

The impact of IC manufacturing on the sustainability of AI

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Presented at the Sustainable computer architecture workshop co-located with MICRO 2026

For 40 years, we have been pioneering the semiconductor roadmap.



imec

What makes us the semiconductor lab of the world?



skilled people
>6000 employees
>100 nationalities



world-class semiconductor R&D infrastructure
~12,000m^2 R&D cleanroom with >250 tools operating 24/7



global ecosystem & open innovation model
>600 partner companies

imec

CO_2 Emissions from Semiconductor Industry in Perspective

~ 36 billion tons



World-wide

Sources: Liu et al. Nature reviews earth & environment 2023 (Fossil fuels and Cement only)

~ 1,2 billion tons



ICT Industry

Source: Freitag, C. Et al. 2021. http://arxiv.org/abs/2102.02622

~ 185 million tons



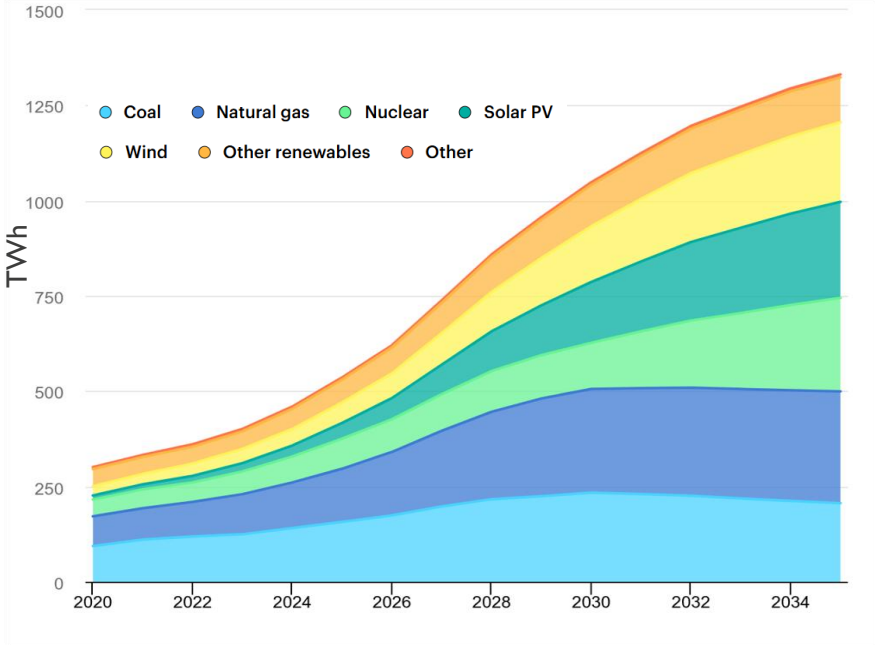
Semiconductor manufacturing

Includes Scope 1, scope 2 and scope 3 consumables and services. For industry in 2021.
Source: SEMI SCC Whitepaper on Transparency, Ambition, and Collaboration - 2023

