SNIA CMSI | COMPUTE, MEMORY, AND STORAGE

Advancing Sustainable Storage

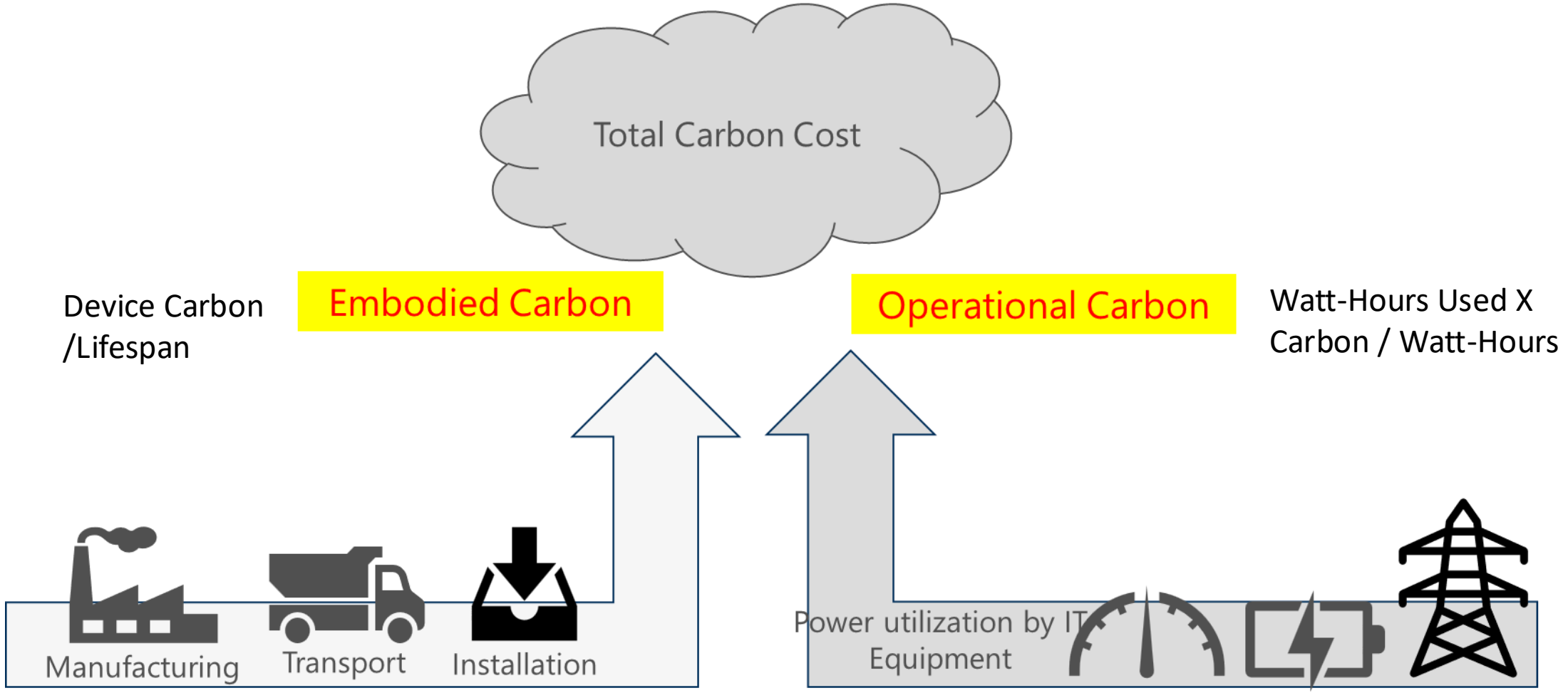
The Impact of the Circular Economy, Media Sanitization Policies, and Carbon Accounting

Presented by

Jonmichael Hands, Co-Chair SSD SIG and Treasurer & Secretary for the Circular Drive Initiative

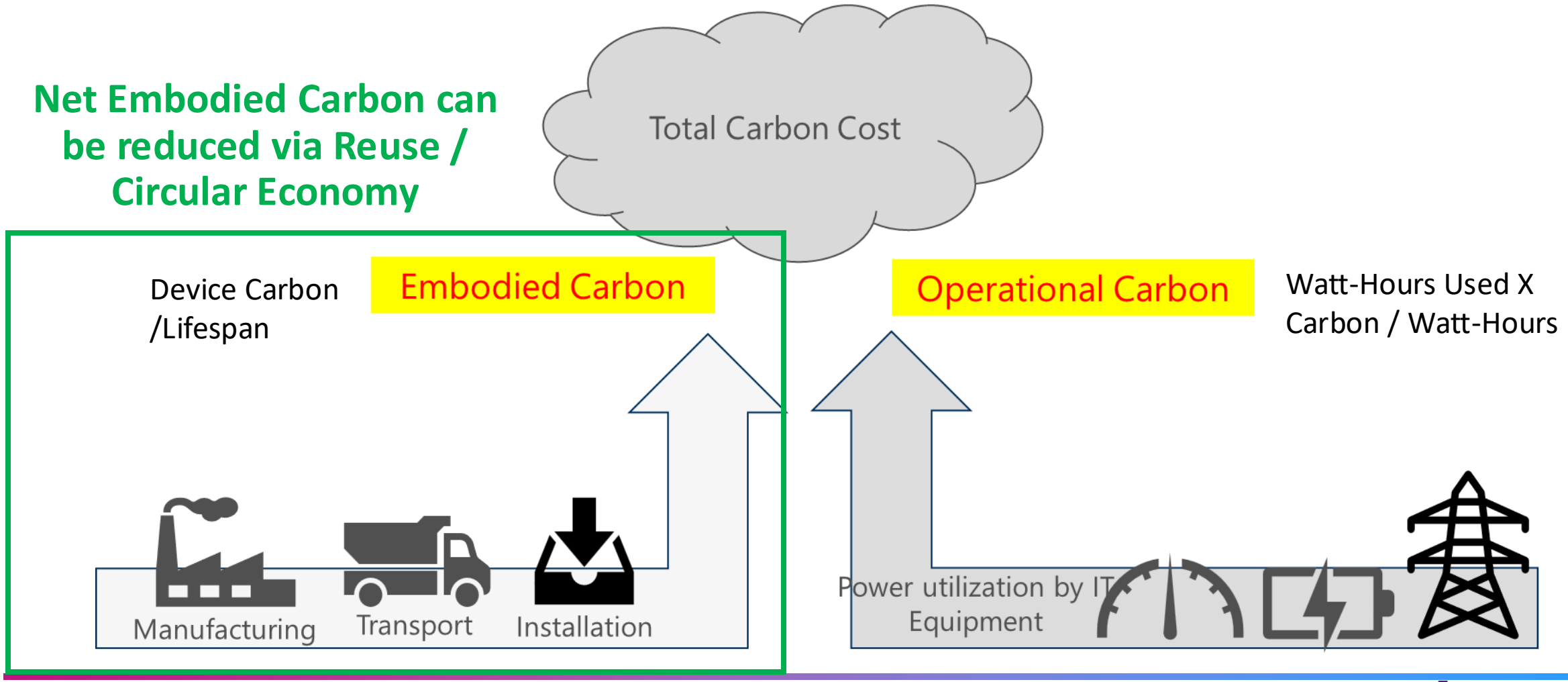
Shruti Sethi, Sr. PM at Microsoft and Leadership Team at Open Compute Project - Sustainability

