Sharpening Our Pencils on Carbon Measurement

Data Impact on the Environment

Presented by Erik Riedel, PhD

Chief Engineering Officer, Flax Computing

revision 6

Abstract

- This talk will show that using carbon footprint as a common metric to assess a set of computing equipment allows straightforward comparison of technologies and designs on a "performance per carbon" basis, bringing together operational (energy use inputs) and scope 3 (production & materials inputs) carbon, along with workload-aligned performance metrics to compare technologies and systems. Our proposed methodology to apply "carbon points" to hardware components and systems can allow system-level, rack-level, and data-center-level quantification of detailed carbon footprints, which can then be optimized and reduced. You cannot improve what you cannot measure, and we believe that carbon footprint can be used today as a successful common metric for comparison, decision-making, and optimization. We will outline our database of footprint calculations and comparisons with real data center systems, and we will review our success in bringing carbon-advantaged computing to large-scale deployment in several real customer scenarios worldwide.

SDC 23

Reduce carbon footprint

focus on efficiency & results
via carbon / performance

scope 1 & 2 operational carbon;
scope 3 embodied carbon

Reduce cost footprint

focus on efficiency & results
via cost / performance

capex, opex, people-ex

DATA IMPACT ON THE ENVIRONMENT

ERIK RIEDEL, PHD

CHIEF ENGINEERING OFFICER

FLAX COMPUTING

MAY 2023

revision 7

read longer scalable storage history at https://storageconference.us/2023/RiedelPresentation.pdf

SCALABLE STORAGE CLOUDS

Background

$/TB

$/TB/month

- high capacity drives
  (as many as possible)

- x86 servers/controllers
  (as few as possible)

- SAS backplanes/cables
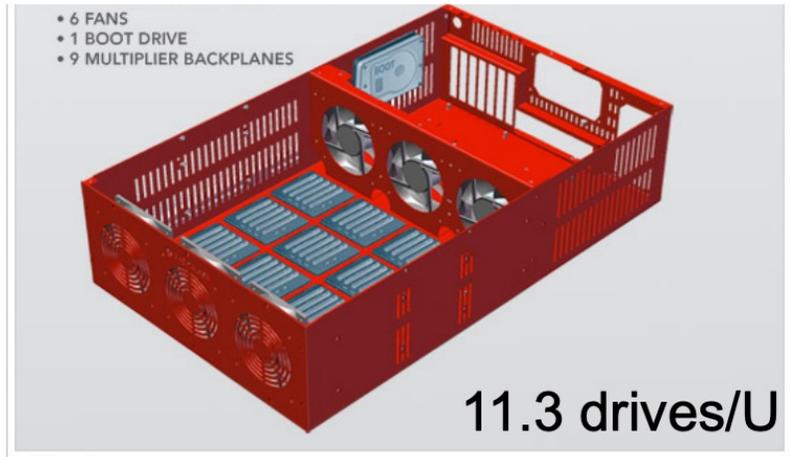 (not too many, not too few)

EMC²

SGI® CloudRack™ C2

8.6 drives/U

Dell

6 drives/U

12 drives/U

Backblaze

Supermicro

11.3 drives/U

- 6 FANS
- 1 BOOT DRIVE
- 9 MULTIPLIER BACKPLANES

11.3 drives/U

EMC²

- high capacity drives
  (as many as possible)
- x86 servers/controllers
  (as few as possible)
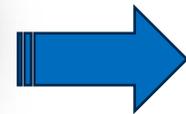- SAS backplanes/cables
  (not too many, not too few)

ATMOS (2008)

>1,000 CUSTOMERS
>1 EXABYTE DEPLOYED

ECS (2013)