Datacenter LCA

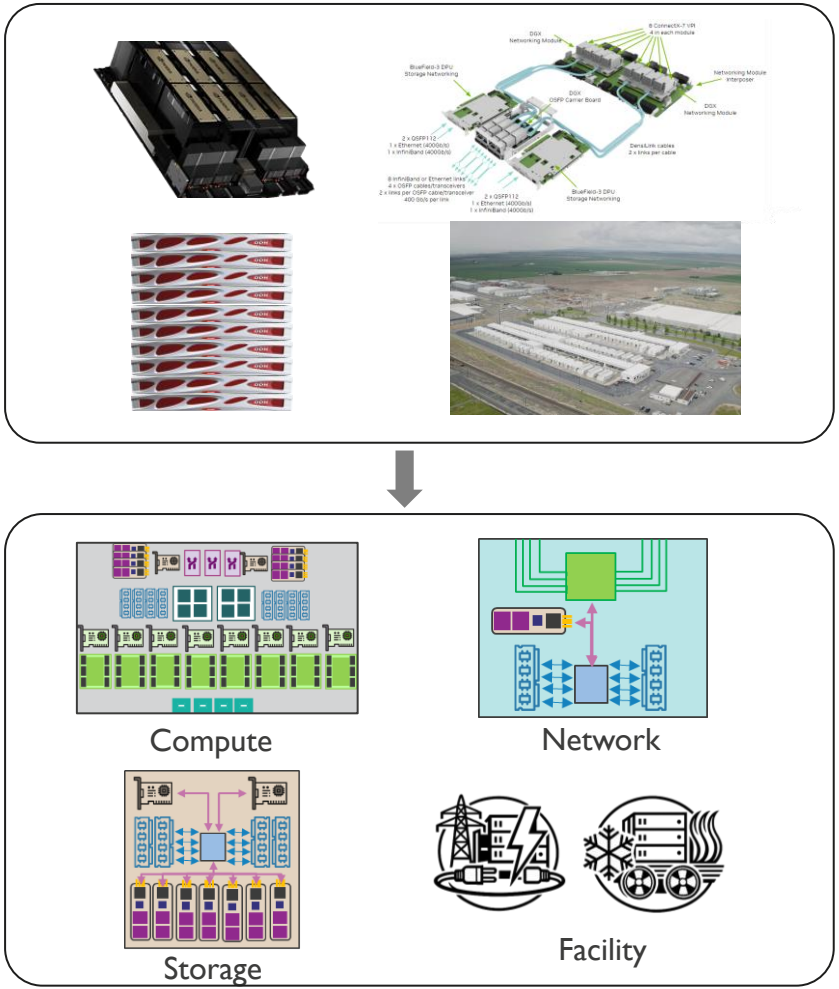
The need for scope completion

Global electricity consumption *of data centers*



IEA base case [April 2025]

Only usage! (Operational)

