

A conceptual illustration of sustainable technology. The background features a city skyline where buildings are integrated with lush green trees and foliage. This city is built upon a large, glowing green circuit board with intricate patterns and small lights. The overall color palette is dominated by greens and yellows, suggesting a harmonious blend of nature and technology.

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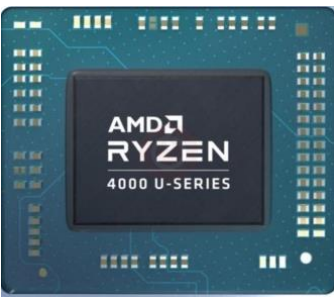
Beyond Silicon Area: Co-Product Allocation for a Binning-Aware Carbon Footprint of Processors

Olivier Weppe, Thibaut Marty, Jean-Christophe Prévotet et Maxime Pelcat

END'25 – électronique & numérique durables, Grenoble, France

Fabrication: Embodied emissions

- How do we estimate embodied carbon footprint of a CPU?



$$C = S \cdot k_{nm}$$

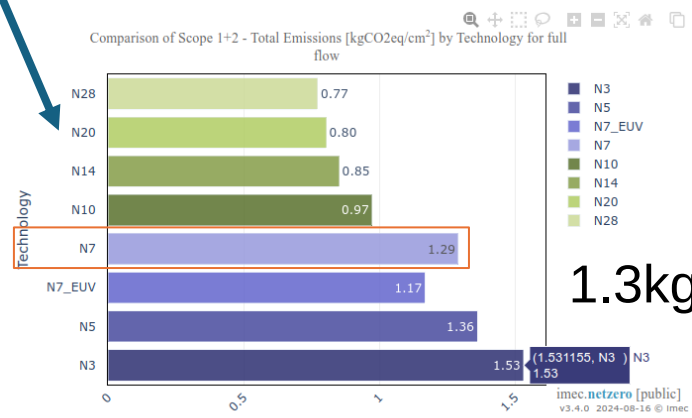
Diagram showing the equation $C = S \cdot k_{nm}$ with arrows pointing from the variables to their respective values:

- C (red) points to $2\text{kgCO}_2\text{e}$
- S points to 1.56cm^2
- k_{nm} points to the bar chart

$2\text{kgCO}_2\text{e}$



1.56cm^2

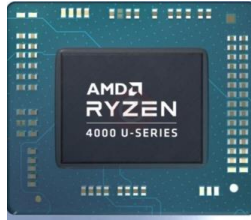


$1.3\text{kgCO}_2\text{e/cm}^2$

IMEC Netzero model

Binning: different products, same die

« Low end »



AMD Ryzen 3 PRO 4450U

- 4 Cores
- Clock 2,4Ghz
- TDP: 24W

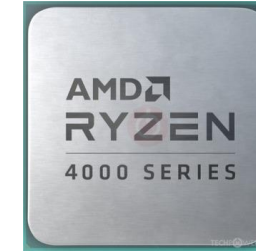


2kgCO₂e

- 156mm²
- 7nm

= ?

« High end »



