Programming Languages and Techniques (CIS1200)

Lecture 37

Advanced Java Miscellany

Announcements

- Final Program Due: (92 points)

  Monday, December 9th at 11:59pm

  - Submit zipfile online, submission *only* checks if your code compiles
  - IntelliJ is **strongly recommended** for this project
  - You may distribute your game (after the deadline) if you do not use any of our code
- Grade based on demo with your TA during/after reading days
  - Grading rubric on the assignment website
  - Recommendation: don't be too ambitious.
- *NO LATE SUBMISSIONS PERMITTED*

CIS 1200 Final Exam

- Tuesday, December 17th 12:00-2:00 PM
  - Meyerson Hall B1 — Last Names A – M
  - Fagin Auditorium — Last Names N – Z

- Students who need accommodations should schedule their exams (ASAP) through the Weingarten Center

- Review Session / Mock exam
  - 2 hour mock exam followed by 2 hour review
  - (The review session will be recorded)
  - Location and Time – TBA
  - Look for details on Ed

Exam Preparation

- *Comprehensive* exam covering the entire course:
  - *Ideas* from OCaml material (but no need to write OCaml)
  - All Java material
    - emphasizing material since midterm 2: subtyping, dynamic dispatch, collections, equality & overriding, exceptions, I/O, inner classes, swing
  - All course content
    - *except:* Bonus Lecture *(Code is Data) and* Guest Lecture *(Jane Street)*
    - *Only simple/shallow questions about Wednesday's lecture*

- Closed book, but…
  - You may use one letter-sized, two-sided, *handwritten* sheet of notes during the exam.

Monday's Guest Lecture

Designing OCaml to be predictably faster at Jane Street

Speaker: Richard Eisenberg, Jane Street

Abstract: Jane Street uses OCaml programs to power millions of market transactions daily. These programs must be fast, and also their performance must be consistent. The way polymorphism is designed in OCaml makes predictable high performance hard to achieve. This talk will explain why this is so, and how we plan to fix it by extending the language and compiler. Along the way, we'll see how careful study of programming languages yields tangible results in a practical setting. The talk will conclude with information about how OCaml is used at Jane Street and some of the exciting opportunities there.

37: How far along are you on the Game?

0

I haven't started yet — 0%

I have the basic design implemented — 0%

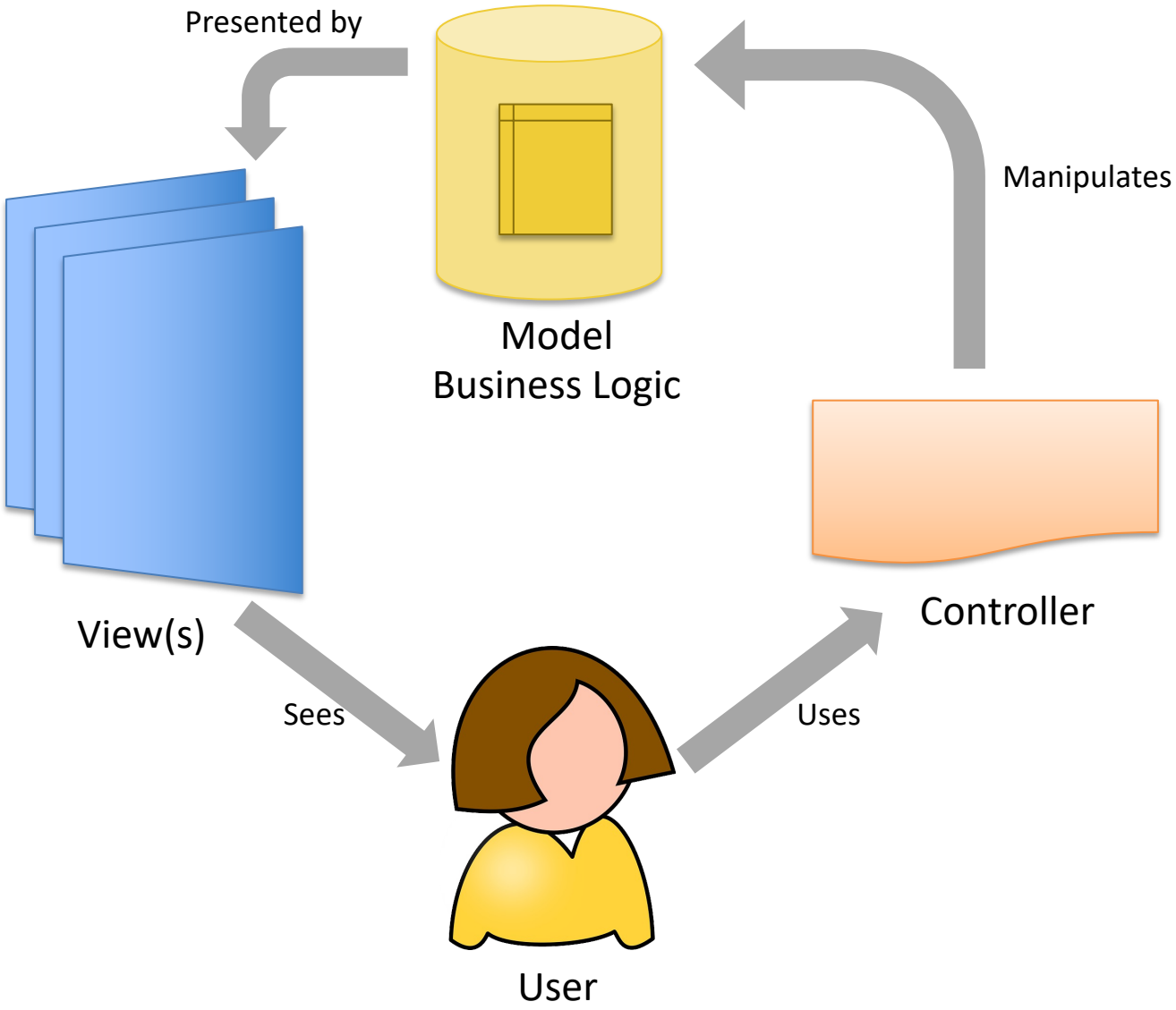
I'm about halfway done, I think — 0%

I'm nearly finished — 0%

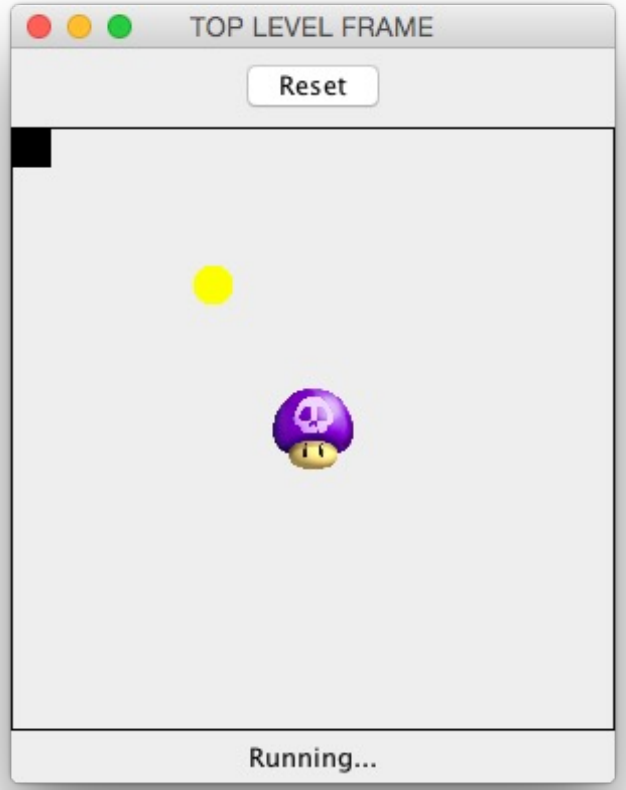
I'm done! — 0%

Model View Controller Design Pattern

Model-View-Controller Design Pattern



Example 1: Mushroom of Doom



Example: MOD Program Structure

- GameCourt, GameObj + subclass local state
  - object location & velocity
  - status of the game (playing, win, loss)
  - how the objects interact with eachother (tick)

Model

- Draw methods
  - paintComponent in GameCourt
  - draw methods in GameObj subclasses
  - status label

View

- Game / GameCourt
  - Reset button (updates model)
  - Keyboard control (updates square velocity)

Controller

Example: Paint Program Structure

- Main frame for application (class Paint)
  - List of shapes to draw
  - The current color
  - The current line thickness

Model

- Drawing panel (class Canvas, inner class of Paint)

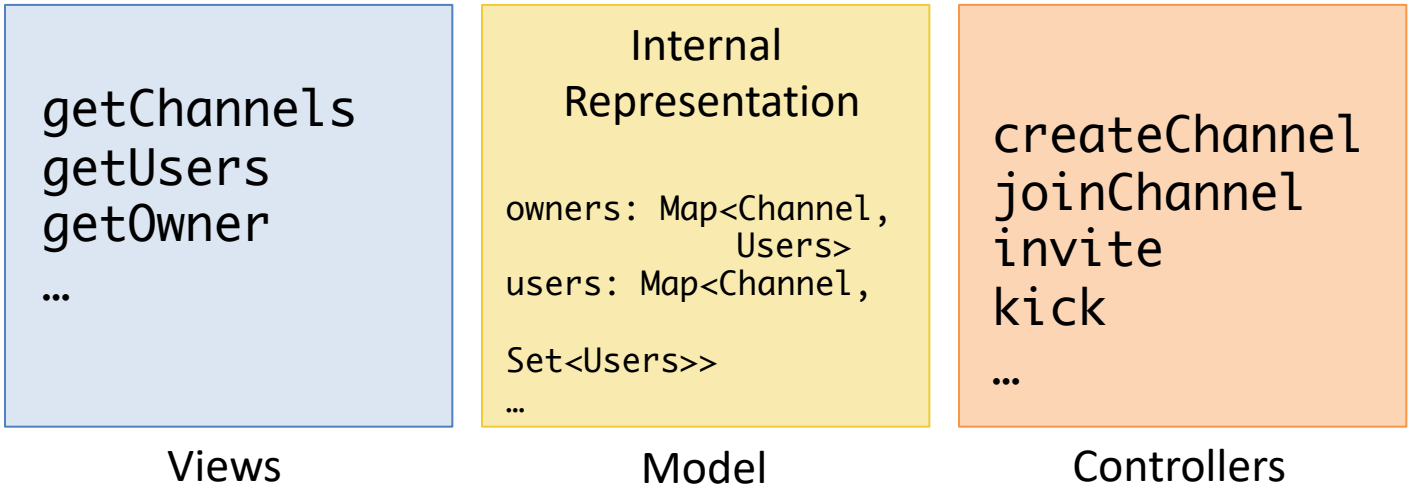
View

- Control panel (class JPanel)
  - Contains radio buttons for selecting shape to draw
  - Line thickness checkbox, undo and quit buttons

