THE CLIMATE COST OF PROGRESS

HOW TECHNOLOGY SHAPES A WARMING WORLD

THE INVENTION OF THE INTERNET AND ITS CLIMATE IMPACT

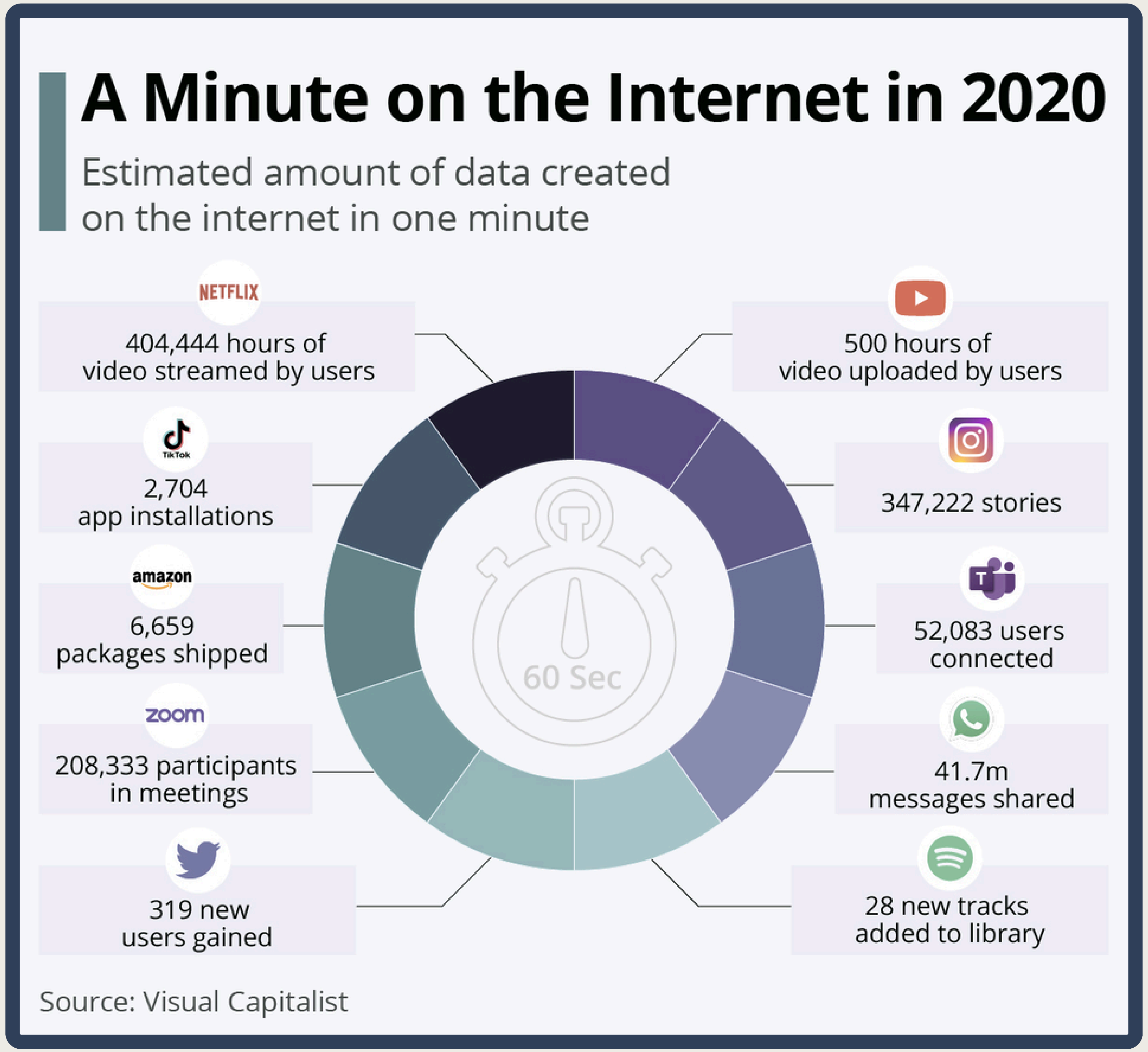
HOW THE RISE OF THE INTERNET TRANSFORMED COMMUNICATION, COMMERCE, AND WORK

AUBREE BERMAN

THE INTERNET & CLIMATE CHANGE

A Double-Edged Sword

- Transformed communication, commerce, and work
- Reduced some emissions (travel, paper, logistics)
- Created new, less visible climate risks
- Shifted emissions into digital infrastructure
- Internet now reaches 5+ billion people (~60% of the global population)
- Global data traffic grew 440% since 2015



Christopher Knittel, Samuel Senga & Jing Wang, Flexible Data Centers and the Grid: Lower Costs, Higher Emissions?, CEEPR Working Paper No. 2025-14 (2025).

INTERNET'S HIDDEN CLIMATE FOOTPRINT

- Internet activity requires phones, laptops, servers, and cables. Devices must be mined, manufactured, shipped, and discarded.
- Frequent upgrades increase carbon emissions. Device manufacturing drives most mineral & metal resource use
- Average user spends ~7 hours/day online. That's over 40% of waking life (Social media & video streaming are the largest drivers).
- ICT sector uses 2–3% of global electricity
- 53+ million tons of electronic waste each year and less than 20% of e-waste is properly recycled
- Toxic waste often harms low-income and marginalized communities

Roxana Istrate et al., The Environmental Sustainability of Digital Content Consumption, 15 Nature Commc'ns 1 (2024).

WHY IT MATTERS FOR CLIMATE GOVERNANCE

Internet use can crowd out basic needs (food, transport, housing)

Electricity use is the largest emissions driver

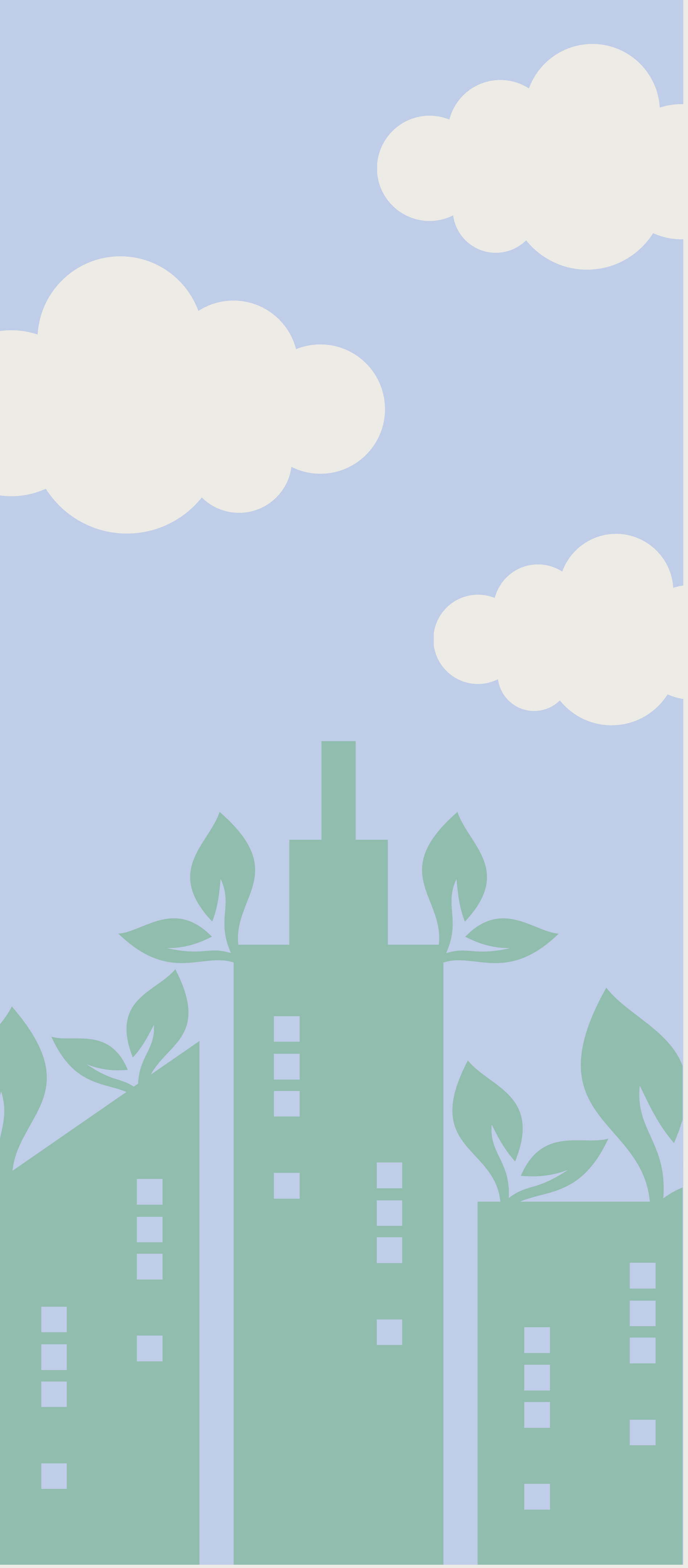
ICT emissions equal 1.8–2.8% of global GHG emissions

