Yale Center

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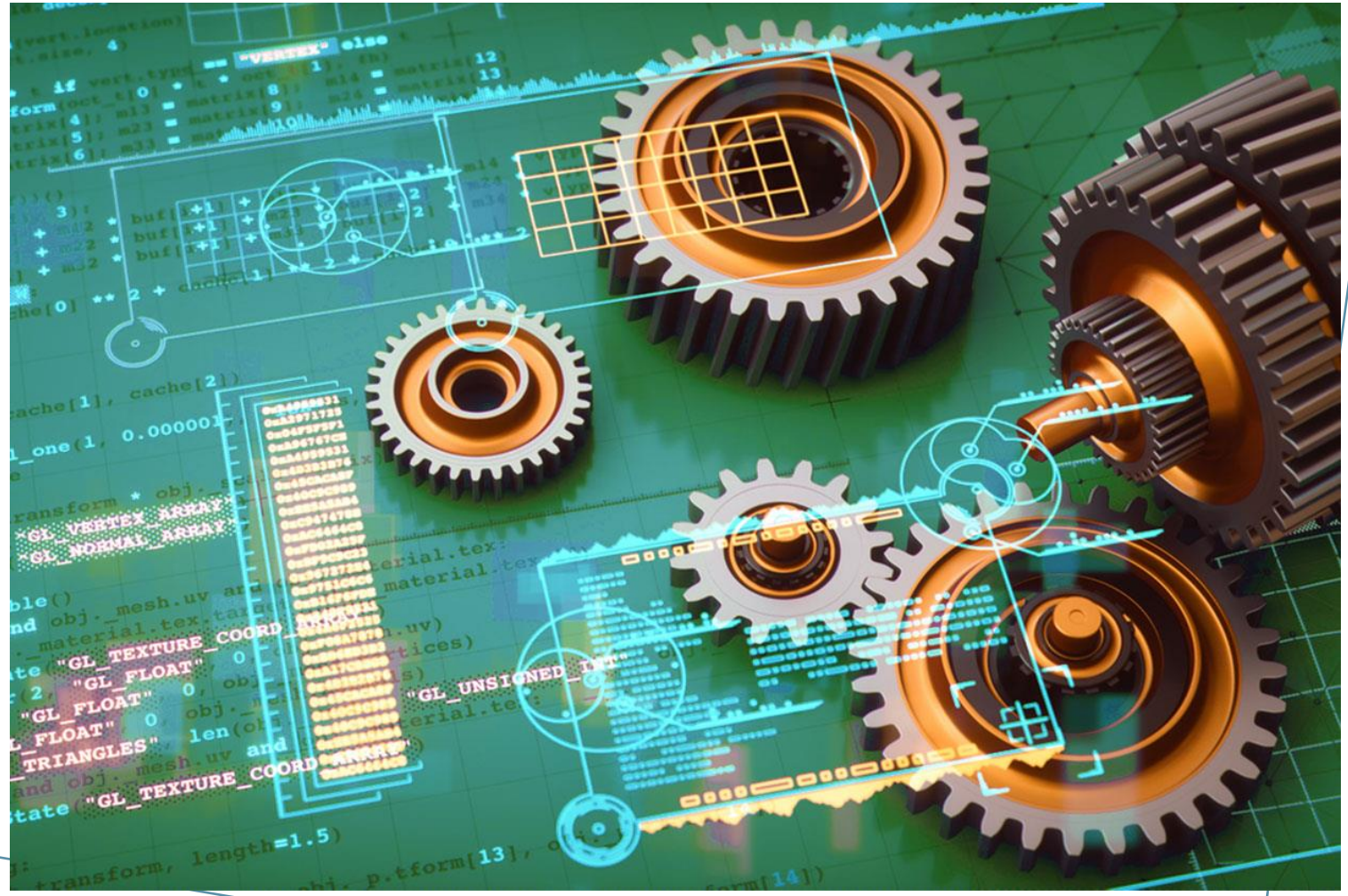
Industrial Ecology

THE DIGITAL ECONOMY *AND* THE ENVIRONMENT



For more information on the lecture series go to

bit.ly/YaleCIE-digital-lectures

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Reducing the Energy Costs and Environmental Impacts of AI: Understanding User Behavior and the Potential for Information Disclosure

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Generative AI is one of the most rapidly adopted technological innovations of all time

...but this innovation comes with significant energy costs and serious environmental impacts

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AI energy consumption outpaces efficiency gains

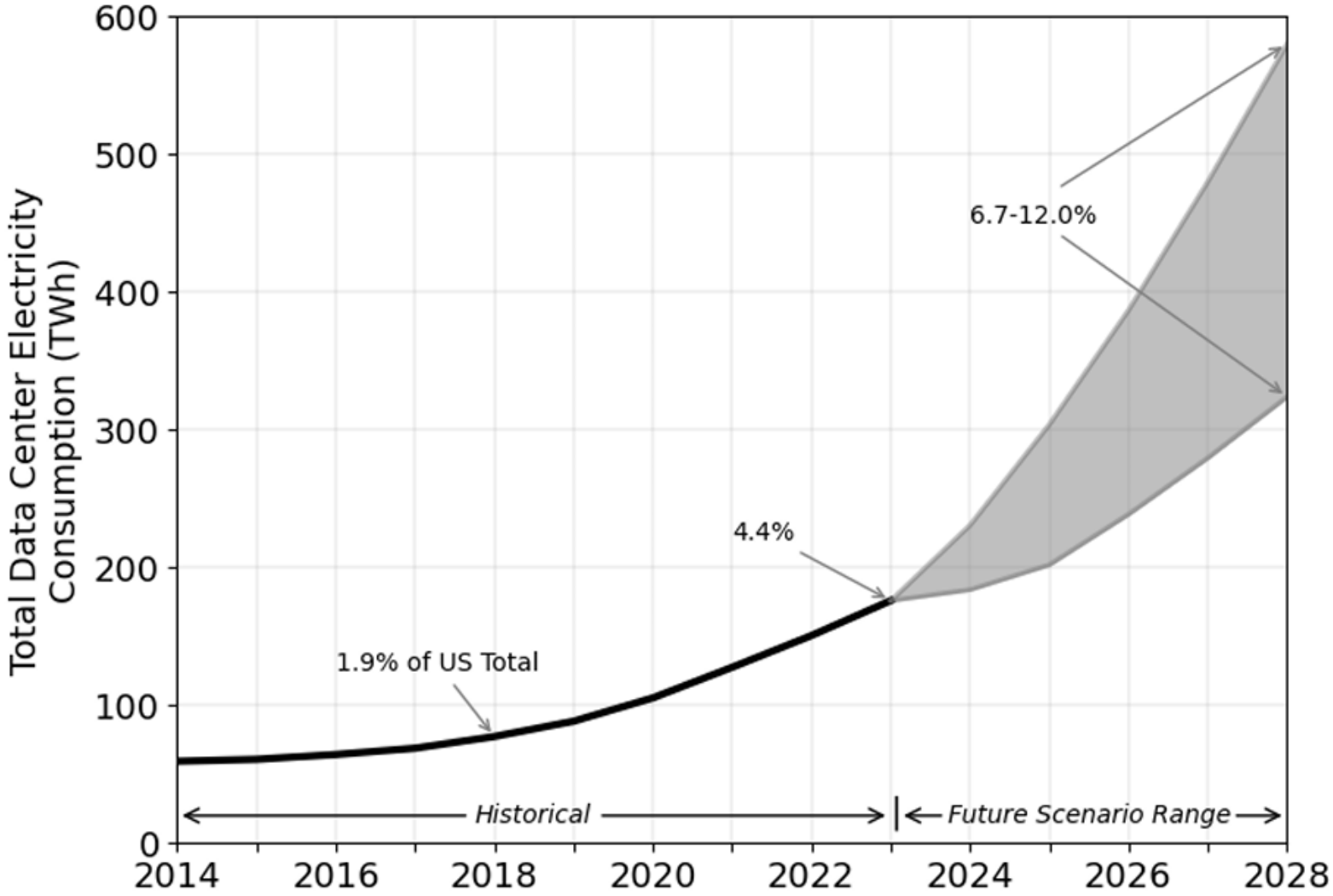

Figure ES-1. Total U.S. data center electricity use from 2014 through 2028.