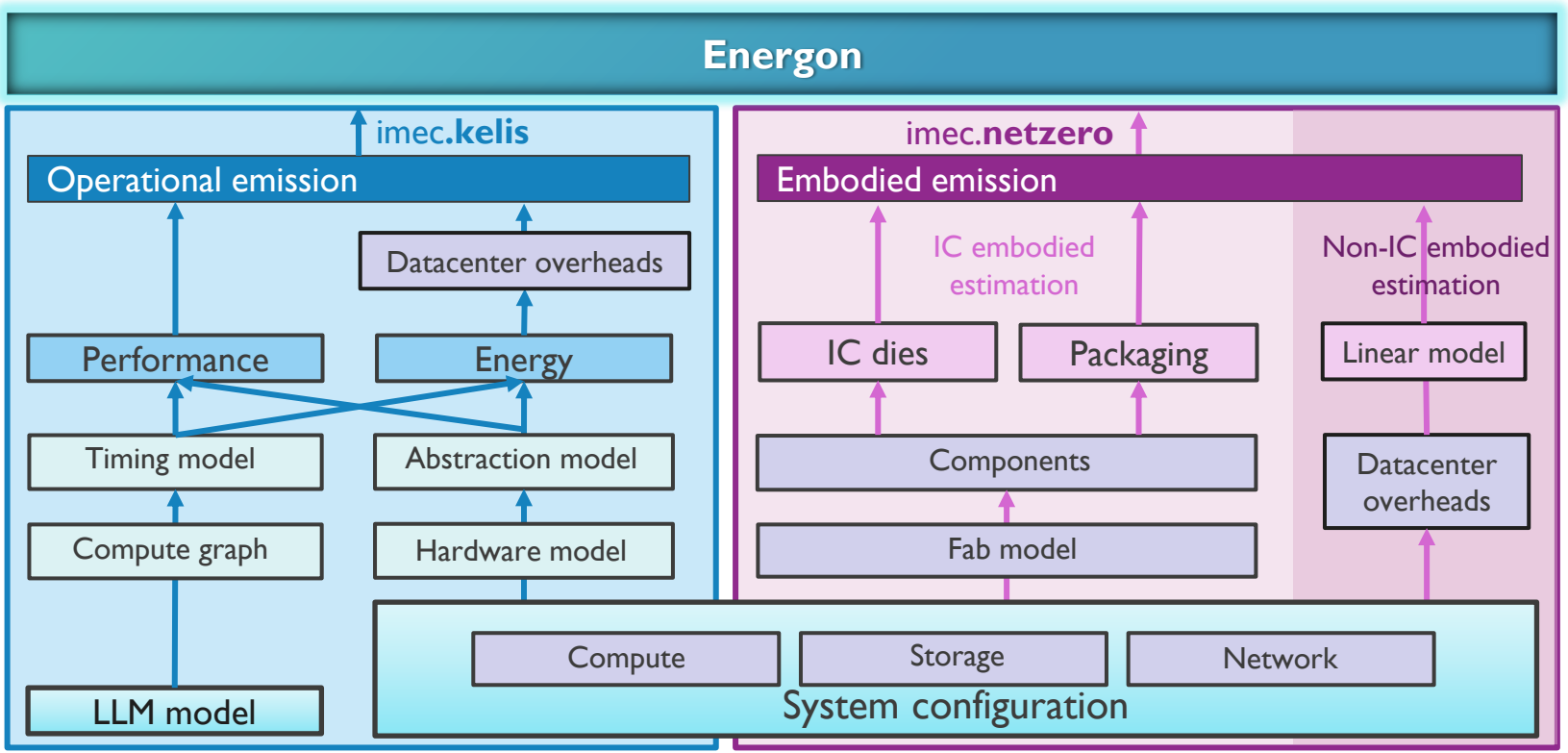


Embodied contributors

public

Energon for Datacenter LCA

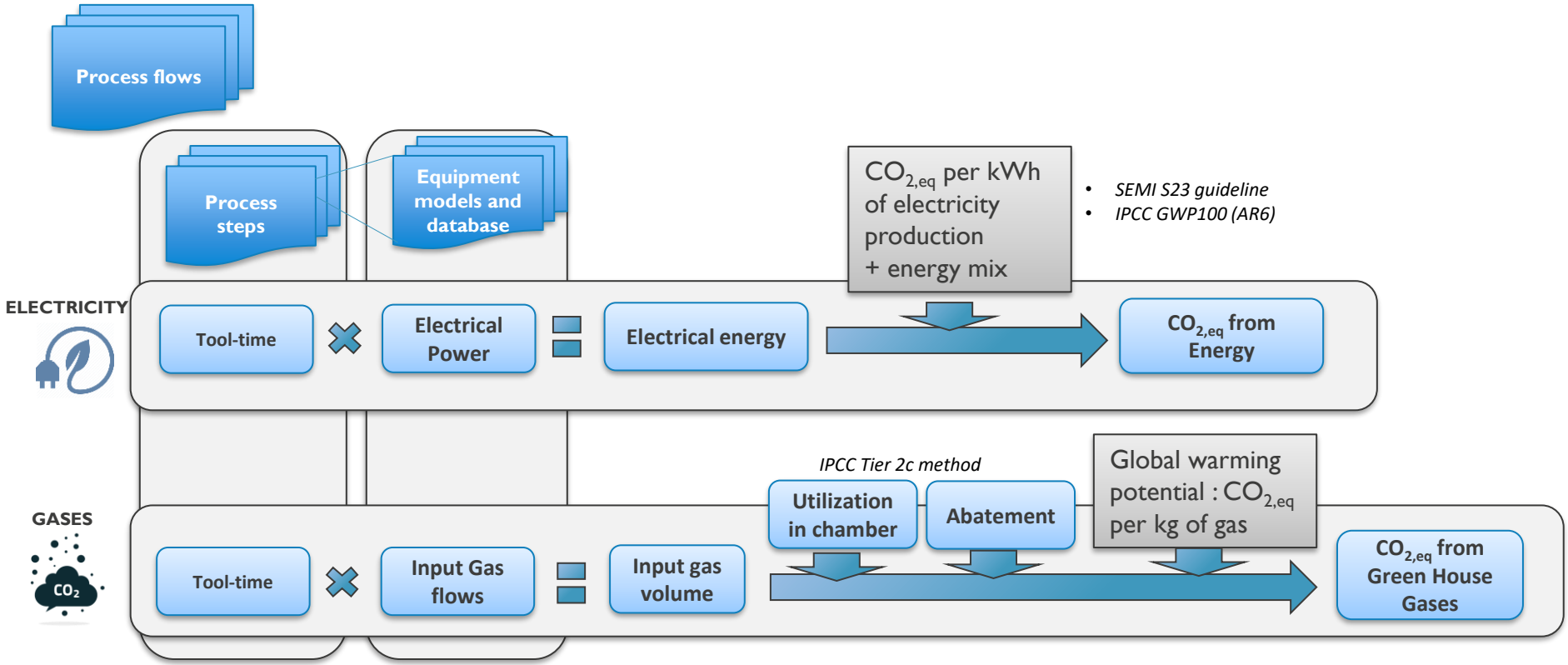
Methodology



public

imec.netzero for IC chip manufacturing

From process flows to CO_2eq footprint



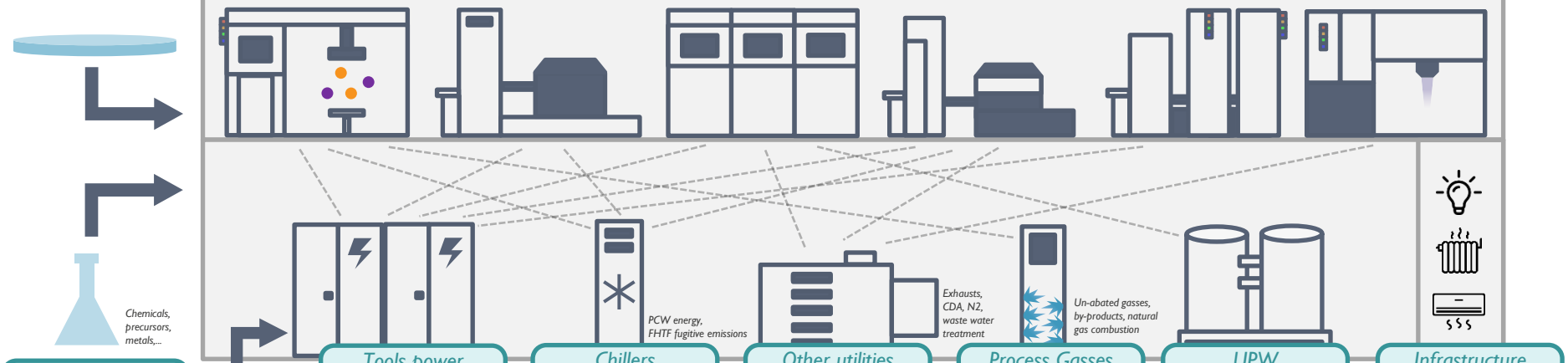
Virtual fab emissions breakdown

High dependence on model parameters

Cleanroom view

Total N28 manufacturing emissions
816 kgCO2e per wafer

Si Wafer	Dry Etch	CVD	Wet clean	PVD	EPI	Litho
79.4 kgCO2e	**171.4** kgCO2e	**121.3** kgCO2e	**100.8** kgCO2e	**85.6** kgCO2e	**79.1** kgCO2e	**85.6** kgCO2e
