SNIA DEVELOPER CONFERENCE

SDC 24

BY Developers FOR Developers

September 16-18, 2024
Santa Clara, CA

Product Circularity

Integrating Sustainability into Storage Design and Development

Presented by Jonmichael Hands, Arie van der Hoeven

What is sustainability – OCP Sustainability Project

Transparency, Reporting and Metrics

For data center operators: Reporting on energy and water usage and carbon (GHG) emissions - scope 1, 2, and 3

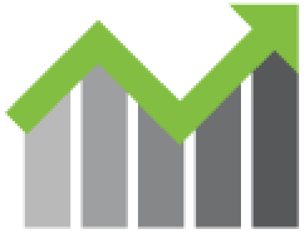
For suppliers: focus on Life Cycle Assessments (LCA) & upstream reporting accuracy

Circularity

Materials maintaining their highest value possible

Products are designed to extend the use period of a product and consider the next use

Extension of use (life), reuse, repair, refurbish, remanufacture, disassembly, and recycling



Efficiency & Interoperability

Efficiency metrics beyond PUE and focus on impact of reporting, and gen over gen improvements

OCP standard firmware for multiple customers, open source tools. Hardware building blocks for servers and racks

Circular Economy Principles

- Use (life) extension
- Reuse
- Sharing
- Repair
- Refurbish
- Remanufacture
- Disassembly
- Recycle
- Disposal

The Circular Drive Initiative

Circular Drive Initiative

Retain
Regen to keep drives in service

Reuse
Secure data erasure and sanitization

Recover
Disassembly, recovery of rare earth materials, and then recycling

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CDI Security, Cryptography, Sanitization, Verification

IEEE 2883 Purge
Media Sanitization

IEEE 2883 Verification

ISO/IEC 27040
Certificate of
Sanitization

Hardware roots of trust
Firmware audits
Forensic Analysis

IEEE SA STANDARDS ASSOCIATION

ISO IEC

OPEN Compute Project®

ADISA®

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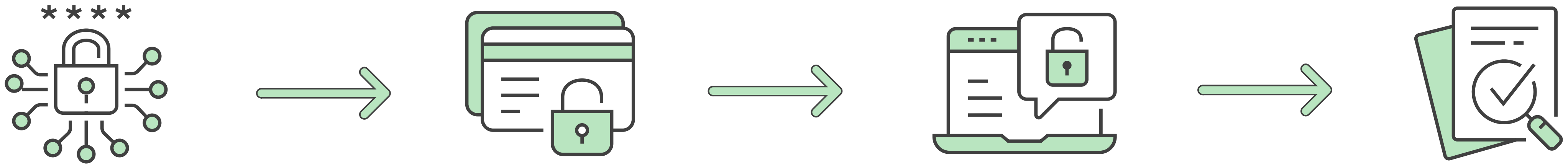
CDI Media Sanitization

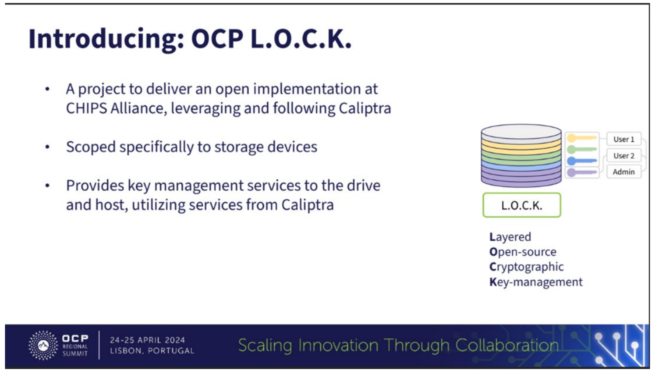


Use IEEE 2883 approved purge technique → Check Sanitize Log → Perform verification on host interface → Generate certificate of sanitization

