CHICAGO
MARCH 4-7

INTERNET2
2024 COMMUNITY exchange

GreenEx

Put the Planet into your TCO

March 7, 2024

Introductions

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SkyPilot spot training across clouds

What about sustainability?

What is the impact of our personal computing choices?

Do sustainability concerns impact what you buy or how often you upgrade?

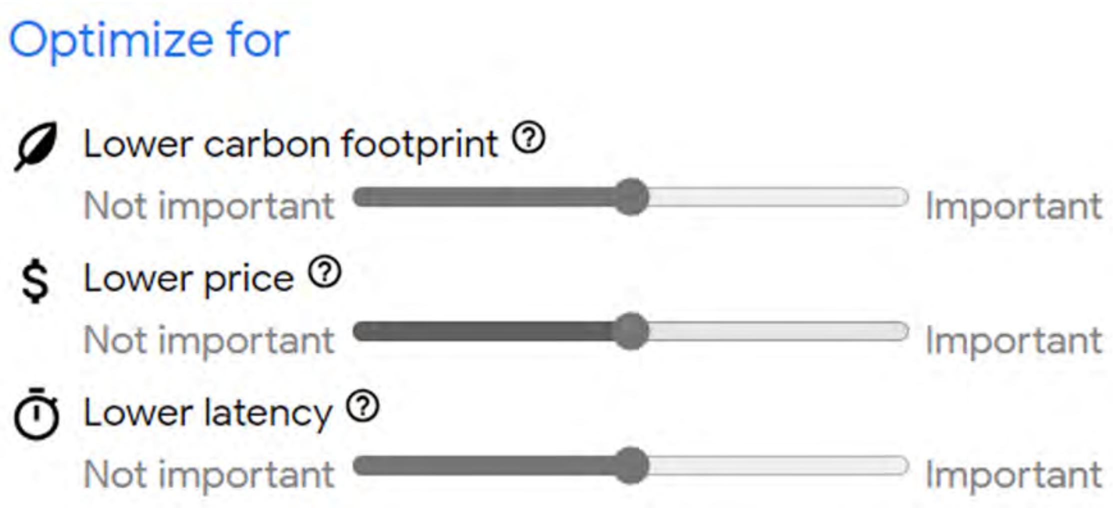
Is cost your only driver? Are needs?

What is the impact of our institutional computing choices?

Do sustainability concerns impact what you buy or how often you upgrade?

Is cost your only driver? Are needs?

We have the answer!



https://cloud.withgoogle.com/region-picker/

Thank you!

What we are not doing

What we are doing

- Asking questions to provoke others to start asking questions
- Talk about the known knowns
- Talk about the known unknowns
- Try to determine if the unknown unknowns are knowable
  …and important?

What we are trying to accomplish?

- Start a conversation
- Get people thinking
- Move us closer to a point where we have *true* TCO for all compute
- What is the right model for TCO?

The “cost” of coffee

The TCO of coffee

Breaking down T. C. O.

- “O” really means *operating* since cloud computing involves no ownership.
- “T” is not really meaningful unless you account for…everything
- “C” requires us to think more broadly (social cost)


Cost is a close proxy
for sustainability

Thank you!

tl;dr

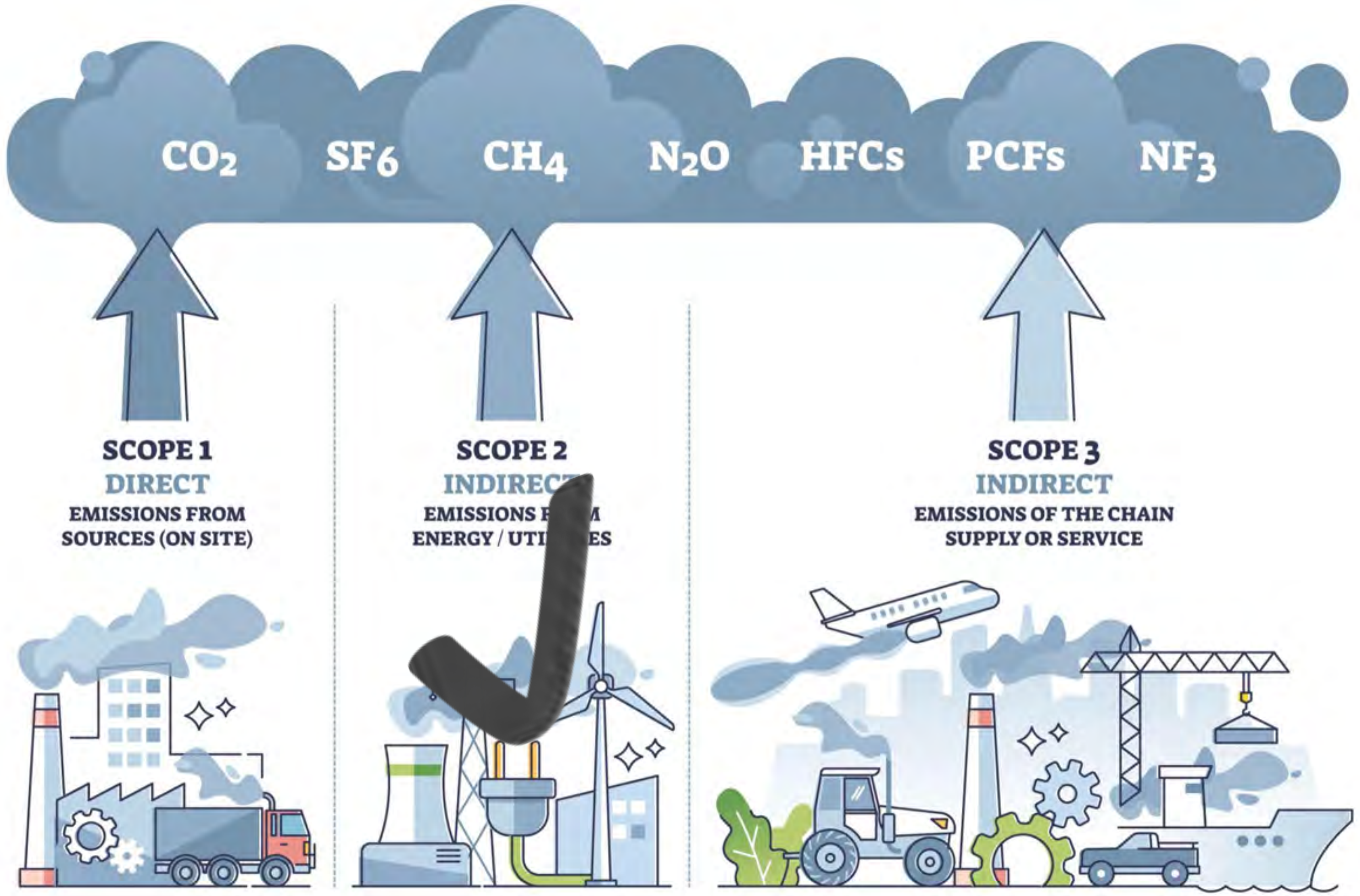
There is no such thing as “free” computing

Challenges

Challenge 1: The consequences of incomplete data

- How many people know the cost of power for their data center?
- And if you don't know. You don't have the incentive to improve.

