Carbon Topography Representation: Improving Impacts of Data Center Lifecycle

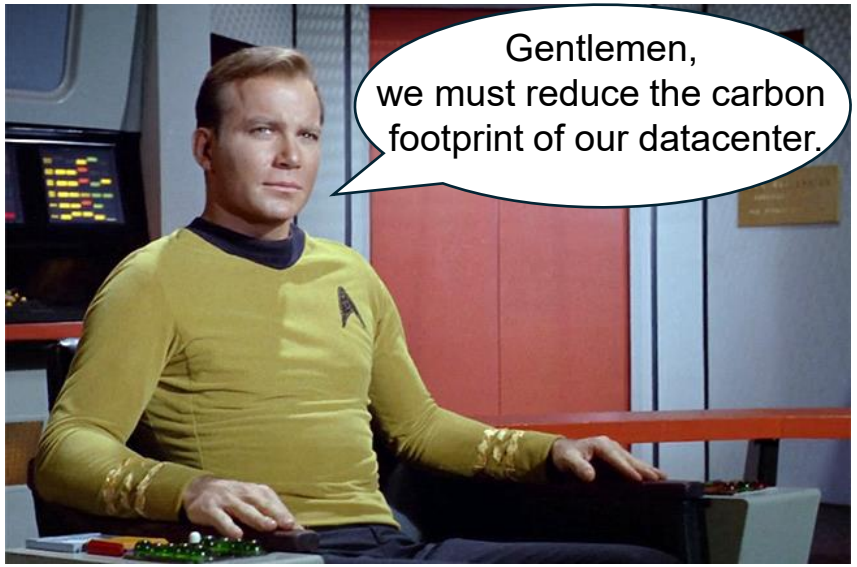
Olivier Weppe, Thibaut Marty, Jean-Christophe Prévotet, Maxime Pelcat: **INSA Rennes**

Louise Aubet: **Resilio**

David Bekri, Loïc Guibert, Sebastien Rumley: **HES-SO**

HotCarbon, 2025-07-11, Cambridge, MA

Context

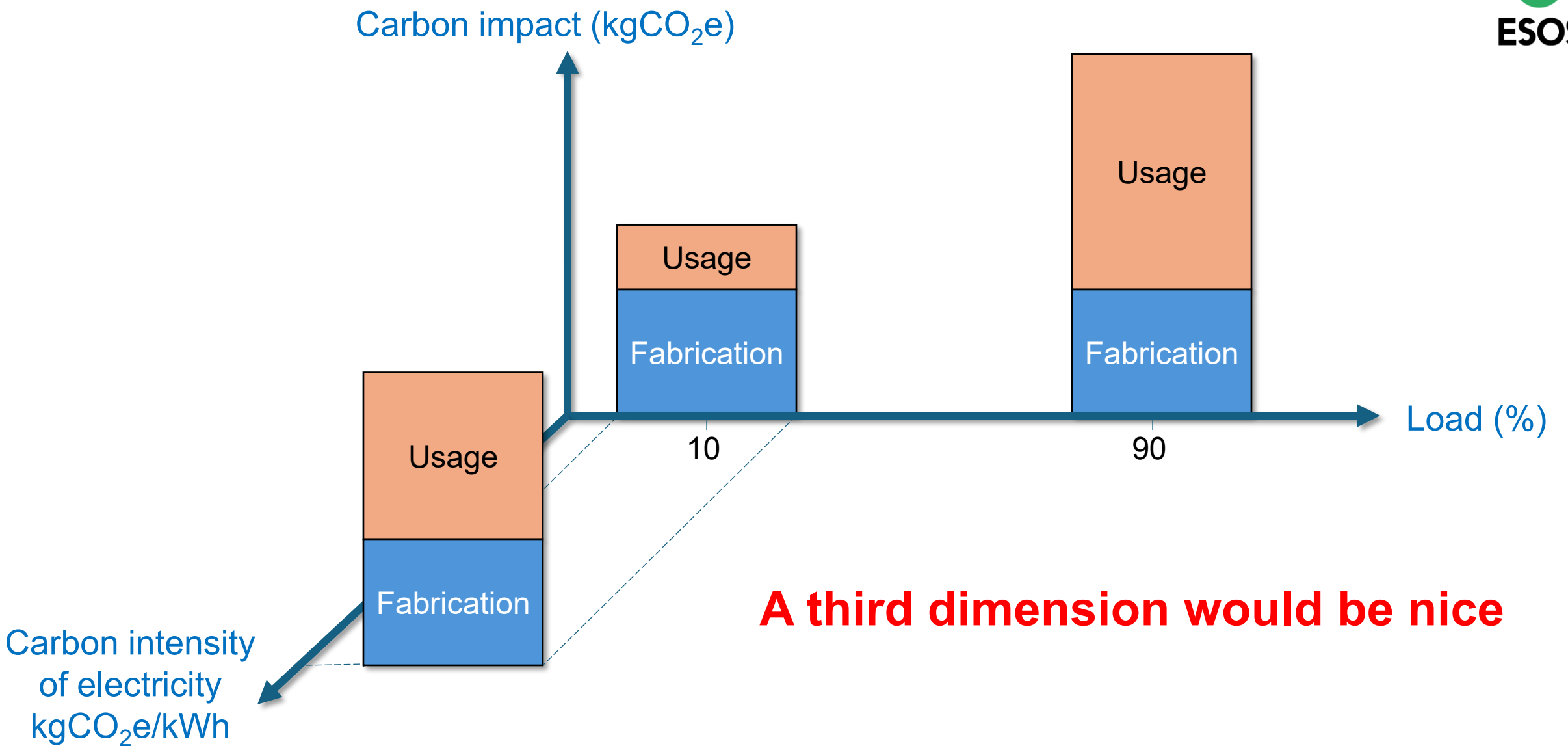


Who is right?

I believe this pollution is caused by Scotty's **server manufacturing**.

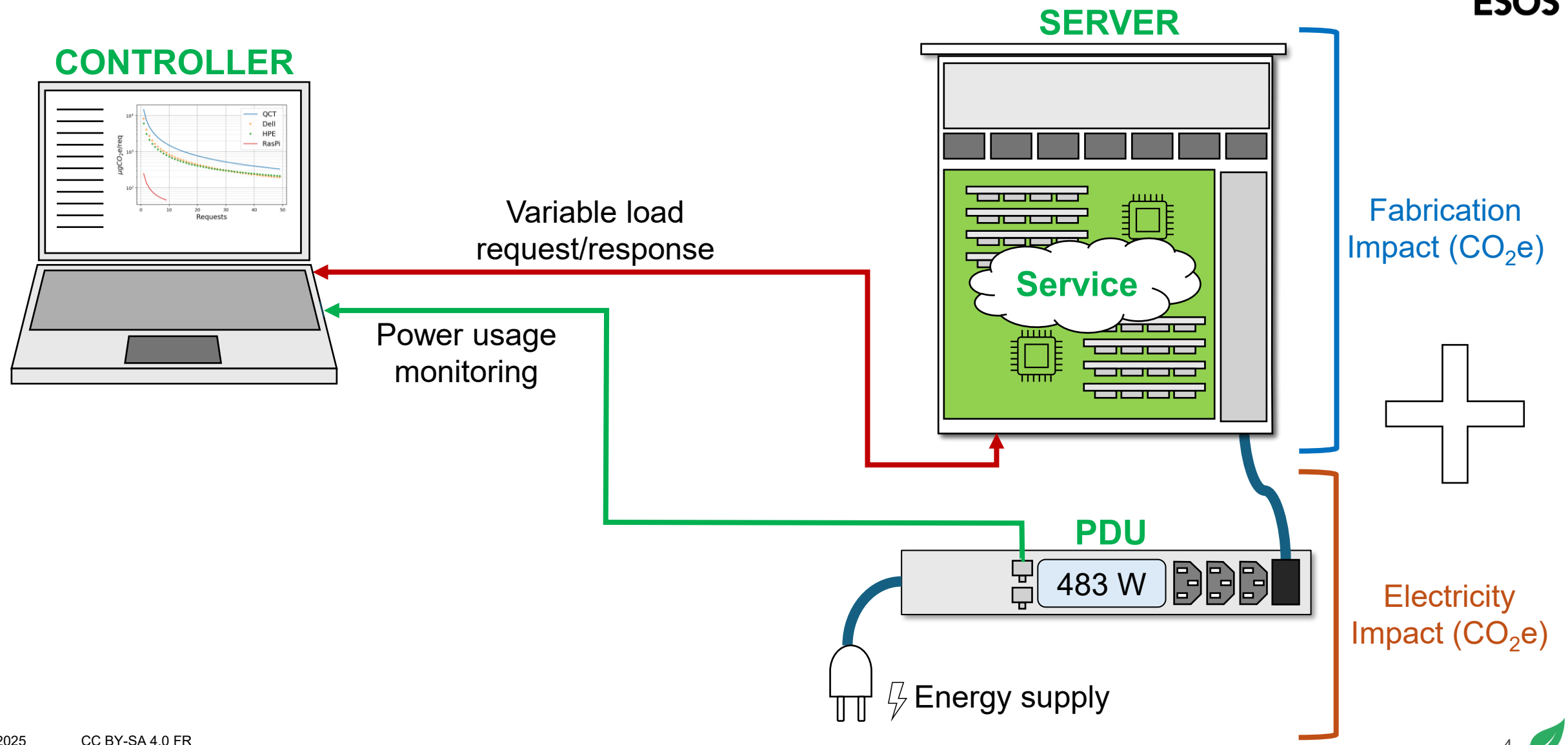
No, it is running Spock's **programs** that drains humongous amounts of **electricity**!