>>1,200 CUSTOMERS
>1 EXABYTE DEPLOYED

OVER $2B LIFETIME
CUSTOMER REVENUE

22.7 drives/U

14.1 drives/U

816x drives
4x servers
2x switches
18x cables

EMC²

The Google File System

Sanjay Ghemawat, Howard Gobioff, and Shun-Tak Leung
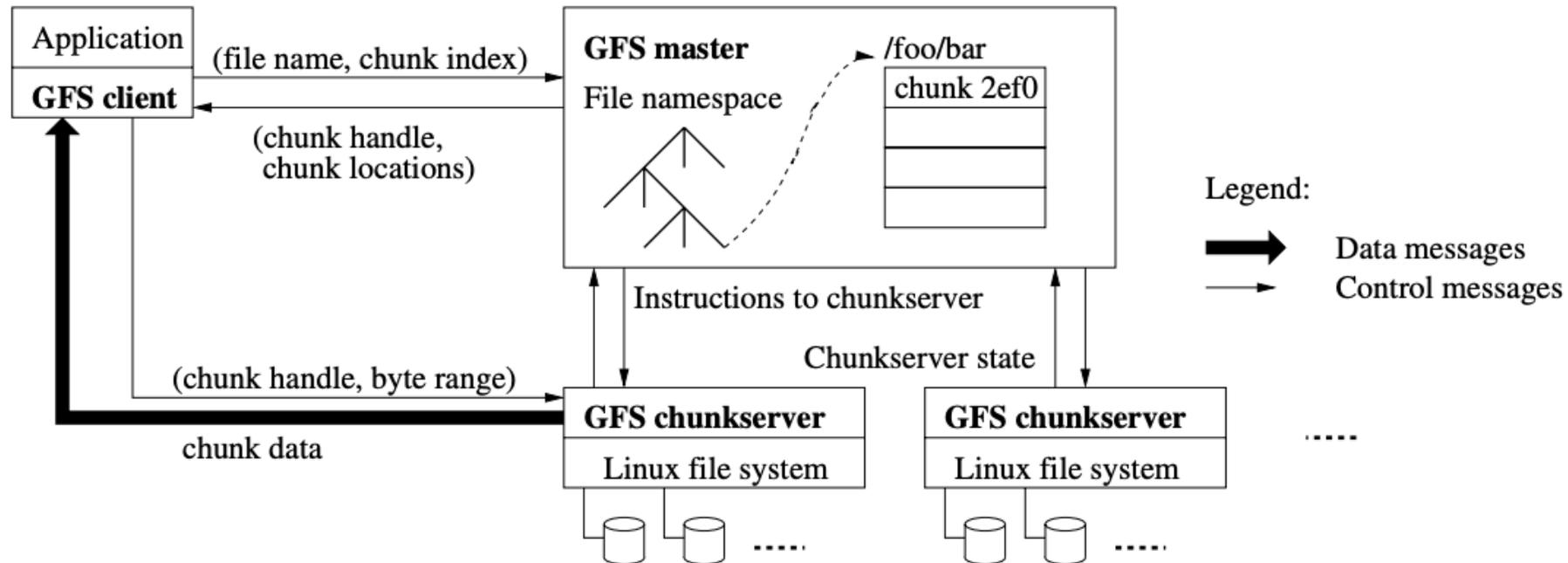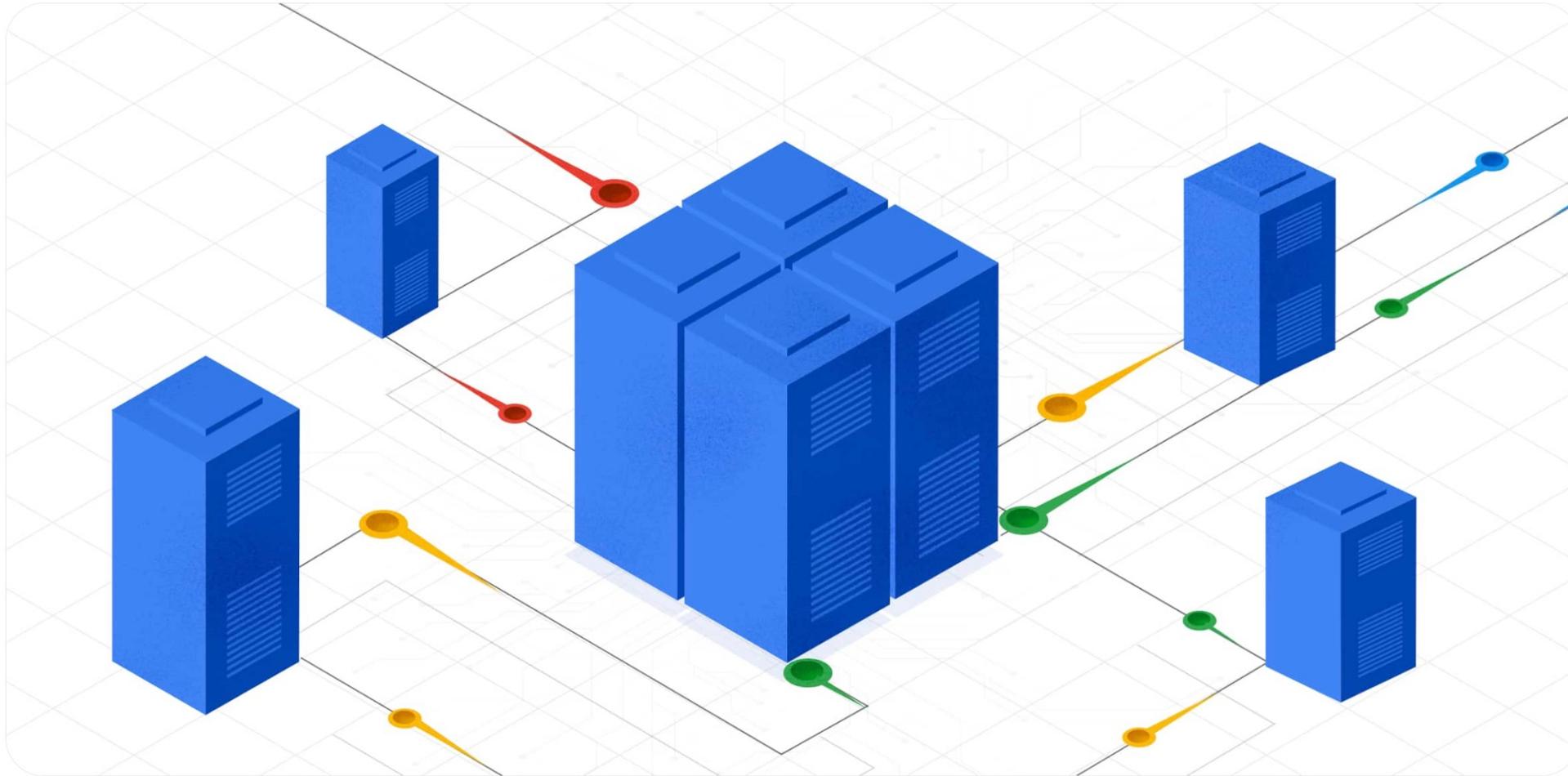
Google*

SOSP 2003

Figure 1: GFS Architecture

Colossus under the hood: a peek into Google's scalable storage system

April 19, 2021

Dean Hildebrand
Technical Director, Office of the CTO, Google Cloud

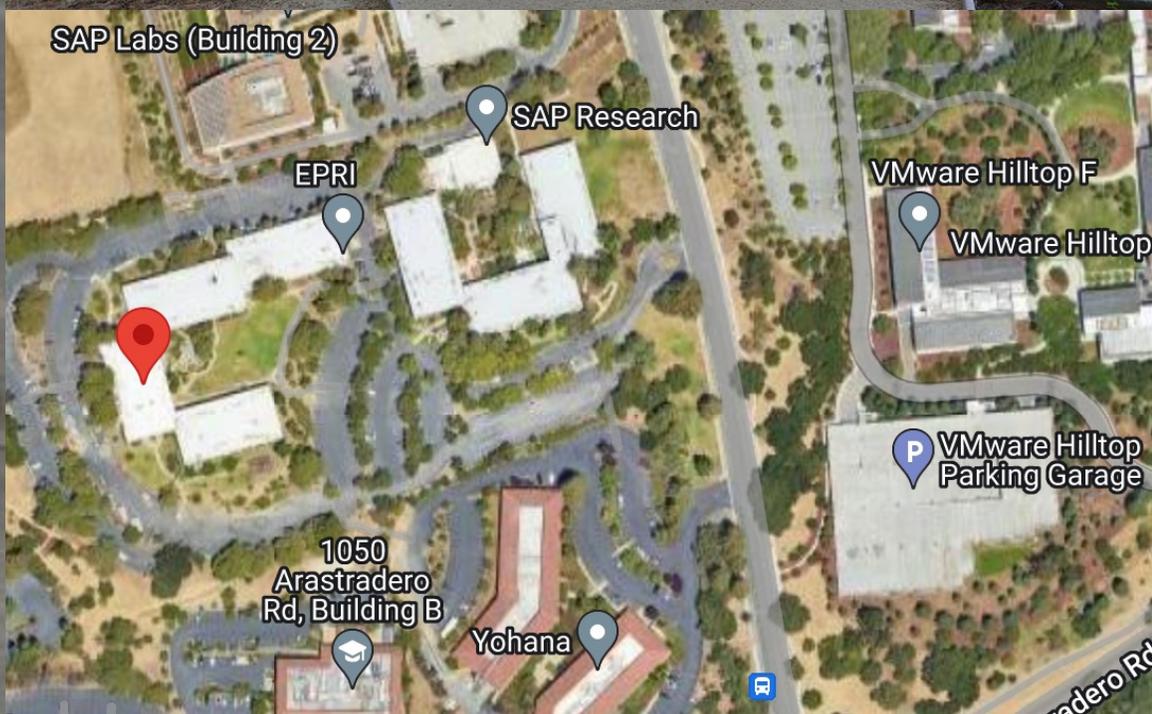**Denis Serenyi**
Tech Lead, Google Cloud Storage

