Climate Change and AI: Opportunities, Challenges, and Considerations

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The World Bank/GFDRR & Climate Change AI

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Based on the ICML 2022 tutorial "Climate Change and ML: Opportunities, Challenges, and Considerations" by Priya Donti, David Rolnick, and Lynn Kaack

Climate change warrants rapid action

One of the most pressing challenges, with impacts felt globally

- Disproportionately affects the most disadvantaged populations

Need net-zero greenhouse gas emissions by 2050 (IPCC 2018)

- Requires rapid transformation across energy, transport, buildings, forestry, agriculture, etc.

The State of Climate Change

Earth has already **warmed over 1°C**, compared to pre-industrial period

Due to excess **greenhouse gas (GHG) emissions** from human activities

- E.g., carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)

Has induced **major changes** in climate

- Extreme weather events, heat waves, droughts, wildfires, etc.

Net zero emission by 2050 **limits global warming to ~1.5°C.**

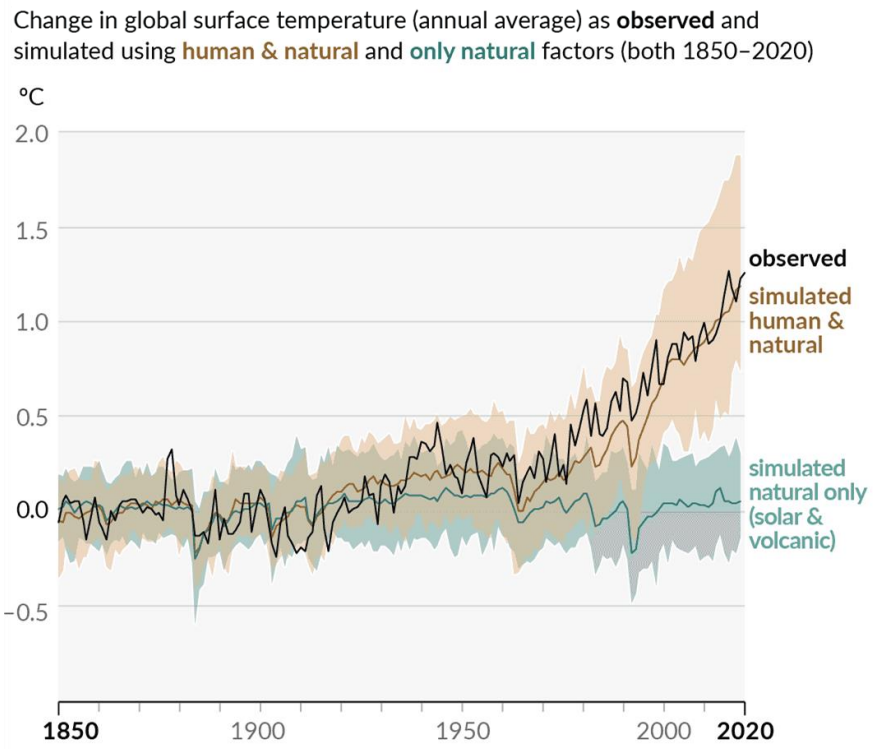

Figure source: IPCC AR6 WG1 Report (2021)

Approaches to addressing climate change

Axes of action

- **Climate science:** Understanding and predicting climate change
- **Mitigation:** Reducing or preventing greenhouse gas emissions
- **Adaptation:** Responding to the effects of a changing climate

Important frameworks

- **Climate justice:** An equity-centered approach to climate change
- **Co-benefits:** Explicitly considering linkages between climate action and other UN Sustainable Development Goals (SDGs)

