Is AI good or bad for the climate?
…it's complicated

David Rolnick

McGill University
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Climate Change AI

Climate change

- Increasingly severe effects
- Disproportionate impact on disadvantaged communities
- How bad it gets depends on what we do now
- Need net-zero greenhouse gas emissions by 2050 (IPCC)

- Action encompasses both **mitigation** (reducing greenhouse gas emissions) and **adaptation** (resilience to consequences)

AI applications relevant to climate change mitigation / adaptation

AI applications that increase greenhouse gas emissions

AI applications with uncertain or systemic impacts

Emissions impacts of AI computation and hardware

L. Kaack, et al. *Aligning Artificial Intelligence with Climate Change Mitigation*, Nature Climate Change 2022.

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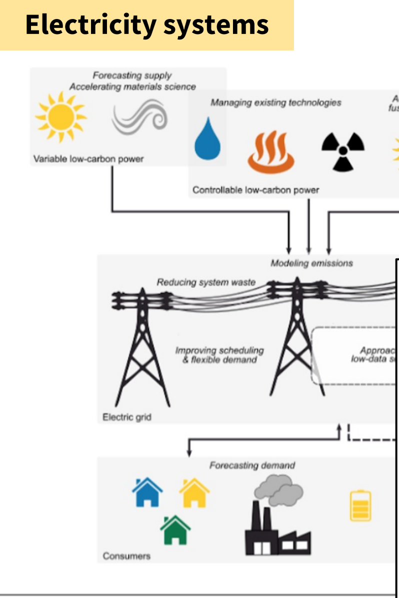

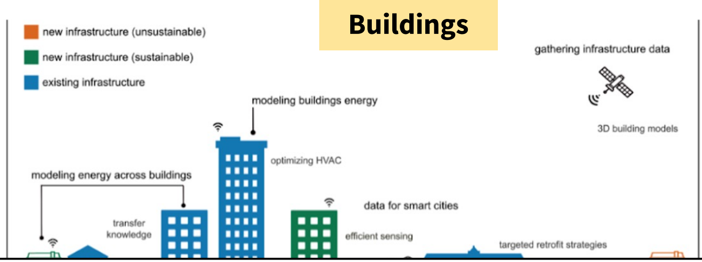

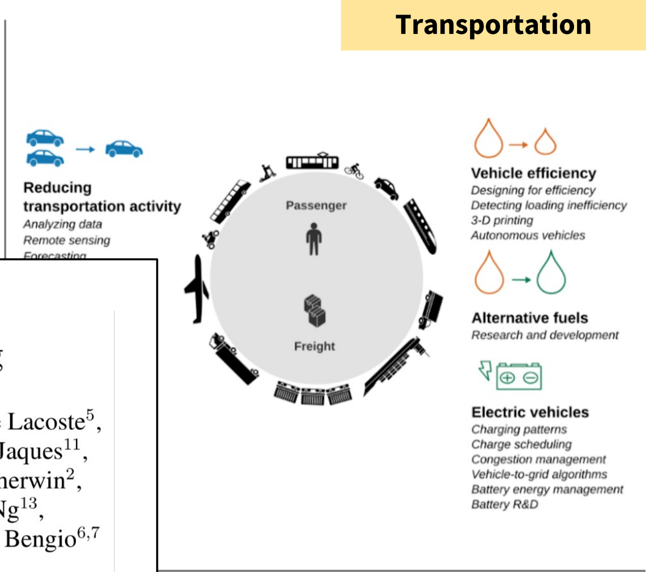

Tackling Climate Change with Machine Learning

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

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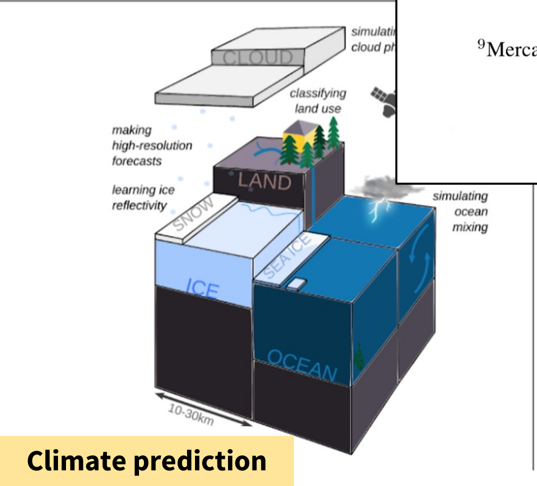

