

Understanding the Implications of Uncertainty in Embodied Carbon Models for Sustainable Computing

Anvita Bhagavathula, **Leo Han**, Udit Gupta

A need for sustainable computer hardware



Existing carbon models are deterministic

GreenChip: A tool for evaluating holistic sustainability of modern computers

Donald Kl
Panos K. C

SCARIF: Towards Carbon Modeling of

Cloud Servers with Accelerators

ACT: Designing Sustainable Computer Systems With An Architectural Carbon Modeling Tool

Udit Gupta
ugupta@g.harvard.edu
Harvard University/Meta
USA

Mariam Elgamal
mariamelgamal@g.harvard.edu
Harvard University
USA

Gage Hills
ghills@g.harvard.edu
Harvard University
USA

Gu-Yeon Wei
guyeon@seas.harvard.edu
Harvard University
USA

Hsien-Hsin S. Lee
leehs@fb.com
Meta
USA

David Brooks
dbrooks@eecs.harvard.edu
Harvard University/Meta
USA

Carole-Jean Wu
carolejeanwu@fb.com
Meta
USA

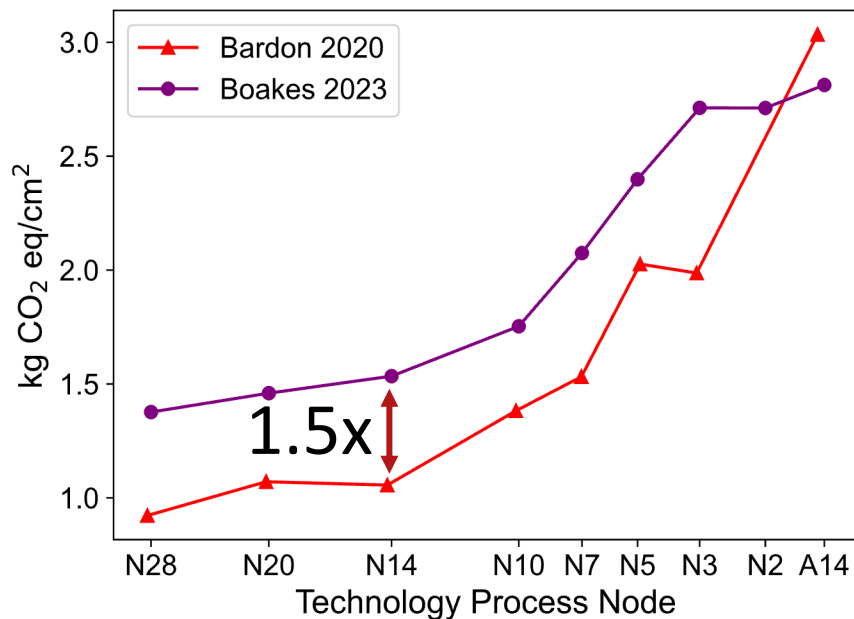
ECO Chip: A Chiplet-based

Chetan Choppali Sudarshan¹, Nikhil Matkar¹, Sarma Vrudhula¹, Sachin S. Sapatnekar², and Vidya A. Chhabria¹

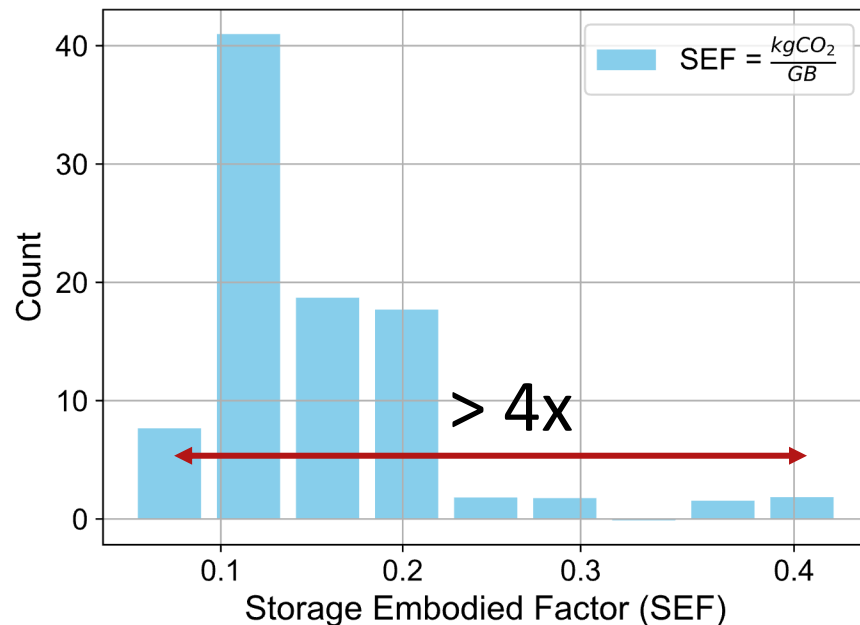
¹Arizona State University; ²University of Minnesota

