

**Junkyard datacenters**

**Carbon-efficient computing systems  
from old phones**

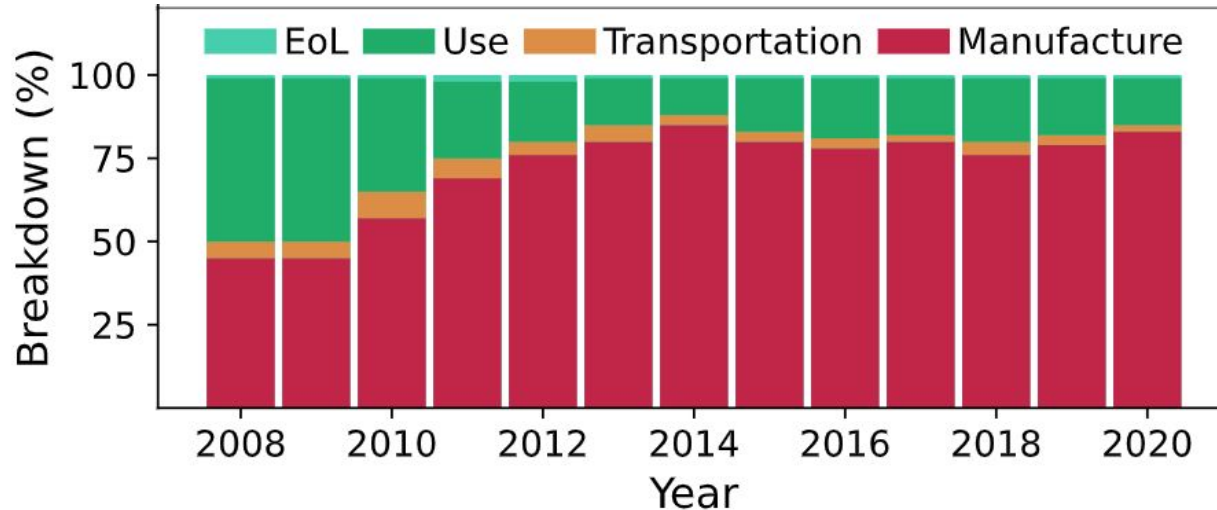
# How many smartphones have you had in your life?





**Most of these phones were still functional!**

**Short lifetimes + low power =  
Majority of carbon emissions from  
manufacturing.**



*Example from Apple.*

# The result: Reducing carbon intensity requires extending lifetimes.

**Takeaway 6:** *Given the energy-efficiency improvements from software and hardware innovation over the last decade, amortizing the manufacturing carbon output requires continuously operating mobile devices for three years—beyond their typical lifetime.*

Gupta et al. “Chasing Carbon: The Elusive Environmental Footprint of Computing” HPCA ‘21.

**If we want  $\text{CO}_2$  manufacture =  $\text{CO}_2$  use,  
we need to double lifespans**

# Problem: Lifetime extension is hard.

Consumers want new phones.

Refurbishing market is limited.

Recycling is hard, and only recovers raw materials.

**Idea: Lifetime extension through *repurposing*.**

# What else can a smartphone be?

A baby monitor?

A parking meter?

A wildlife monitor?

***A datacenter?***



=



?