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Climate change mitigation

Mitigation: Reducing or preventing GHG emissions

Sectors

Energy supply
Transportation
Buildings
Industry

Agriculture
Forestry
Other land use

CO_2 removal

Energy-related emissions

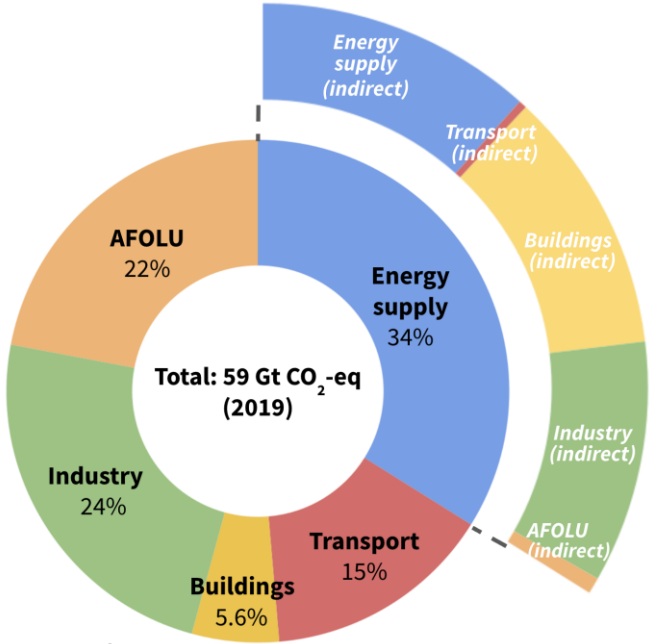
Reducing consumption, improve efficiency, switch to clean energy

Land use (AFOLU) emissions

Reduce fertilizer use, livestock, improve land use management

"Negative emissions"

Carbon capture & storage, enhance natural sinks (afforestation, reforestation, restoration)



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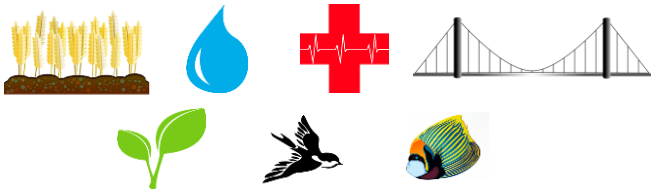
Climate change adaptation

Adaptation: Responding to the effects of a changing climate

1. **Measuring and predicting risk**
   - **Hazard** - likelihood of a destructive event
   - **Exposure** - assets exposed to the hazard
   - **Vulnerability -** susceptibility to damage
   - **Risk** = Hazard x Exposure x Vulnerability

2. **Strengthening adaptive capacity**
   - **Robustness**: Withstanding a range of outcomes with no/minimal impact
   - **Resilience**: Recovering quickly after impact