Challenge 2: Even if you know the cost of power, what is its environmental impact?



Challenge 3: What are the other costs?

The Observer
Computing

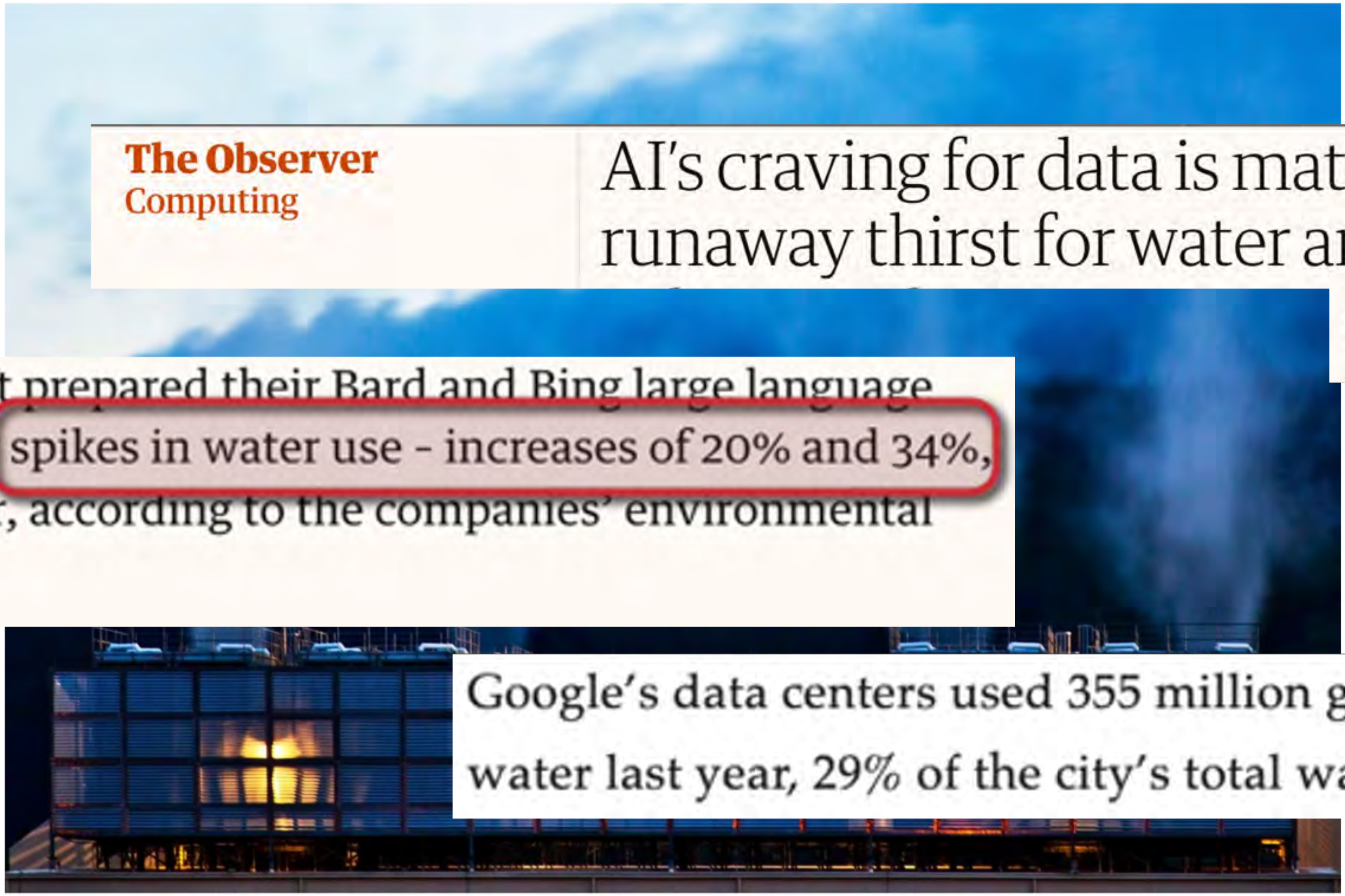
AI's craving for data is matched only by a runaway thirst for water and energy

Sat 2 Mar 2024 10.55 EST

As Google and Microsoft prepared their Bard and Bing large language models, both had major spikes in water use - increases of 20% and 34%, respectively, in one year, according to the companies' environmental reports."

