across three storage media types given their usage patterns and device-level lifespan over five years, the table compares:

- **Operating power in watts,** which is the total power consumed by a drive when actively reading or writing data.
- **Power efficiency,** measured as the average power consumed in watts to write or read 1 TB of data.

Storage media[7]	Operating power in watts	Power efficiency (W/TB)
SSD	20	0.5
Hard drive	9.6	0.32
LTO (Tape)	37	1.1

These figures highlight that hard drives offer the most energy-efficient storage option, and are the greenest storage solution, followed by SSDs, with LTO 9 tape consuming the most power per unit of storage.

7 Based on Seagate's analysis of LTO 9 Tape Drive: IBM LTO Ultrium Product Specifications; 30TB Hard Drive: Seagate 30TB Mozaic 3+; 30TB SSD: Micron 6500 ION 30.72TB.

The survey also found that many data centers underutilize infrastructure-based solutions to reduce emissions.

- Only 23% of respondents use HVAC (heating, ventilation, and air conditioning) systems to cool their data infrastructure.
- Nearly 16.5% had adopted liquid/immersion systems for cooling.
- A small minority (11.5%) reuse heat generated by data infrastructure.

Infrastructure-based solutions can play a pivotal role in improving data center sustainability by addressing energy consumption, carbon emissions, and overall environmental impact.

Traditional data center cooling methods, such as computer room air conditioning and computer room air handler units, focus solely on cooling the air within the data center to maintain optimal temperatures for equipment. While effective, they can be energy-intensive and less efficient in managing overall environmental conditions.

In contrast, advanced infrastructure-based solutions like HVAC systems offer a more comprehensive approach by not only providing cooling, but also managing heating and ventilation. These systems often incorporate advanced technologies like variable speed drives, economizers, and energy recovery ventilators, which optimize energy use and reduce the overall carbon footprint.

Section 4

Turning Challenges Into Opportunities

To make measurable progress in sustainability, businesses can benefit from adopting both immediate and long-term strategies.

In the more immediate, short-to-medium term, a more holistic approach is needed—extending hardware life cycles, optimizing energy efficiency, and implementing circularity programs.

Long-term solutions require industry-wide, across-the-supply-chain collaboration, financial incentives, and AI-driven sustainability innovations to ensure continued reduction of data centers' environmental footprint.

In the Shorter Term

Data centers should develop a holistic strategy that goes beyond adopting renewable energy sources. While integrating renewable energy is a foundational step (though it can be tricky cost-wise), it alone is not enough to address the multifaceted challenges of sustainability.

First, data centers may benefit from implementing regular assessments and monitoring of the life cycle of all components, including servers, storage devices, and networking equipment. Understanding the full life cycle of each component allows data centers to identify opportunities to extend their use and reduce their environmental footprint. Extending the life cycle of storage equipment through regular maintenance, upgrades, and refurbishment programs is crucial. This approach cuts e-waste, minimizes the need for new raw materials, and reduces the energy-intensive processes associated with manufacturing new equipment. Procurement policies can prioritize durable, high-quality components with longer lifespans, ensuring that sustainability is a key criterion in purchasing decisions.

Second, reducing power consumption can be a critical part of sustainability efforts. Data centers can invest in energy-efficient technologies, such as liquid/immersion cooling and HVAC systems, which are more efficient at dissipating heat. These systems can significantly lower energy consumption compared to traditional cooling methods, leading to reduced operational costs and carbon emissions.

Integrating renewable energy sources, like solar and wind power, into data center operations can further decrease reliance on fossil fuels and lower the overall carbon footprint. Optimizing energy management practices—for example, by implementing AI-based systems to monitor and fine-tune energy use—can also contribute to more efficient and sustainable operations.

Third, data centers should prioritize the procurement of innovative, cost-efficient, sustainability-promoting solutions. (For an example from the world of data storage, see Areal Density Innovation and Data Center Sustainability on page 23.)

Lastly, establishing a circularity program for the disposal of data center components can be valuable. Such a program can ensure that components are refurbished, repurposed, or recycled responsibly. Developing processes to recover valuable materials from end-of-life equipment can reduce demand for new raw materials and minimize the environmental impact of disposal. Minimizing e-waste through reuse and repurposing not only supports sustainability goals but also promotes the efficient use of resources.

By focusing on these areas, data centers can significantly enhance their sustainability efforts and work toward reducing their overall environmental impact.

SEAGATE POV

Areal Density Innovation and Data Center Sustainability

Hard drives are the greenest storage medium.[8] Although hard drives contribute relatively little to data centers' overall environmental burden, innovations in hard drive recording technology can help both optimize data centers' TCO and improve sustainability.

