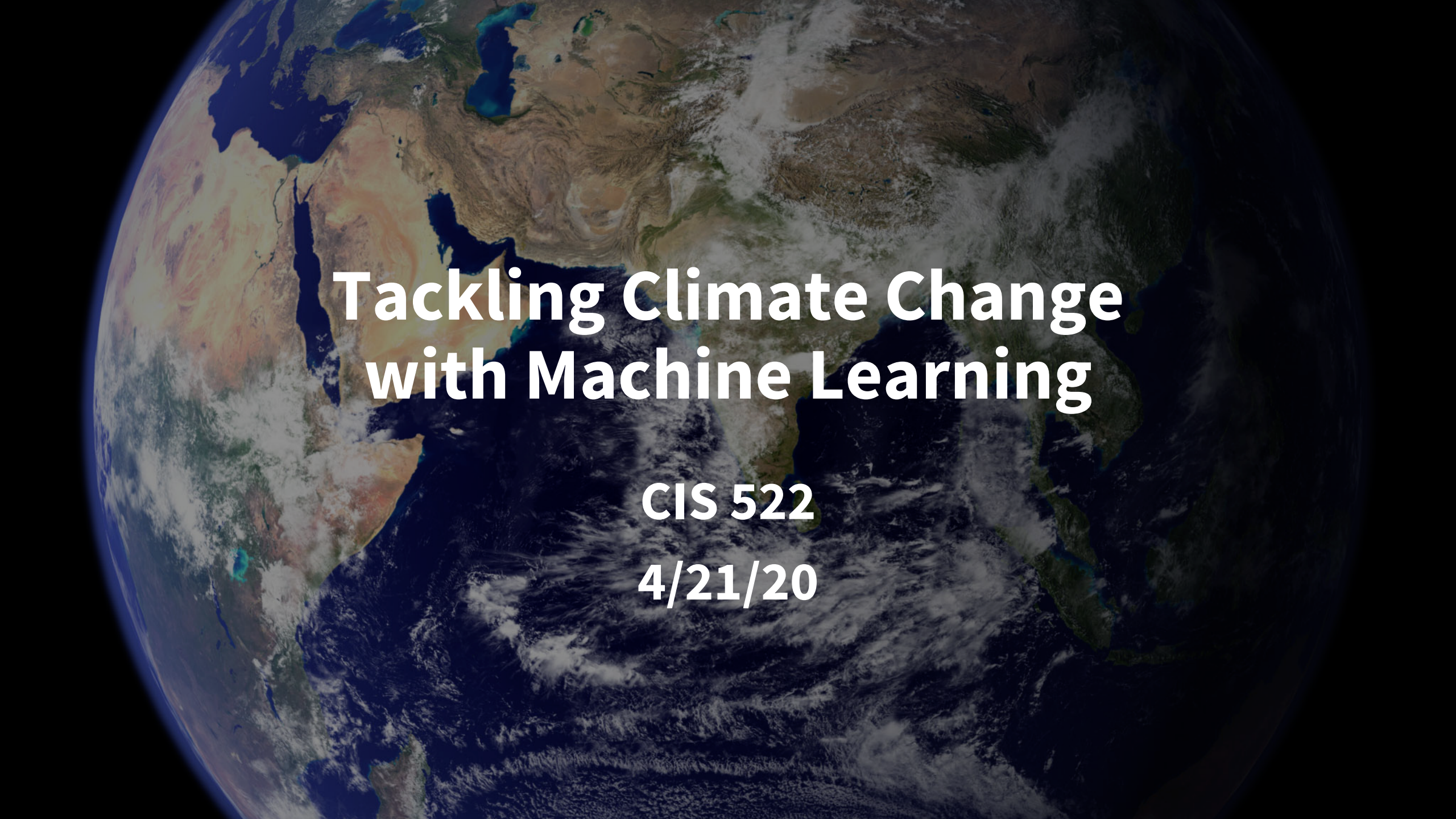


Tackling Climate Change with Machine Learning

CIS 522

4/21/20


Getty Images

Climate change

“Human influence on the climate system is **clear and growing**”
~ UN Intergovernmental Panel on Climate Change (IPCC)

Increasingly severe impacts

- Storms, droughts, fires, flooding, extreme heat, etc.
- Some places hit harder than others

Need net-zero greenhouse gas emissions within 30 years (IPCC)

- Emissions are **still increasing** each year

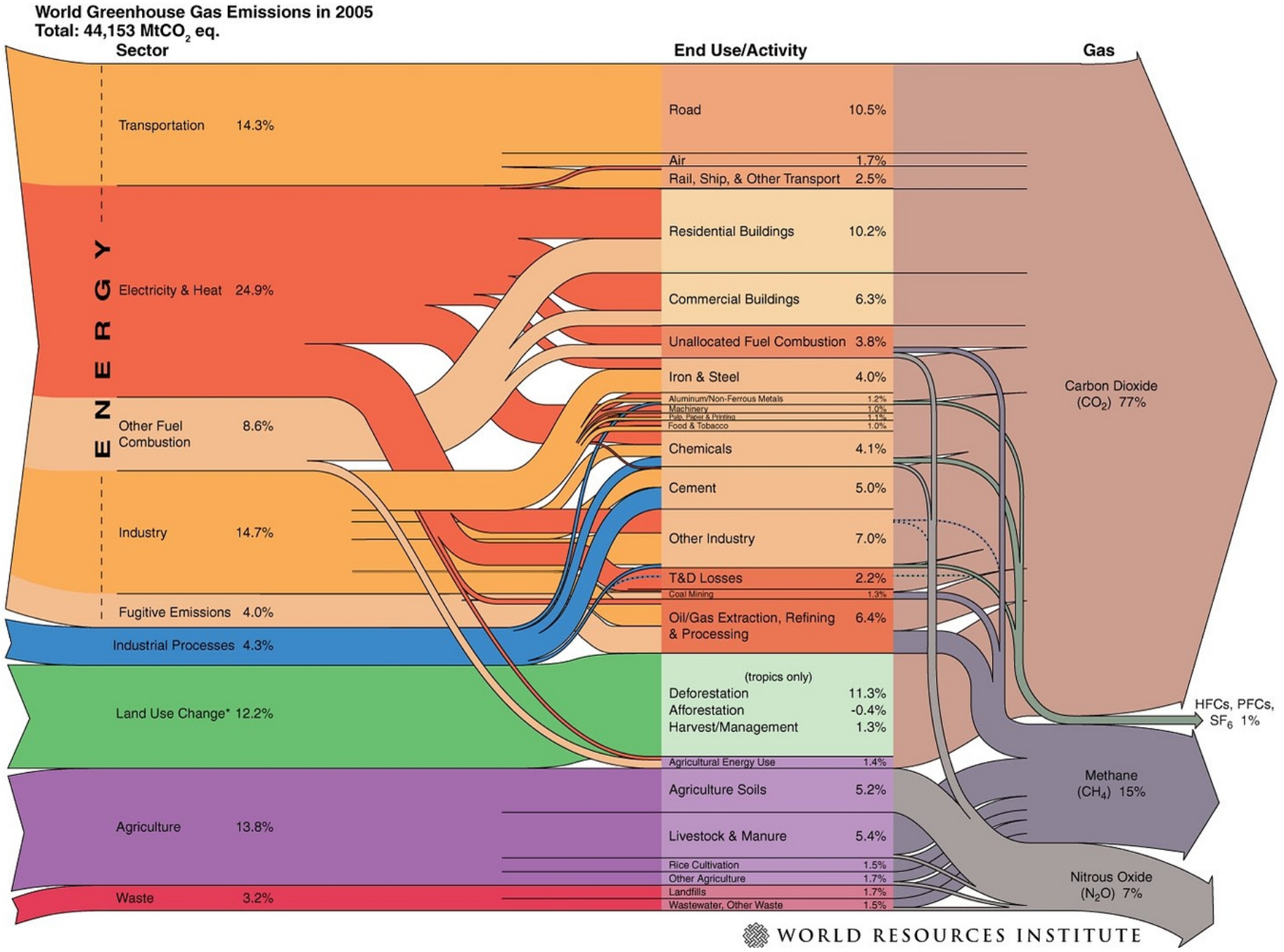
Climate feedbacks - e.g. reduced albedo, permafrost melt

What it means to tackle climate change

Climate change is not an on/off switch

Mitigation: Reducing greenhouse gas emissions

Adaptation: Resilience to consequences of climate change



Source: https://www.wri.org/resources/charts-graphs/world-greenhouse-gas-emissions-2005

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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Many ways to have an impact

	Causal inference	Computer vision	Interpretable ML	NLP	RL & Control	Time-series analysis	Transfer learning	Uncertainty quantification	Unsupervised learning
Mitigation									
1 Electricity systems									
Enabling low-carbon electricity		•	•		•	•		•	•
Reducing current-system impacts		•				•	•	•	•
Enabling global impact		•							•
2 Transportation									
Reducing transport activity	•	•	•		•	•	•	•	•
Improving vehicle efficiency		•	•		•	•		•	
Alternative fuels and electrification			•		•	•		•	
Shifting transportation modes	•	•	•		•	•	•	•	•
3 Buildings and cities									
Optimizing buildings	•				•	•	•		•
Urban planning		•				•	•		•
The future of cities				•		•	•	•	•
4 Industry									
Supply chains		•			•				
Materials and construction	•				•		•		
Production and energy	•	•	•		•	•	•		•
5 Farms and forests									
Remote sensing of emissions		•							
Precision agriculture					•				
Protecting peatlands		•							
Managing forests		•					•		
6 Carbon dioxide removal						•	•	•	

	Causal inference	Computer vision	Interpretable ML	NLP	RL & Control	Time-series analysis	Transfer learning	Uncertainty quantification	Unsupervised learning
Adaptation									
7 Climate prediction									
Uniting data, ML and climate science	•	•	•			•		•	
Forecasting extreme events		•	•			•		•	
8 Societal impacts									
Ecology		•					•		
Infrastructure					•	•		•	
Social systems	•		•			•			
Crisis		•		•					
9 Solar geoengineering									
Understanding and improving aerosols						•		•	
Control systems engineering					•	•		•	
Modeling impacts									
Tools for Action									
10 Tools for individuals									
Personal and household impacts	•	•	•	•	•	•			
Modeling consumer behavior									•
11 Tools for society			•	•		•	•	•	•
12 Education				•	•				
13 Finance				•		•		•	

ML is one piece of the puzzle

ML is a powerful tool, **not a silver bullet**

- Many problems don't need ML, or don't need fancy ML
- ML can be used in counterproductive ways too!

