Computing for sustainability: an applied perspective in the context of solving the global climate crisis

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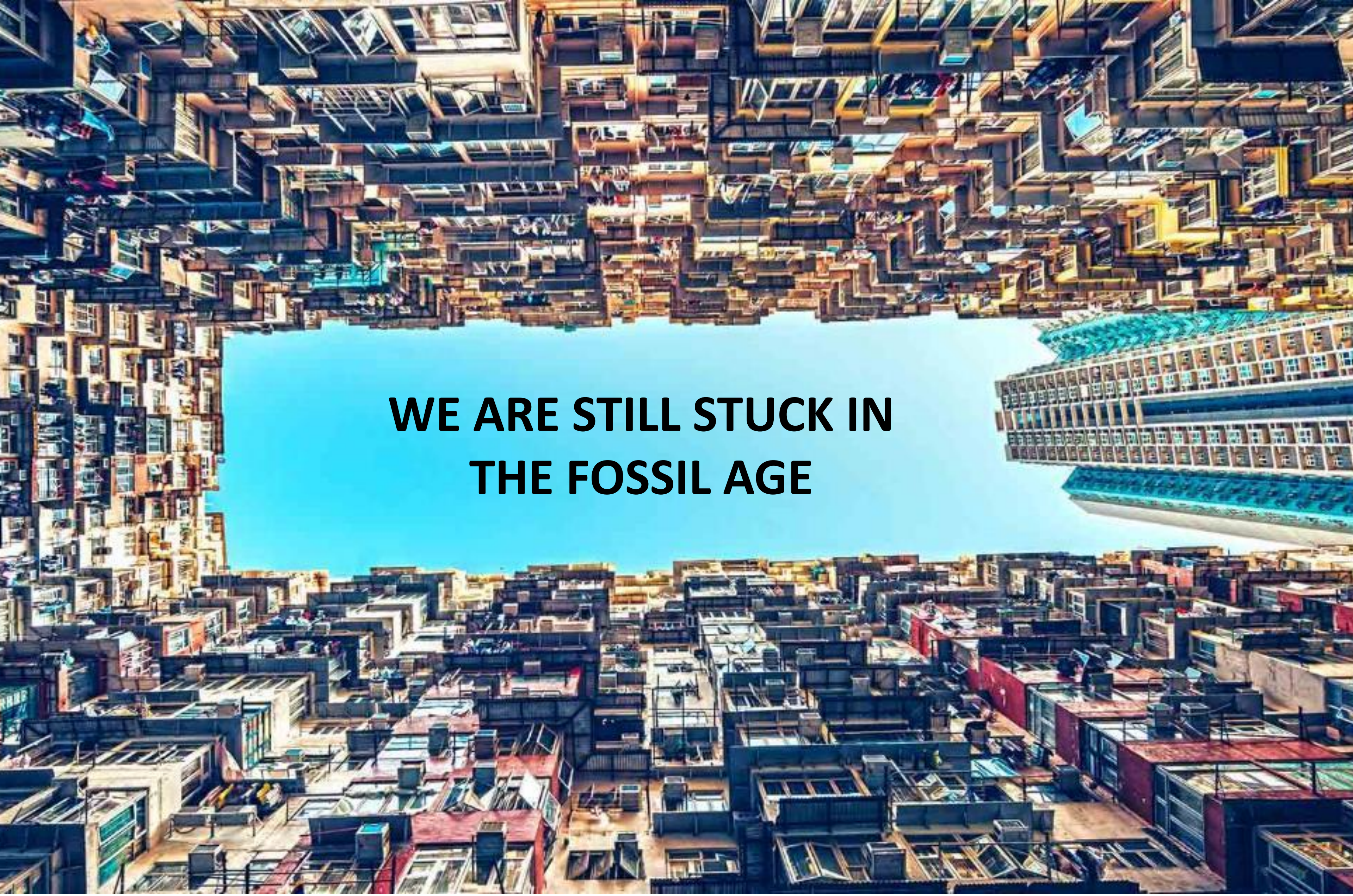


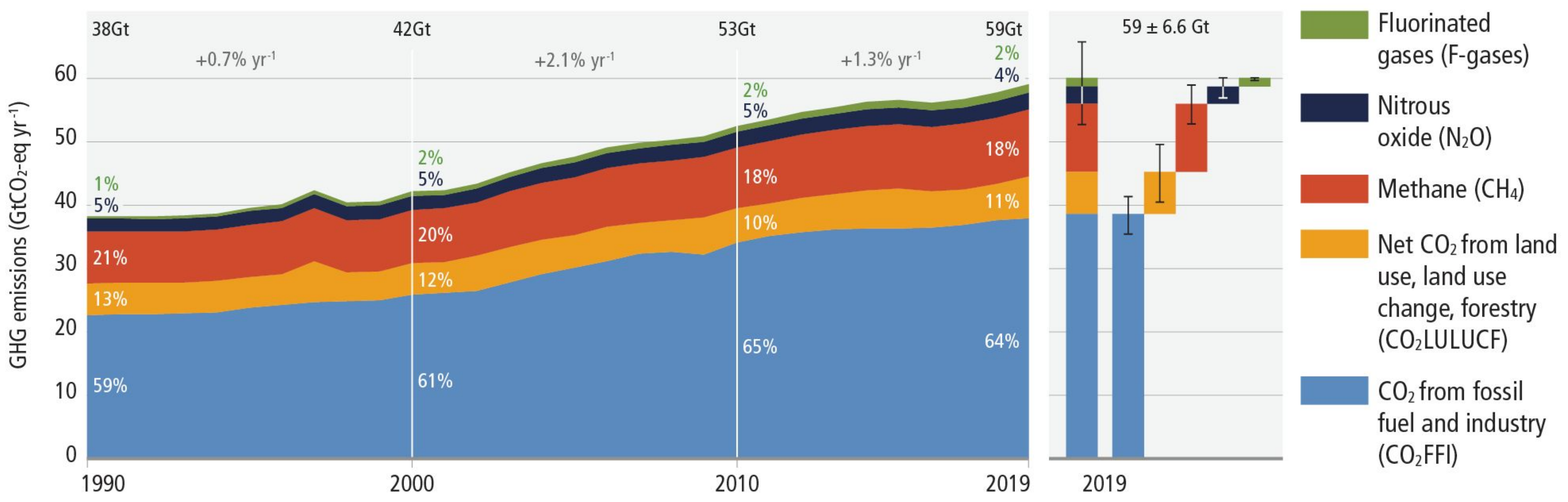
WE ARE STILL STUCK IN THE FOSSIL AGE

Stuck in the age of fossil fuels

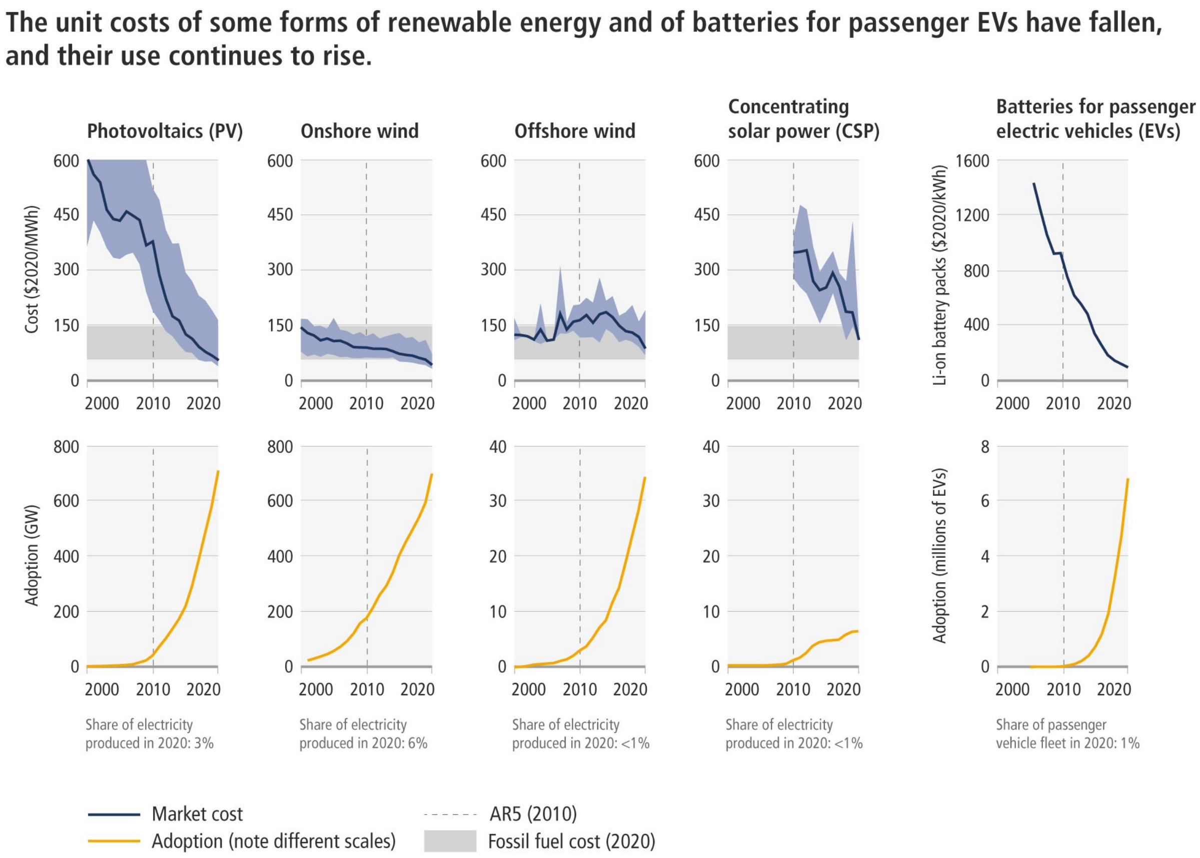
- 2019 emissions 12% higher than in 2010 and 54% higher than in 1990
- Emissions growth slowed
- Decarbonisation of energy is progressing far too slow

Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.

a. Global net anthropogenic GHG emissions 1990–2019 (5)



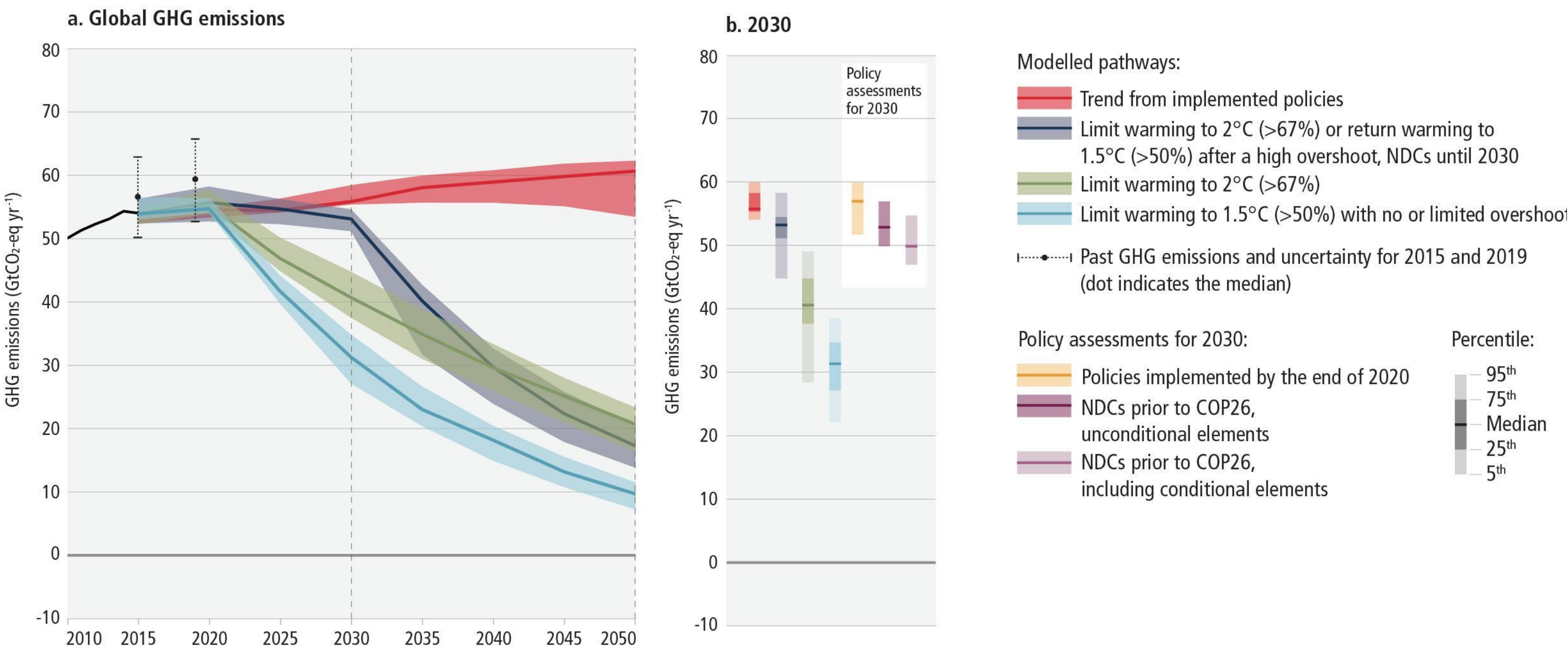
INCREASED EVIDENCE OF CLIMATE ACTION



- A growing number of countries have achieved sustained GHG emissions reductions for longer than 10 years.
- Some key technologies have developed much better than planned. Since 2010, up to 85% decreases in the costs of solar and wind energy, and batteries. Large increases in installed capacity.
- An increasing range of policies and laws have enhanced energy efficiency, reduced rates of deforestation and accelerated the deployment of renewable energy.

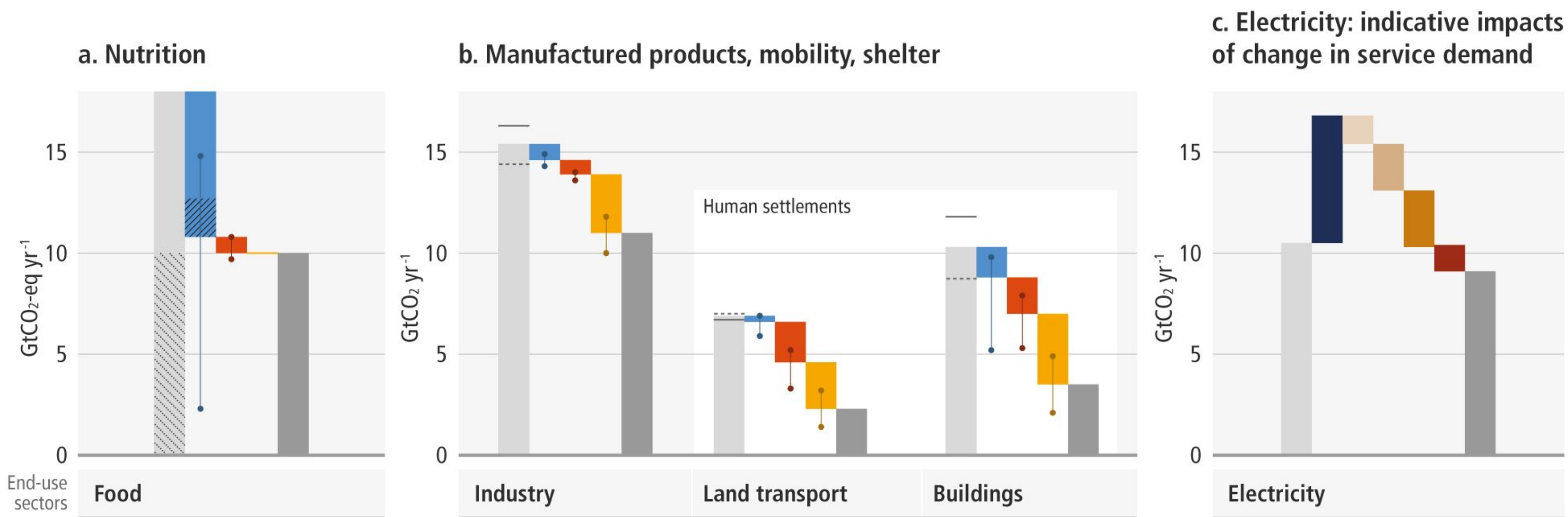
NDCs are insufficient to keep 1.5°C well within reach

Projected global GHG emissions from NDCs announced prior to COP26 would make it likely that warming will exceed 1.5°C and also make it harder after 2030 to limit warming to below 2°C.



End-use interventions can reduce GHG emissions by 40-70% in 2050

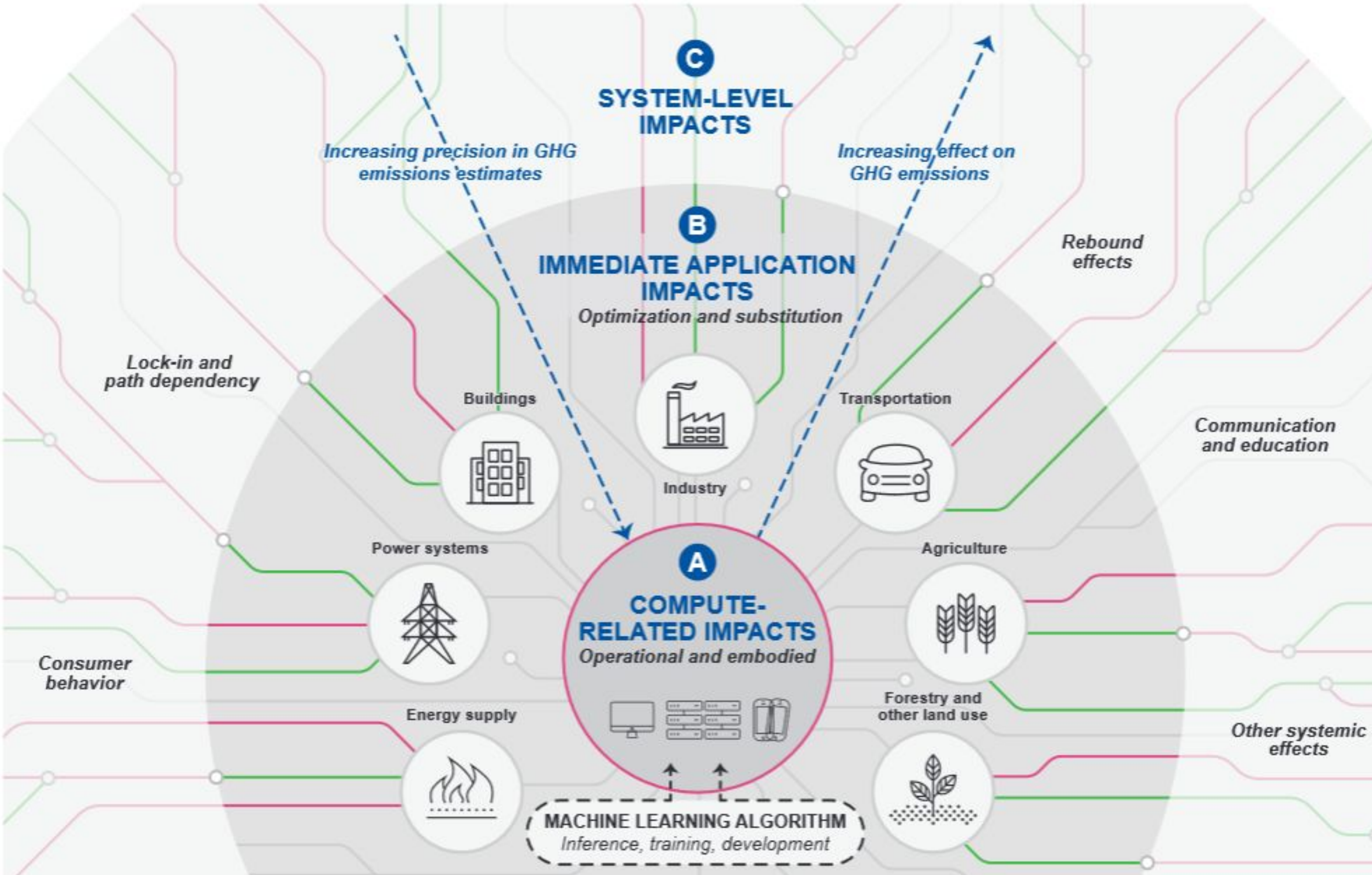
Demand-side mitigation can be achieved through changes in socio-cultural factors, infrastructure design and use, and end-use technology adoption by 2050.