Controller

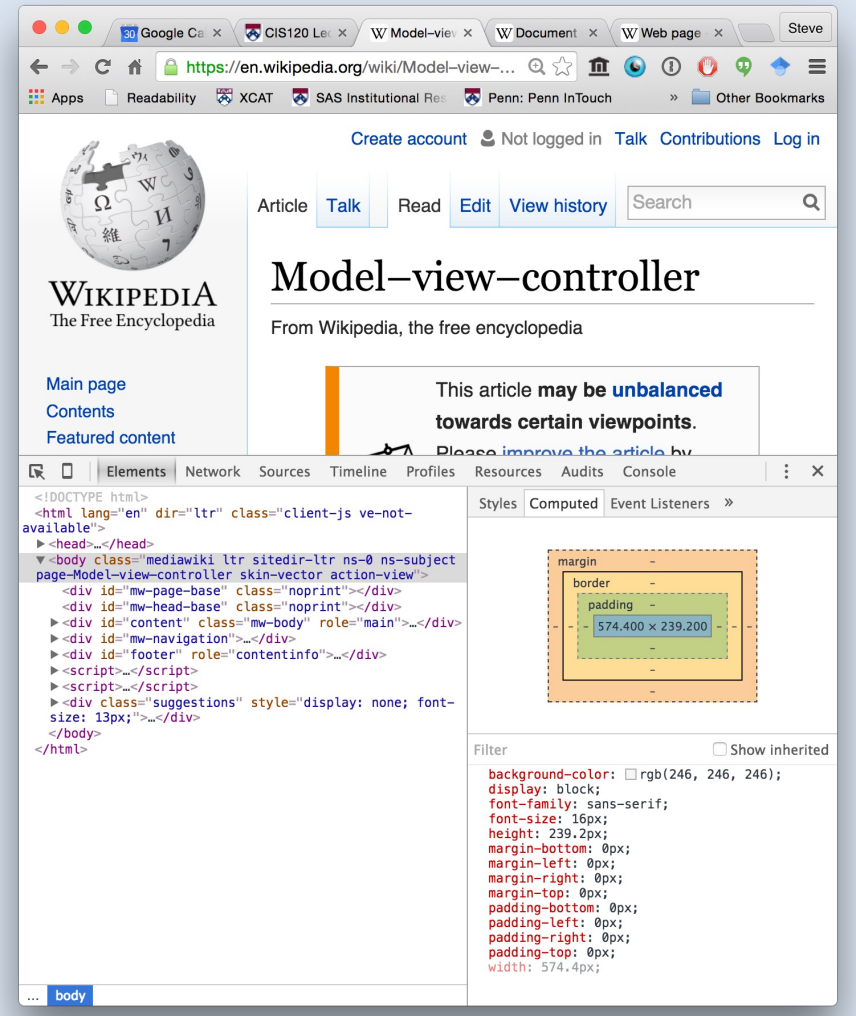
- Connections between Preview shape (if any…)
  - Preview Shape: View <-> Controller
  - MouseAdapter: Controller <-> Model

Example: Chat Server



ServerModel

Example: Web Pages



Views

Internal Representation: DOM (Document Object Model)

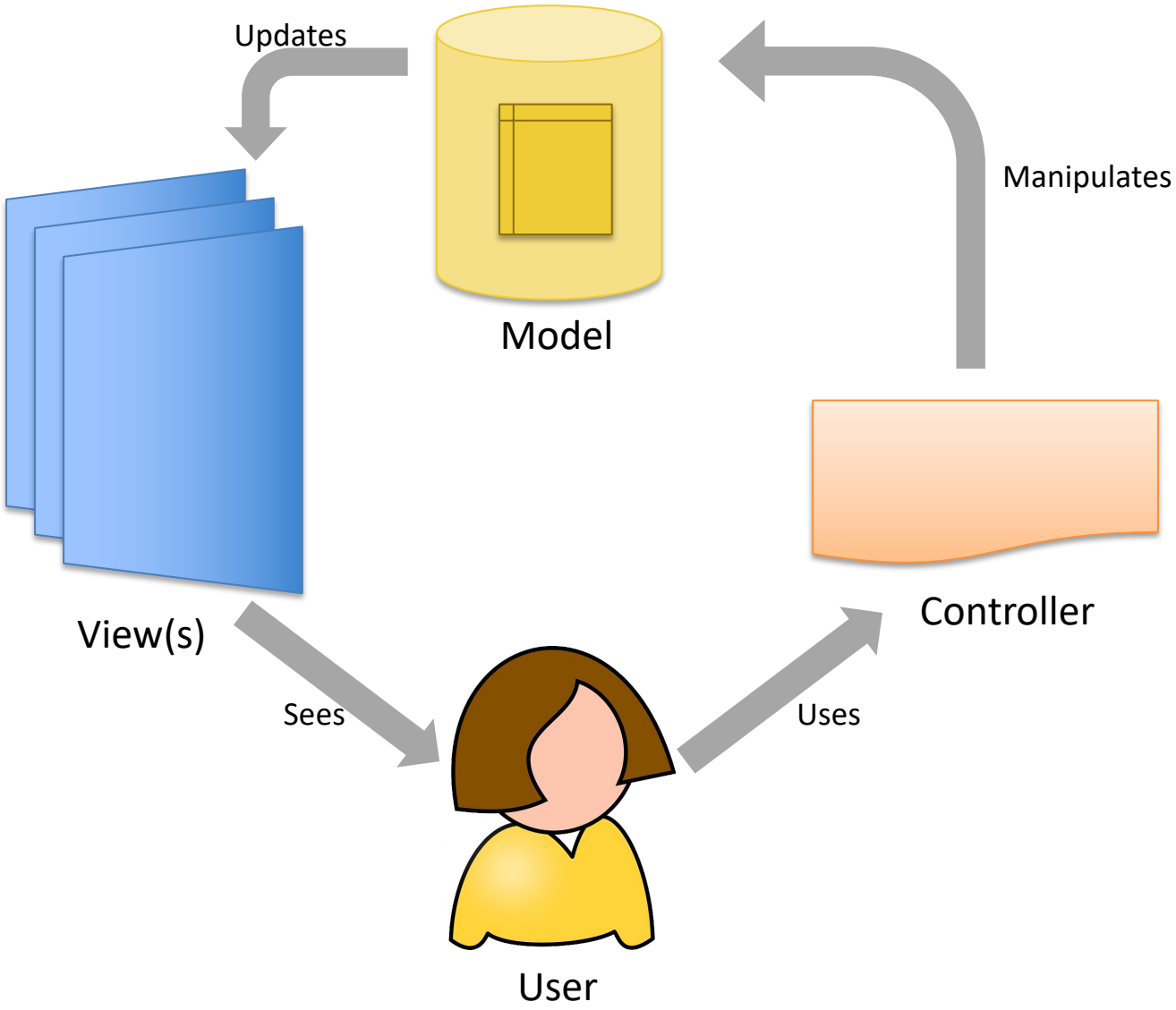
Model

JavaScript API

```
document.
addEventListener()
```

Controllers

MVC Pattern


Updates
Model
Manipulates
View(s)
Controller
Sees
Uses
User

MVC Benefits?

- Decouples "model state" from how that state is presented and manipulated
  - Suggests how to decompose the design to make it more flexible
- Multiple views
  - e.g. from different angles, or for multiple different users
- Multiple controllers
  - e.g. mouse vs. keyboard interaction
- Key benefit: Makes the model **testable** independent of the GUI

MVC Variations

- Many variations on MVC pattern

- Hierarchical / Nested
  - As in the Swing libraries, in which JComponents often have a "model" and a "controller" part

- Coupling between Model / View or View / Controller
  - e.g. in MOD the Model and the View are coupled because the model carries most of the information about the view

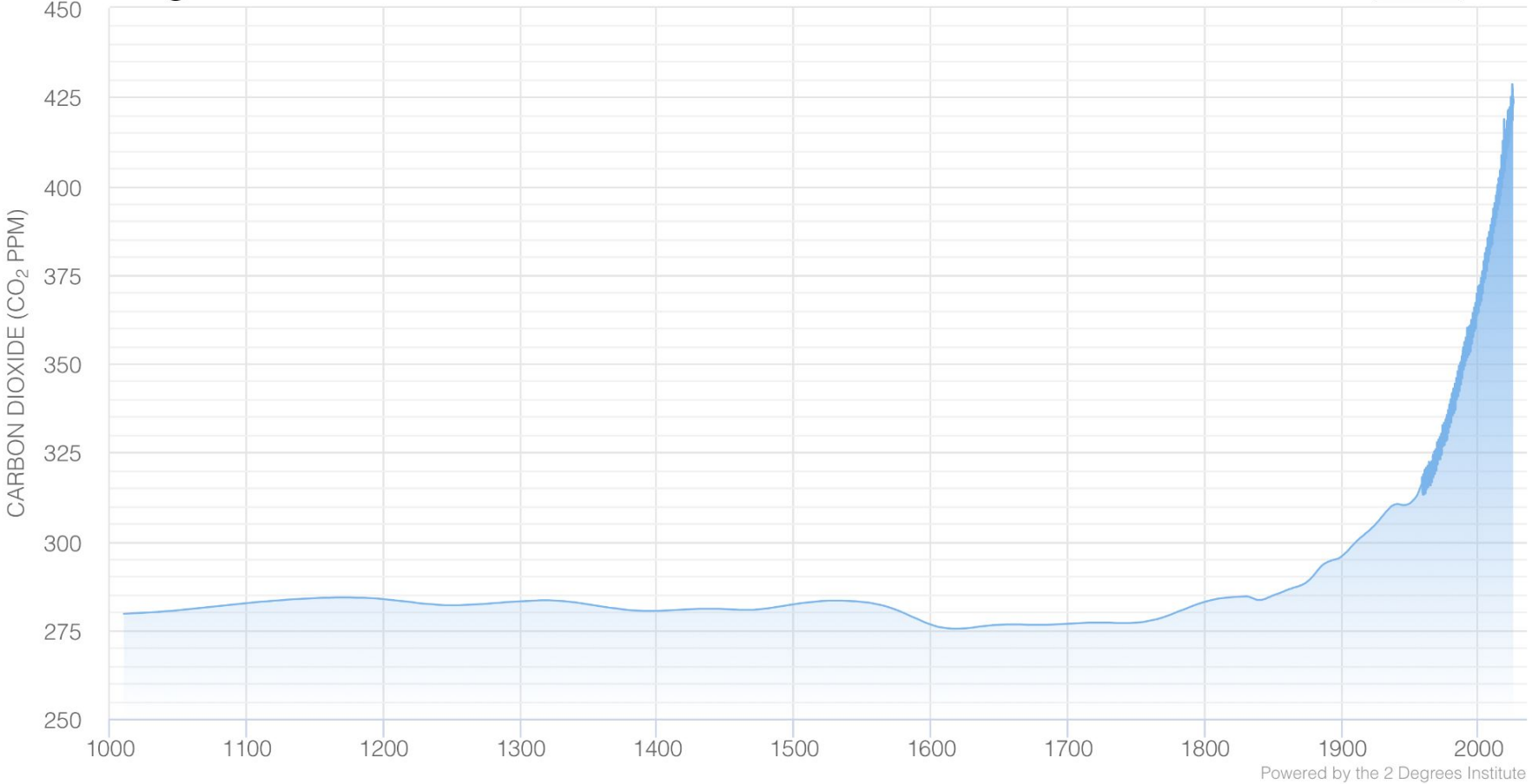
“And now for something completely different…”

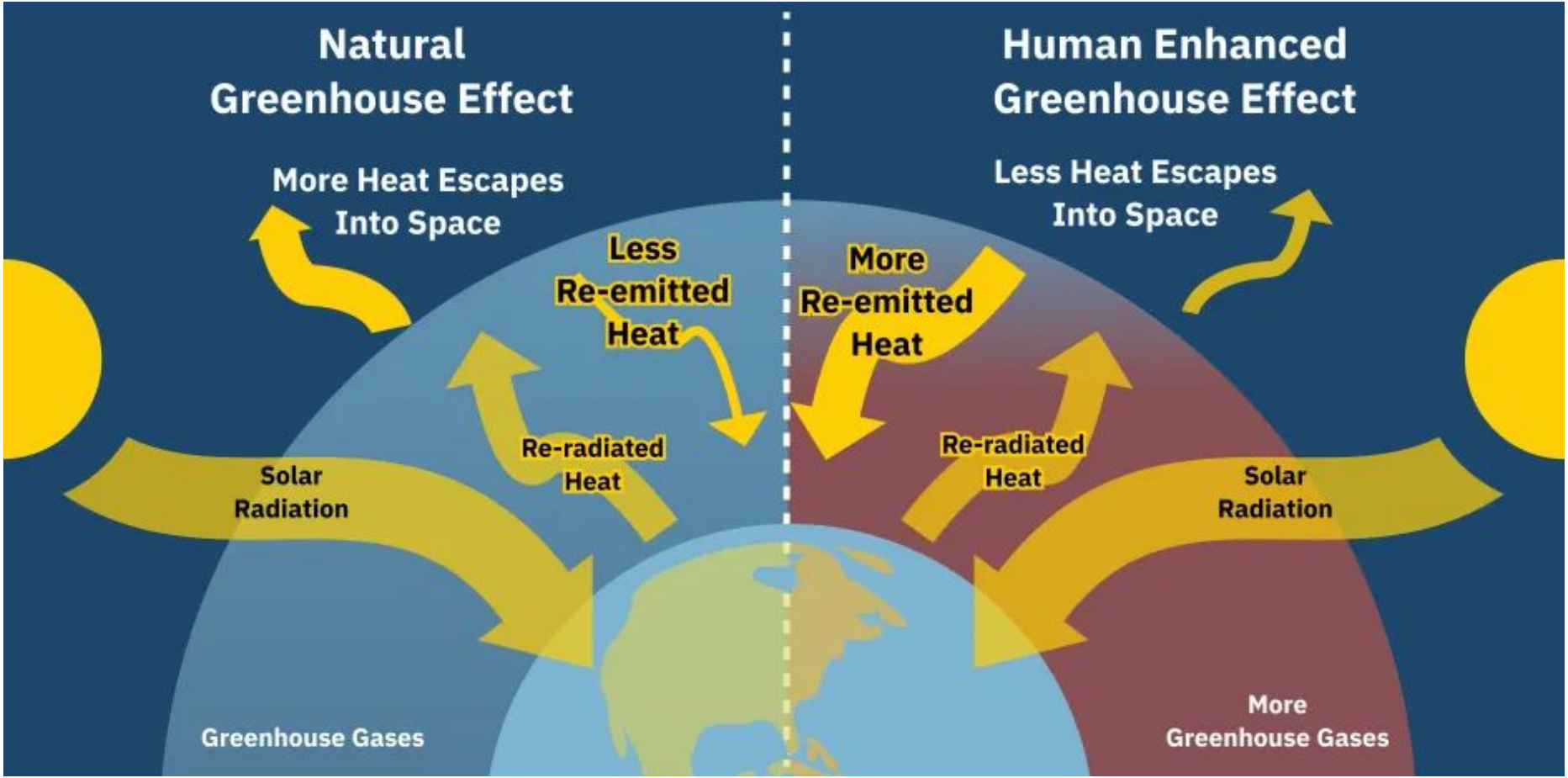
What does Computer Science have to do with Sustainability?