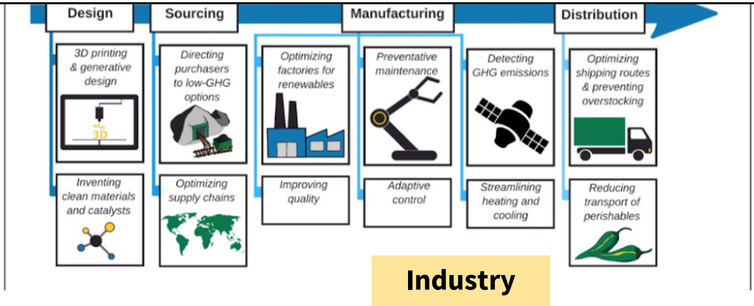

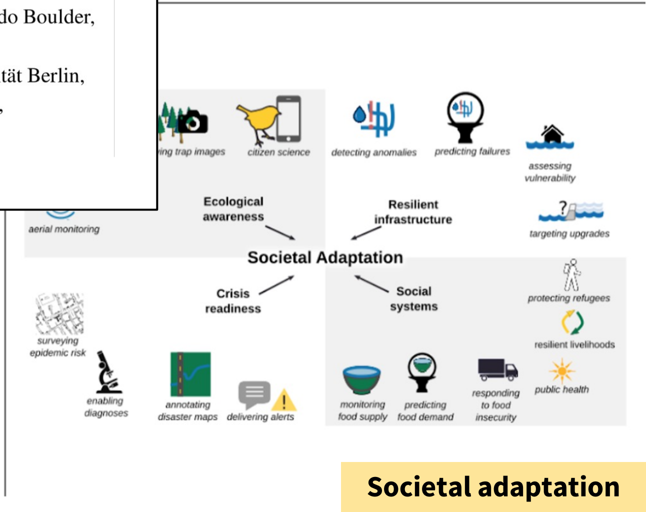

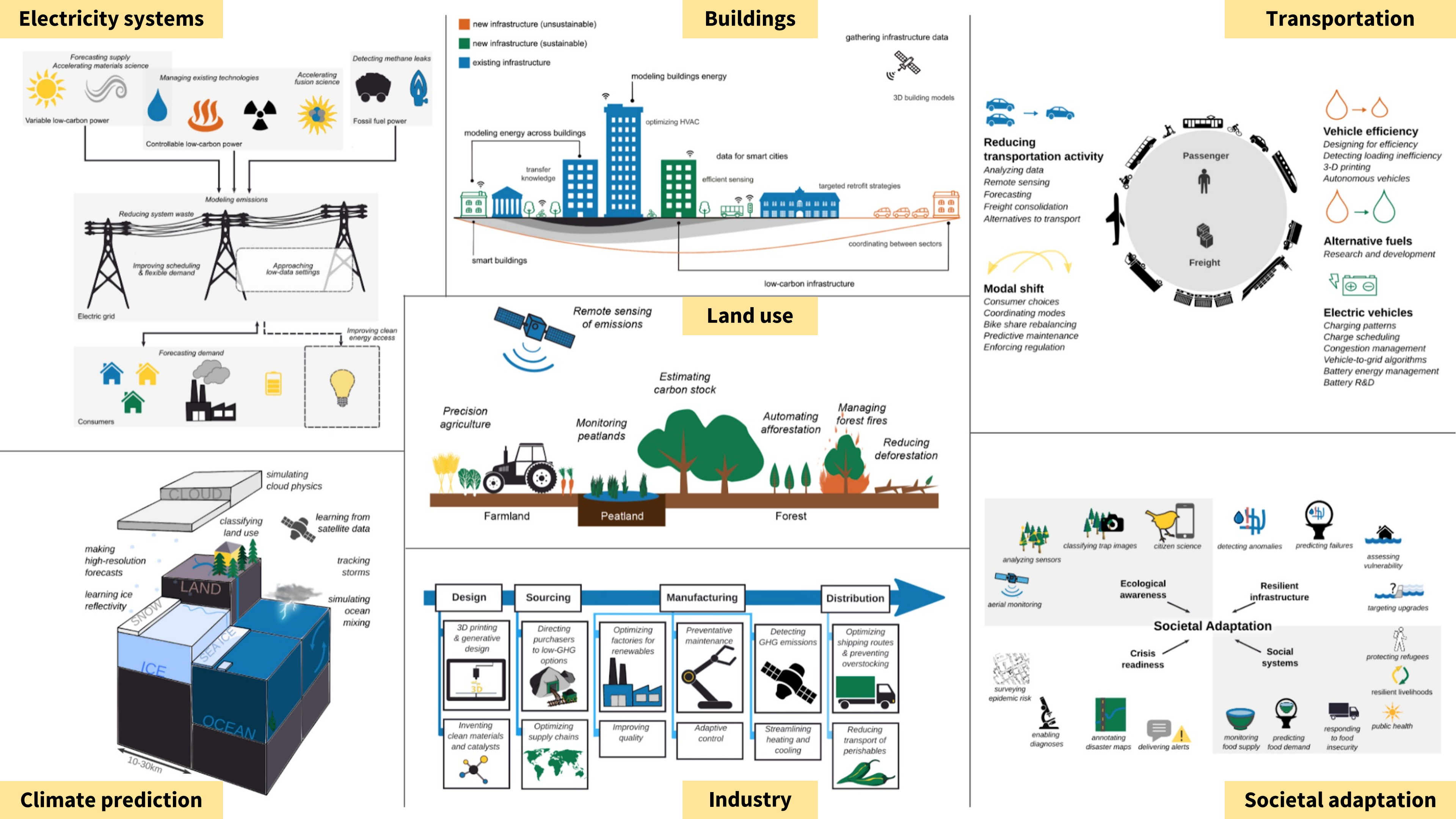
Electricity systems
Forecasting supply
Accelerating materials science
Variable low-carbon power
Managing existing technologies
Accelerating fusion science
Controllable low-carbon power
Detecting methane leaks
Fossil fuel power
Modeling emissions
Reducing system waste
Improving scheduling & flexible demand
Approaching low-data settings
Electric grid
Improving clean energy access
Forecasting demand
Consumers
Buildings
new infrastructure (unsustainable)
new infrastructure (sustainable)
existing infrastructure
gathering infrastructure data
3D building models
modeling buildings energy
optimizing HVAC
modeling energy across buildings
transfer knowledge
data for smart cities
efficient sensing
targeted retrofit strategies
coordinating between sectors
smart buildings
low-carbon infrastructure
Transportation
Reducing transportation activity
Analyzing data
Remote sensing
Forecasting
Freight consolidation
Alternatives to transport
Modal shift
Consumer choices
Coordinating modes
Bike share rebalancing
Predictive maintenance
Enforcing regulation
Passenger
Freight
Vehicle efficiency
Designing for efficiency
Detecting loading inefficiency
3-D printing
Autonomous vehicles
Alternative fuels
Research and development
Electric vehicles
Charging patterns
Charge scheduling
Congestion management
Vehicle-to-grid algorithms