Creutzig et al, Nature Climate Change 2022
and Chapter 5, IPCC 2022

3 WAY HOW AI AND CLIMATE CHANGE INTERACT

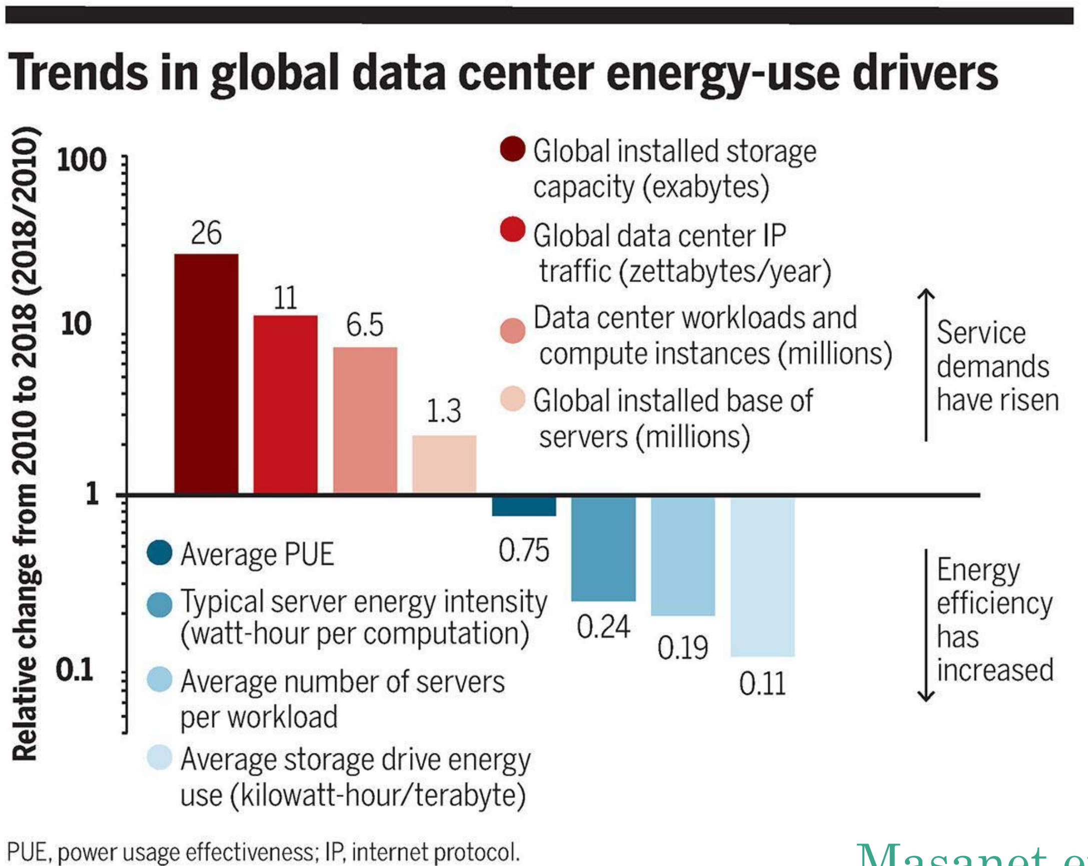
Accounting framework: system level effects dominate but are highly uncertain



Kaack, Creutzig et al (2022) Nature Climate Change

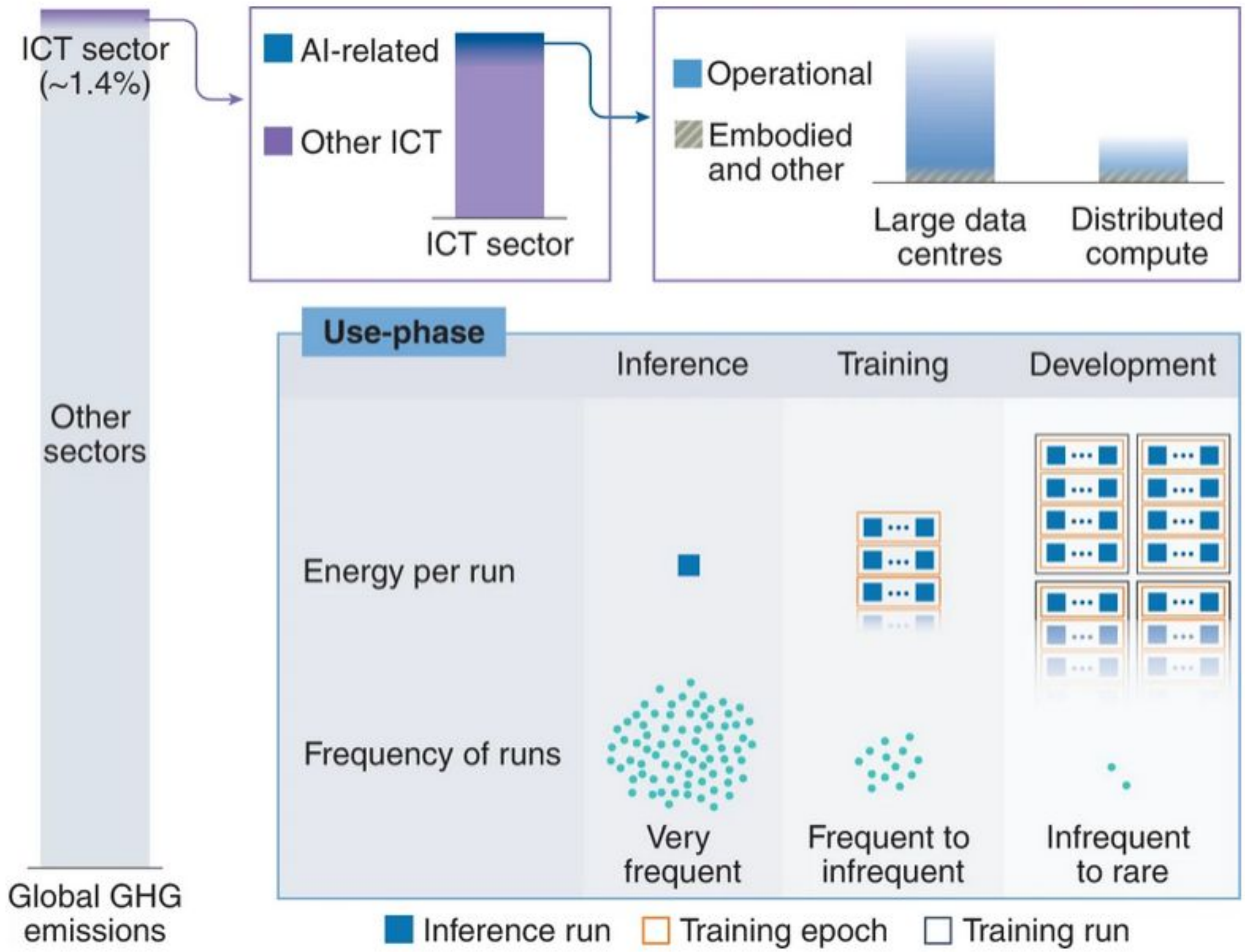

LIFE-CYCLE ASSESSMENT

Energy demand of data center is huge – 1% of global electricity consumption -and growing but efficiency gains mostly compensate



Masanet et al (2020) Science

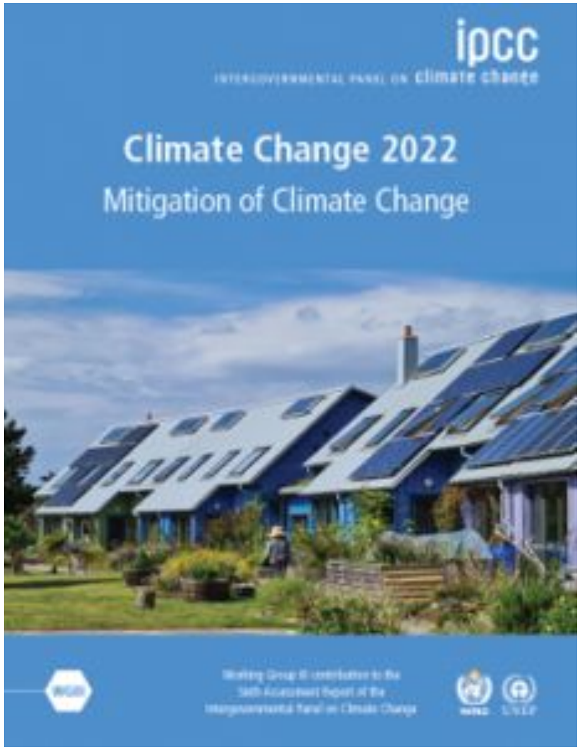
AI contribution can be high (training) but overall energy demand unknown