Total Carbon Cost = Embodied Carbon + Operational Carbon



Total Carbon Cost = Embodied Carbon + Operational Carbon

Net Embodied Carbon can be reduced via Reuse / Circular Economy



OCP Sustainability – Focus Areas

OCP Sustainability – 3 Focus Areas

Carbon 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 / Reuse

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

OCP – Sustainability Workstreams

1

Carbon Transparency, Reporting

LCA Standardization

Carbon Label / Disclosure Format

2

Circularity

Promoting Data Sanitization for Reuse

Carbon Accounting for Circularity

3

Efficiency & Interoperability/ Metrics

Power Telemetry

Sustainability Power Metrics

Cooling efficiency & Heat Reuse

1 Carbon Transparency & Reporting

Carbon Label / Disclosure Format

LCA Standardization

PARTNERS

OPEN Compute Project + Infrastructure Masons

GOAL

- **Deliverable: Standardize Carbon Disclosure Form** for carbon information exchange among value chain members
- Guiding a taxonomy for Embodied Carbon disclosures related to data center materials and equipment, including a digital carbon label providing both calculated carbon levels and its corresponding methodology

**** For further Lifecycle Assessment (LCA) Standardization OCP is pushing for work on Product Category Rule establishment ****

1 Carbon Transparency & Reporting

Carbon Label / Disclosure Format

LCA Standardization

PARTNERS

OPEN Compute Project + Infrastructure Masons

WORKSTREAM LEADERS

Schneider Electric, Microsoft, Google, Meta

ACTIVITIES

1. Survey Existing Standards / Programs
2. Define Disclosure Format
3. Advance Comparability

1 Carbon Transparency & Reporting

OPEN Compute Project®

The iMasons Climate Accord™

Supplier Carbon Disclosure Form

The iMasons Climate Accord (iCA) and the Open Compute Project (OCP) have started an exciting journey in our joint effort to address the crucial issue of embodied carbon and its impact on data center sustainability. The data center industry is responsible for a significant amount of greenhouse gas emissions, with Scope 3 emissions making up the vast majority of this footprint. Almost all of these Scope 3 emissions are upstream, and take the form of embodied carbon in the materials and equipment that go into building a data center.

Scope 3 emissions, specifically embodied carbon in materials and equipment, pose a significant challenge to data center operators striving to achieve net-zero and carbon neutrality goals. As we recognize the urgency to reduce the carbon footprint of data centers, it is essential to engage our vast supply chain in measuring, reporting, and drawing down embodied carbon from data center inputs.

The goal of this Carbon Disclosure Form is to establish a standardized framework for disclosing and managing embodied carbon in data center construction and operation. By establishing a clear and consistent approach, iCA and OCP aim to drive industry-wide collaboration and innovation, enabling data center operators to make informed decisions and take effective actions to reduce their environmental impact.

Disclaimer: Please do not submit any confidential information to the Project Community. All presentation materials, proposals, meeting minutes and/or supporting documents are published by OCP and are open to the public in accordance to OCP's Bylaws and IP Policy. This can be found on the OCP OCP Policies page. If you have any questions please contact OCP.

For any questions about this form or for more information about this effort, please contact the team at Sustainability-Embodied-Carbon@OCP-All.groups.io

alex.rakow@se.com Switch account

Deliverables:
Supplier Carbon Disclosure Form

- A common format to simplify the disclosure process
- Will help the industry to gather **contextual data**, like the method used to calculate the embodied carbon figure
- Our intent is that data will become part of the OCP Marketplace

2 Circularity

Promoting Data Sanitization

Carbon Accounting for Circularity

PARTNERS

OPEN Compute Project + Circular Drive Initiative

GOAL

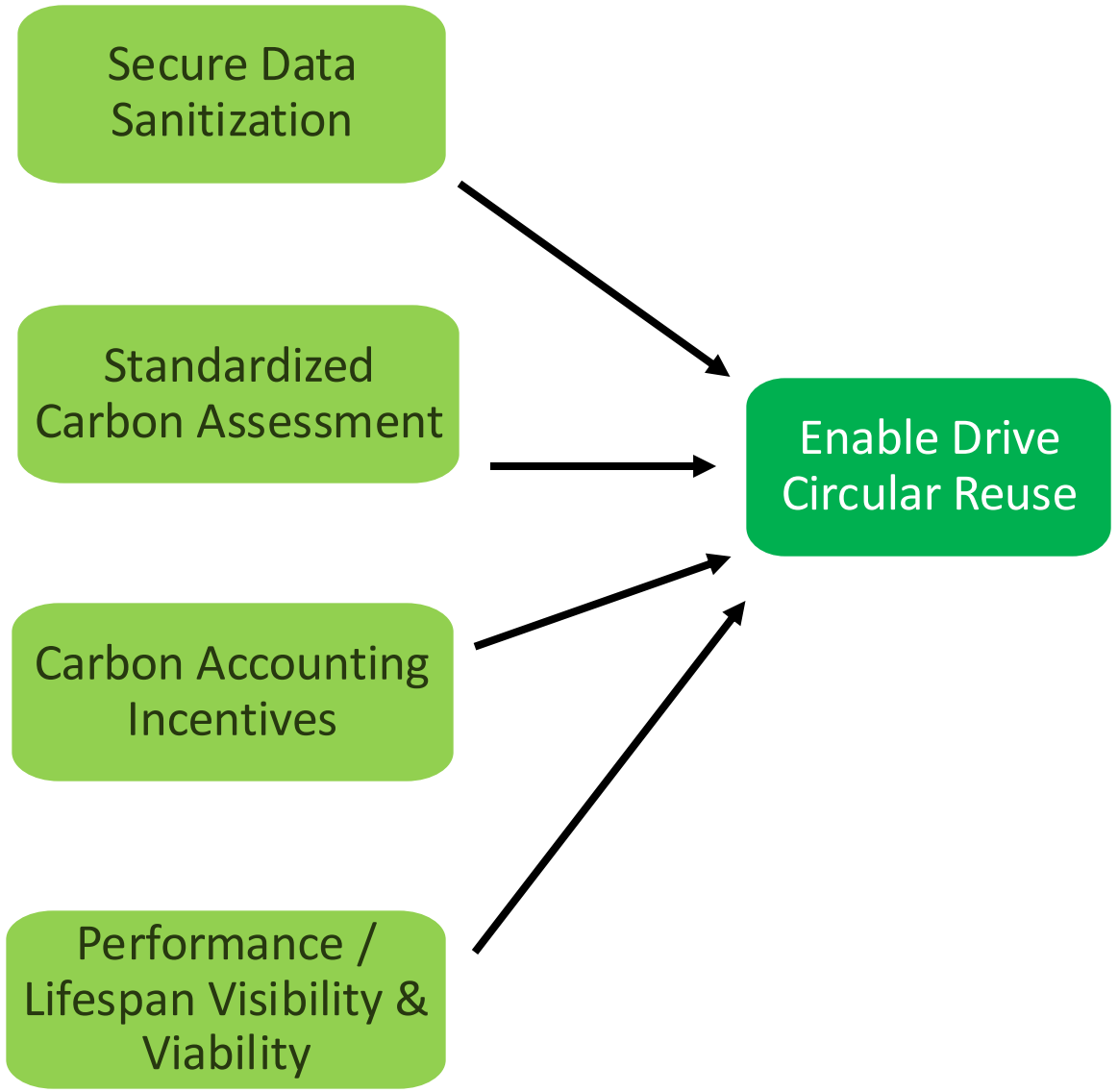
- Formulate the criteria for Drive being “Secure Data Sanitized” → to provide drive reuse security
- Suggest Carbon Accounting for circularity → to incentivize primary & secondary users to enable circular reuse