CARBON

Matters; Measures

SAP   EPRI

3420 / J440

SAP Labs (Building 2)

SAP Research

EPRI

VMware Hilltop F

VMware Hilltop

VMware Hilltop Parking Garage

1050 Arastradero Rd, Building B

Yohana

Outline

- Current state of affairs and industry trends
- Power measurement
  - storage subsystems
  - idle and active modes
  - power supply loading / efficiencies
  - power measurement & monitoring equipment
- Green metrics and taxonomy
  - measuring green-ness
  - storage product categories
- ENERGY STAR™ for Data Center Storage
  - update and overview
- SNIA green storage efforts
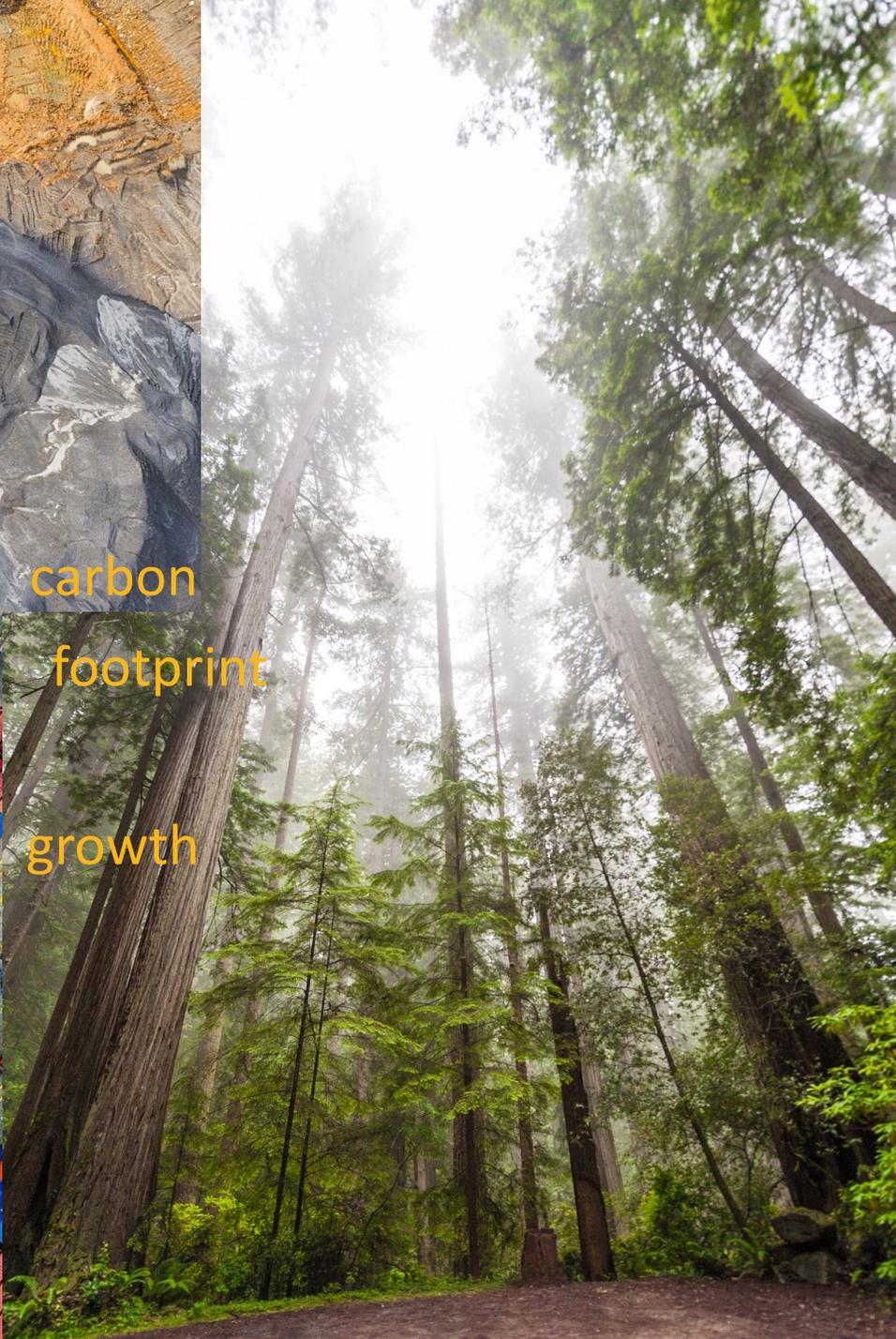 - unplugged fests, green standards, workshops, alliances

natural resources

carbon

footprint

demand growth

Renewable Progress is Strong,
But Are We Looking at the Whole Picture?