Kaack, Creutzig et al (2022) Nature Climate Change

TECHNOLOGICAL OPPORTUNITIES

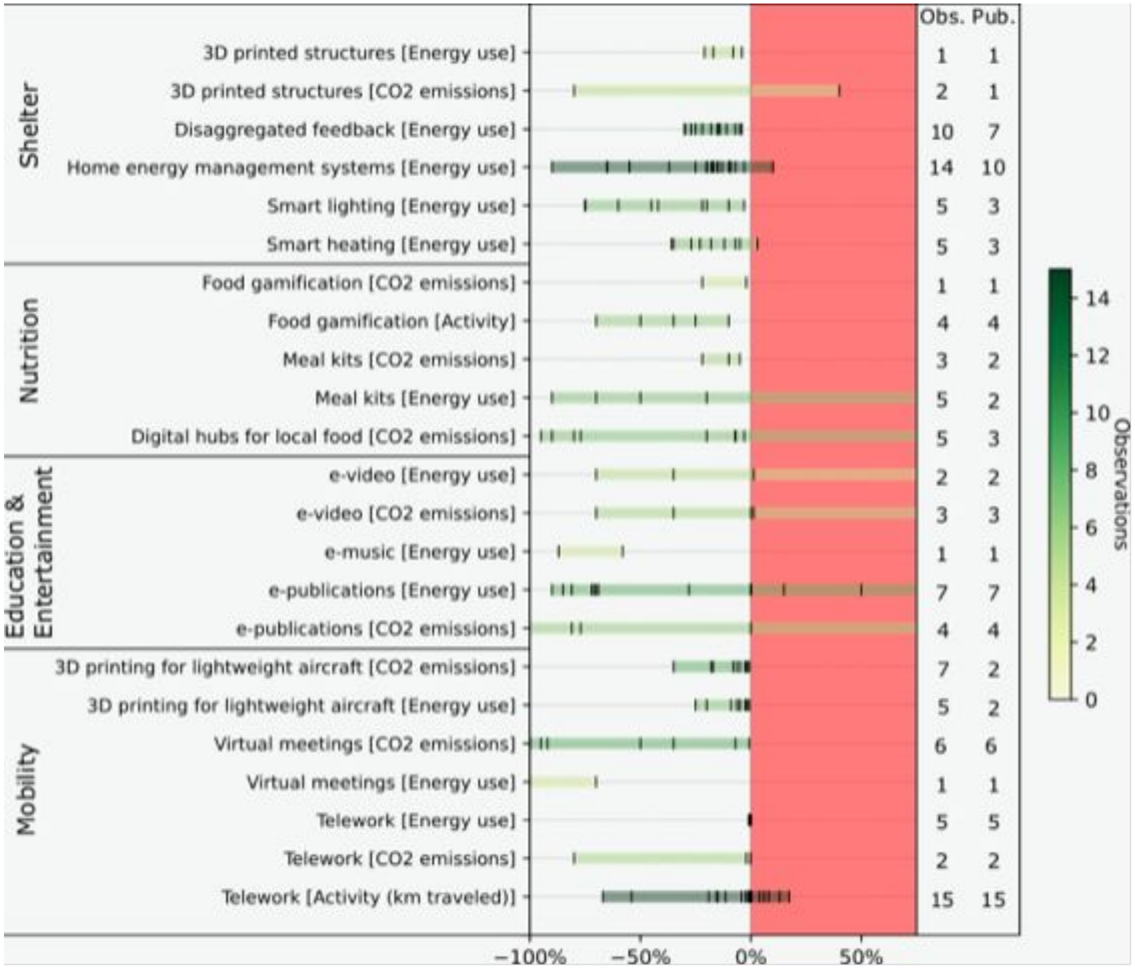
IPCC for the first time assesses potential and risks of digital technologies to climate change mitigation



Cities
Buildings
Mobility
Agriculture

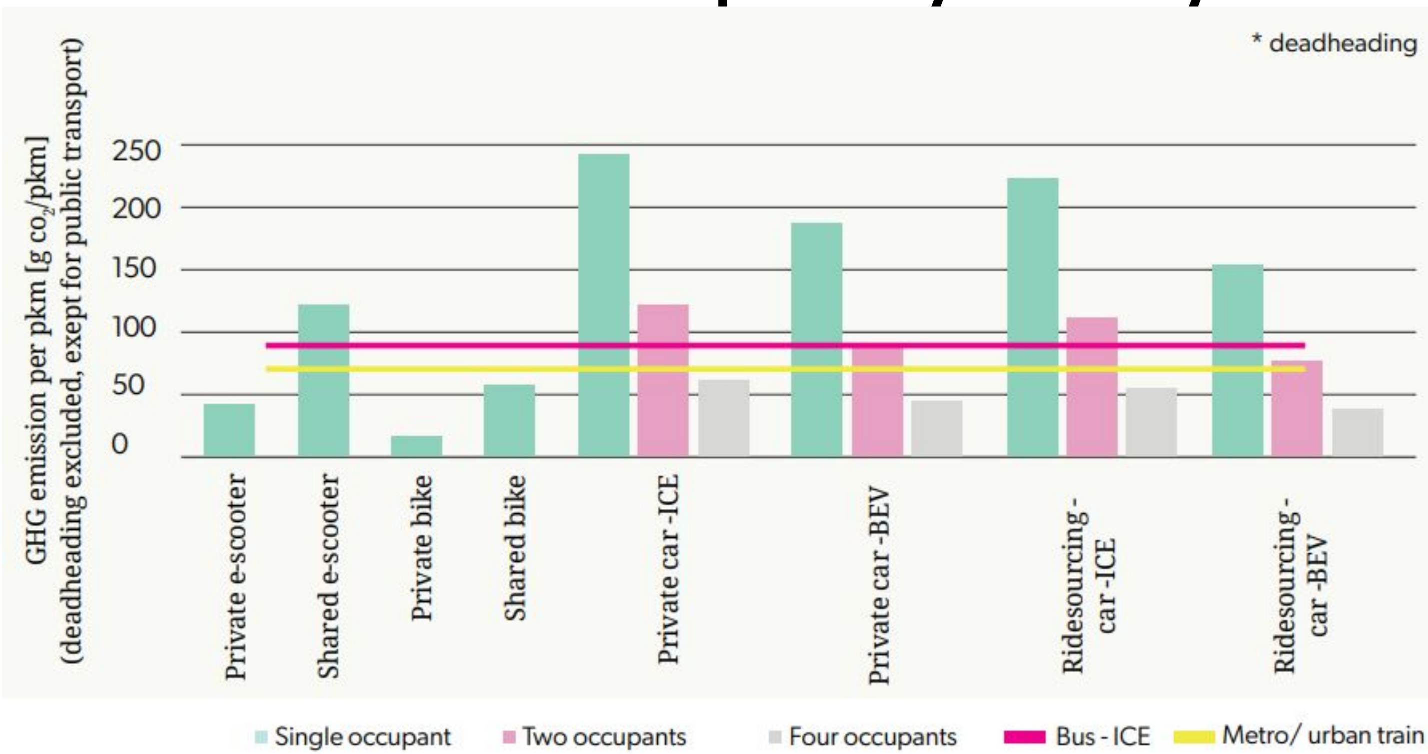
Chapter 16, WGIII, IPCC (2022)

Digitalisation, if steered by standards and pricing, offers new opportunities for GHG emission savings



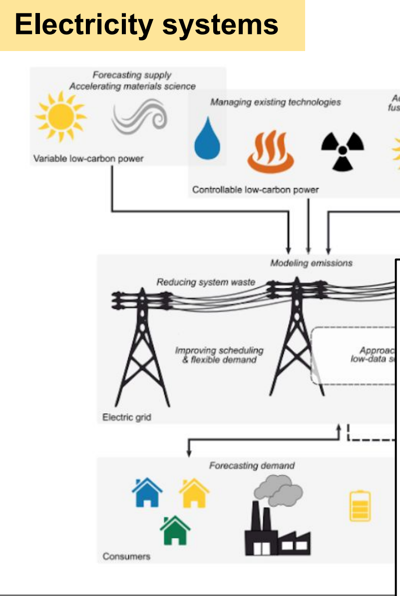
Synthesis by Nico Heeren, Eric Masanet and Alessandro Sanchez Pereira; mostly based on Wilson et al 2020

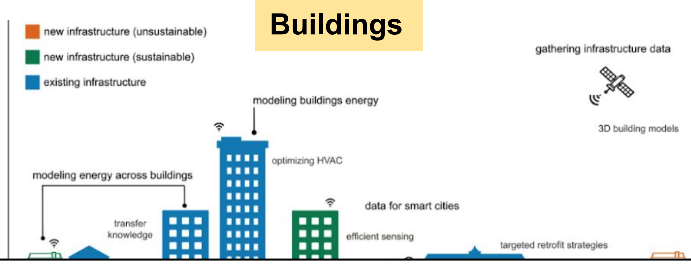
Shared urban mobility systems: occupancy is key

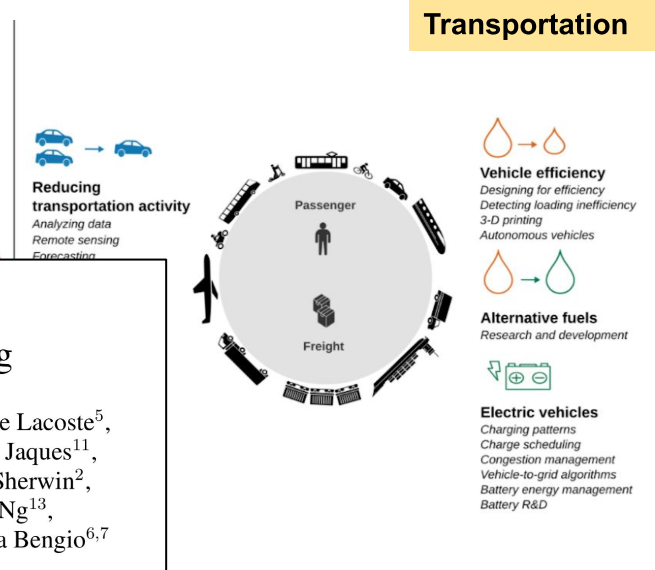


ITF (2020)
Creutzig (2020)