Battery energy management
Battery R&D
Land use
Remote sensing of emissions
Estimating carbon stock
Precision agriculture
Monitoring peatlands
Automating afforestation
Managing forest fires
Reducing deforestation
Farmland
Peatland
Forest
Climate prediction
CLOUD
simulating cloud physics
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learning from satellite data
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tracking storms
LAND
learning ice reflectivity
simulating ocean mixing
SNOW
SEA ICE
ICE
OCEAN
10-30km
Industry
Design
Sourcing
Manufacturing
Distribution
3D printing & generative design
Directing purchasers to low-GHG options
Optimizing factories for renewables
Preventative maintenance
Detecting GHG emissions
Optimizing shipping routes & preventing overstocking
Inventing clean materials and catalysts
Optimizing supply chains
Improving quality
Adaptive control
Streamlining heating and cooling
Reducing transport of perishables
Societal adaptation
analyzing sensors
classifying trap images
citizen science
detecting anomalies
predicting failures
assessing vulnerability
aerial monitoring
Ecological awareness
Resilient infrastructure
targeting upgrades
Societal Adaptation
Crisis readiness
Social systems
protecting refugees
surveying epidemic risk
resilient livelihoods
enabling diagnoses
annotating disaster maps
delivering alerts
monitoring food supply
predicting food demand
responding to food insecurity
public health