PRE-USE PHASE

76%

CO2e and GHG from mining to manufacturing to deployment

Embodied Energy/ Scope 3 emissions

OPERATIONAL PHASE

22%

Electricity to run IT equipment

Scope 1 emissions

POST-USE PHASE

2%

Recycling and EOL Processes

Embodied Energy/Scope 3 emissions

submer

EcoDataCenter

ITRENEW

OCP GLOBAL SUMMIT

NOVEMBER 9-10, 2021

CIRCULAR ECONOMY

Extend The Operational Phase

SD ©23

25,000 to 125,000 servers / month worldwide

Storage Sanitization - Why, When, and How

📅 Wed Sep 20 | 3:35pm - 4:25pm

📍 Salon V

Talks – Wednesday, 20 September at 3:35pm in Salon V

Abstract

Operators of data storage systems are legally obligated to protect customer data, and can be subject to significant penalties. This presentation will explore existing and upcoming standards to show the best practices for sanitizing customer data. These standards will include IEEE 2883-2022 and ISO/IEC 27040,and will describe current work on new standards.

The audience for this presentation includes developers and users of data storage systems, as well as developers of software utilizing those systems.

Paul Suhler
KIOXIA

Related Sessions

Data Security	Data Security	Data Security	Data Security
Storage Security Update for Developers	**An Introduction to the IEEE Security in Storage Working Group**	**Build FIPS into Your Storage Products**	**SPDM 1.3 and Beyond**
2023 has been an interesting and challenging year for storage security.	The IEEE Security In Storage Work Group (SISWG) produces standards that many storage developers, storage vendors, and storage system operators care about, including: a) A family of standards on san	Selling to the US Government can require getting FIPS (Federal Information Processing Standards) certification.Many storage products are based on Linux and Open Source code, which by themselves do	DMTF has released SPDM version 1.3, with a number of enhancements to the protocol.
Eric Hibbard Samsung Semiconductor, Inc.	**Paul Suhler** KIOXIA	**Jeremy Allison** CIQ / Samba Team.	**Chandra Nelogal** Dell Technologies

Storage Sanitization - Why, When, and How

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Samsung Semiconductor, Inc.

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Data Security

Build FIPS into Your Storage Products

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Jeremy Allison
CIQ / Samba Team.

Data Security

SPDM 1.3 and Beyond

DMTF has released SPDM version 1.3, with a number of enhancements to the protocol.

Chandra Nelogal
Dell Technologies

---

chia

Menu ☰

Jonmichael Hands

VP Storage Business Development

Jonmichael Hands partners with the storage vendors for Chia optimized product development, market modeling, and Chia blockchain integration. Jonmichael spent the last ten years at Intel in the Non-Volatile Memory Solutions group working on product line management, strategic planning, and technical marketing for the Intel data center SSDs. In addition, he served as the chair for NVM Express (NVMe), SNIA (Storage Networking Industry Association) SSD special interest group, and Open Compute Project for open storage hardware innovation. Jonmichael started his storage career at Sun Microsystems designing storage arrays (JBODs) and holds an electrical engineering degree from the Colorado School of Mines.

🐦 @lebanonjon

in linkedin
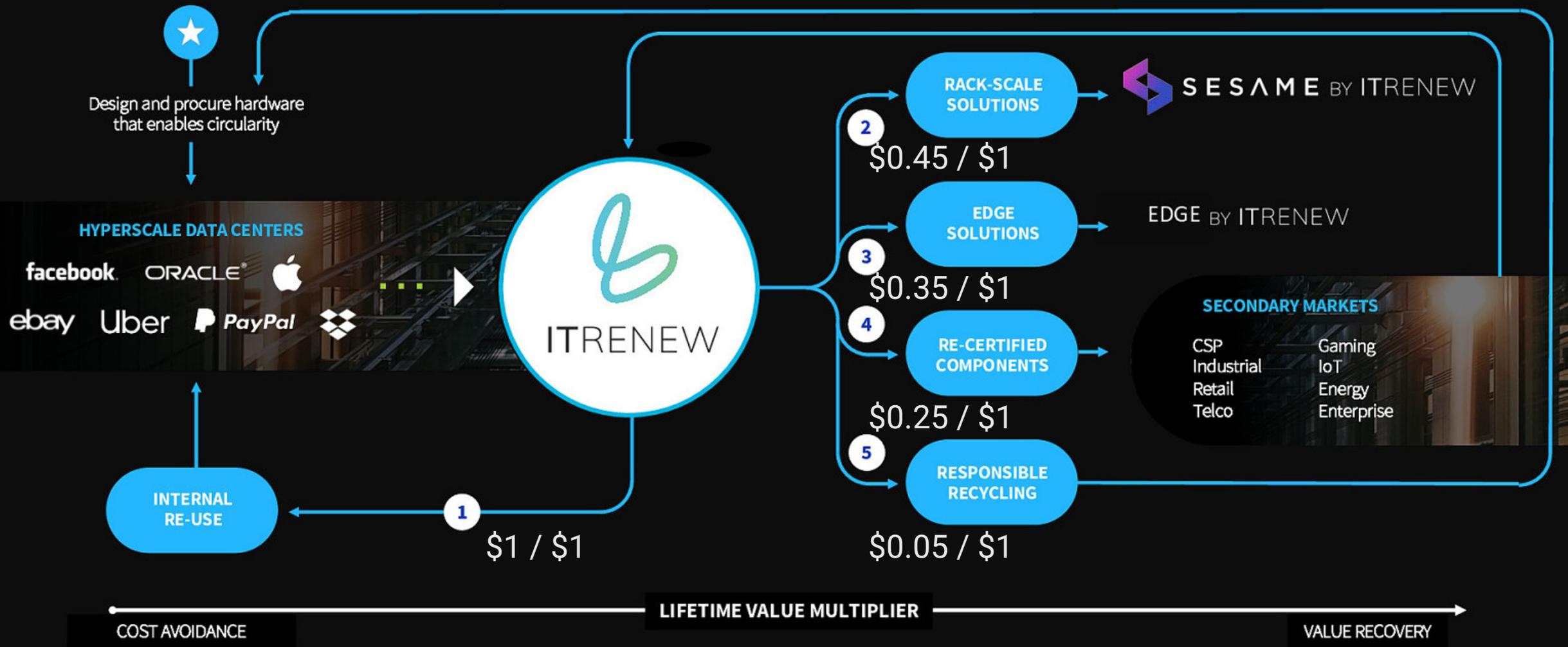
25,000 to 125,000 servers / month worldwide

Renewable Progress is Strong,
But Are We Looking at the Whole Picture?