Shehabi, A., Smith, S.J., Hubbard, A., Newkirk, A., Lei, N., Siddik, M.A.B., Holecek, B., Koomey, J., Masanet, E., Sartor, D. 2024. 2024 United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-2001637

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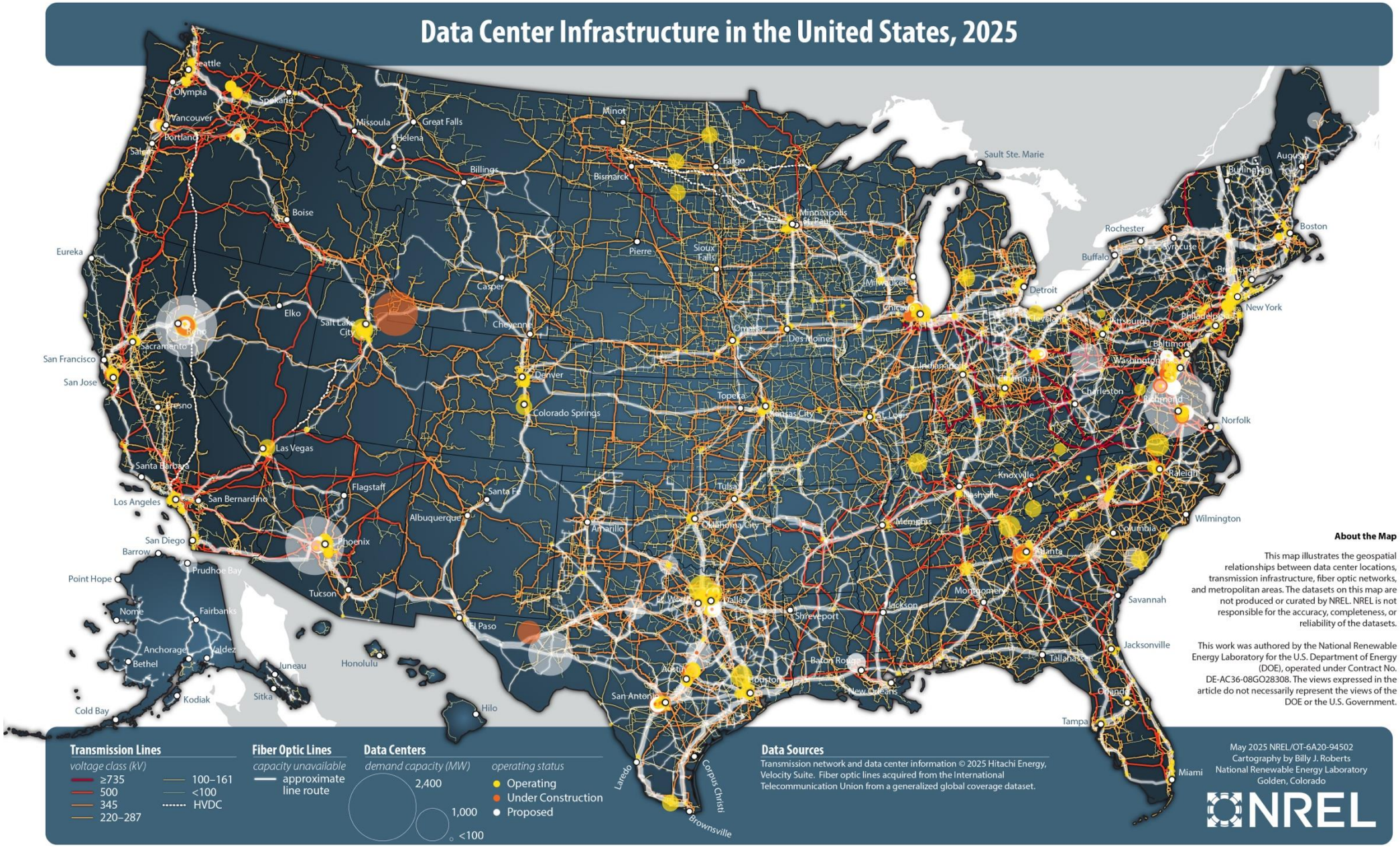

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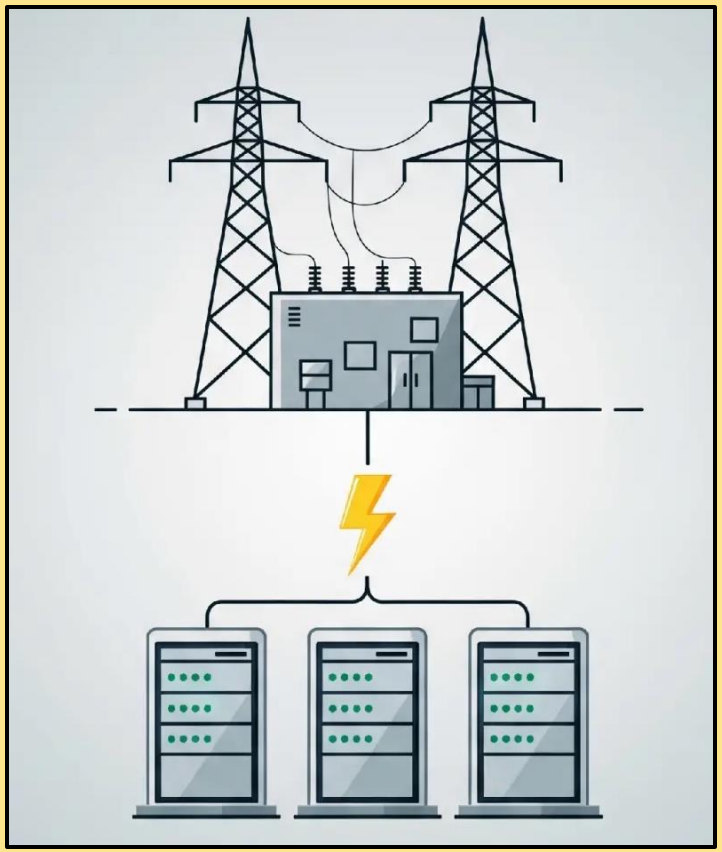
By 2030, projections estimate…



Annual global data center electricity usage

=

Annual Japan electricity usage

See Reuters, Global Data Center Industry to Emit 2.5 Billion Tons of CO2 through 2030, Morgan Stanley Says, REUTERS (Sept. 3, 2024), https://www.reuters.com/markets/carbon/global-data-center-industry-emit-25-billion-tons-co2-through-2030-morgan-stanley-2024-09-03/.

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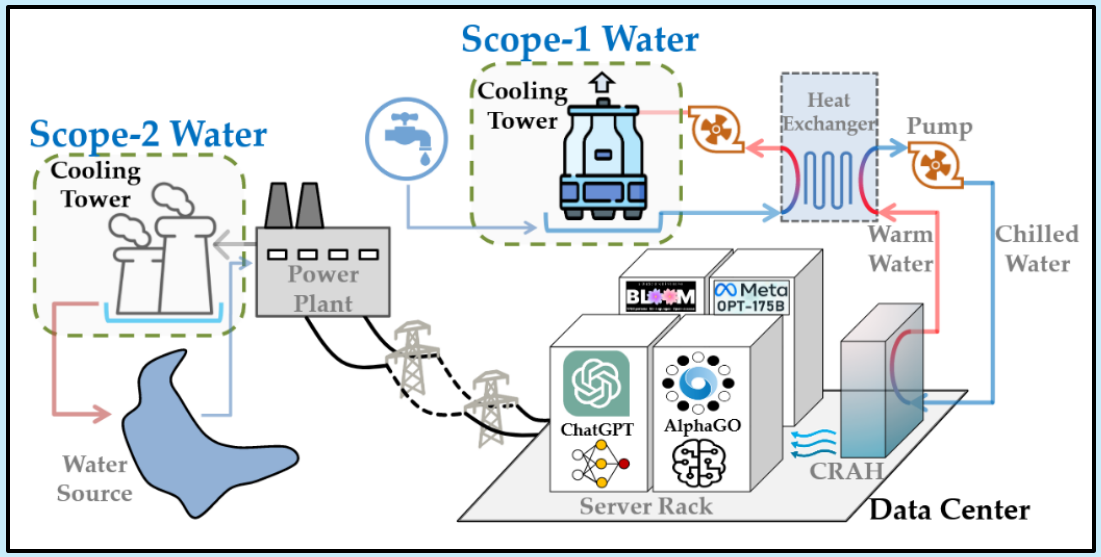
By 2030, projections estimate…



Annual global data center water usage

=

6x annual Denmark water usage

See Reuters, Global Data Center Industry to Emit 2.5 Billion Tons of CO2 through 2030, Morgan Stanley Says, REUTERS (Sept. 3, 2024), https://www.reuters.com/markets/carbon/global-data-center-industry-emit-25-billion-tons-co2-through-2030-morgan-stanley-2024-09-03/.