- Smaller vehicles better than larger ones
- Lifetime of e-scooters matters
- Private bike better than shared bike
- Private motorized transport better than public transport with 4 passengers
- Ridesourcing (Uber) unacceptable choice due to deadheading (=cruising of vehicles in search for passengers)



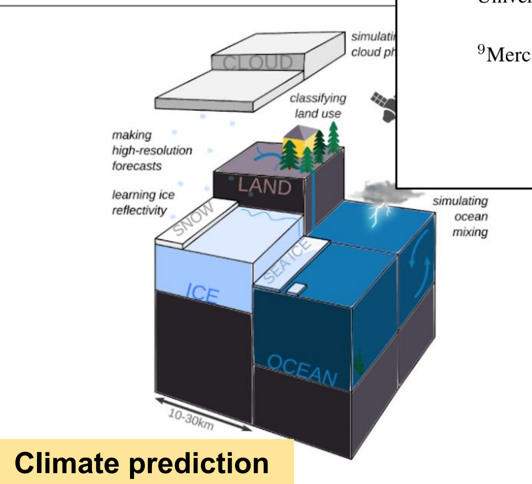


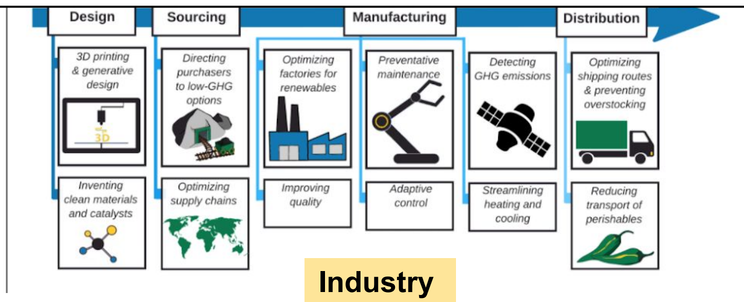


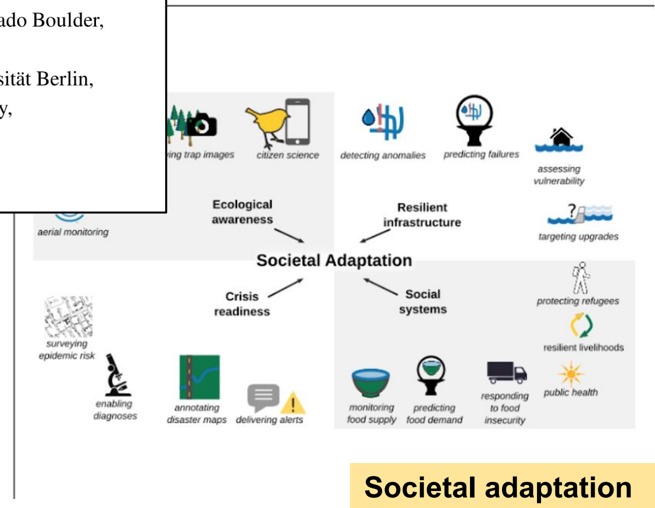
Tackling Climate Change with Machine Learning

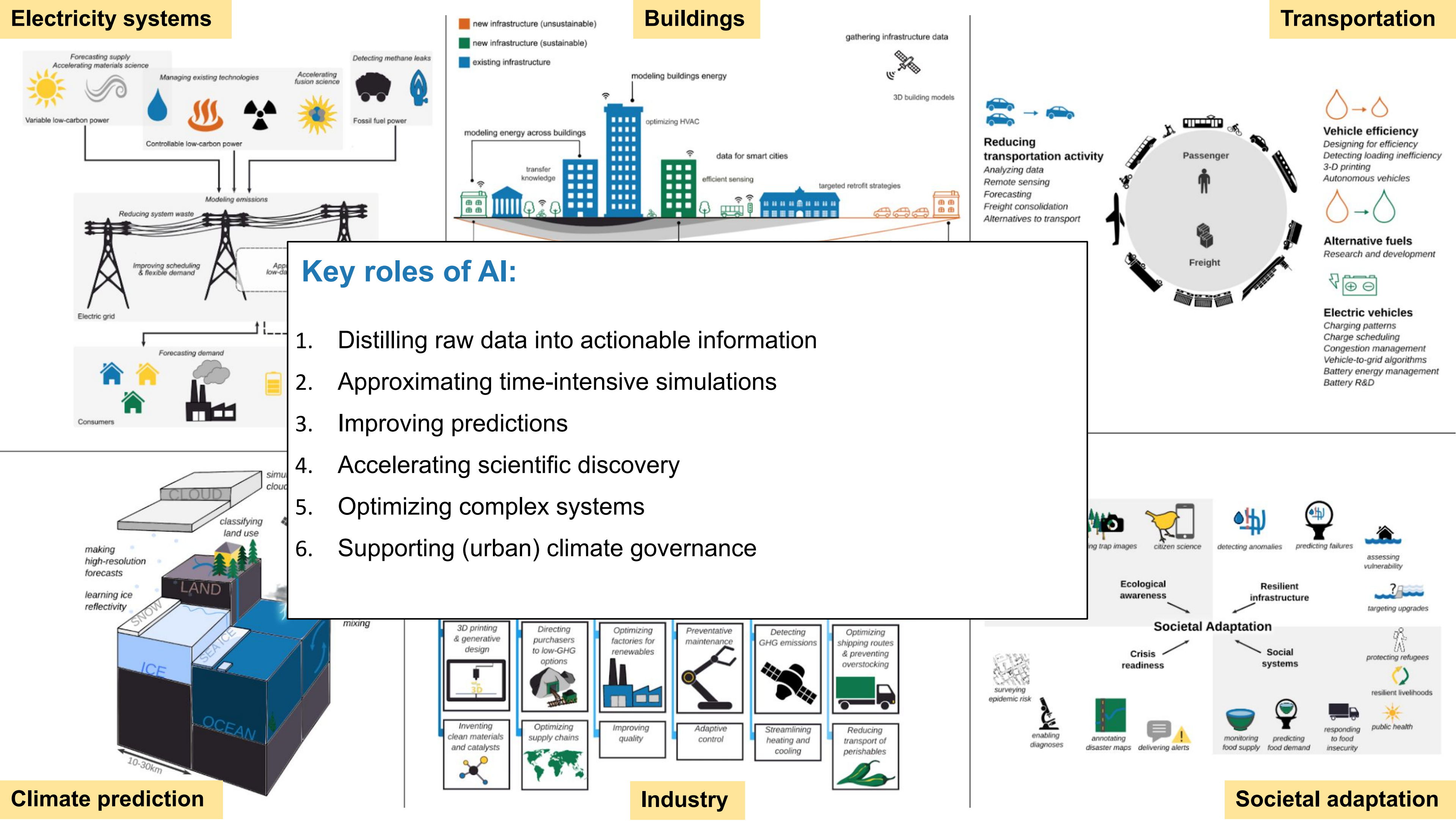
David Rolnick[1]*, Priya L. Donti[2], Lynn H. Kaack[3], Kelly Kochanski[4], Alexandre Lacoste[5], Kris Sankaran[6,7], Andrew Slavin Ross[8], Nikola Milojevic-Dupont[9,10], Natasha Jaques[11], Anna Waldman-Brown[11], Alexandra Luccioni[6,7], Tegan Maharaj[6,7], Evan D. Sherwin[2], S. Karthik Mukkavilli[6,7], 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