Existing carbon footprint estimates vary greatly

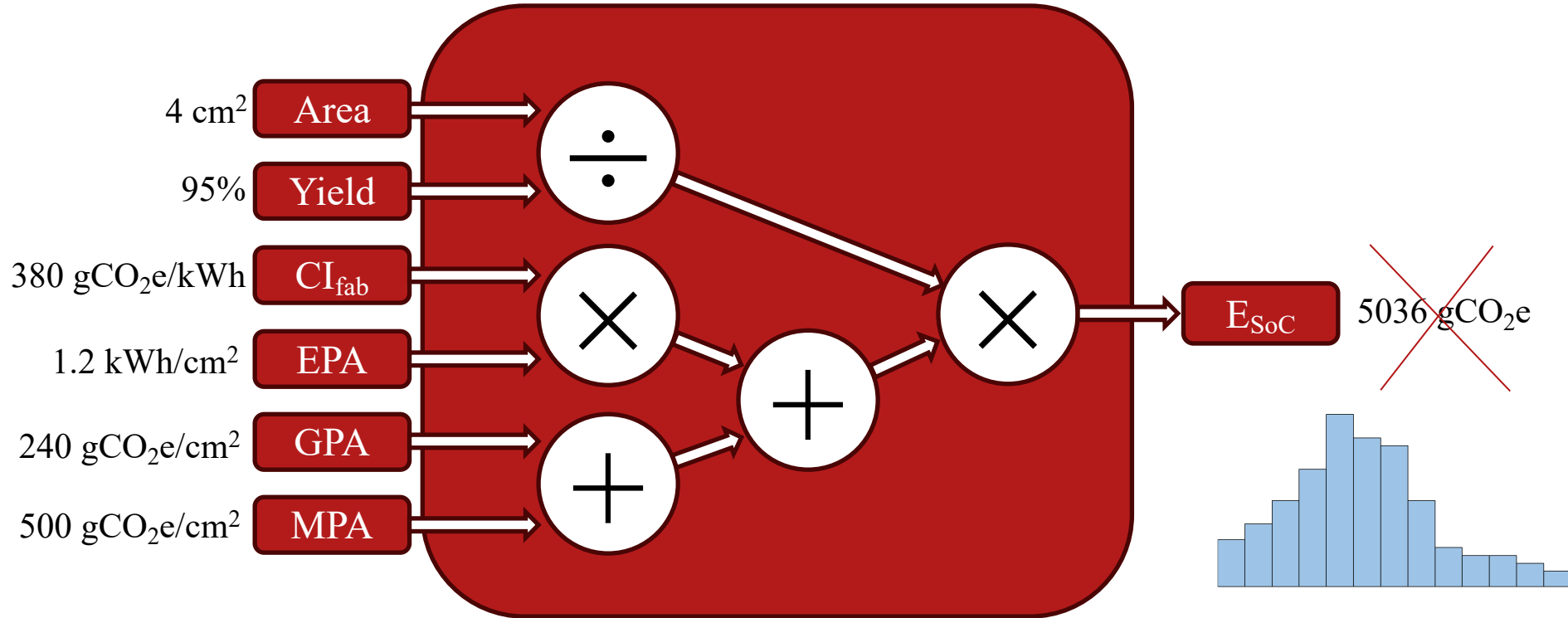
Silicon Carbon Per Area



SSD Carbon Per GB (Tannu and Nair, 2023)