2 Circularity - Factors encouraging Circular Reuse

Paths for raising confidence on data sanitization
LOCK, SAFE, Caliptra & Others

Tied to previous Focus Area of building a standard **Product Category Rule** & Reporting.

Primary Use + Secondary Use → Possible Carbon Amortization to **incentivize**



2 Pushing for **OCP Drive Reuse Certification**

ASK:

Specification providing all aggregated sanitization requirements for a drive to get certified as '***OCP Reusable Drive***'

Specification Builds on Sanitization:

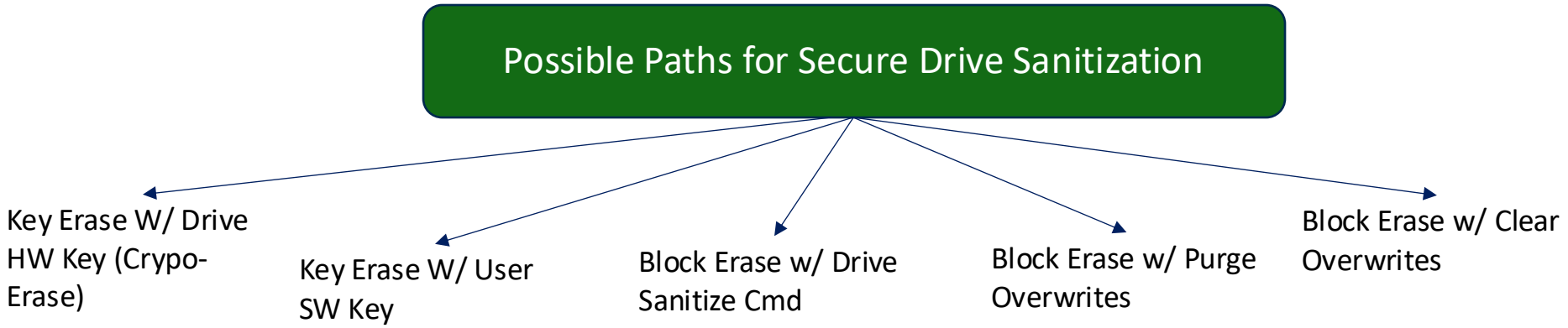
Prior data sanitization specifications such as IEEE 2883, OCP L.O.C.K, OCP S.A.F.E. etc

Specification will provide:

1. Clarity on how these various industry standards for sanitization must come together for raising confidence in sanitization
2. What are various path options (technical implementations) – to raise confidence in drive sanitization

2

Raising confidence in Secure Sanitization – Multipaths Implemented



- Which of these possible paths need L.O.C.K.?
- Which paths need S.A.F.E.?
- How do you use IEEE 2883?
- Which of these paths need Encryption to be enabled from birth (start of drive use) ?
- What level of verification is needed in these paths ?
- What other Sample Set test results need to be made available ?

❷ Embodied Carbon Reduction – via Circular Economy

"Call for Research on Storage Emissions", Microsoft, Carnegie Mellon University

Source: A Call for Research on Storage Emissions (hotcarbon.org)

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.

For Total Carbon Cost of all Storage Nodes/Systems, 61% from Embodied Carbon

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.

❷ Embodied Carbon Reduction – via Circular Economy

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Emission Reduction in Storage…