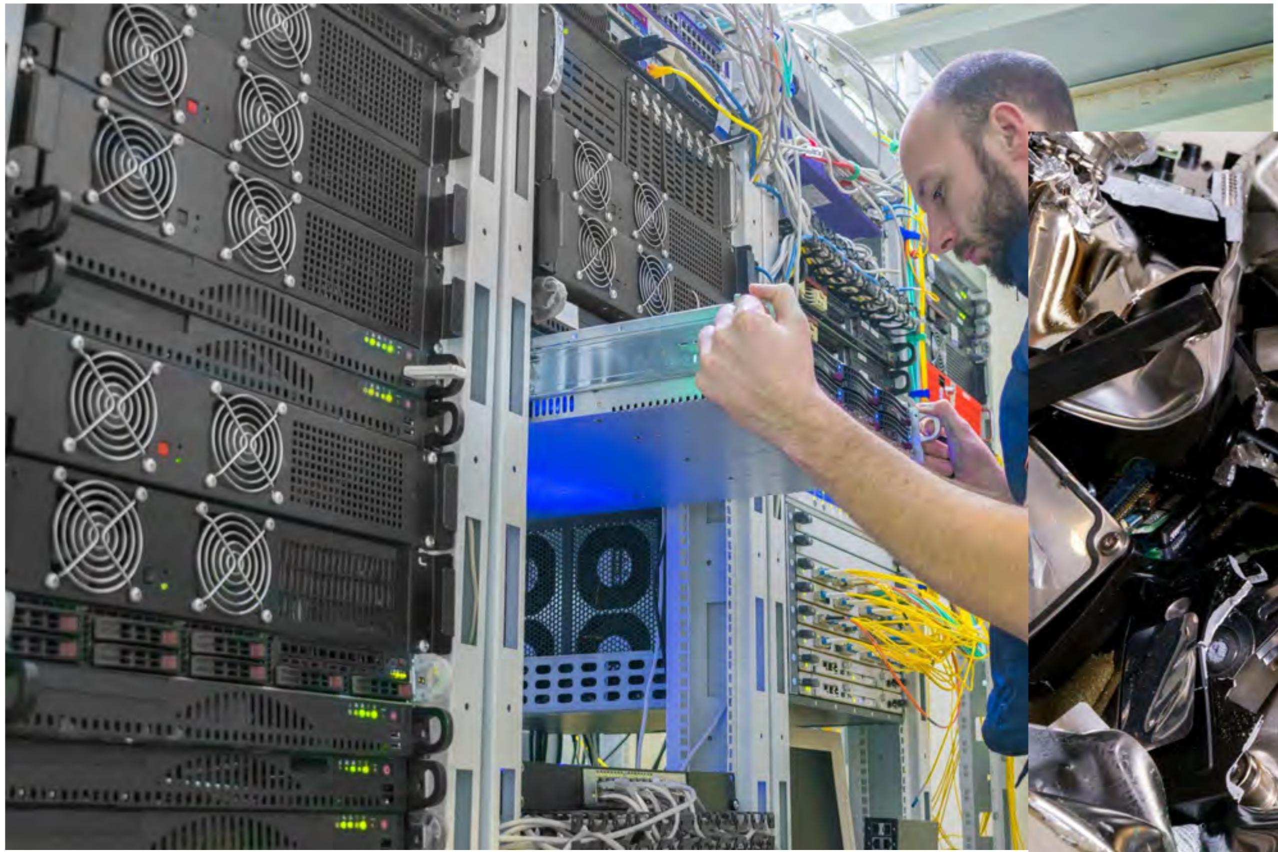
Google's data centers used 355 million gallons of The Dalles' water last year, 29% of the city's total water consumption.

The Oregonian



Steam rises above the cooling towers in The Dalles data center in Oregon. These plumes of water vapor create a mist at dusk. Google photo

Challenge 3: What are the other costs?



Hardware Lifecycle

The Big Takeaway

- You may think your cost is C, but it’s really C+E, with E being the environmental or ”social” cost.
- E is hard to pin down, but we can make a start.

Equation to Determine E for a Datacenter

Water Risk Factor * water price per gallon

E =

Total Water Consumption * Social Cost of Water

In Gallons — In $/Gallon

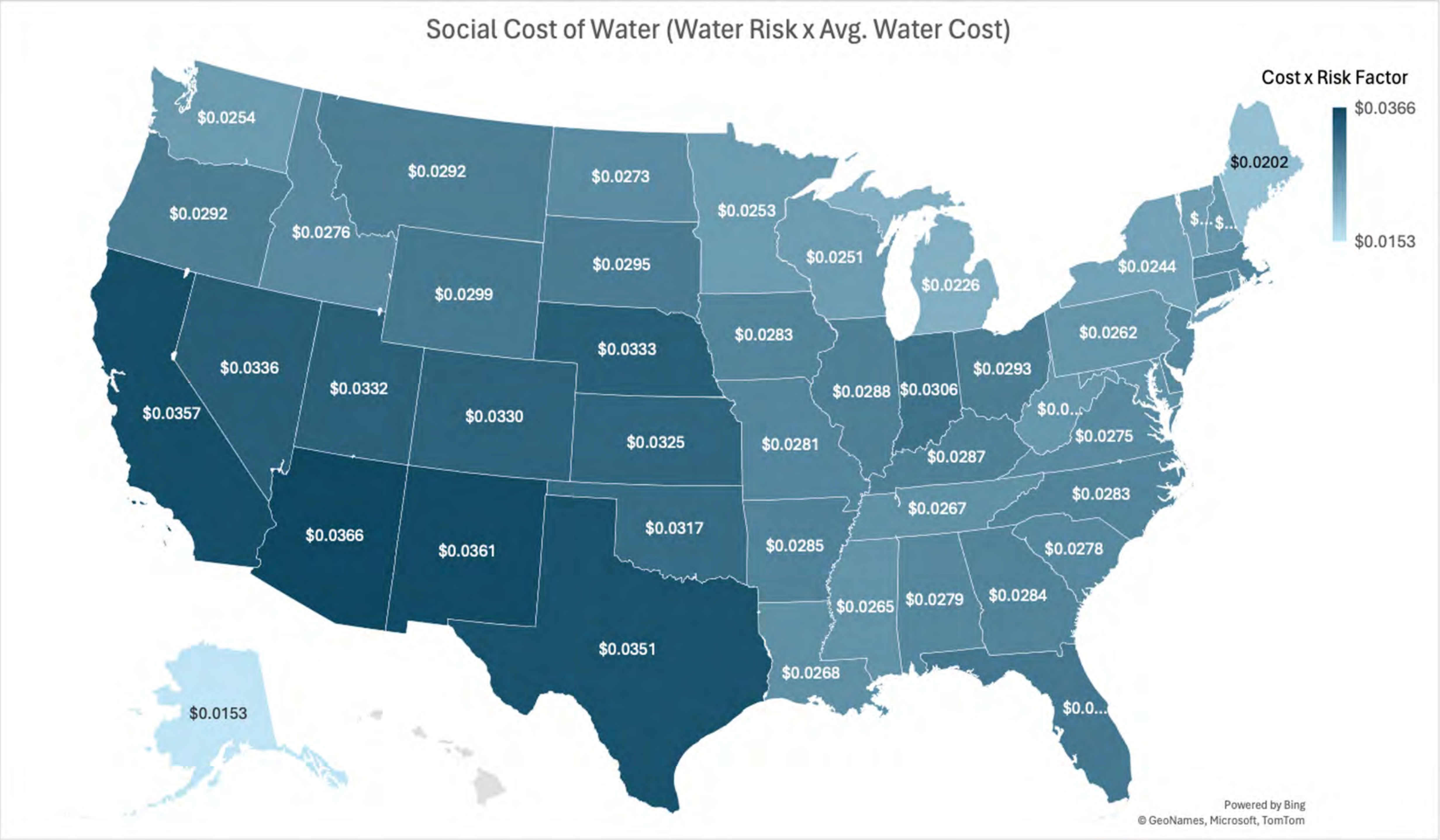
+

(Total Energy Consumption * Power Usage Effectiveness * Carbon Intensity) * Social Cost Carbon