9.7% of total	**21.0%** of total	**14.9%** of total	**12.4%** of total	**10.5%** of total	**9.7%** of total	**8.9%** of total



Materials	Tools power	Chillers	Other utilities	Process Gasses	UPW	Infrastructure
117.5 $kgCO_{2e}$	**225** $kgCO_{2e}$	**82.8** $kgCO_{2e}$	**65.6** $kgCO_{2e}$	**51.1** $kgCO_{2e}$	**21.5** $kgCO_{2e}$	**62.0** $kgCO_{2e}$
14.4% of total	**27.5%** of total	**10.1%** of total	**8.0%** of total	**6.4%** of total	**4%** of total	**7.6%** of total

Transmission losses
101.3 kgCO2e
12.4% of total

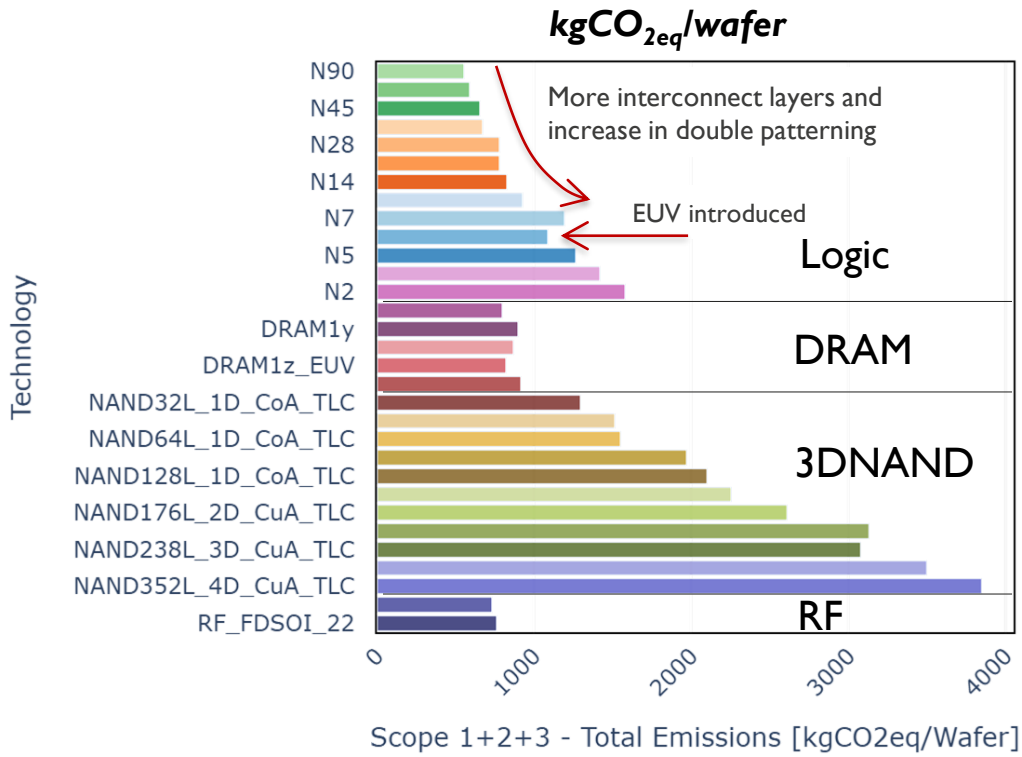
Total N28 manufacturing emissions
816 kgCO2e per wafer