# What's in a phone



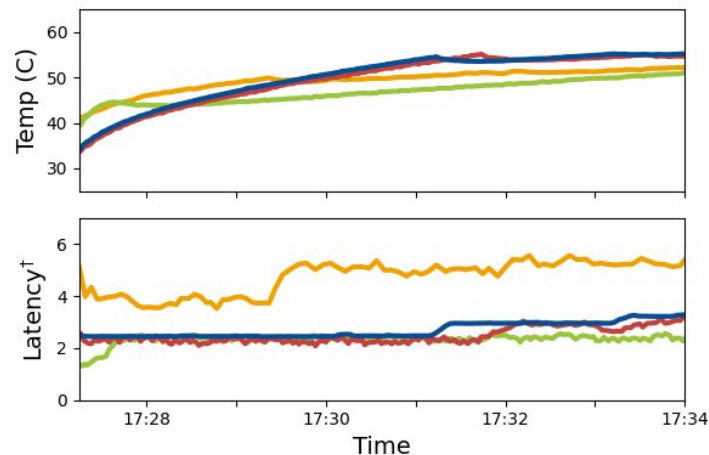
## 1. Network connectivity

## 2. Processors (CPU & GPU)

## 4. Storage

### 3. Power supply & UPS

## 5. Thermal throttling



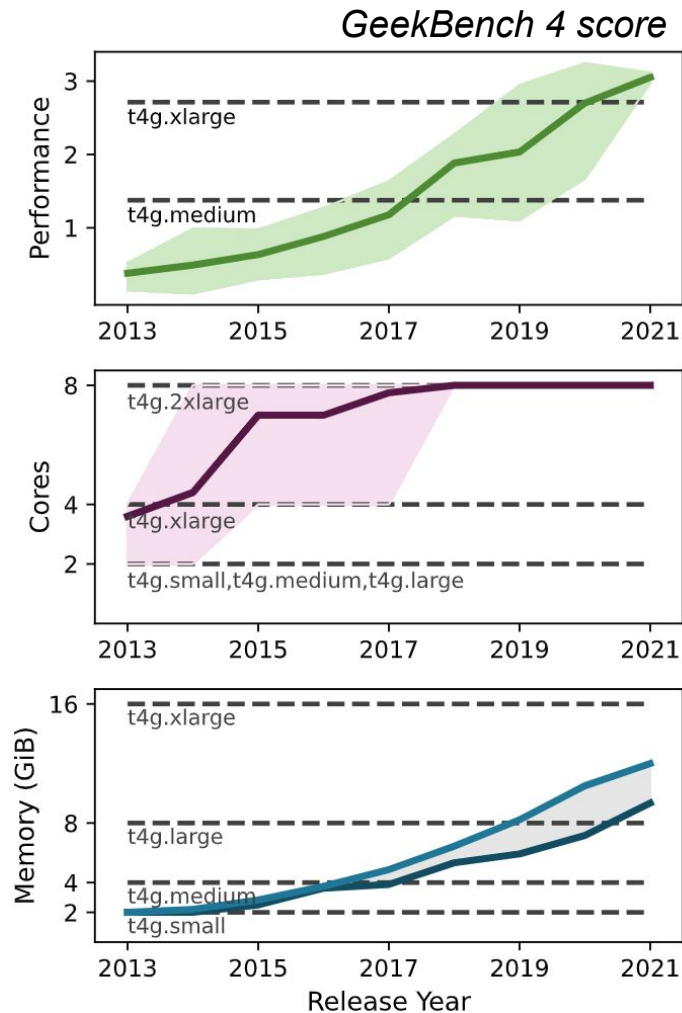


# What's in a phone

Smaller-scale machines are popular for cloud applications.

Dotted lines show AWS' current-day “burstable cloud” offerings.

Curves represent the average from the most popular 5 smartphones released each year.



# What's *not* in a phone (Challenges)

## *Challenge 1. Smartphones aren't meant for continuous operation.*

- They expect human input & may stall without it
- Performance saturates over time
- Battery is not designed for continuous use

# What's *not* in a phone (Challenges)

**Challenge 1.** Smartphones aren't meant for continuous operation.

**Challenge 2.** *They still can't compete with a server.*

	<b>SGEMM</b>	<b>PDF Rendering</b>	<b>Dijkstra</b>
<b>PowerEdge Server</b>	2,170 Gflops	3,140 Mpixels/sec	80.2 MTE/sec
<b>Nexus 5</b>	16.8 Gflops	85.8 Mpixels/sec	3.31 MTE/sec
<i>Slowdown</i>	<i>130x</i>	<i>37x</i>	<i>24x</i>