In kWh — In Carbon Tons/kWh — In $/Carbon Tons

Total Facility Power / IT Equipment Power

In kWh — In kWh



Social Cost of Water (Water Risk x Avg. Water Cost)
Cost x Risk Factor
$0.0366
$0.0153
$0.0254
$0.0292
$0.0273
$0.0292
$0.0276
$0.0295
$0.0253
$0.0202
$...
$...
$0.0251
$0.0226
$0.0244
$0.0299
$0.0283
$0.0262
$0.0333
$0.0336
$0.0332
$0.0293
$0.0288
$0.0306
$0.0330
$0.0357
$0.0325
$0.0281
$0.0...
$0.0275
$0.0287
$0.0283
$0.0267
$0.0317
$0.0366
$0.0361
$0.0285
$0.0278
$0.0265
$0.0279
$0.0284
$0.0351
$0.0268
$0.0...
$0.0153
Powered by Bing
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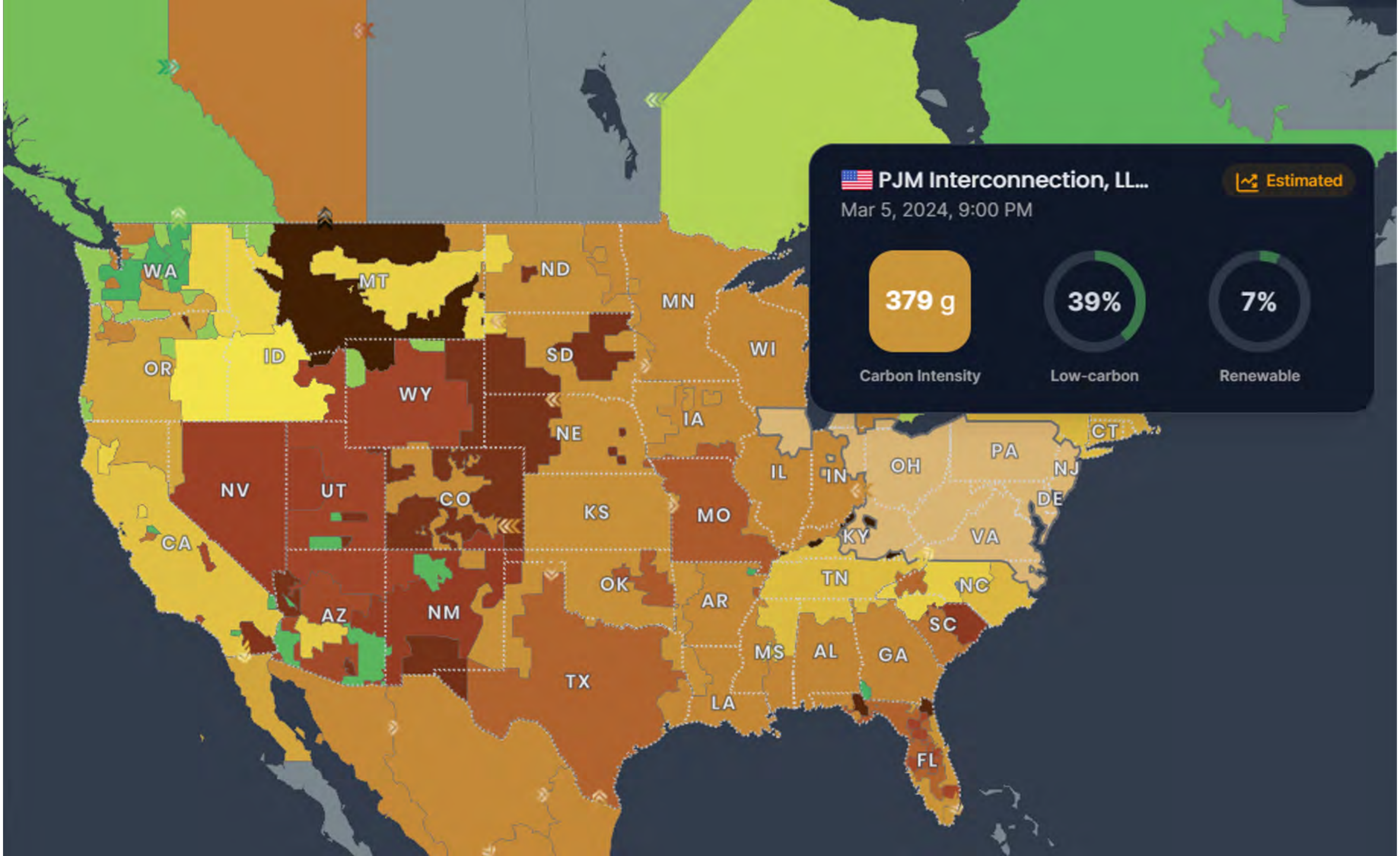
PJM Interconnection, LL...
Estimated
Mar 5, 2024, 9:00 PM
379 g
Carbon Intensity
39%
Low-carbon
7%
Renewable
WA
MT
ND
MN
OR
ID
SD
WI
WY
IA
NE
CT
PA
OH
NJ
IL
IN
NV
UT
CO
KS
MO
DE
KY
VA
TN
NC
OK
AR
SC
AZ
NM
MS
AL
GA
TX
LA
FL

Mockup for Annual Social Cost for Meta Datacenter in Texas

Total Water consumption

Social cost of Water

91,433,892 * $0.0351

In Gallons — In $/Gallon

E =

+

(959,419 * 1.08 * (.334)) * $190

In kWh — In $/kWh

= $60,074,411.84

Total Energy consumption

PUE

Normalized Carbon Emissions

Social Cost of Carbon

What do you do with this information?

What do you do with this information?

- We need to get computing choice included in institutional sustainability and *budgetary* thinking
- Find your own TCO
- Consult your office of sustainability
- Start a conversation with the people paying the bills
- Work together to develop incentive structures for greener computing choices

Thank you!