The environmental impacts may go beyond those resulting from previous technologies (notably more than previous internet-based tools)

Data centers in New Carlisle, Indiana (AJ Mast / The New York Times / Redux)

Problem: The rapid development and uptake of generative AI poses a challenge to achieving net-zero goals (for several reasons).

Most solutions have focused on the supply side…

…But there is potential for low-cost, low-intrusive interventions focusing on demand

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One solution: Making the information readily available to the consumer

Several different types of environmental information disclosure:

Corporate-facing

- Corporate sustainability reports
- Environmental certifications

FSC
www.fsc.org
FSC® C011714
The mark of responsible forestry

RECYCLED 100
claim standard

CERTIFIED
CARBON NEUTRAL®
carbonneutral.com

Cohen, M. A., & Viscusi, W. K. (2012). The role of information disclosure in climate mitigation policy. Climate Change Economics, 3(04), 1250020.

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One solution: Making the information readily available to the consumer

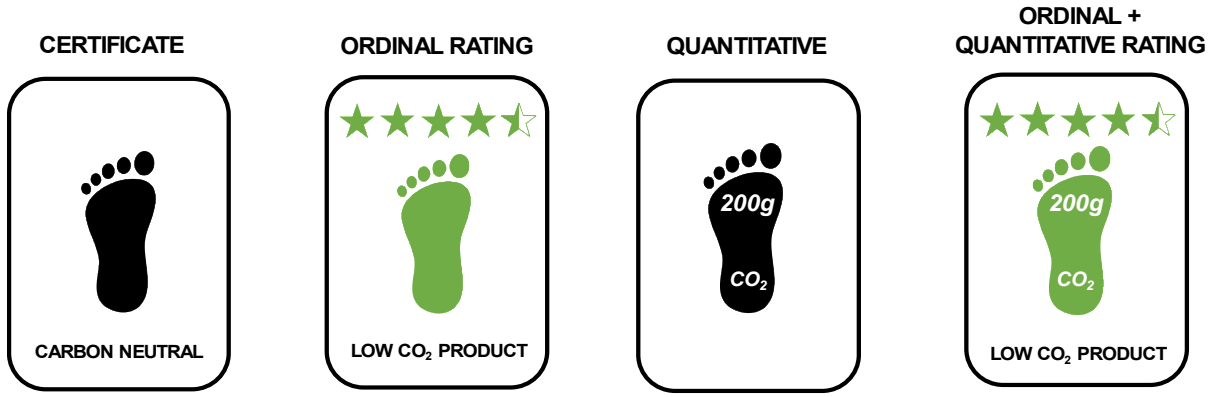
Several different types of environmental information disclosure:

Corporate-facing

- Corporate sustainability reports
- Environmental certifications

Consumer-facing

- Carbon labels



Taufique, K. M., Nielsen, K. S., Dietz, T., Shwom, R., Stern, P. C., & Vandenbergh, M. P. (2022). Revisiting the promise of carbon labelling. Nature Climate Change, 12(2), 132-140.

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One solution: Making the information readily available to the consumer

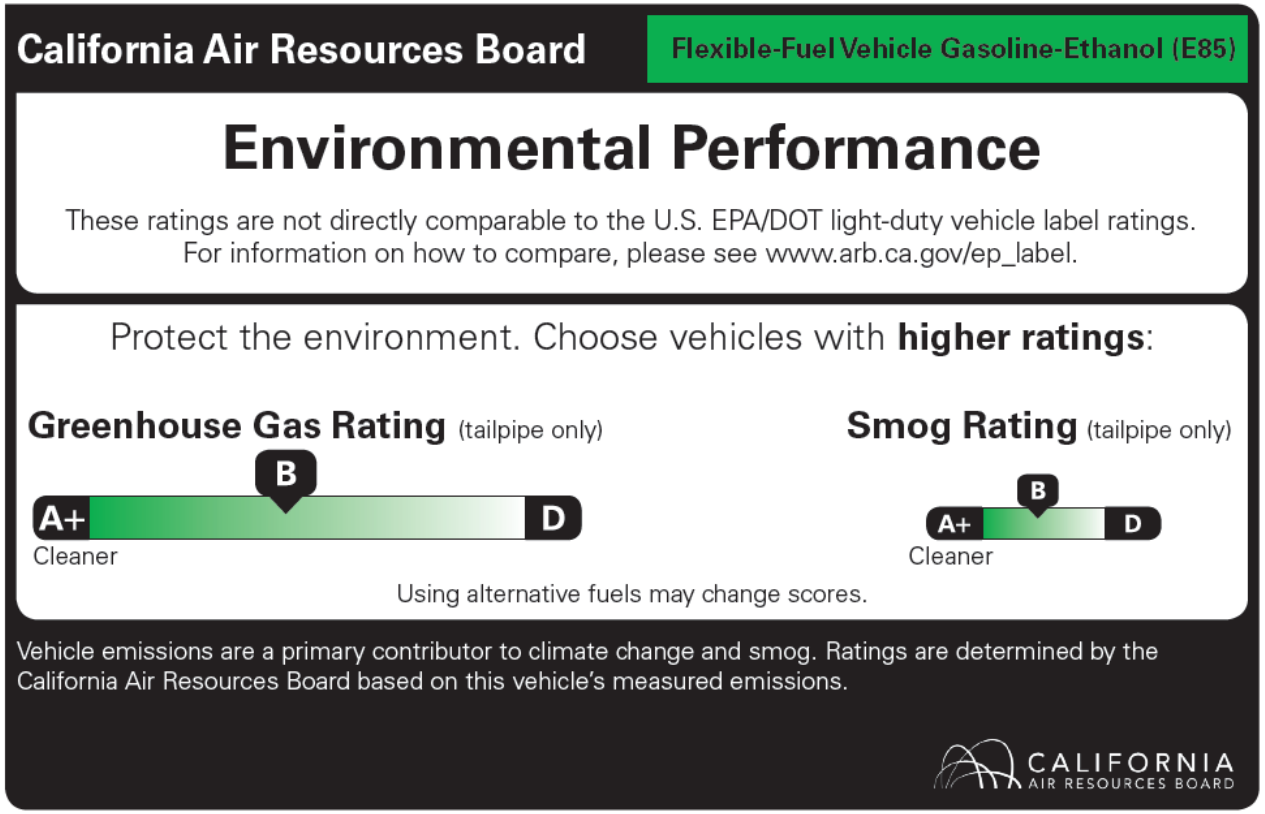
Several different types of environmental information disclosure:

Corporate-facing

- Corporate sustainability reports
- Environmental certifications

Consumer-facing

- Carbon labels
- Environmental impact labels



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One solution: Making the information readily available to the consumer

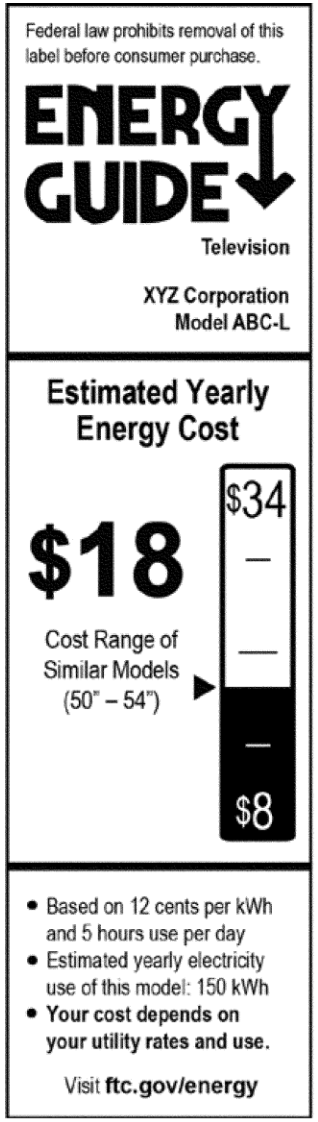
Several different types of environmental information disclosure:

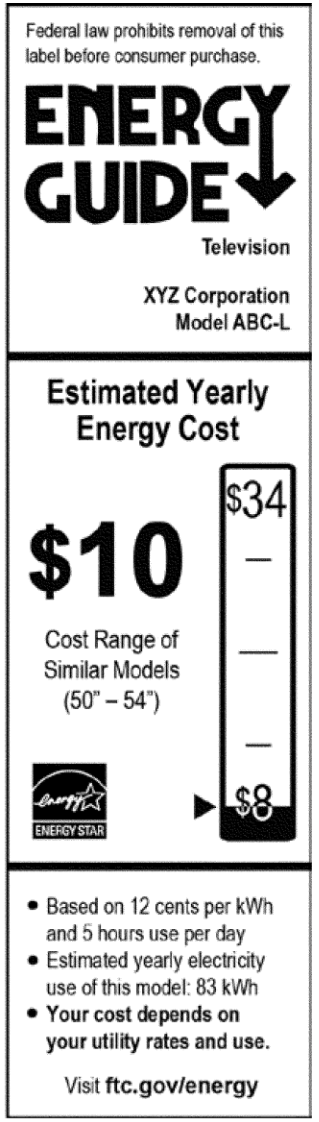
Corporate-facing

- Corporate sustainability reports
- Environmental certifications

Consumer-facing

- Carbon labels
- Environmental impact labels
- Energy ratings





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One solution: Making the information readily available to the consumer

Why the emphasis on environmental information disclosure?

- Low-intrusive
- Cost-effective
- Feasible
- Easy to standardize internationally
- Potential benefit at multiple levels

REVIEW ARTICLE
https://doi.org/10.1038/s41558-021-01271-8
nature climate change
Check for updates

Revisiting the promise of carbon labelling

Khan M. R. Taufique[1,2,10], Kristian S. Nielsen[3,10] ✉, Thomas Dietz[4,5,6], Rachael Shwom[7], Paul C. Stern[8] and Michael P. Vandenbergh[9]

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One solution: Making the information readily available to the consumer

BRIAN LAWLESS/PA/ALAMY

As more data centres crop up in rural communities, local opposition to them has grown.

Light bulbs have energy ratings — so why can't AI chatbots?

Sasha Luccioni, Boris Gamazaychikov, Sara Hooker, Regis Pierrard, Emma Strubell, Yacine Jernite & Carole-Jean Wu

"The programme has helped to achieve more than 4 billion tonnes of greenhouse-gas reductions over the past 30 years, the equivalent of taking **almost 30 million petrol-powered cars off the road per year**."

Lack of transparency about the environmental impacts and energy costs of generative AI

Several conditions are necessary for information disclosure to alter or reduce the environmental footprint of generative AI

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Several conditions are necessary for information disclosure to alter the environmental footprint of generative AI

Technical potential in individual usage

Chat GPT

1 billion users

2.5 billion queries a day

Individual and household emissions = 1/3 of energy related emissions

Lack of awareness about the impacts/costs

Underestimate carbon emissions

Impacts are geographically, financially, and psychologically distant

Behavioral plasticity with individual use

Willingness to alter behavior after learning information

Could be present at several different places

Camilleri, Larrick, Hossain, & Patino-Echeverri, 2019, Grinstein et al., Johnson, Sugerman, Morwitz, Johar, & Morris, 2024; Winterich, Reczek, & Makov, 2024; Vandenbergh & Nielsen, 2019
Cohen, M. A., & Viscusi, W. K. (2012). The role of information disclosure in climate mitigation policy. Climate Change Economics, 3(04), 1250020.
Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenbergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. PNAS, 106(44), 18452-18456.
Vandenbergh, M. P., & Stern, P. C. (2017). The role of individual and household behavior in decarbonization. Envtl. L. Rep. News & Analysis, 47, 10941.

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Several conditions are necessary for information disclosure to alter the environmental footprint of generative AI

Technical potential in individual usage

Frequency of use

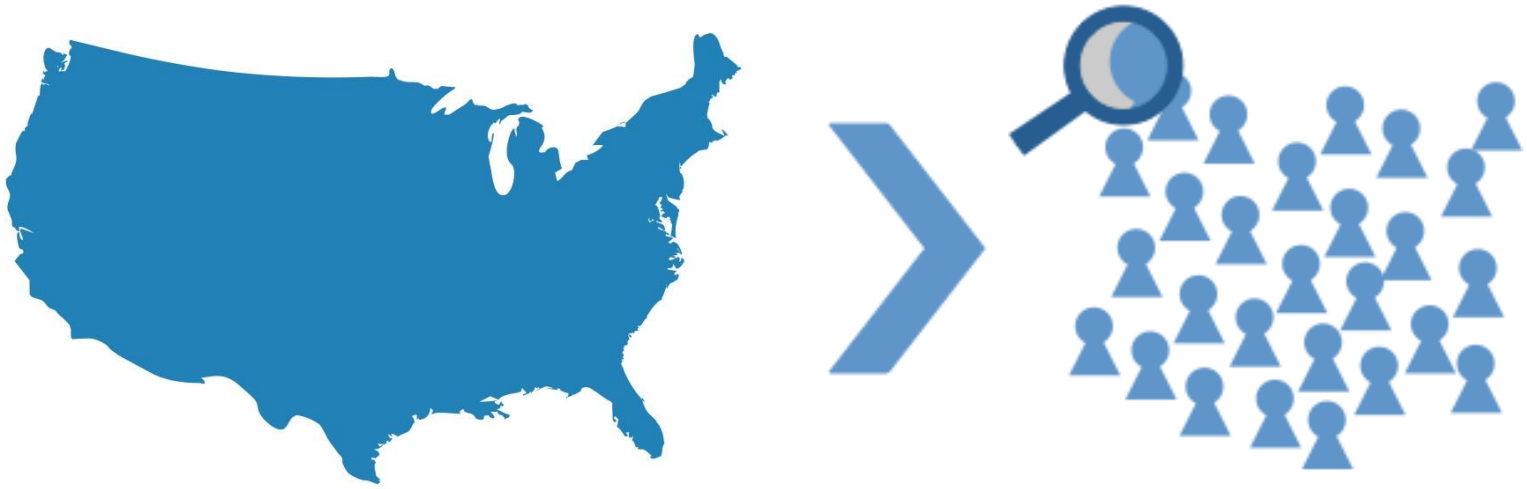
Lack of awareness about the impacts/costs

State of public knowledge

Behavioral plasticity with individual use

Potential for behavioral shifts

The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity



- Two waves of Prolific data collection in Summer 2025
- Total *N* = 3075
- Nationally representative sample (gender, race, age, political party, location)
- Pre-post within-subjects intervention with environmental disclosure

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The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity

- Introduction
- Awareness of costs and impacts
- Frequency/likelihood of use across different tasks/context
- Energy and environmental disclosure information
- Likelihood of shifts in frequency of AI use
- Attitudinal and other moderators

Welcome to the study.

In this study, we are interested in how often you choose to use generative AI models, such as Chat GPT, Google Gemini, or Meta Llama, in your day-to-day life, as well as your attitudes and overall knowledge about generative AI.

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The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity

- Introduction
- **Awareness of costs and impacts**
- Frequency/likelihood of use across different tasks/context
- Energy and environmental disclosure information
- Likelihood of shifts in frequency of AI use
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Please indicate your level of awareness of the following **resources** used by generative AI.

	Not at all aware of the resource use	Slightly aware	Somewhat aware	Moderately aware	Fully aware of the resource use
Generative AI requires a large amount of electricity to power data centers	○	○	○	○	○

Please indicate your level of awareness of the following **environmental implications** related to generative AI.

	Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Fully aware
Generative AI's platform produces a high amount of carbon emissions	○	○	○	○	○

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When given the option, how likely are you to use generative AI to perform the following tasks?

	Not at all likely	Slightly likely	Somewhat likely	Moderately likely	Extremely likely
Text generation (e.g., writing a story, email, or blog post)	○	○	○	○	○
Information search (e.g., searching the internet for an answer to a specific question)	○	○	○	○	○

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The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity

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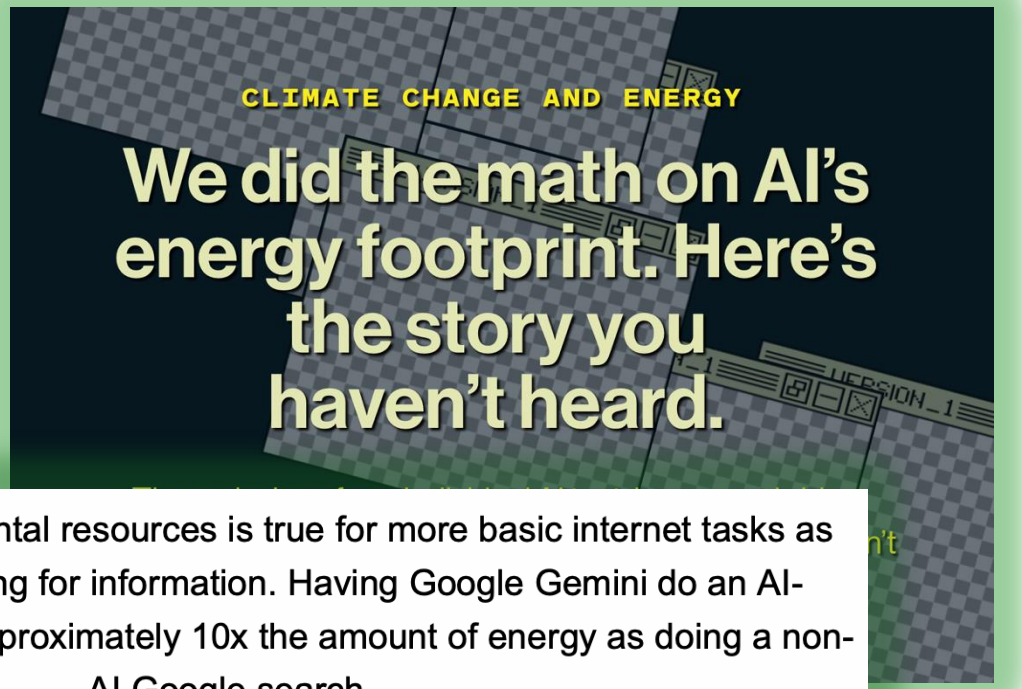

...the use of environmental resources is true for more basic internet tasks as well, such as searching for information. Having Google Gemini do an AI-powered search uses approximately 10x the amount of energy as doing a non-AI Google search.

More complex tasks-- such as image/video generation-- use even more environmental resources. For example, a recent report from MIT found that using generative AI to create a 5-second video uses the same amount of electricity as running a microwave for over an hour...

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The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity

- Introduction
- Awareness of costs and impacts
- Frequency/likelihood of use across different tasks/context
- Energy and environmental disclosure information
- **Likelihood of shifts in frequency of AI use**
- Attitudinal and other moderators

When given the option, how likely are you to use AI Chatbots to perform the following daily tasks in the future?

	Not at all likely	Slightly likely	Somewhat likely	Moderately likely	Extremely likely
Text generation (e.g., writing a story, email, or blog post)	○	○	○	○	○
Information search (e.g., searching the internet for an answer to a specific question)	○	○	○	○	○
Text summarization (e.g., explaining an article or writing a quick summary)	○	○	○	○	○

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The Current Research: Frequency of use, state of public knowledge, and potential for behavioral plasticity

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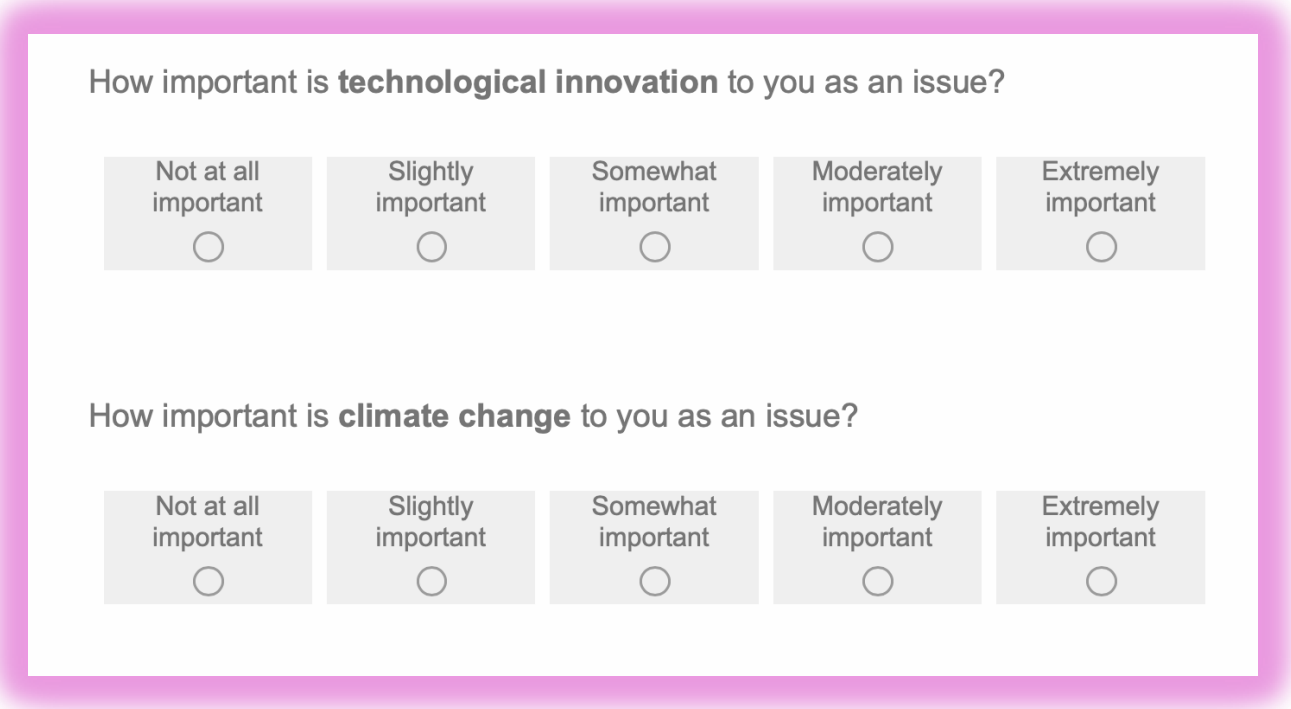