Roadmap – Increase Trust

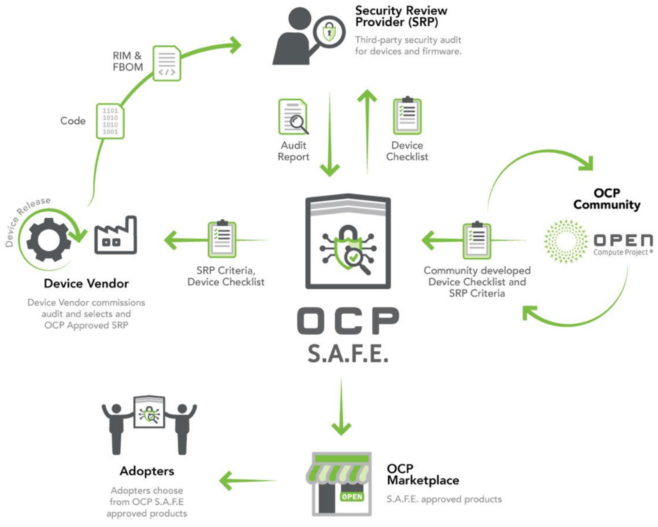
- Vendor validation of sanitize
- Certifications, TCG OPAL, FIPS 140-3
- 3rd party audit
- Firmware attestation / measurement, hardware roots of trust

Roadmap - OCP

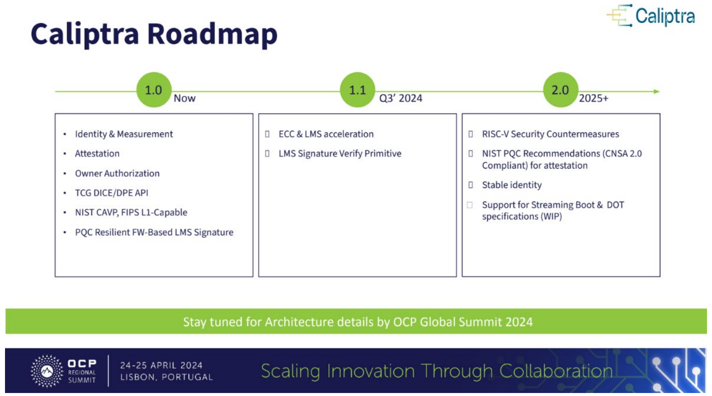


OCP L.O.C.K.

Calitpra ➡️ KMB (Key Management Block) ➡️ Storage Controller Firmware ➡️ AES Crypto Engine



OCP S.A.F.E. Update



Project Caliptra Update

Data Sanitization Research

- IEEE Compute Magazine article
- Storage market, intro to circular economy
- History of media sanitization specs
  - Show that DoD and NIST are old
- Highlight new IEEE 2883-2022 spec
- Review purge techniques

MEMORY AND STORAGE

EDITOR TOM COUGHLIN
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New IEEE Media Sanitization Specification Enables Circular Economy for Storage

Jonmichael Hands, Chia Network
Tom Coughlin, Coughlin Associates

Modern media sanitization techniques can securely eliminate data on digital storage devices. This enables more effective efforts to reuse and recycle these devices, enabling a circular economy for data storage.

Digital Object Identifier 10.1109/MC.2022.3218364
Date of current version: 9 January 2023

Data growth has exploded, creating amazing opportunities and enabling quality of life improvements. The amount of data being created has far outpaced the amount of data being stored, with the International Data Corporation (IDC) forecasting that, in 2026, the massive 20.5 ZB of data being stored in the world will make up only about 10% of the total data generated that year (see Figure 1). This growth of stored data needs to be sustainable, with more companies than ever involved in the storage of digital data setting net-zero emission goals by 2030.

RAPID DATA GROWTH DEMANDS SUSTAINABLE PRACTICES

A modern high-capacity 3.5-in hard drive has an environmental footprint of 2.55 kg CO_2 emitted per terabyte per year.[2] One study estimated the embedded carbon from manufacturing solid-state drives (SSDs) to be as high as 0.16 kg CO_2 emitted

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IEEE 2883.1: Recommended Practice for Use of Storage Sanitization Methods

- Storage Lifecycle, Risk and Management, Cryptography

- Choosing the Appropriate Sanitization Method: (clear, purge, or destruct) based on the intended use of the storage media, considering factors like risk and the sensitivity of the information

- Verification of Sanitization: Knowing that the data is gone

Example of Likelihood of Data Recovery after Sanitization

Sanitization Method	Adversary Capability		
	Novice	Expert	Virtuoso
None	Almost Certain	Almost Certain	Almost Certain
Clear	Unlikely	Likely	Almost Certain
Purge	Almost Impossible	Almost Impossible	Unlikely
Destruct	Almost Impossible	Almost Impossible	Almost Impossible