(for real this time)

Acknowledgements

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  - Stephen Kim, Bhargava Mangalagiri, Jake Schoenegge, Adam Warner
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- TechEx 2023: Cloudy with a Chance of Conservation
  - Keith Wessel, Rob Carter, Netta Caligari, Scott Woods

Acknowledgements

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  - Tommy Johnston, Rick Friedman, Scott Friedman, and John Dittmer
- Google
  - Tazzie Green, and Trinity Lloyd
- Microsoft
  - Sundar Ramakrishnan
- Crew Universal
  - Gim Crew

Questions?

Appendix

For Further Research

- General
  - TCO for Cloud Services: A Framework | EDUCAUSE Library
  - Cloudy With a Chance for Conservation (TX23 Presentation)
  - Recalibrating global data center energy-use estimates | Science
  - Measuring the Carbon Intensity of AI in Cloud Instances | Proceedings of the 2022 ACM Conference on Fairness, Accountability, and Transparency
  - Sustainable Computing Research (several reports and research papers we collected along the way)
- In the News
  - AI's craving for data is matched only by a runaway thirst for water and energy | John Naughton | The Guardian
  - Artificial intelligence technology behind ChatGPT was built in Iowa — with a lot of water | AP News
  - AI's craving for data is matched only by a runaway thirst for water and energy
  - The Growing Environmental Footprint Of Generative AI
  - Markey, Heinrich, Eshoo, Beyer Introduce Legislation to Investigate, Measure Environmental Impacts of Artificial Intelligence
- GreenOps
  - Future IT: FinOps, GreenOps and sustainable cloud strategies | Capgemini
  - Cloud Sustainability – A Union of FinOps and GreenOps - Xebia
  - FinOps and GreenOps Strategies in 2023 - IDC Europe Blog
  - FinOps and GreenOps: How do They Relate?
  - IT Sustainability Think Tank: Embedding GreenOps into enterprises | Computer Weekly
  - What are Scopes 1, 2 and 3 of Carbon Emissions?
  - What Is GreenOps? Putting a Sustainable Focus on FinOps - The New Stack

For Further Research

- **AWS**
  - 2022 Sustainability Report Highlights
  - Cloud powers faster, greener, and more collaborative research, according to new IDC report | AWS Public Sector Blog
  - AWS Makes Water Positive Commitment to Return More Water to Communities Than It Uses by 2030
  - Reducing carbon by moving to AWS
  - Renewable Energy Methodology
  - The Cloud - Amazon Sustainability
- **Google**
  - Google Data Centers
  - Google Data Center Water Use in the US Revealed To Be a Lot.
  - Secret Cost of Google's Data Centers: Billions of Gallons of Water | TIME
  - Restoring Ecosystems through Water Stewardship - Google Sustainability
  - Achieving Our 100% Renewable Energy Purchasing Goal and Going Beyond
  - Cloud sustainability
  - Efficiency – Data Centers – Google
- **Microsoft**
  - Microsoft commits to achieve ‘zero waste’ goals by 2030 - The Official Microsoft Blog
  - Videos to configure Sustainability Manager (to get the emission report of on-prem and in Azure):
    - Get Started with Microsoft Sustainability Manager
    - Microsoft Cloud for Sustainability Demo
  - Documentation:
    - Microsoft Sustainability Calculator helps enterprises analyze the carbon emissions of their IT infrastructure | Azure Blog | Microsoft Azure
    - Microsoft Sustainability Manager overview - Microsoft Cloud for Sustainability | Microsoft Learn

EPA Social Cost of Carbon

Table 3.1.1: Social Cost of Carbon (SC-CO_2) by Damage Module, 2020-2080 (in 2020 dollars per metric ton of CO_2)

Emission Year	Near-Term Ramsey Discount Rate and Damage Module								
	2.5% Near-Term Rate			2.0% Near-Term Rate			1.5% Near-Term Rate		
	DSCIM	GIVE	Meta-Analysis	DSCIM	GIVE	Meta-Analysis	DSCIM	GIVE	Meta-Analysis
2020	110	120	120	190	190	200	330	310	370
2030	140	150	150	230	220	240	390	350	420
2040	170	170	170	280	250	270	440	390	460
2050	210	200	200	330	290	310	500	430	520
2060	250	220	230	370	310	350	550	470	570
2070	280	240	250	410	340	380	600	490	610
2080	320	260	280	450	360	410	640	510	650

How did they calculate the carbon tax? What was the logic, and how can we apply it to water

- There are two ways of taxation:
  1) Levy on energy suppliers on carbon emissions
  2) Credits to induce a reduction of emissions
  3) IMF reports such taxations to help reduce the amount of emissions.
     (The organisation tracks the reductions by years and the price level)

- Formula:
  - Amount of Carbon emission (ton) * price
  - The expected monetary amount of the taxation: $15/ton
    (The Brookings Institute)
  - 'Carbon Pricing' can be an alternative to taxation rates.

- Carbon taxation implementation in America: CA, MA, OR, PA, WA,
  - But it is implemented globally.

The Ideal Equation

E =

(Total Water Consumption * Social Cost of Water)

In Gallons — In $/Gallon

+

(Total Energy Consumption * Power Usage Effectiveness * Carbon Intensity)* Social Cost Carbon

In kWh — In Carbon Tons/kWh — In $/Carbon Tons

Inclusion of WUE & its challenges

E =

(Total Water Consumption * Water Usage Effectiveness) * Social Cost of Water

In Gallons — In Gallons/kWH — In $/Gallon

+

(Total Energy Consumption * Power Usage Effectiveness * Carbon Intensity)* Social Cost Carbon

In kWh — In Carbon Tons/kWh — In $/Carbon Tons

Note: WUE is the water used for all the energy used by the equipment in the datacenter. So, I am not sure how it can be incorporated in the first part of the equation

The Broken-down Equation without WUE

Water Risk Factor * price per gallon in region

E =

Total Water Consumption * Social Cost of Water

In Gallons In $/Gallon

+

(Total Energy Consumption * Power Usage Effectiveness * Carbon Intensity) * Social Cost Carbon

In kWh In Carbon Tons/kWh In $/Carbon Tons

Total Facility Power / IT Equipment Power

In kWh In kWh

The Broken-down Equation with WUE

Water Consumption/ IT Equipment Power

Water Risk Factor * price per gallon in region

E =

(Total Water Consumption * Water Usage Effectiveness) * Social Cost of Water

In Gallons | In Gallons/kWH | In $/Gallon

+

(Total Energy Consumption * Power Usage Effectiveness * Carbon Intensity) * Social Cost Carbon