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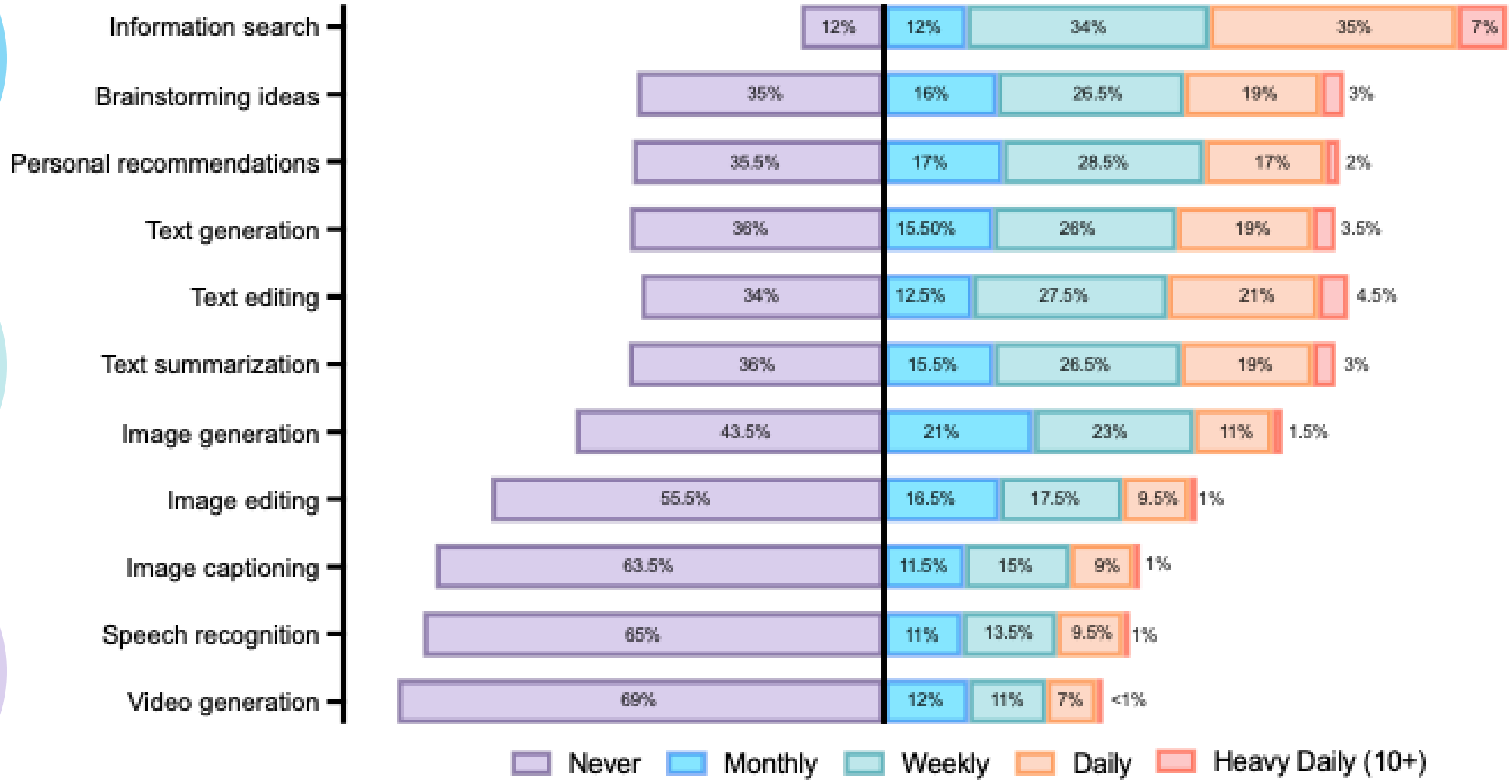
There is widespread use of Generative AI among the general public.

88% in past month

75% weekly use

6% never used



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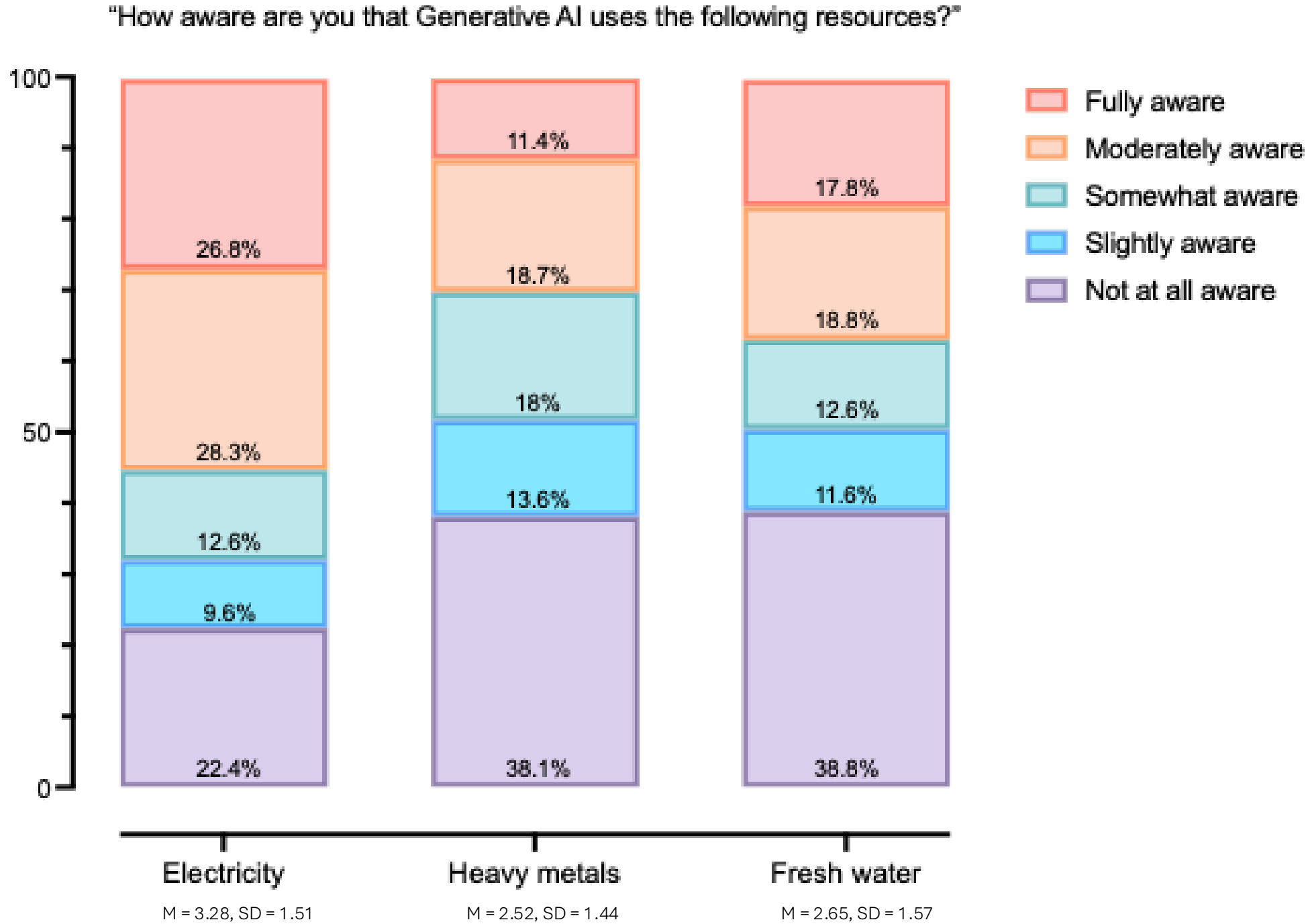