Quick answer: It depends…



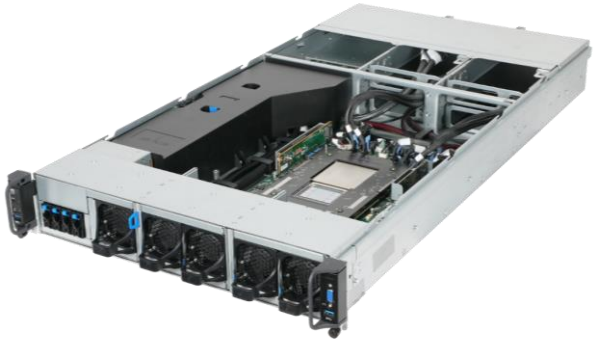
A third dimension would be nice

How to decide: experiment



Author : Olivier WEPPE

Setup: hardware platforms



QuantaGrid S74G-2U (QCT)
2024
ARM64
800 req/s

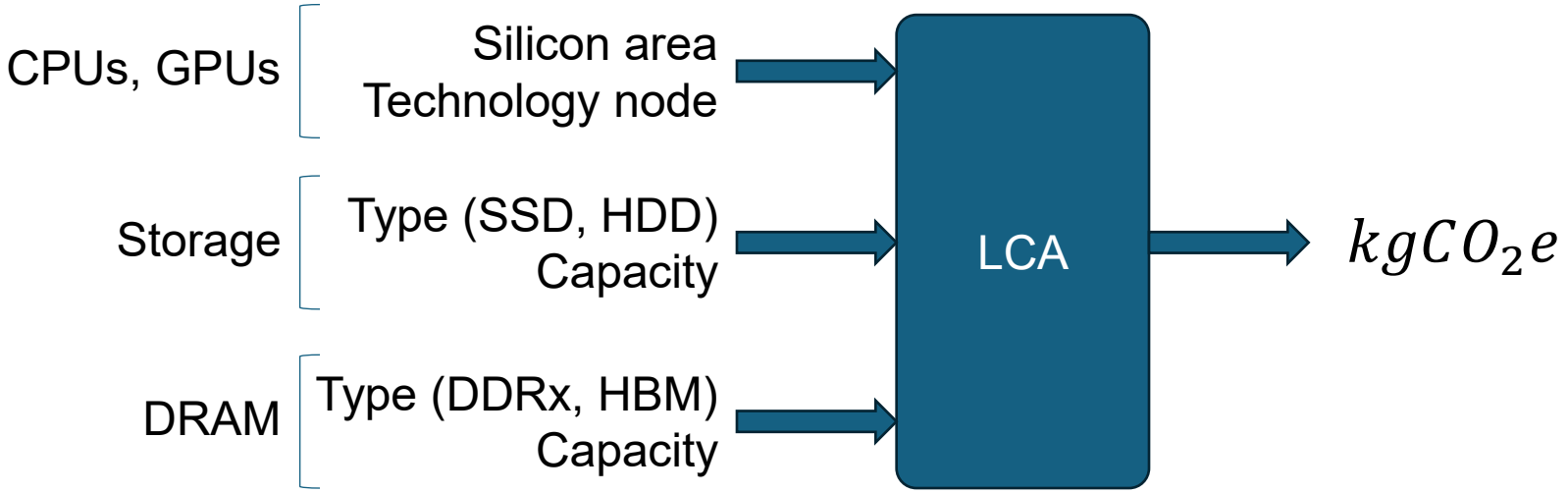
PowerEdge T430 (Dell)
2015
x86_64
200 req/s

ProLiant DL360 Gen9 (HPE)
2015
x86_64
120 req/s

Raspberry Pi 4B
2019
ARM64
2 req/s

Embodied carbon: Life Cycle Analysis methodology

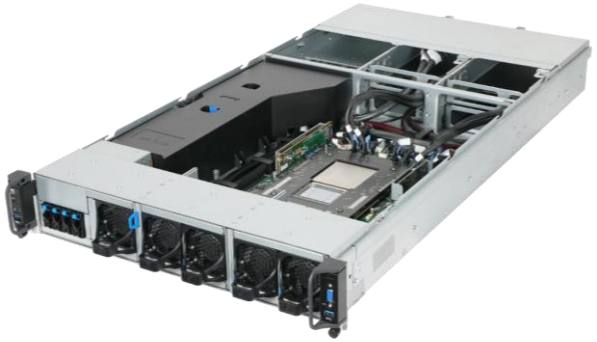
Simplified carbon footprint estimation = Streamlined methodology*



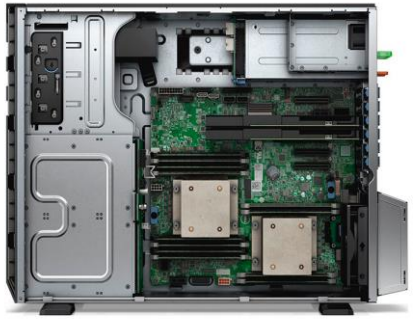
* Except for Raspberry Pi, found in litterature

Philippe Loubet et al.. 2023. Life cycle assessment of ICT in higher education: a comparison between desktop and single-board computers.