Human & ecological systems



Connections with UN SDGs

Figure source (bottom): United Nations

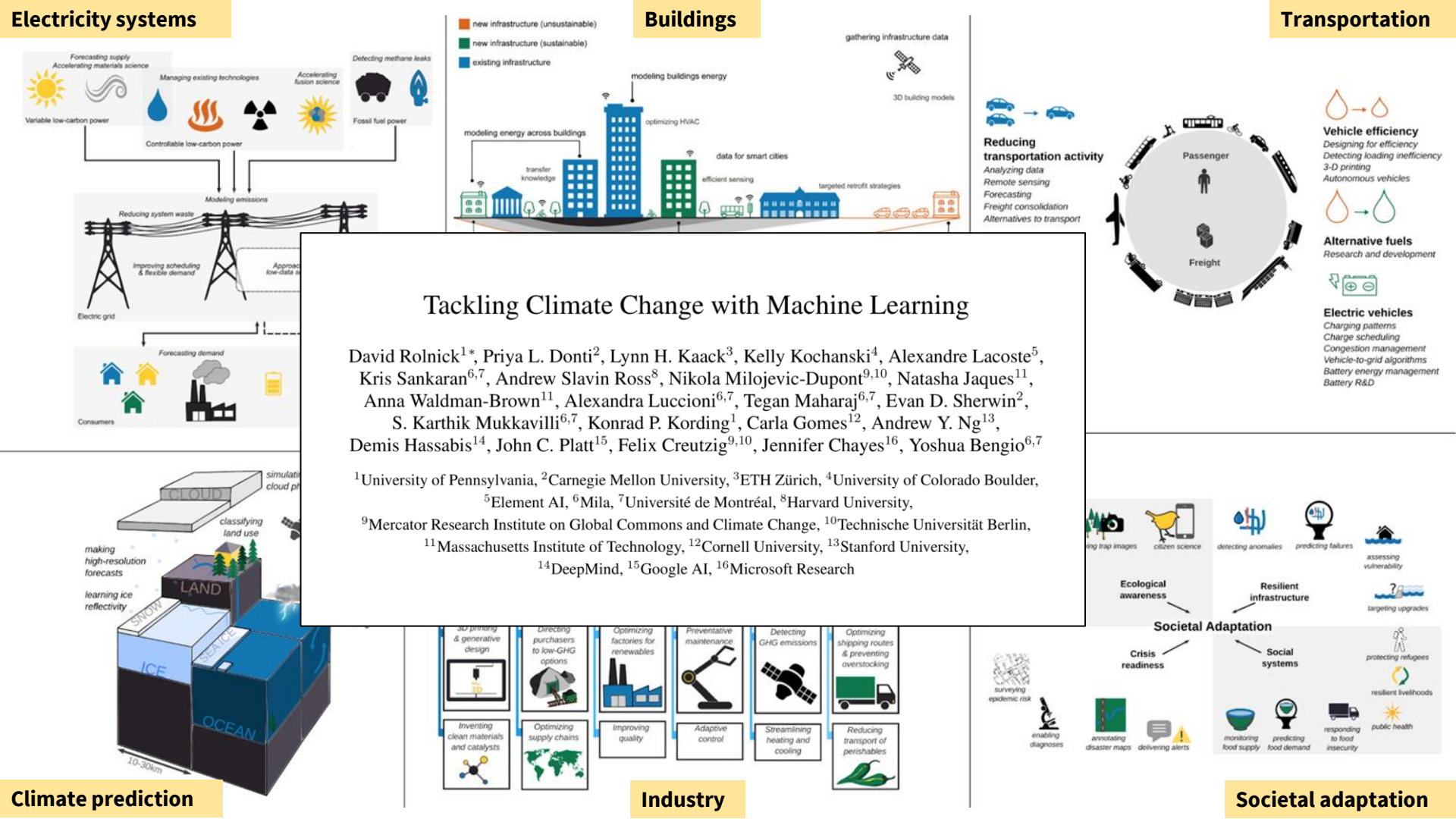
Climate Change & Digital Transformation

- Climate Change and digital transformation are the two most powerful trends of this century.
- The rise of AI shows promise in supporting climate action, but may also carry risks itself and needs to be developed responsibly.

Artificial intelligence (AI): Algorithms that make predictions or recommendations based on a set of objectives

↓

Machine learning (ML): Techniques that automatically extract patterns from large amounts of data, which can then be used to make predictions on new data



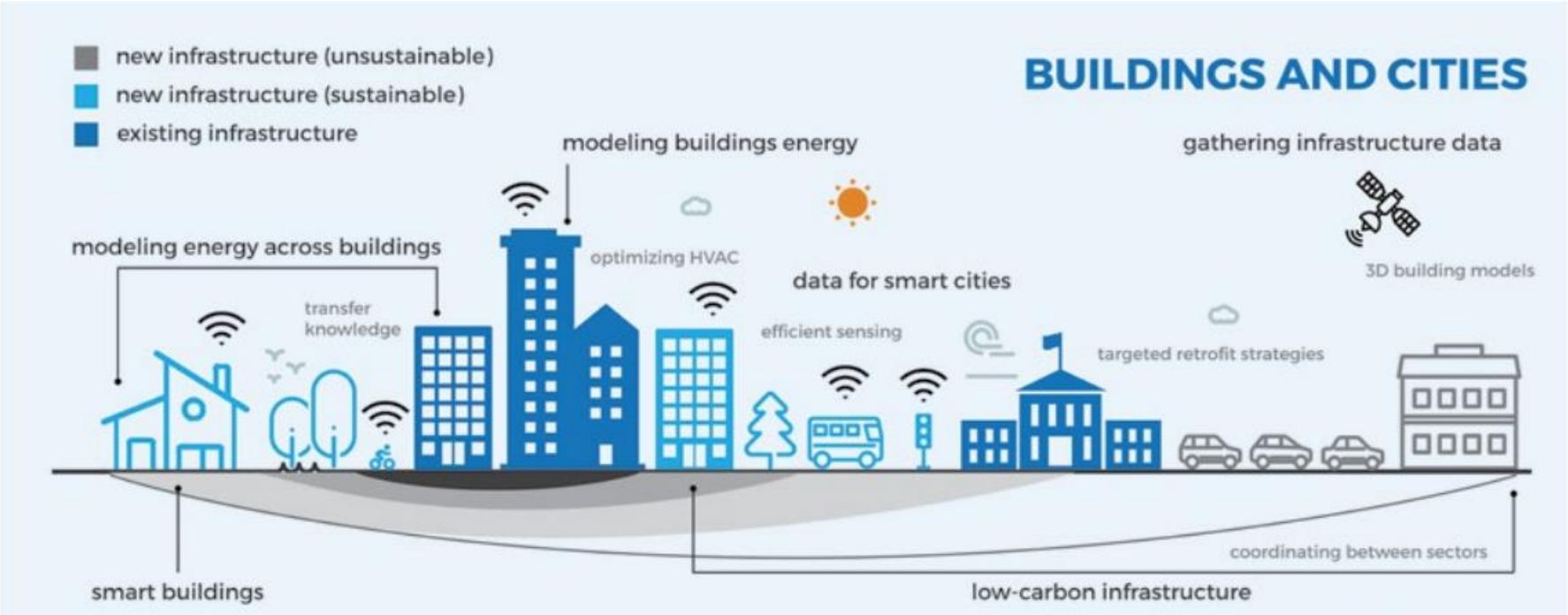
Tackling Climate Change with Machine Learning