PRE-USE PHASE — **76%**

CO2e and GHG from mining to manufacturing to deployment

Embodied Energy/ Scope 3 emissions

OPERATIONAL PHASE — **22%**

Electricity to run IT equipment

Scope 1 emissions

POST-USE PHASE — **2%**

Recycling and EOL Processes

Embodied Energy/Scope 3 emissions

submer EcoDataCenter ITRENEW

OCP GLOBAL SUMMIT

NOVEMBER 9-10, 2021

EXTEND

Further, Longer

Why it works

3 years primary	3 years secondary	3 years tertiary

9 year design lifetime
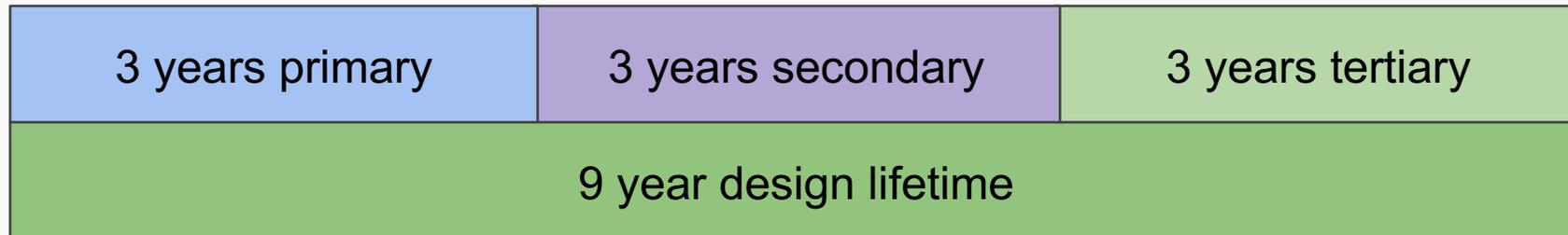
Recertified hardware approach – facilitate secondary and potentially tertiary use stages for technology assets in various forms

Why it works

3 years primary	3 years secondary	3 years tertiary

9 year design lifetime	10-12 years

5 years primary	3 years secondary

5 years primary

3 years primary	4 years secondary

2 yrs primary	3 yrs secondary

3 years primary	4 years secondary
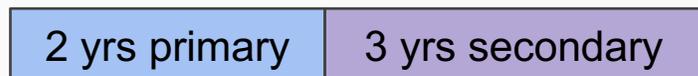
In fact, anything that keeps technology running longer will be beneficial, as long as the technology is still **useful** for something by somebody, plus **maintainable** & **serviceable**. SO use those actual criteria to evaluate ALL technology: workload performance, ongoing maintenance complexity & ongoing service costs.

REDUCE

A Worked Storage Example

Reduce carbon footprint

focus on efficiency & results
via carbon / performance

scope 1 & 2 operational carbon;
scope 3 embodied carbon

Reduce cost footprint

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via cost / performance

capex, opex, people-ex
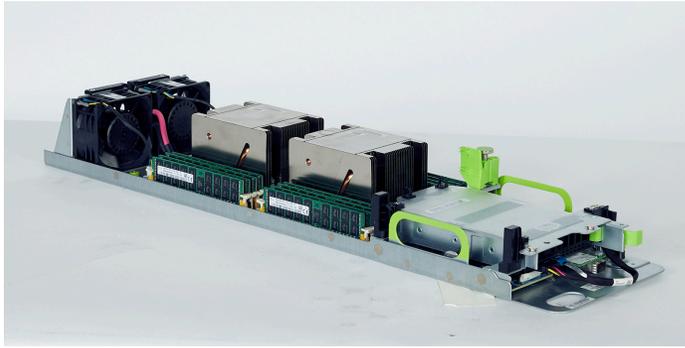
2.3U/30
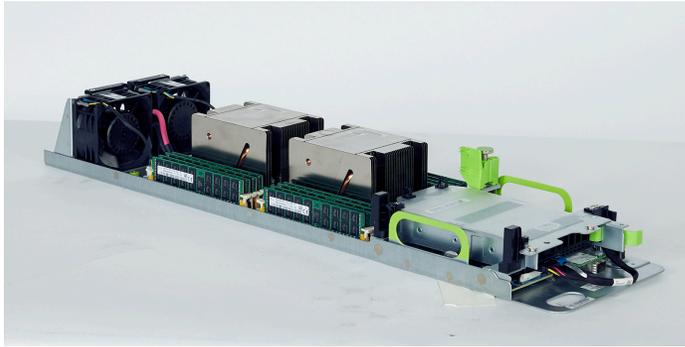
2U/12

2.3U/30

				iops	W/iops	W/TB
Knox	30x HDD	30 TB	30x 1TB SATA HDD	7.5k	47.0	9.5

2.3U/30

2U/12

				iops	W/iops	W/TB
Knox	30x HDD	30 TB	30x 1TB SATA HDD	7.5k	47.0	9.5
Knox	30x SSD	29 TB	30x 960GB SATA SSD	2.4m	0.13	11.5
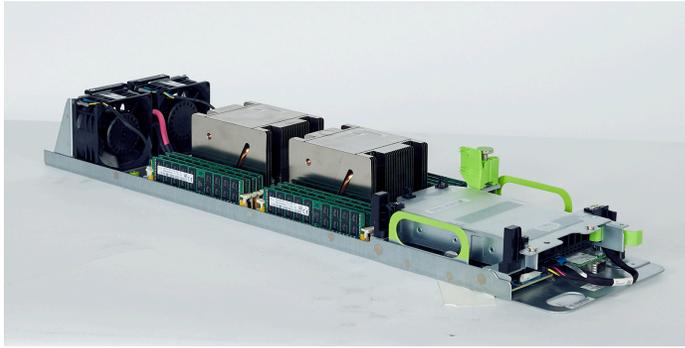
2U/12

2.3U/30

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Knox	30x HDD	30 TB	30x 1TB SATA HDD	7.5k	47.0	9.5
Knox	30x SSD	29 TB	30x 960GB SATA SSD	2.4m	0.13	11.5
AVA	4x NVMe	15 TB	4x 3.84TB NVMe SSD	1.6m	0.03	2.9