AMD Ryzen 7 4700G

- 8 Cores
- Clock 3,6GHz
- TDP: 65W



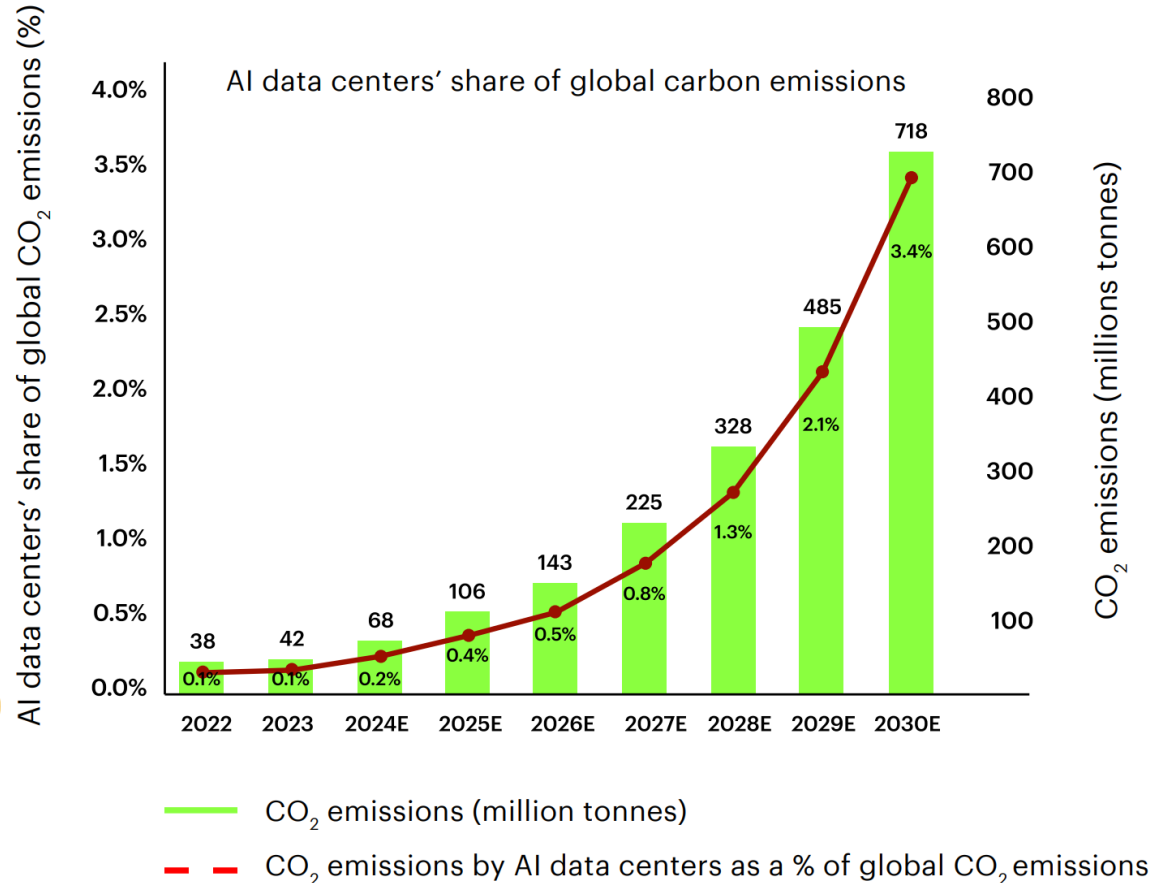
2kgCO₂e

- 156mm²
- 7nm



Computing carbon emissions

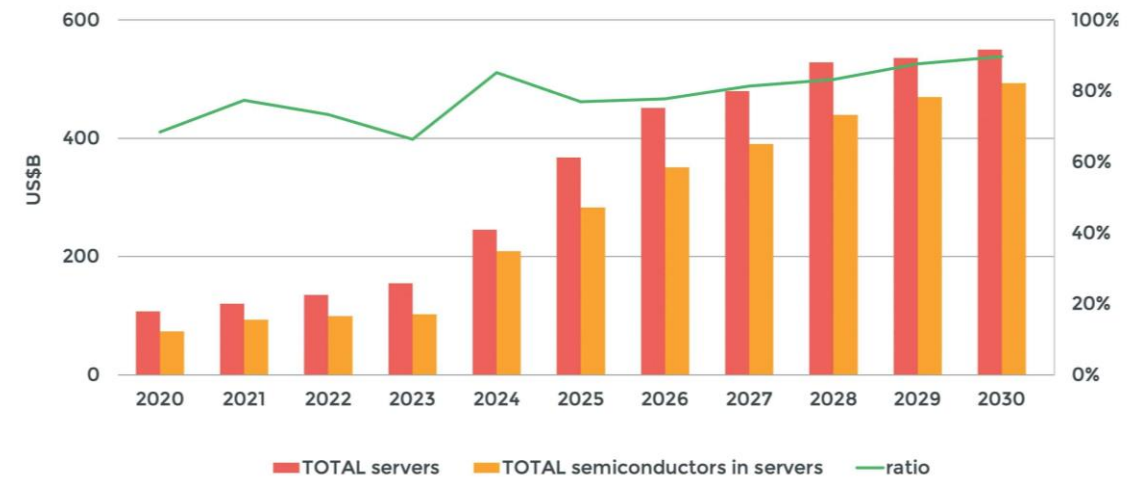
Carbon emissions



Source: Powering sustainable AI – Accenture 2025

SEMICONDUCTORS FOR DATA CENTERS - TOTAL FORECAST IN US\$B AND % SHARE, COMPARED TO THE SERVER MARKET

Source: Data Center Semiconductor Trends 2025 report, Yole Group



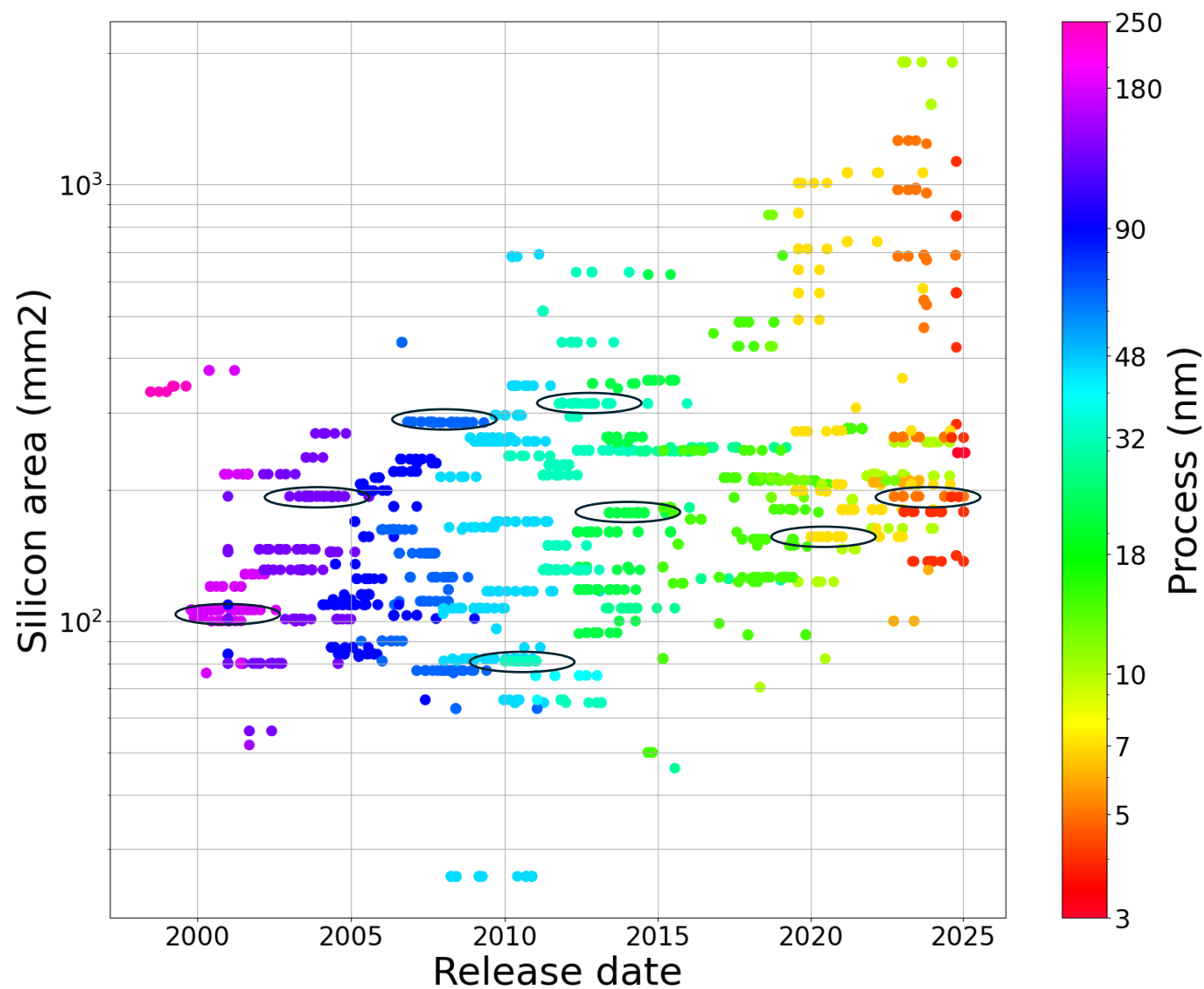
Source: Data Center Semiconductor Trends – Yole 2025

Lower carbon electricity → Higher relative impact of ICs

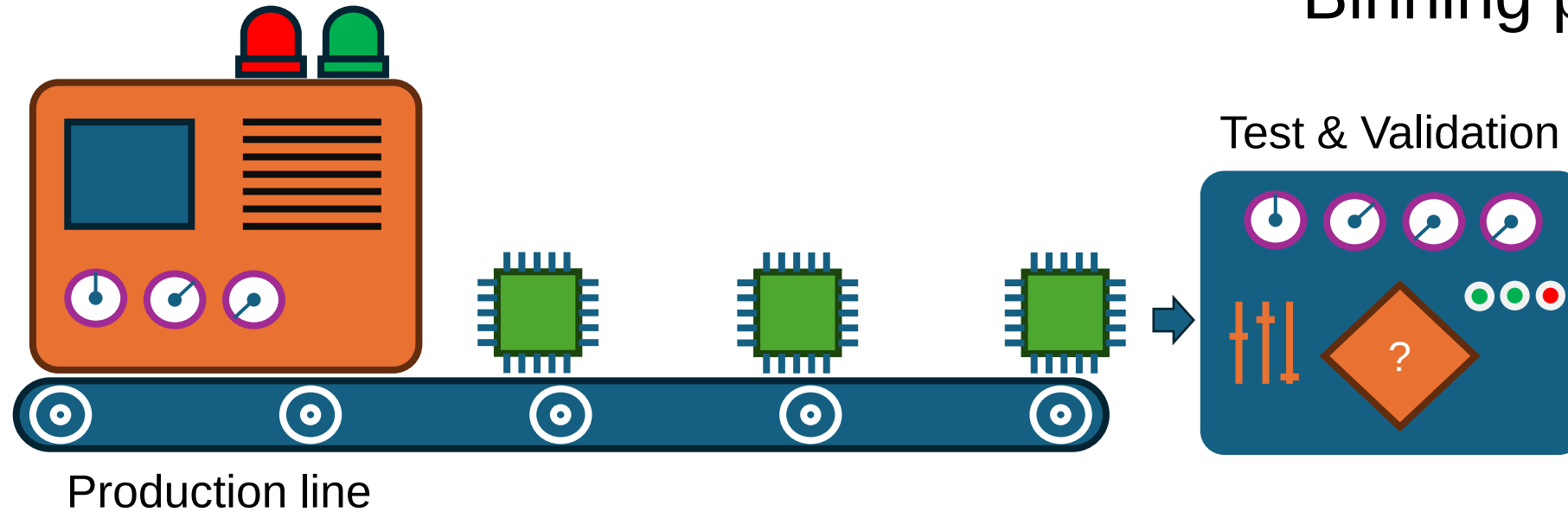




- Dataset exploration
- Binning clusters?



Binning process



Low end product

OK @3GHz

4 cores OK

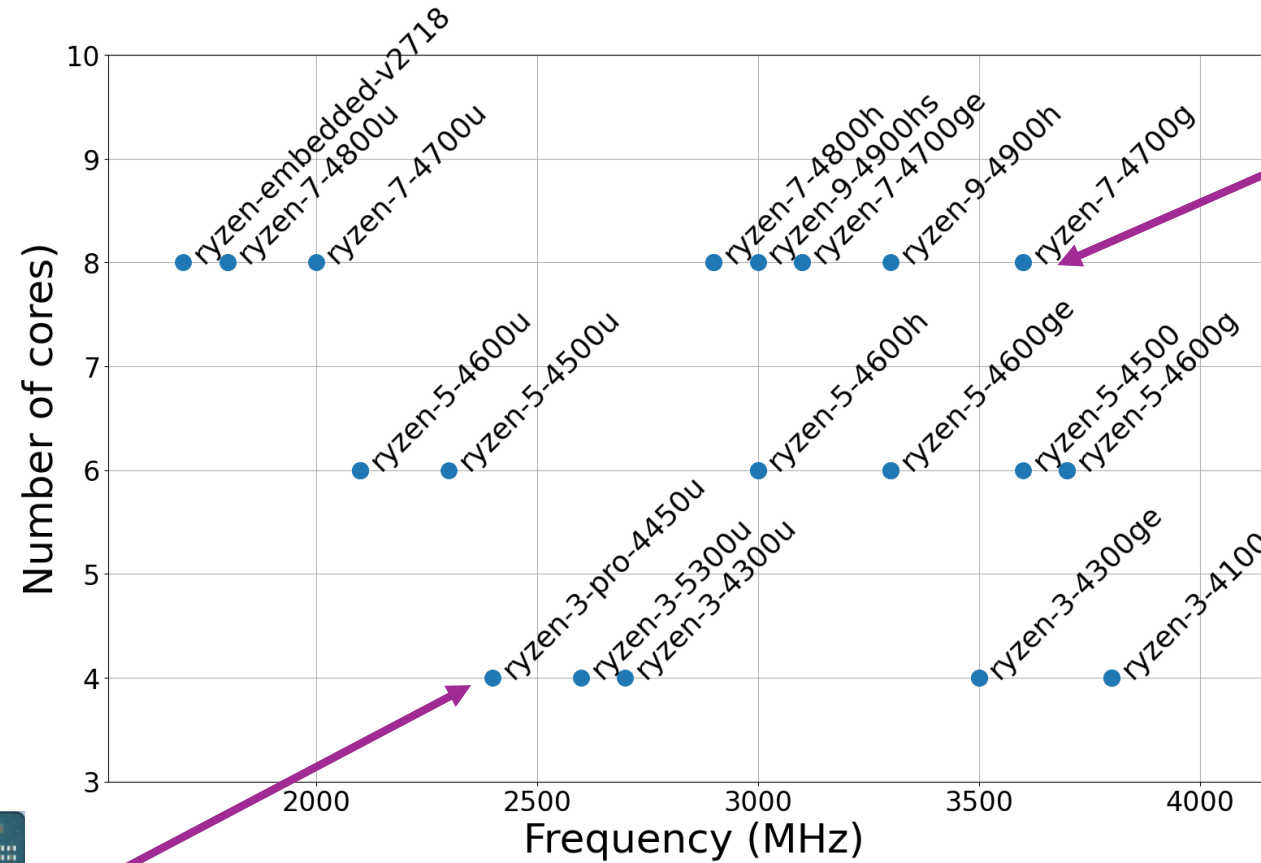
8 cores OK

OK @4GHz

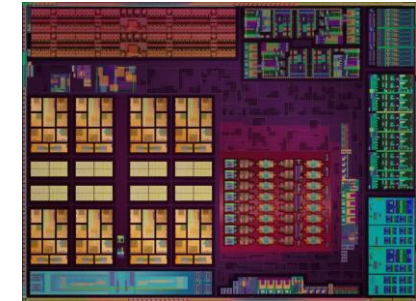
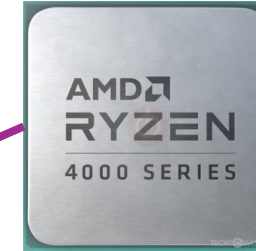
High end product

« Bins » → different product references

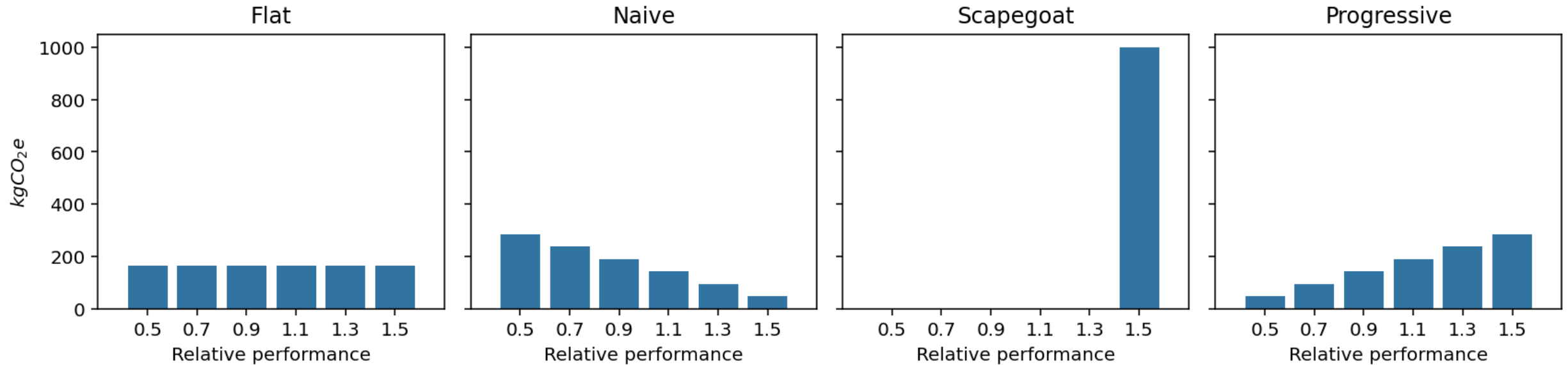
CPU co-production



AMD 156mm², 7nm serie (36 products)