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]

[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]Harvard University, [9]Mercator Research Institute on Global Commons and Climate Change, [10]Technische Universität Berlin, [11]Massachusetts Institute of Technology, [12]Cornell University, [13]Stanford University, [14]DeepMind, [15]Google AI, [16]Microsoft Research

Buildings and Cities

AI can help conserve building energy by enabling **low-carbon urban planning**, **energy use modeling**, and **building function optimization** (e.g. heating, lighting).

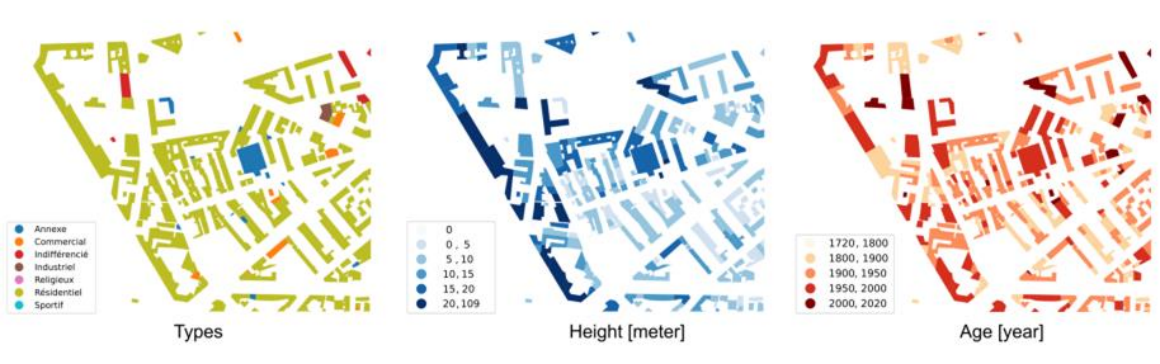


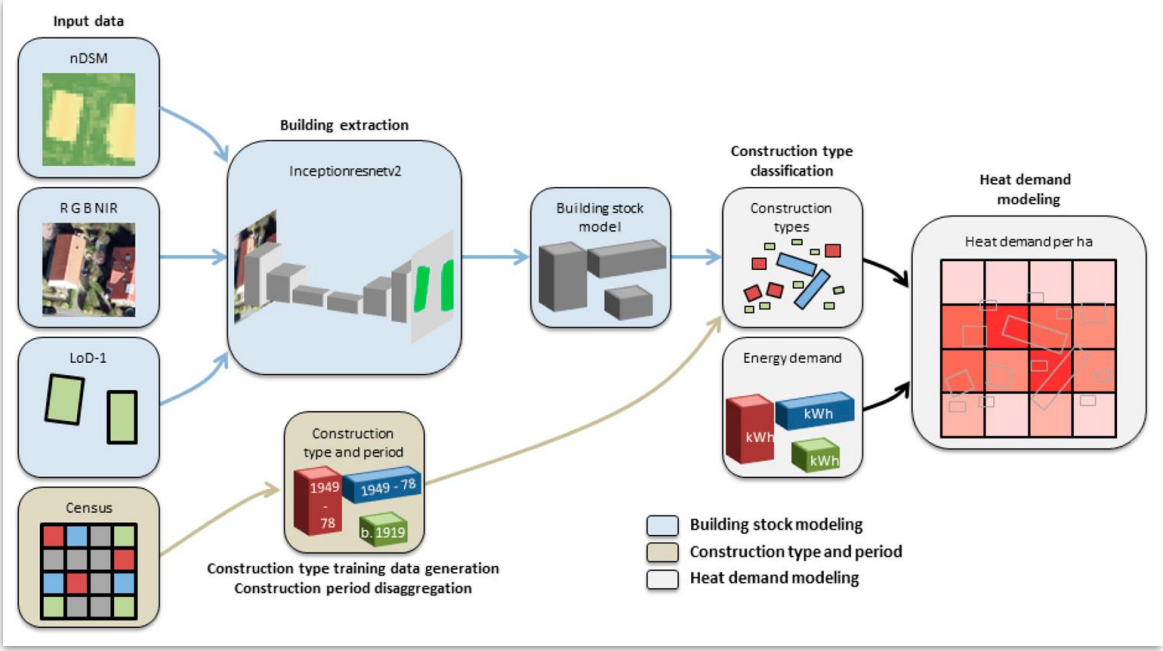
Source: Clutton-Brock, Peter, et al. *Climate change and AI. recommendations for government action*. GPAI, Climate Change AI, Centre for AI & Climate, 2021.