Risk and Risk Management

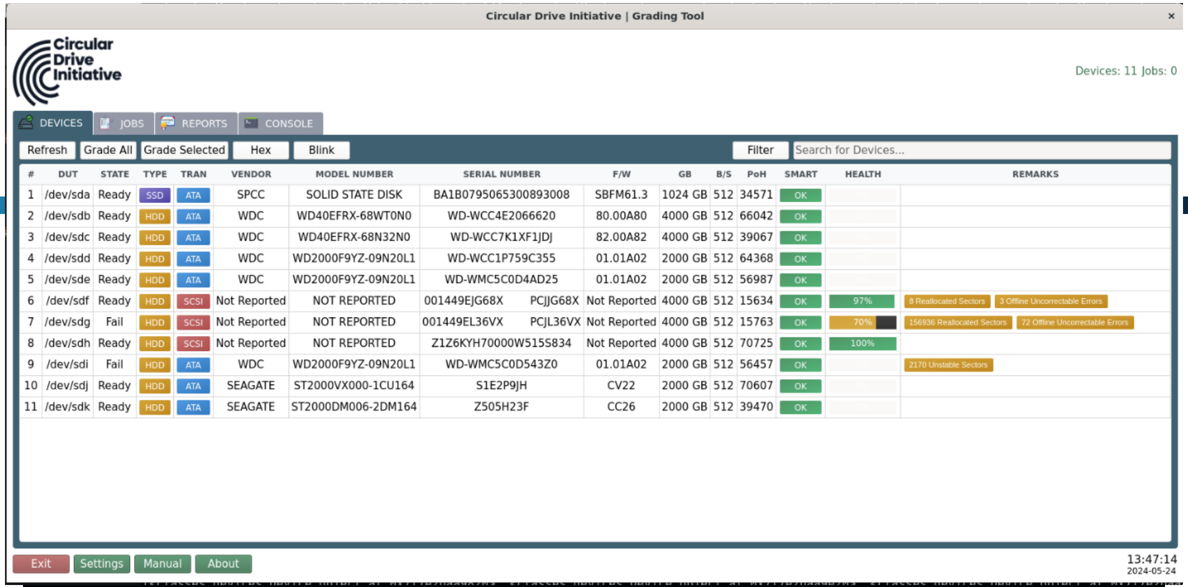
- Classify data based on data sensitivity: low, medium, and high
- Interest=f(Gain, WorkFactor, LikelihoodOfSuccess)
- Managing risk: Accept, Avoid, Transfer, Treat/Mitigate

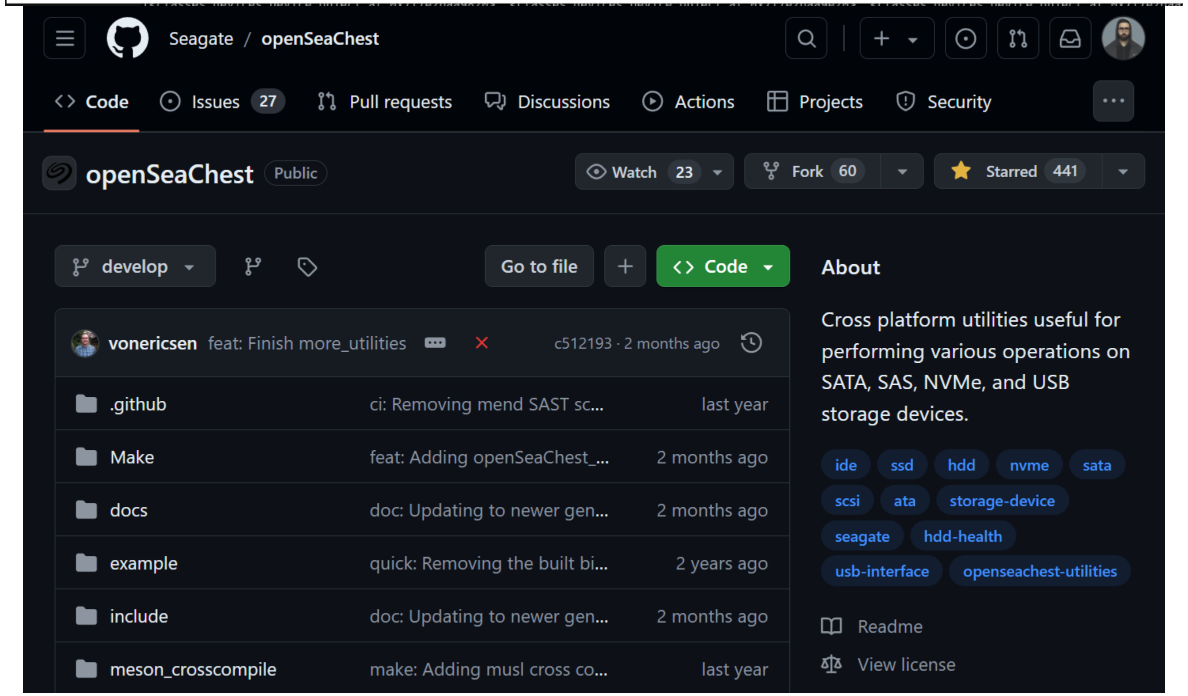
Table 4—Risk as a function of likelihood and magnitude of loss