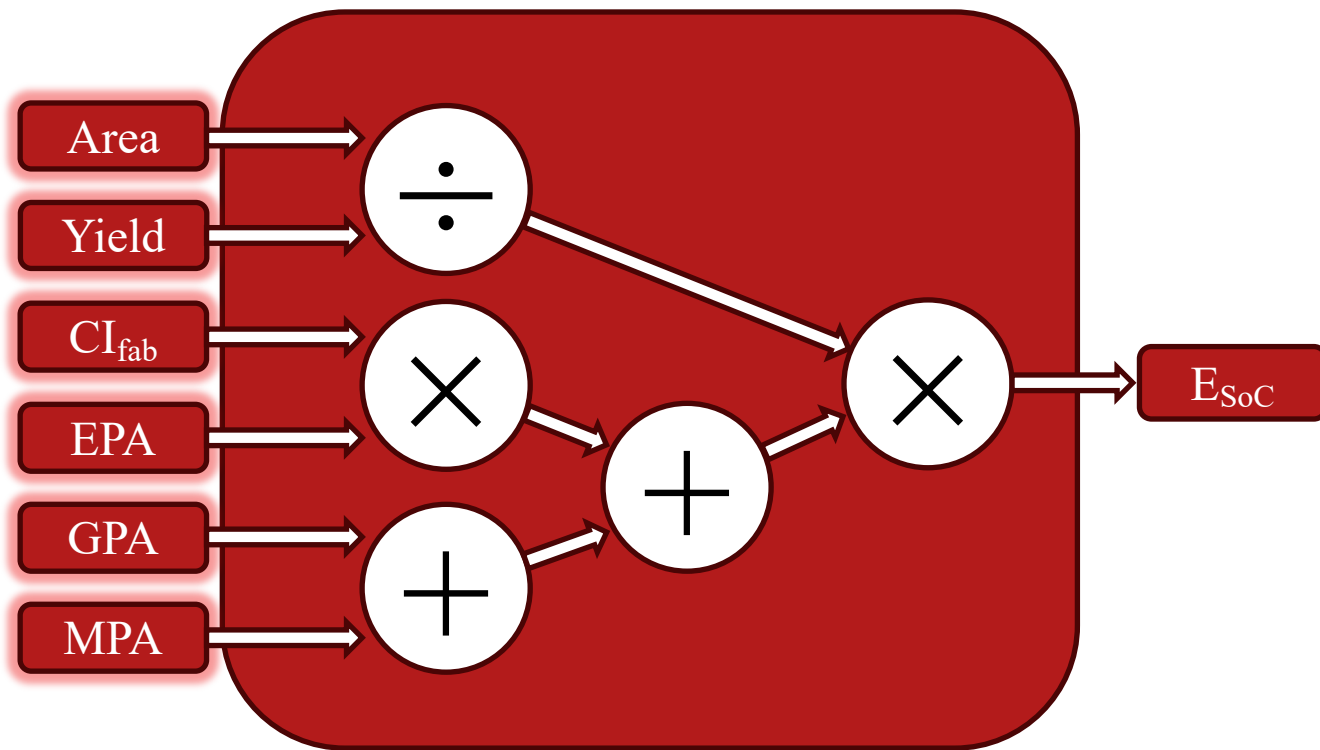


We augment ACT to be probabilistic

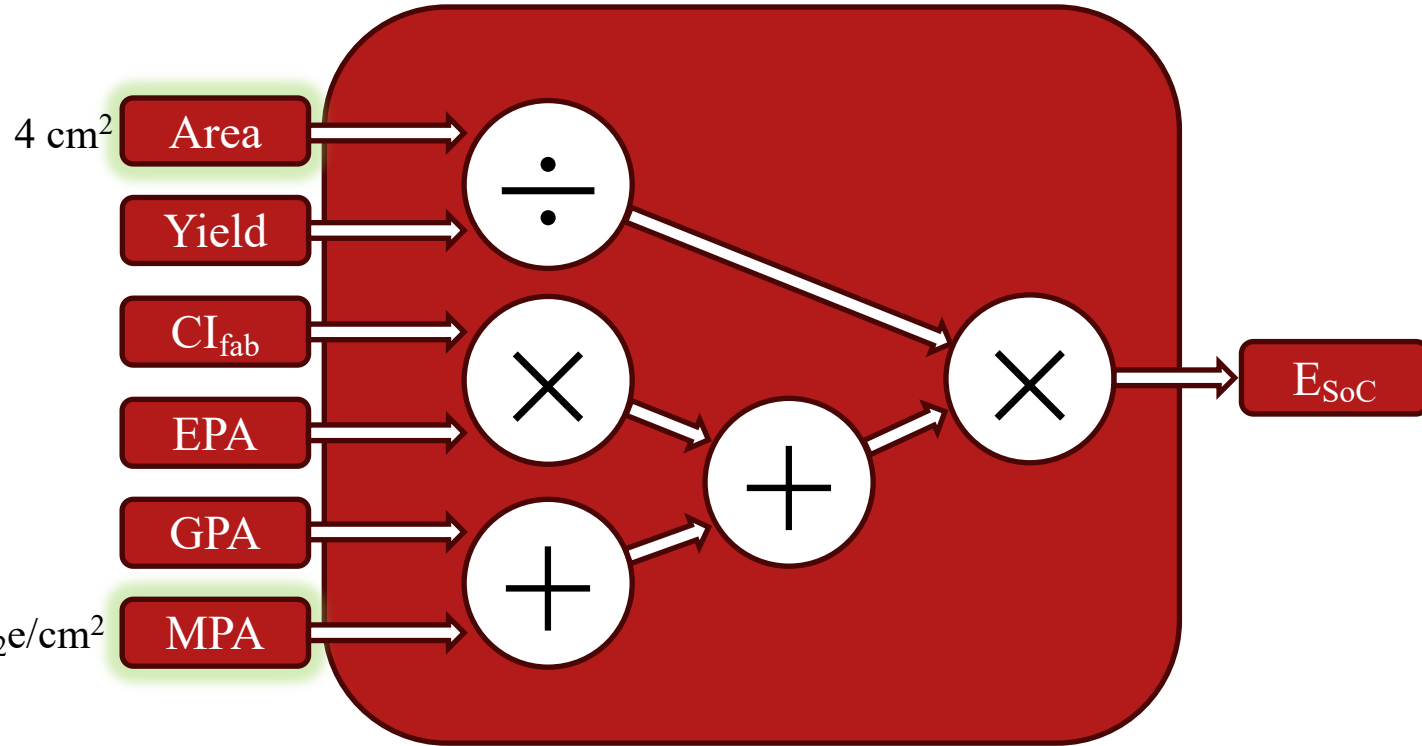


$$E_{SoC} = \text{Area} \times \text{CPA} = \frac{\text{Area}}{Y} \times (CI_{fab} \times \text{EPA} + \text{GPA} + \text{MPA})$$

How do we model inputs?