Case Study

AI for Energy Use Modeling

Researchers at TUM, TU Berlin, and MCC are using ML to **predict building use, height, and year of construction** to estimate energy demand for heating & cooling buildings.





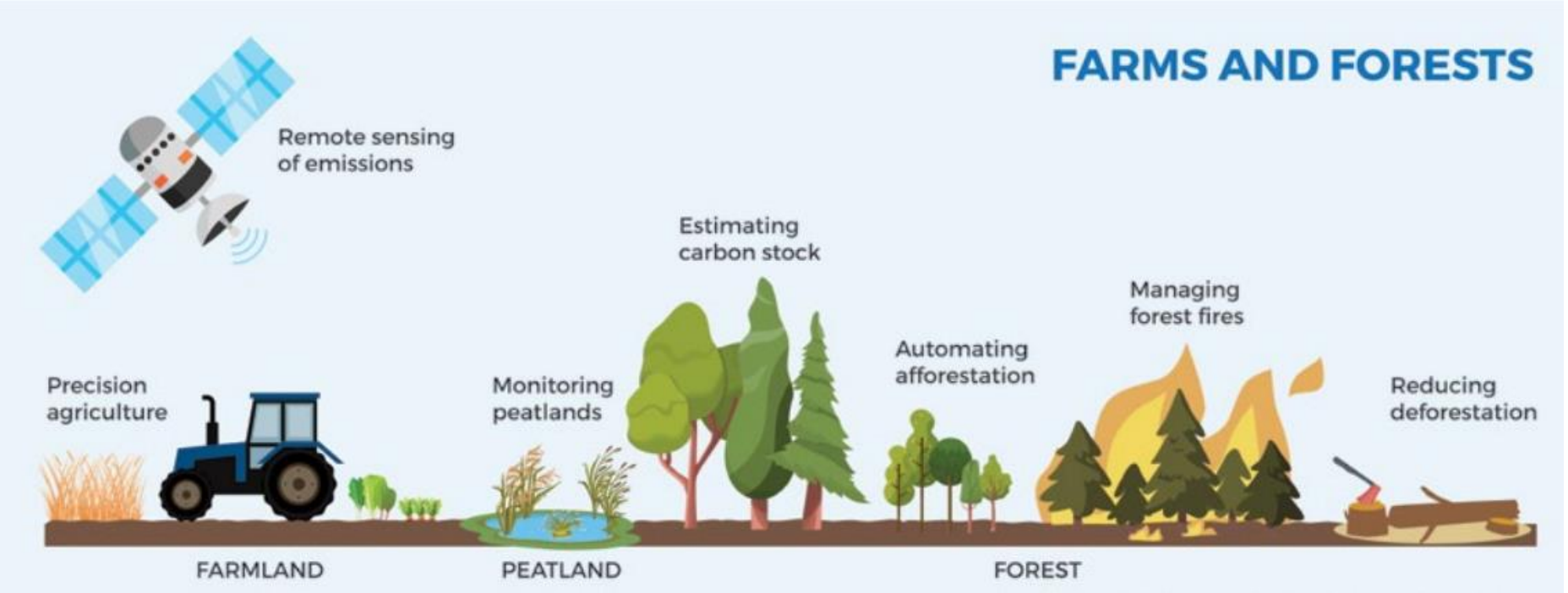
Sources: Milojevic-Dupont, Nikola, et al. "EUBUCCO v0. 1: European building stock characteristics in a common and open database for 200+ million individual buildings." *Scientific Data* 10.1 (2023): 147.

Wurm, Michael, et al. "Deep learning-based generation of building stock data from remote sensing for urban heat demand modeling." *ISPRS International Journal of Geo-Information* 10.1 (2021): 23.

*Mercator Research Institute on Global Commons and Climate Change (MCC)

Farms and Forests

AI can facilitate **nature-based solutions**, **precision agriculture**, estimate **carbon stock**, detect **illegal deforestation**, and **accelerate afforestation**.



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Case Study

AI for Precision Agriculture

Researchers at UMD & NASA Harvest are using ML for **crop type classification & crop yield estimation** using AI and satellite images.