Likelihood of Retrieving Meaningful Data	Magnitude of Loss		
	Low	Medium	High
Almost certain	Medium	High	Very High
Likely	Low	Medium	High
Unlikely	Very Low	Low	Low
Almost impossible	Very Low	Very Low	Very Low

CDI Health Grading Tool

- Open-source software suite for SSD and HDD health and reliability
- Transparency required to build trust in secondhand market
- CDI workgroup deep understanding of SSD and HDD quality and reliability
- Grading system designed to accurately assess the health and remaining use left
- Includes endurance, power on hours, errors, device self-test, signed vendor firmware





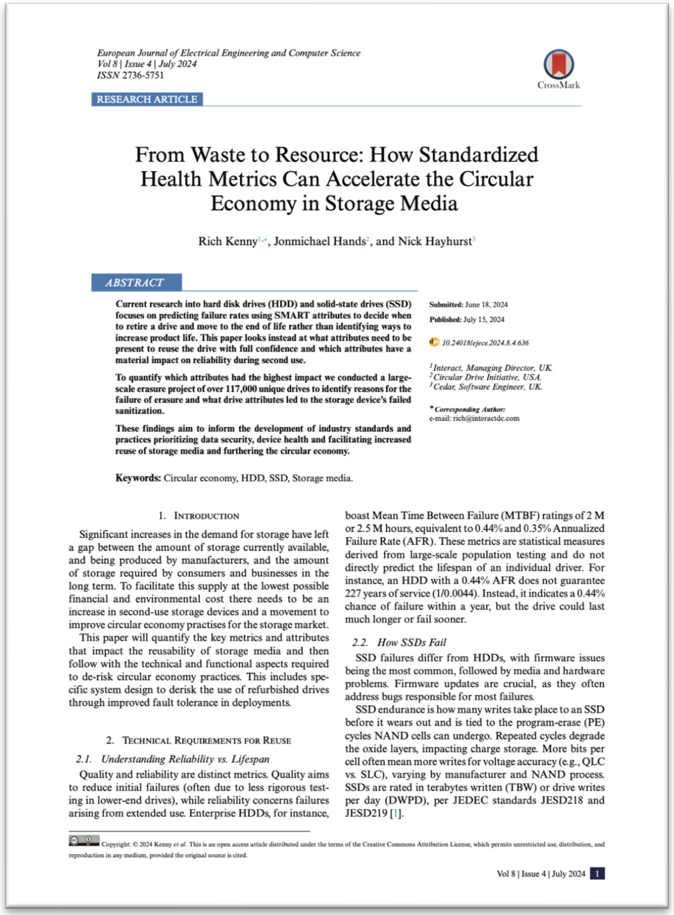
Use (life) extension

- One of the strongest levers for circular economy. Use until energy / TCO crossover.
- Device Reliability – AFR to get to move from 5 > 7 year deployments
- Firmware and platform resilience – do not brick drive on faults, recovery from asserted states
- Variable capacity, runtime capacity change
- Health monitoring and telemetry
  - AI/ML predictive failure

- Examples: OCP Datacenter NVMe SSD Spec
- AFR of 0.35% (2.5M hr MTBF)
- Firmware update without reset (no downtime)
- SMART / Health Information Extended log page (C0)
- Error Recovery (Log Identifier C1h)