In kWh | In Carbon Tons/kWh | In $/Carbon Tons

Total Facility Power / IT Equipment Power

In kWh | In kWh

Explanation of Water variables

- Total Water Consumption (Gallons)
  - Facility's water intake per year
- WUE
  - WUE = Data Center Water Consumption / IT Equipment Energy
  - WUE is the water used per kilowatt of energy used by the equipment
  - Unit is Gallon/kWh
  - Sources - https://www.sunbirddcim.com
- Social Cost of water ($ per gallon)
  - Price per gallon in region for a data center
  - Sources - https://riskfilter.org/water/explore/data-and-methods

Explanation of Energy variables

- Total Energy Consumption (kWH)
  - Facility's Energy intake per year
- PUE
  - Total facility Power / IT Equipment Power
- Carbon Emissions (grams of carbon per KWH)
  - Emissions of Carbon in that area
  - Sources - https://app.electricitymaps.com/map?lang=en
- Social Cost of Carbon ($ per carbon ton)
  - Price of Carbon Emissions
  - Sources - https://www.rff.org/topics/scc/

Mockup for Meta Data Center in Fort Worth, TX

Equation doesn't include WUE

Total Water consumption

Social cost of Water

E = 91,433,892 * $0.351 + (959,419 * 1.08 * (233g/1000)) * $51 = $44,406,134.15

91,433,892 — In Gallons; Gallons/kWh; $0.351 — In $/Gallon

959,419 — In kWh; $51 — In $/kWh

Total Energy consumption

PUE

Carbon Emissions

Social Cost of Carbon

Sources we used

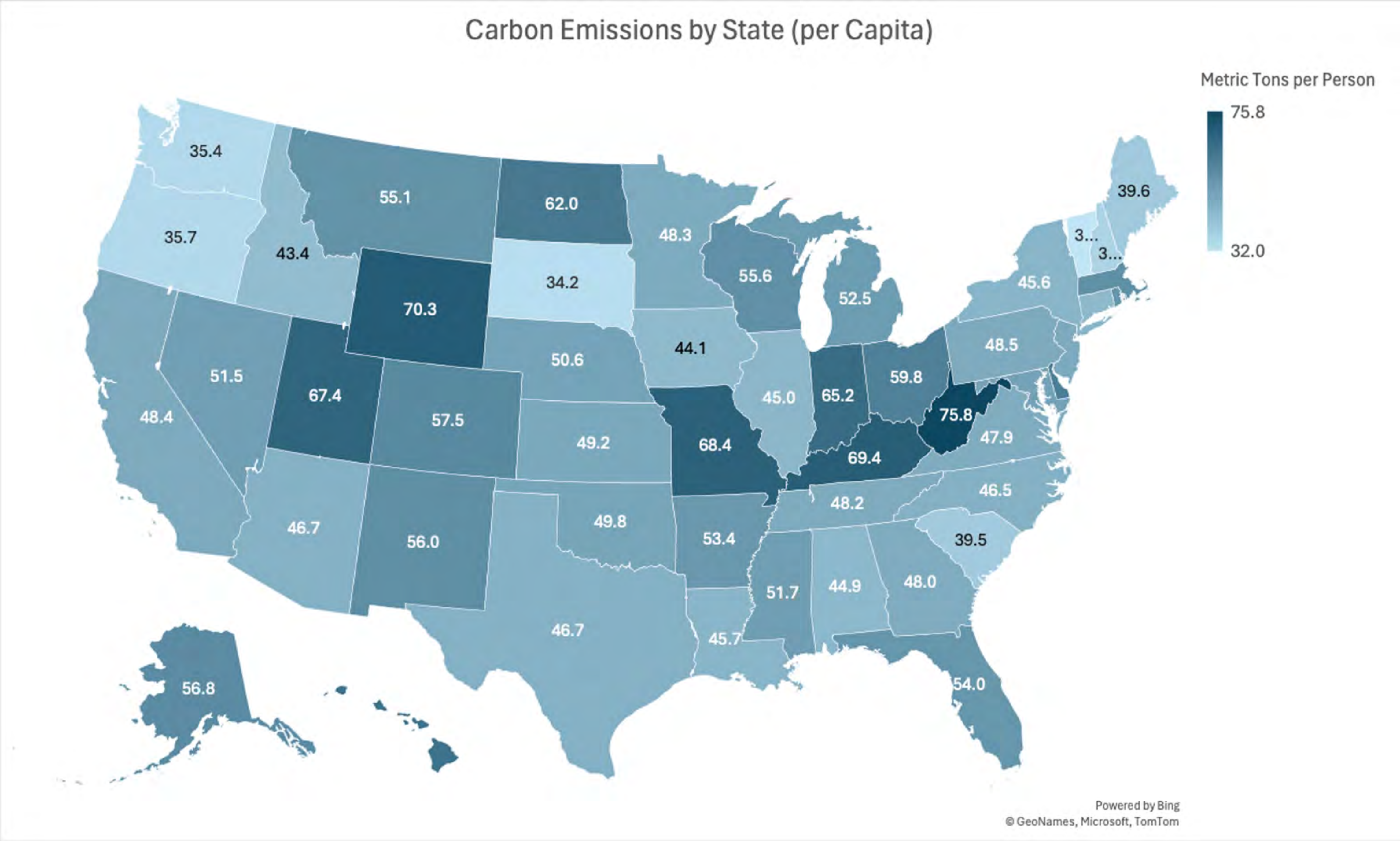
- 2 gallons per KWH (2016)
  - https://www.osti.gov/servlets/purl/1372902/

Question to be asked:

- Would this only be used if Water Consumption isn't provided?