Opportunities for AI in climate action

- Improving operational efficiency
  e.g. optimizing HVAC control or steel/cement manufacture
- Gathering information
  e.g. estimating carbon stock or parsing financial disclosures
- Forecasting
  e.g. nowcasting electricity supply or predicting demand
- Speeding up simulations
  e.g. emulating parts of climate models or grid planning models
- Accelerating scientific discovery
  e.g. suggesting materials for use in batteries and perovskites

See: *Tackling Climate Change with Machine Learning*, ACM Computing Surveys 2022.

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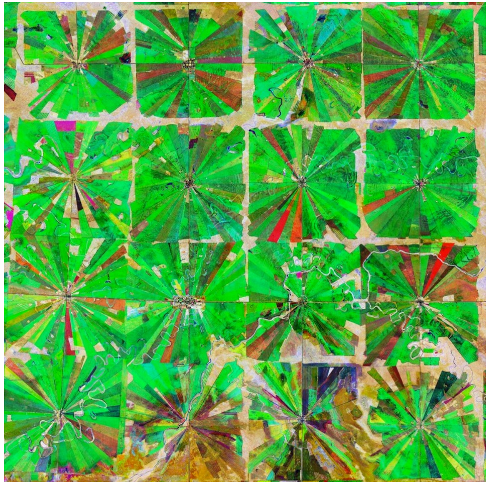

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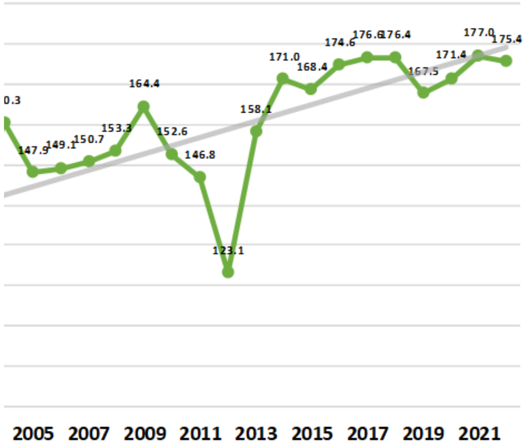

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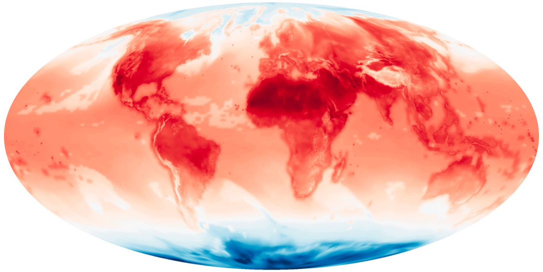

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Efficient operation of electrical grids

AC Optimal Power Flow (ACOPF): nonconvex optimization problem to determine power to produce at each generator in a power grid

Exact solutions take too long, so grid operators simplify the problem and waste power, especially w/ solar & wind

Naïve AI algorithms can approximately solve ACOPF fast, but violate power flow constraints, risking blackouts

We show how to enforce these constraints, solving ACOPF problems 10-100x faster than traditional methods without violating power flow

$$\begin{array}{ll}\underset{p_g\in\mathbb{R}^b,\ q_g\in\mathbb{R}^b,\ v\in\mathbb{C}^b}{\text{minimize}} & p_g^T A p_g + b^T p_g \\ \text{subject to} & p_g^{\min} \le p_g \le p_g^{\max} \\ & q_g^{\min} \le q_g \le q_g^{\max} \\ & v^{\min} \le |v| \le v^{\max} \\ & (p_g - p_d) + (q_g - q_d)i = \operatorname{diag}(v)\overline{W}\overline{v}.\end{array}$$

$$\begin{array}{ll}\min_y f_x(y) & \\ \text{s.t.} & g_x(y) \le 0 \\ & h_x(y) = 0\end{array}$$