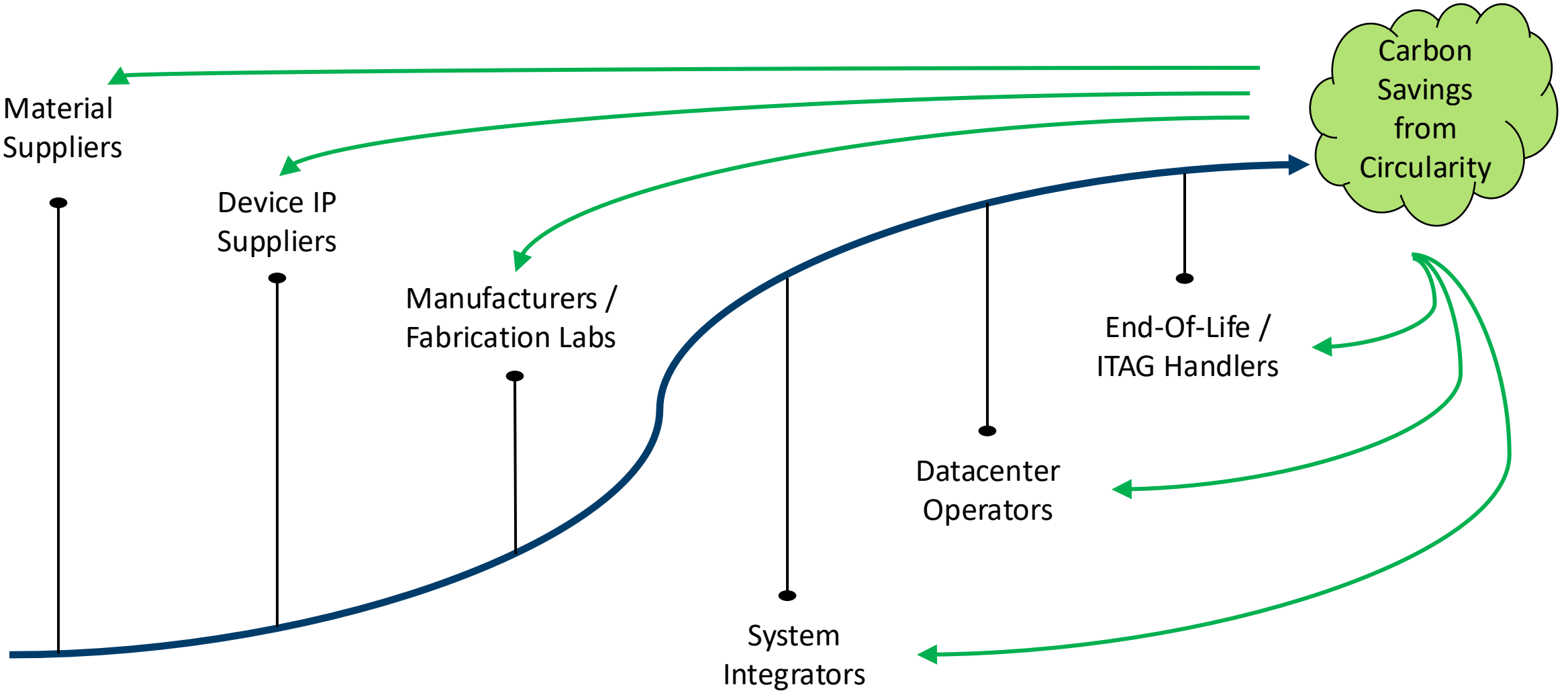
Lowering and shifting power

Fewer, denser drives

Extending lifetime

Second life and recycling.

2 Carbon Accounting Incentives - Need

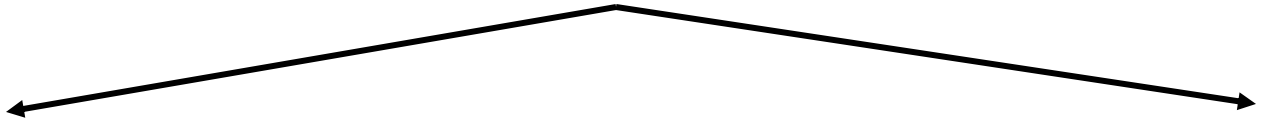


3 Efficiency & Metrics

Sustainability
Power Metrics

GOAL

Improving / Establishing definitions for PUE (Power Utilization Efficiency), IUE (Infrastructure Usage Efficiency) & CUE (Carbon Utilization Efficiency) metrics to reflect sustainability impact



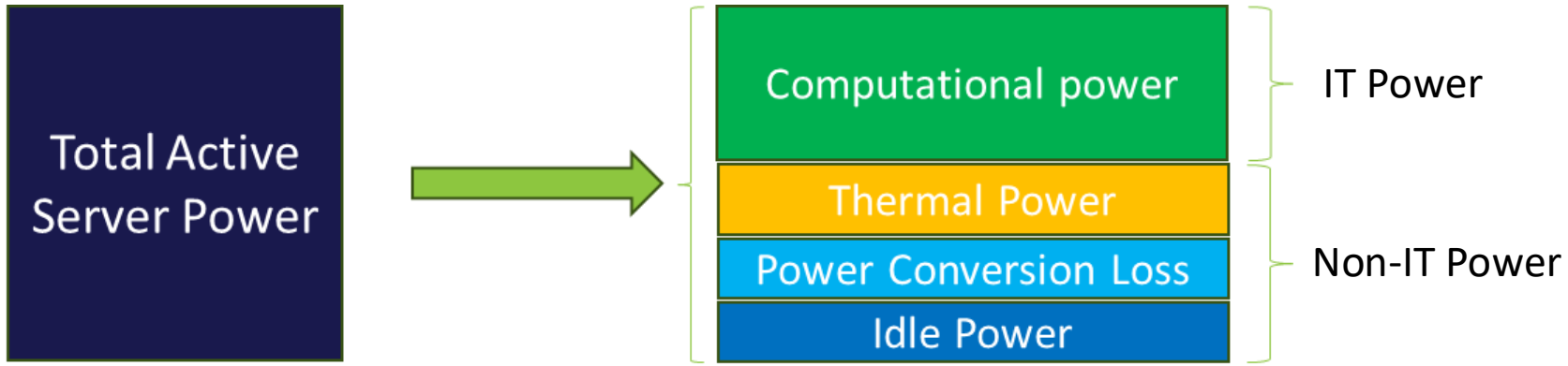
System-IUE$_{Load}$

Defined Infrastructure Utilization Efficiency (IUE) metrics and related measurements. ETA v1.0 Oct'24

PUE$_{Load}$

WHITE PAPER: SUSTAINABILITY METRICS CONSIDERATIONS – PUE

3 Efficiency & Metrics



$$System\text{-}IUE_{Load} = \frac{Computational\ Power_{Load}}{Total\ Active\ System\ Power_{Load}}$$

$$PUE_{Load} = \frac{Total\ Energy\ Consumption}{Total\ IT\ Energy\ Consumption} = \frac{Total\ Energy\ Consumption}{IT\ Computation\ Power + IT\ Non\text{-}computation\ power} = \frac{Total\ Energy\ Consumption}{IT\ Computation\ Power/DC\_IUE}$$

Why Measure at load?

3 Efficiency & Metrics

Power Telemetry

GOAL

Template requirements for providing power data related to sustainability efforts. This includes power and energy (use phase) measurements, location data, and device identification.

“Sustainability Power Profile” :

- ✓ Basic product identification
- ✓ Product-level power and energy reporting
- ✓ Measurement sample rates
- ✓ Product location data

This Sustainability data is made available using Redfish, the hardware management standard utilized by OCP products