Embodied carbon: results



QuantaGrid S74G-2U (QCT)
2024
ARM64
500 req/s
1023 kgCO_2e

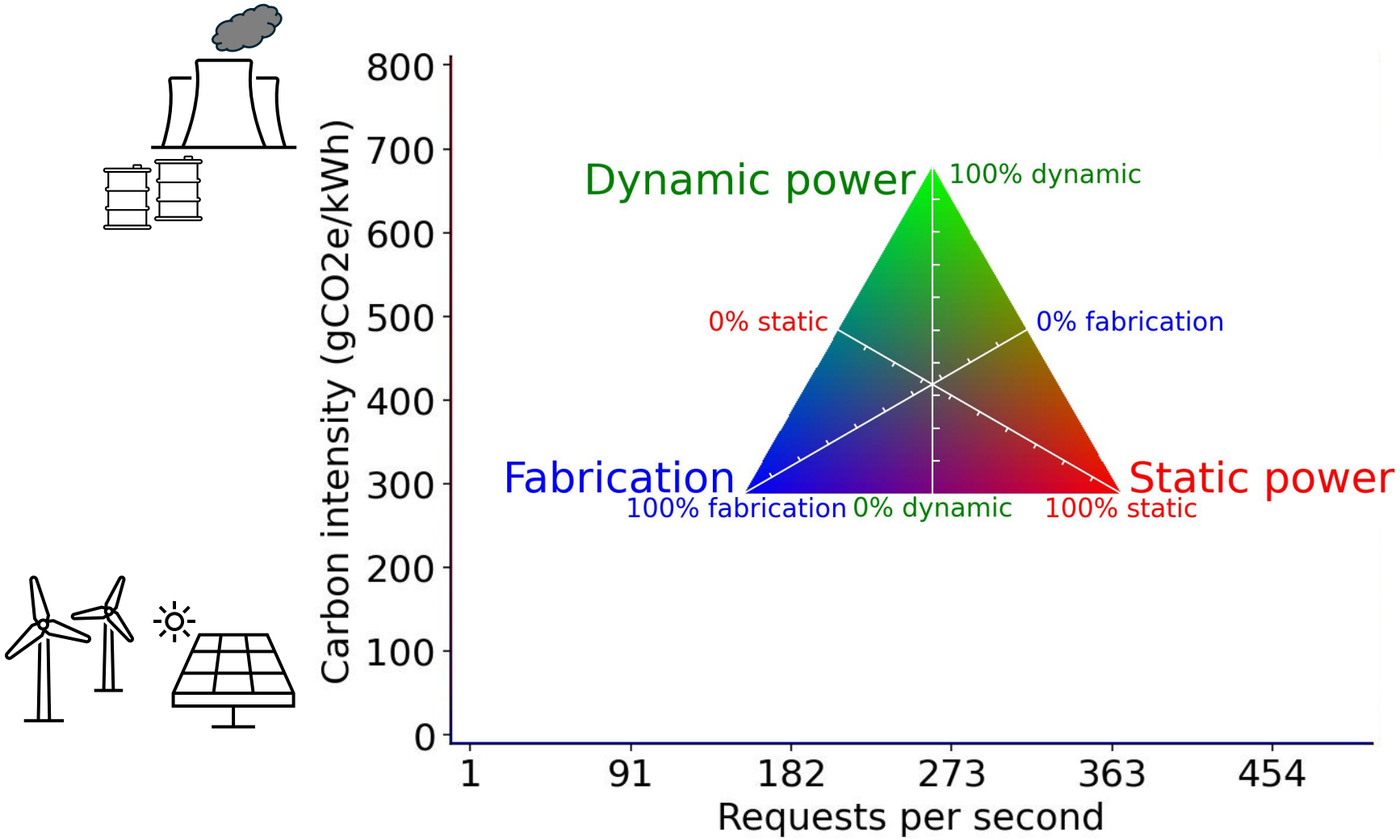


PowerEdge T430 (Dell)
2015
x86_64
200 req/s
514 kgCO_2e

ProLiant DL360 Gen9 (HPE)
2015
x86_64
130 req/s
345 kgCO_2e

Raspberry Pi 4B
2019
ARM64
10 req/s
14 kgCO_2e

Carbon Topography representation



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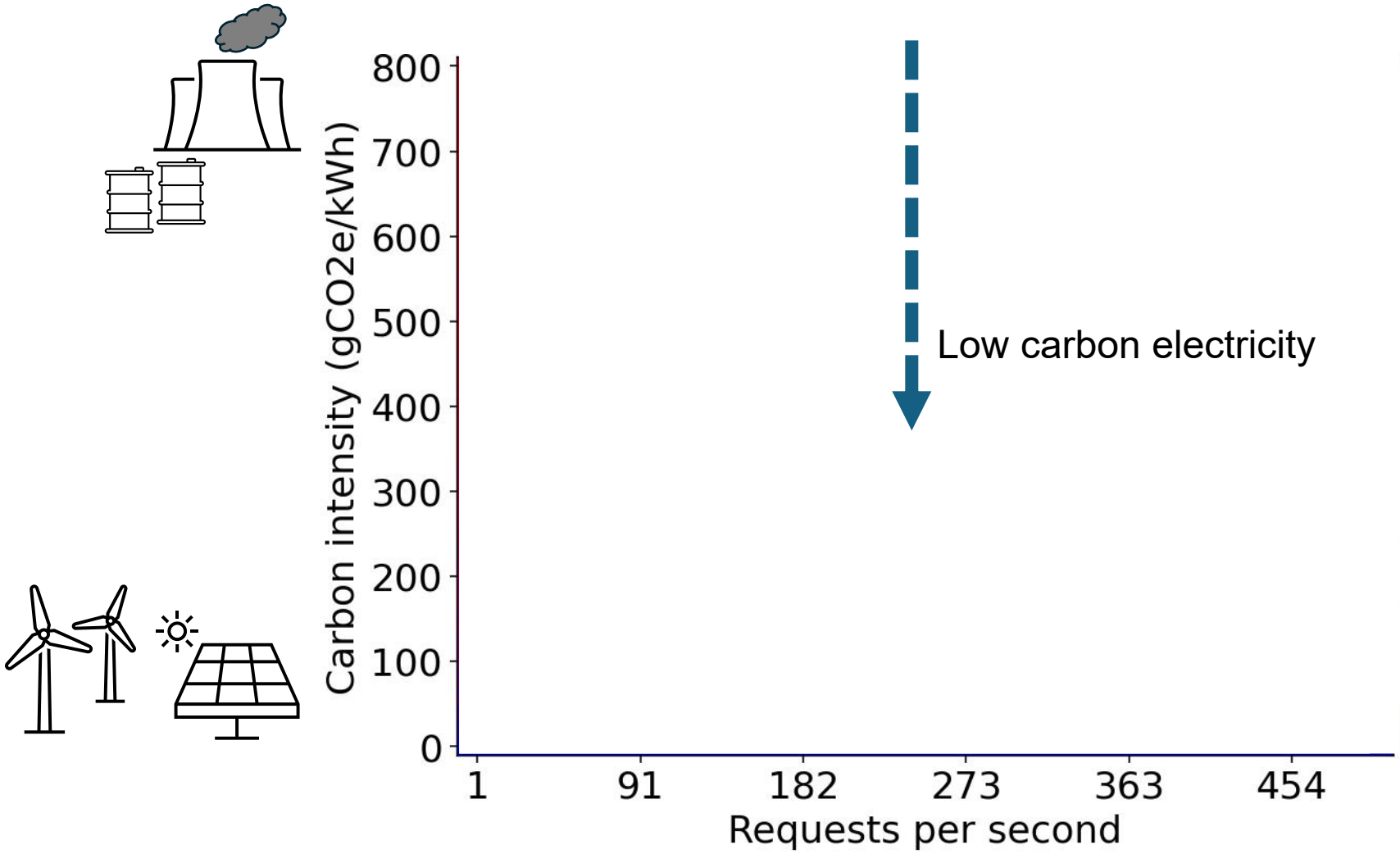
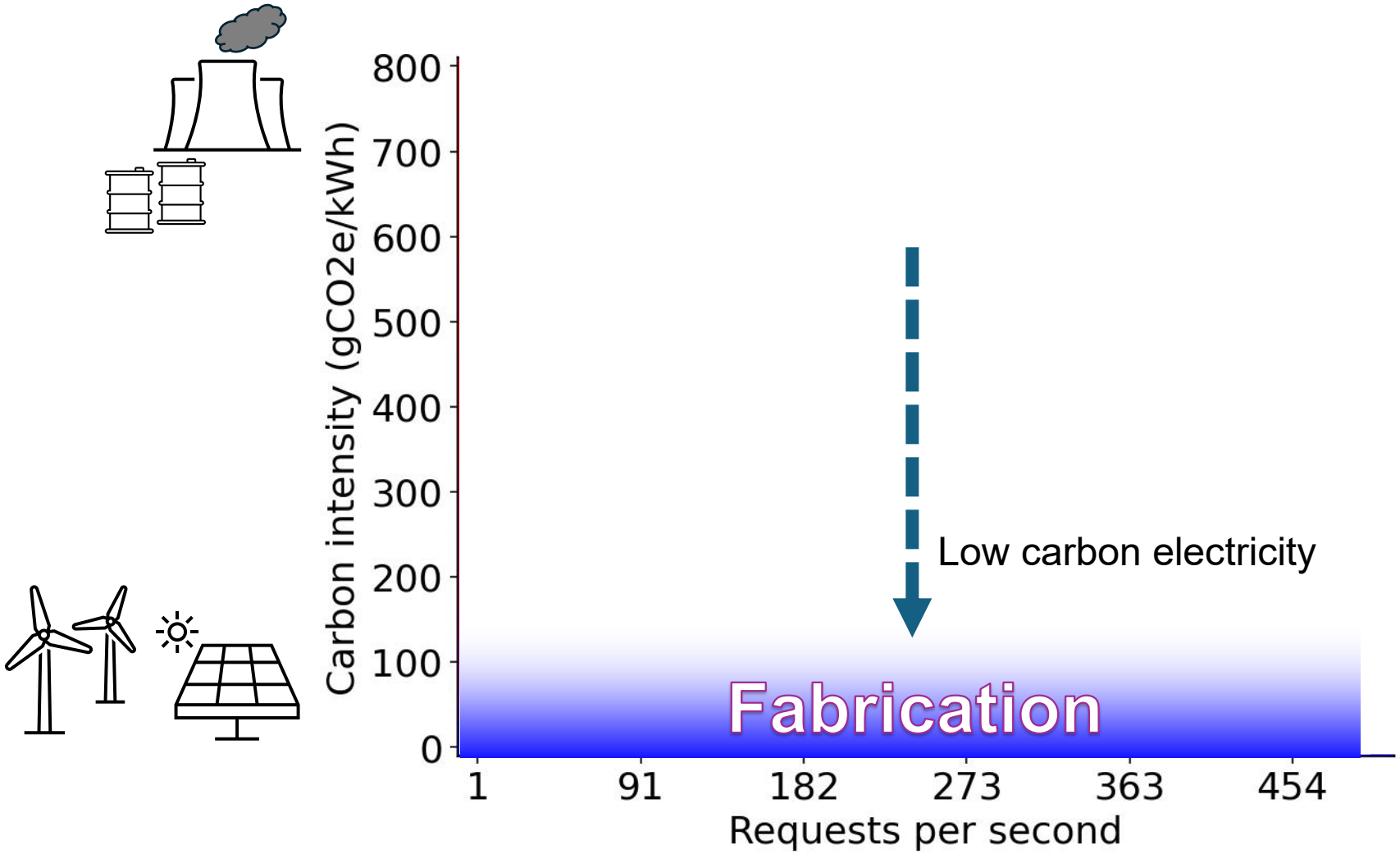


Carbon Topography representation



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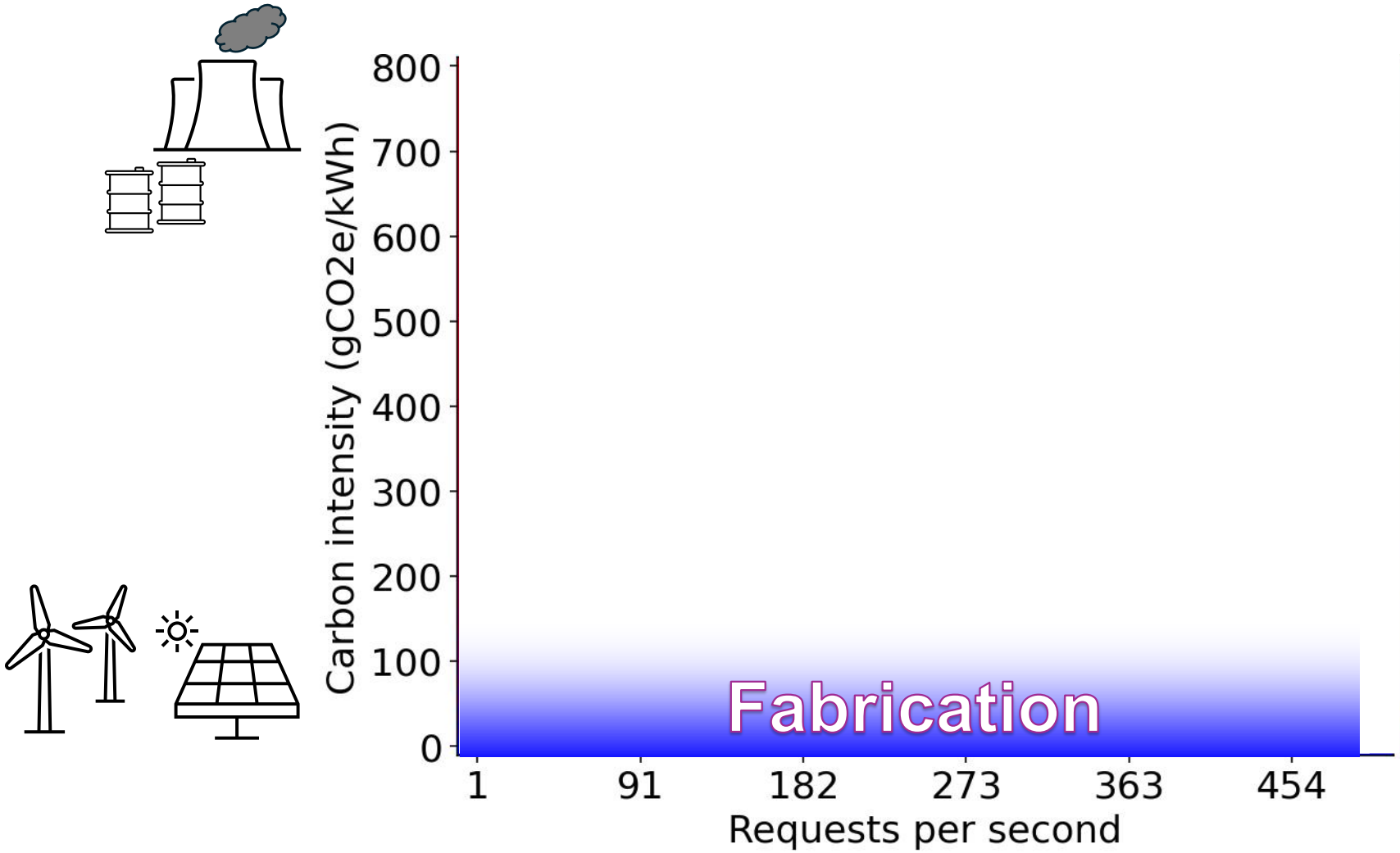

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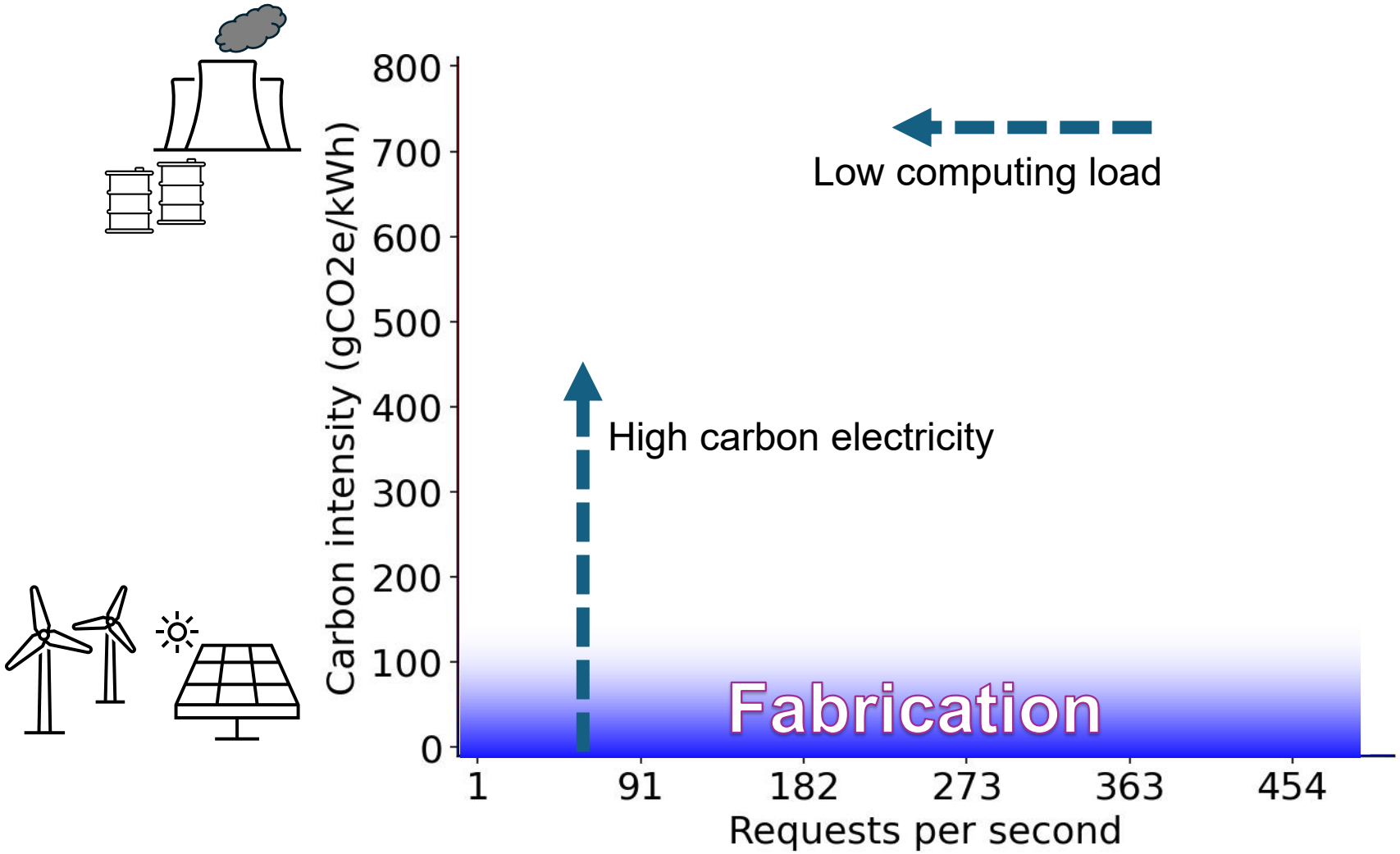