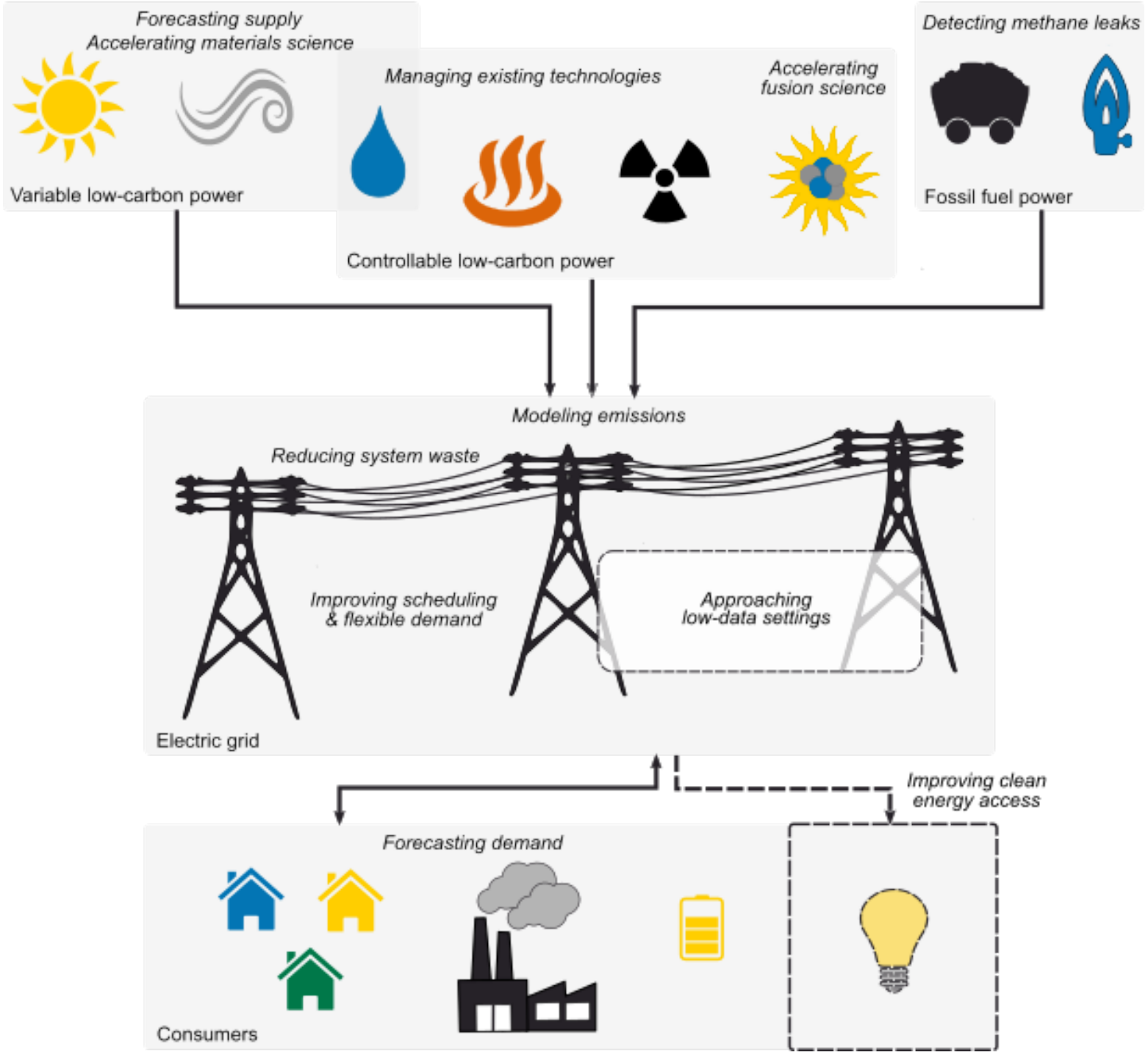
Assessing impact is hard

- Jevons paradox
- Long-term vs short-term effects

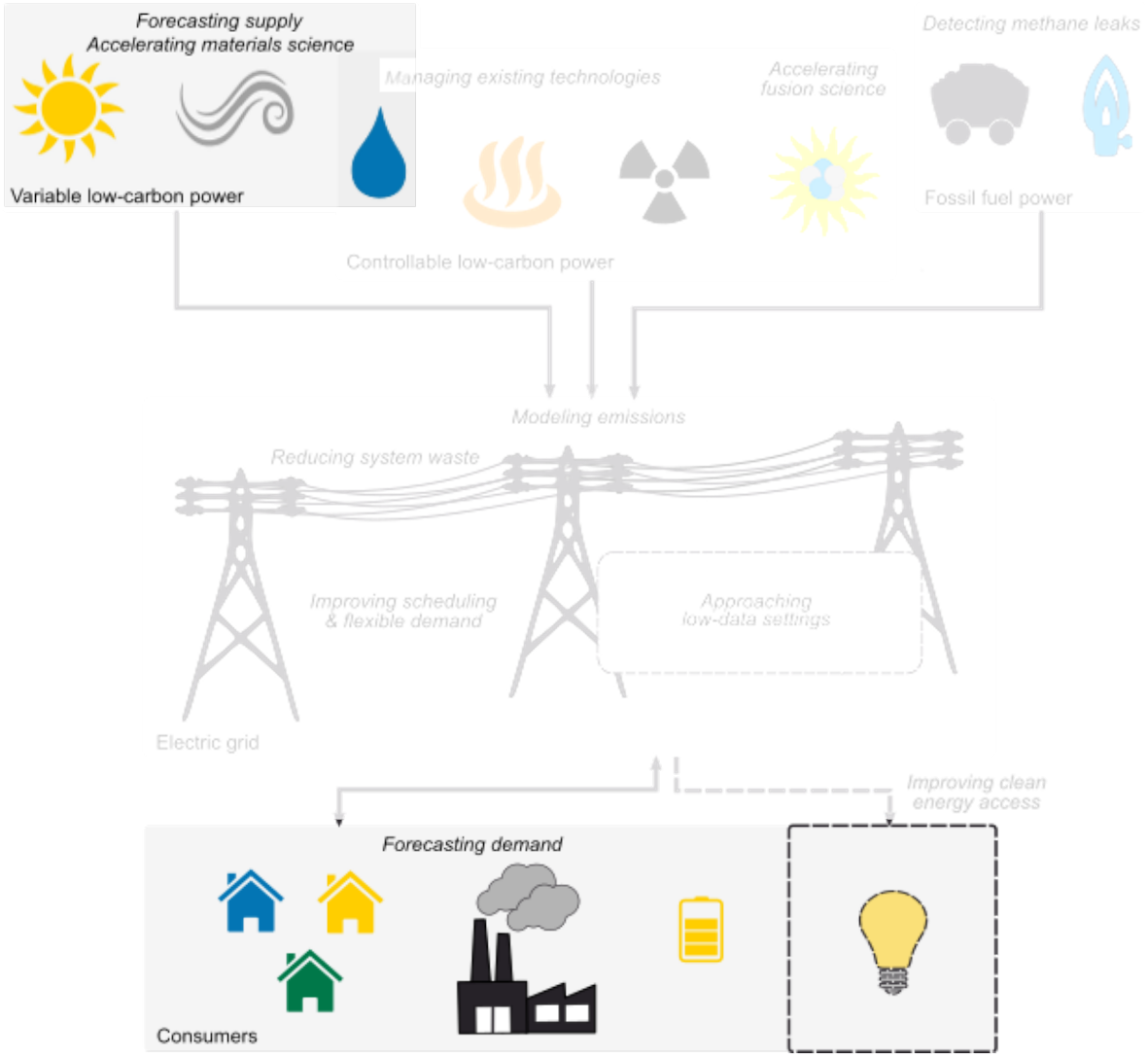
Takeaway: **work with domain experts outside ML**