Comparable to emissions of entire countries

Internet use alone ≈ 40% of a 1.5°C carbon budget of challenges towards environmental sustainability.

Video streaming = 40–50% of digital impacts

Istrate et al., The Environmental Sustainability of Digital Content Consumption, Nature Commc'ns (2024).



CLIMATE LAW & THE PATH FORWARD

- Climate law must address digital systems, not just energy use
- Climate law is shifting from products → systems
- Digital emissions are difficult to trace and regulate
- Current internet law focuses on data, not carbon
- “Digital sobriety” promotes mindful use and design reform

Goal: a greener internet, not no internet

Aude-Solveig Epstein, EU Environmental Law in the Digital Age, Eur. J. Risk Reg. (2025).
Istrate et al., Nature Commc’ns (2024).

CLEAN ENERGY INNOVATION AND ELECTRIFICATION

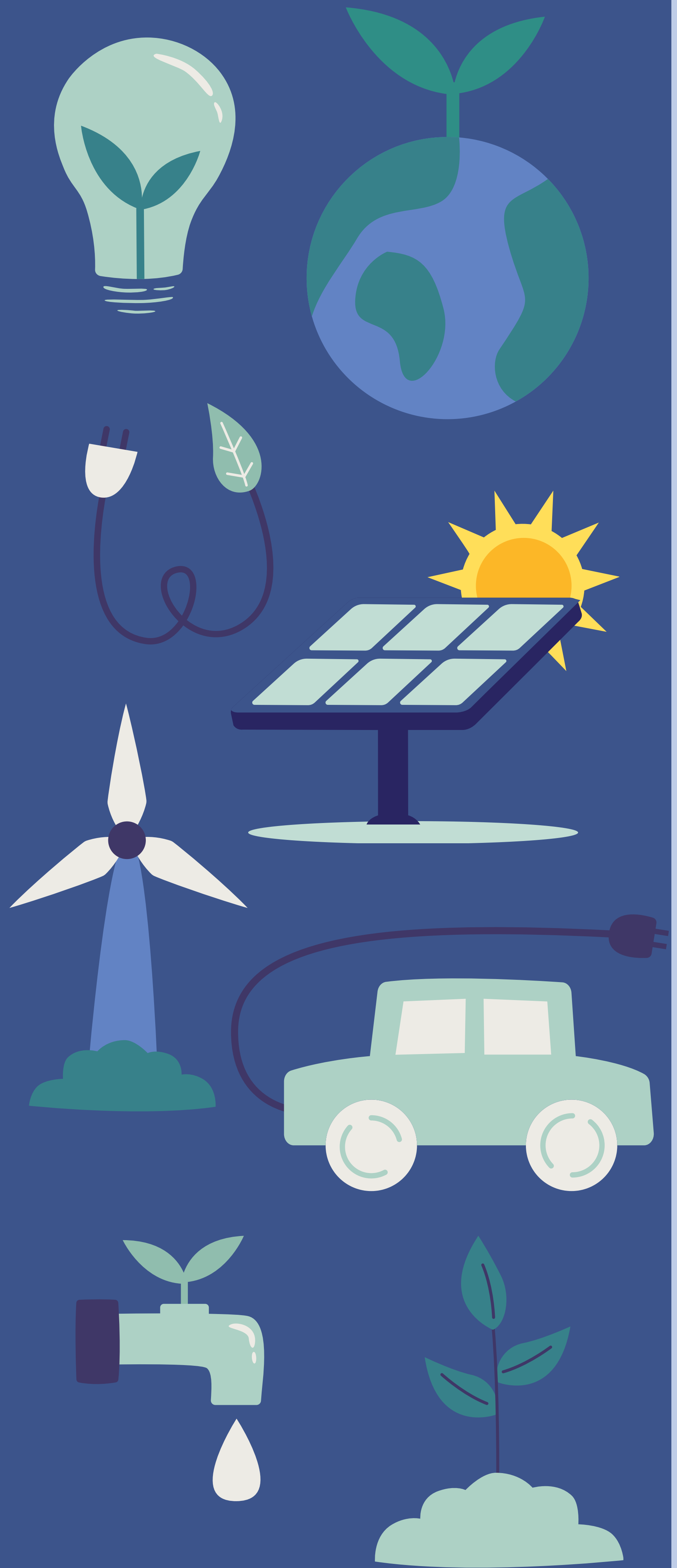
HOW ADVANCES IN RENEWABLE ENERGY, BATTERIES, AND ELECTRIFICATION TECHNOLOGIES HAVE REDUCED EMISSIONS AND ENABLED THE TRANSITION AWAY FROM FOSSIL FUELS.

SIERRALYNN ANDERSON

THE SHIFT TOWARDS CLEAN ENERGY

- Recognition of fossil fuels' role in climate change
- Innovation driven by science, policy, and markets
- Transition toward low-carbon energy systems
- Growing global investment in clean energy
- Climate law and energy policy incentives

Intergovernmental Panel on Climate Change, Climate Change 2023: Synthesis Report (2023).
International Energy Agency, World Energy Outlook 2023 (2023).