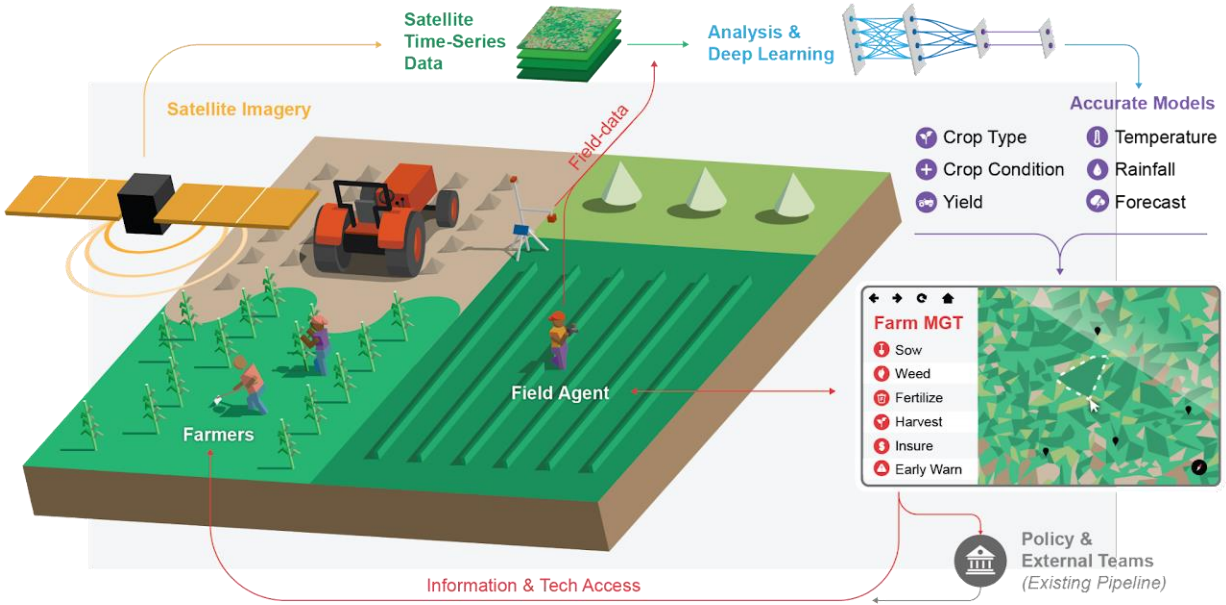
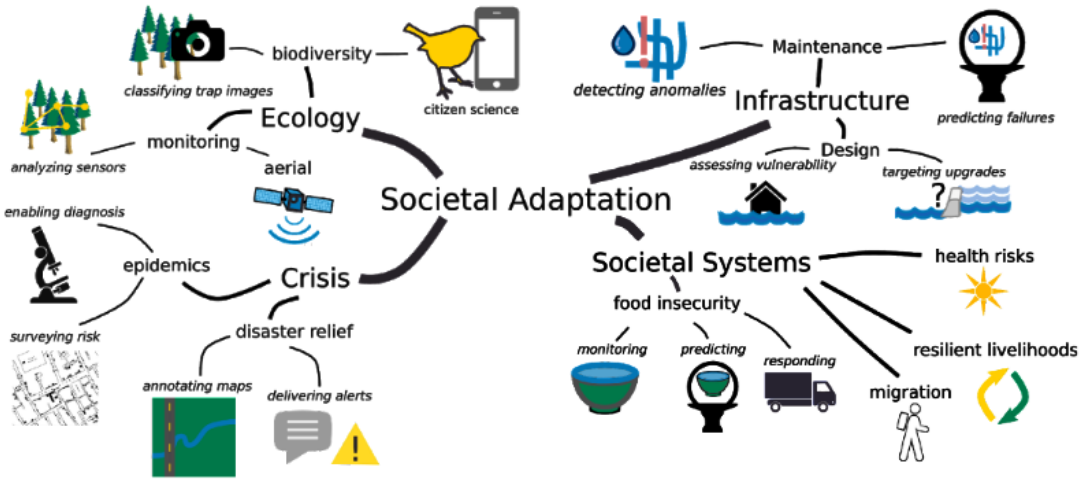


Figure Source: https://www.catherinenakalembe.com/research/projects

Societal Adaptation

Example applications:

- Biodiversity monitoring and ecological conservation
- Improve public health models for climate-influenced diseases
- Disaster reduction: Identify vulnerable/at-risk population & infrastructure
- Disaster response: Detect damaged structures