CDI Health Grading – Academic Paper

- From Waste to Resource: How Standardized Health Metrics Can Accelerate the Circular Economy in Storage Media
- Background on how HDDs and SSDs fail
- Designing systems for high durability with used drives
- Importance of media sanitization
- Results from Interact – 117k drives decommissioned and sanitized
- **87**% suitable for reuse



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RESEARCH ARTICLE

From Waste to Resource: How Standardized Health Metrics Can Accelerate the Circular Economy in Storage Media

Rich Kenny[1,*], Jonmichael Hands[2], and Nick Hayhurst[3]

ABSTRACT

Current research into hard disk drives (HDD) and solid-state drives (SSD) focuses on predicting failure rates using SMART attributes to decide when to retire a drive and move to the end of life rather than identifying ways to increase product life. This paper looks instead at what attributes need to be present to reuse the drive with full confidence and which attributes have a material impact on reliability during second use.

To quantify which attributes had the highest impact we conducted a large-scale erasure project of over 117,000 unique drives to identify reasons for the failure of erasure and what drive attributes led to the storage device's failed sanitization.

These findings aim to inform the development of industry standards and practices prioritizing data security, device health and facilitating increased reuse of storage media and furthering the circular economy.

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Keywords: Circular economy, HDD, SSD, Storage media.

1. Introduction

Significant increases in the demand for storage have left a gap between the amount of storage currently available, and being produced by manufacturers, and the amount of storage required by consumers and businesses in the long term. To facilitate this supply at the lowest possible financial and environmental cost there needs to be an increase in second-use storage devices and a movement to improve circular economy practises for the storage market.

This paper will quantify the key metrics and attributes that impact the reusability of storage media and then follow with the technical and functional aspects required to de-risk circular economy practices. This includes specific system design to derisk the use of refurbished drives through improved fault tolerance in deployments.

2. Technical Requirements for Reuse

2.1. *Understanding Reliability vs. Lifespan*

Quality and reliability are distinct metrics. Quality aims to reduce initial failures (often due to less rigorous testing in lower-end drives), while reliability concerns failures arising from extended use. Enterprise HDDs, for instance, boast Mean Time Between Failure (MTBF) ratings of 2 M or 2.5 M hours, equivalent to 0.44% and 0.35% Annualized Failure Rate (AFR). These metrics are statistical measures derived from large-scale population testing and do not directly predict the lifespan of an individual driver. For instance, an HDD with a 0.44% AFR does not guarantee 227 years of service (1/0.0044). Instead, it indicates a 0.44% chance of failure within a year, but the drive could last much longer or fail sooner.

2.2. *How SSDs Fail*

SSD failures differ from HDDs, with firmware issues being the most common, followed by media and hardware problems. Firmware updates are crucial, as they often address bugs responsible for most failures.

SSD endurance is how many writes take place to an SSD before it wears out and is tied to the program-erase (PE) cycles NAND cells can undergo. Repeated cycles degrade the oxide layers, impacting charge storage. More bits per cell often mean more writes for voltage accuracy (e.g., QLC vs. SLC), varying by manufacturer and NAND process. SSDs are rated in terabytes written (TBW) or drive writes per day (DWPD), per JEDEC standards JESD218 and JESD219 [1].