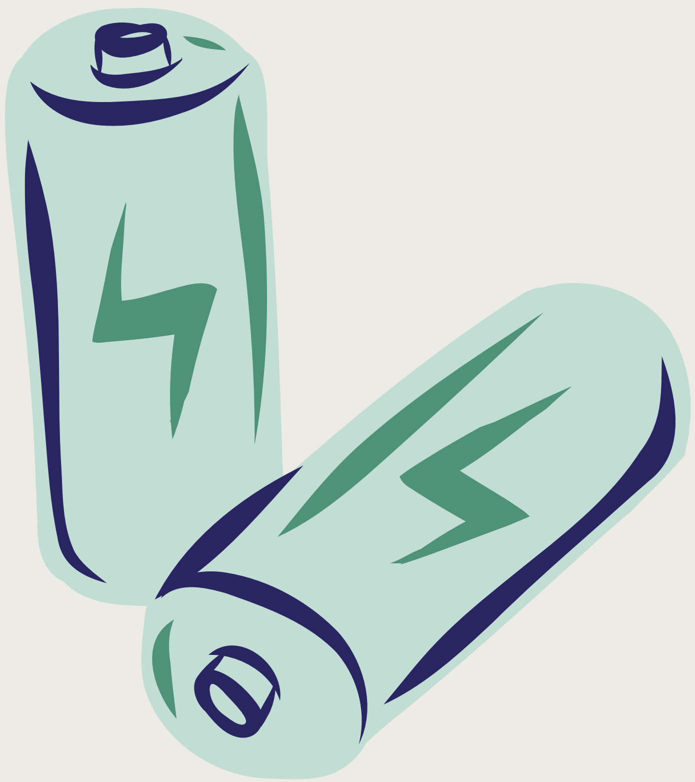
RENEWABLE ENERGY TECHNOLOGIES

Cheaper, Cleaner, and Rapidly Expanding

- Solar and wind power rapidly expanding
- Costs have declined significantly
- Increased efficiency and scalability
- Reduced reliance on coal and oil
- Supported by subsidies and renewable mandates

International Renewable Energy Agency, Renewable Power Generation Costs in 2022 (2023).
International Energy Agency, Renewables 2023 (2023).

BATTERY STORAGE AND GRID INNOVATION



Energy storage addresses intermittency

Advances in battery technology

Smart grids improve efficiency

Better integration of renewables

U.S. Department of Energy, Energy Storage Grand Challenge Roadmap (2020).
International Energy Agency, Electricity Grids and Secure Energy Transitions (2023).

ELECTRIFICATION OF TRANSPORTATION AND BUILDINGS

- Electric vehicles replacing gas-powered cars
- Heat pumps and electric appliances
- Reduced direct fossil fuel use
- Emissions shift to power sector
- Driven by emissions standards and building codes

International Energy Agency, Global EV Outlook 2023 (2023).
U.S. Environmental Protection Agency, Electrification and Decarbonization Overview (2022).

CLIMATE IMPACT AND LIMITATIONS

- Significant emissions reductions
- Infrastructure and resource challenges
- Environmental impacts of mining materials
- Success depends on clean electricity supply
- Requires ongoing legal oversight

Intergovernmental Panel on Climate Change, Climate Change 2022: Mitigation of Climate Change (2022).
World Bank, Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition (2020).

TECHNOLOGY, EFFICIENCY, & INCREASED CONSUMPTION - THE REBOUND EFFECT

HOW TECHNOLOGICAL EFFICIENCY CAN LOWER COSTS AND UNINTENTIONALLY DRIVE HIGHER OVERALL ENERGY USE AND EMISSIONS.

LILLY EDWARDS

EFFICIENCY ≠ SUSTAINABILITY

- New technologies often make energy use cheaper, faster, and more efficient
- Lower costs change behavior — people use the technology more
- Emissions reductions per unit ≠ reductions overall
- This tension is known as the rebound effect

John R. Ehrenfeld, Efficiency Does Not Equal Sustainability (Dec. 15, 2010), https://johnrehrenfeld.substack.com/p/efficiency_does_not_equal_sust.
Urban Sustainability Directors Network, Why Efficiency Is Not Enough, USDN Sustainable Consumption (n.d.).

WHAT IS THE REBOUND EFFECT?

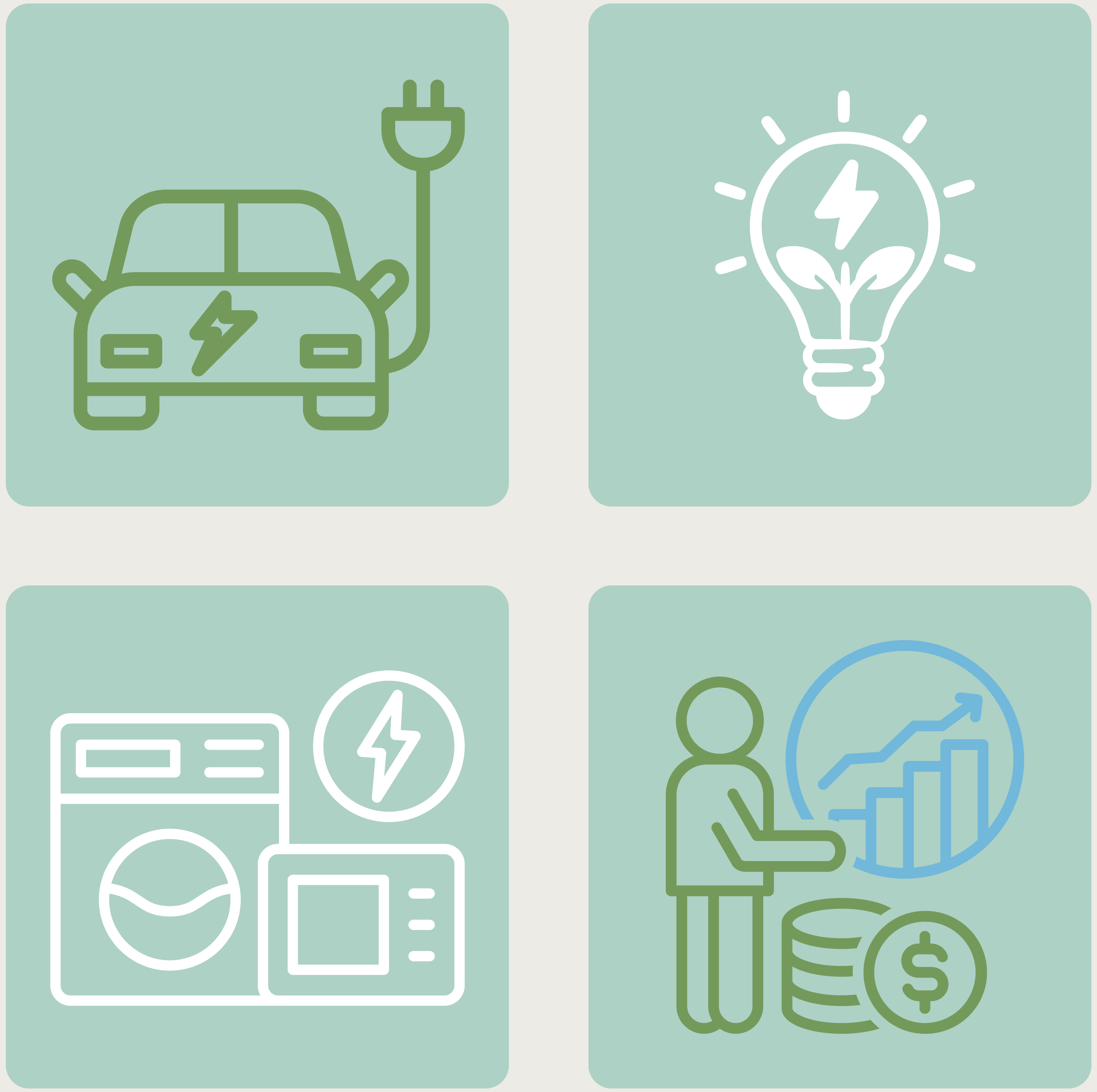
- Efficiency lowers energy costs
- Lower costs increase demand and total consumption
- Reduces expected emissions savings
- In some extreme cases there is a backfire