Carbon footprint: identical for all products



- Current methodology
- No allocation

- Low-end is a waste
- Misses the point

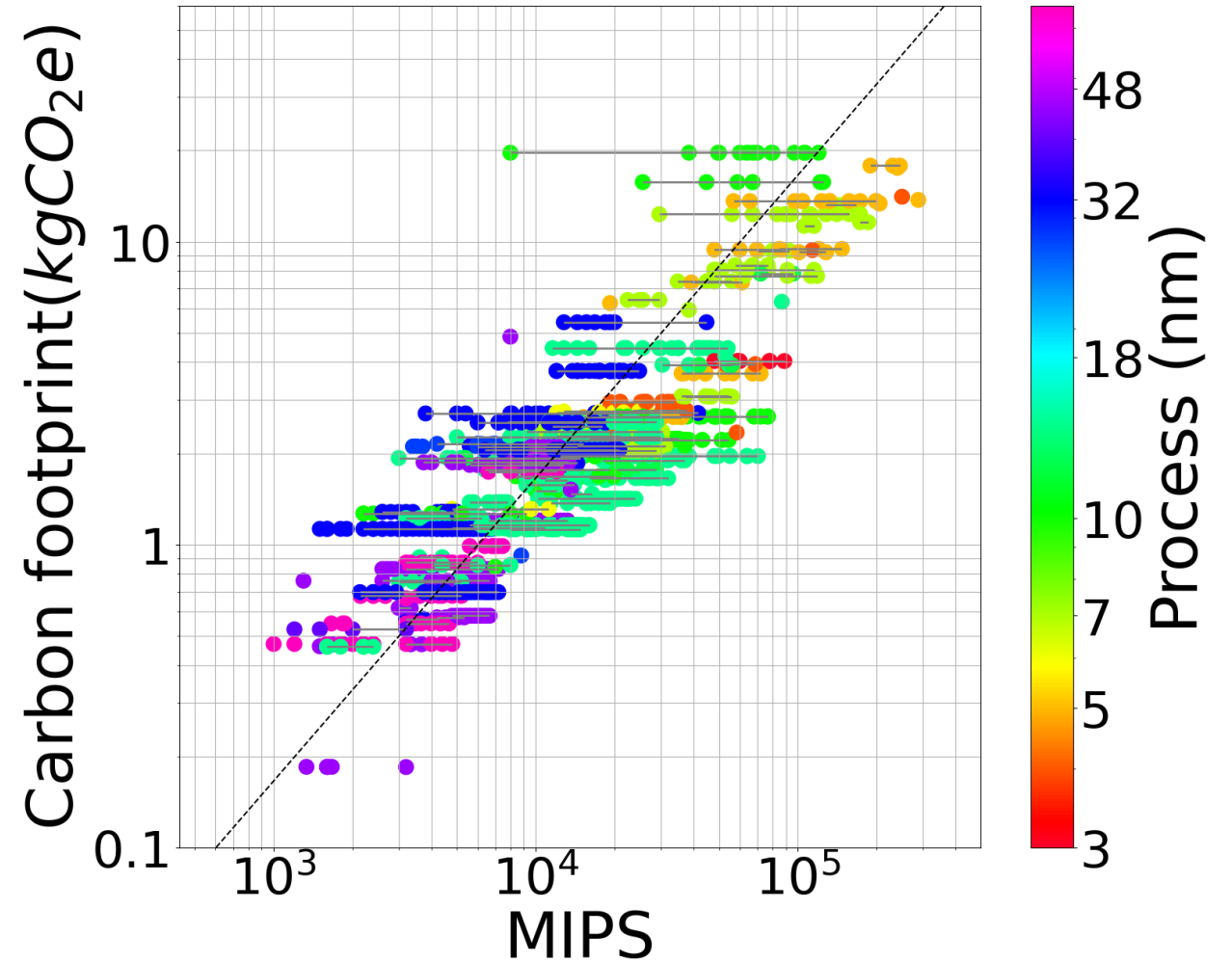
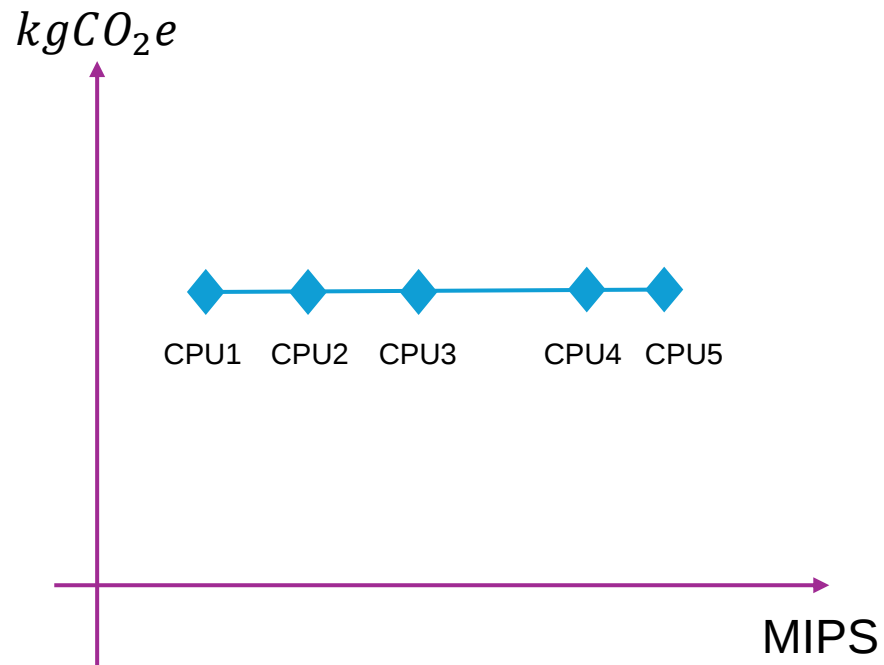
- The culprit is high-end
- A bit extreme

- More impact for high-end
- Follows performance



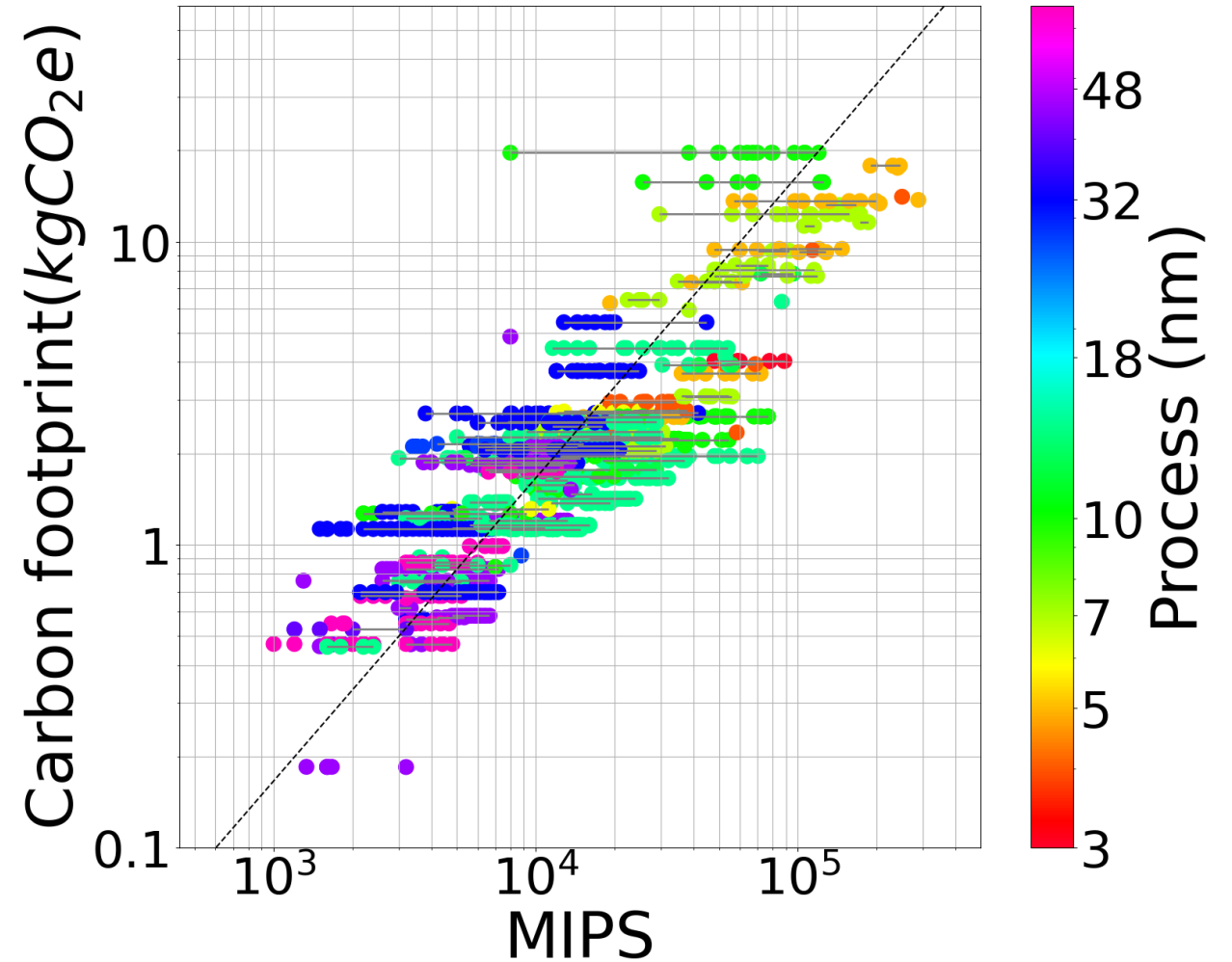
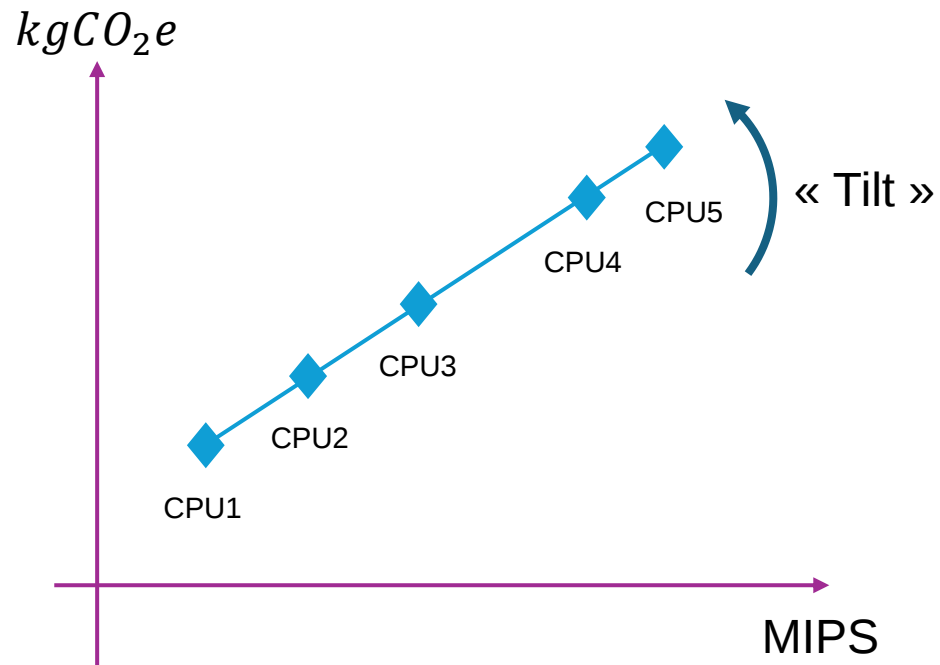
Proposed allocation (MIPS)