Case Study

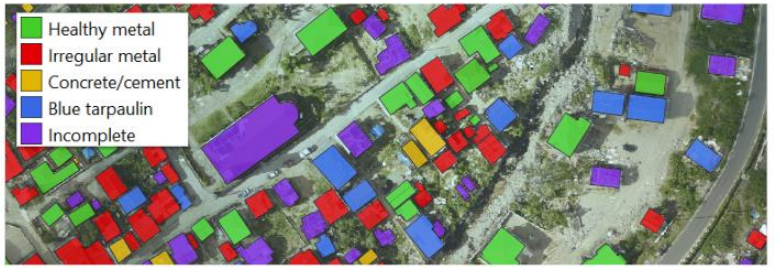
AI for Disaster Reduction and Recovery

The World Bank is using AI and drone images to scalably **identify high-risk structures** and **rapidly assess building damage** after disaster events in the Caribbean.

(a) Pre-disaster drone image (2017)

(b) Post-disaster orthophoto (2018-2019)

(c) Pre-disaster roof material classification map

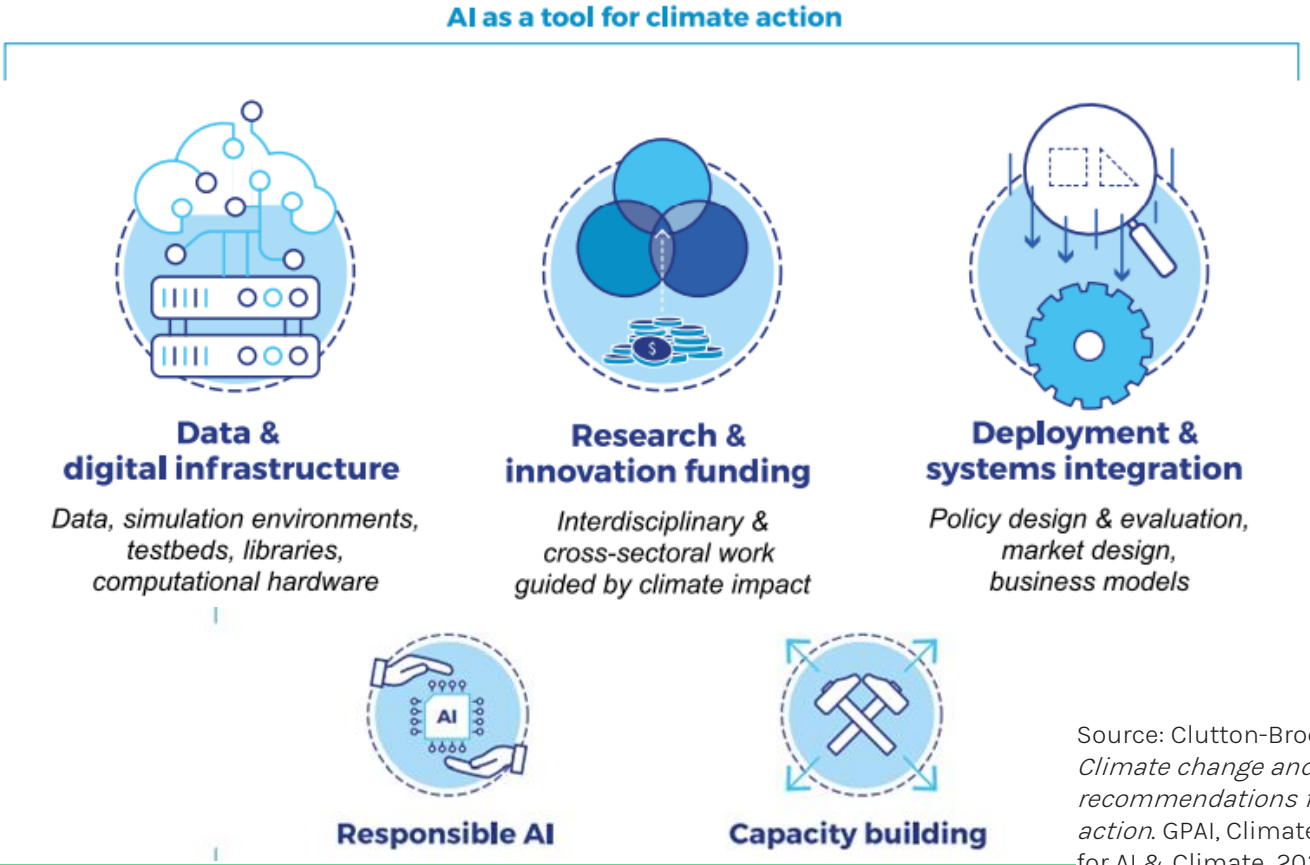


(d) Post-disaster roof material classification map

Source: Tingzon, Isabelle, Nuala Margaret Cowan, Pierre Chrzanowksi. “Fusing VHR Post-disaster Aerial Imagery and LiDAR Data for Roof Classification in the Caribbean.” Artificial Intelligence for Humanitarian Assistance and Disaster Response (AI+HADR) Workshop at ICCV 2023