Example opportunities

Electricity systems



Electricity Systems >> Forecasting supply & demand



Need: Scheduling and planning

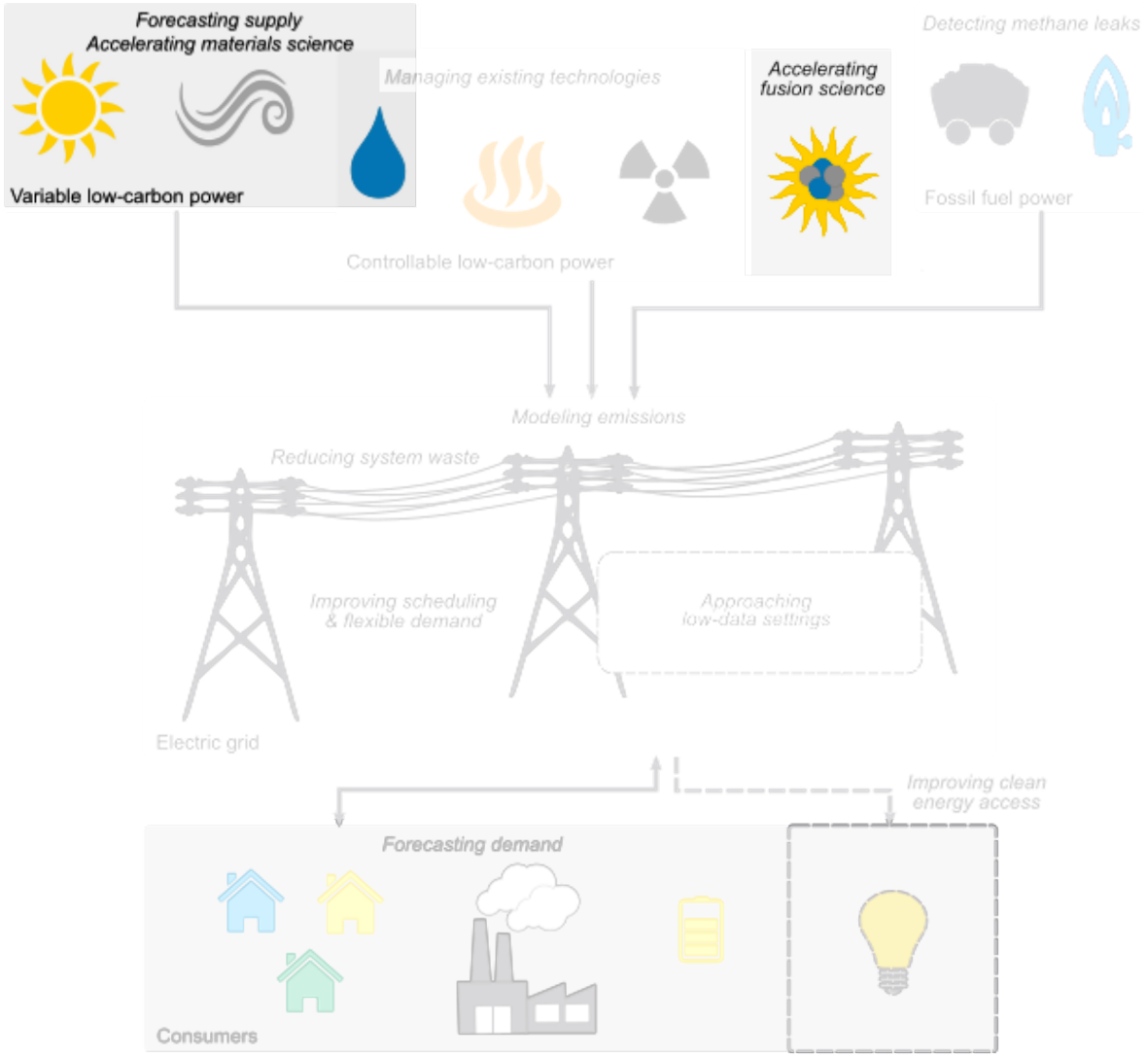
ML: Short- and long-term forecasts

- Historical data, physical model outputs, image/video data

Recommendations for ML:

- Incorporate system physics & goals
- Characterize uncertainty
- Interpretable forecasts

Electricity Systems >> Accelerating experimentation



Need: New clean technologies

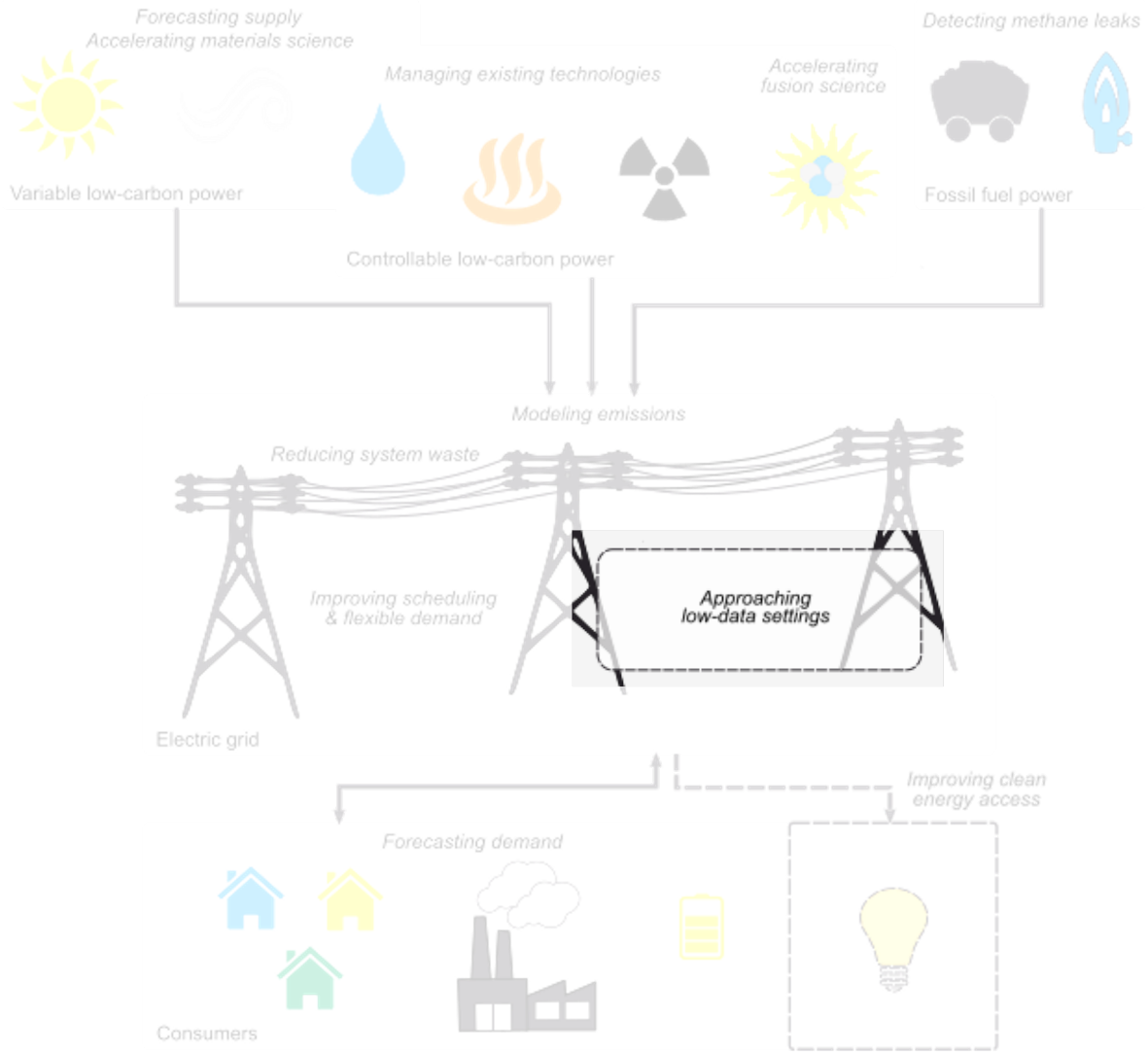
ML: Characterize proposed materials (solar fuels, batteries, etc.)

- Combine heuristics with data, physics, and reasoning

ML: Aid nuclear fusion development

- Parameter exploration
- Control and disruption detection

Electricity Systems >> Approaching low-data settings



Need: Global mitigation strategies

ML: Obtain insights from non-traditional data streams (satellite imagery, cellular networks)

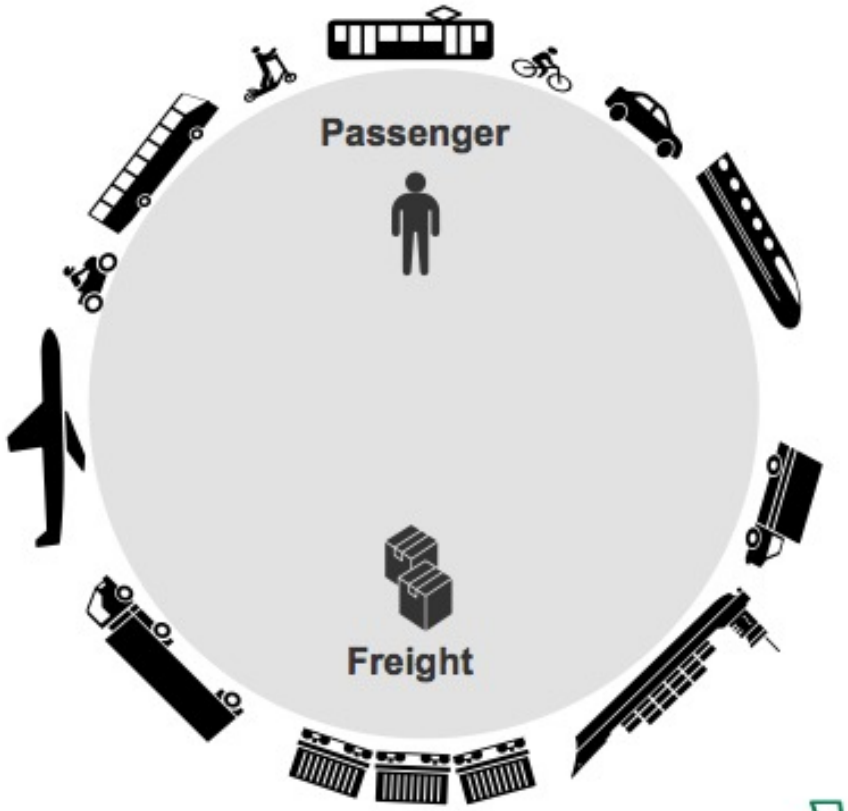
Recommendations for ML:

- Transfer learning
- Data-efficient ML (e.g. gray-box models)

Transportation

ML and reducing transportation activity
Analysing transport data
Remote sensing transport data
Forecasting

ML and modal shift
Modeling consumer choices
Coordinating modes
Bike share rebalancing
Predictive maintenance
Enforcing regulation



ML and vehicle efficiency
Designing for efficiency (aerodynamics, engine, etc.)
Detecting loading inefficiency
3-D printing
Autnomous vehicle technologies

ML and alternative fuels
Research and development

ML and electric vehicles
Analyzing and predicting charging
Charge scheduling
Congestion management
Vehicle-to-grid algorithms
Battery energy management
Battery research and development

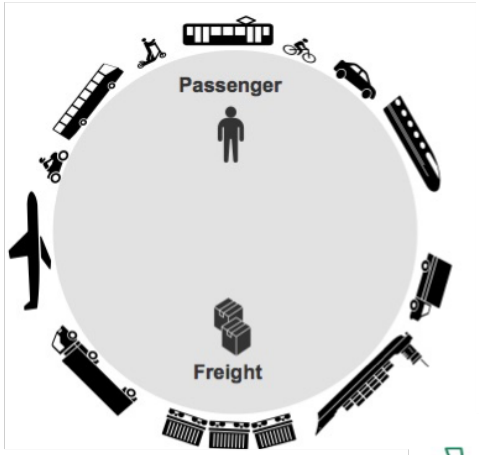
Transportation >> Freight routing and consolidation

Need: Reduce freight emissions

ML: Bundle and optimize shipments

- Predict arrival times or disruptions
- Cluster suppliers
- Predict demand
- Improve routing and auctions

Transportation >> Electric vehicles



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Battery energy management
Battery research and development