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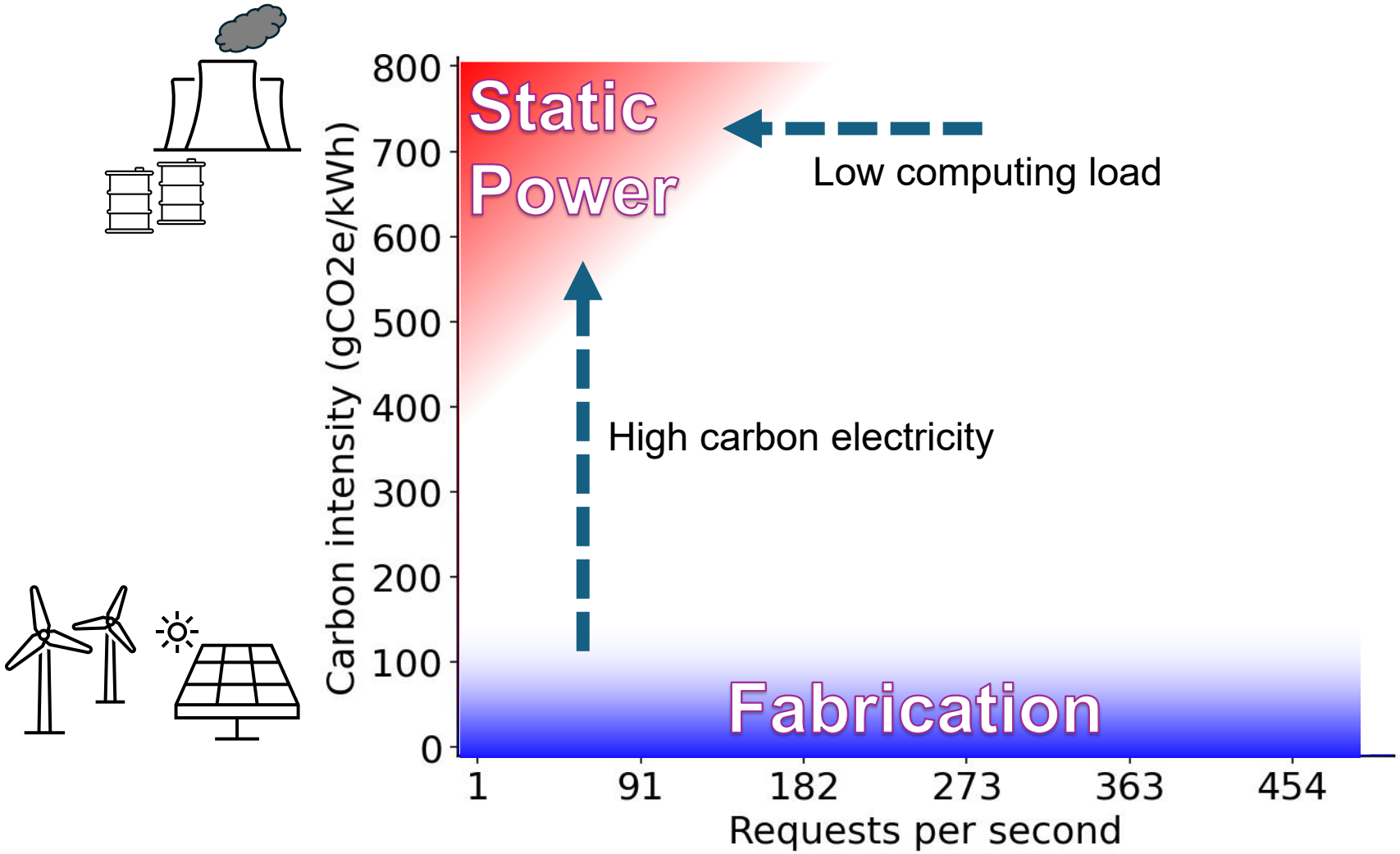
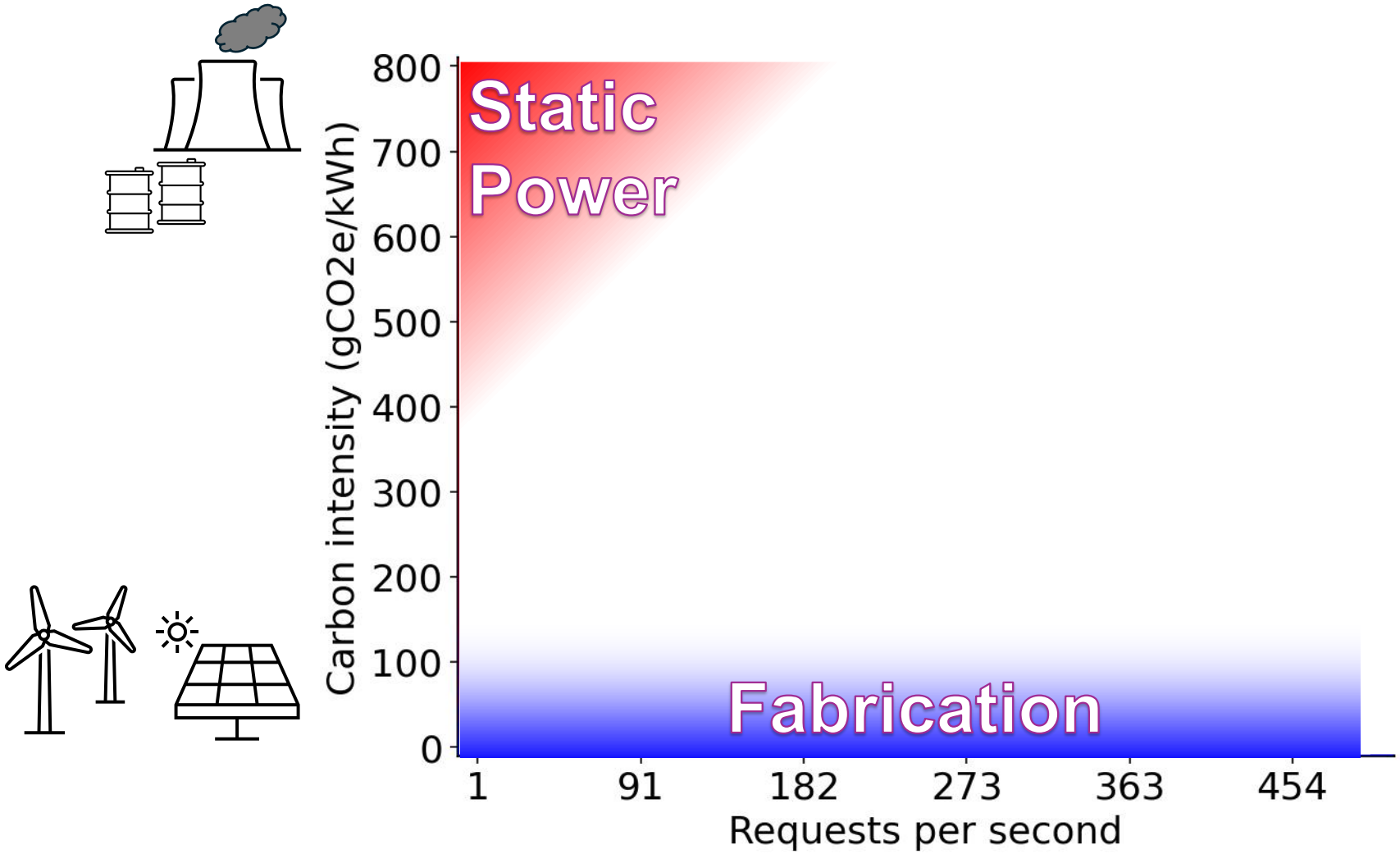
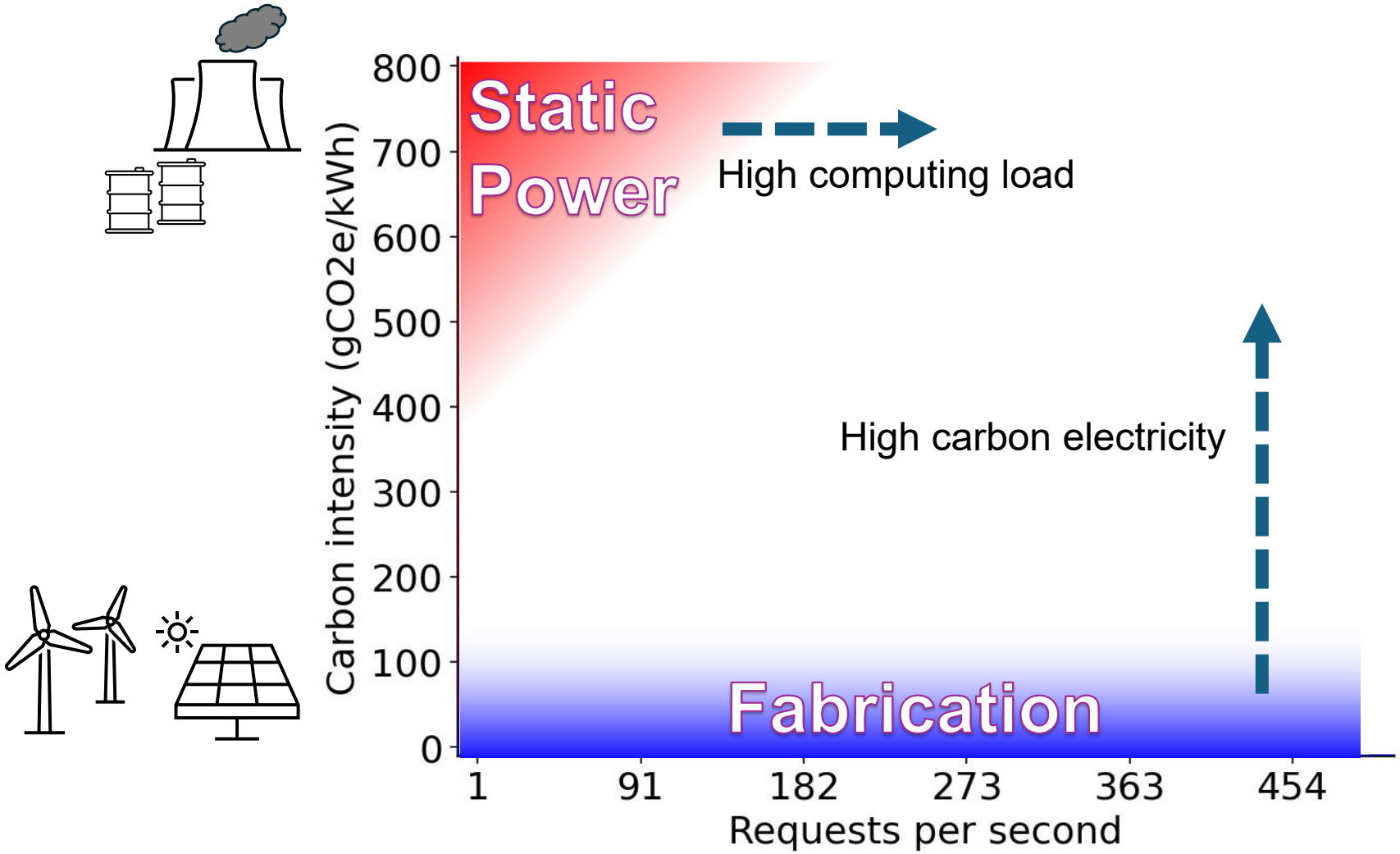