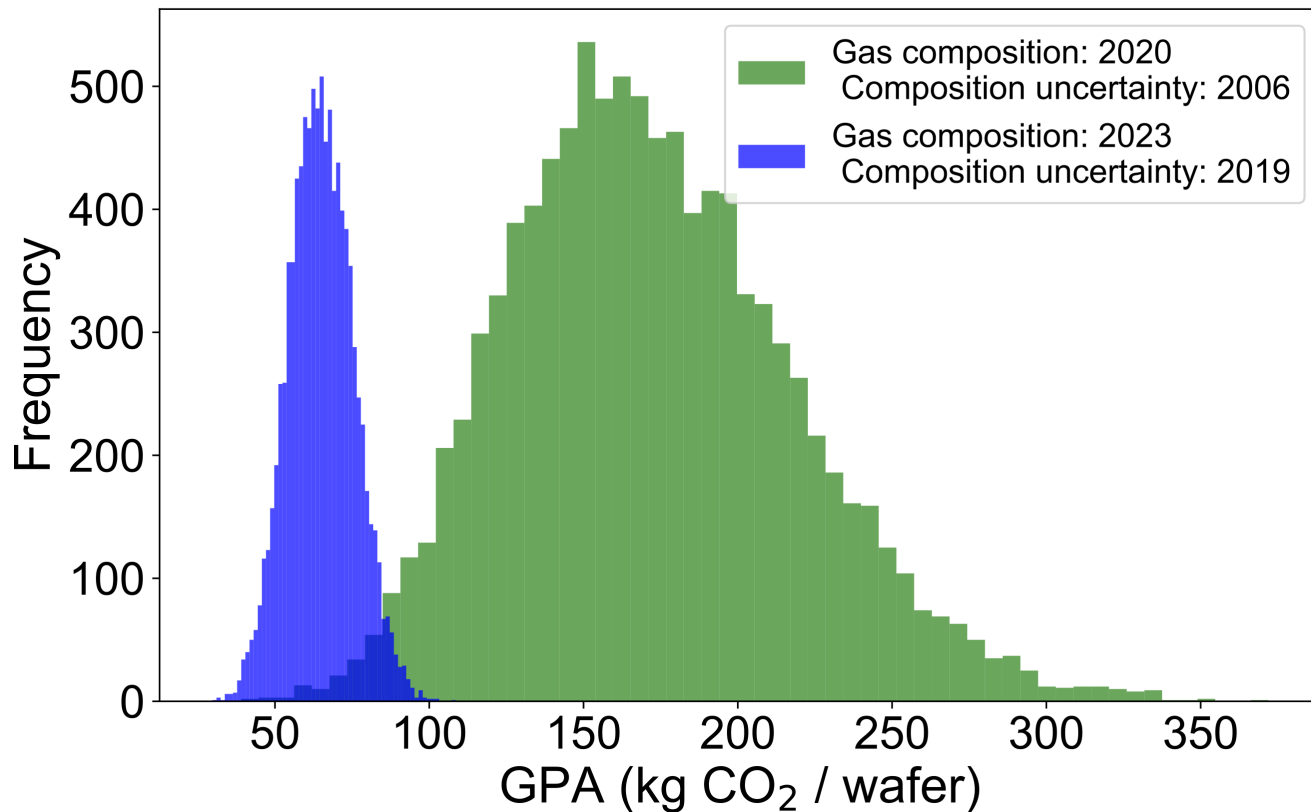


Inputs as **single-values**



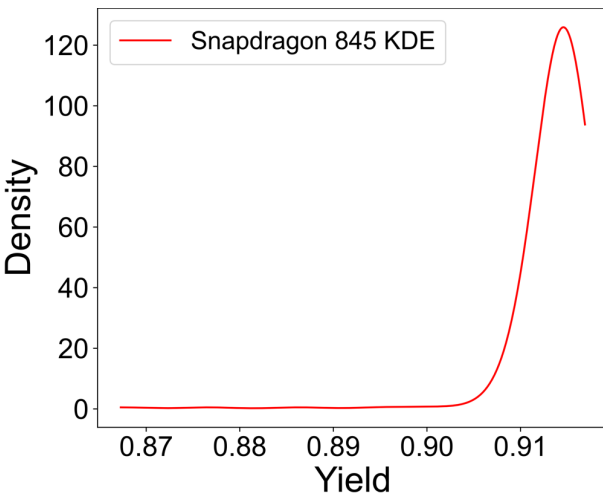
Inputs as **synthetic distributions**

GPA

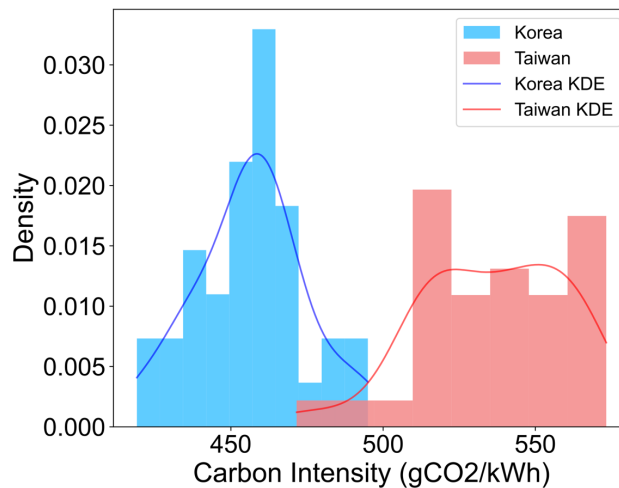


Inputs as **kernel density estimates (KDEs)**