With unrivaled economies of scale, areal density innovation has become critical to both AI innovation and sustainable data centers.

Areal density, the measurement of data stored per unit of surface area on any medium, in a hard drive specifically refers to the data capacity of a single disk. Areal density innovation directly influences storage efficiency within limited physical space and enables businesses to increase their data storage capacity in the same space using fewer materials and less power, effectively reducing their carbon emissions per unit of data storage.

The advancement directly addresses several sustainability challenges flagged by the survey. By increasing storage capacity without requiring additional physical space, higher areal density helps alleviate space constraints in data centers, a barrier cited by 45.5% of respondents. Additionally, the reduction in power consumption it enables aligns with efforts to lower energy usage and carbon emissions, a primary concern for about 53.5% of respondents.

Scaling While Lowering Total Global Energy and Carbon Impact

For data centers managing large-scale workloads, replacing legacy storage devices with next-generation HAMR (heat-assisted magnetic recording) drives can lead to a net decrease in total power use. At scale, these improvements translate into meaningful reductions in absolute energy consumption and operational carbon footprint, even as storage infrastructure grows.

On a global level, this effect compounds across the datasphere. The transition to higher areal density drives means that, despite the projected 167% increase in total cloud data storage demand by 2028[9], the proportion of total data center power consumed by hard drives in data centers around the globe can drop from ~8% to ~3%. That is a 62% total reduction in energy consumption by storage infrastructure.

This represents a fundamental shift: not only is storage becoming more efficient, but it is also directly enabling a net reduction in total energy use and carbon emissions across data centers worldwide, even as data retention increases. It's great news on both data center TCO and sustainability fronts.

8 As measured by examining embodied carbon and power consumption.

9 *IDC Cloud Infrastructure Index*, IDC, 2024.

These large-scale benefits are reinforced by efficiency improvements at the device level. Based on Seagate's analysis of power consumption across multiple storage media types (see Storage Media and Power Consumption on page 19), hard drives provide the most energy-efficient, high-capacity storage option. Drive-level power efficiency factors—including operating power in watts (total power consumed when actively reading or writing data) and watts per TB efficiency—demonstrate how denser capacities reduce energy consumed per unit of stored data.

By integrating storage solutions with higher areal density, data centers can expand capacity without requiring additional space, reduce total energy usage, and cut operational carbon impact, all while meeting the increasing demands of AI-driven workloads and cloud expansion.

For storage at scale, the impact of increased areal density is profound. Higher areal density allows data centers to significantly increase their capacity without expanding their physical footprint, and to achieve sustainability goals by minimizing the use of space, energy, and natural resources.

Imagine a 10-disk hard drive, with each disk (also known as platter) holding 3TB of data. In total, the drive stores 30TB. Consider a data center upgrading each hard drive in its fleet from 10TB to 30TB, a realistic modern-day upgrade scenario. This leap in areal density enables:

- Three times or more storage capacity in the same data center footprint[10]
- More than a 60% power reduction per TB
- More than a 70% reduction in embodied carbon per TB[11]
- 25% lower cost per TB[12]

Now, consider how these benefits multiply as HAMR-enabled hard drive technology increases capacities to 40TB and 50TB.

- Imagine the same drive—but with each disk increased to 4TB. The same 10 disks now provide 40TB, a more than 30% increase in capacity in the same physical space.
- With 5TB per disk areal density advancements on the horizon, the same 10-disk drive will soon store 50TB, and beyond, further multiplying data center capacity and power benefits.

10 Comparing Seagate Exos X10 to Seagate Exos X 30TB Mozaic drive
11 Comparing Seagate Exos X10 to Seagate Exos X 30TB Mozaic drive
12 *IDC Worldwide 1Q24 HDD Shipments and 4-Quarter Outlook by HDD Segment*, IDC, 2024

In the Long Term

In the long term, businesses should explore and leverage AI across their operations to curb carbon emissions, demonstrating technology's role to drive sustainability. The survey found that 55.5% of respondents believed AI can optimize data storage operations to enhance sustainability. While AI offers significant potential to drive sustainability efforts, it is crucial to recognize that, if not developed with efficiency in mind, AI can also increase power consumption and GHG emissions.