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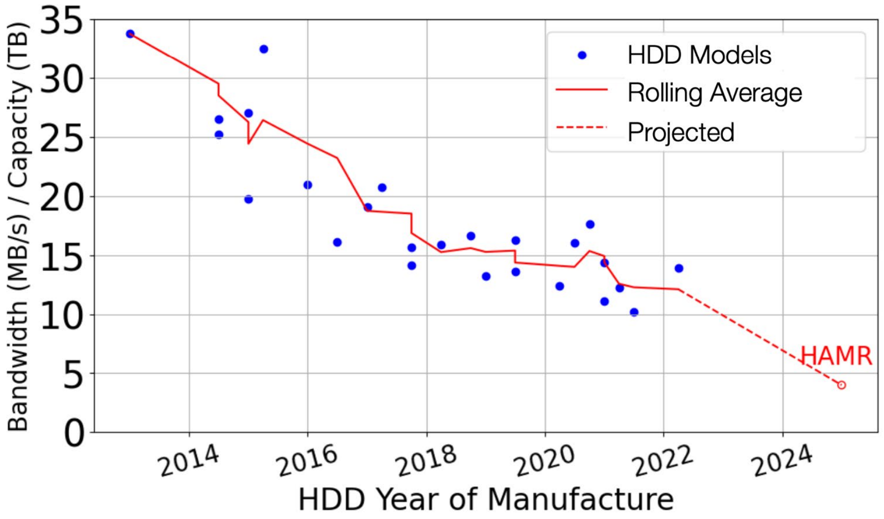
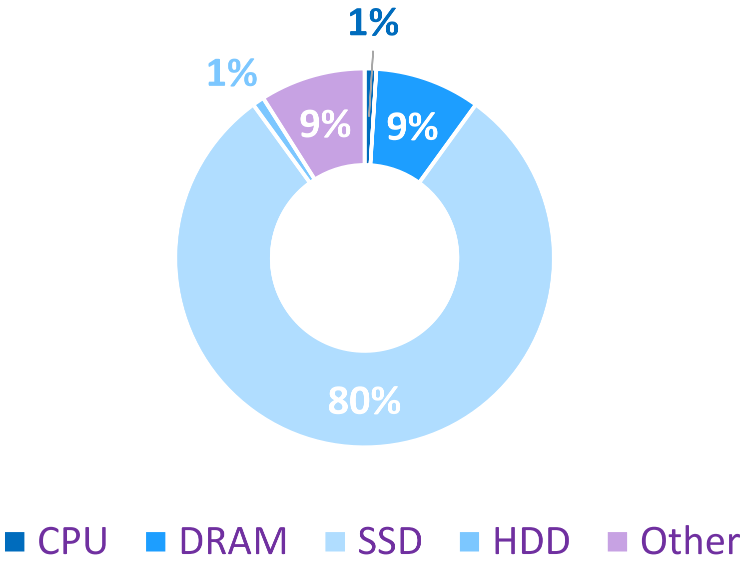
A Call for Research on Storage Emissions

- Carnegie Mellon University, Microsoft Azure
- Storage accounts for **33%** of operational and **61%** of embodied emissions in Azure DCs
- LCAs leveraging IMEC and Makersite (its likely much worse)
- Suggest extension of use and second life as ways to reduce impact



Increase of areal density on HDD helps but performance challenges



SSD Rack

Operational Emissions	CPU	DRAM	SSD	HDD	Other
Compute Rack	42%	18%	19%	0%	21%
SSD Rack	32%	8%	**38%**	1%	21%
HDD Rack	26%	5%	7%	**41%**	21%

Table 2: Operational emission breakdown for Azure rack types.

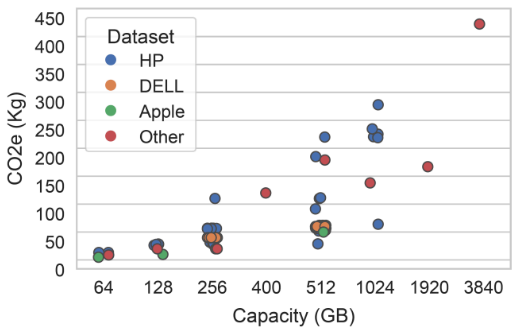
Embodied Emissions	CPU	DRAM	SSD	HDD	Other
Compute Rack	4%	40%	30%	0%	26%
SSD Rack	1%	9%	**80%**	1%	9%
HDD Rack	2%	11%	14%	**41%**	33%

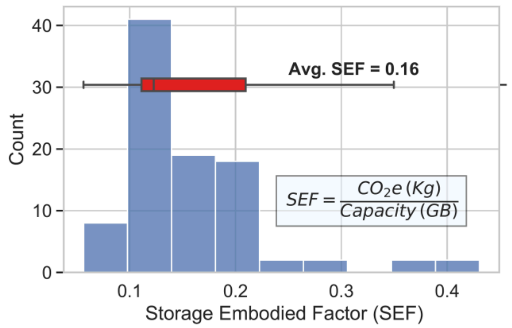
Table 3: Embodied emission breakdown for Azure racks.