All challenges that can serve as a datapoint in their research

- Generally gathering data on datacenters, Companies don’t like to give specific numbers on energy consumption, water consumption, PUE, WUE, etc.
- We have struggled to convert the units into being time-based
- We have struggled to convert geographic datasets into being comparable



Carbon Emissions by State (per Capita)
Metric Tons per Person
75.8
32.0
35.4
35.7
55.1
62.0
43.4
48.3
39.6
3...
3...
34.2
70.3
55.6
52.5
45.6
51.5
44.1
50.6
48.5
67.4
45.0
65.2
59.8
57.5
75.8
48.4
68.4
49.2
69.4
47.9
46.5
48.2
49.8
46.7
56.0
53.4
39.5
51.7
44.9
48.0
46.7
45.7
56.8
54.0
Powered by Bing
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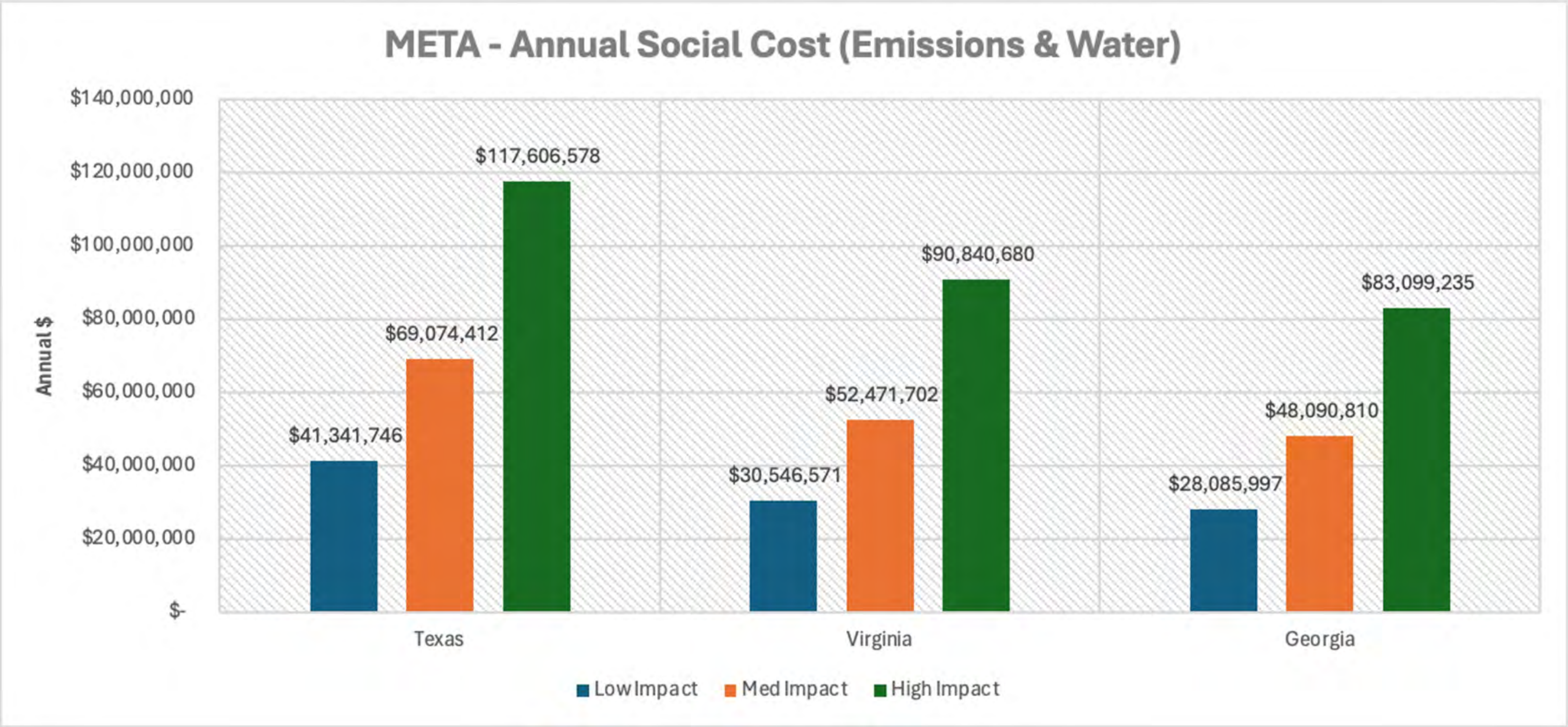
Source: WWF Methodology
Source: EPA

Water Data

State	Risk Cost/Cubic Meter	Risk Cost/Gallon	Normalized	x10
Alabama	$7.34	$0.0279	0.592	5.920
Alaska	$4.02	$0.0153	0.000	0.000
Arizona	$9.63	$0.0366	1.000	10.000
Arkansas	$7.51	$0.0285	0.622	6.219
California	$9.41	$0.0357	0.960	9.602
Colorado	$8.68	$0.0330	0.831	8.308
Connecticut	$7.31	$0.0278	0.587	5.871
Delaware	$7.31	$0.0278	0.587	5.871
District of Columbia	$6.92	$0.0263	0.517	5.174
Florida	$7.90	$0.0300	0.692	6.915
Georgia	$7.48	$0.0284	0.617	6.169
Hawaii				
Idaho	$7.26	$0.0276	0.577	5.771
Illinois	$7.59	$0.0288	0.637	6.368
Indiana	$8.07	$0.0306	0.721	7.214
Iowa	$7.45	$0.0283	0.612	6.119
Kansas	$8.57	$0.0325	0.811	8.109
Kentucky	$7.56	$0.0287	0.632	6.318
Louisiana	$7.06	$0.0268	0.542	5.423
Maine	$5.33	$0.0202	0.234	2.338
Maryland	$6.98	$0.0265	0.527	5.274
Massachusetts	$7.37	$0.0280	0.597	5.970
Michigan	$5.95	$0.0226	0.343	3.433
Minnesota	$6.67	$0.0253	0.473	4.726
Mississippi	$6.98	$0.0265	0.527	5.274
Missouri	$7.40	$0.0281	0.602	6.020
Montana	$7.68	$0.0292	0.652	6.517
Nebraska	$8.76	$0.0333	0.846	8.458
Nevada	$8.85	$0.0336	0.861	8.607
New Caledonia	$6.09	$0.0231	0.368	3.682
New Hampshire	$6.81	$0.0259	0.498	4.975
New Jersey	$7.31	$0.0278	0.587	5.871