Kenneth Gillingham, David S. Rapson & Gernot Wagner, The Rebound Effect and Energy Efficiency Policy, 10 Rev. Envtl. Econ. & Pol'y 68 (2016), https://doi.org/10.1093/reep/rev017
Nuri C. Onat et al., Rebound Effects Undermine Carbon Footprint Reduction Potential of Autonomous Electric Vehicles, 14 Nature Commc'ns art. 6258 (2023), https://doi.org/10.1038/s41467-023-41992-2

HISTORICAL EXAMPLES

Lower cost leads to higher demand

- Fuel-efficient cars → more driving
- Efficient lighting → more lighting use
- Faster appliances → increased usage



Urban Sustainability Directors Network, What Are Examples of Rebound Effects?, Sustainable Consumption Toolkit (Apr. 2, 2026), https://climate.sustainability-directory.com/question/what-are-examples-of-rebound-effects/

TECHNOLOGY & CONSUMER BEHAVIOR

- Efficiency changes incentives
- Convenience influences consumption
- Behavioral responses matter
- Technology alone does not control use

TechTarget, The Role of Technology in Shaping Consumer Behavior (2025), https://www.techtarget.com/whatis/feature/The-role-of-technology-in-shaping-consumer-behavior

MANAGING THE REBOUND: CLIMATE LAW & POLICY

- Markets reward efficiency, not restraint
- Climate law often assumes efficiency = emissions reduction
- Without caps, pricing, or planning → demand keeps rising
- Regulation must address systems, not just technologies

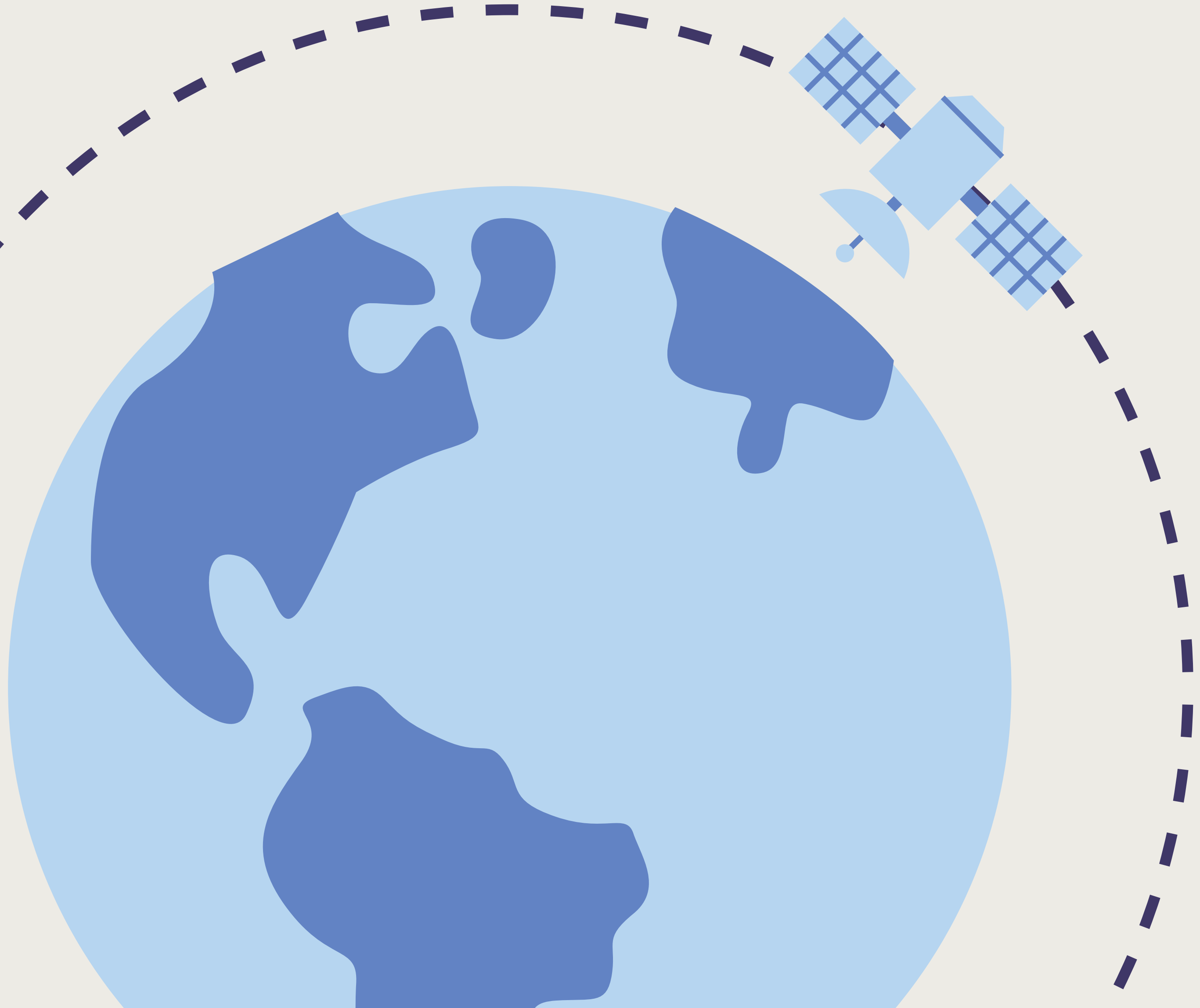
- Pair efficiency with:
  - Carbon pricing
  - Clean electricity mandates
  - Demand-side management
  - Infrastructure planning
- Goal is decoupling growth from emissions
- Climate policy must anticipate human behavior

David Font Vivanco, René Kemp & Ester van der Voet, How to Deal with the Rebound Effect? A Policy-Oriented Approach, 94 Energy Pol'y 114 (2016), https://doi.org/10.1016/j.enpol.2016.03.054.
Urban Sustainability Directors Network, How Do Policies Address Rebound Effects? (Nov. 28, 2025), https://energy.sustainability-directory.com/question/how-do-policies-address-rebound-effects/

CLIMATE OBSERVATION TECHNOLOGIES: SATELLITES, SENSORS, AND BIG DATA

HOW MODERN MONITORING TECHNOLOGIES HAVE IMPROVED DETECTION OF CLIMATE CHANGE, ATTRIBUTION OF EXTREME EVENTS, AND ENFORCEMENT OF ENVIRONMENTAL POLICY.

MADDY VANN



WHY DOES CLIMATE OBSERVATION MATTER?