Udit Gupta, Harvard
Benjamin C. Pierce, Penn

GLOBAL CO_2 LEVELS

Click and drag in the plot area to zoom in




Natural
Greenhouse Effect
More Heat Escapes
Into Space
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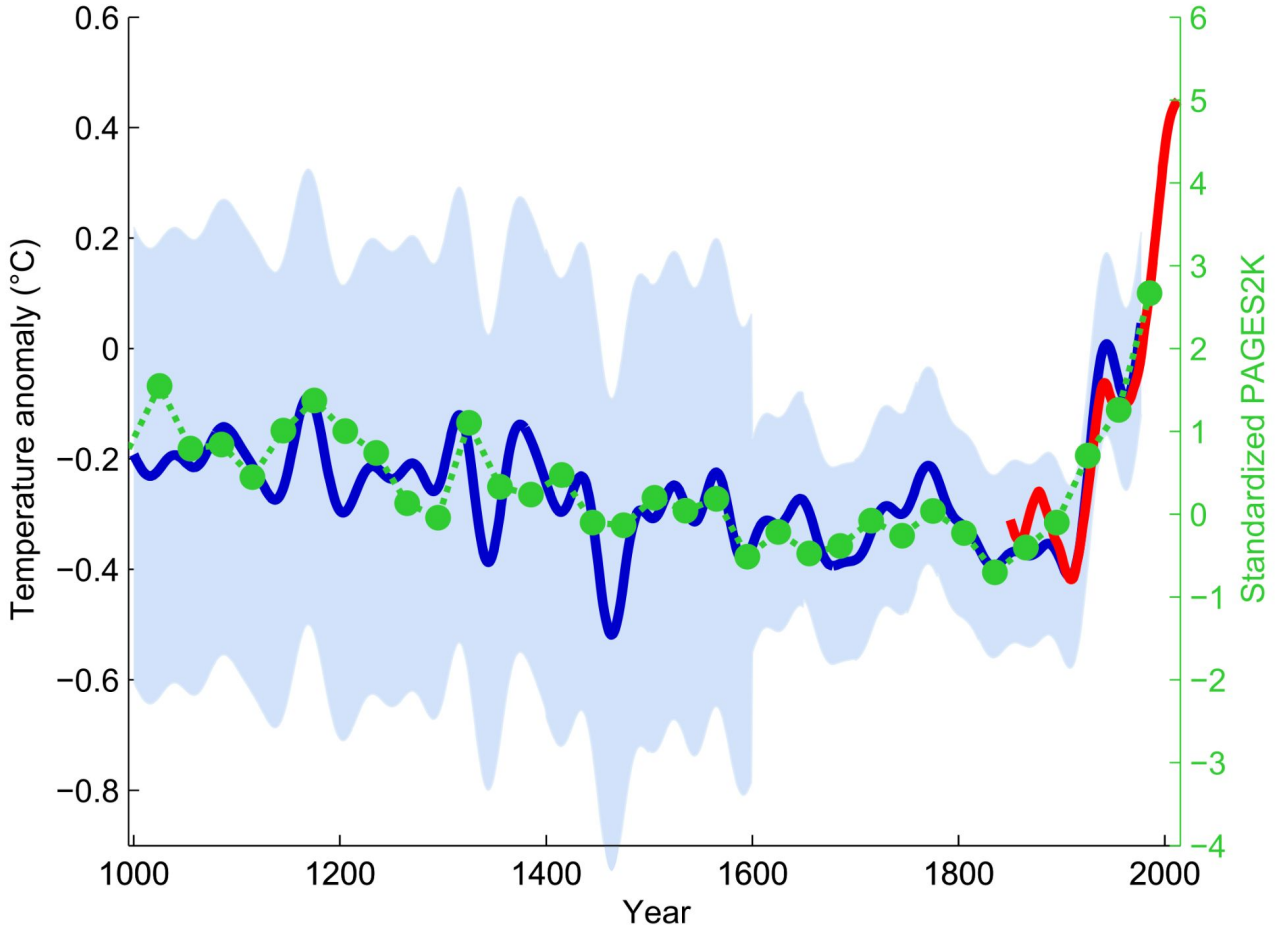
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Temperature anomaly (°C)
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Standardized PAGES2K
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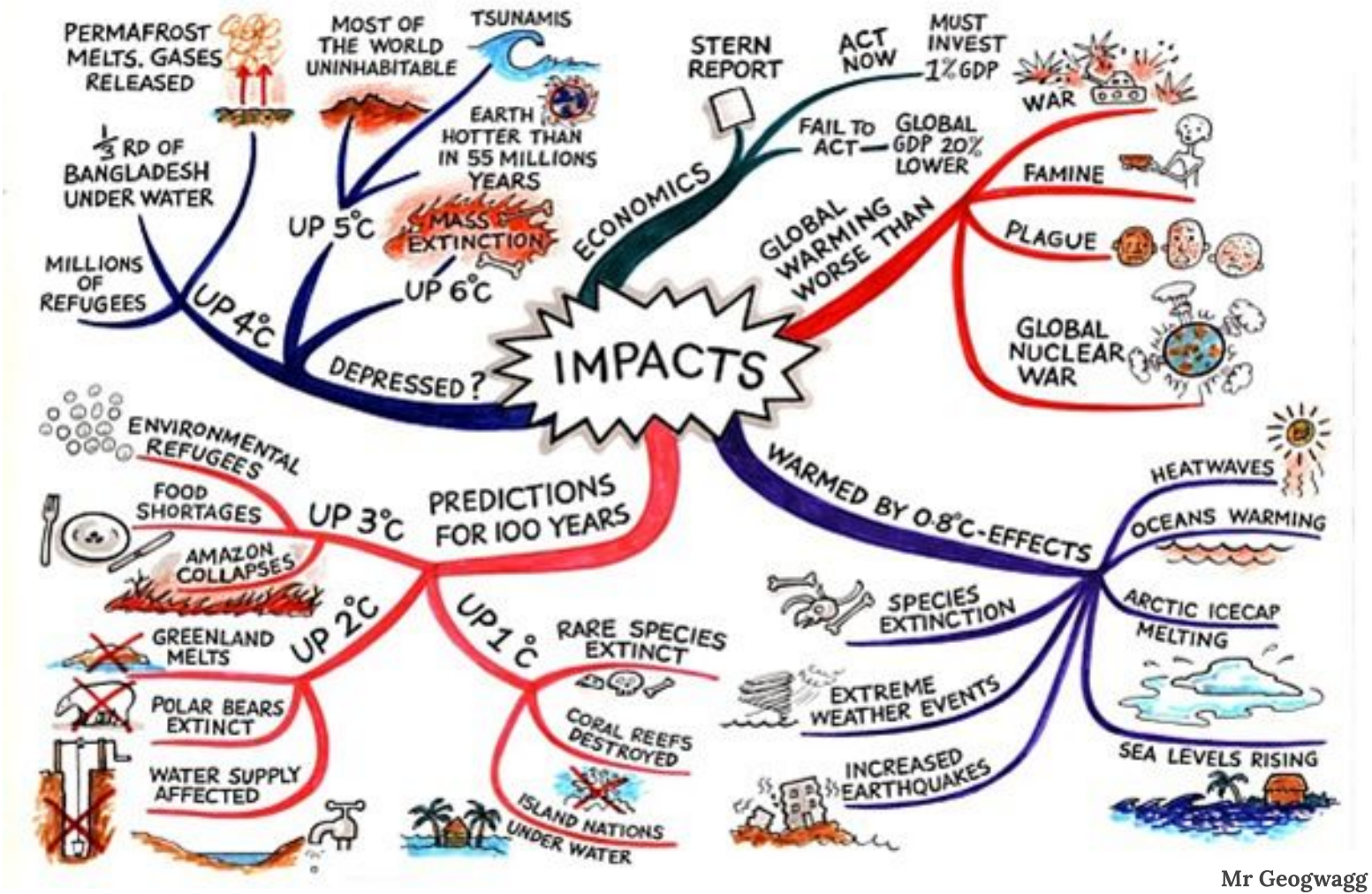
How big a problem is this?




Climate change is an *existential threat* to human society requiring *immediate, collective* action *at every level,* across *every community and industry*

Global

National

State / City

?

Institutional

Individual

What about universities?

Universities are about…

Creation of knowledge

Community engagement

Training new generations of leaders

Penn Sustainability

UNIVERSITY OF PENNSYLVANIA

Climate & Sustainability Action Plan 4.0

Penn
University of Pennsylvania

pcv

Penn Clima

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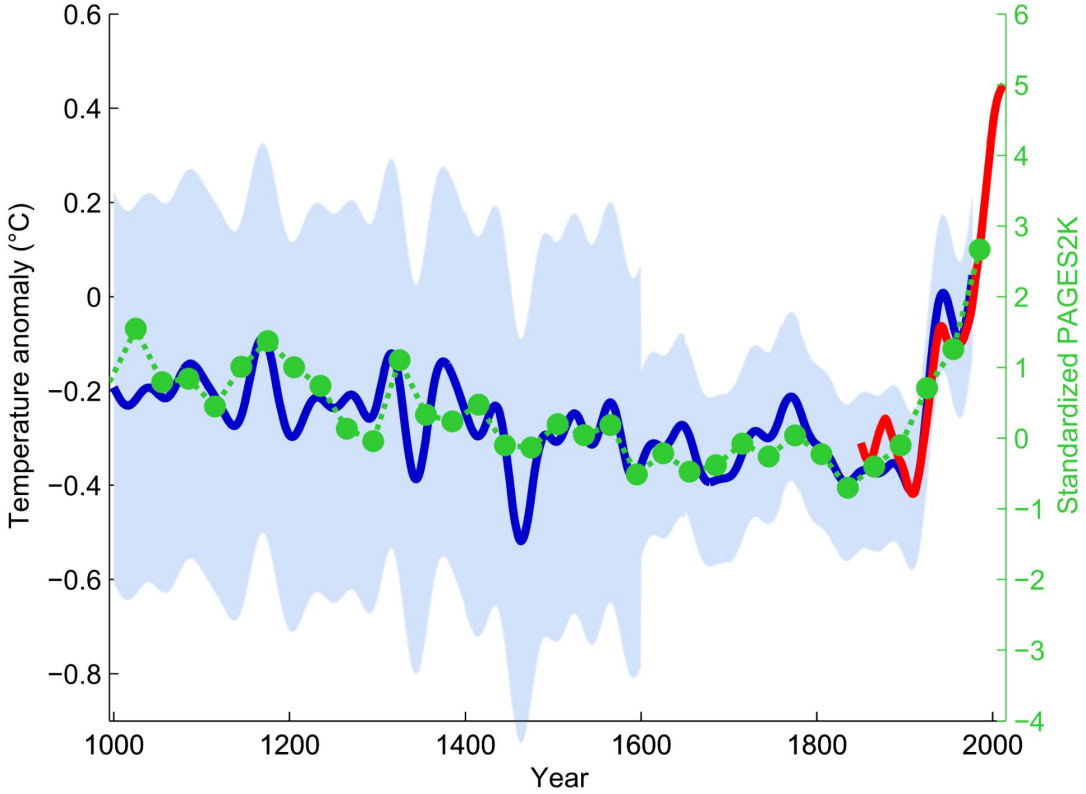
FOSSIL FREE PENN

Fossil Free Penn

GROUP

Penn Environmental Group (PEG)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Temperature anomaly (°C)
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Standardized PAGES2K
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1600
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2000
Year

MICHAEL E. MANN

ABOUT

PRESIDENTIAL DISTINGUISHED PROFESSOR OF EARTH & ENVIRONMENTAL SCIENCE

DIRECTOR, PENN CENTER FOR SCIENCE, SUSTAINABILITY AND THE MEDIA

BIOGRAPHICAL SKETCH:

Dr. Michael E. Mann is Presidential Distinguished Professor in the Department of Earth and Environmental Science at the University of Pennsylvania, with a secondary appointment in the Annenberg School for Communication. He also serves as Vice Provost for Climate Science, Policy, and Action and Director of the Penn Center for Science, Sustainability, and the Media (PCSSM).