Need: Clean transport

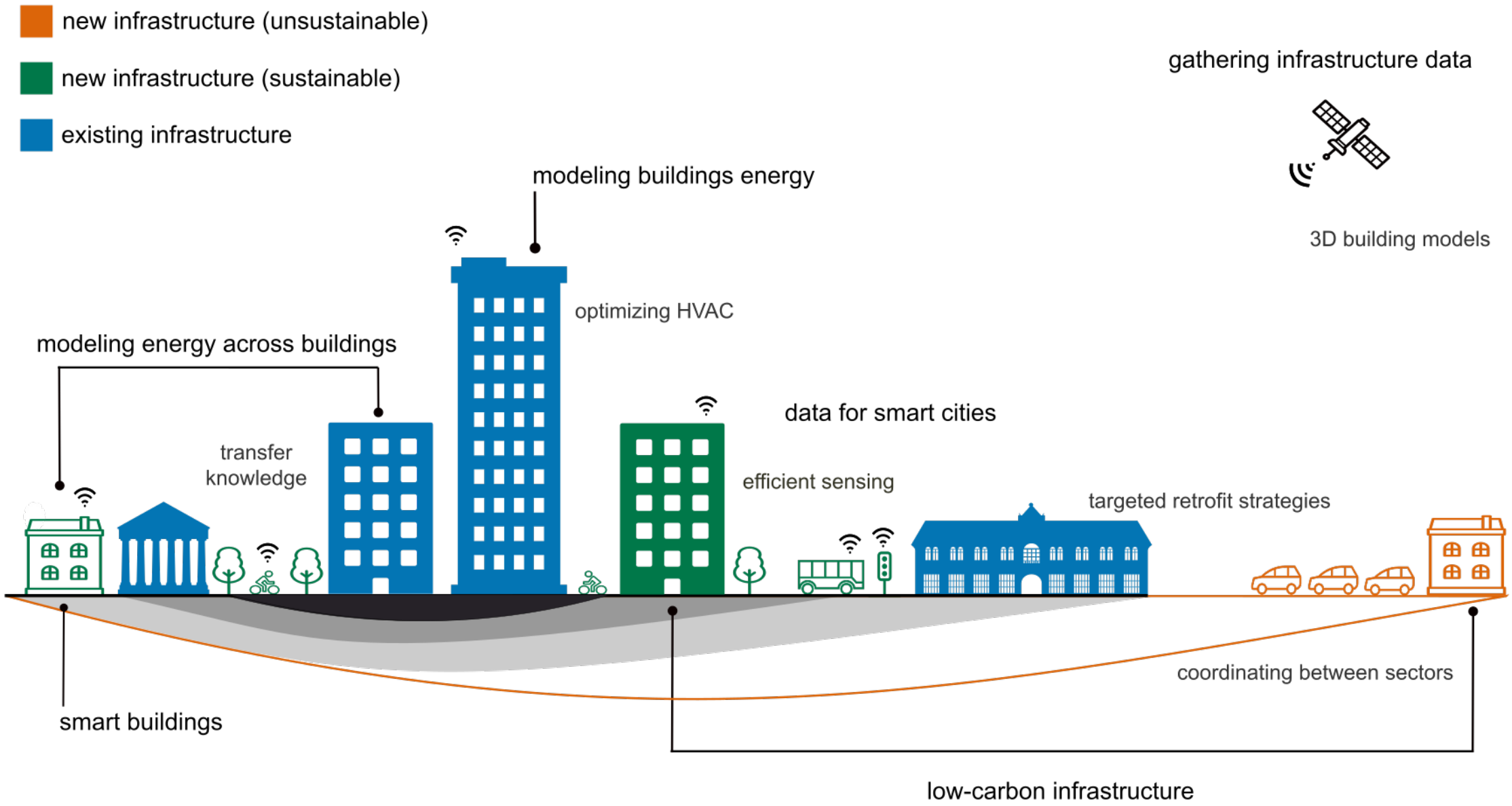
ML: Improve EV technology

- Battery development
- Battery management

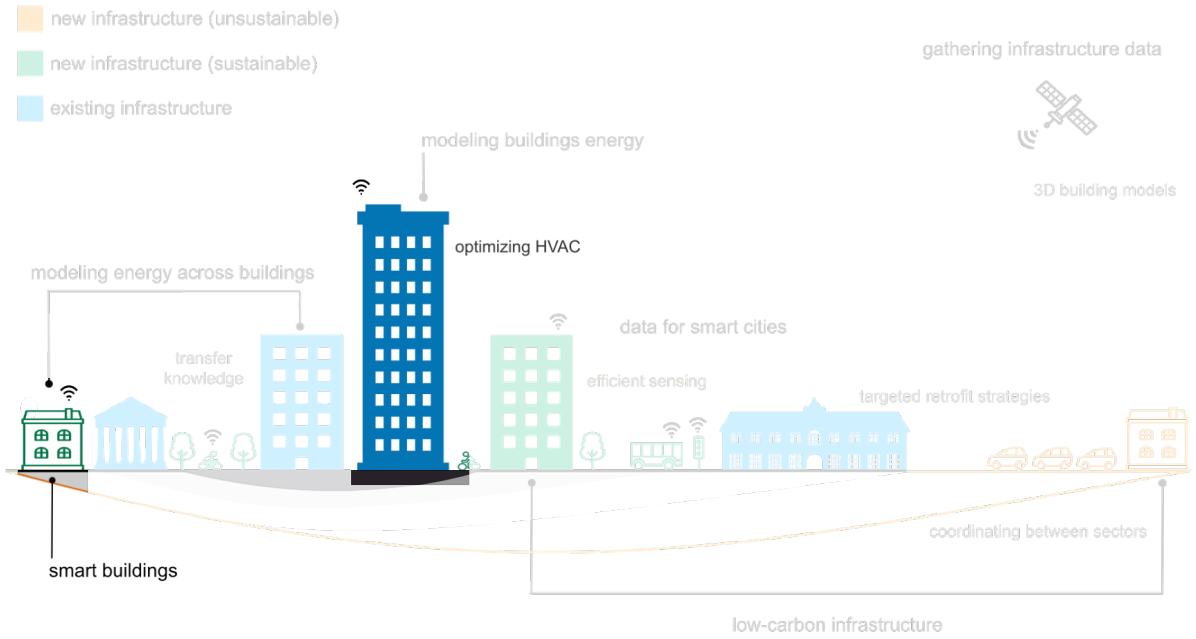
ML: Integrate EVs with electric grid

- Analyze charging behavior
- Vehicle-to-grid

Buildings and cities



Buildings and cities >> Smart buildings

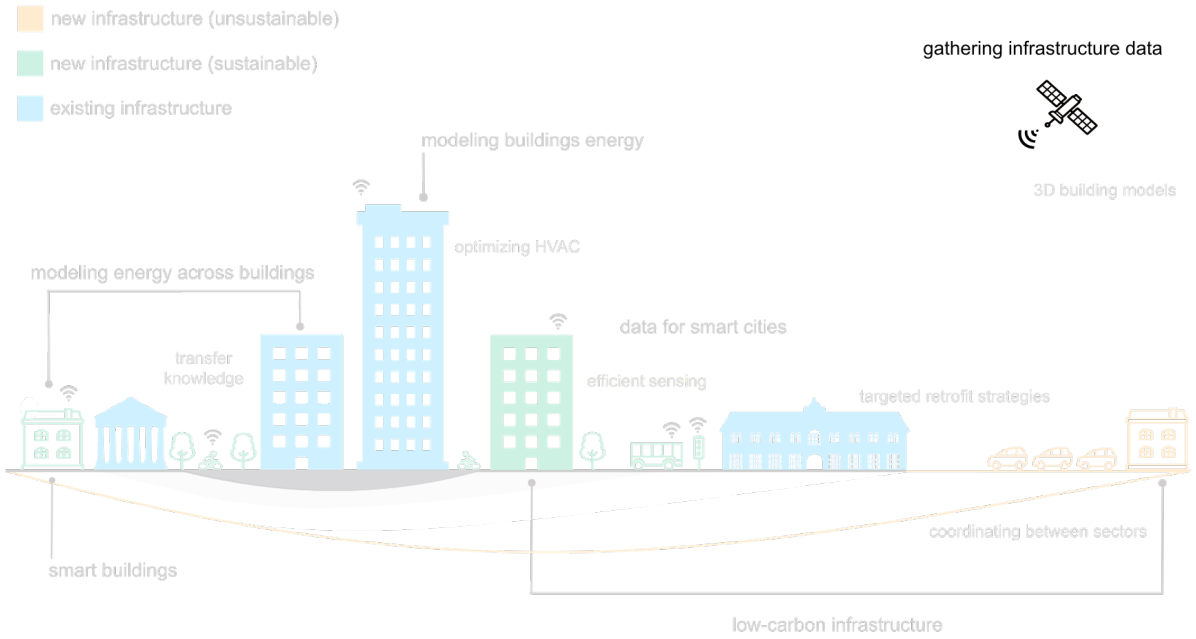


Need: Reduce and shift building energy consumption*

ML: Smart control of appliances

- HVAC: forecasting, control, fault detection
- Adjusting to occupancy patterns
- Demand response

Buildings and cities >> Gathering infrastructure data

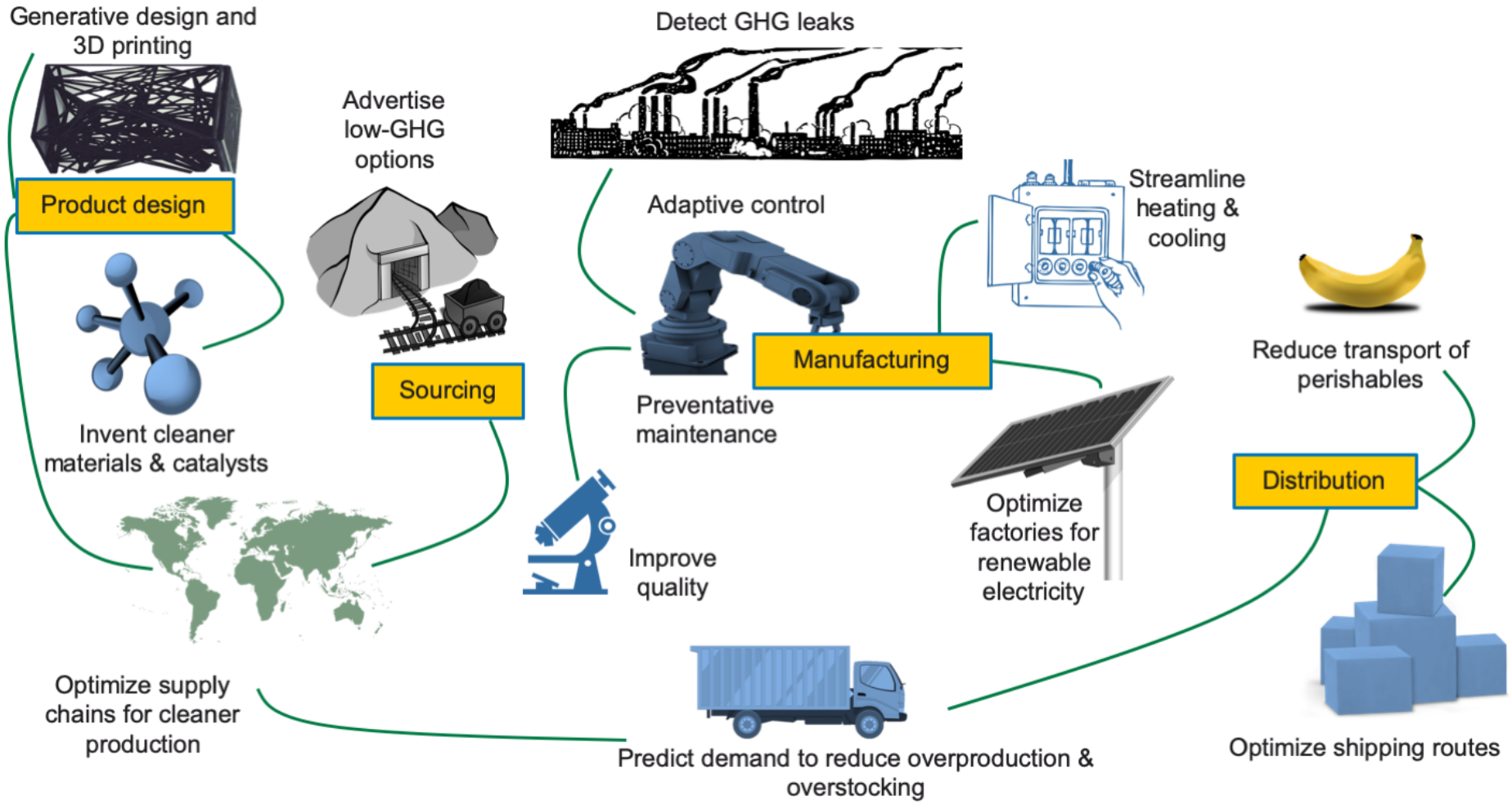


Need: Understand building attributes for simulations and policy

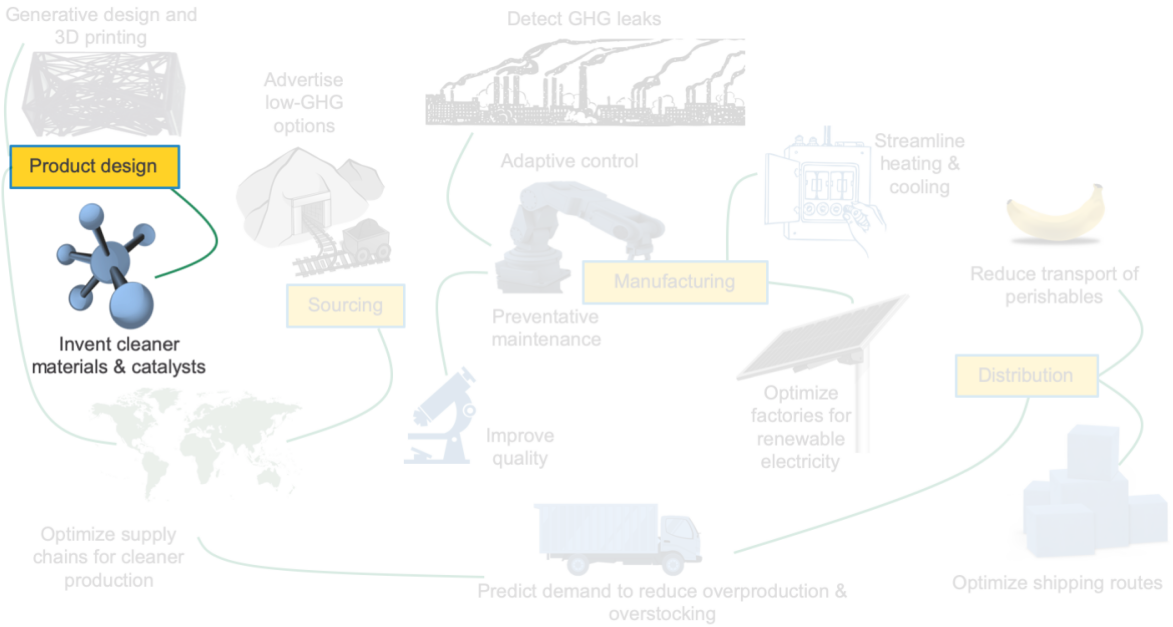
ML: Remote sensing

- Coarse localization (global)
- Precise neighborhood models

Industry


Generative design and 3D printing
Product design
Invent cleaner materials & catalysts
Optimize supply chains for cleaner production
Advertise low-GHG options
Sourcing
Detect GHG leaks
Adaptive control
Preventative maintenance
Improve quality
Manufacturing
Streamline heating & cooling
Optimize factories for renewable electricity
Reduce transport of perishables
Distribution
Optimize shipping routes
Predict demand to reduce overproduction & overstocking