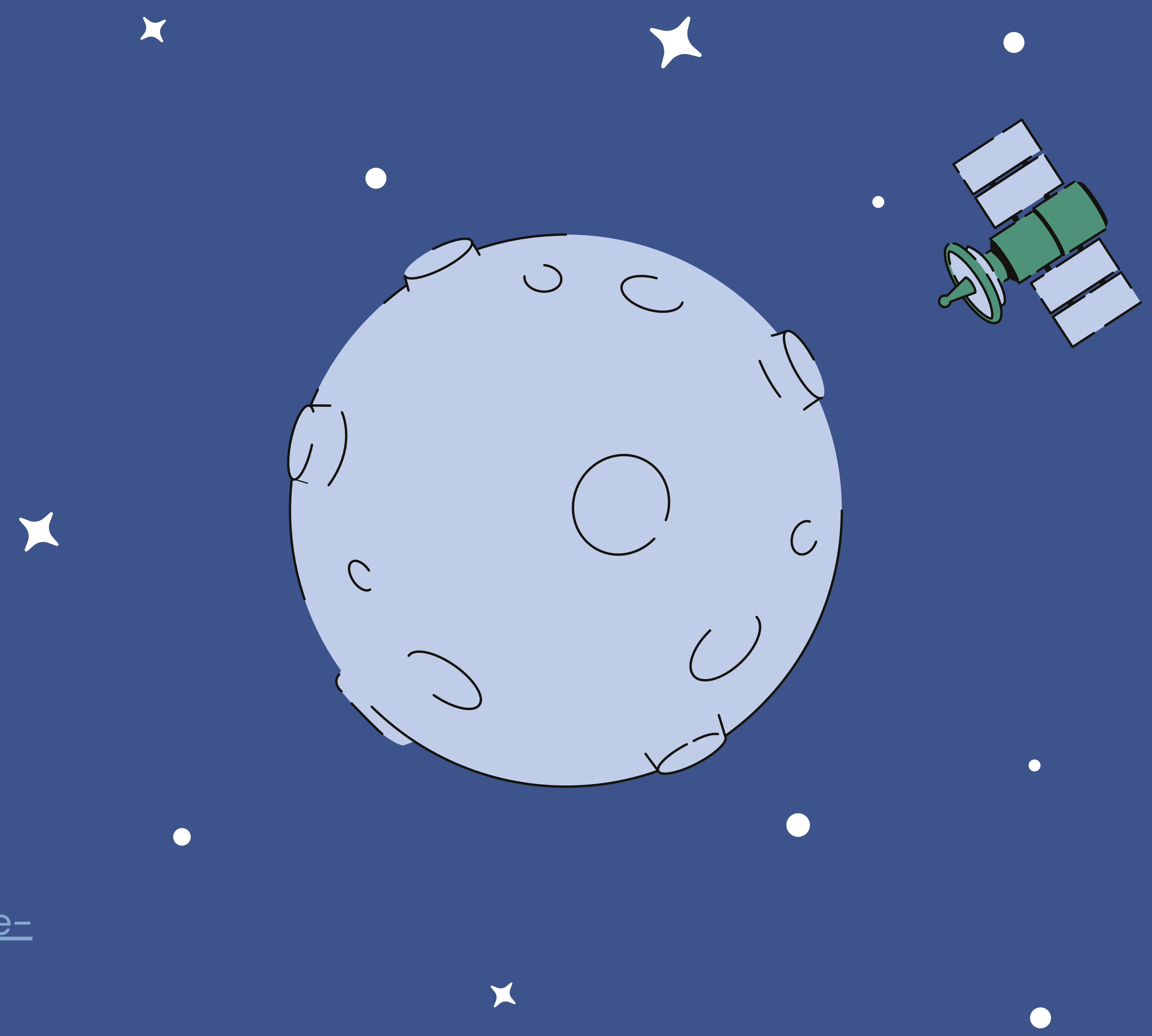
"You can't manage what you can't measure"

- Sparse stations → global, real time monitoring
- Satellites + sensors + big data
- Foundation for climate law & policy

Discover UK Research and Innovation. (2021, October 21). A brief history of climate change discoveries. https://www.discover.ukri.org/a-brief-history-of-climate-change-discoveries/
History.com Editors. (2025, September 2). History of climate change. History. https://www.history.com/articles/history-of-climate-change

SATELLITES: GLOBAL MONITORING & ACCOUNTABILITY

- Track temperature, sea level, ice loss, and emissions
- Detect deforestation & land use change
- Independent, real-time verification
- Used by governments & NGOs



Jet Propulsion Laboratory. (n.d.). 6 things to know from NASA about new U.S.-European sea satellite. NASA. https://www.jpl.nasa.gov/news/6-things-to-know-from-nasa-about-new-us-european-sea-satellite/

United Nations Framework Convention on Climate Change. (n.d.). The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement

Freethink. (n.d.). Protecting the rainforest from space. https://www.freethink.com/sponsored/protecting-the-rainforest-from-space

Bezos Earth Fund. (n.d.). What to know about MethaneSAT: Taking climate surveillance to new heights. https://www.bezosearthfund.org/news-and-insights/what-to-know-about-methanesat-taking-climate-surveillance-new-heights

SENSORS & IOT: LOCAL EVIDENCE FOR POLICY DECISIONS

- Air quality monitors, buoys, weather stations
- Hyper local pollution & heat data
- Early warning systems
- Supports environmental justice & regulation

National Park Service. (n.d.). How we measure ozone. U.S. Department of the Interior. https://www.nps.gov/subjects/air/howwemeasure-ozone.htm
Environmental Protection Agency. (n.d.). Process to determine whether areas meet the NAAQS (designations process). https://www.epa.gov/criteria-air-pollutants/process-determine-whether-areas-meet-naaqs-designations-process
IQAir. (n.d.). Unequal air: How gaps in air monitoring undermine health and justice. https://www.iqair.com/newsroom/unequal-air-how-gaps-in-air-monitoring-undermine-health-and-justice
StateScoop. (n.d.). AI cameras, sensors, and drones used in LA wildfires. https://statescoop.com/ai-cameras-sensors-drones-la-wildfires-2025/
American Lung Association. (n.d.). Disparities in the impact of air pollution. https://www.lung.org/clean-air/outdoors/who-is-at-risk/disparities

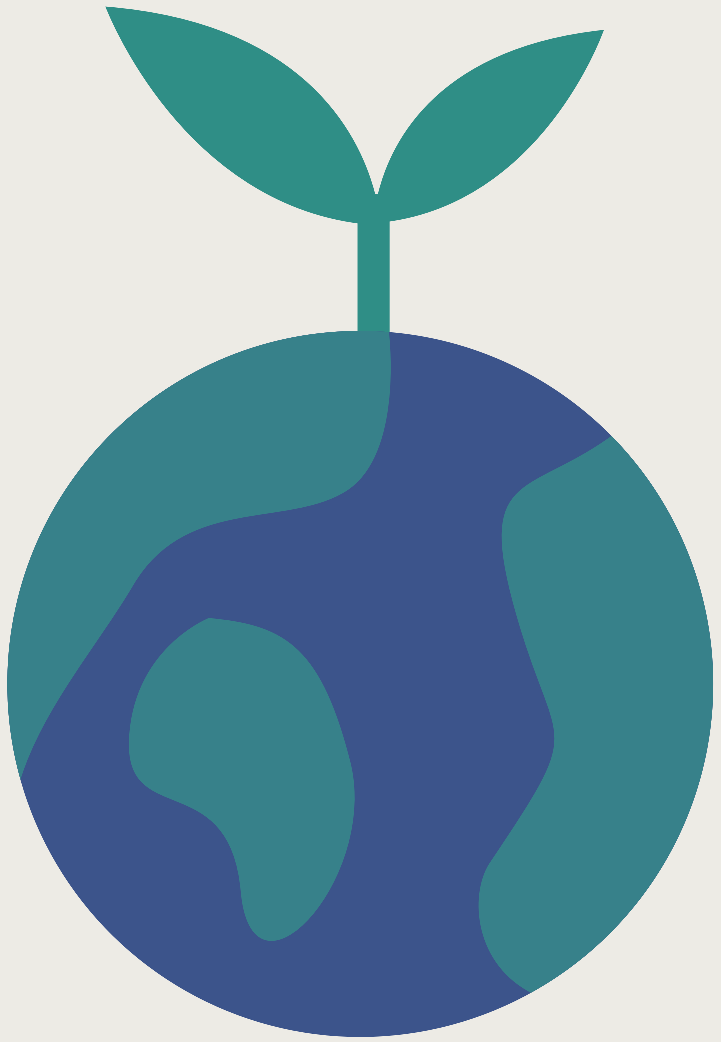
BIG DATA, AI, & LEGAL ENFORCEMENT

- Massive datasets → AI analysis
- Attribute extreme events to climate change
- Verify emissions & compliance
- Evidence for regulation & lawsuits