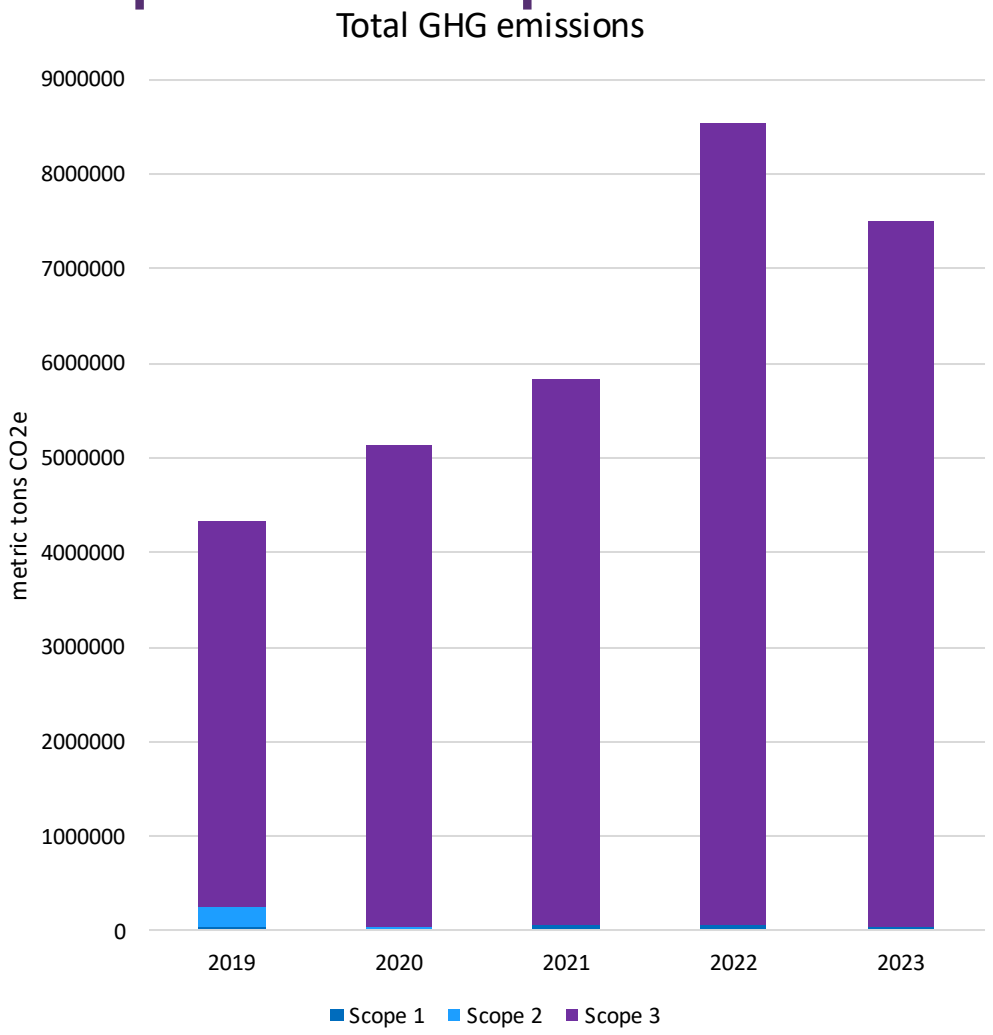
```
"EnvironmentMetrics": {
    "UseCases": [
        {
            "UseCaseTitle": "Chassis",
            "UseCaseType": "Normal",
            "ReadRequirement": "Supported",
            "Purpose": "Power and energy values must be provided for
            "URIs": [
                "/redfish/v1/Chassis/{ChassisId}/EnvironmentMetrics"
            ],
            "PropertyRequirements": {
                "PowerWatts": {
```


Call To Action

OCP Sustainability Work for Circularity & Sustainability :
https://www.opencompute.org/projects/sustainability

Incentivizing Circularity and Closing the Gap

Scope 3 is a problem



Meta

2024 Sustainability Report

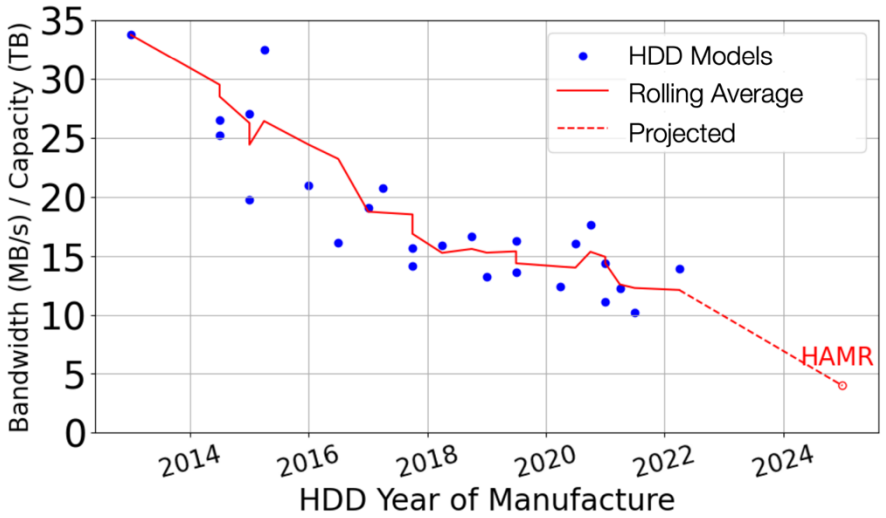
1.1 GHG emissions

Market-based vs. location-based					
Scope 3 emissions (in metric tons CO_2e)					
	2019	**2020**	**2021**	**2022**	**2023**
Total	4,078,000	5,091,000	5,772,583	8,466,264	7,445,621
Category 1: Purchased goods and services	1,428,000	1,846,000	2,956,909	2,545,466	2,045,470
Category 2: Capital goods	1,671,000	2,516,000	2,466,041	5,346,583	4,835,270
Category 3: Fuel and energy- related activities	264,000	56,000	10,483	12,658	8,454
Category 4: Upstream transportation and distribution	65,000	49,000	180,183	176,636	124,324
Category 5: Waste generated in operations	4,000	10,000	18,430	18,519	38,468
Category 6: Business travel	529,000	129,000	8,653	251,807	317,841
Category 7: Employee commuting	90,000	61,000	23,163	45,054	54,256
Category 8: Upstream leased assets	16,000	24,000	1,185	3,444	2,249
Category 9: Downstream transportation and distribution	5,000	10,000	37	16	47
Category 11: Use of sold products	5,000	390,000	106,232	62,306	16,476
Category 12: End-of-life treatment of sold products	<500	<500	1,267	3,775	2,765