0.3U/6
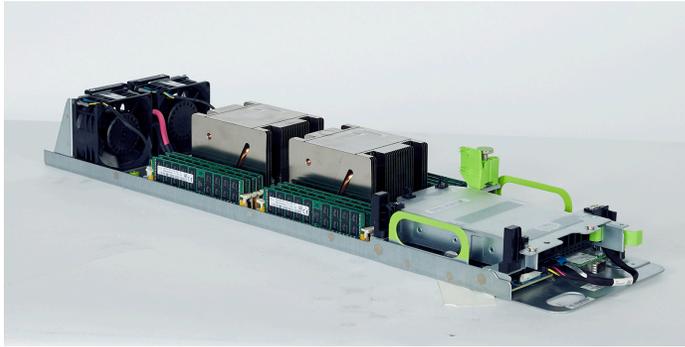
2U/12

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AVA	6x NVMe	24 TB	6x 3.84TB NVMe SSD	2.4m	0.03	2.9

0.3U/6

2U/12

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Knox	30x HDD	540 TB	30x 18TB SATA HDD	7.5k	46.0	0.6

0.3U/6

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Knox	30x HDD	540 TB	30x 18TB SATA HDD	7.5k	46.0	0.6
BC	72x HDD	1,296 TB	72x 18TB SATA HDD	18k	37.1	0.5

0.3U/6

2.3U/30

2U/12

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BC	**72x HDD**	**1,296 TB**	**72x 18TB SATA HDD**	**18k**	**37.1**	**0.5**

0.3U/6

	type	year	AI score
V100	GPU	2018	34,394
P100	GPU	2016	22,466
T4	GPU	2018	14,558
K80	GPU	2014	6,582
Gold 6126	CPU	2017	3,514
E5-2640v4	CPU	2016	2,569
Samsung Galaxy	Phone	2023	2,053

Networking

25G
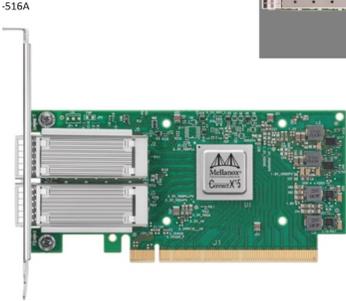
100G

GPUs

UPGRADES

Memory

8GB DDR4

64 GB DDR4

	type	year	AI score	GCP monthly
V100	GPU	2018	34,394	$815/m
P100	GPU	2016	22,466	$479/m
T4	GPU	2018	14,558	$116/m
K80	GPU	2014	6,582	$206/m
Gold 6126	CPU	2017	3,514	--
E5-2640v4	CPU	2016	2,569	--
Samsung Galaxy	Phone	2023	2,053	--

Networking

-516A

25G

100G

GPUs

UPGRADES

Memory

8GB
DDR4

64 GB
DDR4

SDC 23
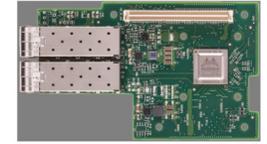
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capex, opex, people-ex

Comparison

Upgrading Your Ride

17 MPG fuel economy	0 to 60 in 12 seconds
25 MPG fuel economy	0 to 60 in 2 seconds

Comparison

Upgrading Your Ride

| 17 MPG fuel economy | 0 to 60 in 12 seconds |
| — MPG fuel economy | 0 to 60 in 4 seconds |

REDUCE

Optimize

How it works

Step 1 - Audit
Audit systems, servers, and applications.

Step 2 - Quantify
Match per-unit, per-device carbon inventory, performance, and capacity.

Step 3 - Optimize
Report, review, and optimize - changes might be hardware, software, operations, or design.

buy new hardware $$-

extend life of existing hw $0

re-purpose existing hw $+

add recertified hardware $-

LONG-TERM STORAGE CLOUDS

Shoutouts

Home

Green, sustainable, long-term storage

Tue Sep 19 | 7:00pm - 8:00pm

Salon IV

Abstract

- Who: Archive & Cold Storage users interested in green, sustainable longterm storage such as Ceramic, Glass, DNA and Molecular Storage.
- What: A session on establishing a new long-term storage tier. Green and sustainable storage, typically not requiring migration of data. Not requiring human involvement or energy while retaining data on media. The session may include organic & inorganic physical storage media technologies (complementing SSD, HDD or Tape in active Archive implementations).

SW Worth
WorthIT

BOF – join us Tuesday, 19 September at 7pm in Salon IV

Update on Standards for Consuming DNA Data Storage Archives

📅 Mon Sep 18 | 8:30am - 9:20am

📍 Salon IV

Abstract

DNA lacks many key attributes found in other traditional storage media types including locality and addressability. The Rosetta Stone workgroup is aiming to solve the issue of enabling archive readers to understand key metadata about the archive and position them to be able to consume its contents. This session will provide an overview of where the Rosetta Stone workgroup is in the process of creating a recommended approach for this issue.

Daniel Chadash
Twist Bioscience

Sessions Yesterday – review the slides

Related Sessions

DNA Data & Archival Storage	DNA Data & Archival Storage	DNA Data & Archival Storage	DNA Data & Archival Storage
Establishing Endurance and Data Retention Metrics in a DNA Data Storage System	**Bit-to-DNA Writing Machines: a Microfluidic Platform and Future Data Center Operation Overview**	**Approximate DNA Storage with High Robustness and Density for Images**	**DNAe2c ECC for DNA Data Storage: 10x Improvement over RS Codes**
Users of DNA as a digital data storage medium must have confidence that they can reliably recover their stored data, and to understand the competing capabilities and claims of codecs, readers, writ	Synthetic DNA-based data storage has been on the rise as a candidate for Data Storage due to its longer shelf life and higher data density.	Deoxyribonucleic Acid (DNA) as a storage medium with high density and long-term preservation properties can satisfy the requirement of archival storage for rapidly increased digital volume.	A new error correction code for DNA data storage is presented.
David Landsman Western Digital	**Henrique Reis Wisinewski** Institute For Technological Research **Bruno Marinaro Verona** Institute For Technological Research	**Bingzhe Li** University Of Texas At Dallas	**Mario Montana** DNAalgo