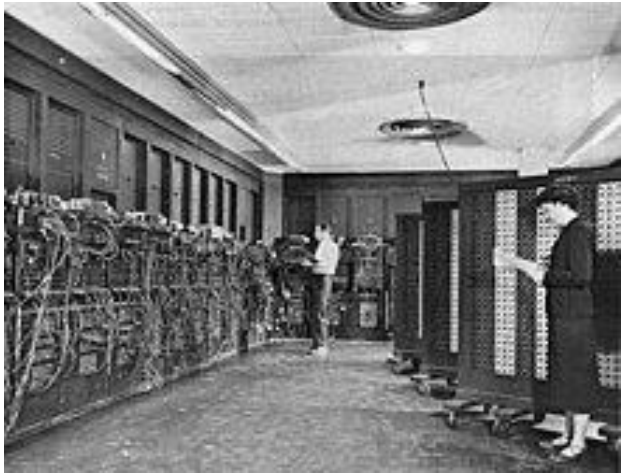
Dr. Mann received his undergraduate degrees in Physics and Applied Math from the University of California at Berkeley, an M.S. degree in Physics from Yale University, and a Ph.D. in Geology & Geophysics from Yale University. His research interests include the study of Earth's climate system and the science, impacts and policy implications of human-caused climate change.

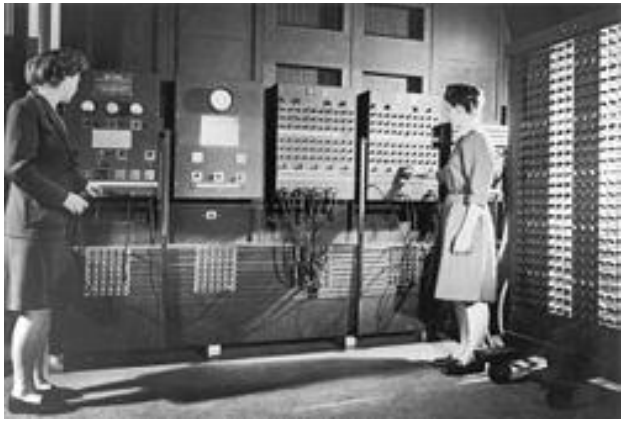
Dr. Mann was a Lead Author on the *Observed Climate Variability and Change* chapter of the Intergovernmental Panel on Climate Change (IPCC) Third Scientific Assessment Report in 2001 and was organizing committee chair for the National Academy of Sciences *Frontiers of Science* in 2003. He has received a number of honors and awards including NOAA's outstanding publication award in 2002 and selection by *Scientific American* as one of the fifty leading visionaries in science and technology in 2002. He contributed, with other IPCC authors, to the award of the 2007 Nobel Peace Prize. He was awarded the Hans Oeschger Medal of the European Geosciences Union in 2012 and was awarded the National Conservation Achievement Award for science by the National Wildlife Federation in 2013. He made Bloomberg News' list of fifty most influential people in 2013. In 2014, he was named Highly Cited Researcher by the Institute for Scientific Information (ISI) and

What does this have to do with intro CS?

Computing is part of the problem!

(What’s this?)



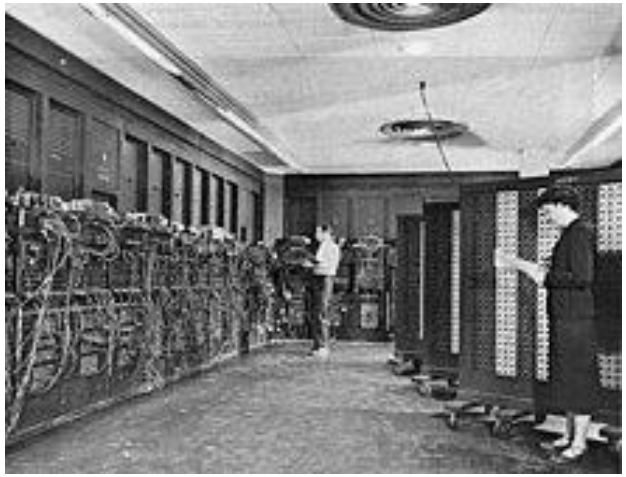


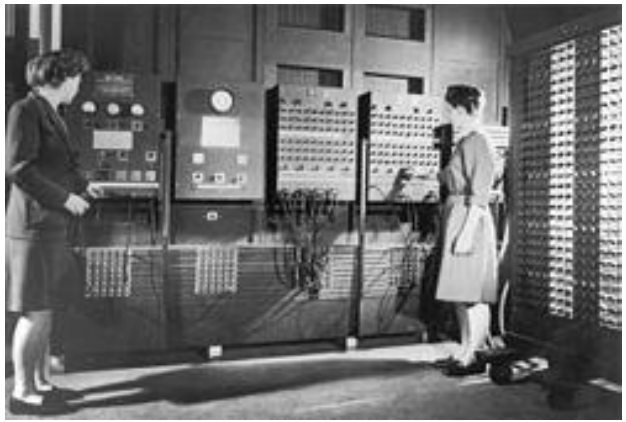
The first digital computer! (1945)

Electronic, programmable, general purpose

- Designed primarily by **John Mauchly** and **J. Pesper Eckert**

- Programmed primarily by **six mathematicians**:
  - *Jean Jennings, Marlyn Wescoff, Ruth Lichterman, Betty Snyder, Frances Bilas, and Kay McNulty*





The first digital computer! (1945)

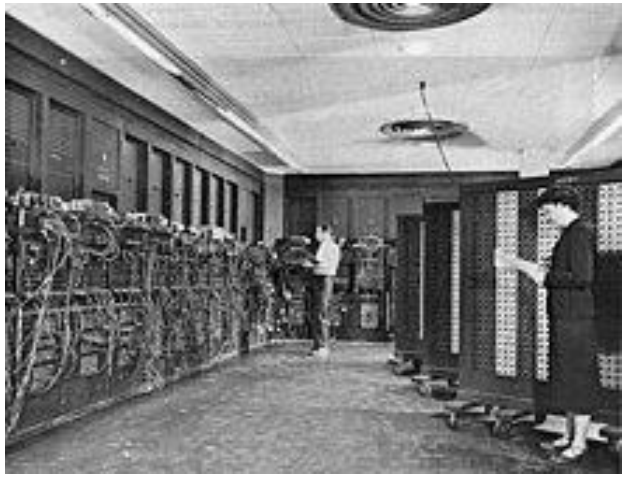
Electronic, programmable, general purpose

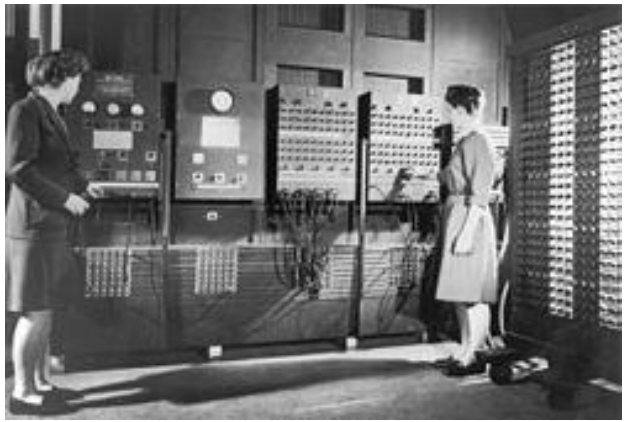
ENIAC consisted 18,000 vacuum tubes, 7,200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors, and approximately 5M hand-soldered joints.

- It weighed 30 Tons!
- Took up a room 1800 sq. feet in size
- And consumed 150 kW of electricity

How many FLOPS?

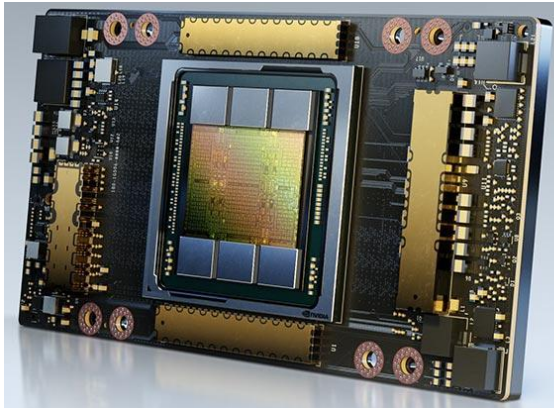
500!





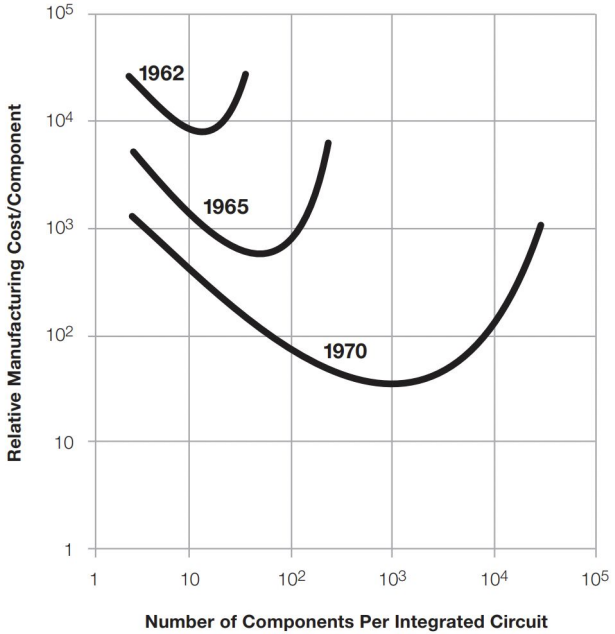
Modern computers

iPhone 15
100mm^2
5W
~2TFLOPs



NVIDIA A100
12x5x2 inches
250+Watts
~100 TFLOPs

Original prediction by Gordon Moore



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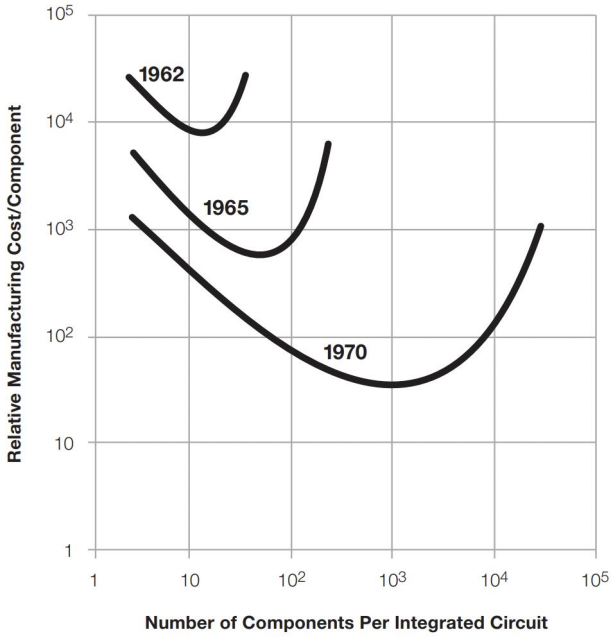
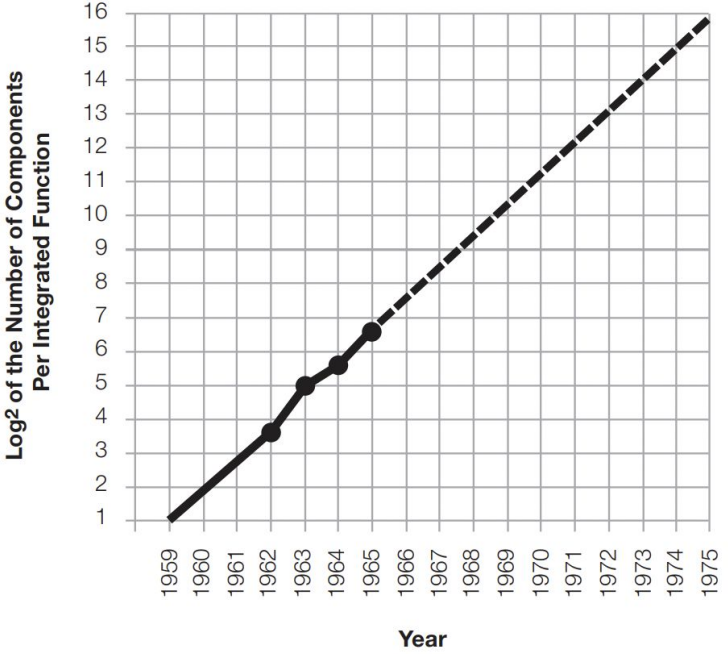