Source: Hotcarbon

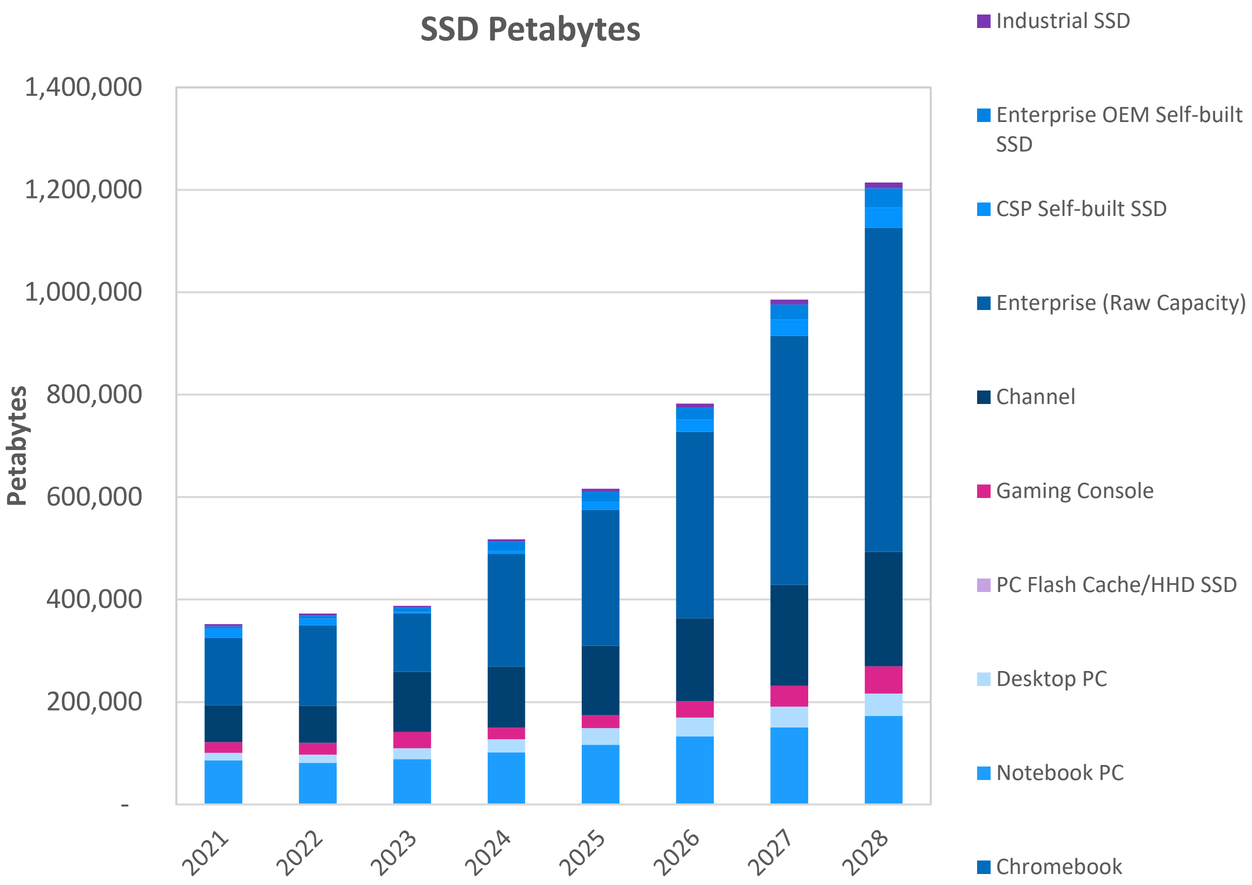
Carbon Accounting

- The problem
- SSD carbon scales with capacity
- Apple [2023 sustainability]report – carbon from iPhone flash only is 59.88g/GB
- at 517EB in 2024, rough math is 31M MT C02e





Tannu, S. and Nair, P.J. (2023) *The dirty secret of ssds: Embodied carbon*, *arXiv.org*. Available at: https://arxiv.org/abs/2207.10793