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

Source: Hotcarbon



Increase of areal density on HDD helps but performance challenges

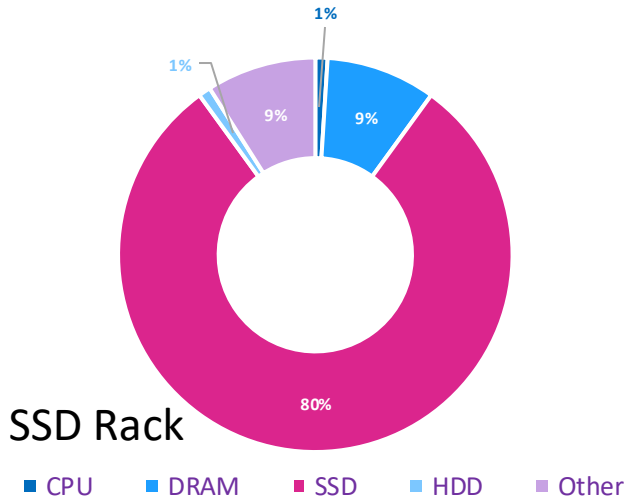


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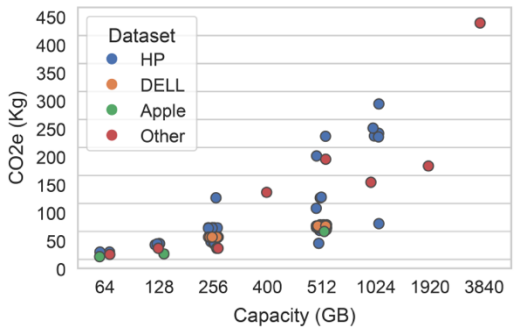
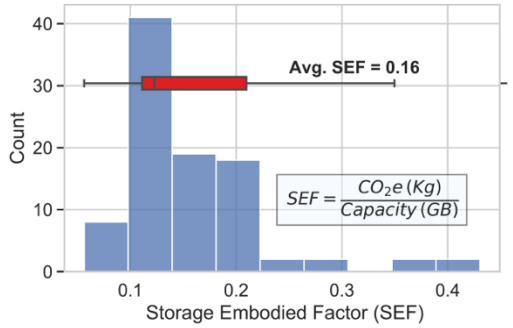
Table 3: Embodied emission breakdown for Azure racks.

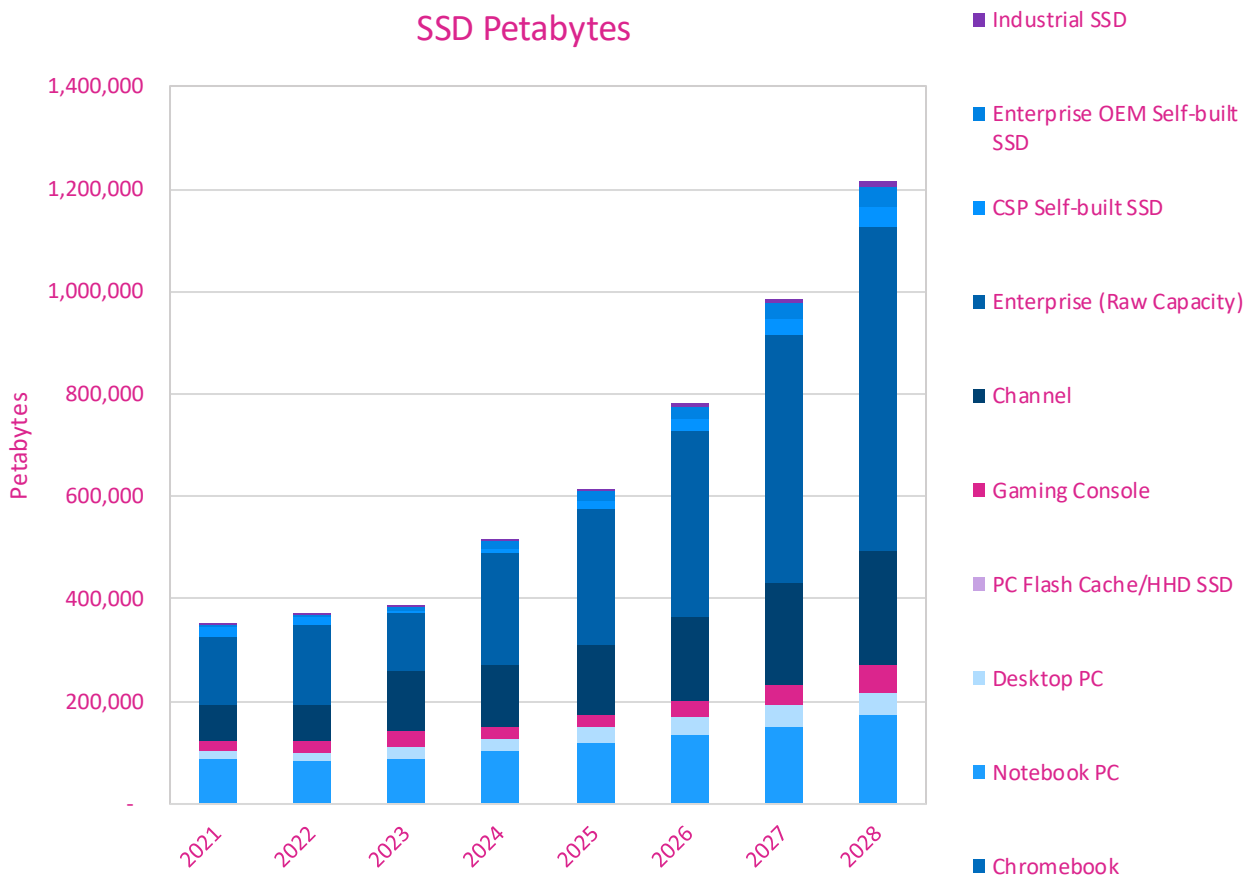
Carbon Accounting

- 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**



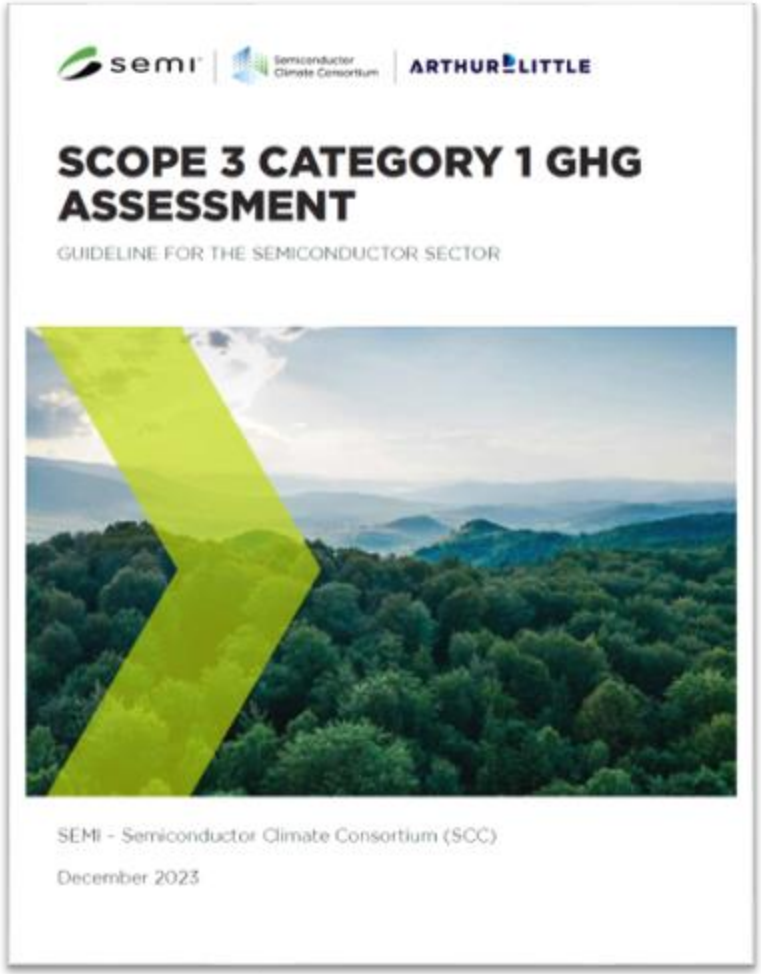


Tannu, S. and Nair, P.J. (2023) *The dirty secret of ssds: Embodied carbon*, *arXiv.org*. Available at: https://arxiv.org/abs/2207.10793