- Match the progression observed with series average



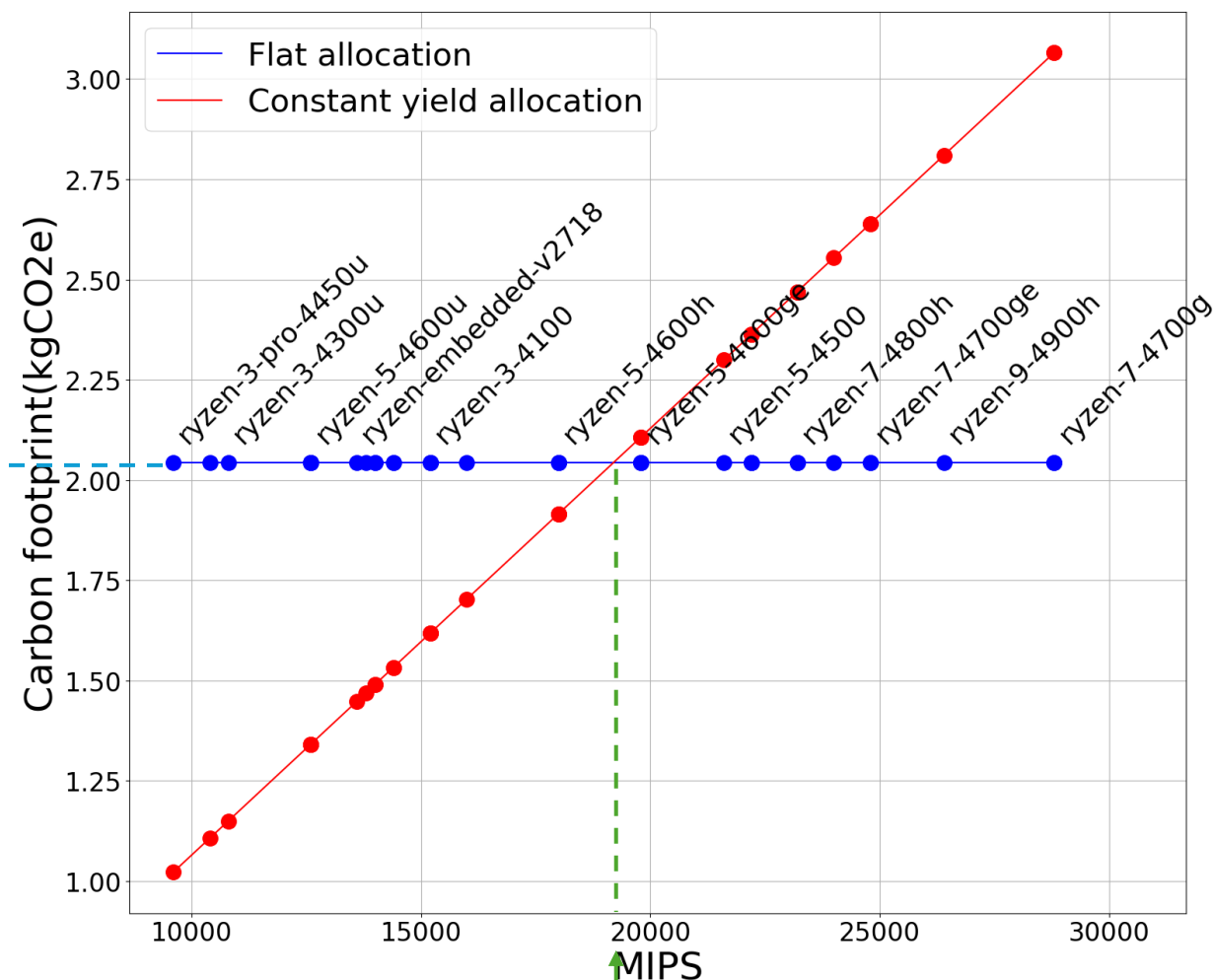
Proposed allocation (MIPS)

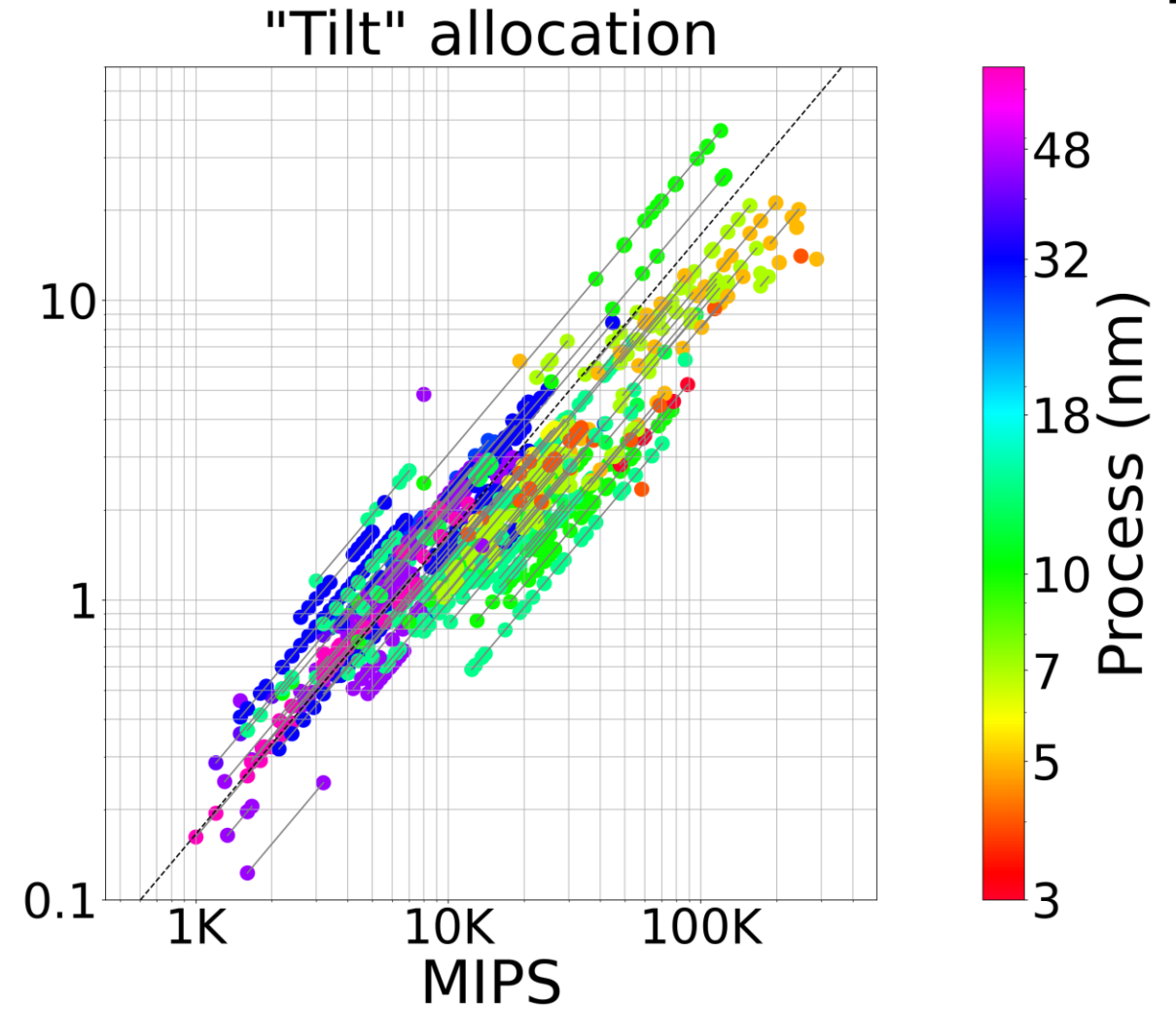
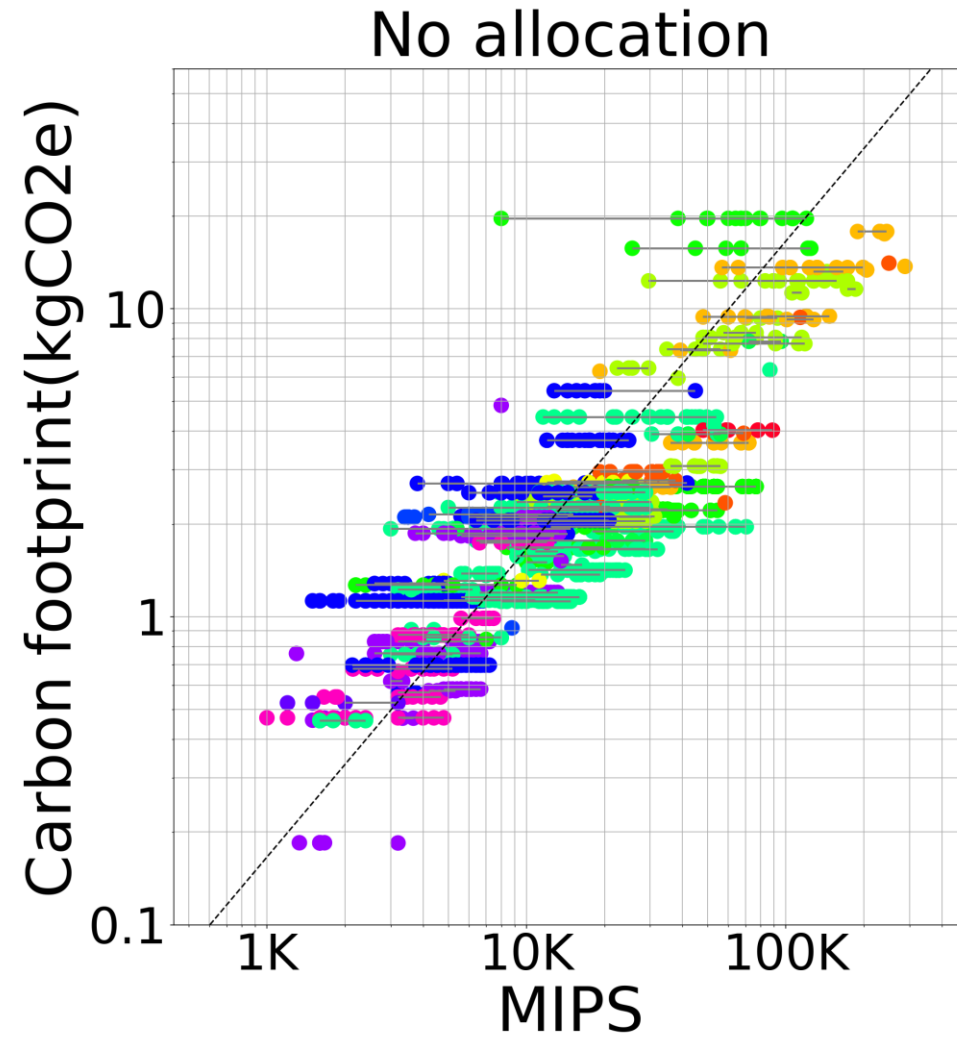
- Match the progression observed with series average