P. Donti, D. Rolnick, Z. Kolter, *DC3: A learning method for optimization with hard constraints*, ICLR 2021.

Gathering information on biodiversity

Ecosystems are collapsing, but evaluating biodiversity requires specialized experts

AI can help scale up ecological monitoring

We're developing automated sensors to monitor insect populations, with a coalition of partner ecologists

Solar-powered device attracts & photographs insects, and AI algorithms identify them

Data then sent to experts for interpretation and proof-reading

Partners include: Aarhus University, Montreal Insectarium, eButterfly, UK Centre for Ecology & Hydrology, Naturalis, Université de Sherbrooke, Université Laval, Natural Resources Canada

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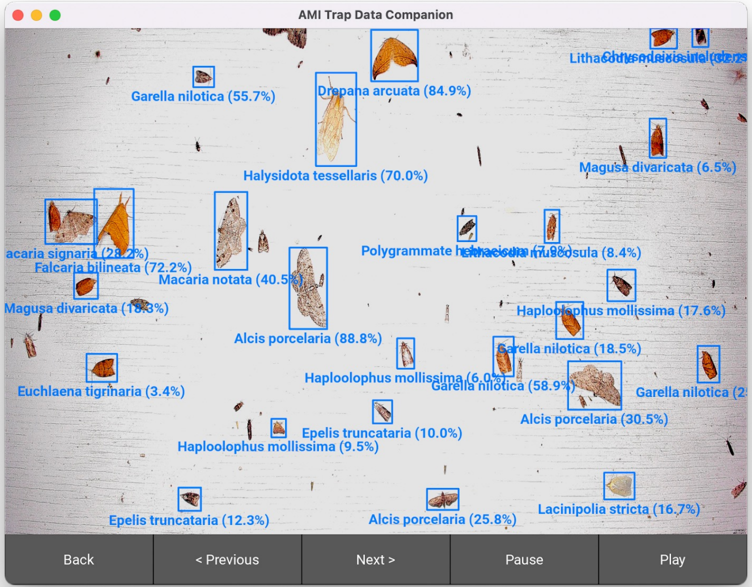

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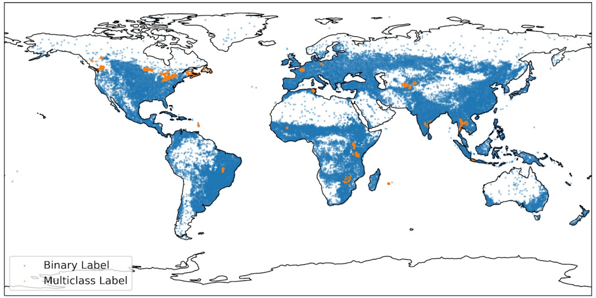
Forecasting crop yield

Forecasting crop yield is essential to averting food insecurity in a changing climate

AI can help predict yield from satellite imagery

But it needs labeled data – and data can be scarce and uneven across different locations

In work with NASA Harvest, we develop meta-learning algorithms for crop yield prediction that can quickly adapt with minimal new data, by leveraging metadata on location and crop type



Gabriel Tseng, Hannah Kerner, David Rolnick, *TIML: Task-Informed Meta-Learning for agriculture,* preprint arXiv 2202.02124.

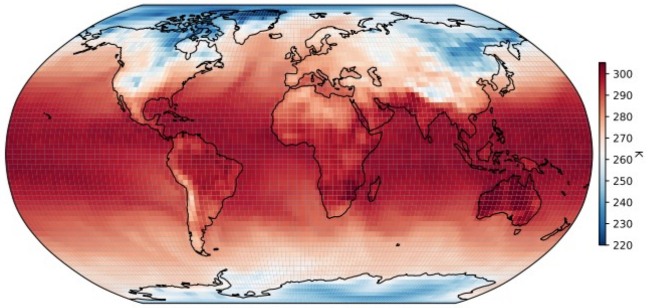
Speeding up climate simulations

Climate simulations are accurate but can be slow (e.g. months even on a supercomputer)

This makes it harder to get localized predictions that help in adapting to climate change

With Environment & Climate Change Canada, we use AI to quickly approximate radiative transfer computations, an especially slow part of standard climate models

Our algorithms incorporate known physical relations to improve accuracy



Salva Rühling Cachay*, Venkatesh Ramesh*, Jason N. S. Cole, Howard Barker, David Rolnick, *ClimART: A Benchmark Dataset for Emulating Atmospheric Radiative Transfer in Weather and Climate Models*, NeurIPS 2021, and forthcoming work.