Source: Forward Insights SSD Insights Q2'24

SEMI Guidance



3.2.2.2 Focus: reused, refurbished, or repaired goods

Reused, refurbished, and repaired goods encompass goods that were formerly owned by a distinct entity and subsequently restored to a usable state, if required, before being purchased by the acquiring company. When reporting emissions arising from the purchasing of goods with recycled content, being repaired or refurbished, it is important to note that the reporting company's Scope 3.1 inventory boundary should not encompass the emissions arising from the initial extraction from raw materials, subsequent production, or transportation linked to the original manufacturing of the used goods. This can be particularly relevant, for example, when fluorinated GHGs such as SF6 are widely used within the original manufacturing of the used goods, e.g., in the preliminary stages of the semiconductor value chain.

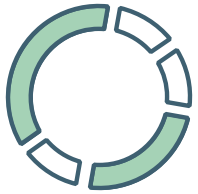
However, the upstream emissions of the recycling/repairing/refurbishment processes are built into the cradle-to-gate emission factor for that product and would, therefore, be reflected in the Scope 3 Category 1 GHG inventory. Moreover, any emissions derived from further extraction, production, or transportation linked to these goods need to be accounted for by the company in the reporting year when the goods are procured.

Source: SCOPE 3 CATEGORY 1 GHG ASSESSMENT

The Circular Drive Initiative

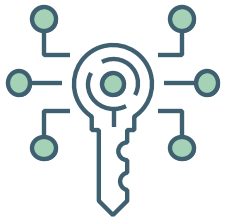
Circular Drive Initiative

circulardrives.org



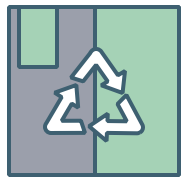
Retain

Regen to keep drives in service



Reuse

Secure data erasure and sanitization



Recover

Disassembly, recovery of rare earth materials, and then recycling

Smith & Associates: Advancing Carbon Accounting & Avoidance in Electronics

- **Key Focus Areas**
  - **Amortization:** Spread embodied carbon across device lifespan and multiple users
  - **Reuse Strategies:** Encourage device resale and refurbishment to minimize waste
  - **Carbon Insets:** credits generated from emission reduction activities within a company's **own value chain**
- **Challenges Identified**
  - **Carbon Accountability:** Risk of double accounting without standardized reporting
  - **Incentive Gaps:** Limited rewards for first and subsequent users to prioritize reuse
- **Recommendations**
  - **Unified Carbon Accounting:** Standardize amortization of embodied carbon, feedback to GHG protocol
  - **Insets:** Create platforms for trading verified carbon insets
  - **Strengthen Support Systems:** Enhance maintenance, partnerships, and reverse logistics
- **Path Forward**
  - Balance data security with sustainability through clear sanitization guidelines
  - Foster a circular economy with robust financial and regulatory incentives

Circular Drive Initiative

+

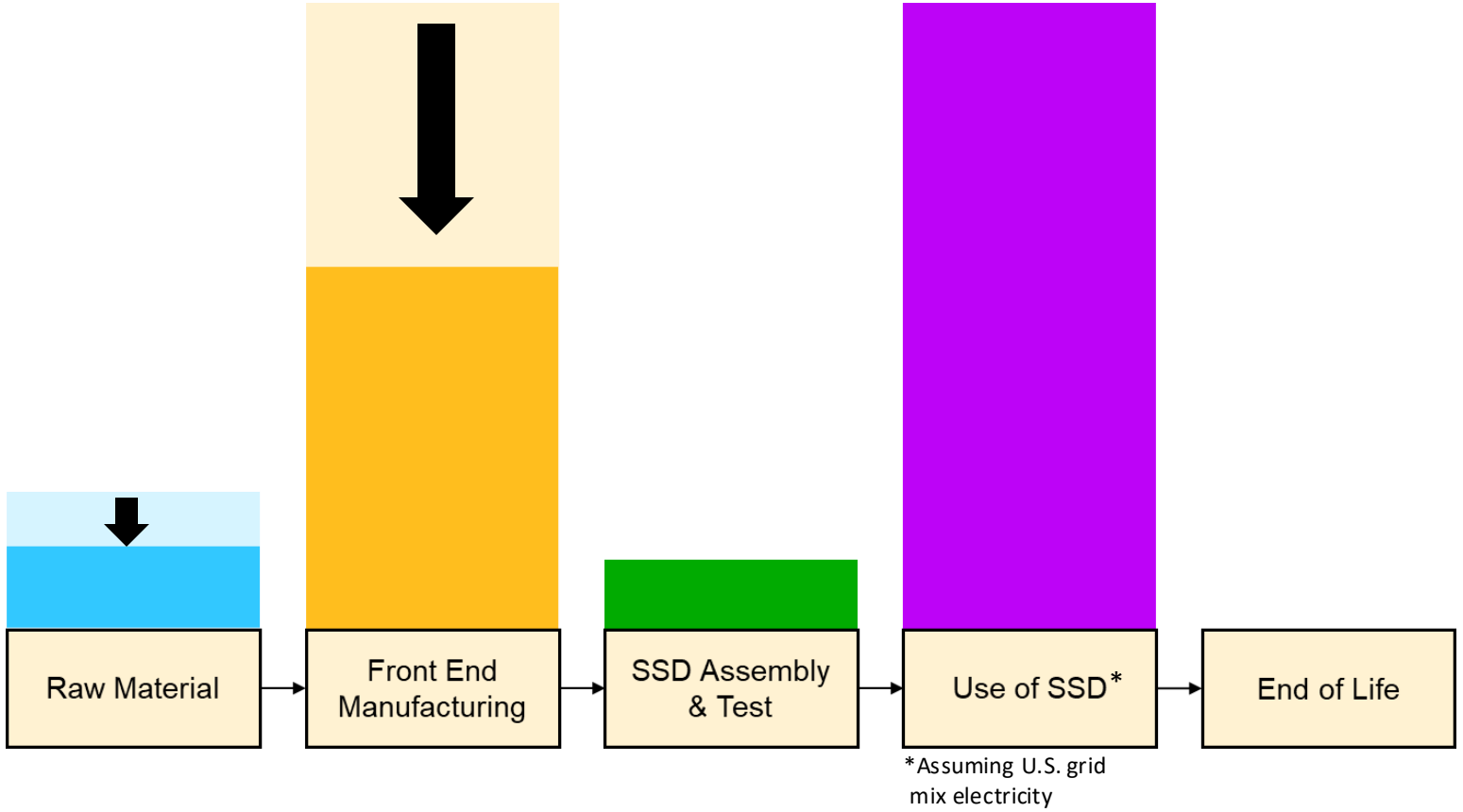
OPEN Compute Project

https://circulardrives.org/blog/

GHG emissions from SSDs: circular use (Micron FMS '23)
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