Industry >> Improving materials

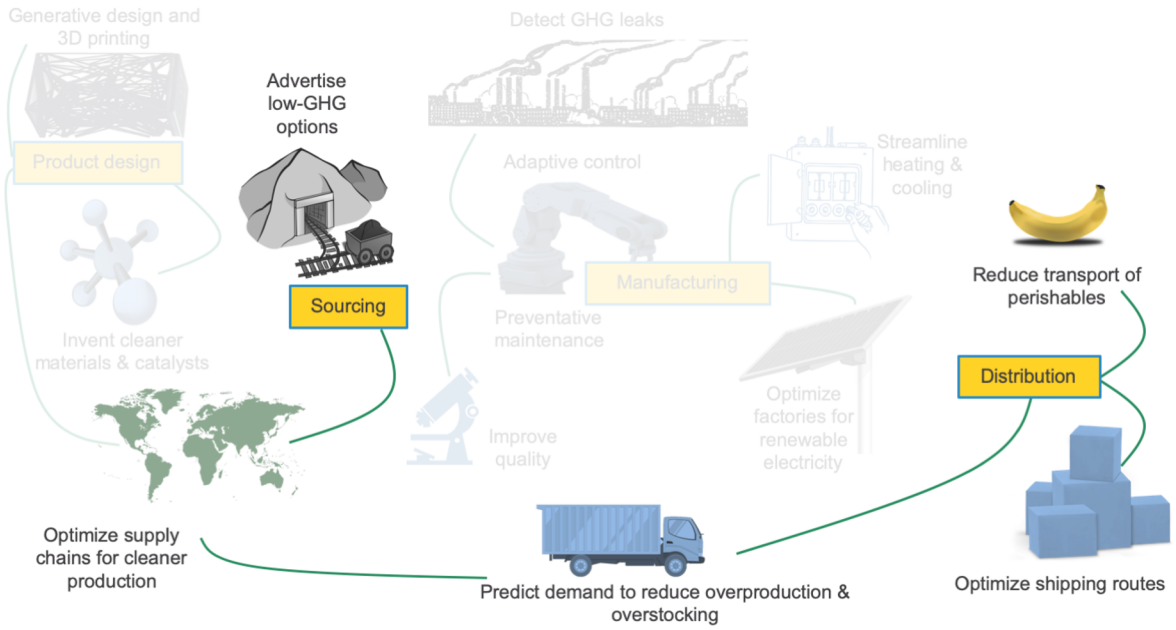


Need: Efficient production / use of materials

ML: Optimize construction materials, e.g. cement & steel

ML: Optimize synthesis methods, e.g. catalysts for ammonia

Industry >> Supply chains

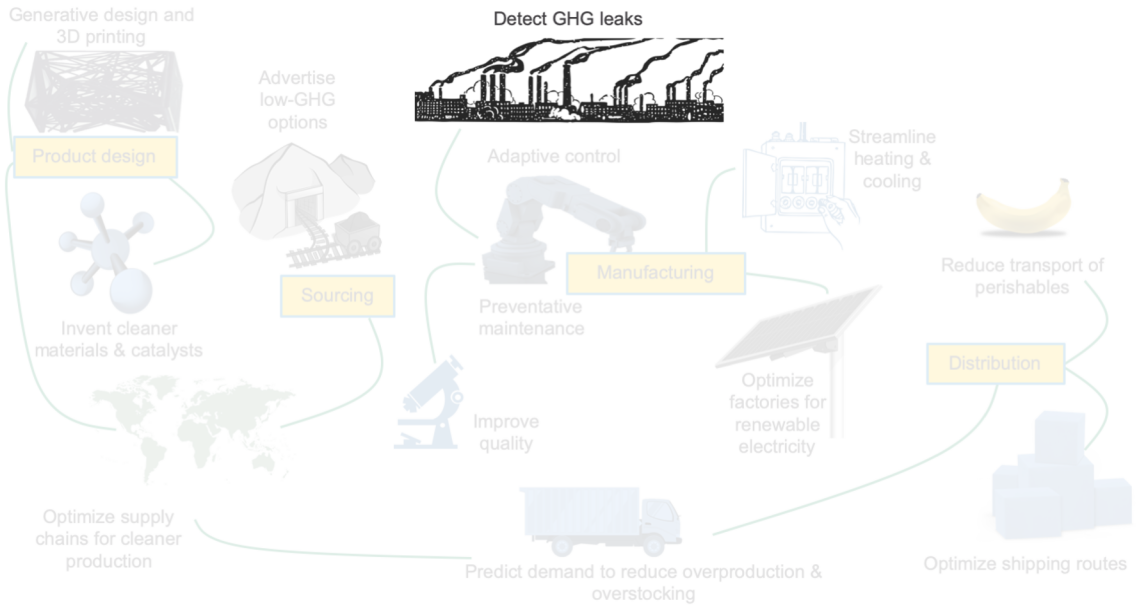


Need: Lower GHG emissions from transport and waste

ML: Reducing overproduction / overstock

ML: Recommender systems for low-emissions choices

Industry >> Detecting methane leaks



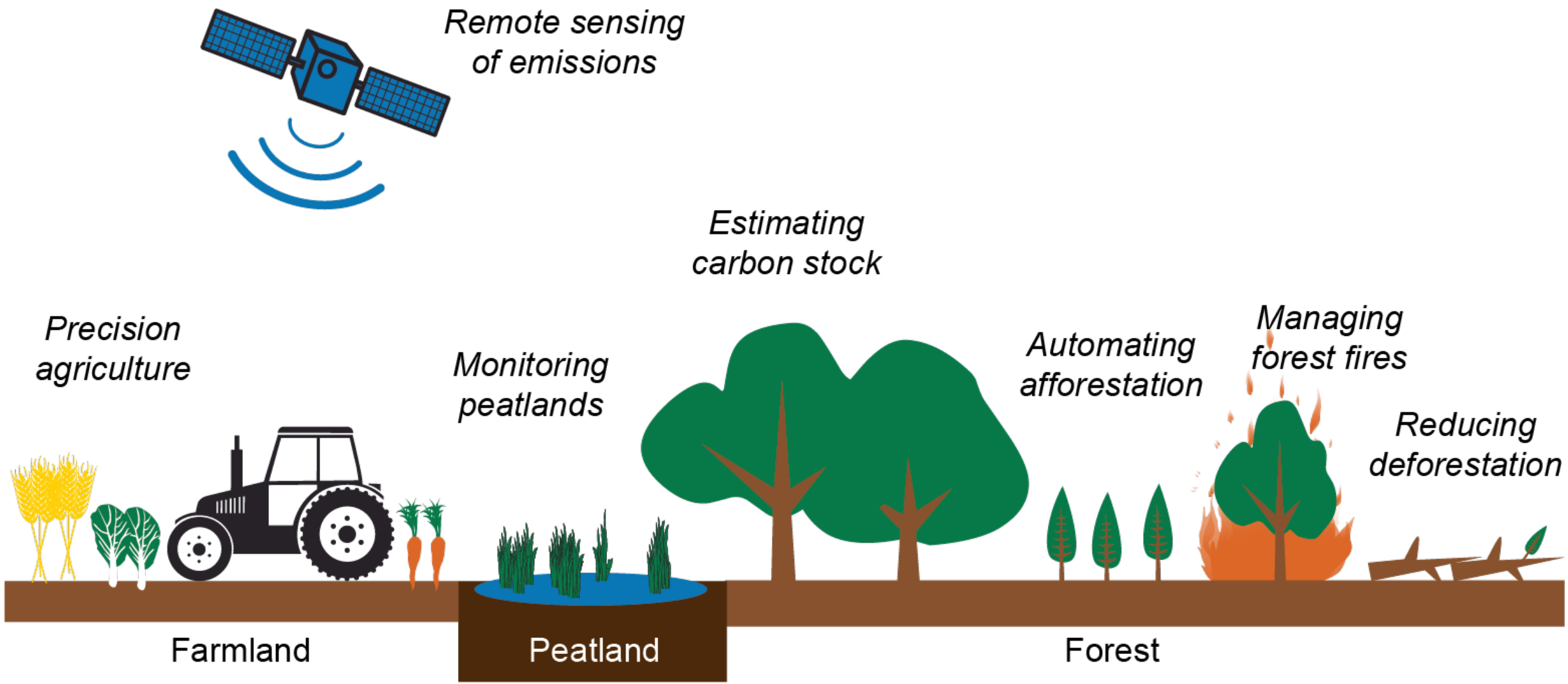
Need: Understand and reduce methane emissions