Key considerations

AI is never a silver bullet and is only relevant sometimes

Partnership between stakeholders with complementary expertise is crucial

High-impact applications are not always flashy

Even when working with data, sometimes simple methods work

Technosolutionism can be counterproductive or contribute to greenwashing

Equity considerations

- Empowering diverse stakeholders
- Selecting and prioritizing problems
- Ensuring data is representative

AI applications relevant to climate change mitigation / adaptation

AI applications that increase greenhouse gas emissions

AI applications with uncertain or systemic impacts

Emissions impacts of AI computation and hardware

AI applications that increase greenhouse gas emissions

- AI used to accelerate fossil fuel exploration and extraction
  - AI and advanced analytics estimated to yield $400B+ additional profit for fossil fuel companies by 2025
  - Many leading technology companies have partnered on such uses
- Direct facilitation of other high-emissions activities, e.g. fast fashion
- AI is often used to optimize systems, but sometimes optimizing for cost ≠ optimizing for emissions (e.g. if labor costs outweigh energy costs)

Further reading: Greenpeace “Oil in the Cloud.”

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AI applications with systemic impacts

Many AI applications have systemic impacts on climate action which are poorly quantified but likely significant

Consumer behavior:

- Advertising recommender systems designed to boost consumption may be greatly increasing GHG emissions
- Autonomous vehicles – may reduce emissions in public transportation context but increase miles driven (and emissions) for personal transport. *Depends on goals as the technology is developed.*

Credit: Grendelkhan, Wikimedia Commons

L. Kaack, et al. *Aligning Artificial Intelligence with Climate Change Mitigation*, Nature Climate Change 2022.

AI applications with systemic impacts

Many AI applications have systemic impacts on climate action which are poorly quantified but likely significant

Rebound effects

- Efficiency gains in a sector may be partially counterbalanced by corresponding increases in use
- E.g. lower energy used in making some consumer products

Lock-in effects

- Applications facilitated by technology may become more entrenched (can be positive or negative)

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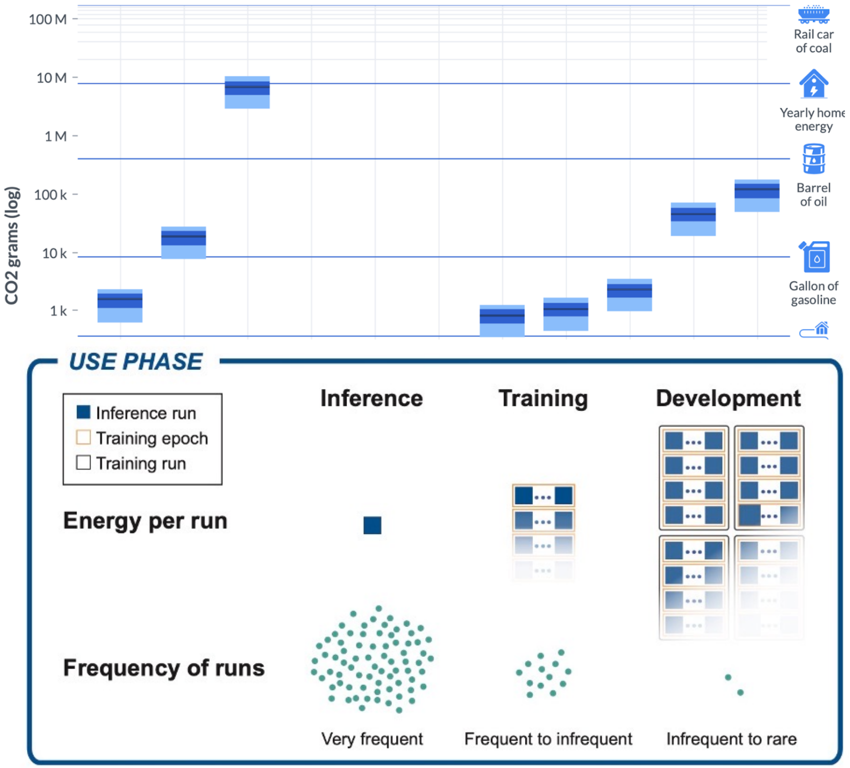
The ICT sector contributed 1 to 4 % of global GHG emissions in 2020, with two thirds from operational energy and one third from hardware