Carbon Topography representation



Carbon Topography representation



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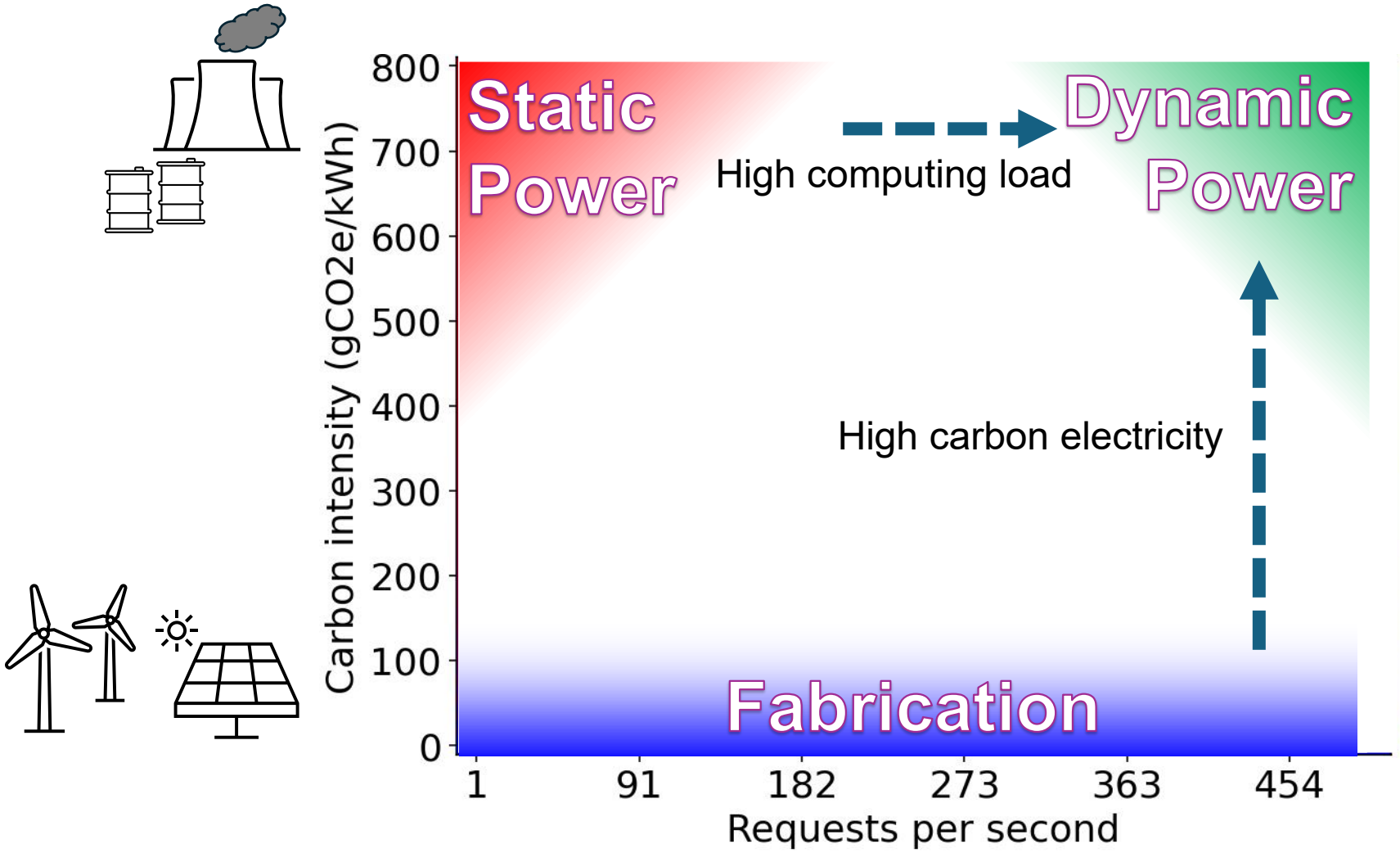

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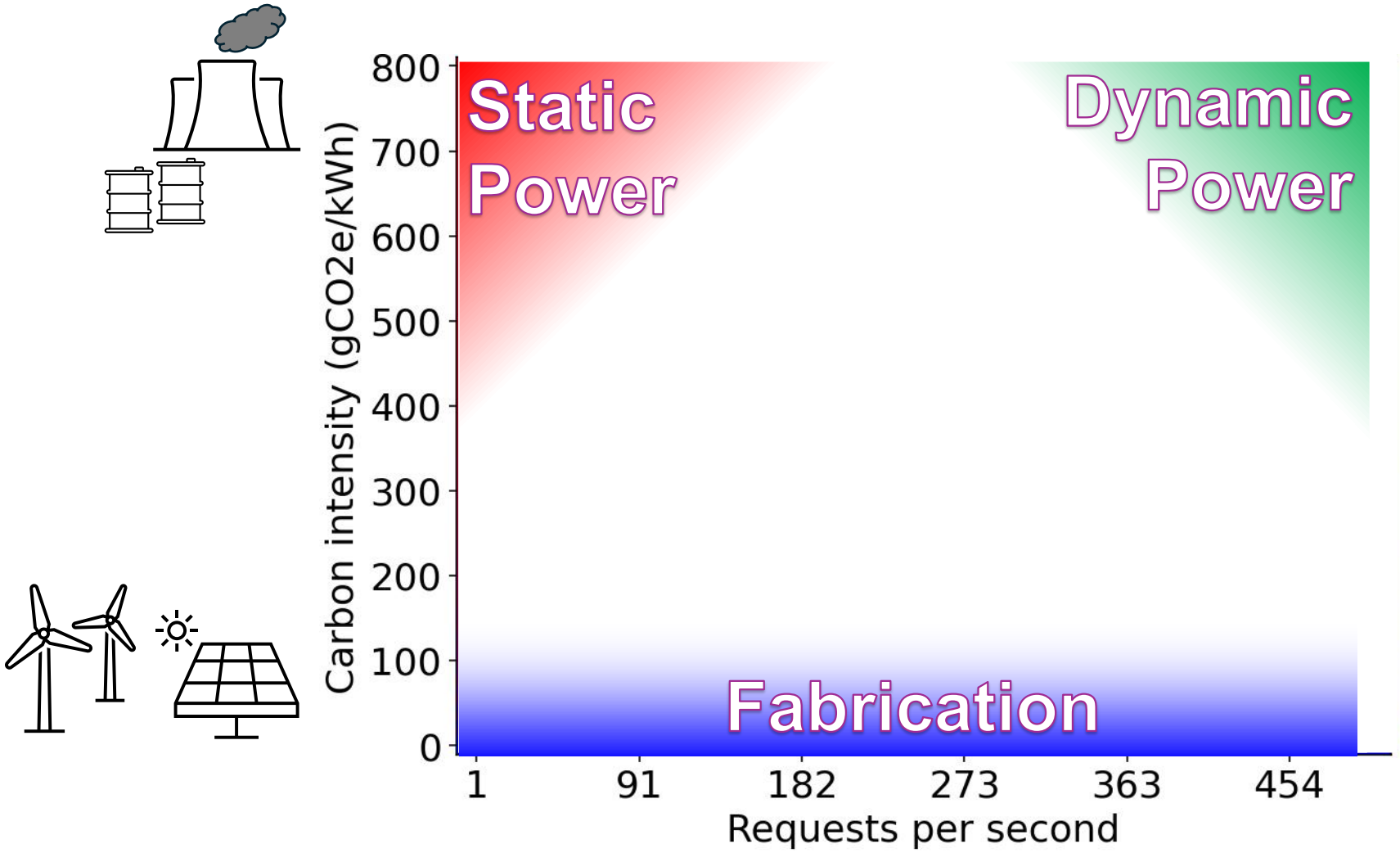
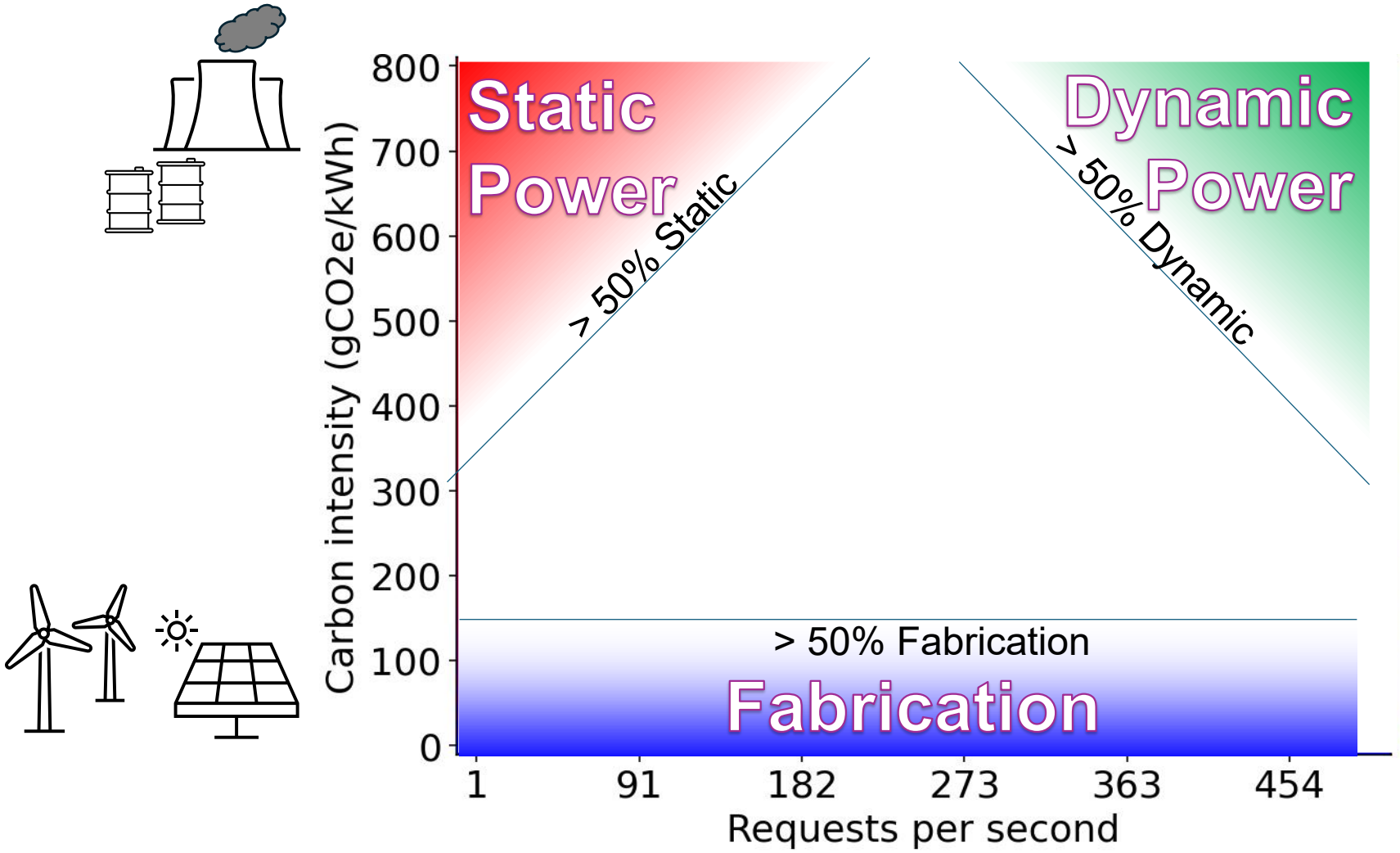