DNA Data & Archival Storage	DNA Data & Archival Storage	DNA Data & Archival Storage	DNA Data & Archival Storage
Pantheon DNA Data Storage CODEC: Experiences, Challenges, and Innovations	**Long Term Preservation and Archive Storage**	**Ceramic Nano Memory – Data Storage for the Yottabyte Era**	**Cerabyte – Permanent Data Storage**
There are several well-known advantages of using synthetic DNA for cold-data storage, such as higher density, reduced energy consumption, and durability compared with the standard storage mediums u	The long-term retention and backup requirements of many organizations continue to grow as their data estate grows.	The demand for data storage continues to grow exponentially with the overall data storage temperature cooling down with most data becoming cold after one month and subsequently infrequently accesse	The demand for data storage continues to grow exponentially with the overall data storage temperature cooling down with most data becoming cold after one month and subsequently infrequently access
André Da Costa Martins IPT	**Shashidhar Joshi** Microsoft	**Christian Pflaum** Cerabyte - Ceramic Data Solutions Holding GmbH	**Christian Pflaum** Cerabyte - Ceramic Data Solutions Holding GmbH

SDC 23

THE WIDER VIEW

Beyond Computing

TED RADIO HOUR

LISTEN & FOLLOW

< Shoham Arad: Ideas Into Action

October 22, 2021 · 12:01 AM ET

51-Minute Listen   + PLAYLIST

TED Speaker   TED Fellow   TED Attendee

Mundano

Graffiti artist + activist

🔗 PimpMyCarroca.com   🐦 @Mundano_sp   🔗 Flickr: Artetude

TED Speaker

TED Fellow

Personal profile

Mundano's bold, colorful street art isn't just eye candy. His projects call attention to social, environmental and political issues, while raising chuckles from passersby.

Why you should listen

Mundano is a Brazilian street artist and activist whose work makes people stop and think about the issues swirling around them everyday. In 2007, he began using his graffiti skills to paint "carroças," the wooden and metal carts used by the trash collectors throughout Brazil who haul off junk and recyclables. He painted 200 carroças and in the process made these invisible superheroes visible—not only in the streets, but also in the media. The effort led to "Pimp My Carroça," which made this initiative do-it-yourself, crowdfunded and global. It has brought in 170 trash collectors in cities around the world, teaming them up with 200 street artists and 800 volunteers. It is quickly becoming a movement.

00:00 / 05:13

Trash cart superheroes

1,085,571 views | Mundano • TEDGlobal 2014

Share   Add   Like (32K) | Read transcript |

In Brazil, "catadores" collect junk and recyclables. But while they provide a vital service that benefits all, they are nearly invisible as they roam the streets. Enter graffiti artist Mundano, a TED Fellow. In a spirited talk, he describes his project "Pimp My Carroça," which has transformed these heroic workers' carts into things of beauty and infused them with a sense of humor. It's a movement that is going global.

About the speaker

Mundano
Graffiti artist + activist

See speaker profile >

https://www.npr.org/transcripts/1048050024

Mundano's bold, colorful street art isn't just eye candy. His projects call attention to social, environmental and political issues, while raising chuckles from passersby.

CATADORES

#COLABORAMER

"SE EU PUDESSE,
RECICLARIA TODOS
OS POLÍTICOS!"

FERMETAL
RECICLAR É TER PARA SEMPRE

2009   2019

2109

26 likes

fermetalmacae .

A importância do catador para reciclagem se destaca... more

March 7 · See translation

Liked by **catakiapp** and **360 others**

pimpmycarroca Consumir de maneira consciente e reciclar somente o que é necessário. A gente apoia essa ideia... more

View all 2 comments

October 8, 2020 · See translation

WGBH

Platform...

Tilynda

China Dialogue

ABC

Atlas of the...

Platform...

The Guardian

Alamy
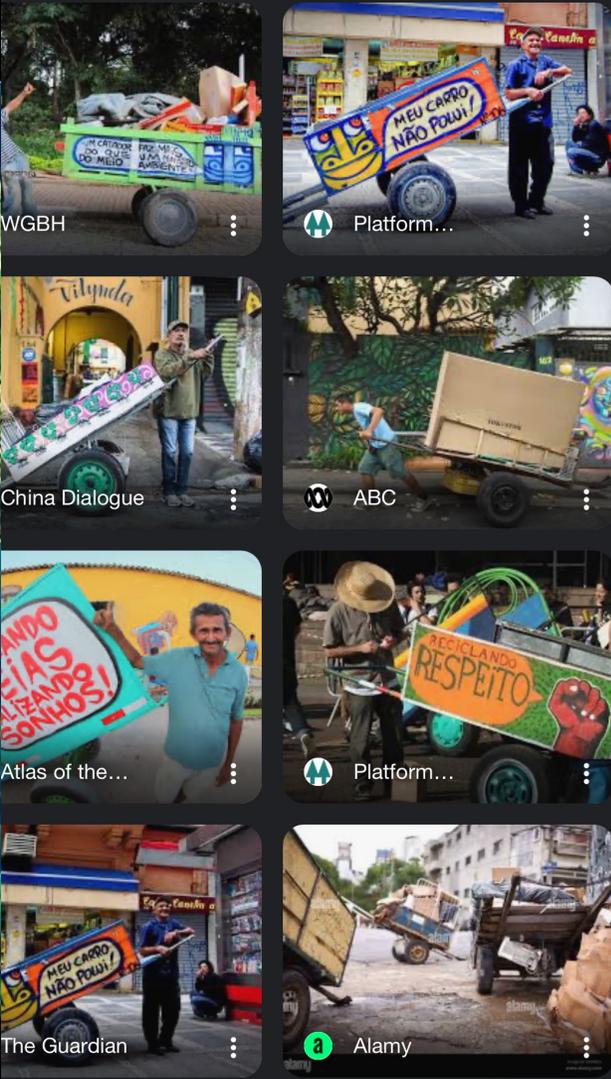
NPR
https://www.npr.org · 2015/01/17

Pimps Cars, Brazil Pimps Trash Carts :
s and Soda

🔍 catadores carts

pimpmycarroca Yes: 90% of everything Brazil recycles is collected by pickers. Yes: that's a lot of work for little recognition.

One simple way to help change this scenario is voting for Cataki in the global innovation award that the app is competing for. Only 1 day left for voting to end, so go to vote.cataki.org [clickable link there in our bio] and do your part!

Liked by mundano_sp and 3,973 others

LIXO

RESÍDUO

Liked by catakiapp and 711 others

pimpmycarroca How many times haven't we thrown "trash in the trash" and thought we were doing something great for the planet?