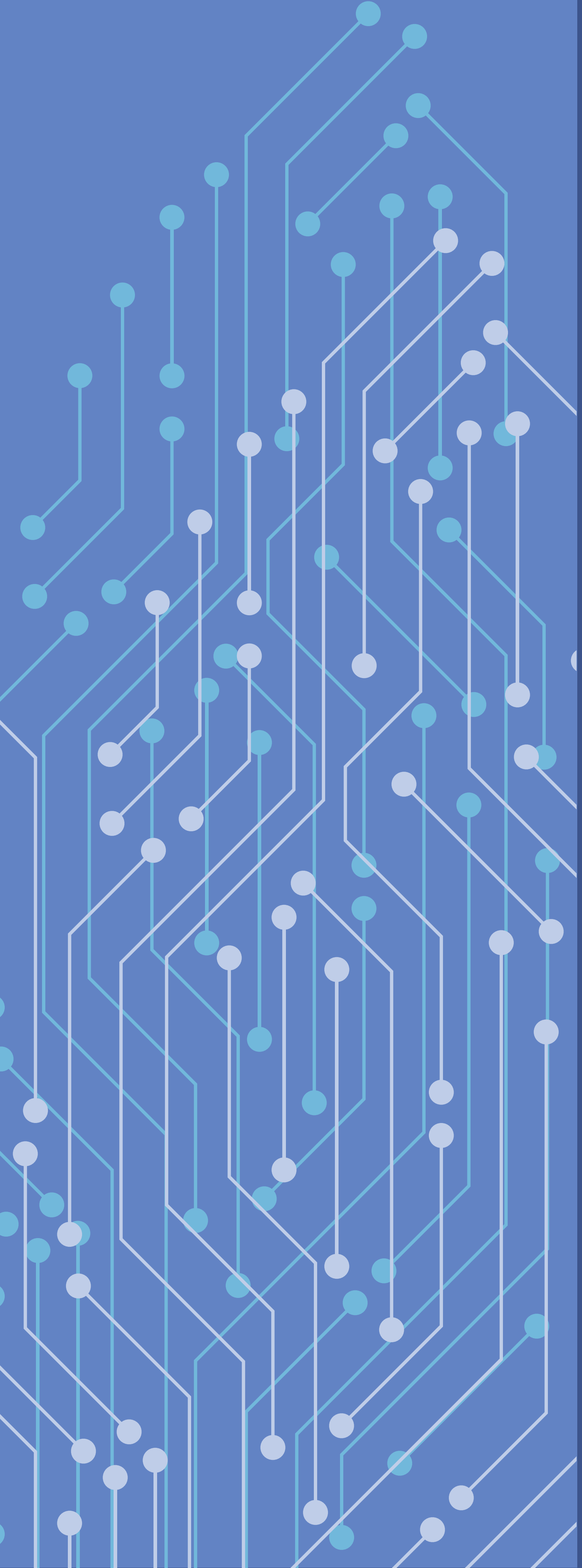
MDPI. (n.d.). The effectiveness of AI techniques in climate science. Atmosphere.
Cutter Consortium. (n.d.). AI takes orbit: Transforming satellite data for environmental action.
https://www.cutter.com/article/ai-takes-orbit-transforming-satellite-data-environmental-action
Yale School of the Environment. (n.d.). Yale experts explain climate lawsuits.
https://sustainability.yale.edu/explainers/yale-experts-explain-climate-lawsuits

WHAT'S NEXT FOR TECHNOLOGY IN THE CLIMATE CHANGE SPACE?

- Policy-driven innovation & global regulatory signals
- Software + Consulting for compliance & ESG requirements
- AI scaling climate solutions & emissions tracking
- Ocean/"Blue Economy" as a frontier of climate tech



Benoit, N., & Brightest. (2025, September 15). What's next in climate tech? Here are 5 trends experts say you can't ignore. Sustainability News. https://sustainabilitynews.substack.com/p/whats-next-in-climate-tech-here-are

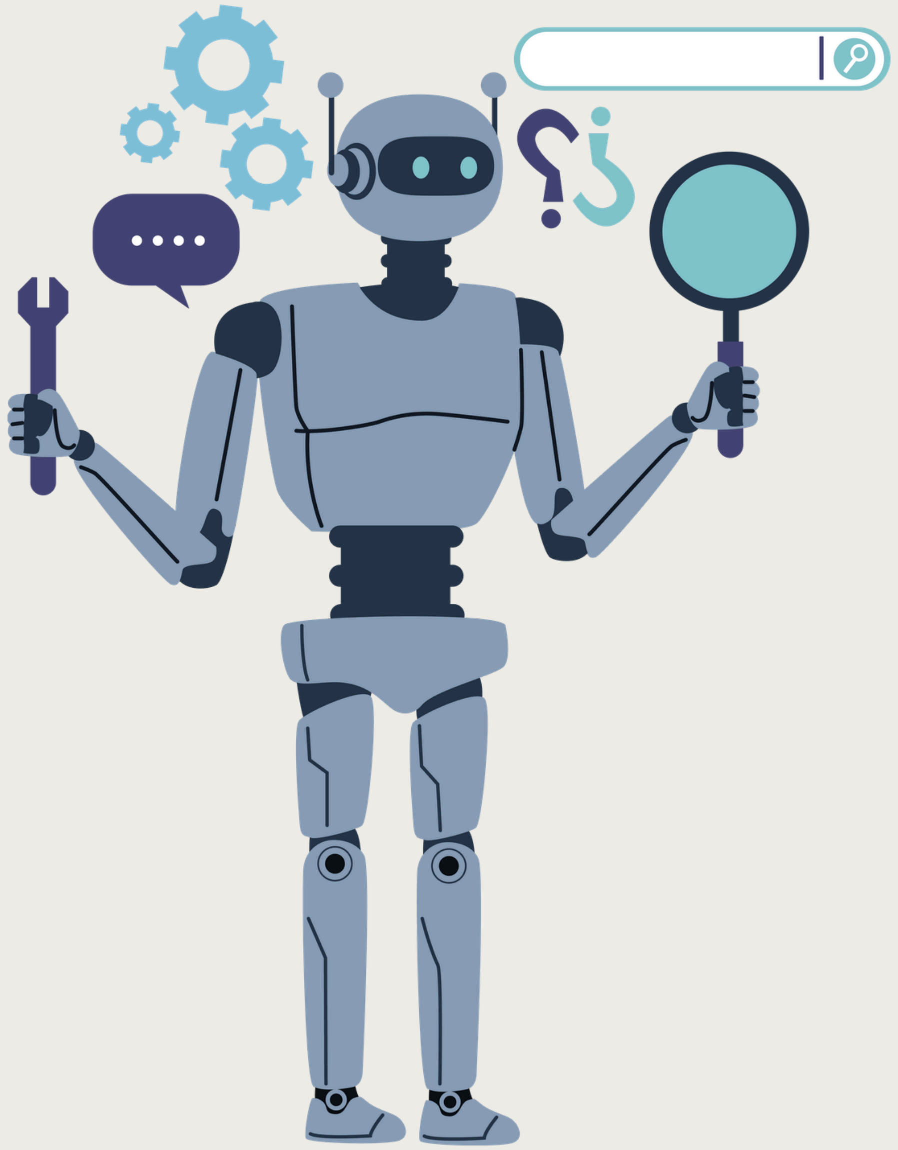


ARTIFICAL INTELLIGENCE & DATA CENTERS

ARTIFICIAL INTELLIGENCE ENHANCES CLIMATE MODELING, IMPROVES EXTREME WEATHER FORECASTS, AND SUPPORTS FASTER, MORE ACCURATE CLIMATE ANALYSIS.