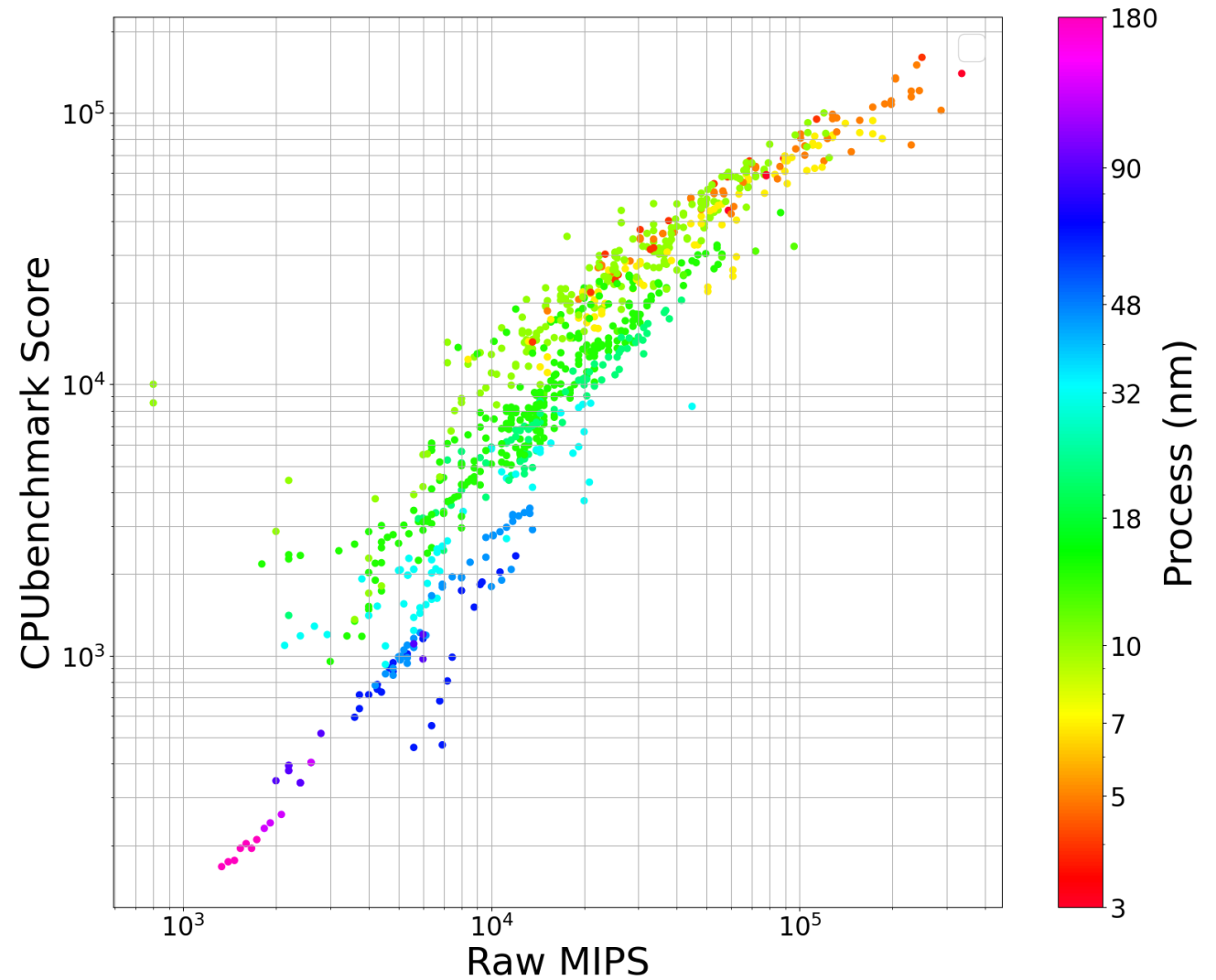
“Tilt” allocation model

$$C_i = C_{avg} \cdot \frac{MIPS_i}{MIPS_{avg}}$$





- Simple to calculate
- Objective
- How about CPU efficiency?
 - + IPC
 - + Cache
 - + Pipeline
 - + ...



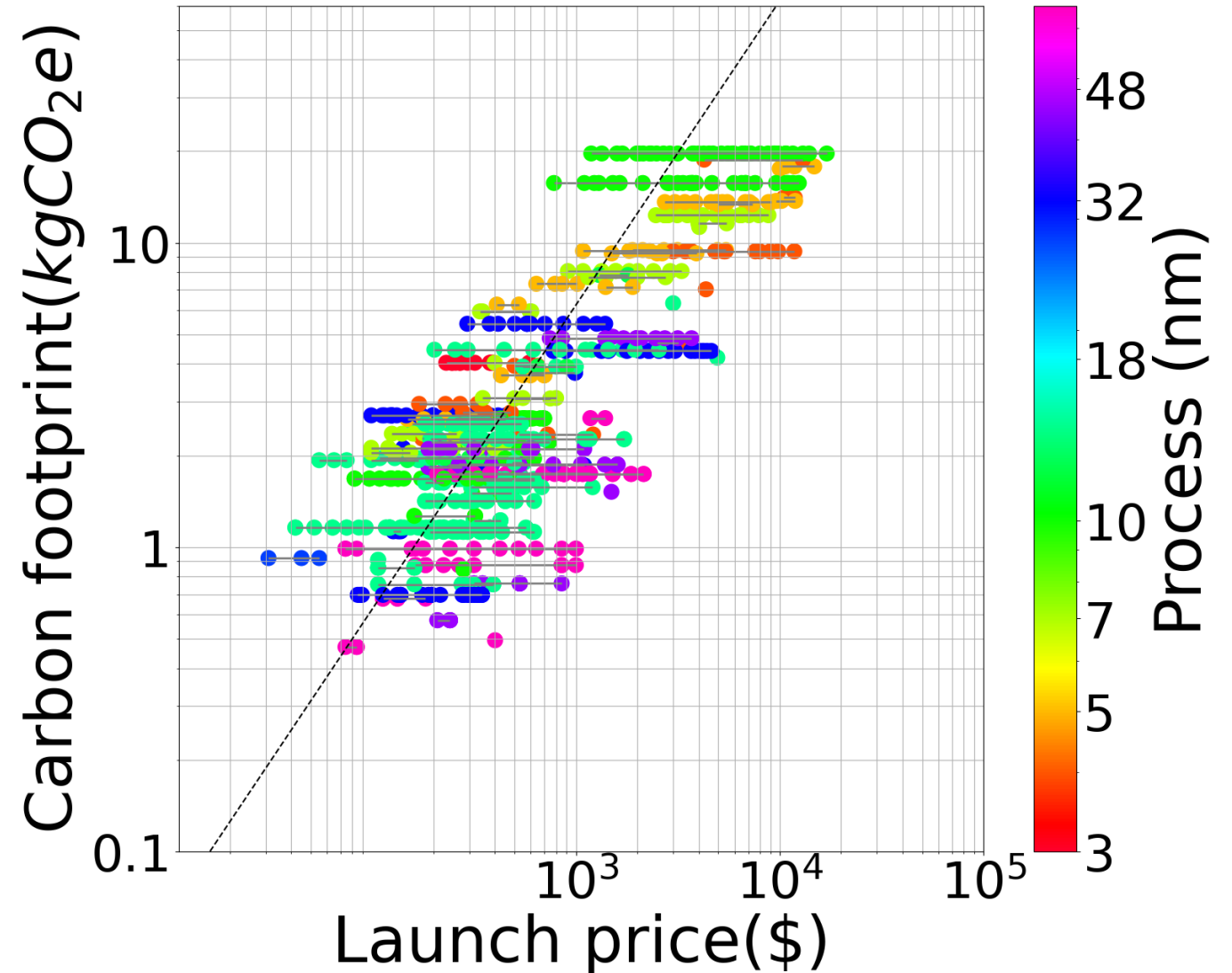
Generalized formula:

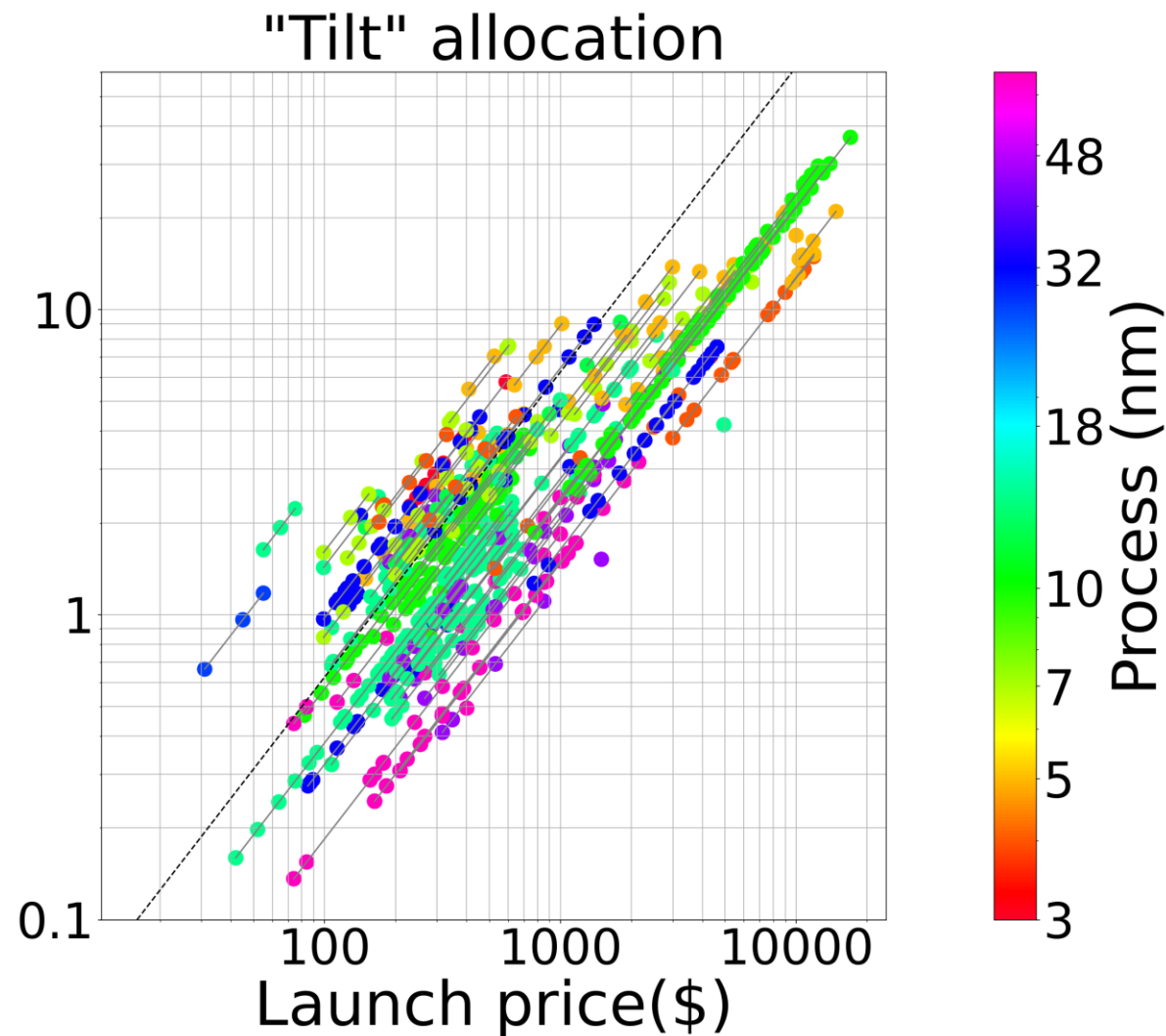
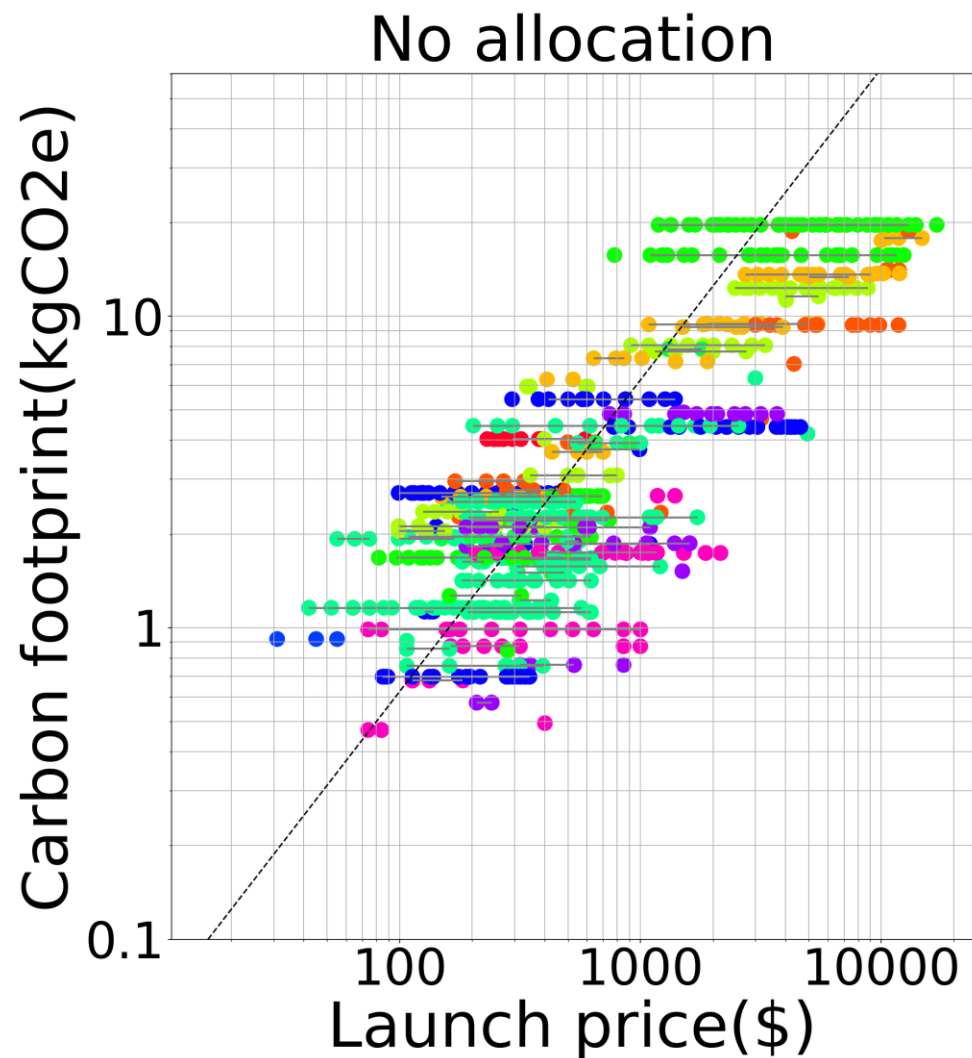
$$C_i = C_{avg} \cdot \frac{K_i}{K_{avg}}$$

K_i : bin-value

Relevant metrics

- MIPS
- Benchmark score
- **Launch price**
- ... ?



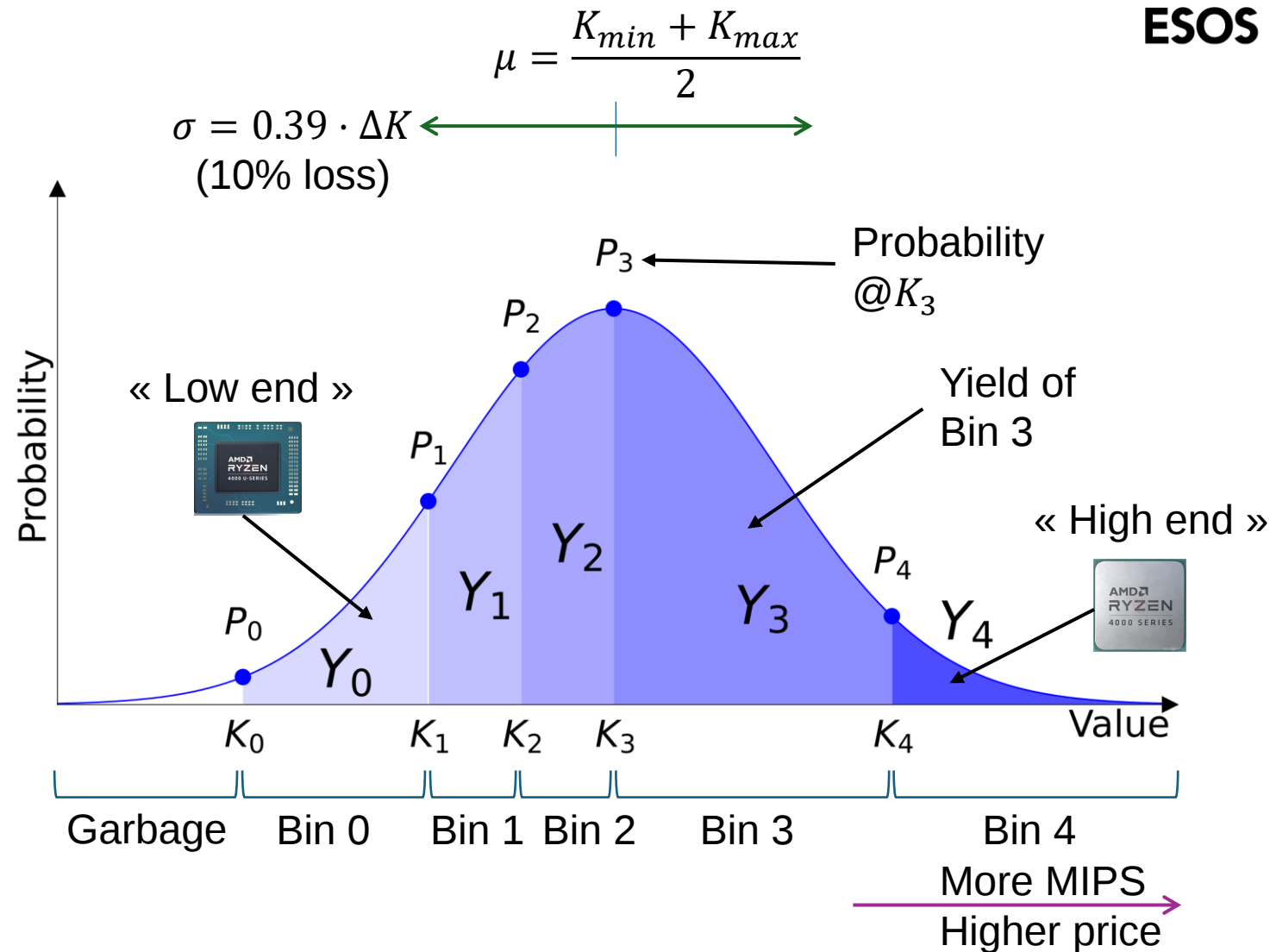


Bins don't have the same size !