Subfab view

public

Imec.netzero example: Total emissions across technologies

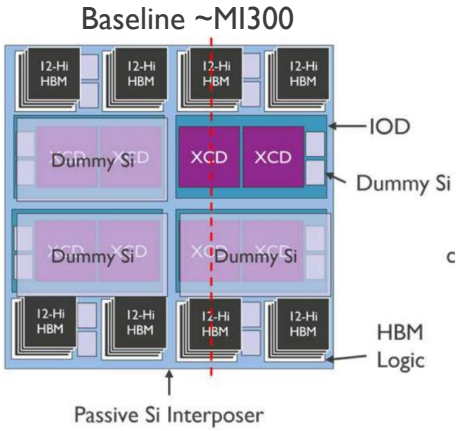
Logic – DRAM – NAND – other (RF/GAN/Photonics/…)



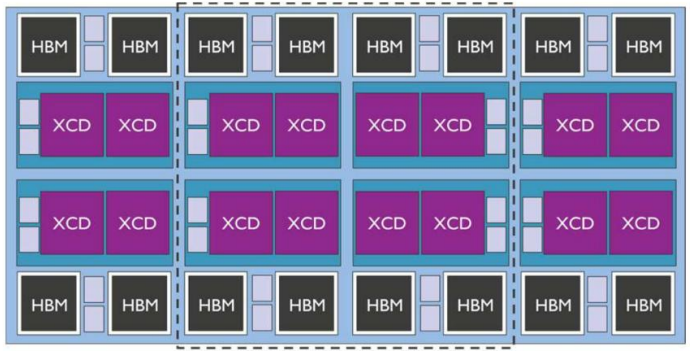
public

Src: Watson et al. Embodied Emissions of 2.5D and 3D Scaling in Chipletized GPUs for Low-Carbon AI. https://arxiv.org/abs/2610.32830

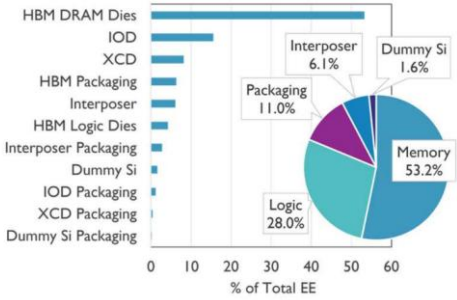
Imec.netzero example: packaging



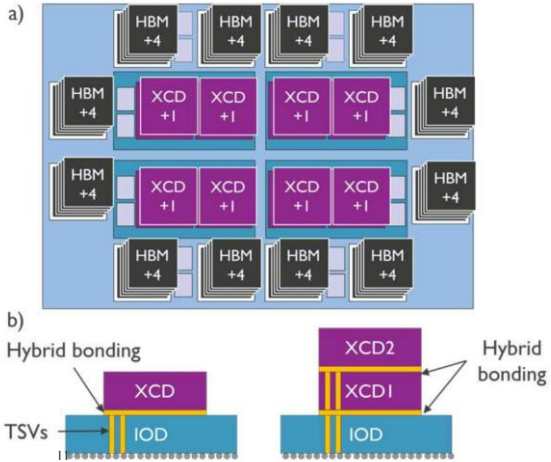
2x peak perf
2x memory
by scaling **2.5D**