Carbon Topography representation



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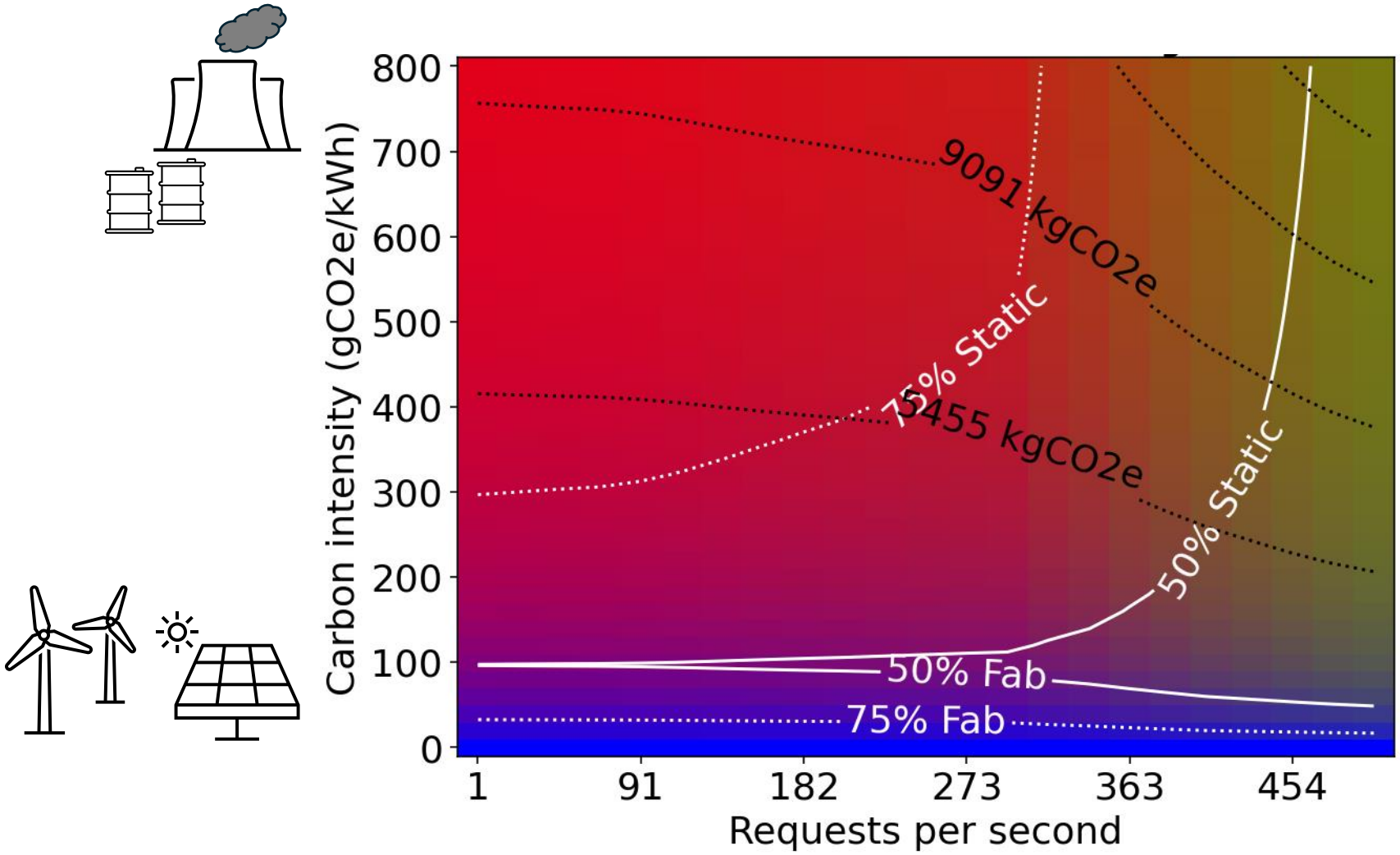
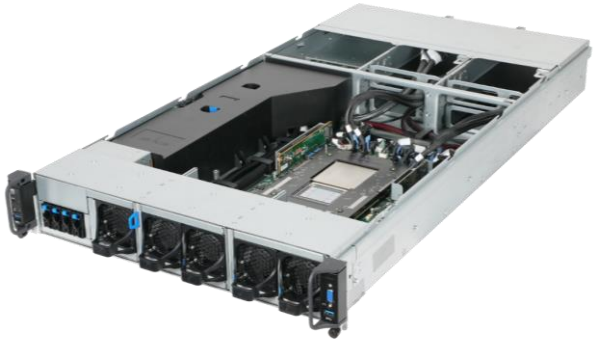
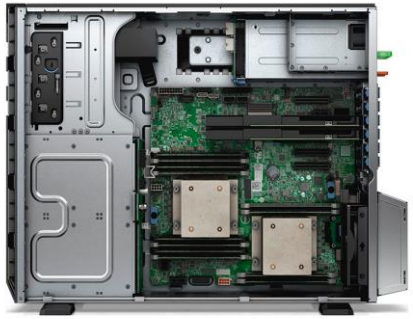


Results (5 years lifetime)



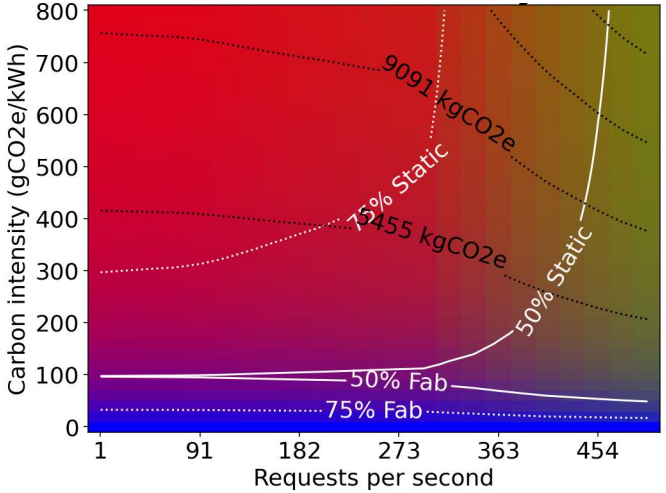
QuantaGrid S74G-2U (QCT)
ARM64
2024



PowerEdge T430 (Dell)
x86_64
2015

ProLiant DL360 Gen9 (HPE)
x86_64
2015

Raspberry Pi 4B
ARM64
2019



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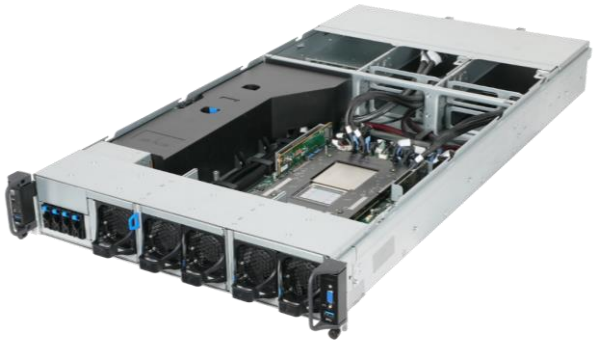

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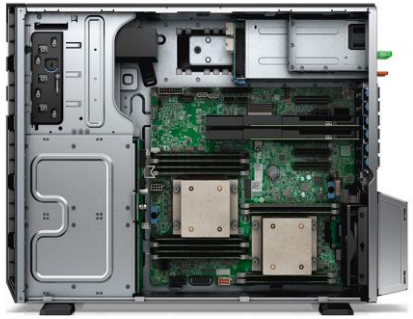