The decades-long impact of Moore's Law

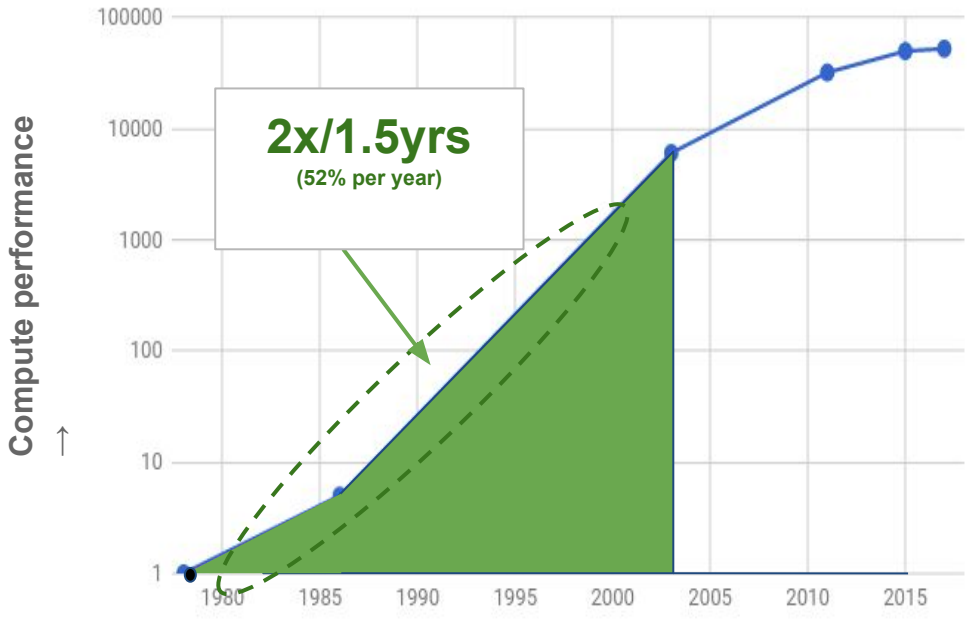


Image source: Hennessy and Patterson

The decades-long impact of Moore's Law

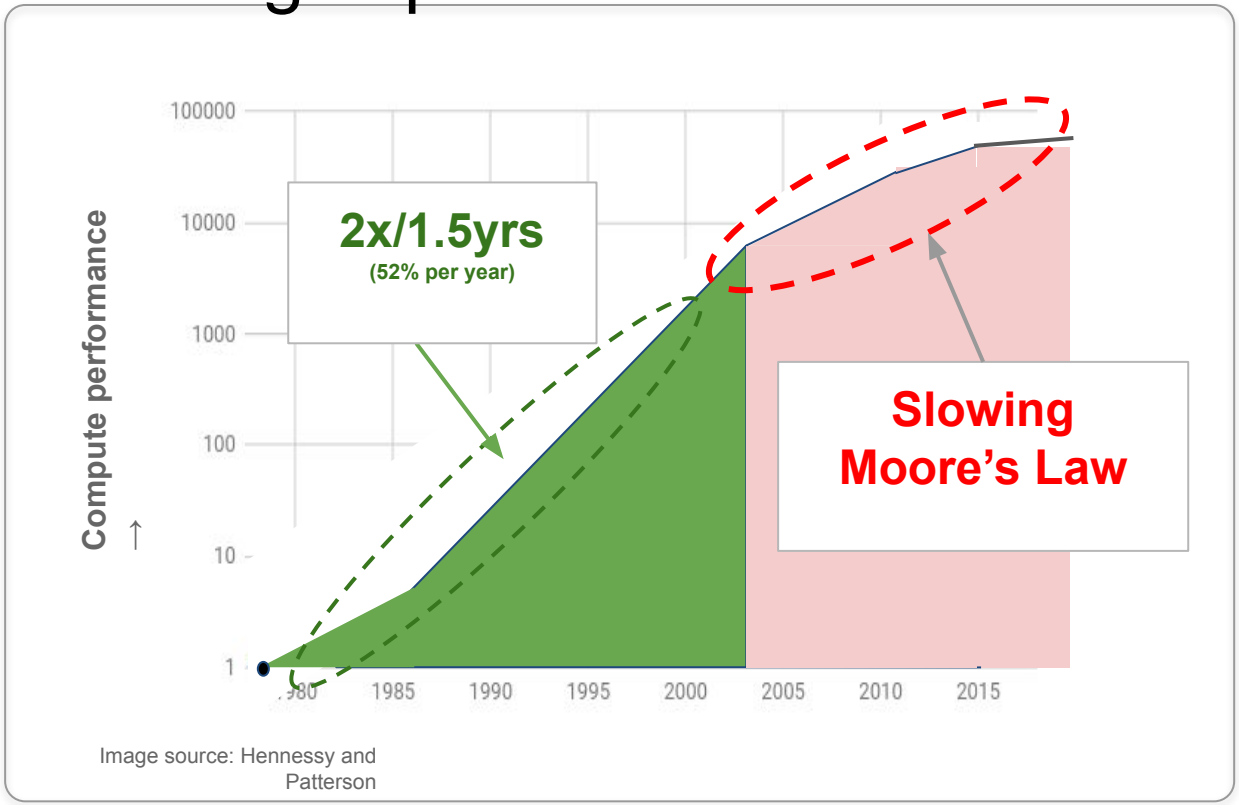
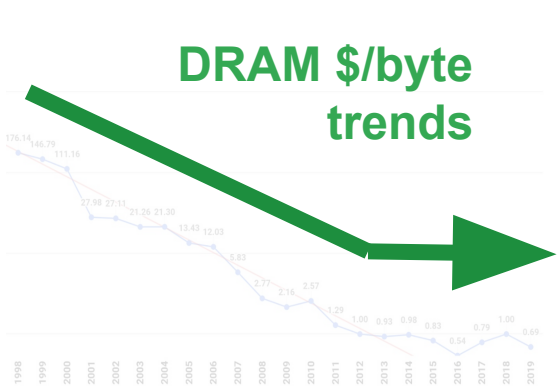
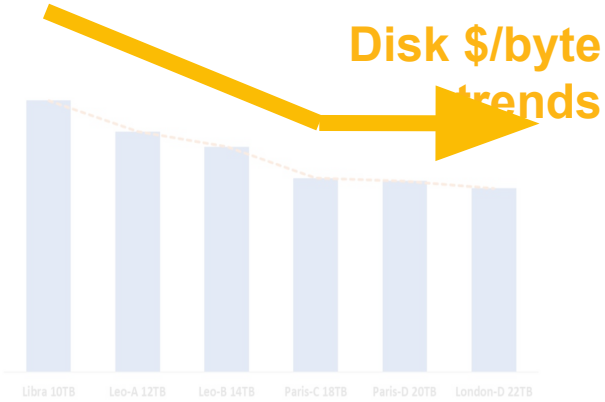


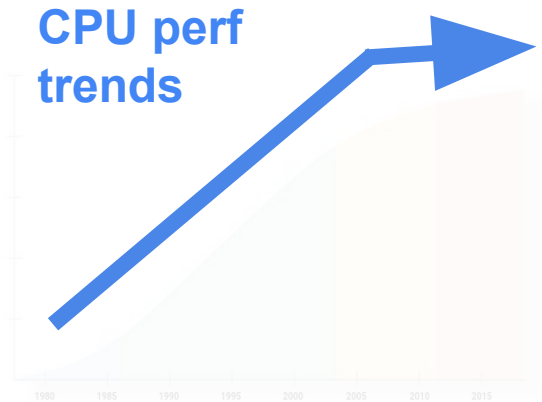
Image source: Hennessy and Patterson

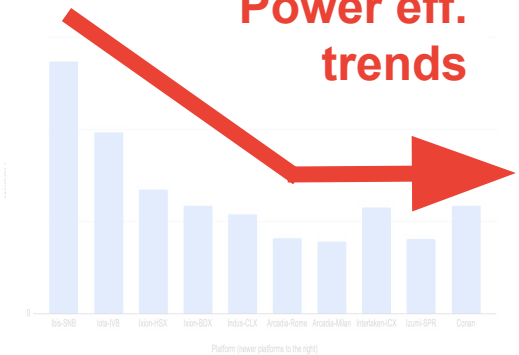
The impact of Moore's Law slowing down

Technology Plateaus









Over the last 20 years, hardware and software advancements have drastically optimized for performance and energy efficiency

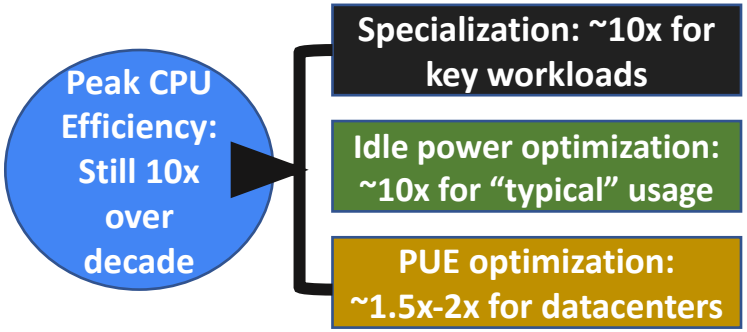
Pre-2000:
"Moore's Law"

10x energy efficiency every 5 years

2000-2010:
"Moore's Hangover"

10x energy efficiency over *decade*

2010-2020:
"Beyond Moore"



Koomey et. al., 2011
Naffziger and Koomey, 2016

Over the last 20 years, hardware and software advancements have drastically optimized for performance and energy efficiency

Pre-2000:
"Dennard Scaling"

10x energy efficiency every 5 years

2000-2010:
"Dennard's Hangover"

10x energy efficiency over *decade*

2010-2020:
"Beyond Dennard"

Peak CPU Efficiency: Still 10x over decade

- Specialization: ~10x for key workloads
- Idle power optimization: ~10x for "typical" usage
- PUE optimization: ~1.5x-2x for datacenters

Koomey et. al., 2011
Naffziger and Koomey, 2016

But how have these advances affected computing's environmental sustainability (e.g., carbon footprint)?