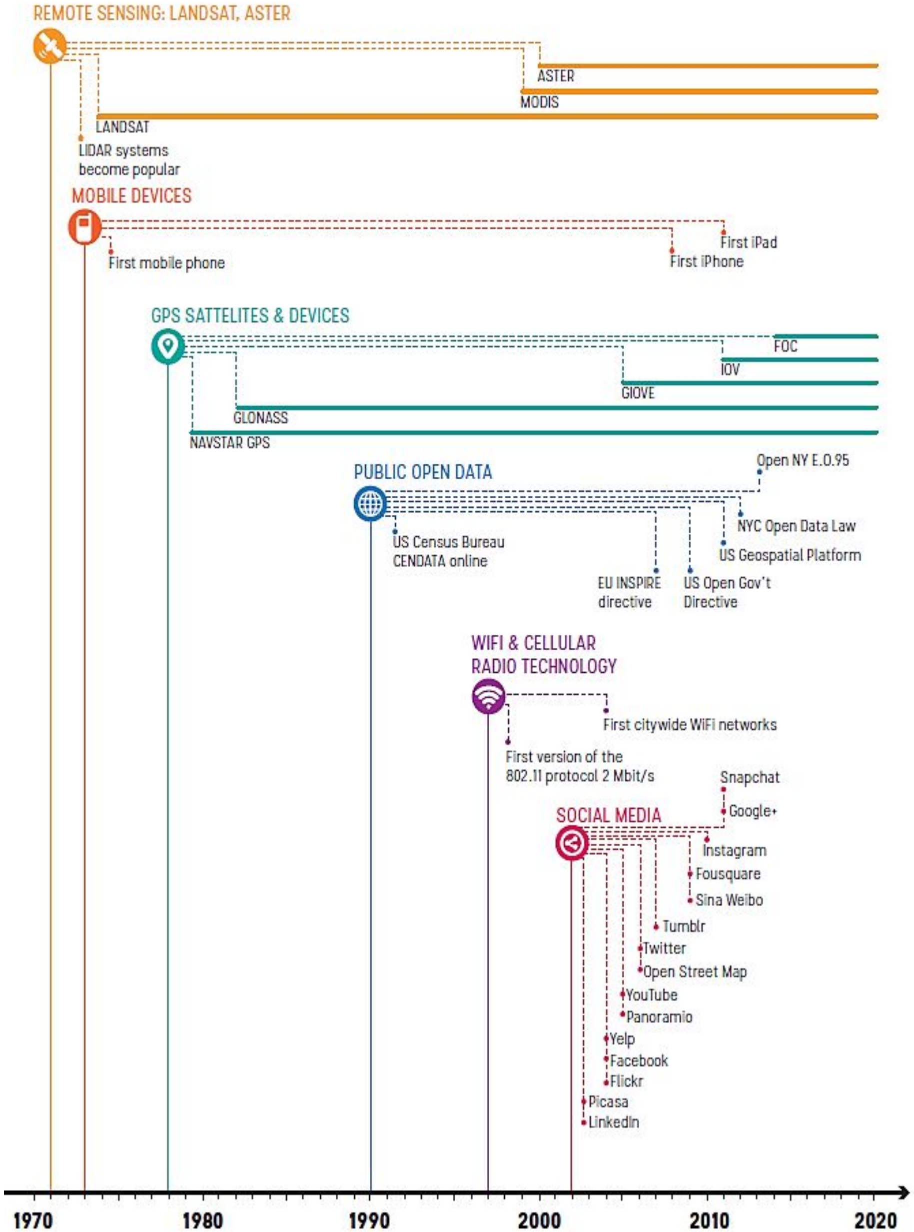




Key roles of AI:

1. Distilling raw data into actionable information
2. Approximating time-intensive simulations
3. Improving predictions
4. Accelerating scientific discovery
5. Optimizing complex systems
6. Supporting (urban) climate governance

Deep dive: The role of AI in urban governance and solutions



Big data in urban sciences

Evolution of key "Big Data" sources and technologies and the rise of Social Media Data (SMD).

- increasing availability of location-based social, infrastructural, and landscape/biophysical data.
- SMD represents major new phase in ability to understand links between human behavior, values, and preferences and infrastructural, climatological, or other core components of urban, peri-urban, and rural systems that are important for driving transformative change for improving sustainability

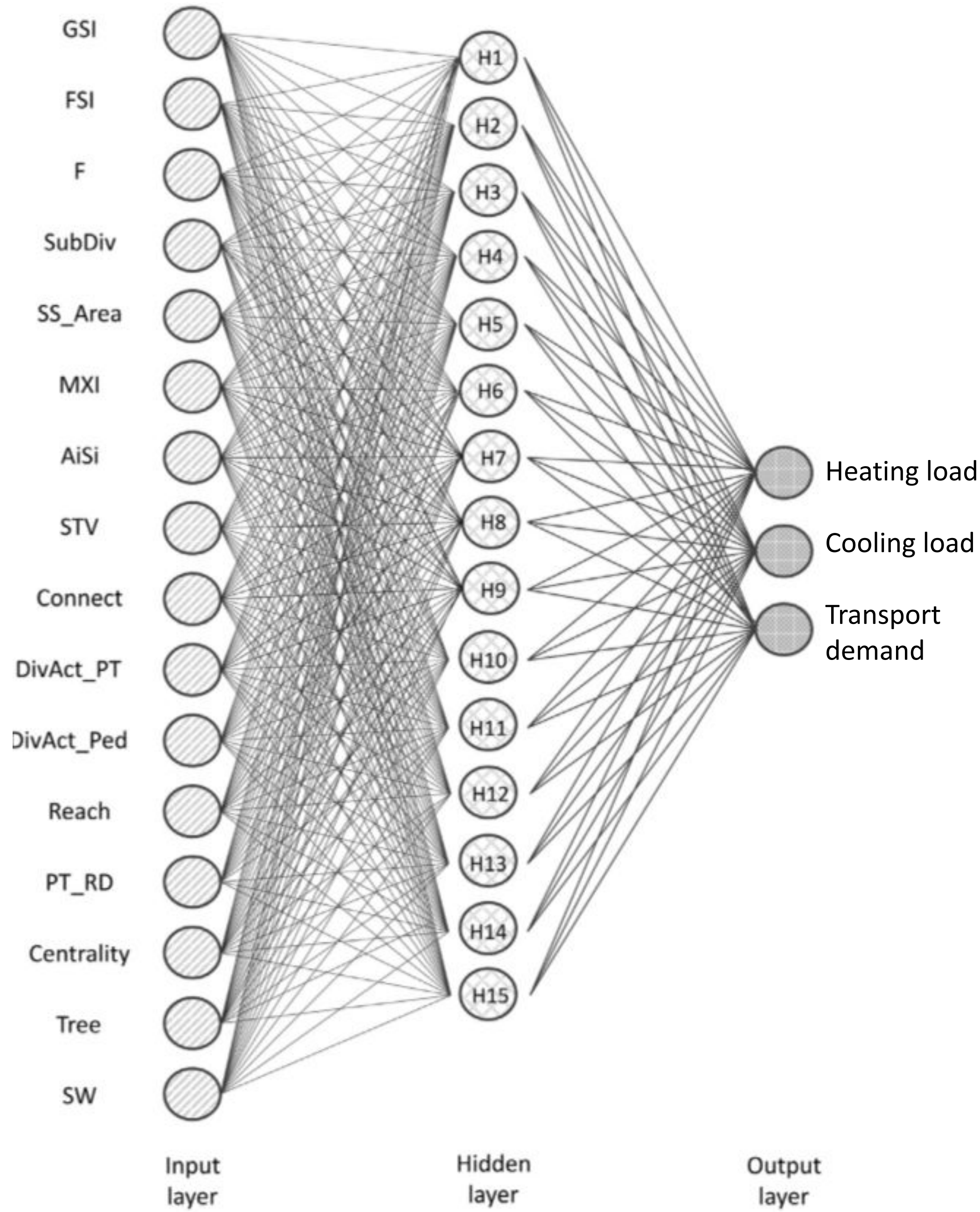
Ilieva and McPhearson (2018) Nature Sustainability

Creutzig et al (2019a) Global Sustainability

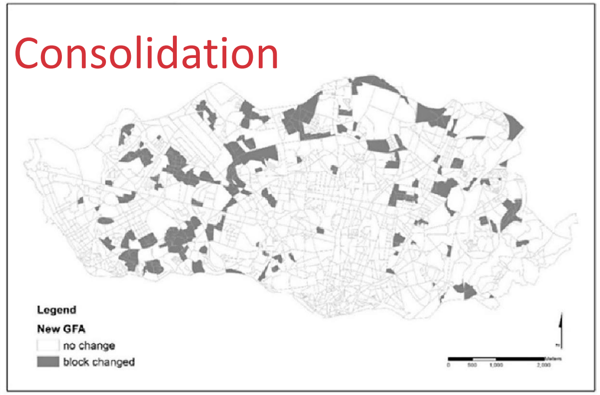
Predict energy use with urban structure data

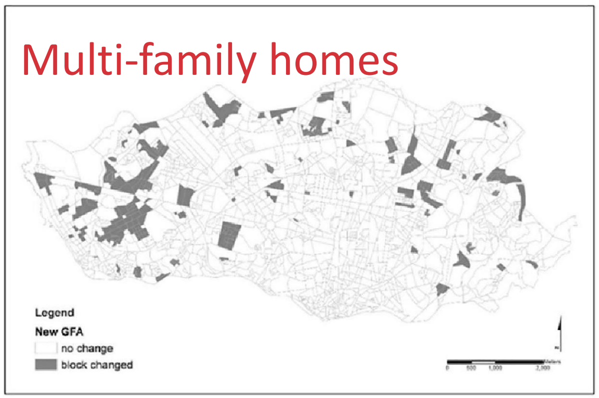
- 16 urban properties, such as compactness, accessibility, centrality, etc.
- Train ANN with data for heating, cooling, and transport demand
- Predict energy use at block-scale

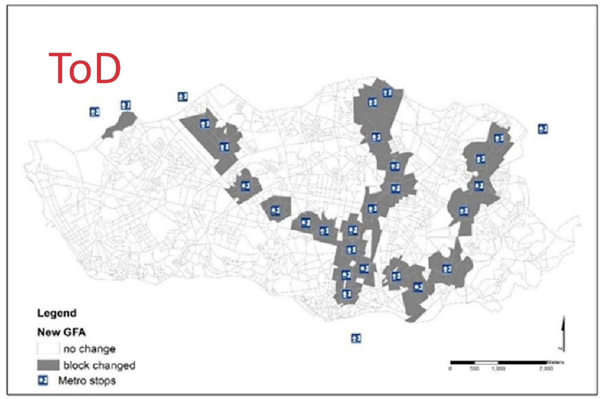
Silva et al (2017)