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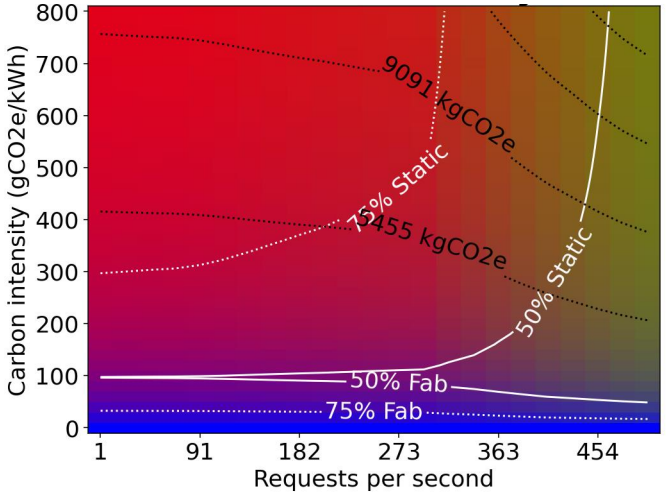
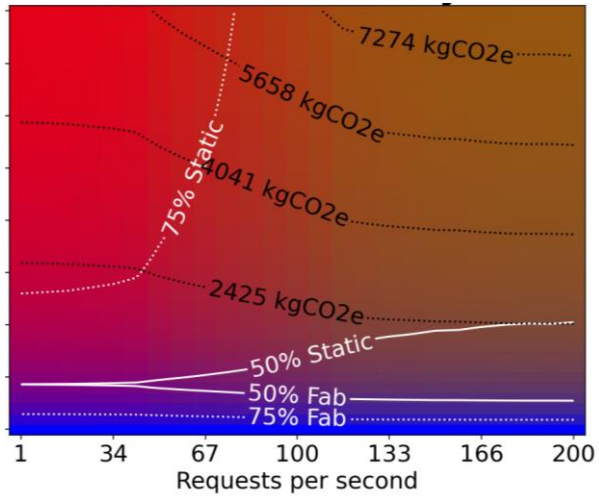
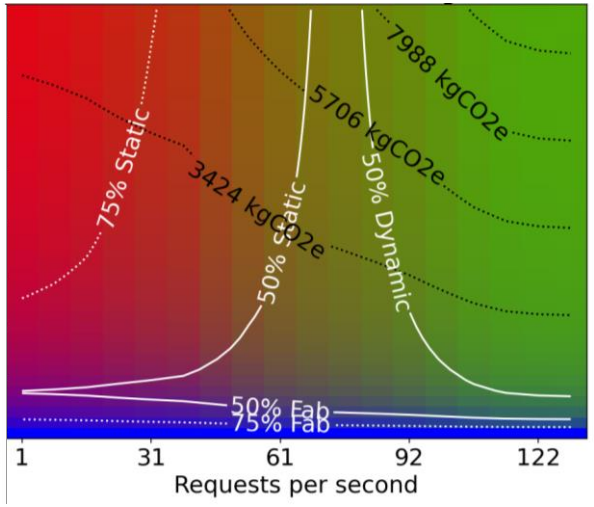
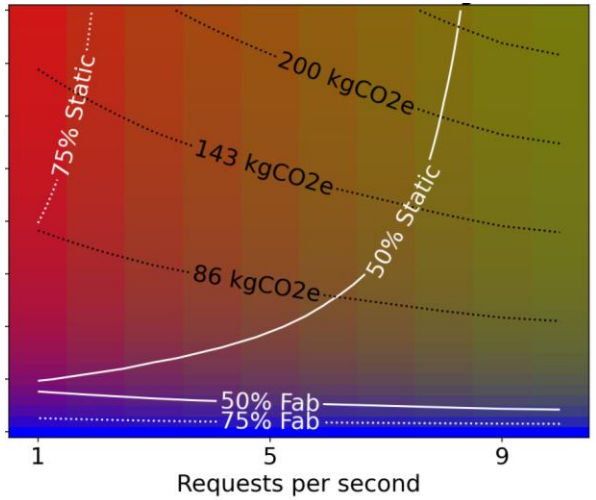






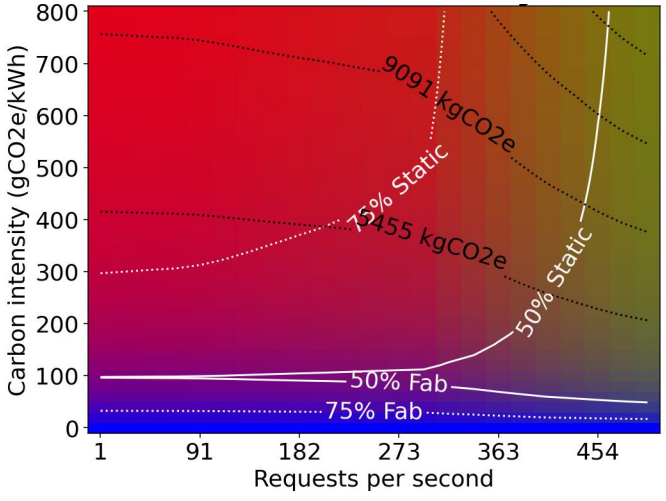


Results: Interpretation

Blue is scarce: Fabrication only dominates when electricity is very low carbon

Red dominance: High Idle power consumption

QuantaGrid S74G-2U (QCT)
ARM64
2024



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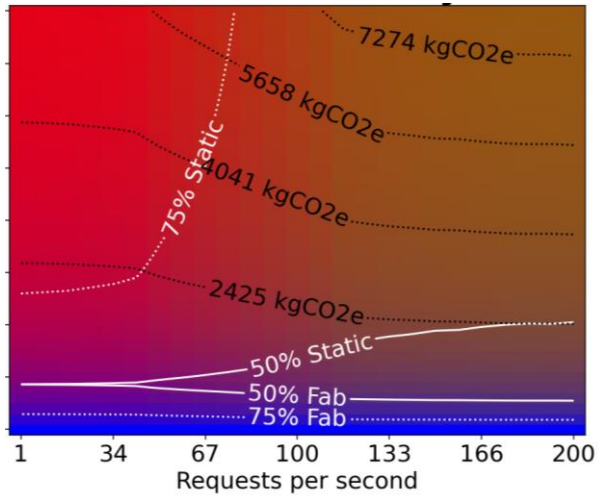

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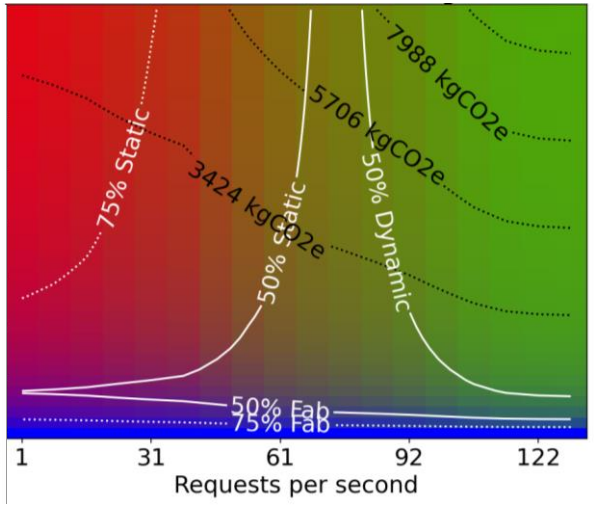
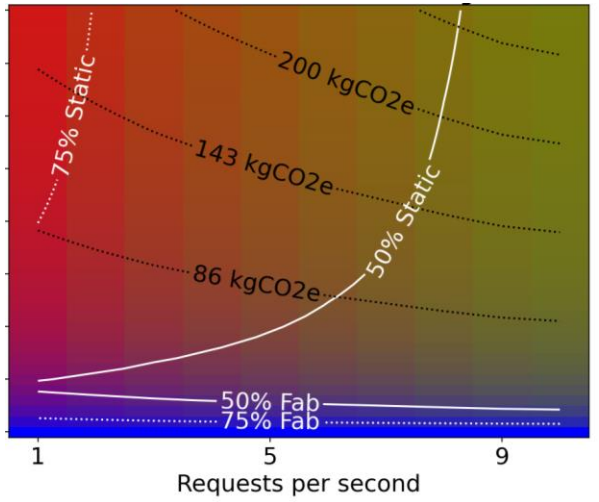