Areas of action in Government

Supporting responsible AI for climate action



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AI as a tool for climate action

Data and Digital Infrastructure

Challenges

- **Data Scarcity**. Data required for AI applications (e.g. census surveys, cadastral maps) is often limited, incomplete, inaccessible, or completely non-existent.
- **Unequal data availability**. Data collection is often concentrated in the Global North, potentially leading to biased models/systems.
- **Privacy, security, & reputational risks**. Incentives for organizations to share data are often outweighed by the costs and risks of doing so.

AI as a tool for climate action

Data and Digital Infrastructure

Recommendations

- **Fundamental data governance**: Invest in the digital infrastructure and processes needed for the consistent collection, management, and processing of massive amounts of data.
- **Eliminate data silos** across government agencies and support the development of standards and protocols for data sharing.
- **Create initiatives to increase data sharing and access.** e.g. data portals for easy access to climate-relevant datasets.

AI as a tool for climate action

Research and Innovation Funding

- **Prioritize AI-for-climate research innovation and funding**. Focus on projects that are impact-driven, rather than technology-driven.
- Innovation funding for AI-for-climate solutions should encourage **open IP, open data, and open model development** so as to accelerate wider use of the technology.

AI as a tool for climate action

Deployment and Systems Integration

- **Many solutions get stuck in the pilot phases** and face difficulties scaling due to lack of financial incentives, slow adoption, etc.
  - Policy and market play an important role in supporting/blocking AI-for-climate deployment
- Need innovation pathways that ensure **routes for innovators to deliver and scale revenue** from their innovations
- **Include digitalization/AI experts into governmental climate policy teams and advisor groups** to ensure that AI considerations are incorporated into policies designed to support net zero transition

Capacity Building

Challenges

- **Biases in data and models**, e.g. geographic disparities in data collection, systems optimized for particular regions
- **Need for localized solutions** → local context and perspectives:
  - Who will be using the model, and how will the model be used?
  - What decisions will be made based on the model outcomes?
  - How will these decisions impact people/systems on the ground?
- **Disconnect between AI experts and climate-relevant sectors.** Need an interdisciplinary approach that draws insights from domain experts, policymakers, and affected communities.

Capacity Building

Recommendations

- **Strengthen local capacity.** Implement AI literacy programs for policymakers, industry leaders, and civil society.
  - Understand requirements, capabilities, and limitations of AI solutions
- Support **interdisciplinary higher education & research programs**, e.g. MS/PhD Programs in AI/Data Science at UPD, AIM, etc.
  - Bridge AI and climate-relevant sectors to help build experts who can translate between fields.
- Incorporate curricular elements on data and on climate into **primary, secondary, and higher education**.

Responsible AI in the context of climate change

Avoid techno-solutionism. AI is not a silver bullet solution and is not applicable everywhere; only use AI when necessary and truly impactful.

- What problem needs to be solved?
- What does a solution look like ***without AI/ML?***
- Which parts of the process can AI/ML optimize?

AI is a means, not an end.

- AI solutions should be informed by problems and societal contexts
- AI is only **a component of the solution** and not a solution in and of itself.

AI can have both positive and negative impacts on the environment.

- e.g. energy use from compute-intensive resources → negative impacts
- Quantify negative & positive impacts of AI development, e.g. Code Carbon

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

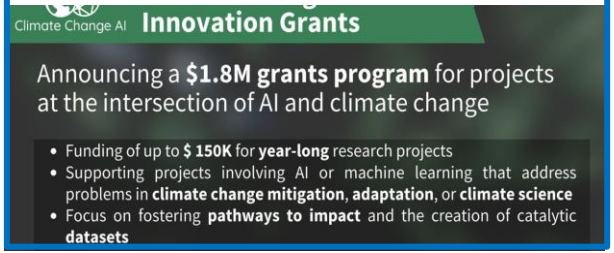
Workshop series

- Attend @ ICLR '23
- Mentorship programs
- www.climatechange.ai/papers

Summer school

Funding programs

Global research funding for impactful projects



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