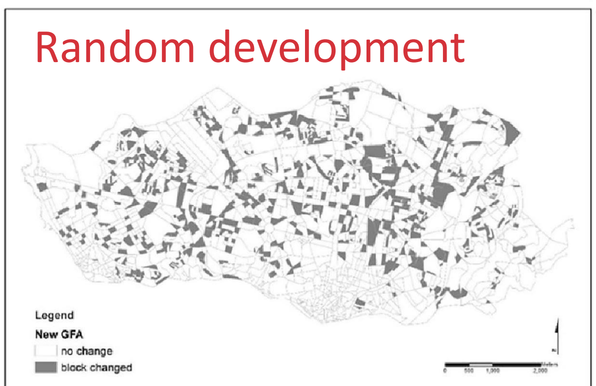


Porto: scenarios





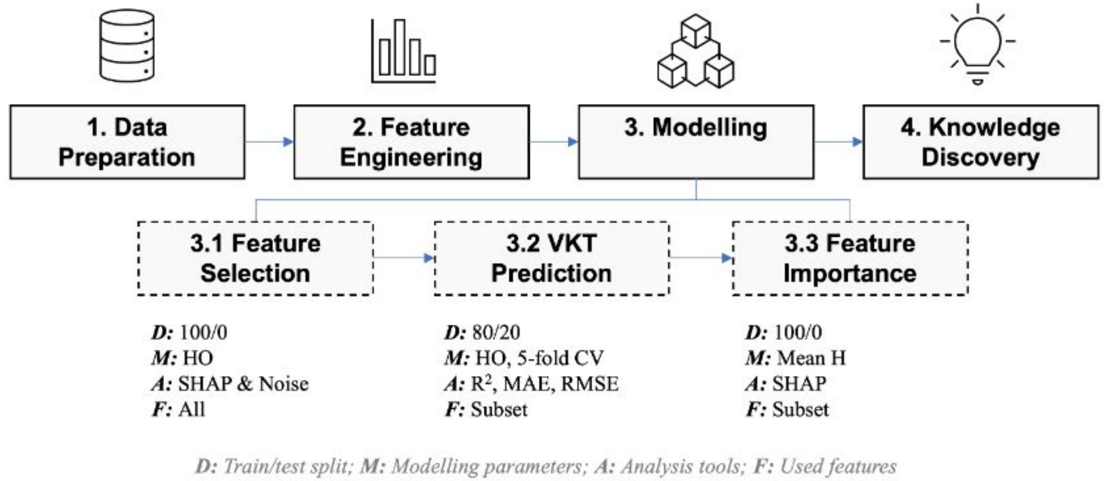




Silva et al (2018)

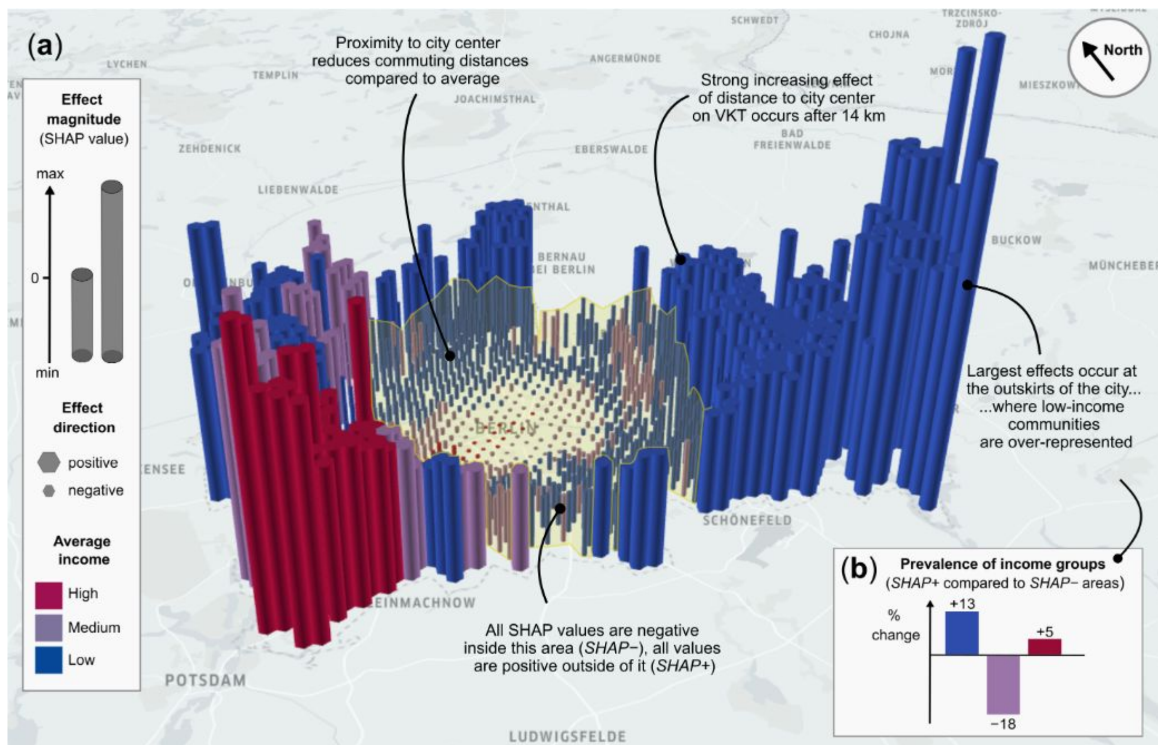
- Design scenarios with 10% additional residential space
- Apply ANN on new scenarios
- Predict change in energy use

- Marginally it is best to compactify, larger changes go along well with ToD

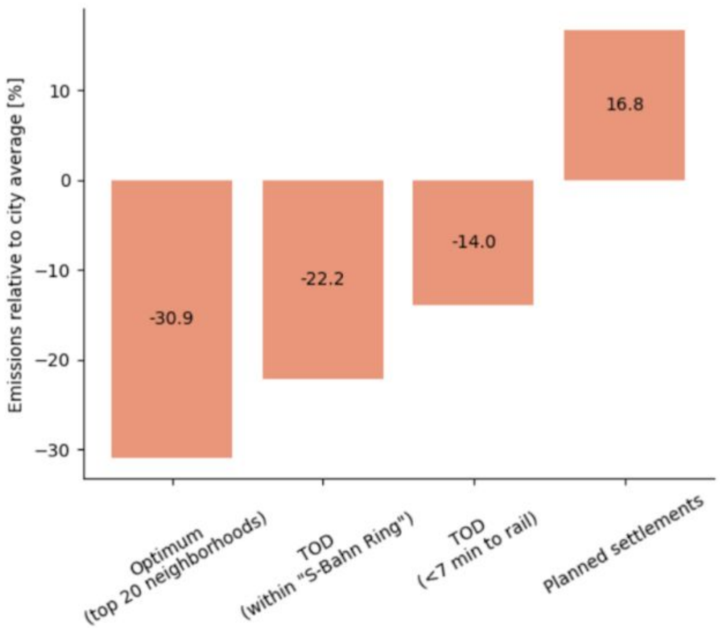


New AI platform to compute urban form metrics relevant to inducing GHG emissions at street and building level

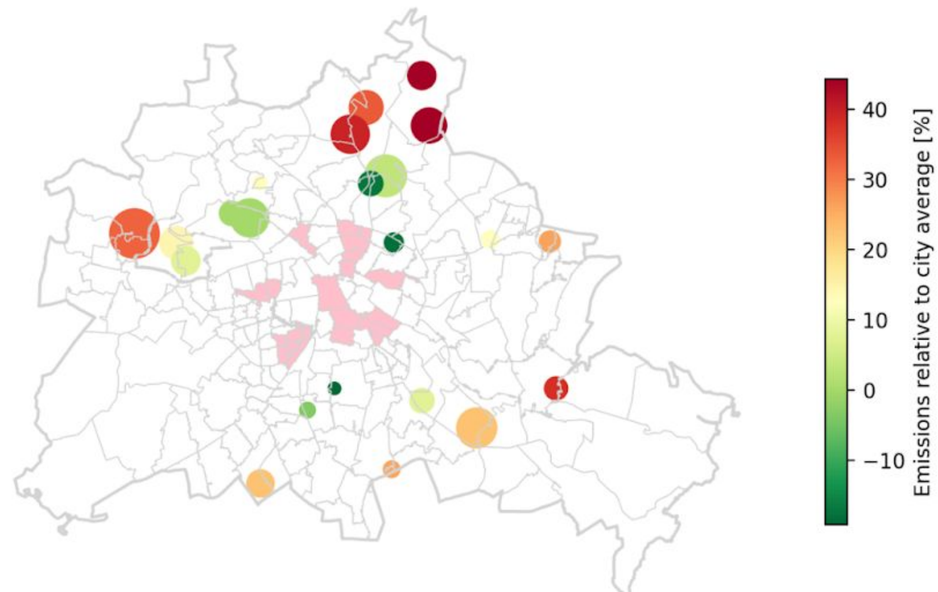
Wagner, Creutzig et al, TRD (2022)



High-resolution AI methods can support urban planning – as demonstrated in evaluating new settlements in Berlin