Computing incurs a huge environmental footprint

1.2-2.2 Billion tons of CO_2

- **On par with** the aviation industry's footprint
- **2.1 - 3.9%** of worldwide emissions (Freitag'21)

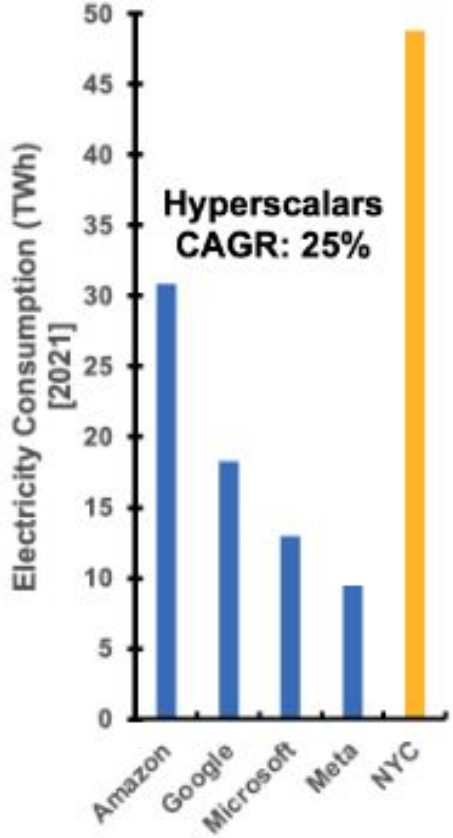
And emissions are rising with growing demand!

Data center energy consumption

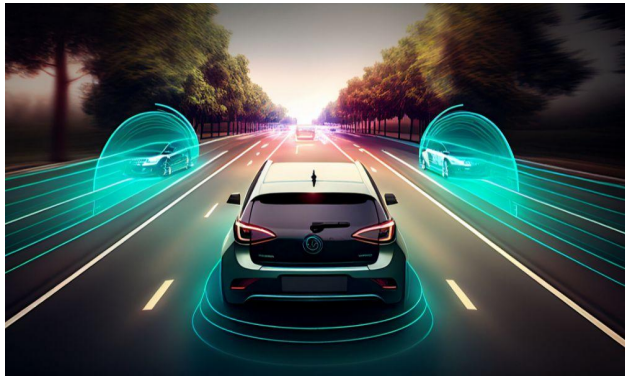
Data centers use more electricity than entire countries

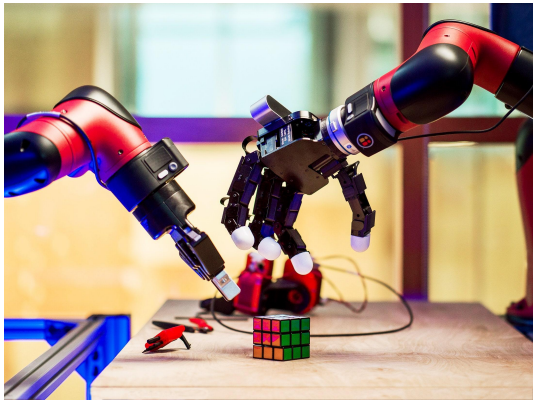
Domestic electricity consumption of selected countries vs. data centers in 2020 in TWh

Source: Enerdata, IEA



Emerging applications introduce new requirements





Big Tech. companies are pledging carbon neutrality

Google The Keyword Latest stories Product updates Company news

A MESSAGE FROM OUR CEO

Our third decade of climate action: Realizing a carbon-free future

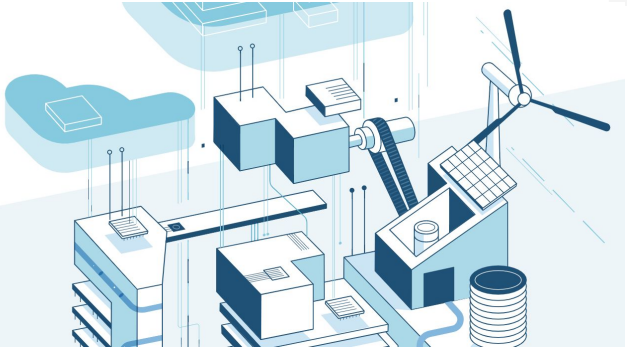
Microsoft | Official Microsoft Blog Microsoft On the Issues The AI Blog Transform

Microsoft will be carbon negative by 2030

Jan 16, 2020 | Brad Smith - President

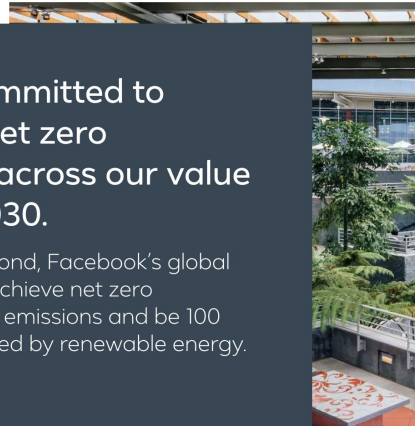
Sustainability in the Cloud

Amazon Web Services (AWS) is committed to running our business in the most environmentally friendly way possible and achieving 100% renewable energy usage for our global infrastructure.



FACEBOOK Sustainability

Innovation for our world Collaboration for good



We are committed to reaching net zero emissions across our value chain in 2030.

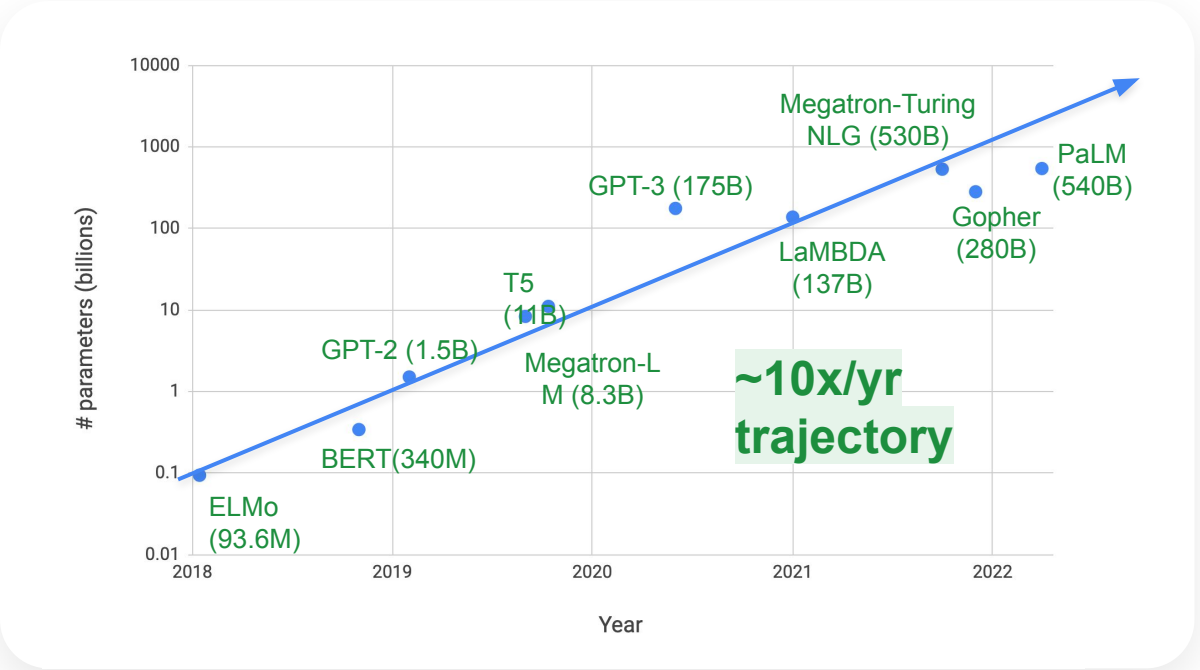
In 2020 and beyond, Facebook's global operations will achieve net zero greenhouse gas emissions and be 100 percent supported by renewable energy.

PRESS RELEASE
July 21, 2020

Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030

But wait… it just got worse!

AI’s footprint continues to grow!



Scaling of "dense" large language models

Is AI a big footprint?

Energy and Policy Considerations for Deep Learning in NLP

Emma Strubell **Ananya Ganesh** **Andrew McCallum**
College of Information and Computer Sciences
University of Massachusetts Amherst
{strubell, aganesh, mccallum}@cs.umass.edu

Abstract

Recent progress in hardware and methodology for training neural networks has ushered in a new generation of large networks trained on abundant data. These models have obtained notable gains in accuracy across many NLP tasks. However, these accuracy improvements depend on the availability of exceptionally large computational resources that necessitate similarly substantial energy consumption. As a result these models are costly to train and develop, both financially, due to the cost of hardware and electricity or cloud compute time, and environmentally, due to the carbon footprint required to fuel modern tensor processing hardware. In this paper we bring

Consumption	CO_2e (lbs)
Air travel, 1 passenger, NY↔SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car, avg incl. fuel, 1 lifetime	126,000
Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experimentation	78,468
Transformer (big)	192
w/ neural architecture search	626,155

Table 1: Estimated CO_2 emissions from training common NLP models, compared to familiar consumption.[1]

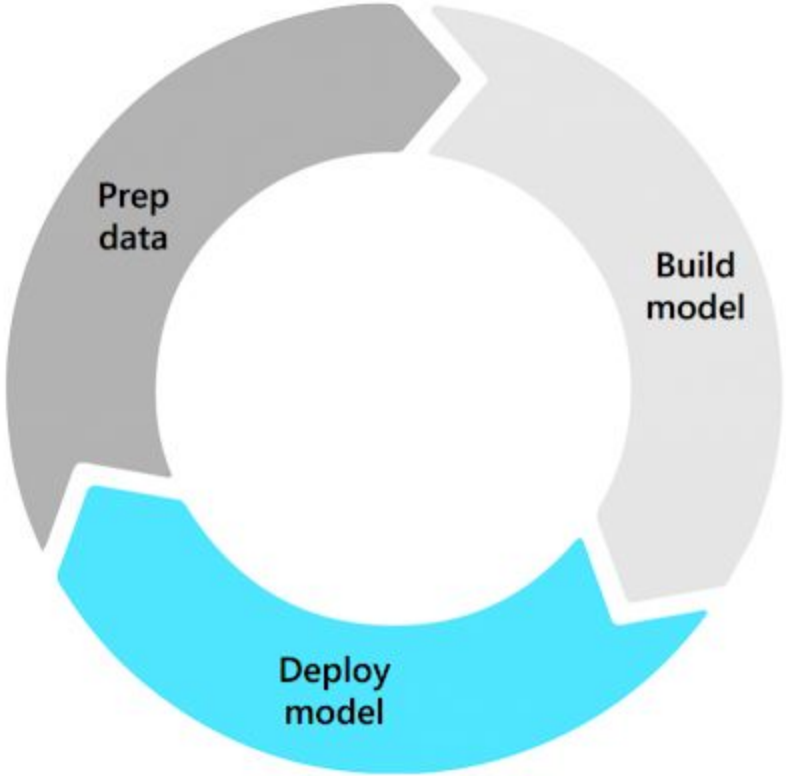
Is AI the new cryptocurrency?

Mark Zuckerberg said last Spring that, by the end of **2024**, the company's computing infrastructure will include 350,000 H100 graphics cards.

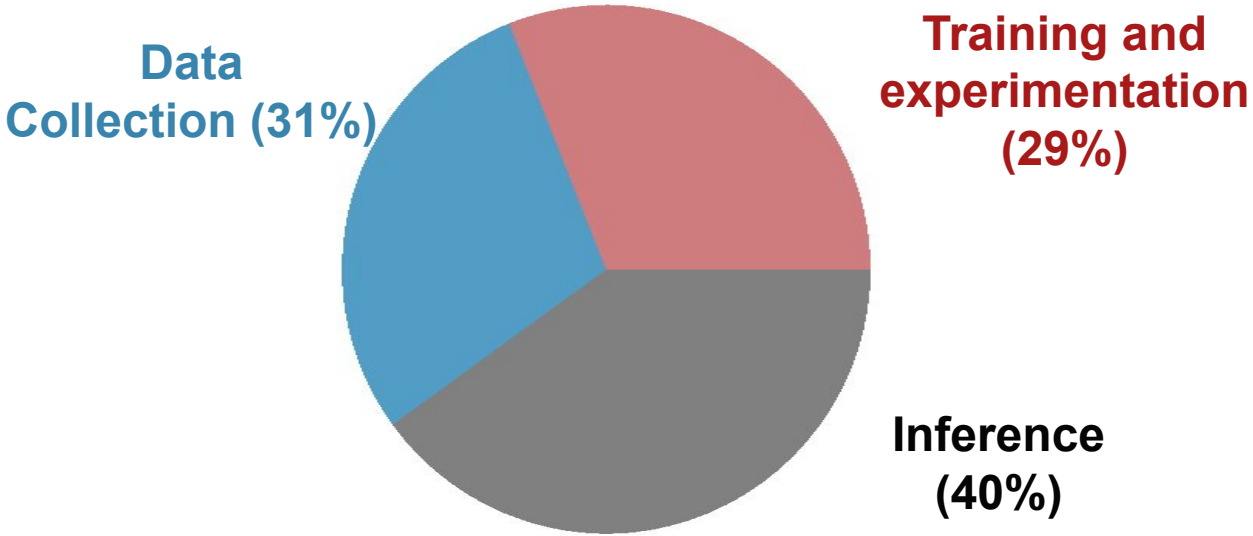
350MW / 1275 MW = 28% of Meta's compute fleet runs AI

Zuckerberg also said Meta's compute infrastructure will contain "almost 600k H100 equivalents of compute if you include other GPUs."