$$C_i = C_{avg} \cdot \frac{K_i}{\sum K_i \cdot Y_i}$$

↓
Bin yield

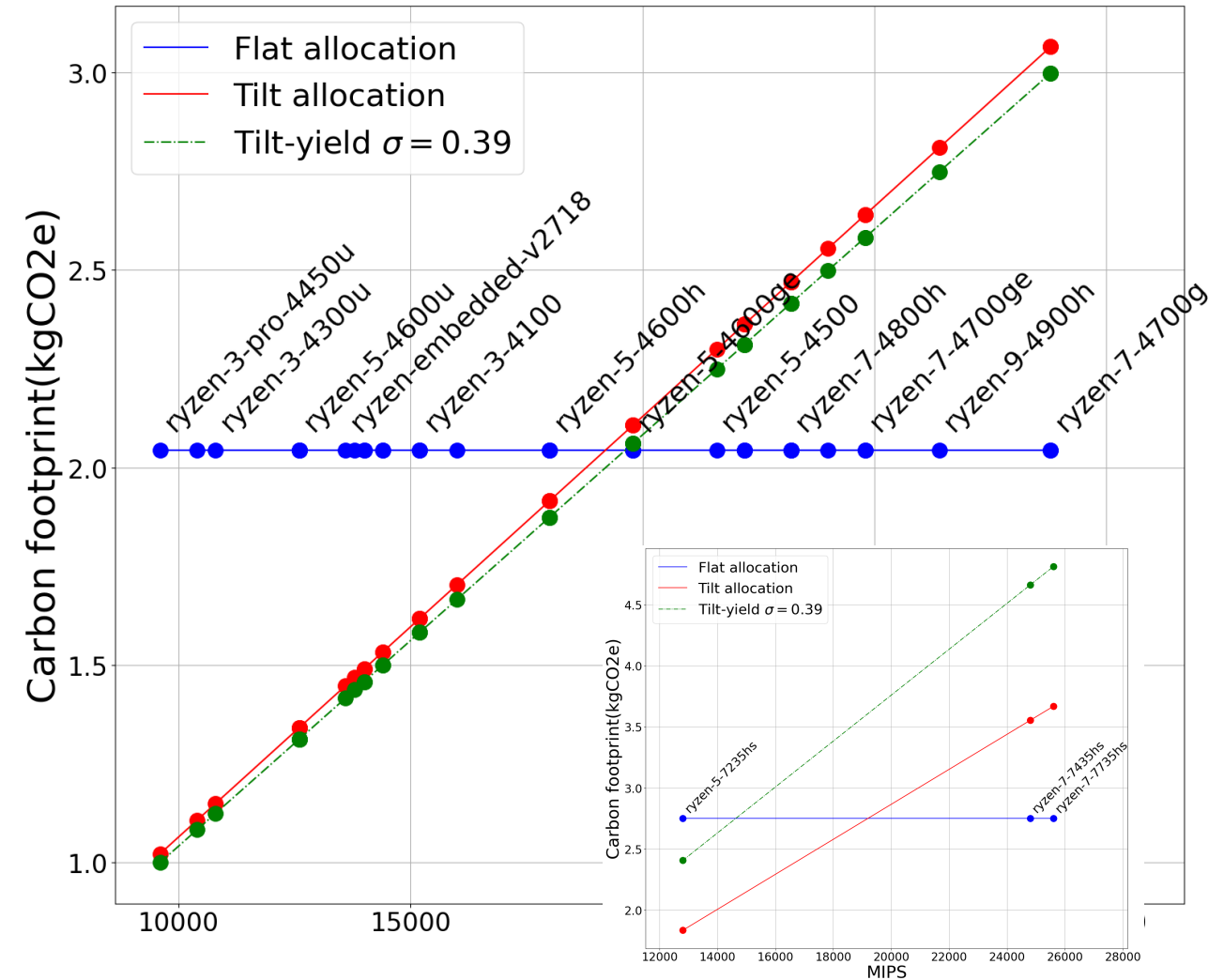
“Tilt-yield”



“Tilt-yield” Results

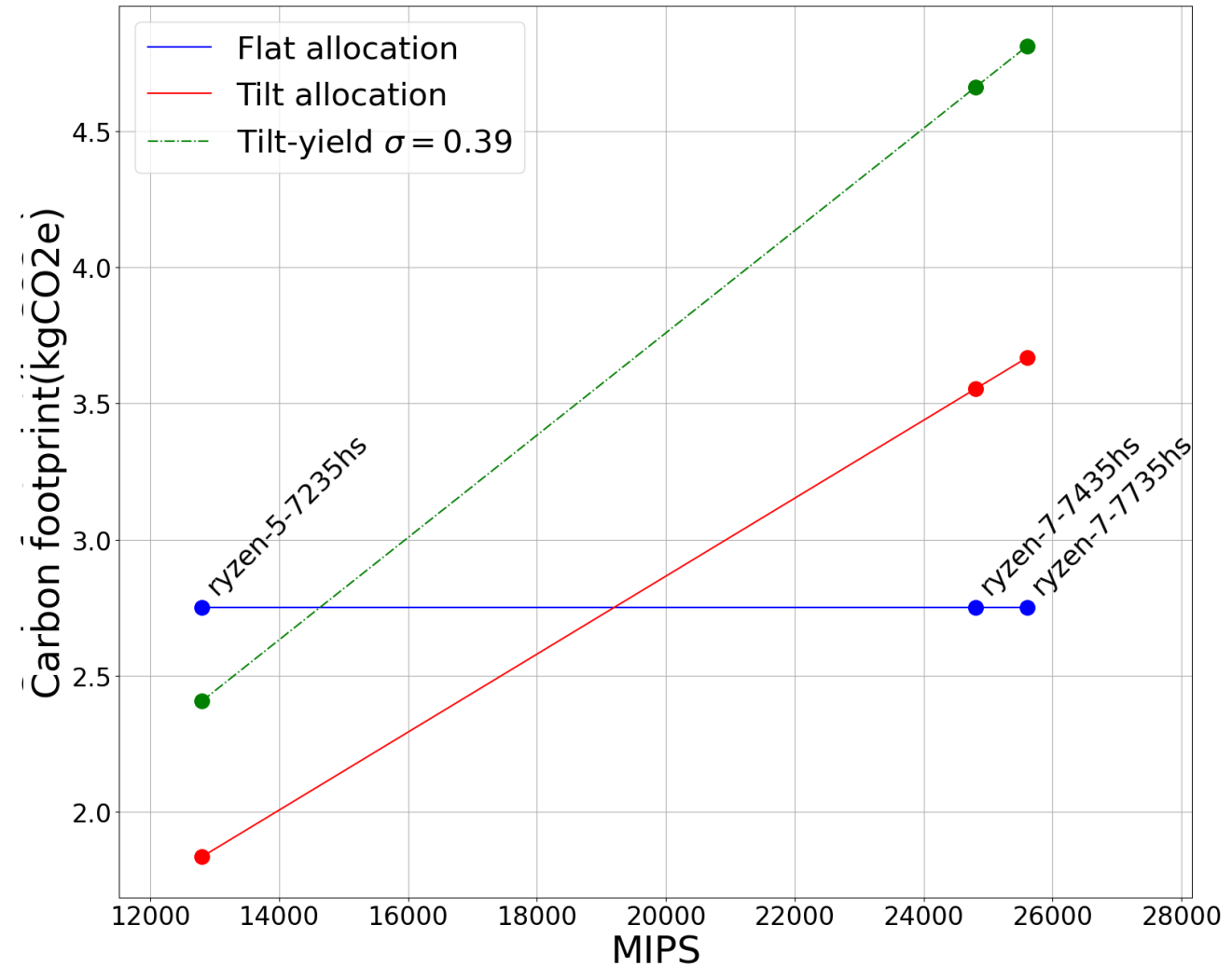
“Tilt-yield” model:

- Sensitive to yield hypothesis
- Depends on series distribution



“Tilt-yield” model:

- Sensitive to yield **hypothesis**
- Depends on series distribution

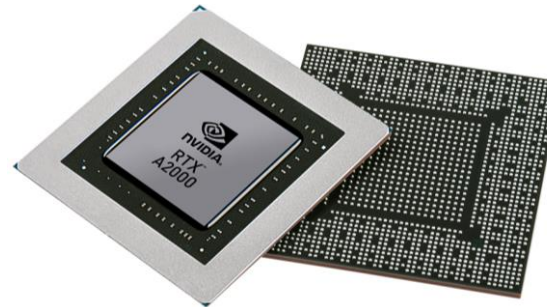


We propose new models for CPU embodied carbon
“Tilt” model: operational model for IC **co-production**
Available results: <https://gitlab.insa-rennes.fr/esos/cpuallocation>



Extensible to other circuits:

- GPUs
- FPGAs
- NPUs ?