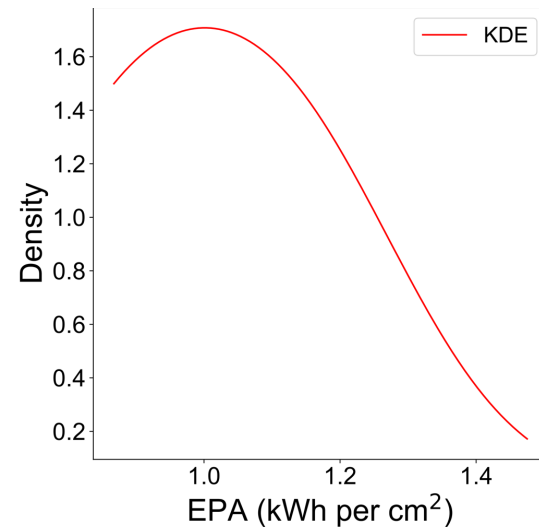
Yield



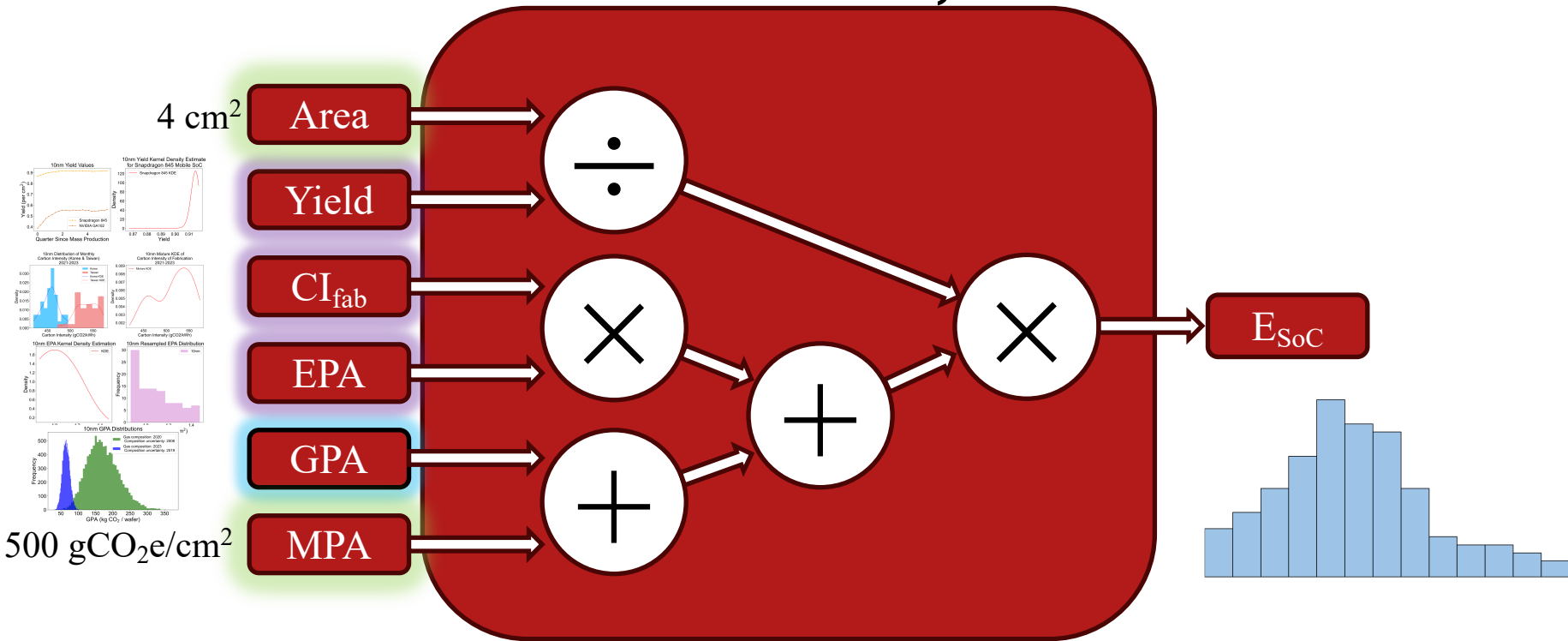
Carbon Intensity



EPA



Inputs as **single-values**, **synthetic distributions**, **KDEs**

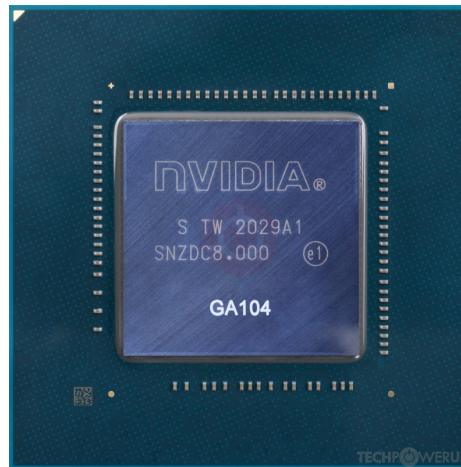


Case study: Notebook GPU selection



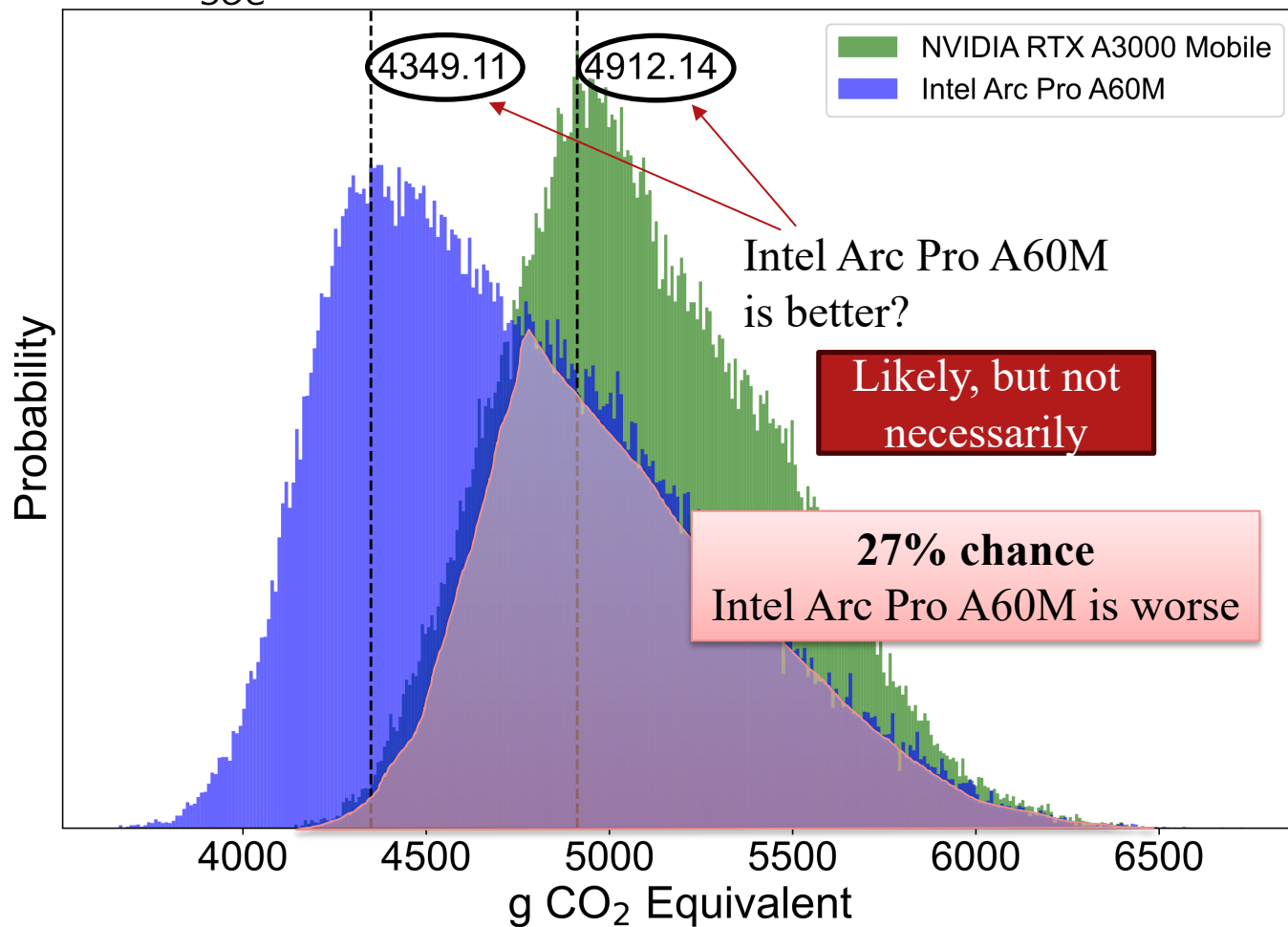
Intel Arc Pro A60M

TSMC N6
 4.06 cm^2
60 W



NVIDIA RTX A3000 Mobile

Samsung 8N
 3.92 cm^2
70 W

E_{SOC} of NVIDIA RTX A3000 and Intel Arc Pro A60M

Considering both Operational and Embodied
with Normalized Carbon Footprint (NCF)
(Eeckhout, 2024)