The ML Lifecycle



Crucial to look at emissions across ML lifecycle



Wu et. al. Sustainable AI: Environmental Implications, Challenges, and Opportunities (MLSys 2022)

The New York Times

Hungry for Energy, Amazon, Google and Microsoft Turn to Nuclear Power

Large technology companies are investing billions of dollars in nuclear energy as an emissions-free source of electricity for artificial intelligence and other businesses.

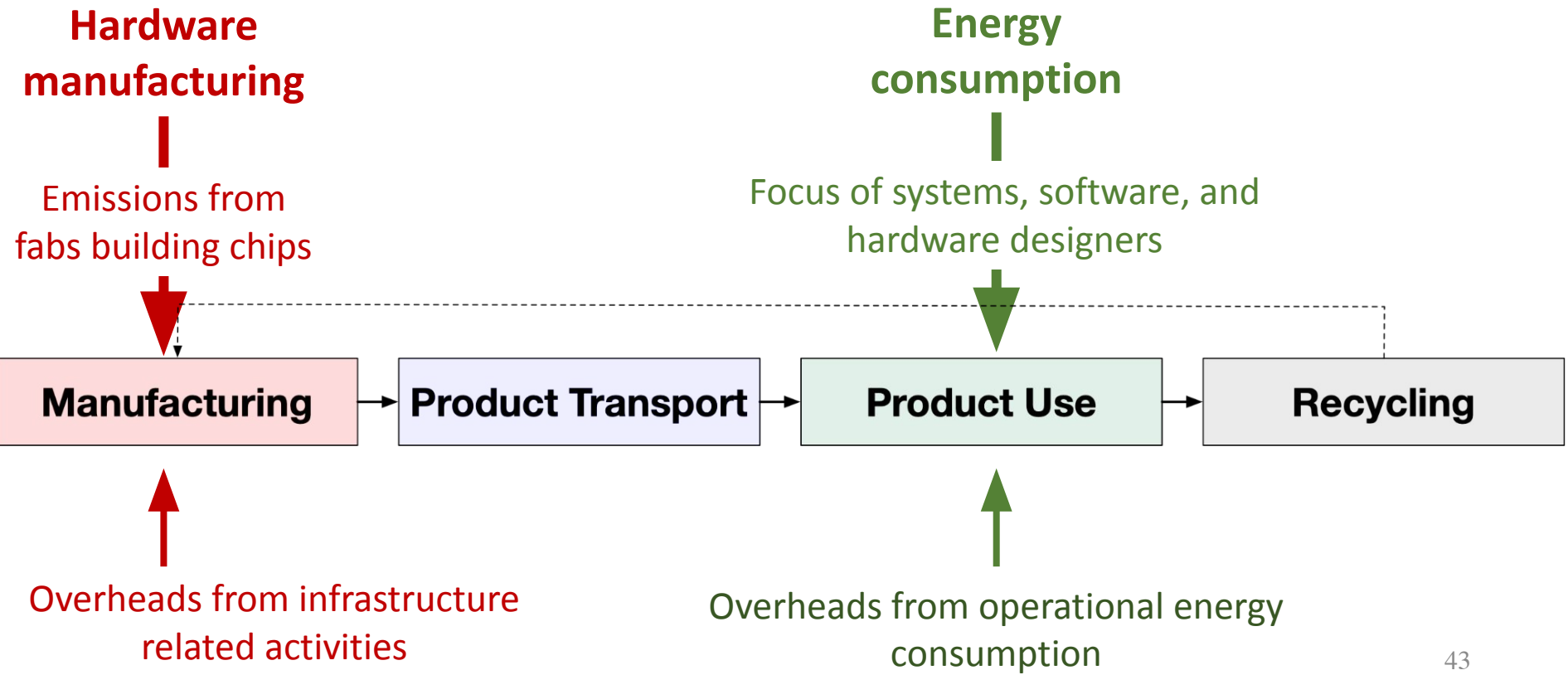
The Vogtle nuclear power plant in Waynesboro, Ga. The last two nuclear units at Vogtle ran tens of billions of dollars over budget and were years late in completion. Kendrick Brinson for The New York Times

Yikes

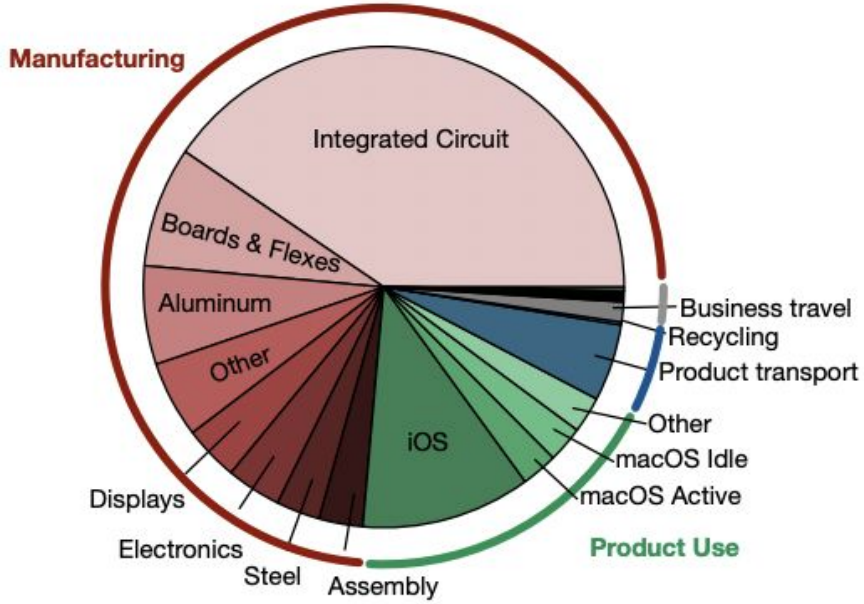
It’s time to think harder about this…


Sustainable
Computing

Hardware **L**ife **C**ycle **A**nalysis

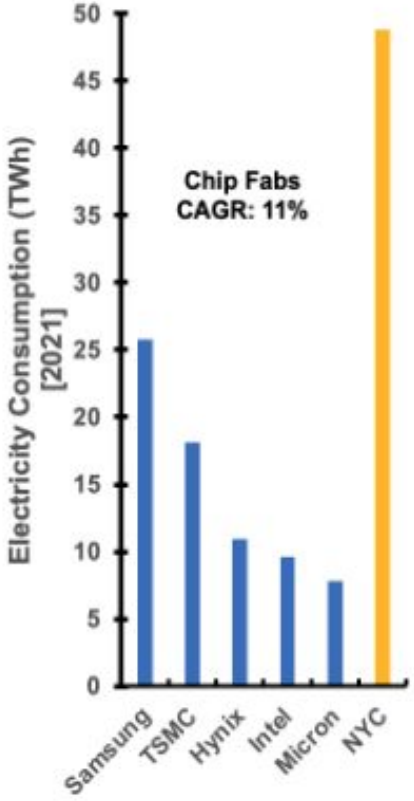


Apple’s mobile carbon footprint



Apple produces 25 million metric tons of CO2 every year

Semiconductor Fabrication



Semiconductor Fabs

- Located in places with **less carbon-free energy**
- Must contend with **direct emissions** (gasses)

TSMC Announces Updates for TSMC Arizona

Issued by: TSMC
Issued on: 2022/12/06

PHOENIX, Arizona, Dec. 6, 2022 – TSMC (TWSE: 2330, NYSE: T
addition to TSMC Arizona's first fab, which is scheduled to begi
technology in 2024, TSMC has also started the construction of
begin production of 3nm process technology in 2026. The over
be approximately US$40 billion, representing the largest foreigr
and one of the largest foreign direct investments in the history

October 4, 2022 at 9:40 AM EDT

Micron Announces Historic Investment of up to $100 Billion to Build Megafab in Central New York

Sustainably built and operated, leading-edge memory fab to create nearly 50,000 New York jobs; New Green CHIPS Community Fund to invest $500 million in community and workforce development over time

NSF Design for Environmental Sustainability in Computing

← Search for more funding opportunities

Print

Important information for proposers
All proposals must be submitted in accordance with the requirements specified in this funding opportunity and in the NSF Proposal & Award Policies & Procedures Guide (PAPPG) that is in effect...

+

Supports foundational research addressing the substantial environmental impacts of computing. Projects should surpass studies of energy efficiency alone, pursuing dramatic improvements to overall sustainability.

Synopsis

The goal of the Design for Environmental Sustainability in Computing (DESC) program is to address the substantial environmental impacts that computing has through its entire lifecycle from design and manufacturing, through deployment into operation, and finally into reuse, recycling, and disposal. These impacts go well beyond commonly-considered measures of energy consumption at

Upcoming due dates

Full proposal

2024

September 13 2024 - Deadline date

Type I and Type II projects

January 1 2024 - December 31, 2024 - Window

January 1 - December 31, Annually Thereafter

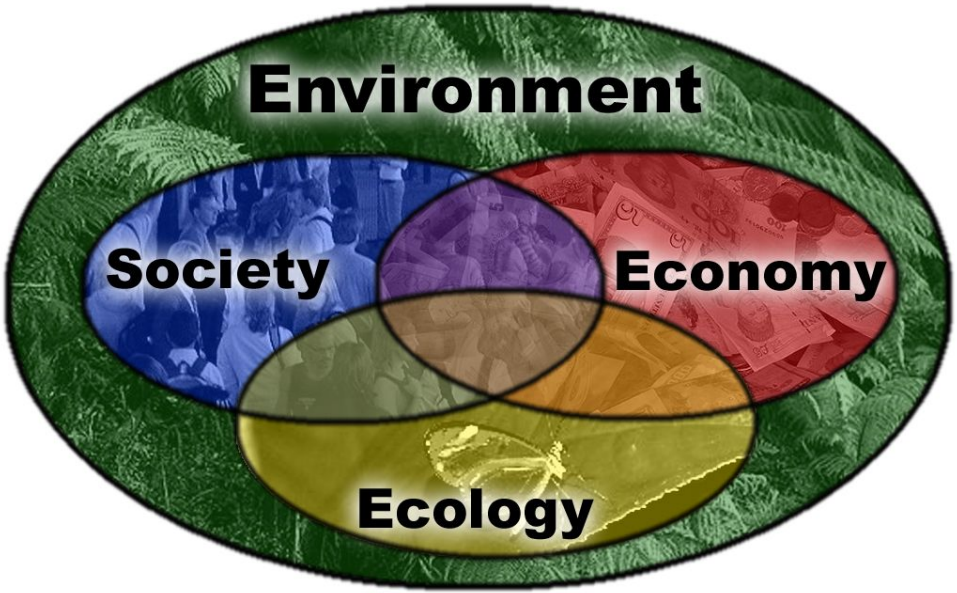
Type III projects

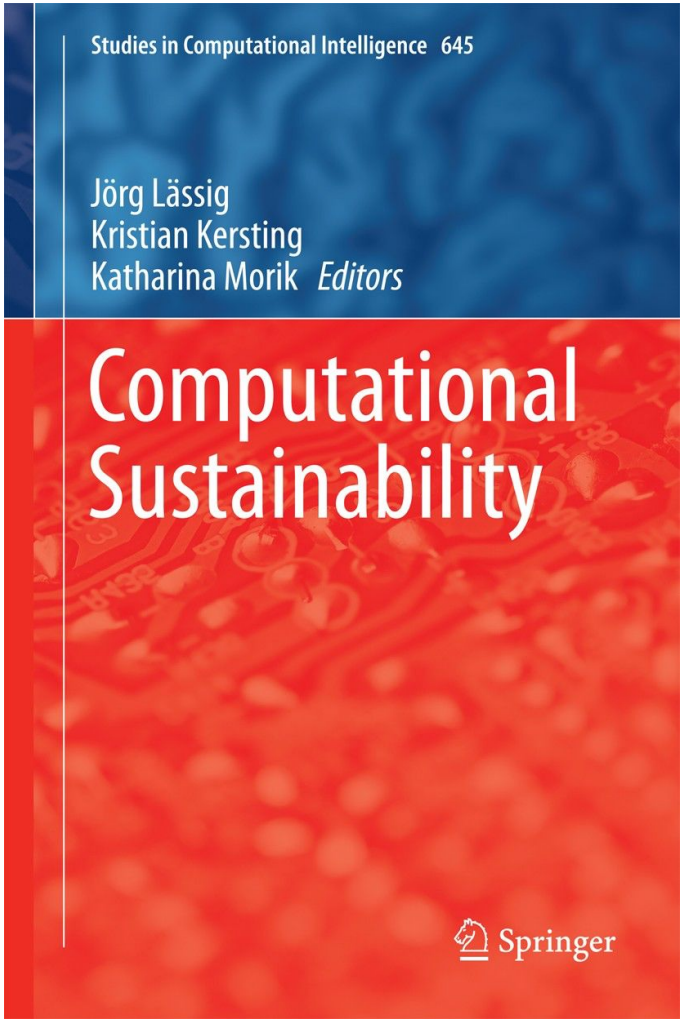
https://www.nsf.gov/pubs/2022/nsf22060/nsf22060.jsp

So… computing could hurt less…

Could it also help?