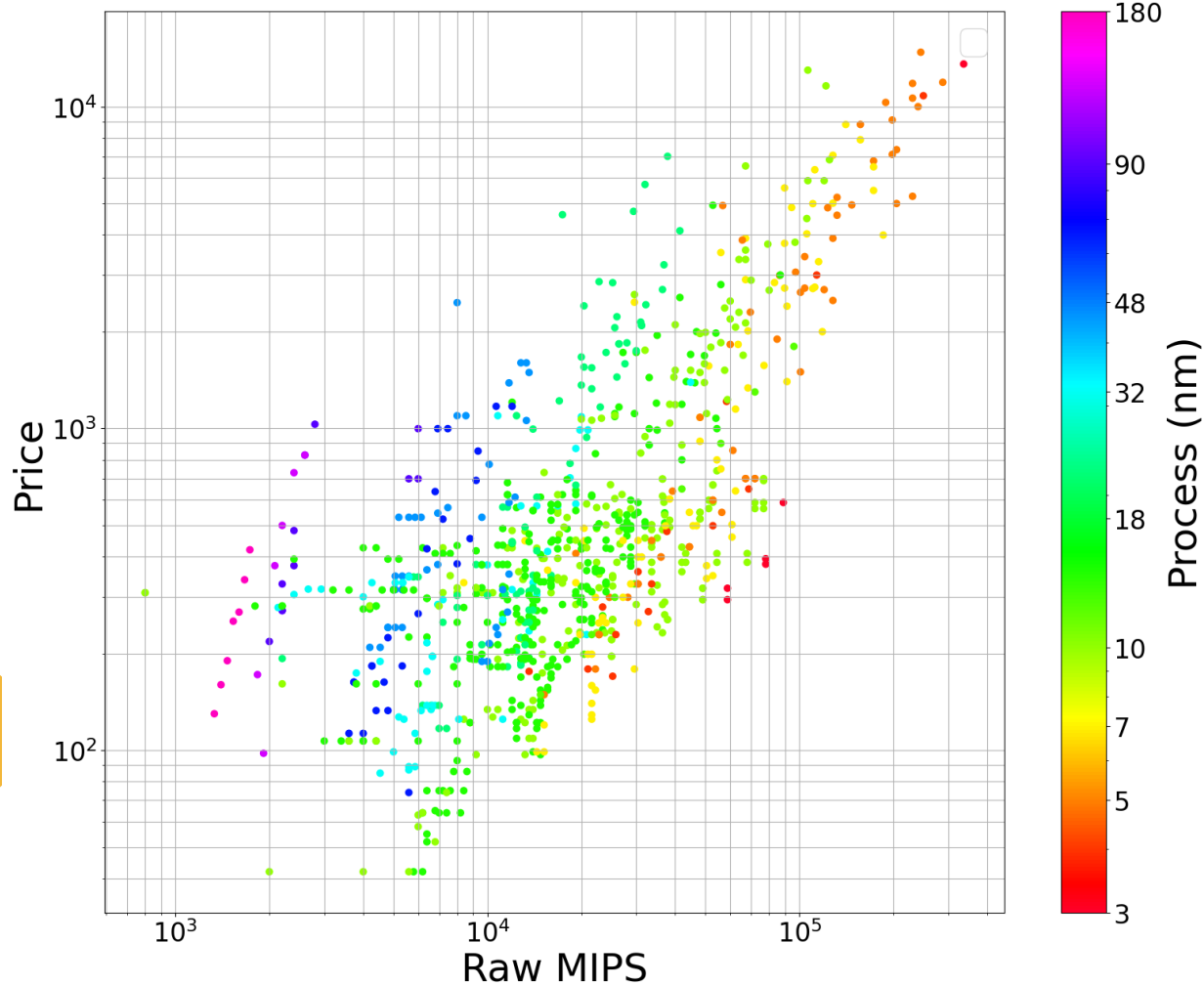


The background of the image is a vibrant, futuristic cityscape. The city is built upon a glowing, green circuit board that serves as the ground. The buildings are tall, slender, and green, with some featuring yellow lights. Lush green trees and foliage are integrated into the architecture, growing from the tops of buildings and along the circuitry. The overall color palette is dominated by greens and yellows, with a dark, teal background. The scene is illuminated with a warm, golden light, creating a sense of energy and innovation.

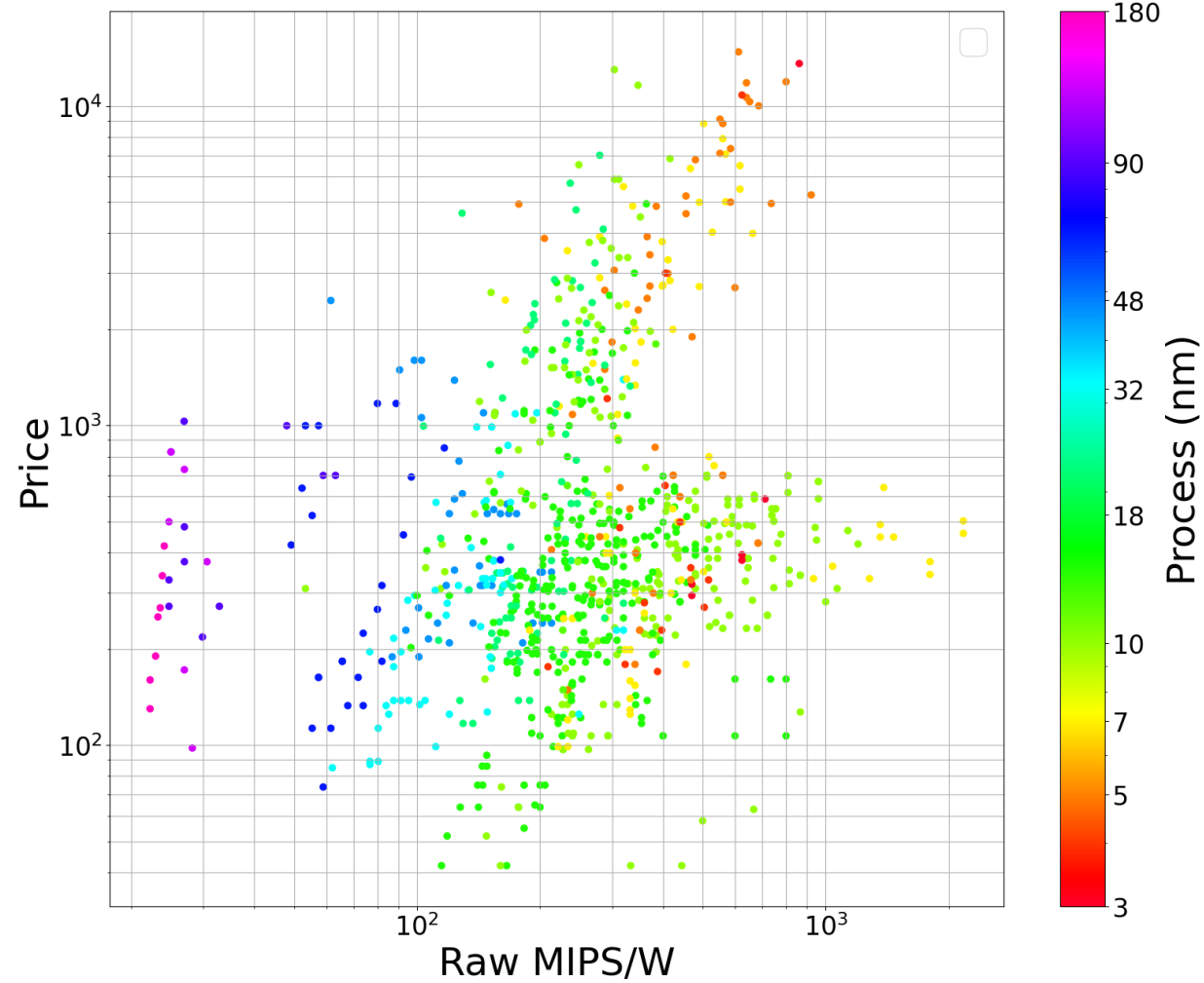
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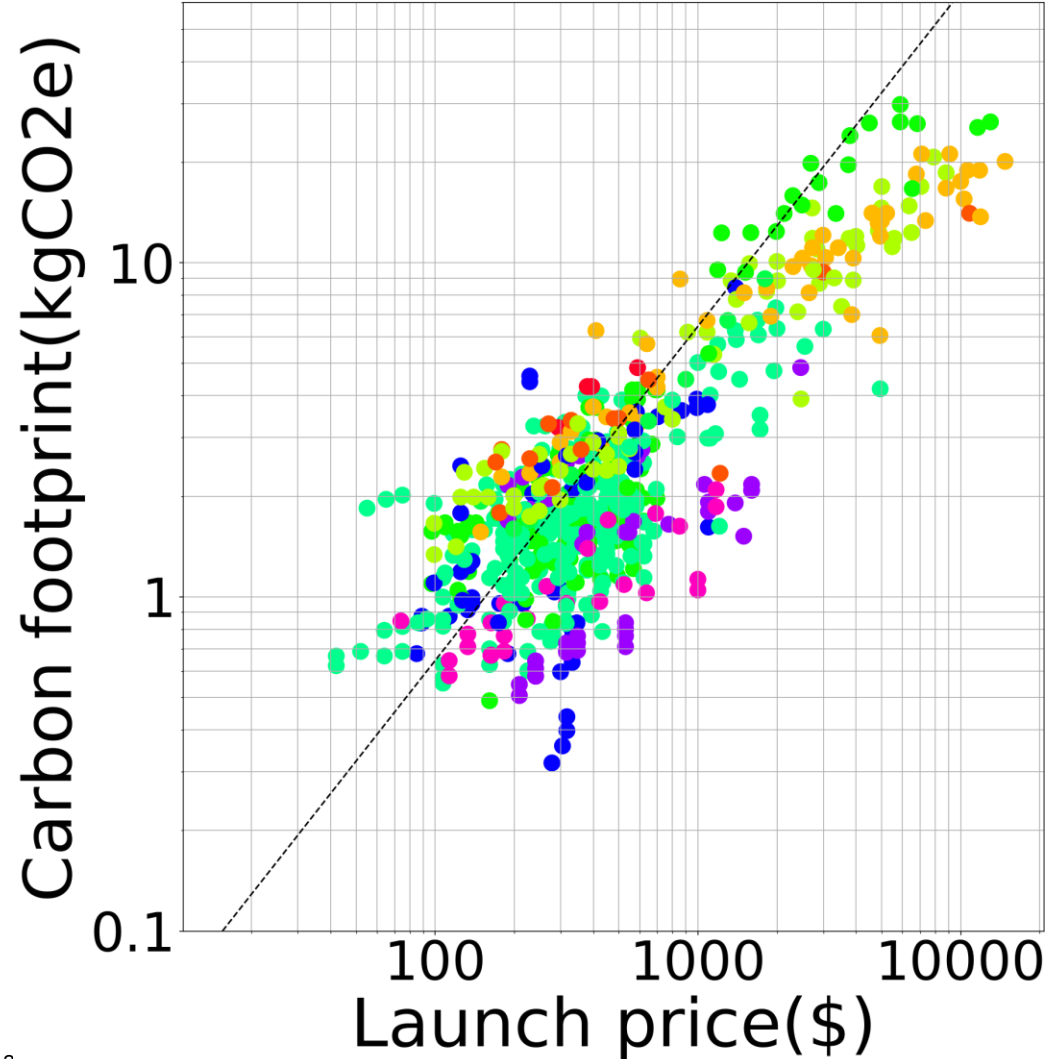
Correlation: 0.84



Correlation: 0.17



MIPS-based allocation



Price-based allocation