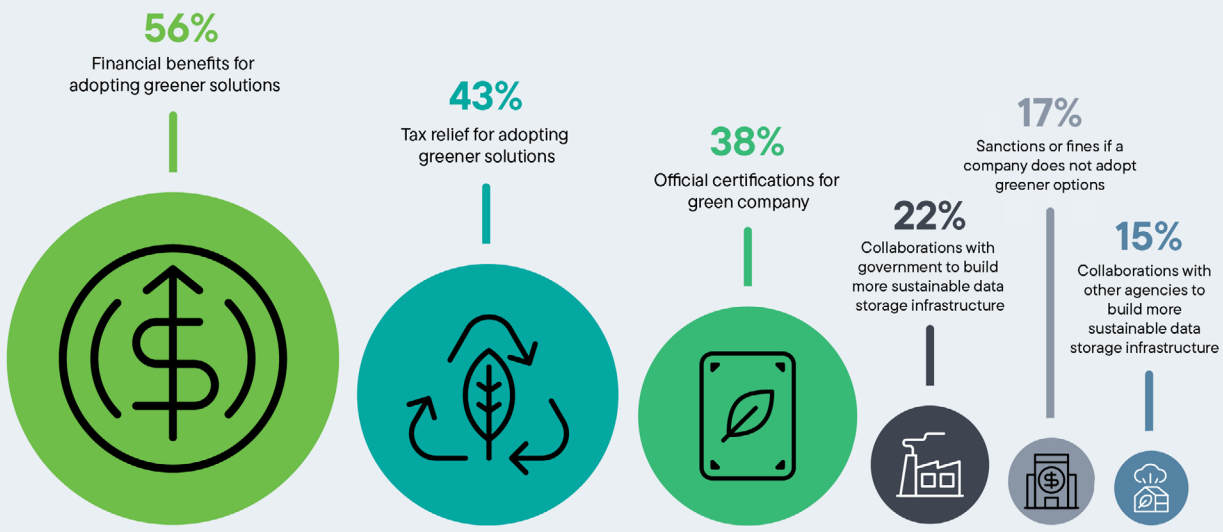
To balance AI's potential with sustainability goals, optimizing its efficiency will be critical. By focusing on power-efficient resource planning, optimized training, and life cycle management, AI innovation can be integrated with sustainable practices, ensuring its benefits do not come at the expense of the environment.

Part of longer-term sustainability planning is the work of changing minds and culture. It is much easier to secure leadership's buy-in when sustainability measures enable greater efficiency, and vice versa. To encourage business leaders to consider sustainable approaches to scaling operations and storage infrastructure, data center professionals worldwide identified what they believe to be the top three motivators:

- Over 56% cited financial benefits for adopting greener solutions.
- More than 40% pointed to tax relief for adopting greener solutions.
- At least 38% highlighted the value of official green company certifications.

FIGURE 4

What would persuade leaders in your company to consider adopting greener options for their data storage practices?



Source: *The Decarbonizing Data Survey*, Dynata, commissioned by Seagate, 2025.

An expert from the US elaborated on the financial benefits:

> "Companies might not want to outlay (a large sum of money) for a solar array, but they might want to do it and just can't because their shareholders would never go for that. If it was basically a net zero for everybody, it's a no-brainer. From a federal standpoint, I got a 30% tax credit on my solar array; it still cost a lot, but I got 30% tax credit back, which offset that cost a little bit."

Experts emphasized the importance of financial incentives like tax relief and grants from governments or regional trade blocs like ASEAN and the European Union.

For example, Germany's KfW 45 standards specify target energy consumption levels for buildings, with lower numbers indicating higher environmental efficiency. Meeting these standards qualifies businesses for tax relief and government bonuses, encouraging adherence to practices that lead to more sustainable outcomes.

Collaboration provides businesses with additional avenues to reduce emissions. Data center professionals saw value in partnering with governments (around 22%) and other agencies (over 15%) to develop more sustainable data storage infrastructure.

Data centers may find value in collaborating with industry partners to develop standardized tools and procedures for assessing the environmental impact of data storage practices. Such collaboration can help establish industry-wide benchmarks and best practices, enabling companies to evaluate performance and identify areas for improvement more effectively.