ML: Detect size and location of leaks

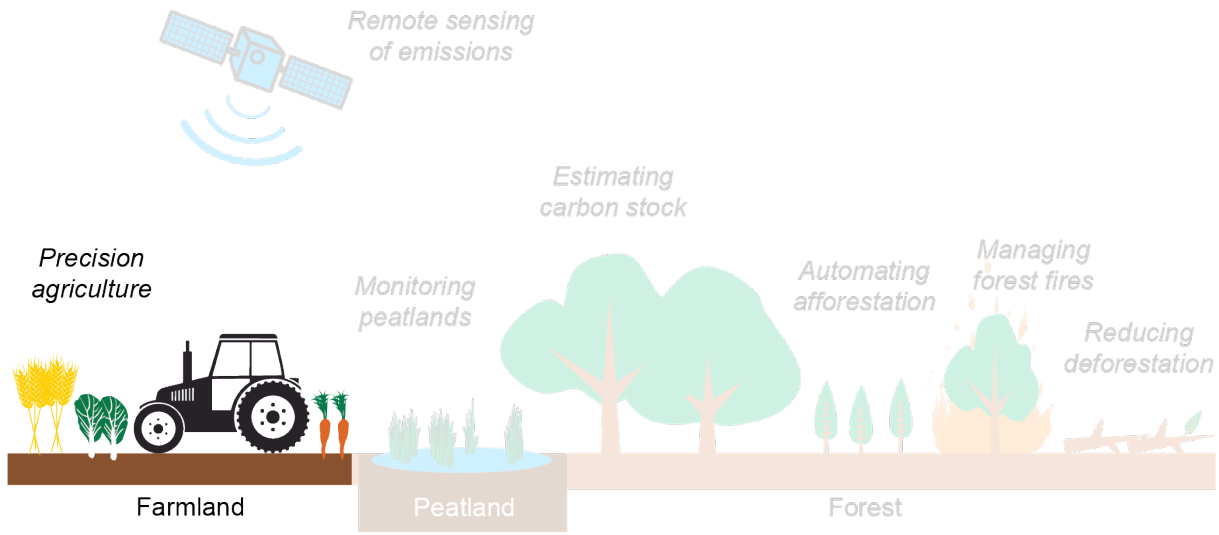
- Sensors, visual/hyperspectral satellite imagery