Computational sustainability is an emerging field that attempts to balance societal, economic, and environmental resources for the future well-being of humanity using methods from mathematics, computer science, and information science fields. (Wikipedia)




Studies in Computational Intelligence 645
Jörg Lässig
Kristian Kersting
Katharina Morik Editors
Computational Sustainability
Springer

Several slides on computational sustainability (5-10 min)

ML-based (rather than physics-based) modeling

Google, NVIDIA, HP have teams working on it


Carla Gomes
Prof. of Computer Science, Cornell University

Tackling Climate Change with Machine Learning

David Rolnick[1]*, Priya L. Donti[2], Lynn H. Kaack[3], Kelly Kochanski[4], Alexandre Lacoste[5], Kris Sankaran[6,7], Andrew Slavin Ross[9], Nikola Milojevic-Dupont[10,11], Natasha Jaques[12], Anna Waldman-Brown[12], Alexandra Luccioni[6,7], Tegan Maharaj[6,8], Evan D. Sherwin[2], S. Karthik Mukkavilli[6,7], Konrad P. Körding[1], Carla Gomes[13], Andrew Y. Ng[14], Demis Hassabis[15], John C. Platt[16], Felix Creutzig[10,11], Jennifer Chayes[17], Yoshua Bengio[6,7]

[1]University of Pennsylvania, [2]Carnegie Mellon University, [3]ETH Zürich, [4]University of Colorado Boulder, [5]Element AI, [6]Mila, [7]Université de Montréal, [8]École Polytechnique de Montréal, [9]Harvard University, [10]Mercator Research Institute on Global Commons and Climate Change, [11]Technische Universität Berlin, [12]Massachusetts Institute of Technology, [13]Cornell University, [14]Stanford University, [15]DeepMind, [16]Google AI, [17]Microsoft Research

What does
Computer Science
have to do with
Sustainability?

It is part of the problem

and of the solution(s)

Sustainable

computing

Computational

Sustainability

Questions?

Discussion?

Overflow slides

Instructor: Udit Gupta

Graduated from Cornell in 2016 (ECE Major and CS Minor)!

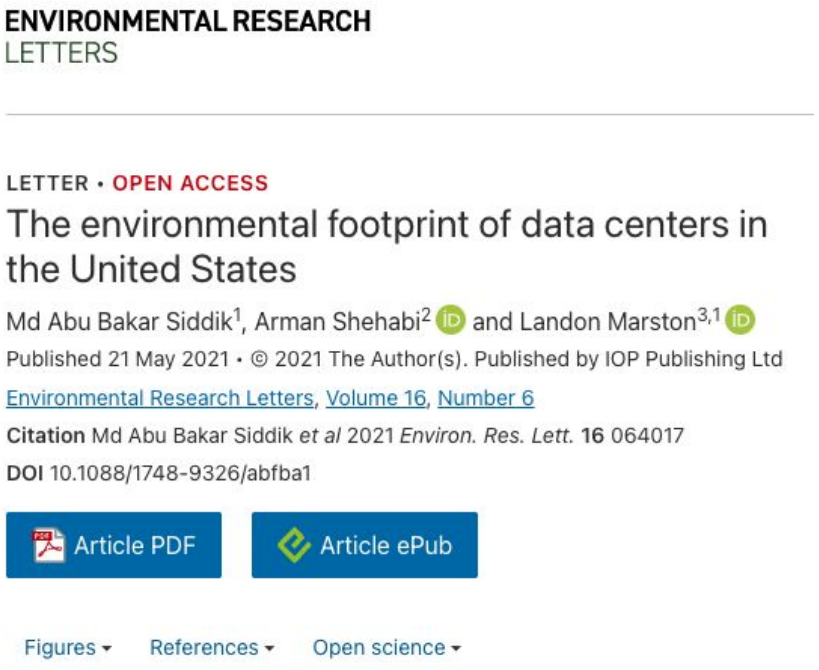
PhD from Harvard in 2022

Enabling High Performance, Efficient, and Sustainable Deep Lea

Visiting Research Scientist at Meta (2019-2022)

I love to play chess, try new restaurants and food (vegetarian), hike, and find new TV shows!

Data center water consumption



ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

The environmental footprint of data centers in the United States

Md Abu Bakar Siddik[1], Arman Shehabi[2] and Landon Marston[3,1]

Published 21 May 2021 • © 2021 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 16, Number 6

Citation Md Abu Bakar Siddik *et al* 2021 *Environ. Res. Lett.* **16** 064017

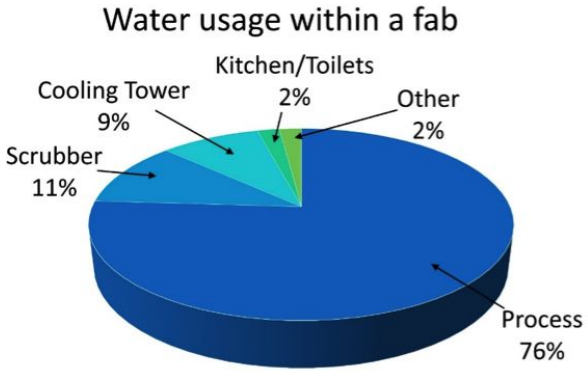
DOI 10.1088/1748-9326/abfba1

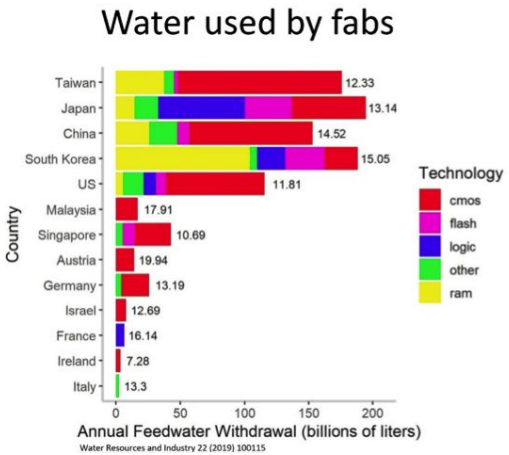
Article PDF Article ePub

Figures ▾ References ▾ Open science ▾

Data centers rank among the top 10 water-consuming commercial industries in the United States, using approximately 513 million cubic meters of water in 2018. Much of that water use comes from **electricity use — coal, nuclear and natural gas plants take water to operate**, and **hydropower also consumes water** — but about a quarter is due to **using water for direct cooling**.

Semiconductor water consumption





/ ABA Groups / Section of Environment, Energy, and Resources / Publications / Water Resources

February 01, 2023

A Tale of Two Shortages: Reconciling Demand for Water and Microchips in Arizona

Sarah Brunswick

Share:

Semiconductor chips are vital to modern existence: they allow us to drive to work, call our mothers, and much, much more. Unfortunately, demand has far outstripped supply. Manufacturers produced more than one trillion chips in 2021, and yet, shortages abounded. In Arizona, semiconductors have a surprisingly long history, dating back to the mid-1950s. As Steven Zylsta, president and CEO of the Arizona Technology Council aptly observed to a local NPR reporter, "We have no floods, hurricanes, tornadoes, earthquakes—all those things that could really upset semiconductor manufacturing."

TIME

SUBSC

TECH • INNOVATION

The World Has an E-Waste Problem

s sort through discarded electronics at ERI's Fresno facility Christie Hemm Klok for TIME

BY ALANA SEMUELS/FRESNO, CALIF.

MAY 23, 2019 6:27 AM EDT

As a tech-hungry nation flush with cash gets ready to upgrade to the next generation of lightning-fast 5G devices, there is a surprising environmental cost to be reckoned with: a fresh mountain of obsolete gadgets. About 6 million lb. of discarded electronics are already processed monthly at

Consumers can't resist faster products with more storage and better cameras, but constant upgrades have created a growing global waste challenge. In 2019 alone, people discarded 53 million metric tons of electronic waste.

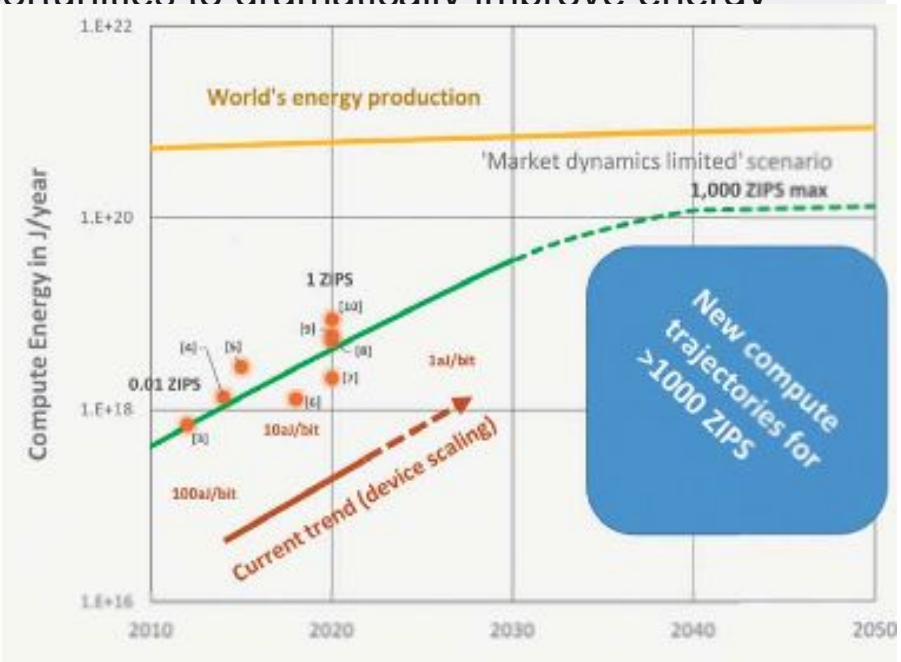
The bad news is that only about 35% of U.S. e-waste is recycled.

The U.S. exports up to 40% of its e-waste. Some goes to regions such as Southeast Asia that have little environmental oversight and few measures to protect workers who repair or recycle electronics.

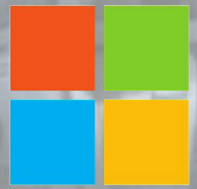
SRC decadal plan calls attention to ICT rising energy footprint

Ever-rising energy demand for computing vs. global energy production is creating new risk,

and new computing paradigms offer opportunities to dramatically improve energy efficie



Economic incentives and carbon sequestration



Microsoft: Incentivizes reductions by applying an internal carbon tax of **$100/tCO2e** amounting to an annual cost of over **$1 billion**

Google: Estimates **$50-$300/tCO2e** as carbon sequestration scales up to **20%** of the cost of a server!

https://cloudblogs.microsoft.com/industry-blog/sustainability/2022/03/24/how-microsoft-is-using-an-internal-carbon-fee-to-reach-its-carbon-negative-goal/
https://www.youtube.com/watch?v=W7uTbxCxmPg