+141%
embodied emissions



2x peak perf
2x memory
scaling **3D**

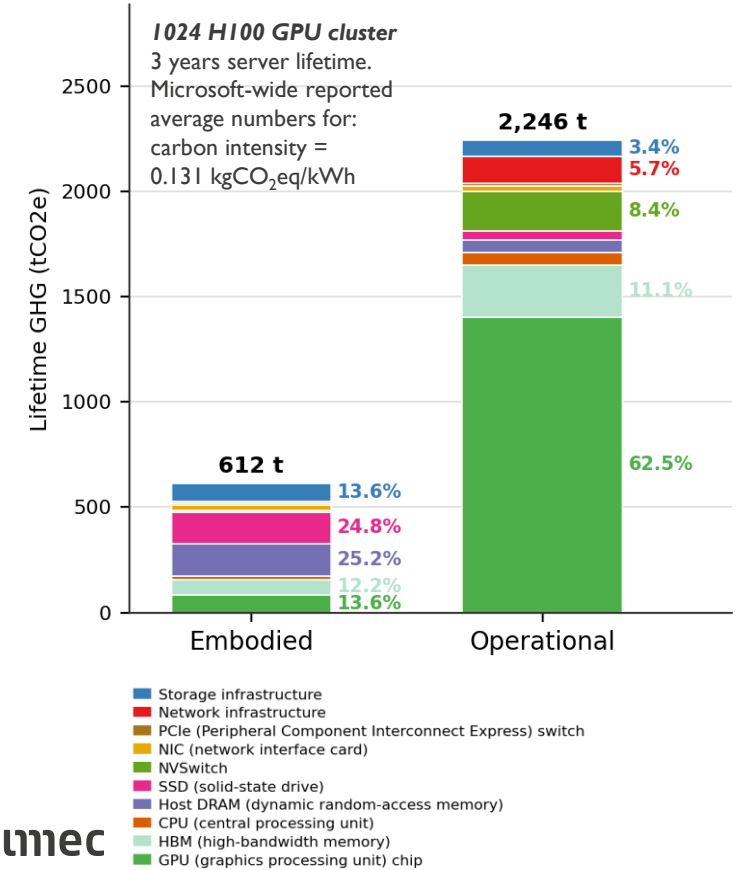


+89%
embodied emissions

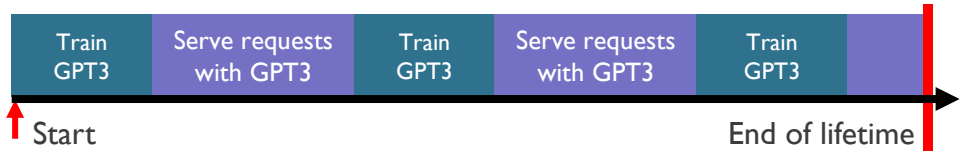
From integrated circuits embodied emissions to datacenter total emissions: a 1024 H100 cluster example