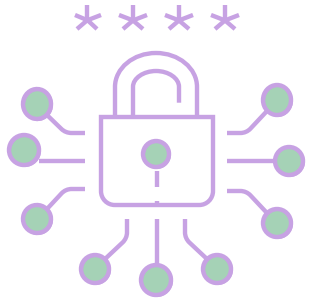
Option	Perspective	Description	Incentives	Problems
No Carbon Impact for Circularity	Data Center Operator	First user takes 100% of embodied carbon on scope 3.	Value recovery for circularity.	ICT devices have high embodied carbon, leading to a large impact.
Amortization	Data Center Operator	Amortize embodied carbon over device use period (life).	First user takes % of carbon, second user takes % of carbon	Reporting doesn't exist. No consensus on product use percentage.
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.

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

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

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®

CDI Media Sanitization

Use IEEE 2883 approved purge technique

Check Sanitize Log

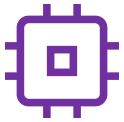
Perform verification on host interface

Generate certificate of sanitization

Purge Media Sanitization Techniques

Overwrite

Using interface specific sanitize command, overwrite all LBAs with a fixed pattern, minimum of one pass. Multiple pass optional, but is not required anymore.



Block Erase

Use NAND erase blocks, can sanitize a modern SSD in a few seconds to a few minutes.

Doesn’t waste NAND endurance, but verification requires no-deallocate.

Crypto Erase

Requires that the devices supports encryption. Sanitize by deleting the media encryption key (MEK), leaving all the data scrambled.

Very fast, completes in seconds.

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

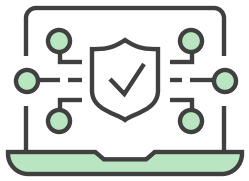
- Classify data based on data sensitivity: low, medium, and high
- Interest=f(Gain, WorkFactor, LikelihoodOfSuccess)
- Managing risk: Accept, Avoid, Transfer, Treat/Mitigate

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

Roadmap – Increase Trust

Vendor validation of sanitize

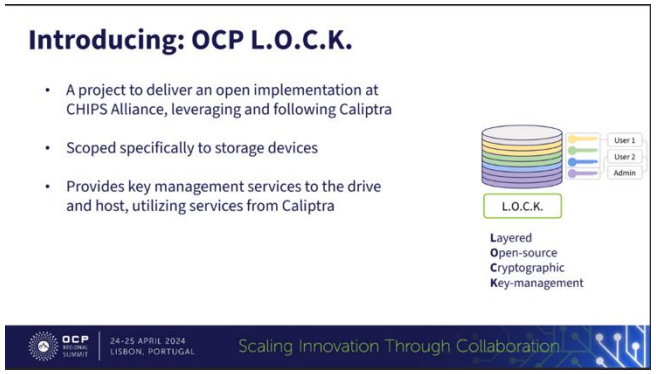


Certifications, TCG OPAL, FIPS 140-3

3rd party audit

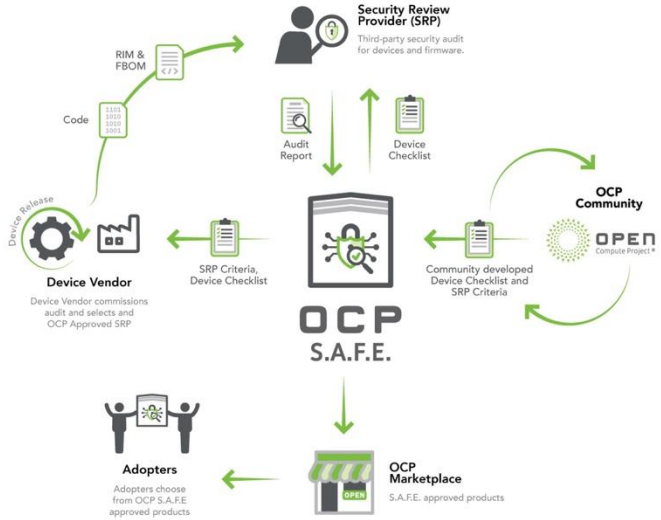
Firmware attestation / measurement, hardware roots of trust

Roadmap - OCP

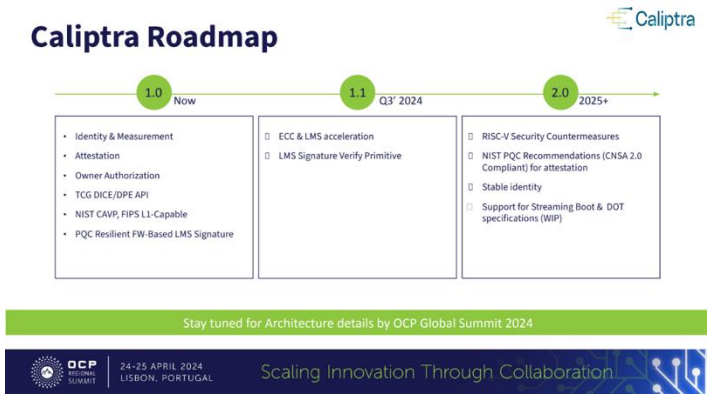


[OCP L.O.C.K.]

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



[OCP S.A.F.E. Update]



[Project Caliptra Update]

Join the efforts

- OCP specifications on media sanitization, storage security, and circularity
- Get involved in sustainability project workgroups
- New whitepaper = Q4’24
- Where to find additional information (URL links)
  - CDI: https://circulardrives.org/
  - Whitepaper: https://www.opencompute.org/documents/ocp-sustainability-pdf
  - Mailing list: https://ocp-all.groups.io/g/Sustainability

Appendix

Agenda

- Embodied Carbon & Operational Carbon
- OCP Sustainability formation & history
- OCP Sustainability – 3 Focus Areas
- Workstreams
  - LCA Standardization + Carbon Label / Disclosure Standardizing
  - Data Sanitization + Carbon Accounting for Circularity
  - Power + Sustainability Power Metrics

Thanks to folks & companies involved-in & driving this OCP Sustainability / Circularity work

OCP Sustainability – Formation & History

Vision & Growth

"Offer an open framework and standardized resources for data center industry to deploy industry best practices that promote reusability & circularity"

Sustainability is the youngest established Core Project under OCP