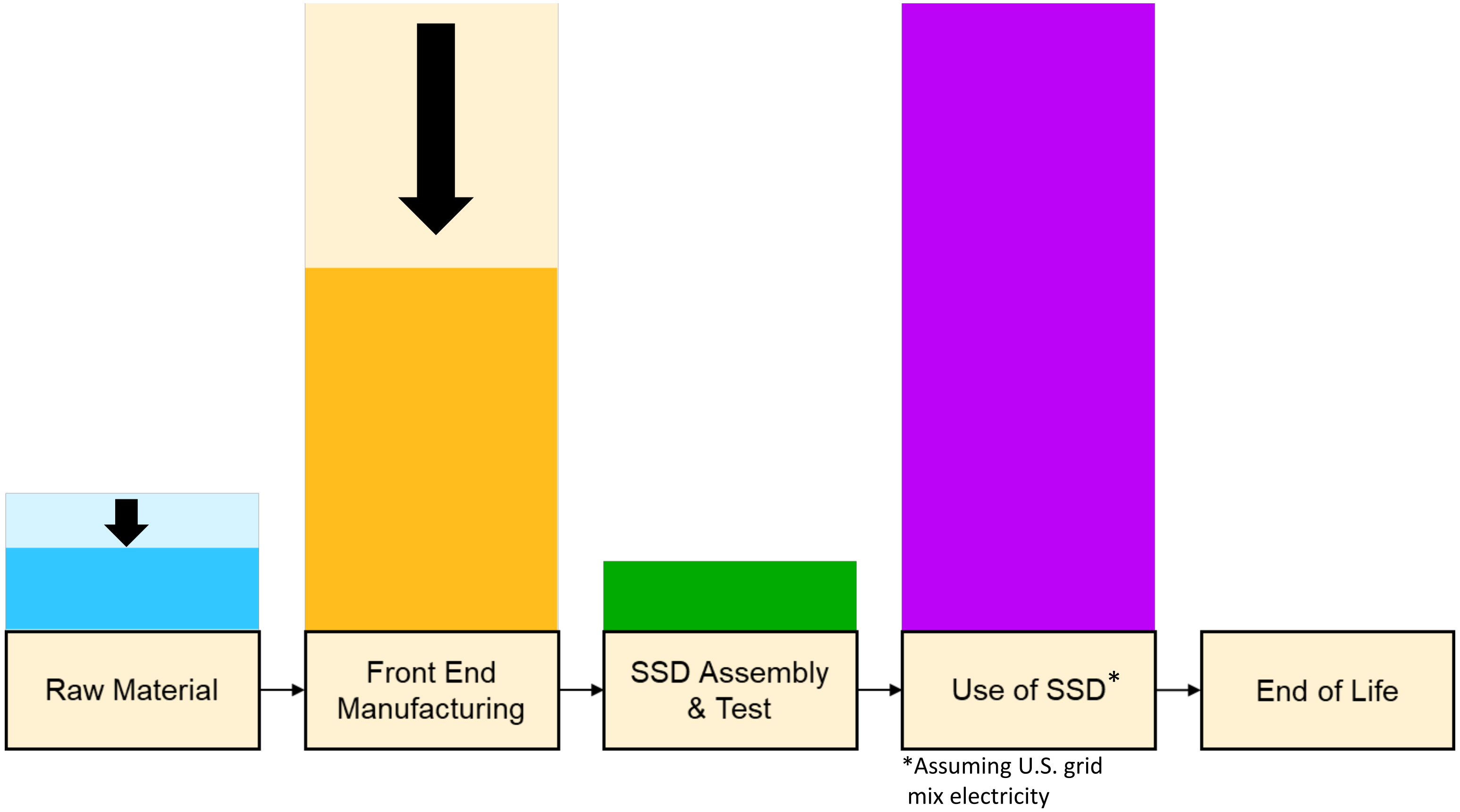


Source: Forward Insights SSD Insights Q2’24

GHG emissions from SSDs: circular use (Micron)
Per TB-yr, circular life (remanufactured, 8.5yr total use)

- SSDs can often be used (refurbished or remanufactured if needed) significantly longer than their original deployment, without requiring additional intensive raw material and manufacturing steps.

- Extending life by 70% may reduce supply chain GHG impact per TB-yr by ~40%.



Carbon Accounting for Circularity

Option	Perspective	Description	Incentives	Problems
No carbon impact for circularity	Data center operator	First user takes 100% of embodied carbon on scope 3	Value recovery for circularity	ICT devices have high embodied carbon, large impact
Amortization	Data center operator	Amortize embodied carbon over device use period (life)	First user takes % of carbon, second user takes % of carbon	Proper downstream reporting. Reporting doesn't exist. No consensus on product use %
Recertified products	Second User	Low embodied carbon for second use since manufacturing goes to first	Incentive buyers of recertified equipment Lower cost	No incentive on carbon for first user

Section Title

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Section Subtitle

Light Slide Title

- Bullets 1
  - Bullets 2
    - Bullets 3
      - Bullets 4
        - Bullets 5

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