N = 3063

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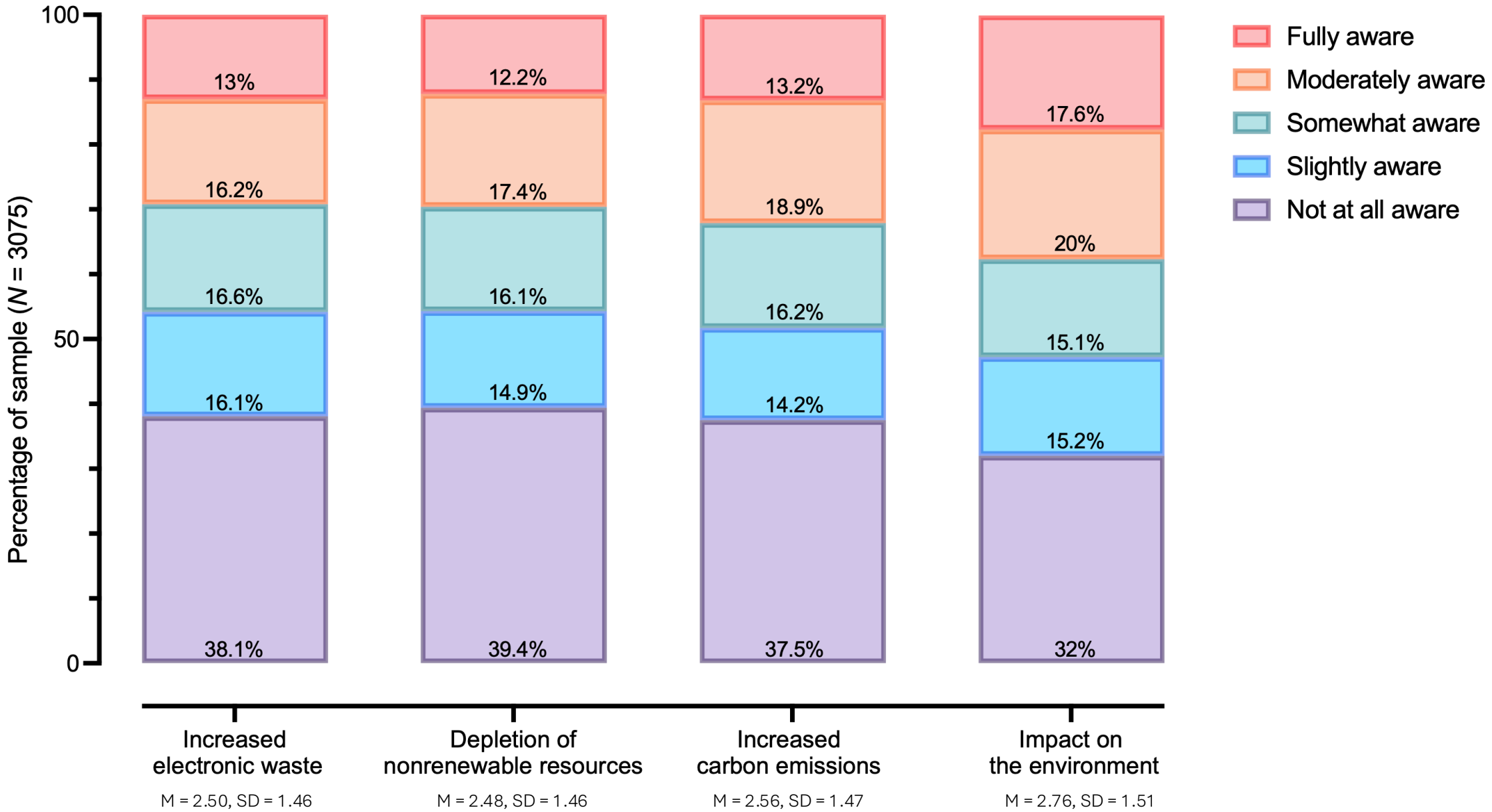
"How aware are you of the following impacts of Generative AI?"



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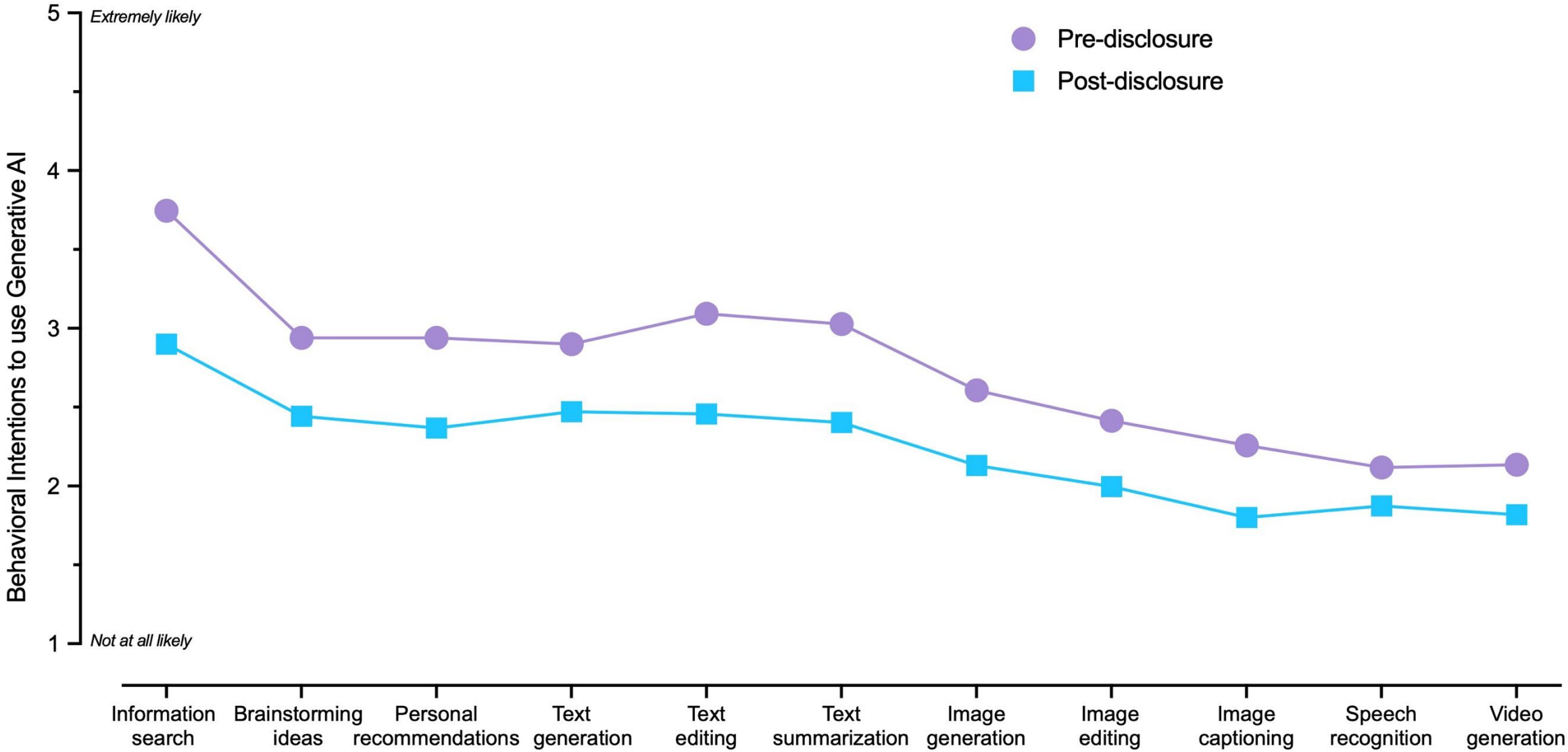
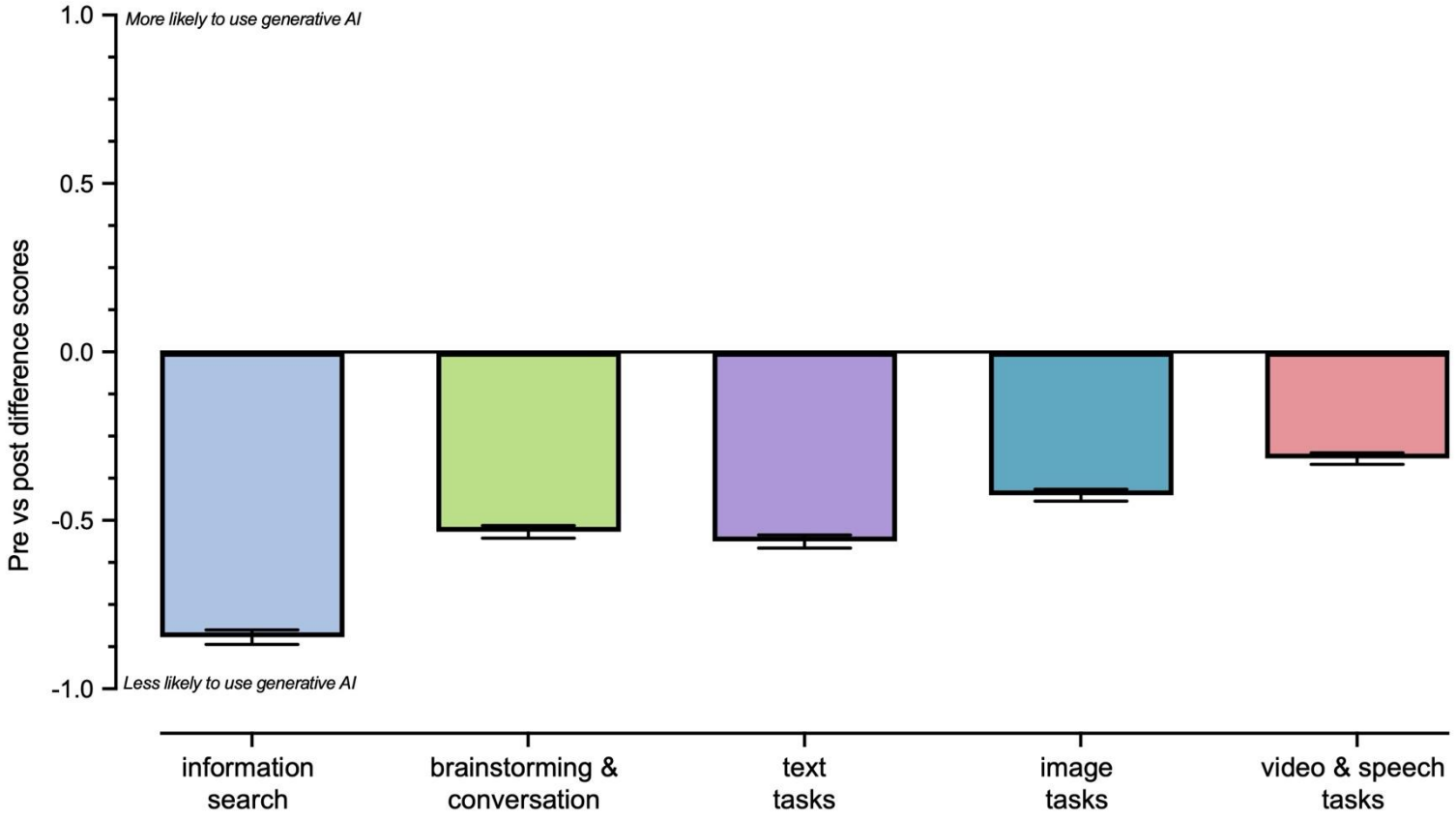