$$NCF(X, Y) = \alpha \frac{E_X}{E_Y} + (1 - \alpha) \frac{P_X}{P_Y}$$

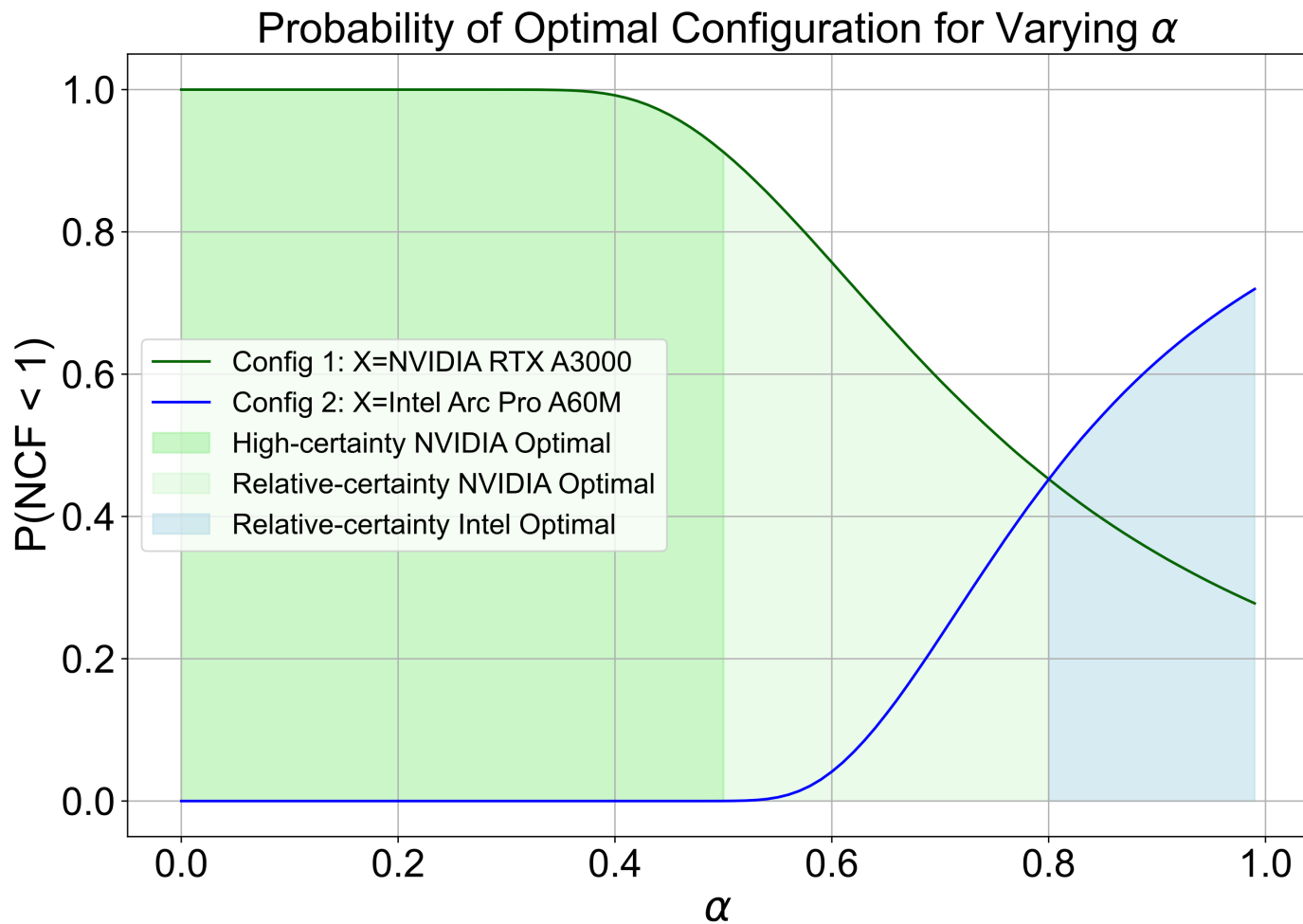
Operational Emissions Dominant

Embodied Emissions Dominant

$\alpha = 0$

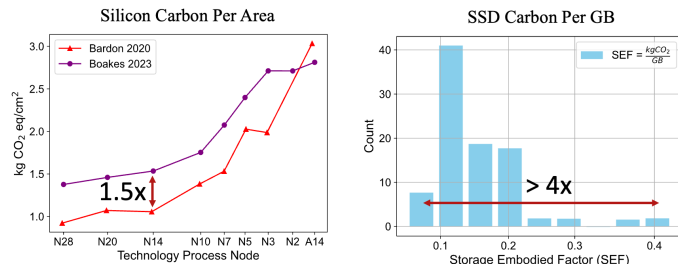
$\alpha = 1$

Choose X if $NCF < 1$

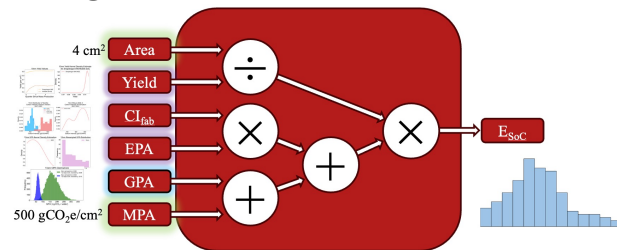


Probabilistic Carbon Modeling for Computer Hardware

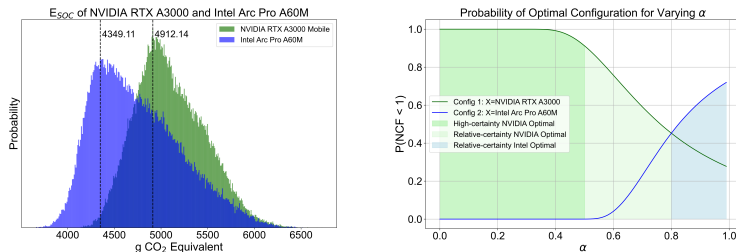
Large uncertainties exist in carbon estimates



We augment ACT with probabilistic modeling



Probabilistic carbon estimates enable risk-aware sustainable design



Thank you!

Please connect with us via email at:

lxh4@cornell.edu (Leo)