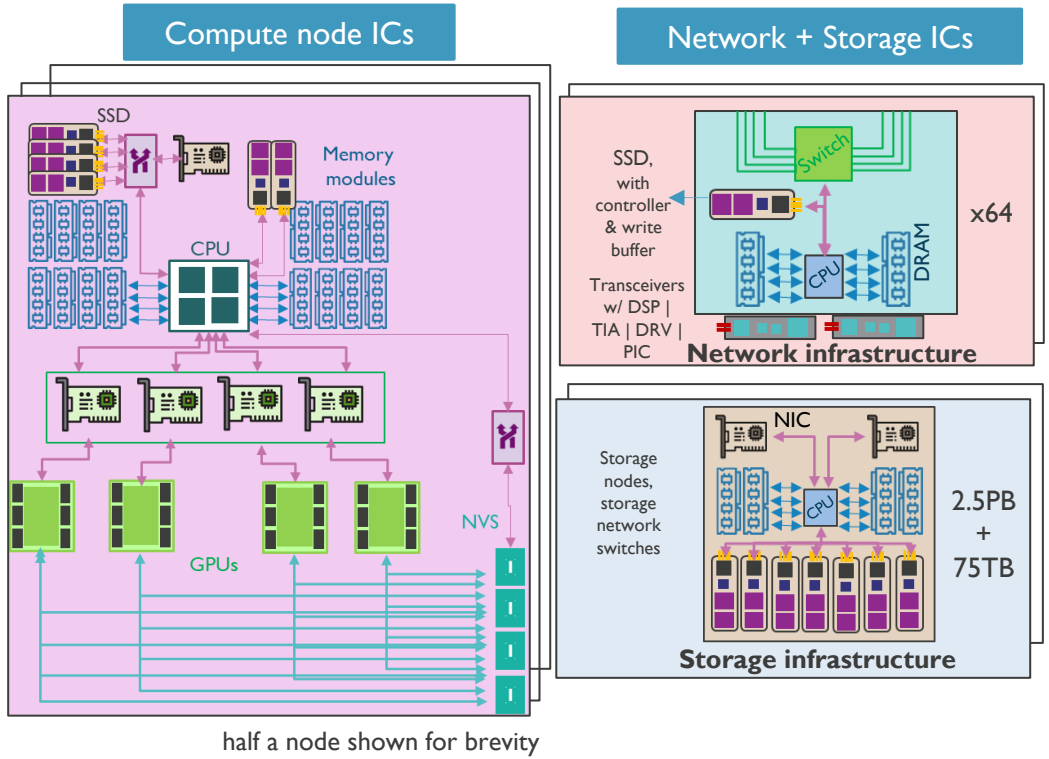
IC carbon emissions modelling

Compute + Storage + Network nodes



Performance and power for real workloads modeled for operational energy





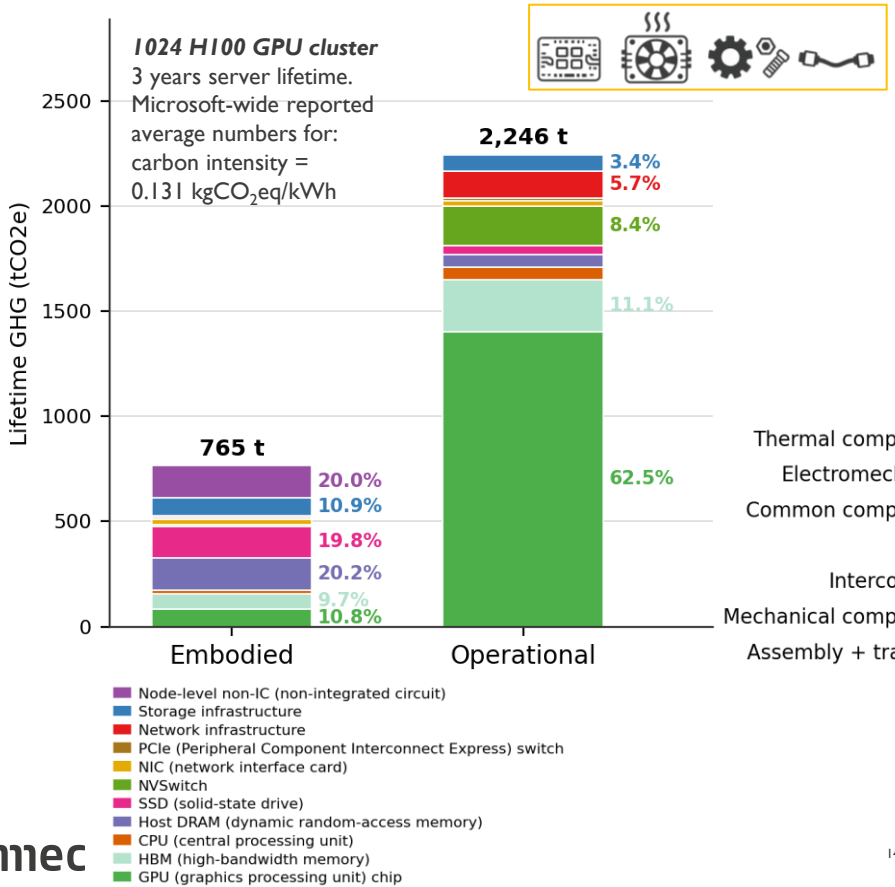
half a node shown for brevity

Using imec.netzero for embodied emissions

public

Non-IC carbon (embodied) emissions modelling

There is more to a server node than its chips





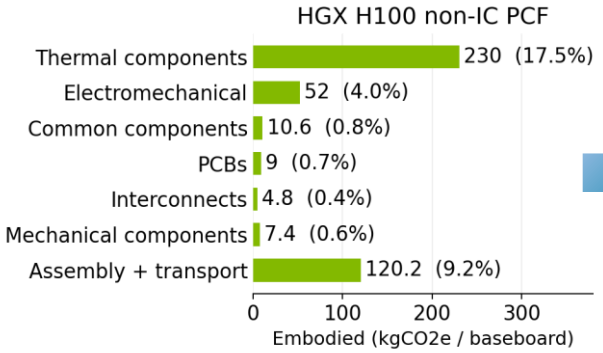
HGX H100 baseboard
8 H100 GPUs, NVswitches
~5600 W, 24 kgs

Netzero for ICs:
+ CPUs
+ DRAM
+ SSDs
+ NICs
+ PCIe switches

Linear model for:
+ Thermal
+ Electromechanical
+ Common
+ PCBs
+ interconnects
+ Mechanical
+ Assembly
+ Transport