Raspberry Pi 4B
ARM64
2019



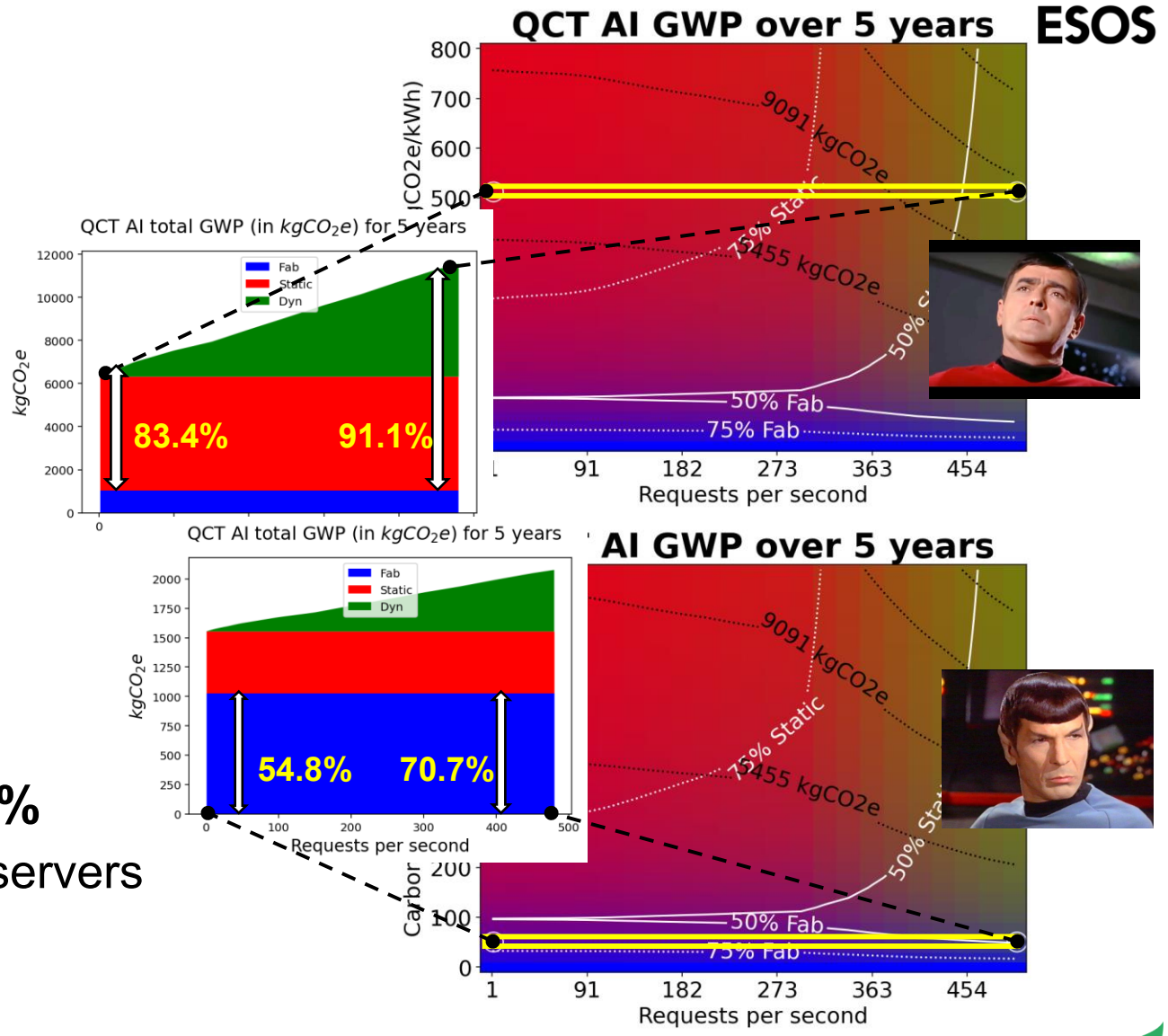
Take away: Carbon accounting

- High carbon electricity:
  @$500gCO_2e/kWh$, during 5 years

  ➔**Usage** between **83.4% and 91.1%**
  - ➢ impact driven by power usage

- Low carbon electricity:
  @$40gCO_2e/kWh$, during 5 years

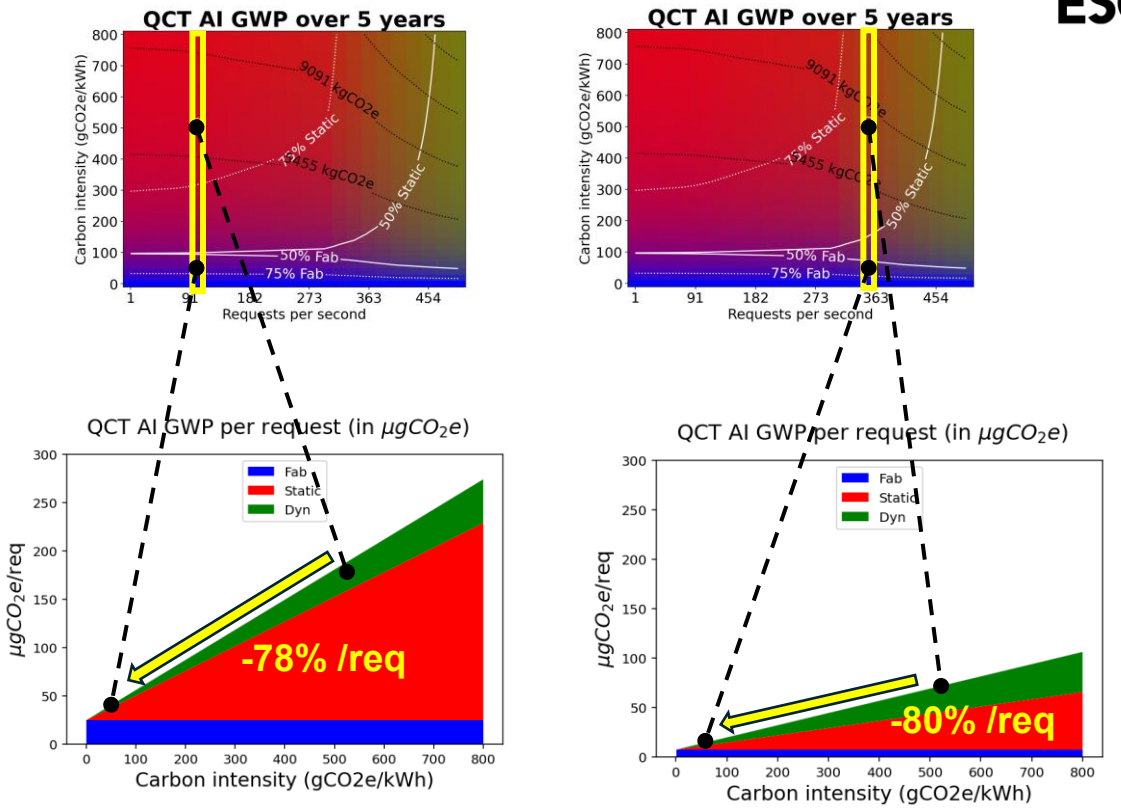
➔ **Fabrication** between **54.8% and 70.7%**
- ➢ impact mainly driven by the number of servers



Take away: Optimization strategies

1. High Carbon electricity: <u>use low carbon energy</u>
   Ex: $500\ gCO_2e/kWh \rightarrow 50\ gCO_2e/kWh$

   - At 20% load:
     $-121\ \mu gCO_2e$ /req (**-78%**)
   - At 70% load:
     $-56\ \mu gCO_2e$ /req (**-80%**)



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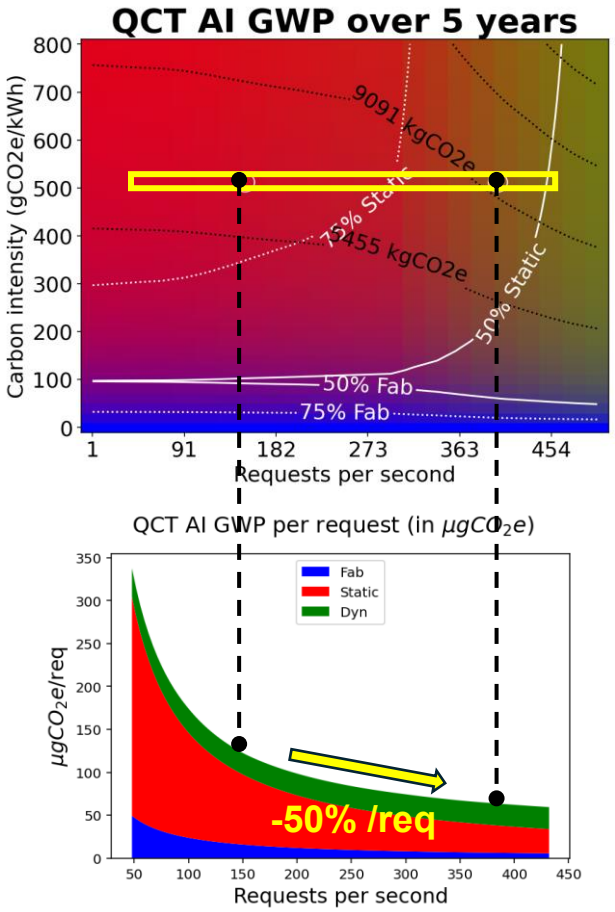
   - At 70% load:
     $-56\ \mu gCO_2e$ /req (**-80%**)

2. If not feasible: maximize server load
   - 30% load to 80% load:
     $-62\ \mu gCO_2e$ /req. (**-50%**)



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2. If not feasible: maximize server load
   - 30% load to 80% load:
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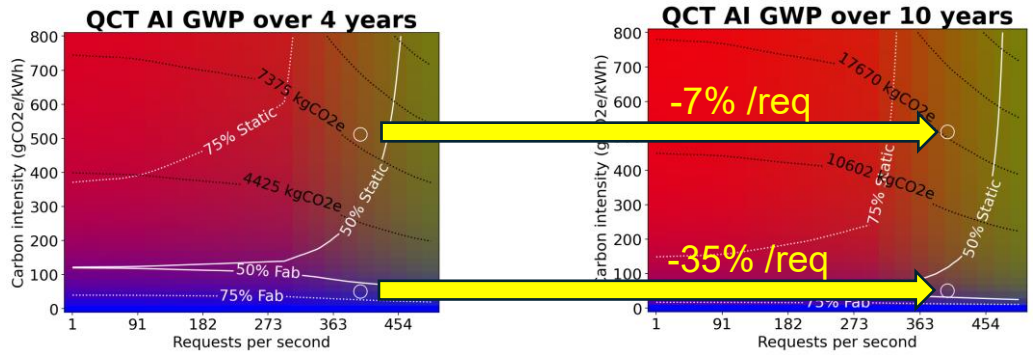
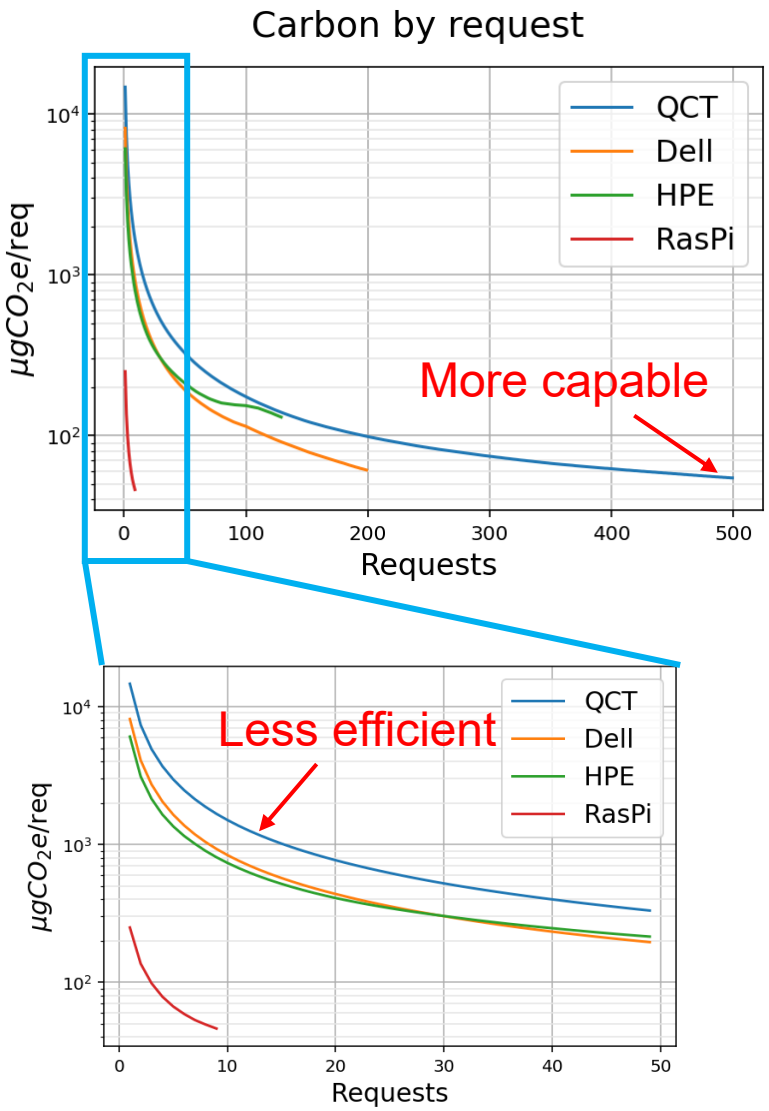
3. Low carbon & high load: increase server lifetime
   Ex: from 4 years lifetime to 10 years lifetime
   - At 80% load with $50 gCO_2e/kWh$:
     $-5.5\ \mu gCO_2e$ /req. (**-35%**)
   - At 80% load with $500 gCO_2e/kWh$:
     $-4.6\ \mu gCO_2e$ /req. (**-7%**)



Final thoughts: What is obsolete ?

- Hardware efficiency gains seems to have stopped
  - ➢ Is hardware systematic replacement required ?
    - Newer hardware is more capable
    - But no longer more efficient
  - ➢ Device lifetime can be extended
  - ➢ Need long time support (repair, software updates)



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Thanks

- Chat with authors:

urlr.me/T6MsZS

Olivier Weppe, Thibaut Marty, Jean-Christophe Prévotet, Maxime Pelcat: **INSA Rennes**
Louise Aubet: **Resilio**
David Bekri, Loïc Guibert, Sebastien Rumley: **HES-SO**

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