Conclusion

The Path to a Sustainable Datasphere

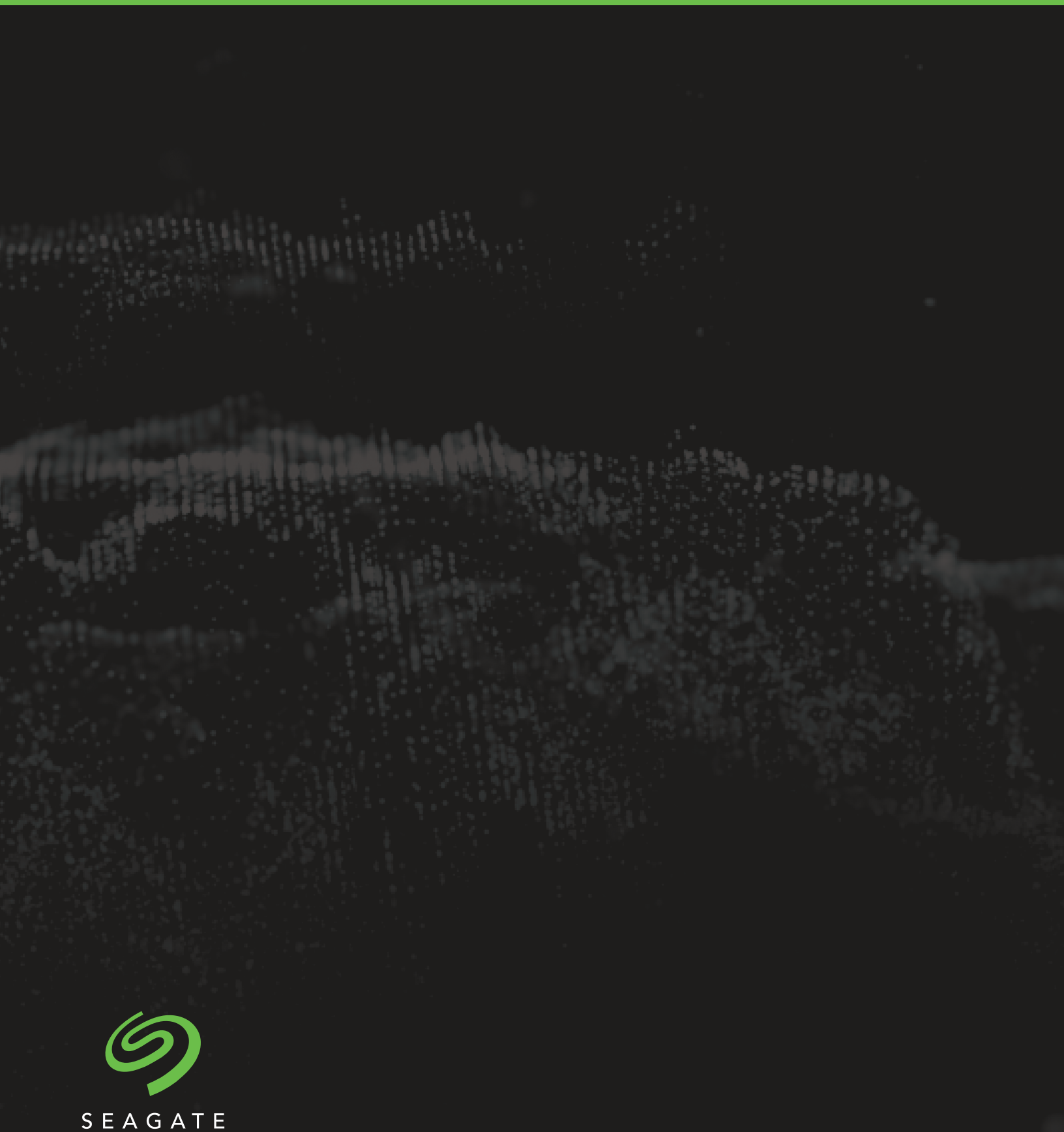
The findings of this research highlight the role of industry-wide collaboration in supporting a sustainable datasphere.

By working together, data centers, technology providers, component suppliers, and regulatory bodies can develop and implement innovative solutions that reduce energy consumption, minimize carbon emissions, and promote the efficient use of resources. This includes adopting advanced cooling solutions, integrating renewable energy sources, extending the life cycle of storage equipment, choosing suppliers based on their sustainability commitments, and implementing circularity programs for the responsible disposal of components. Innovation by suppliers can play a key role in paving the way to more sustainable and efficient data centers.

Transparent reporting and real-time monitoring of environmental impact are also tools that can provide insights for managing sustainability in data centers. Providing comprehensive environmental impact reports, conducting life cycle assessments, and sharing case studies of successful sustainability interventions can foster accountability and continuous improvement throughout the supply chain. Financial incentives, tax relief, and official green certifications can further encourage data centers to adopt more sustainable practices.

By adopting a comprehensive approach to sustainability and engaging industry stakeholders, companies can balance the growing demands of AI and data center operations with environmental considerations.

Through collaboration and innovation, data centers can help create a datasphere that is scalable, efficient, and sustainable.



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