AI is some fraction of ICT; Google reports AI is 15% of server energy use

Highly variable between algorithms, the *biggest* AI algorithms are getting bigger (300,000x since 2012)

Machine learning algorithm lifecycle of development, training, inference



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Emissions impacts of AI computation and hardware

Impact assessment needed for computation-related emissions, including cloud compute

That said, these effects are likely significantly smaller than application-related negative impacts

Major tech players may have incentive to focus attention on efficient computation, rather than also re-evaluating what algorithms *do* (Scope 1 & 2 vs Scope 3 emissions)

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Failures in the AI innovation landscape

AI continues to rely on benchmarks like ImageNet-1k to evaluate models and pre-train for applied settings.

Such benchmarks are often derived from Internet data, chosen & labeled without relevant experts in the room.

Example: We worked with ecologists to analyze the 27% of ImageNet-1k that is wild animals.

- 12% of the images are wrong, 12% of categories are contradictory.
- Species heavily biased towards United States.

Exemplary of AI innovations developed without stakeholders relevant to societal impact.

Alexandra Sasha Luccioni and David Rolnick, *Bugs in the Data: How ImageNet Misrepresents Biodiversity*, preprint arXiv 2208.11695.

AI and climate change

- AI can either help or hinder climate action, depending on how it is used
- Overall impacts poorly understood and complex to measure, but may be significant and *can be shaped*
- Consideration of impacts and inclusion of relevant stakeholders must be part of AI innovation
- Aligning AI with climate action means more than adding “AI for Good” applications on top of business as usual – implicit choices matter

CLIMATE CHANGE AND AI

Recommendations for Government Action

Global Partnership on AI Report

In collaboration with Climate Change AI and the Centre for AI & Climate

GPAI Climate Change AI CENTRE FOR AI & CLIMATE

Selected policy recommendations

- Improve **data standards** & **data sharing** via task forces & platforms
- Ensure **impact-driven funding** for AI research & innovation
- Develop **cross-sectoral innovation centers** with private & public stakeholders to incubate projects & facilitate collaboration
- Build AI **capacity & literacy** in climate-relevant industries, government, & civil society, via upskilling & secondment programs
- Establish best practices for responsible & **participatory design**
- Consider potential **positive/negative climate impact** in shaping new technology development

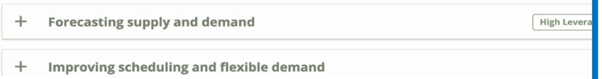
Climate Change AI

Catalyzing impactful work at the intersection of climate change & ML

Digital resources

Reports with opportunities for researchers, practitioners, and policymakers

New community-driven Wiki w/ datasets & additional resources



Conferences & events

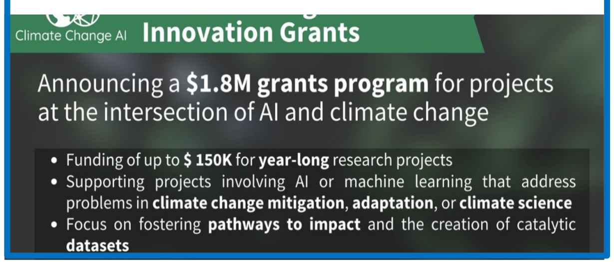
Workshop series

- Attend @ NeurIPS '22
- Mentorship programs
- www.climatechange.ai/papers

Summer school (multiple tracks)

Funding programs

Global research funding for impactful projects



Newsletter, blog, & community

- Calls for Submissions
- Funding
- Projects & Courses
- Readings
- Jobs

Webinars & happy hours

Webinar series (monthly)

Virtual happy hours (biweekly)

Learn more & join in:

www.climatechange.ai

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