STAN THOMAS

THE AI CLIMATE PARADOX

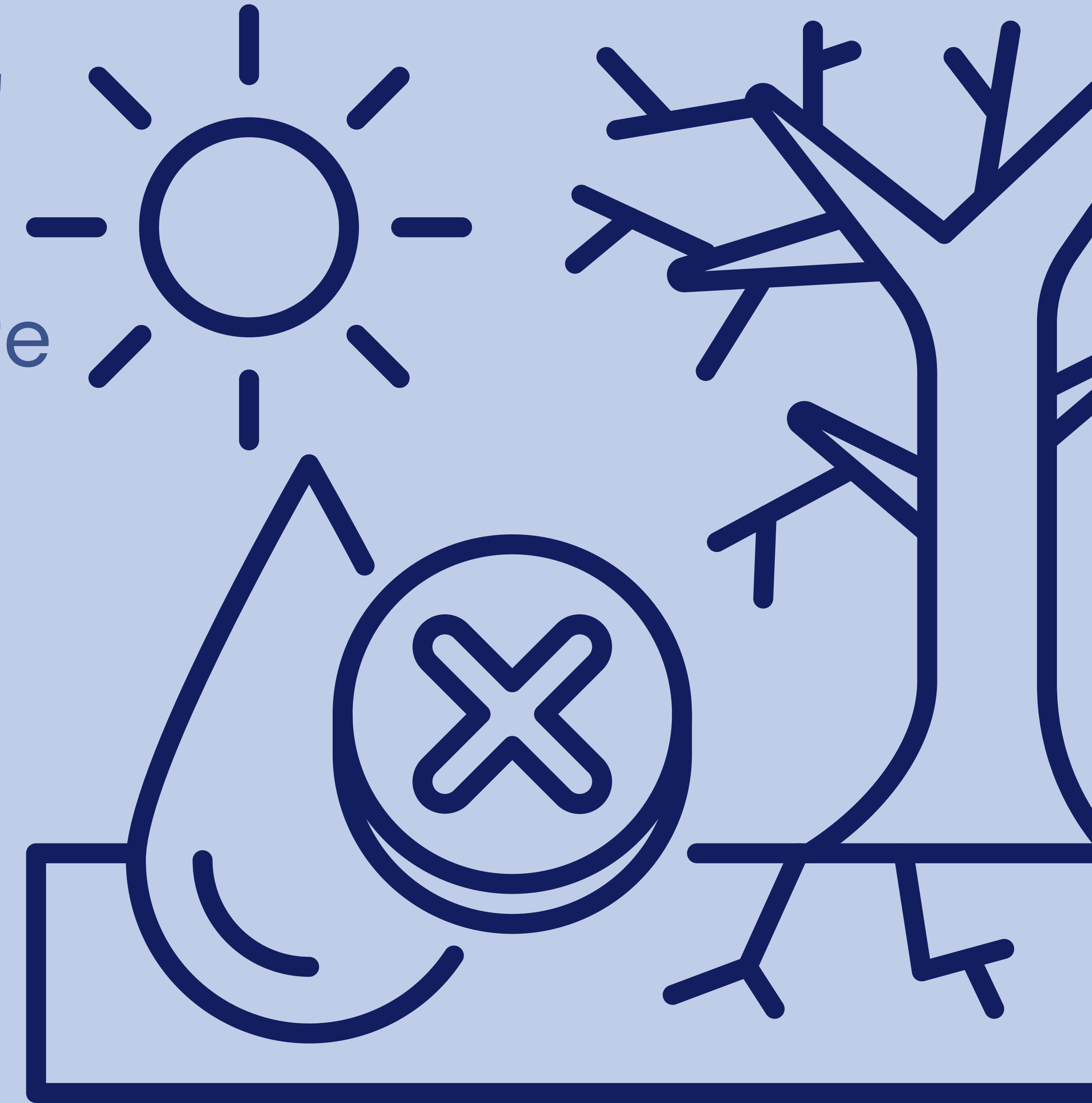


- **The Dual Reality:** AI is both a powerful climate tool and a massive consumer of resources.
- **The Solution Side:**
  - **Grid Optimization:** AI balances variable wind/solar flow in real-time.
  - **Material Discovery:** AI accelerates finding new battery electrolytes and carbon capture materials.
  - **Forecasting:** Models like GraphCast predict extreme weather faster than supercomputers.
- **The Problem Side:** Generative AI (LLMs) is highly energy-intensive; a ChatGPT query uses ~10x the energy of a standard search.

Boston Consulting Group, How AI Can Be a Powerful Tool in the Fight Against Climate Change (2023).
DeepMind, GraphCast: AI Model for Faster and More Accurate Global Weather Forecasting, Science (2023).

EXPLODING DEMAND & WATER SCARCITY

- Data center energy use is projected to double by 2026 (reaching consumption levels of Japan).
- Cooling servers generate heat; "evaporative cooling" consumes millions of gallons of potable water.
- Fossil Fuel Relapse: Utilities in Virginia and Kansas are delaying coal plant retirements to meet 24/7 AI power demand.
- Training GPT-3 consumed ~700,000 liters of freshwater.



Yale E360, A.I. Is Keeping Aging Coal Plants Online (Jan. 2026).
Pengfei Li & Shaolei Ren, Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models (2023).