**Goal: Build a server from old smartphones that is *carbon-efficient* despite these challenges.**

# Quantifying Carbon

We define a new metric: Computational Carbon Intensity (CCI)

$$\text{CCI} = \frac{\text{Carbon}}{\text{Computational work done}}$$

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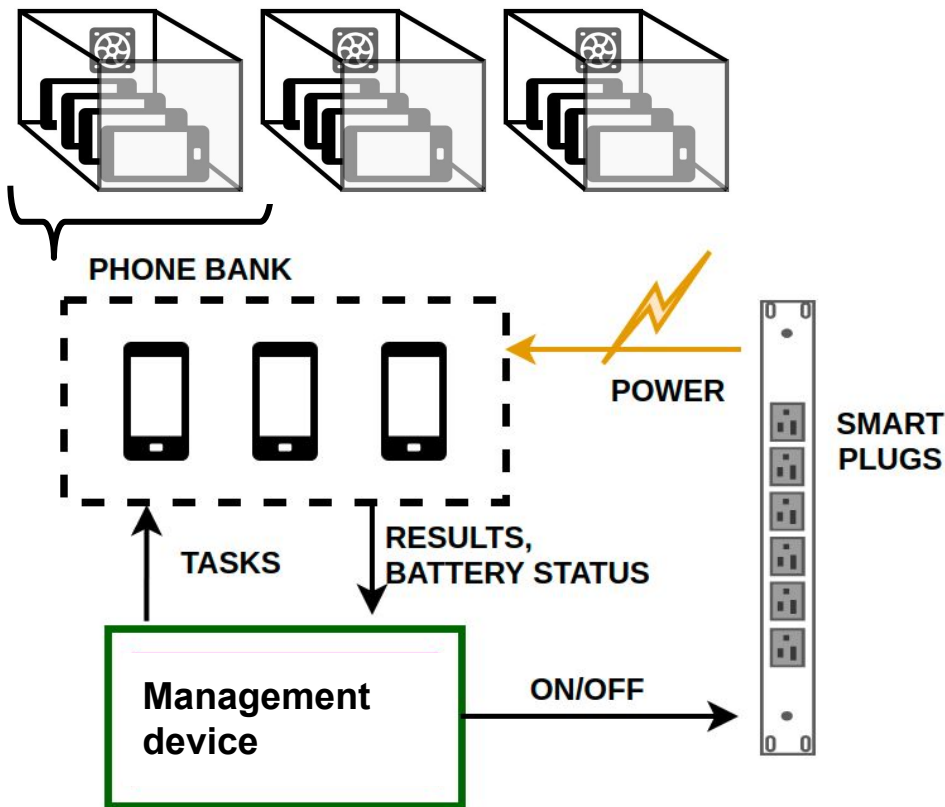
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Definitions might vary depending on application