ML: Predictive maintenance, e.g. pipelines and compressor stations

Farms and forests



Farms and forests >> Precision agriculture

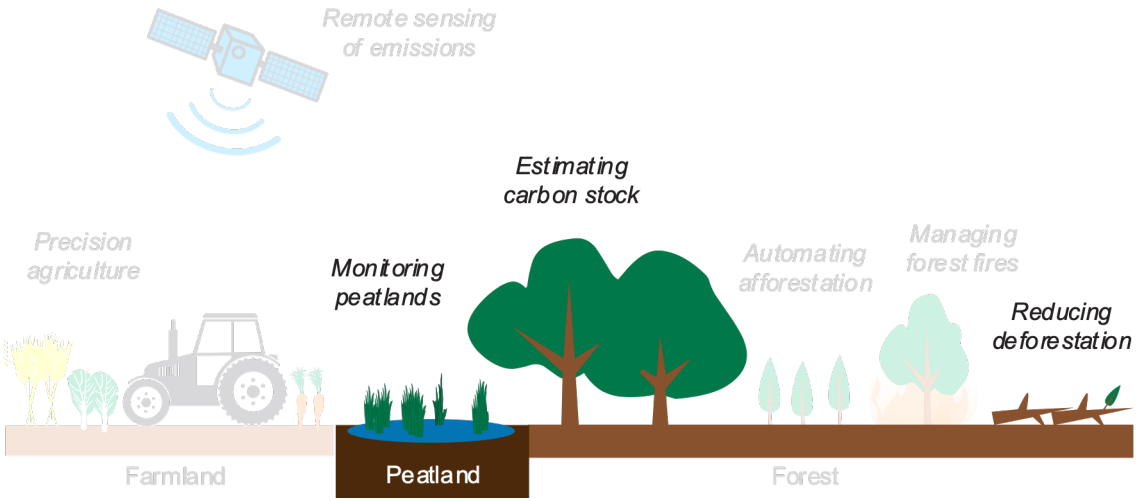


Need: Reduce emissions from soil displacement and fertilizer use

ML: Enable scalable farming of heterogeneous crops

- Robotic farming
- Intelligent irrigation

Farms and forests >> Monitoring land use

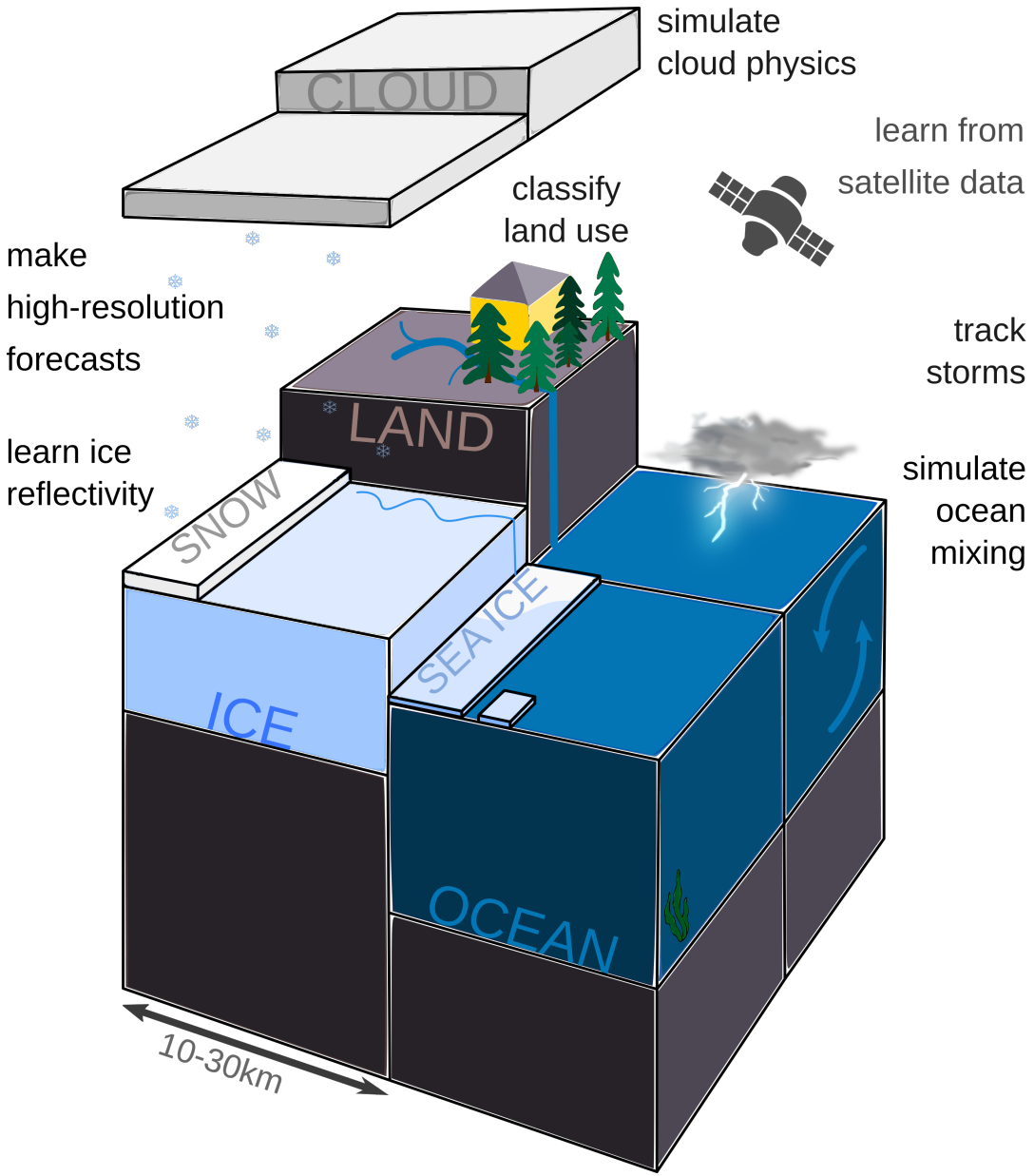


Need: Understand how land is naturally sequestering carbon

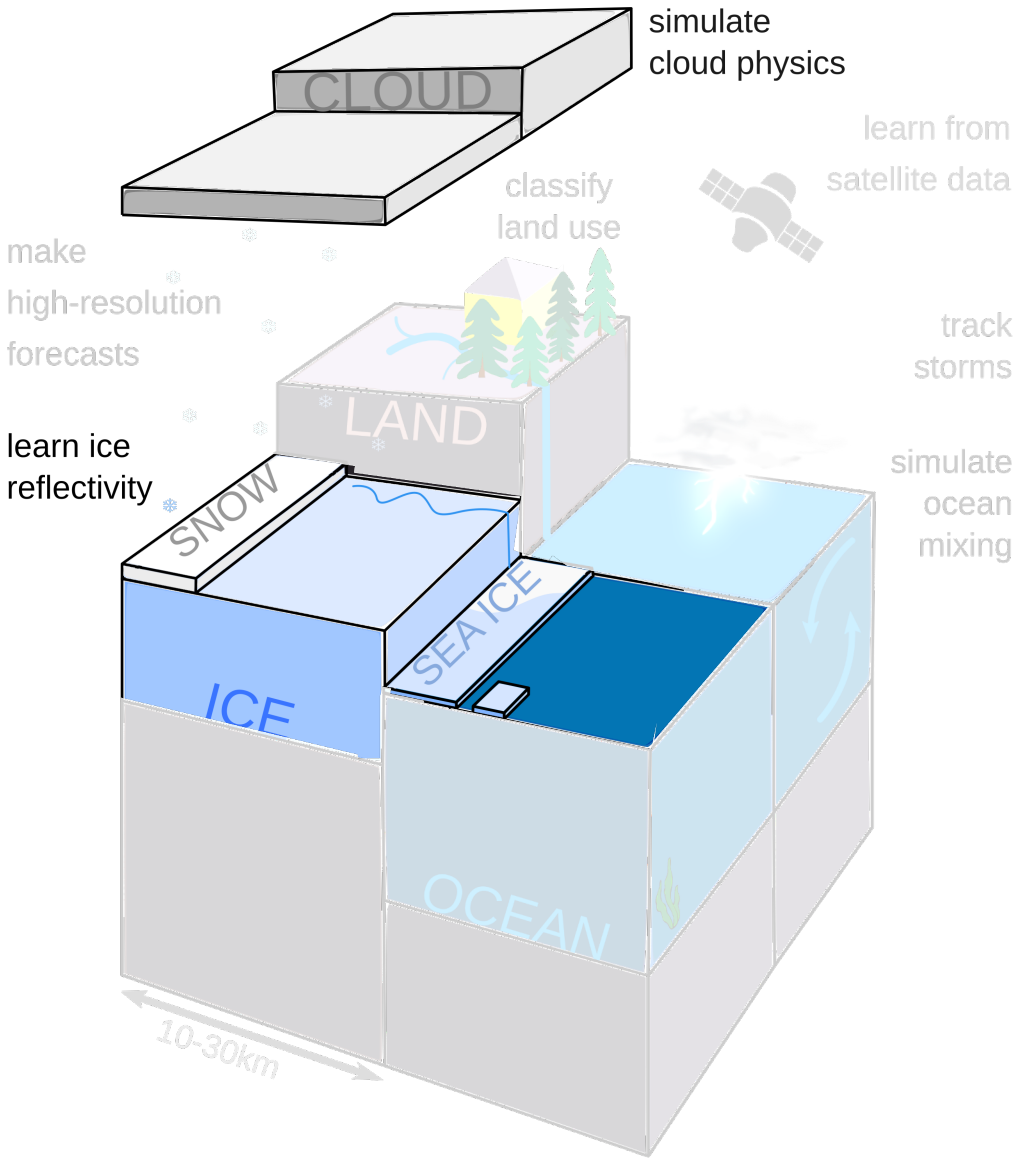
ML: Remote sensing of land use

- Estimating carbon stock in forests
- Tracking deforestation in real time
- Monitoring health of peatlands

Climate prediction



Farms and forests >> Accelerating climate simulations

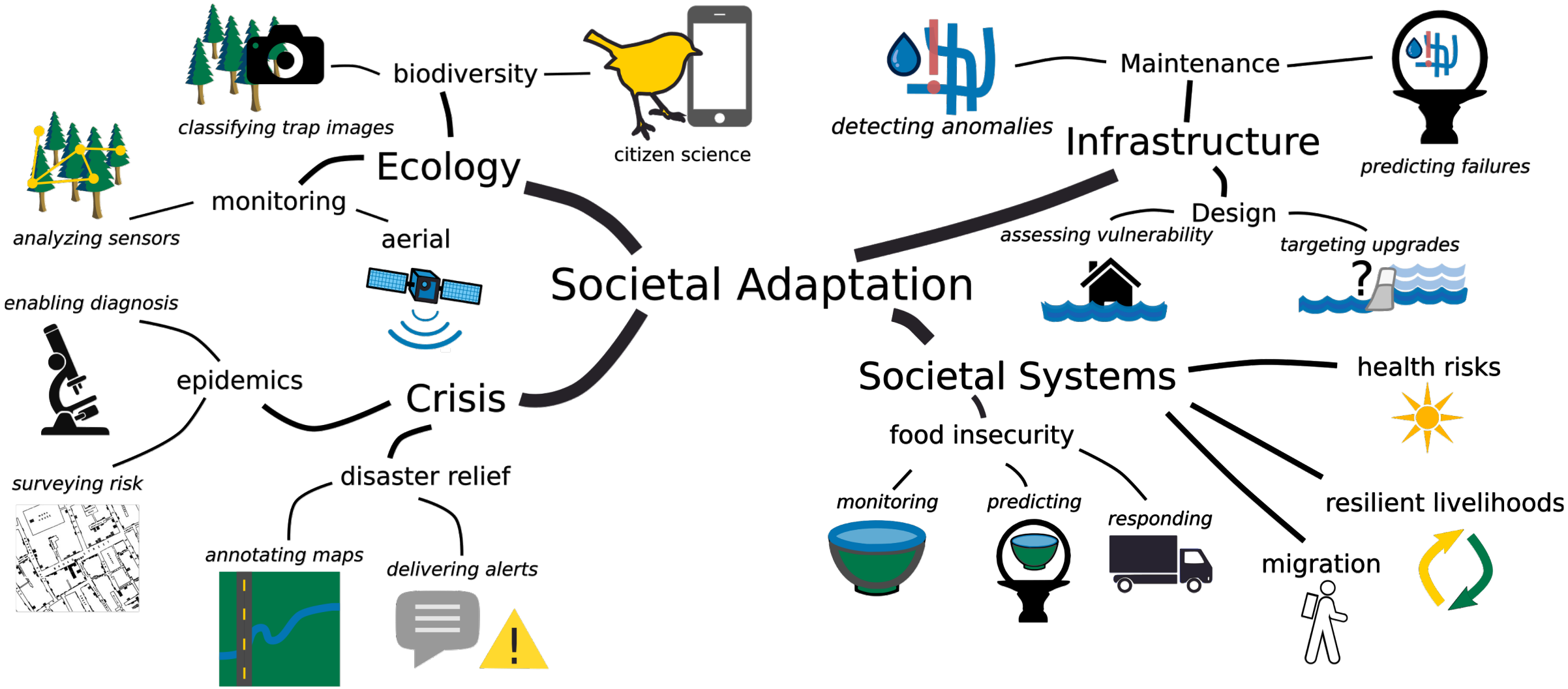


Need: Efficient, accurate climate simulations

ML: Improve portions of simulations

- Approximate cloud physics through reduced-form models
- Gather satellite data about ice sheets and sea level rise

Societal impacts



Carbon capture and solar geoengineering

Example opportunities:

- Discovering CO_2 sorbents
- Sequestering CO_2
- Geoengineering control
- Modeling geoengineering impacts

Tools for action

Example opportunities:

- Understanding and reducing personal impacts
- Informing behavior change
- Informing policy and designing markets
- Education
- Climate investment and analytics

Recurring themes

Accelerated experimentation (batteries, nuclear fusion, new materials)

Remote sensing (emissions, infrastructure data, deforestation)

Improving efficiency (freight consolidation, food waste)

Approximating time-intensive simulations (climate, energy, policy)

Need for **interpretable**, **causal**, and **gray-box models**
(solar forecasting, disaster planning, informing policy-makers)

How to get involved

Opportunities for action

Research and engineering

- Conceptual innovation, new ML and new applications of ML

Entrepreneurship and investment

- Startups & nonprofits deploying that innovation

Traditional industry

- Cost savings & lower climate impact

Local and national government

- Efficient, robust systems and informed decision-making

Roadmap for action

Learn: Identify how your skills may be useful.

Collaborate: Find collaborators (e.g. researchers, entrepreneurs, established companies, NGOs, or policy-makers).

Listen: Listen to what your collaborators say is needed.

Deploy: Ensure a path to impactful deployment.

Challenges

Finding collaborators

- Targeting impactful problems
- Identifying risks
- Guiding deployment

Finding data

- Can be confidential, disorganized, heterogeneous, or skewed

Resources at www.climatechange.ai

Climate Change AI

- Non-profit initiative, volunteers from academia/industry
- Workshops and events
- Datasets / advice on what to work on
- Tools for team-building
- Upcoming grant program

Upcoming 5-day workshop at ICLR 2020

- “Tackling Climate Change with Machine Learning”
- Talks, panels, discussion streamed online
- Next week! April 26-30
- Part of the International Conference on Learning Representations (ICLR)
  - One of the leading deep learning conferences
- Can register for the whole conference at iclr.cc (50 dollars for students)
- Or watch for free at the workshop website www.climatechange.ai/ICLR2020_workshop.html

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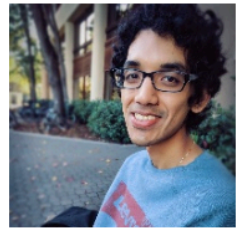

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Website

Kelly Kochanski
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Stanford University

Tobias Schmidt
ETH Zürich

Craig Smith
Eye on AI

Discussion

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Shifting transportation modes	•	•	•		•	•	•	•	•
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Optimizing buildings	•				•	•	•		•
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Modeling consumer behavior									•
11 Tools for society			•	•		•	•	•	•
12 Education				•	•				
13 Finance				•		•		•	

Example opportunities

- Nowcasting solar + wind power
- Forecasting power demand
- Designing better materials
- Optimizing public transportation and infrastructure
- Consolidating freight shipments
- Reducing energy use in “smart buildings”
- Optimizing supply chains
- Making industrial processes (e.g. cement, steel, ammonia) more energy efficient
- Enabling precision agriculture (both software and hardware)
- Remote sensing of solar panels, wind turbines, deforestation, forest composition, methane, buildings, etc.
- Approximating physical models fast
- Inferring ecosystem health
- Improving disaster response
- Helping people understand and reduce their personal impact
- Predicting financial impacts of climate change
- ….