TRAINING VS. INFERENCE : WHERE THE EMISSIONS ARE

TRAINING

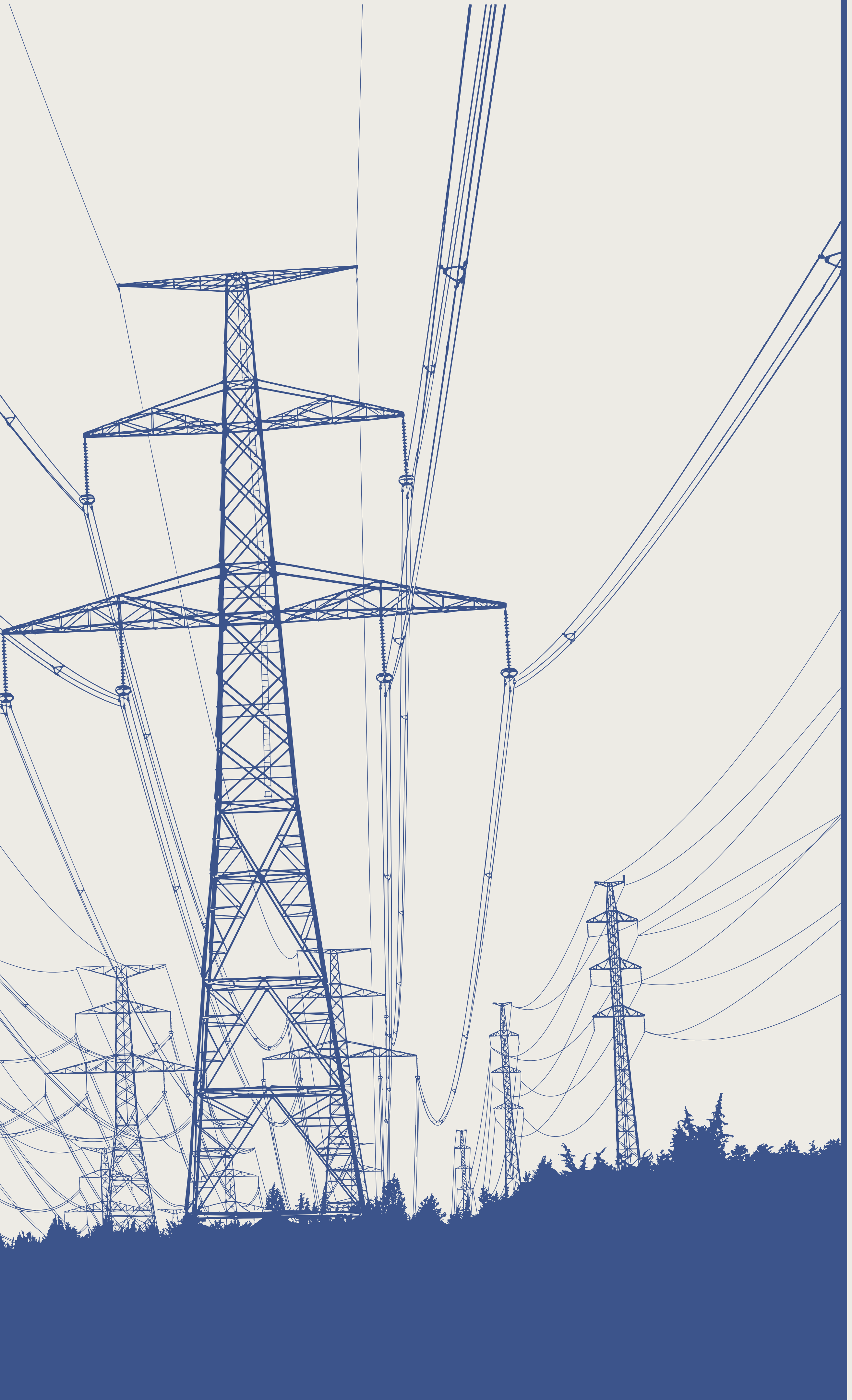
The one-time energy cost of building a model (intense but finite).

INFERENCE

The continuous energy cost of using the model (querying chatbots, generating images).

- **The Scale:** Inference accounts for ~80-90% of a model's lifecycle emissions.
- **Efficiency Rebound:** As models become more efficient (cheaper), usage spikes, potentially canceling out energy savings

Sasha Luccioni et al., Estimating the Carbon Footprint of BLOOM, J. Mach. Learning Rsch. (2023).



LDES & THE LEGAL LANDSCAPE

"Capacity" is measured by AC output to the grid, not DC potential.

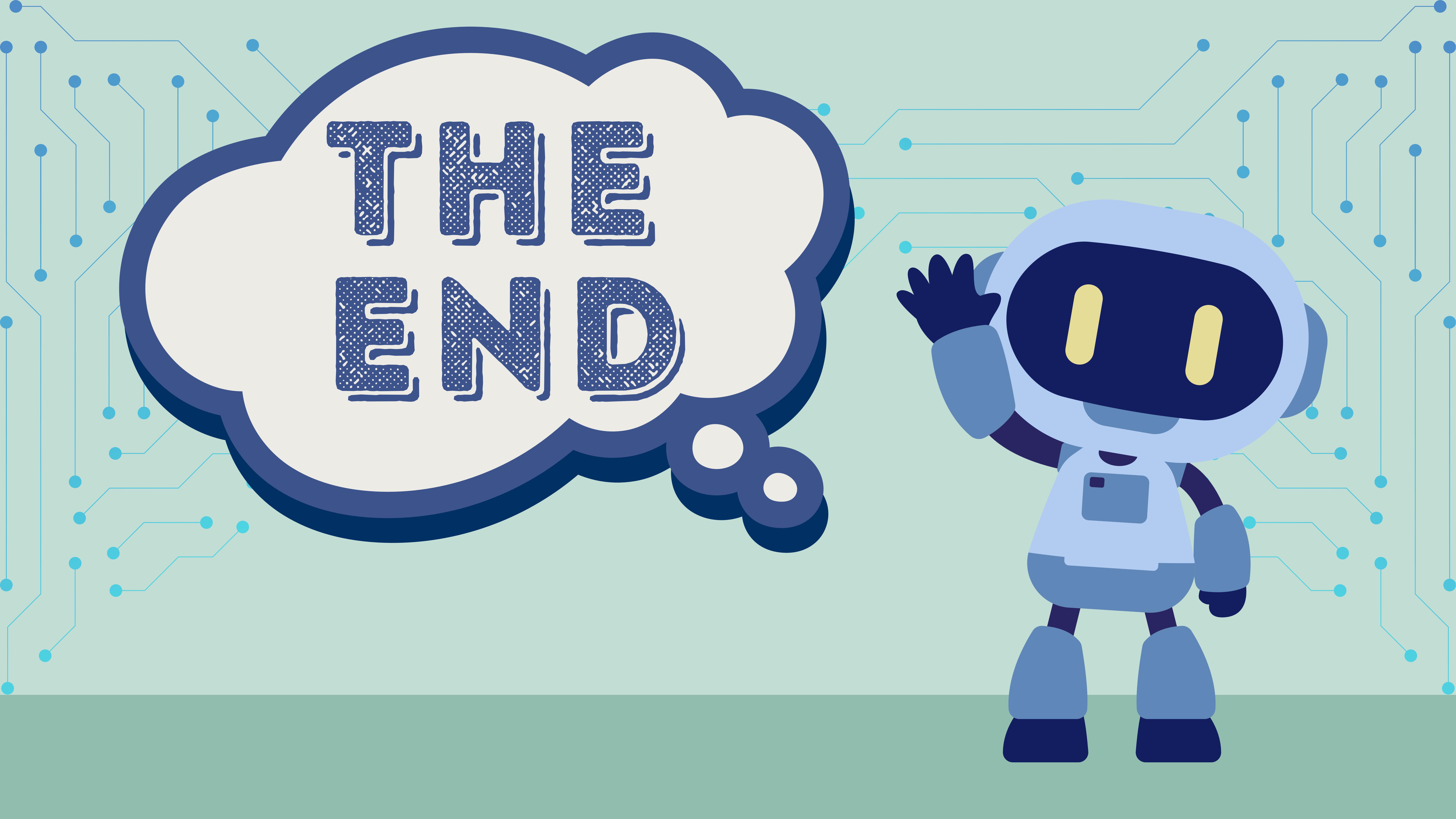
- **E**nergy storage technologies – Flow batteries, Iron, Zinc, (Less Lithium)
- (Broadview Solar) (D.C. Cir. 2025).
- **The Siting Hurdle:** Piedmont Environmental Council v. FERC, No. 07-1651 (4th Cir. 2009).

Solar Energy Industries Association v. FERC, No. 24-1045 (D.C. Cir. Sept. 9, 2025).
Piedmont Envtl. Council v. FERC, 558 F.3d 304 (4th Cir. 2009)

REGULATING THE DIGITAL FUTURE

- **Transparency Laws:**
  - **EU AI Act:** Mandates reporting on energy consumption for high-risk models.
  - **US Clean Cloud Act**: Seeks to standardize data center efficiency metrics. (Proposed)
- **State Regulations:**
  - **California Decision 25-06-005:** Strictly defines LDES as "8+ hours continuous discharge" to prevent greenwashing.

European Parliament, EU AI Act: First Regulation on Artificial Intelligence (2024).
Georgetown Envtl. L. Rev., Consumers End Up Paying for the Energy Demands of Data Centers (Oct. 2025).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