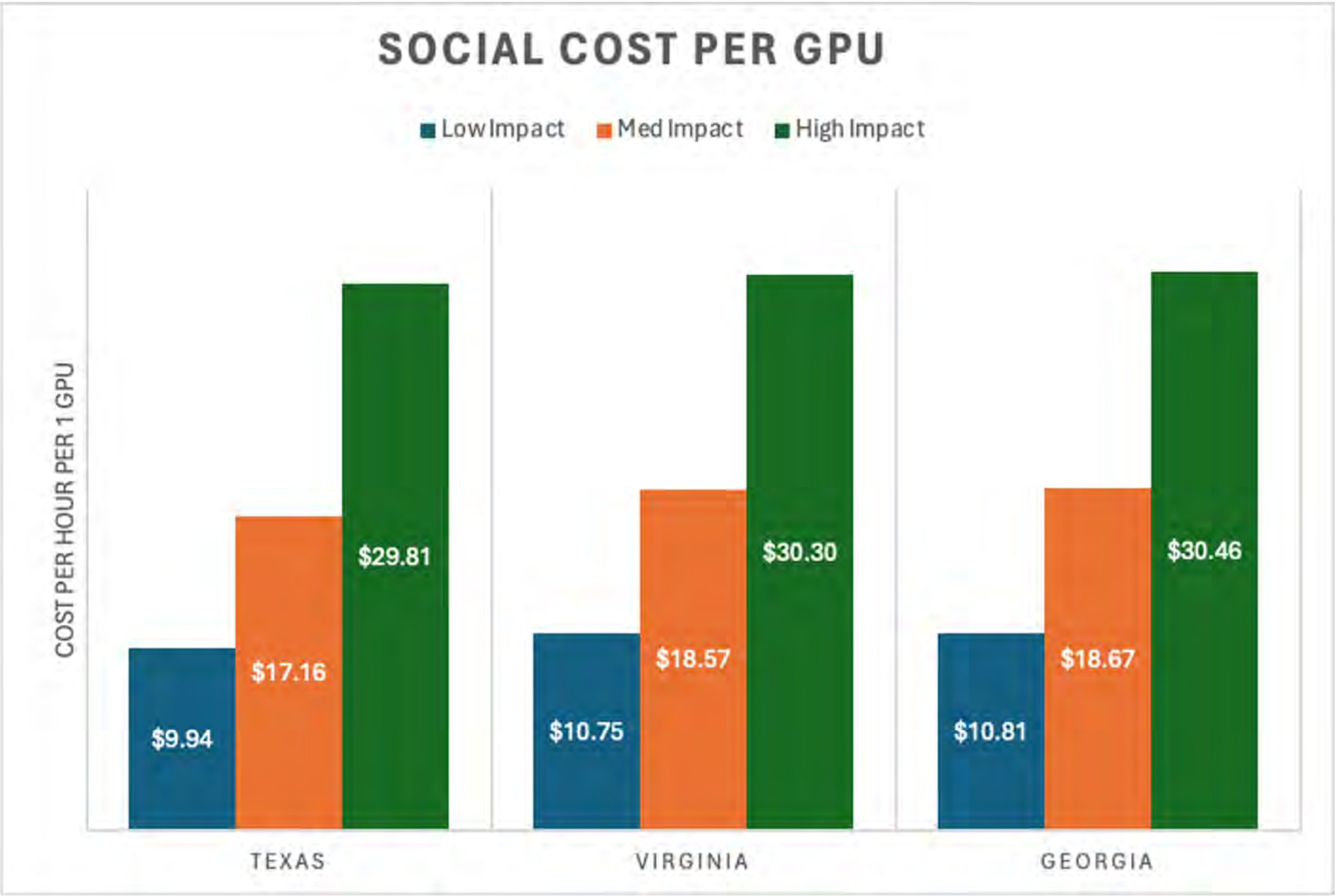
Emissions Data

metric tons/person	2021	Normalized
Alabama	44.9	0.294079869
Alaska	56.8	0.56620835
Arizona	46.7	0.334369885
Arkansas	53.4	0.488066883
California	48.4	0.374786313
Colorado	57.5	0.582479147
Connecticut	44.1	0.276380709
Delaware	60.7	0.65473173
District of Columbia	51.2	0.438243098
Florida	54.0	0.502665569
Georgia	48.0	0.363935053
Hawaii	64.0	0.731358091
Idaho	43.4	0.259561403
Illinois	45.0	0.296373571
Indiana	65.2	0.758438498
Iowa	44.1	0.2755641
Kansas	49.2	0.391079384
Kentucky	69.4	0.855072738
Louisiana	45.7	0.313163667
Maine	39.6	0.173060073
Maryland	50.8	0.428652346
Massachusetts	55.6	0.537768966
Michigan	52.5	0.467524633
Minnesota	48.3	0.370808624
Mississippi	51.7	0.450115315
Missouri	68.4	0.831483124
Montana	55.1	0.527681846
Nebraska	50.6	0.423189703
Nevada	51.5	0.444132606



Factors that could impact social cost:
- State water risk
- State emissions per capita
- Energy efficiency of data center

PUE is from META datacenter average



Incentives for Universities

- Phase 1: Key Question: how to segregate energy bill based on multiple buildings?
- Approach:
  - Build an inventory and classify buildings according to use (academic, residential, data center, laboratories)
  - Identify High energy facilities (ie, those that are expected to have higher energy consumption)
  - Analyse occupancy and utilization levels to know when to expect peaks and lows in utilization
  - Establish baseline expectations based on above data & comparison with similar infrastructure
  - Implement sub-metering plan to be able to gauge electricity usage per building
  - Establish analytics dashboard to compare consumption data and identify outliers.

Incentives for Universities

- Phase 2: Key Question: how to decrease consumption in buildings with high energy usage?
- Approach:
  - Surprises:
    - It is expected that labs with energy heavy equipment might use lots of electricity. But if the analysis reveals that administrative buildings are showing comparable electricity usage then this is an area of improvement.
    - The cumulative effect of small appliances and personal equipment (like mini-fridges in dorm rooms, microwaves, and personal heaters or fans) can lead to a surprisingly high energy draw. This scenario might highlight the need for policies to manage personal energy uses campus-wide.
  - Further investigate those buildings/departments with an IT team
    - Qualify what accounts as IT use:
      - Just all IT systems that are in the classrooms, offices.
      - **Or more specifically, the systems used to host IU software (on prem & cloud)**
        - **If this is the case, then seek bills for cloud usage & electricity bill of IU data center**
        - **This part is more easier to investigate**

Incentives for Universities

- Phase 3: Key Question: how to decrease consumption/ promote sustainable cloud usage in departments high energy usage?
- Approach:
    - This is where TCO formula comes into picture
    - Can cite studies, surveys:
        - https://www.timeshighereducation.com/news/sustainability-more-important-location-mobile-students
            - Applicants are just as likely to rate university sustainability and graduate employment prospects as top priorities
        - https://sos.earth/survey-2020/
            - **92%** agree that sustainable development is something which all universities and colleges should actively incorporate and promote
        - https://blog.thepienews.com/2023/03/the-importance-of-sustainability-in-students-university-choice/
            - The rankings are increasingly taking into account how the universities are working towards the UN SDG
    - As the outcome of these surveys and research shows how it can impact the main consumers of universities, ie, the students, it is a big incentive to work towards becoming carbon neutral.