We found both task and demographic differences in response to the environmental information



The information intervention was more effective (larger intended reductions) for people who…

- Women
- Democrats
- Frequent users
- Care about climate change
- Were aware of the environmental impacts
- Believed the information to be true

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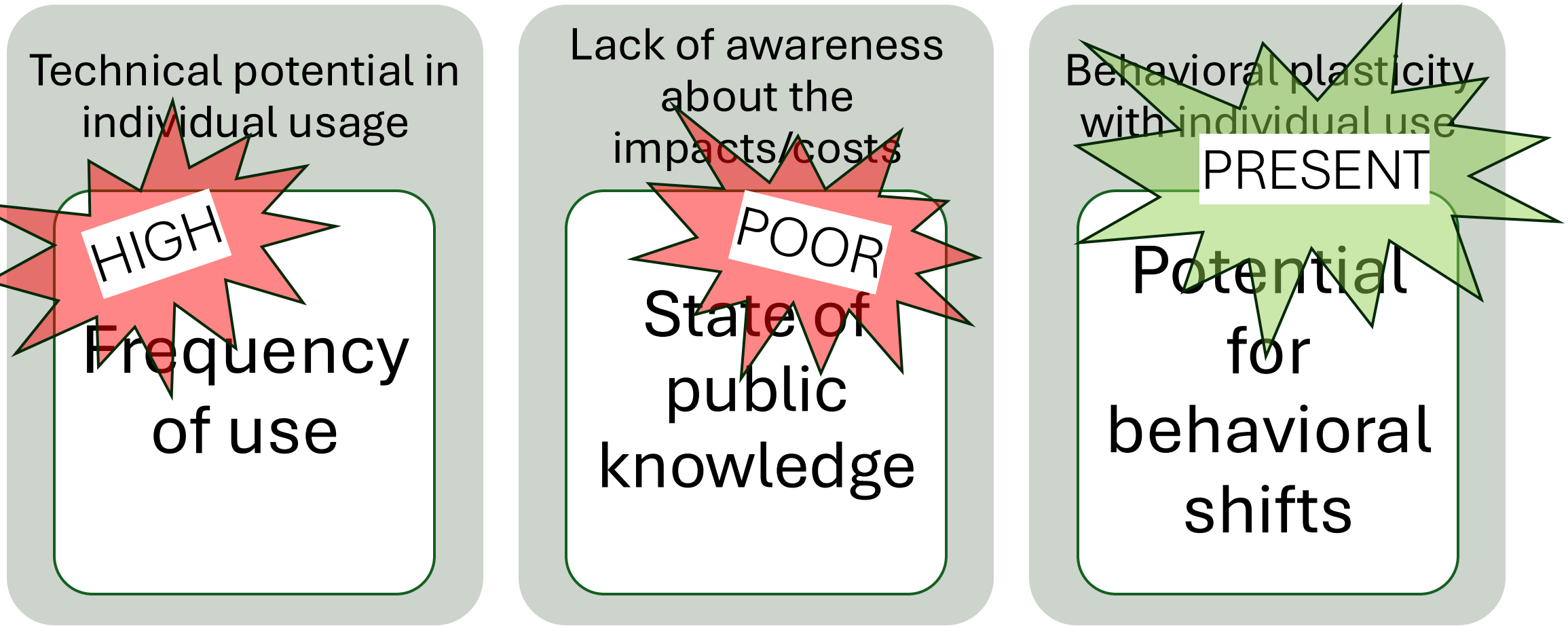
Several conditions are necessary for information disclosure to the environmental footprint of generative AI



There is widespread use of generative AI but also a widespread lack of knowledge about the resulting energy and environmental impacts.

There are perfect conditions for low-cost, low-intrusive information interventions on the demand side for day-to-day casual users.

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Further Implications and Applications

We focused on intention to reduce opt-in use but energy and environmental disclosures can also provide information about…

- Use of appropriate models
- Times of day with less demand on data centers
- Token-efficient interactions

Small changes

=

Cumulative energy savings effects across millions and millions of queries

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Further Implications and Applications

- Social and behavioral scientists can help by assisting AI firms in researching and creating the most effective energy and environmental disclosures

- Must examine several factors about the disclosures themselves:
  - Timing, repetition, and length
  - Framing of information
  - Scope of impacts
  - Bypass polarization

Azad, Cohen, & Hahnel, 2025; Bharadwaj et al., 2024; Chang & Wu, 2015; Nelson, Anggraini, & Schluter, 2020; Nelson, Bauer, & Partelow, 2021; Carfona, Morandi, & Catellani, 2022; Cucchiara, Kwon, & Ha, 2015; Van de Velde, Verbeke, Popp, & Van Huylenbroeck, 2010; Ma & Hmielowski, 2022; Sprengholz et al., 2023; Min, Azevedo, Michalek, & de Bruin, 2014

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Further Implications and Applications

- Outside of individual consumer behavior, environmental information disclosures can be impactful at several points

- Upstream effects:
  - Developers
  - Corporations


comment

Design behaviour for sustainability

An international expert panel probes how engineers, architects and behavioural scientists can work together to learn about design behaviour for sustainability — and what all interested scholars and practitioners might learn from it.

Leidy Klotz, John Pickering, Ruth Schmidt and Elke U. Weber

- "Downstream" effects:
  - Increased attention
  - Positive spillover

Sparkman, G., Attari, S. Z., & Weber, E. U. (2021). Moderating spillover: Focusing on personal sustainable behavior rarely hinders and can boost climate policy support. Energy Research & Social Science, 78, 102150.; Rakitta, M., & Wernery, J. (2021). Cognitive biases in building energy decisions. Sustainability, 13(17), 9960.; Thøgersen, J., & Noblet, C. (2012). Does green consumerism increase the acceptance of wind power? Energy Policy, 51,854–862. https://doi.org/10.1016/j.enpol.2012.09.046; Truelove, H. B., Carrico, A. R., Weber, E. U., Raimi, K. T., & Vandenbergh,M. P. (2014). Positive and negative spillover of pro-environmental behavior: An integrative review and theoretical framework. Global Environmental Change, 29,127–138. https://doi.org/10.1016/j.gloenvcha.2014.09.004

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WHY THIS MATTERS NOW

Timing is critical: AI adoption is accelerating now; intervention windows close rapidly as behaviors become habitual

Preventive approach: Easier to shape behavior during adoption phase than to change entrenched habits later

Precedent setting: Early AI disclosure could establish norms before industry practices become locked in

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Key Takeaways

01

Widespread lack of knowledge

02

Information disclosure can reduce costs and stress on environmental systems

03

May impact a wide range of actors and behaviors

Reducing the Energy Costs and Environmental Impacts of AI: Understanding User Behavior and the Potential for Information Disclosure

Thank you!

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