1 DGX H100 system
~8500 W, 135 kgs



DGX H100
non-IC estimations

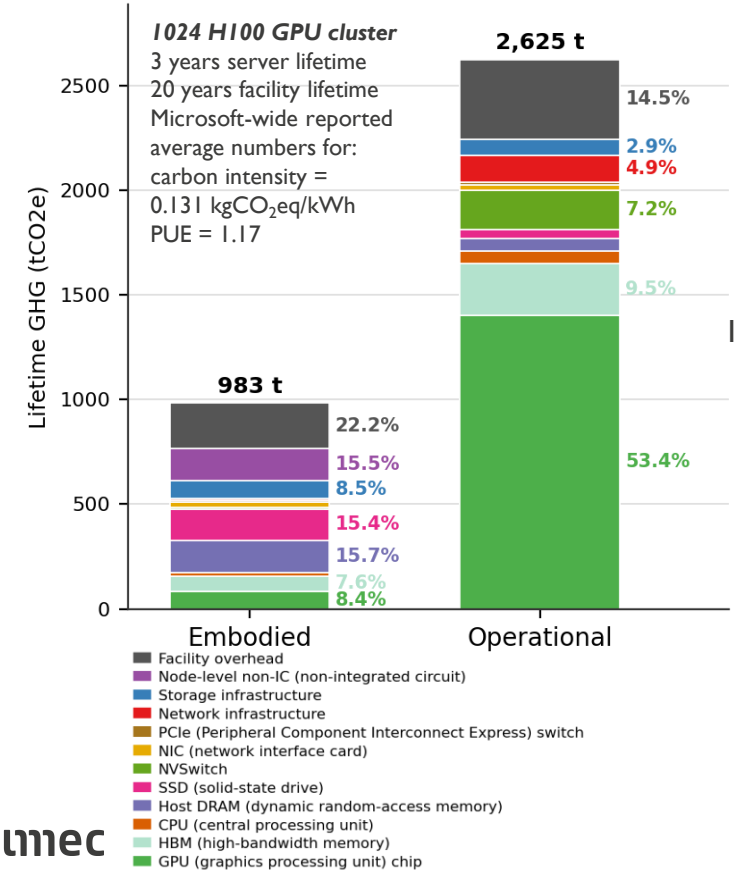
Estimated non-IC overhead at 153t

Using Nvidia published PCF on HGX baseboard + linear model

public

Facility carbon emissions modelling

A datacenter is more than just its servers

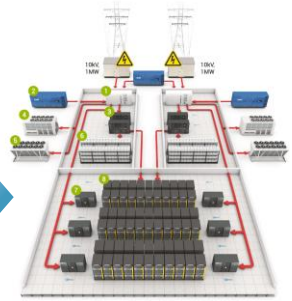




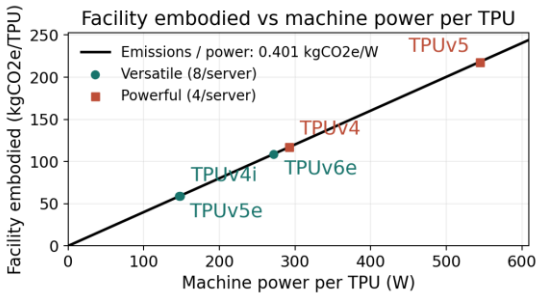
1 DGX H100 system



DGX H100 SuperPod



Facility w/ power delivery & cooling



Lifetime: TPU 6 years; datacenter building 20 years.

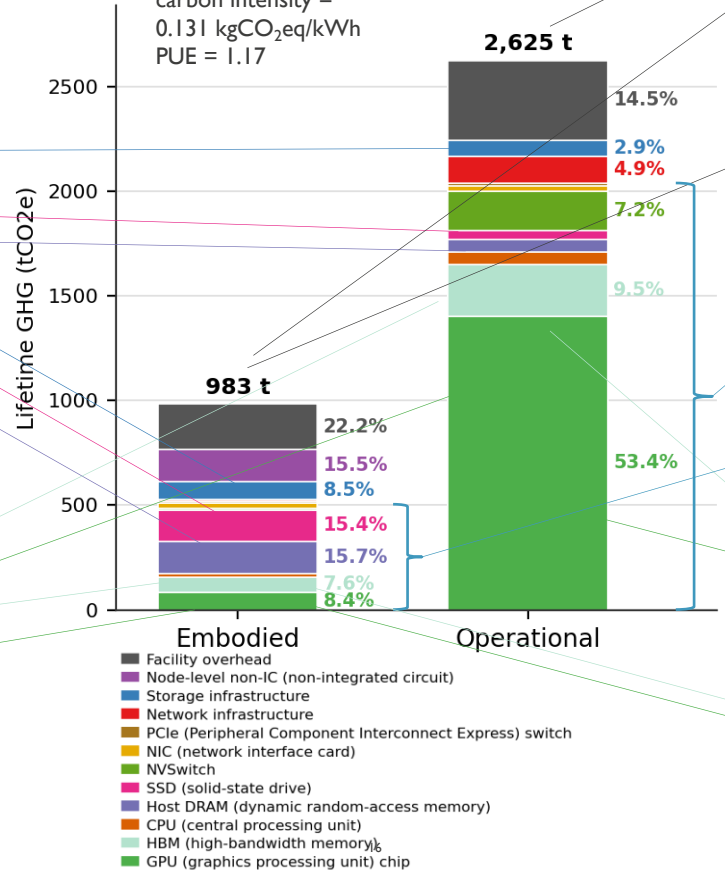
Estimated facility overhead at 218t

Using Google TPU [Schneider et.al.] facility level data
+ model for H100 node, server, building

public

Some learnings

1024 H100 GPU cluster
3 years server lifetime
20 years facility lifetime
Microsoft-wide reported average numbers for:
carbon intensity = 0.131 $kgCO_2eq/kWh$
PUE = 1.17



1k GPU cluster yearly footprint (~1200t) > **120 people** carbon footprint (10t/year in France)

Don't forget about embodied emissions! Even for datacenters (high power, always on)

Compute nodes contribute ~80% of operational emissions

Compute nodes contribute ~ 50% of embodied emissions

GPU operational emissions ~60% of total operational emissions

GPU embodied emissions only ~16% of total embodied emissions

Memory and storage embodied emissions > operational emissions

GPU embodied emissions largely from HBM (~50% for 80GB GPU) operational emissions dominated by logic power

public

Thank you!

Reach out for tool access, collaboration or any general discussions!

Go to https://netzero.imec-int.com and sign-up for imec.**netzero**
Public access for logic nodes up to N2
Contact us for academic or industrial licenses with more access