But do u wanna know? Trash doesn't exist!

The word garbage perpetuates a super negative image for the pickers! The raw material of these professionals is WASTE! Remember: waste is resource.
Collectors are the true environmental agents who collect our

GARBAGE

WASTE

THE LOCAL VIEW

Everyday Actions

LANDFILL

GO REUSABLE, QUIT SINGLE-USE ITEMS

NON-PAPER WRAPPERS	RUBBER & LATEX	SINGLE-USE SERVICEWARE	ADHESIVES

NO FOOD WASTE   COMPOST all food waste and SCU to-go containers

mission zero waste   www.scu.edu/stopwaste

COMPOST

PLANT-BASED MATERIALS ONLY

SCU SERVICEWARE Sandwich Wrappers, To-Go Containers, Cups, Lids, & Straws	FOOD-SOILED PAPER, TOWELS, & NAPKINS	ALL FOOD & PLANT WASTE Including Dairy & Meat

NO PLASTIC ITEMS LANDFILL black plastic utensils   **NO FOIL WRAPPERS**

mission zero waste   www.scu.edu/stopwaste

COMPOST

RECYCLE

EVERYTHING MUST BE CLEAN, EMPTY, AND DRY

PAPER & CARDBOARD	PLASTIC Bundle bags together	GLASS	METAL

NO SCU COFFEE CUPS   COMPOST lid, sleeve, and cup

mission zero waste   www.scu.edu/stopwaste

CLOSE THE CARBON LOOP

Practical Today

npr

☰ NEWS   ✦ CULTURE   ♪ MUSIC   🎧 PODCASTS & SHOWS   🔍 SEARCH

PLANET MONEY

LISTEN & FOLLOW   🟣 🟢 ⠇⠇   ⌄

< Sell Me Your Climate Bombs

September 25, 2020 · 6:41 PM ET

https://www.npr.org/transcripts/917060248

Tim & Gabe

▶ 26-Minute Listen   + PLAYLIST   ⬇ <> ☰

GET PAID TO FIGHT CLIMATE CHANGE.

(HINT: LOOK AT YOUR AIR CONDITIONER….)

Your company may be sitting on some of the most potent greenhouse gases ever created: old refrigerants. These climate-warming gases often go unnoticed in chillers, air conditioning, and refrigerated systems.

We've teamed up with Intuit, the global financial platform, to help more businesses take positive steps to reduce their carbon emissions.

Ensure that your climate commitment includes monitoring these greenhouse gases – and get paid to see them destroyed or recycled.

Contact Tradewater

Get paid for your existing refrigerant, with no-cost shipping

Includes chlorofluorocarbon (CFC) refrigerants

Free recovery services of refrigerants in building chillers and other systems

Includes chlorofluorocarbon (CFC) refrigerants

Up to 50% off on recovery, reclamation, and recycling services

Includes hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbon (HFC) refrigerants

224	Lyme Mountaineer Timberlands II, LLC	3,921,355
225	Passamaquoddy Joint Tribal Council	4,513,042
226	Mescalero Apache Tribe	4,569,074
227	Green Diamond Resource Company	4,666,739
228	Tradewater, LLC	4,846,851
229	Reclamation Technologies, Inc.	5,130,894
230	EOS Climate, Inc.	5,726,319
231	Usal Redwood Forest Company, LLC	5,943,301

How it Works

Tradewater is an EPA-certified organization reclaimer with the technical expertise to handle refrigerant safely and responsibly. Unlike others who purchase refrigerant, however, we do this work to fight climate change.

We first aggregate the dangerous greenhouse gases we collect. Depending on the refrigerant type, we either destroy the gases through incineration or send them through a regulated recycling process.

Tim & Gabe

Tradewater
Refridgerant Finders

refrigerant finders

About Us   What We Buy ▾   How It Works ▾   Blog   FAQs

GET A QUOTE

OUR TECHNICIANS ARE EPA-CERTIFIED

We Buy Your Old Refrigerant

Get Your Free Quote

Refrigerant Finders Nationwide Buyback Program Pays Competitive Prices For Your Old Or Used Refrigerants.

Our Mail-In Program Makes It Easier Than Ever To Sell Your Freon. We Offer **Free Nationwide Shipping** To Ensure You Get Paid Even Quicker For Your Refrigerant.

First Name

Last Name

Phone * ?

Email Address *

(555) 555-5555

Refrigerant Type

Refrigerant Container

Please Select

Please Select

Approximate Quantity (Lbs) * ?

Zip Code *

Security code

HCQE7

Enter code *

reCAPTCHA
Privacy - Terms

THANK YOU

For Listening

SDC 23

OCP Experience Center - Nautilus (Stockton, CA) - hosted by Flax Computing

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Computing The Sustainable Server Lab (SSL) center for open hardware i...

Solution Provider: Flax Computing

Model #: OCP Experience Center - Nautilus (Stockton, CA)

OCP Experience Center - MGHPCC (Holyoke, MA) - hosted by Flax Computing

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Model #: OCP Experience Center - MGHPCC (Holyoke, MA)

Efficient Computing and Energy Reduction Test Center - Hosted by Flax Computing

The Recertification for Efficient Computing and Energy Reduction Test (RECERT) design and manufacturing center hosts a range of activities related to advancing ...

Solution Provider: Flax Computing

Model #: N/A

Carbon Footprint Analysis and Reduction (CFAR) Center - Hosted by Flax Computing

The Carbon Footprint Analysis and Reduction (CFAR) analysis and design process allows everyone to succinctly and accurately measure the carbon footprint of thei...

Solution Provider: Flax Computing

Model #: Carbon Footprint Analysis and Reduction Center

Reduce carbon footprint

focus on efficiency & results
via carbon / performance

scope 1 & 2 operational carbon;
scope 3 embodied carbon

Reduce cost footprint

focus on efficiency & results
via cost / performance

capex, opex, people-ex

Call To Action

- Reach out to us to get involved
- Engage us to evaluate / quantify your server carbon footprints
    - www.flaxcomputing.com
- Evaluate your own servers, share the results with us report @ flaxcomputing.com
- If you have servers that you don't want, send them to:

    Flax Computing, Suite A2

    530 West Street

    Braintree, MA 02184
- Or if you want us to arrange pickup
  servers @ flaxcomputing.com

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www.linkedin.com/in/er1p

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