## Challenge 1: Continuous Operation

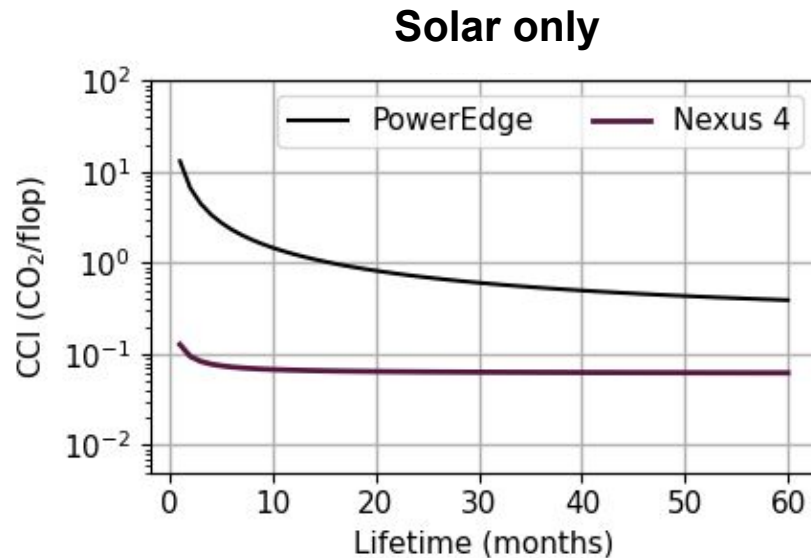
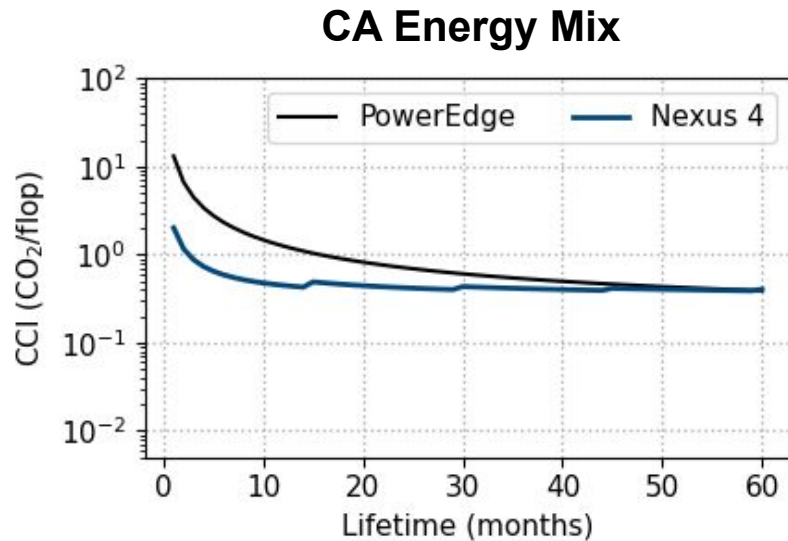


### Proposal: Phones in a box.

- Redundancy
- Power management
- FaaS-like interface for programmability



# Projections



This assumes that:

- Batteries are replaced periodically
- Moderate cooling employed
- 80% of devices are computing

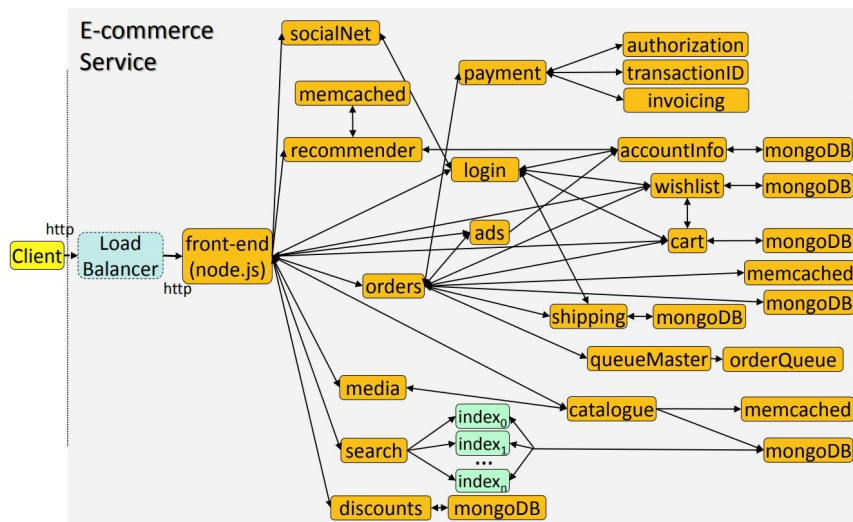
$$CCI = \frac{C_{manufacture} + C_{use}}{\text{Computational work done}}$$

## Challenge 2: Per-device Computational Power (WIP)

Q: How can we make a cluster of small devices do large-scale work?

A: Microservices.

Microservices break down large applications into smaller, single-purpose components



Gan, Yu, et al. "An open-source benchmark suite for microservices and their hardware-software implications for cloud & edge systems." *ASPLOS '19*.

# Summary

Smartphones are carbon intense to manufacture, and discarded quickly.

They are capable of so much more than what we ask of them!

Let's open up new avenues for reuse, and recover some of the

**450 million tonnes** = 2 million statues of liberty 

of sunk carbon that we carry around in our pockets.