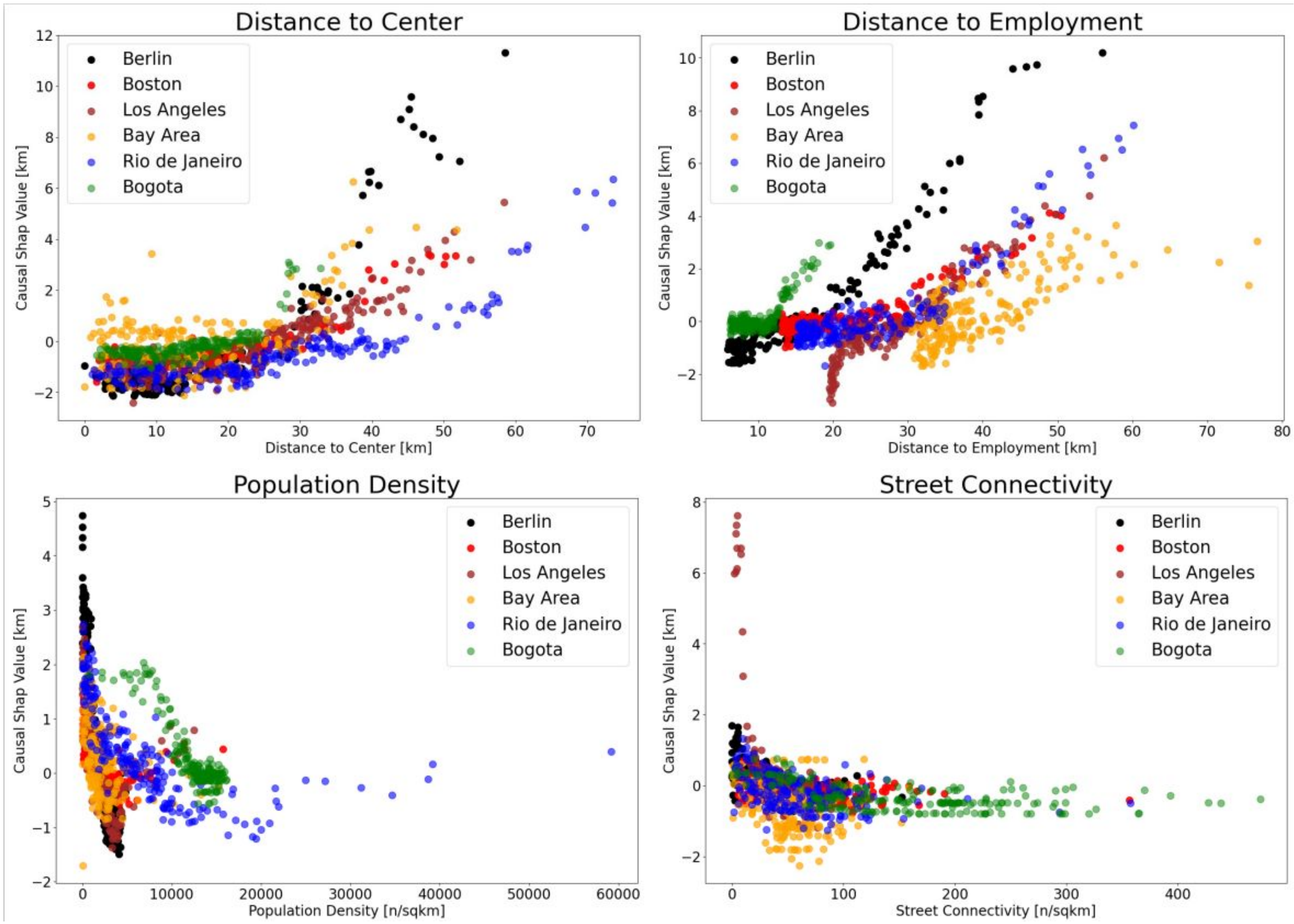
(A)



(B)

Nachtigall, Creutzig et al, in preparation

Identifying urban form causal influence at neighborhoodlevel across cities



Wagner, Creutzig et al, in prepration

Joint governance of data, AI and physical infrastructure

Digital infrastructure

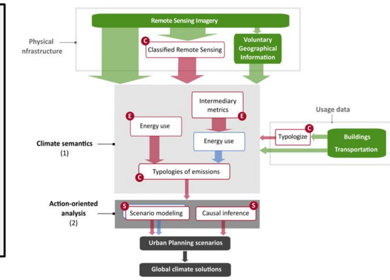
Telework. Confinement dramatically increased telework levels and demand for videoconferencing tools.

- Ready to go
- Institutional alignment

Use digitalization to optimize public transit. Contactless payment and time-specific ticketing to optimize capacity consistent with physical distancing.

Sustainable urban planning. Use big data and machine learning tools to optimize transport and urban planning. Build up urban data governance.

- Vision
- Political stamina



Physical infrastructure

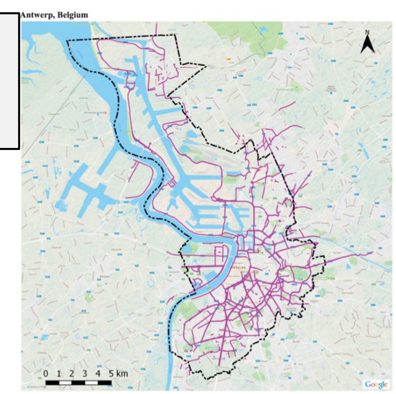
Desolation. High level of confinement emptied streets, especially in cities with high exposure to COVID-19, such as Wuhan, Milan, and New York.

- Ready to go
- Institutional alignment

PUI. Municipalities providing pop-up infrastructure to incentivize more walking and cycling.

Consolidation. PUI made permanent and safe. Continuous network provided.

- Vision
- Political stamina



Confinement | Smart physical distancing | Post-COVID-19

Creutzig et al, ERIS (2022)


SYSTEMIC CONSEQUENCES

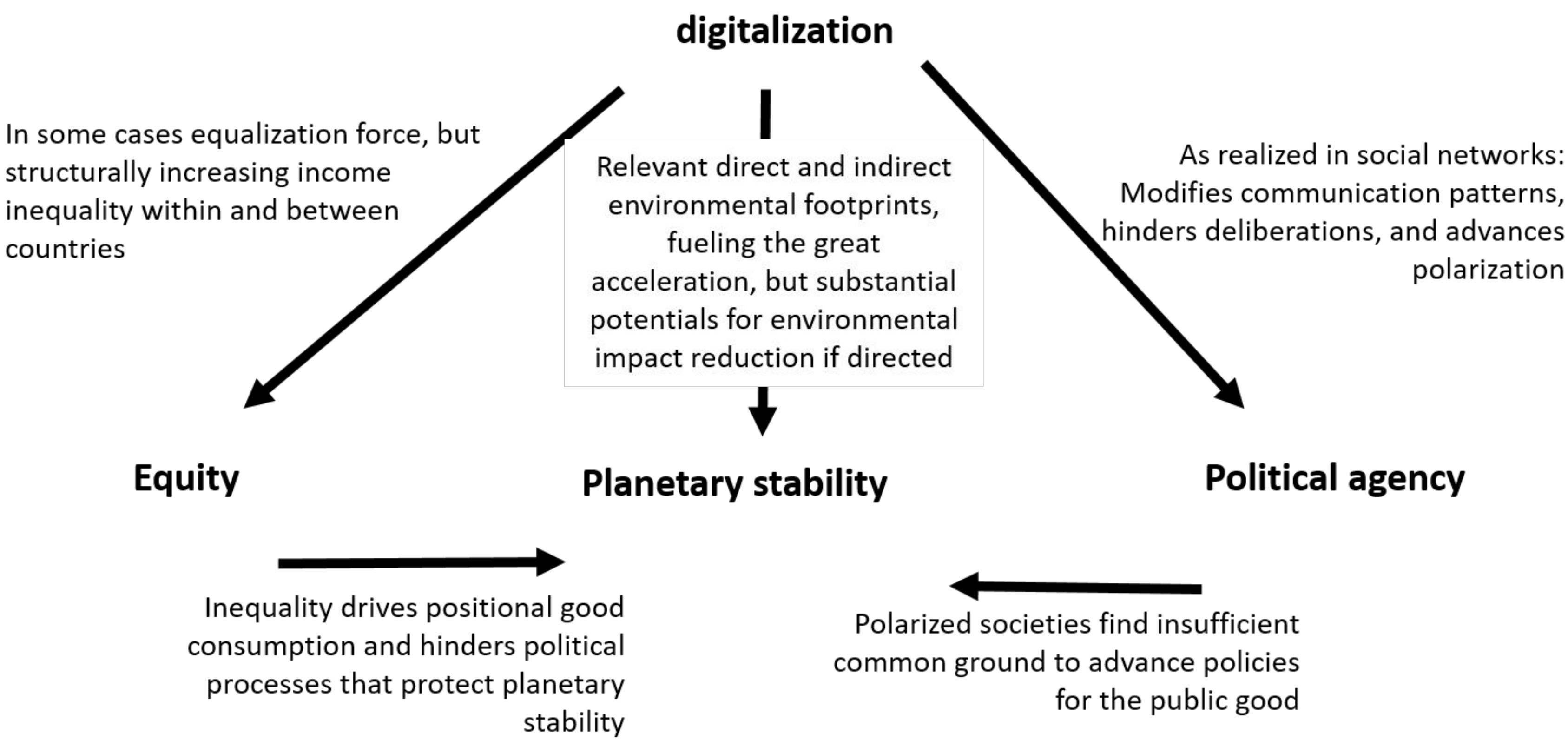
Planetary stability: Accelerating forces trump efficiency gains

- Digitalization force of great acceleration
- Enables both accelerated resource consumption and accelerated efficiency deployment
- Ressource demand long-tailed: proportional shift from few fossils to many minerals

Rapid integration of renewable energy
Vehicle-to-grid technologies
Shared pooled mobility

Energy use in data centers
AI use for oil field exploration
Unlimited deployment of autonomous vehicles

Digitalization, society and planetary stability

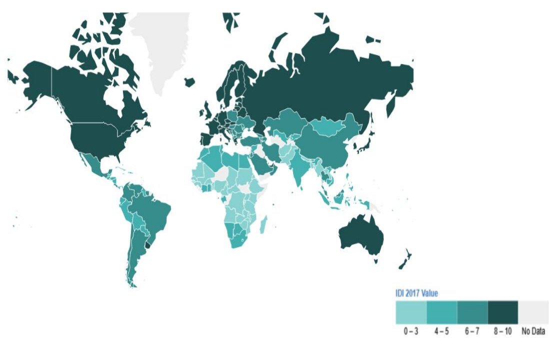


Creutzig et al, Digitalization and the Anthropocene, Ann. Rev. Env. Res. 2022

In balance, digitalization increases inequality

Global

- More opportunities for developing countries to contribute to global markets in the service sector (flat world)
- ICT-based rationalizations substitute for labor-intensive processes and thus erode the competitive advantage of developing countries (74% of all robot installations in USA, China, Germany, South Korea, Japan)



National

- Results in polarization of income, substituting middle-class jobs

Supply side

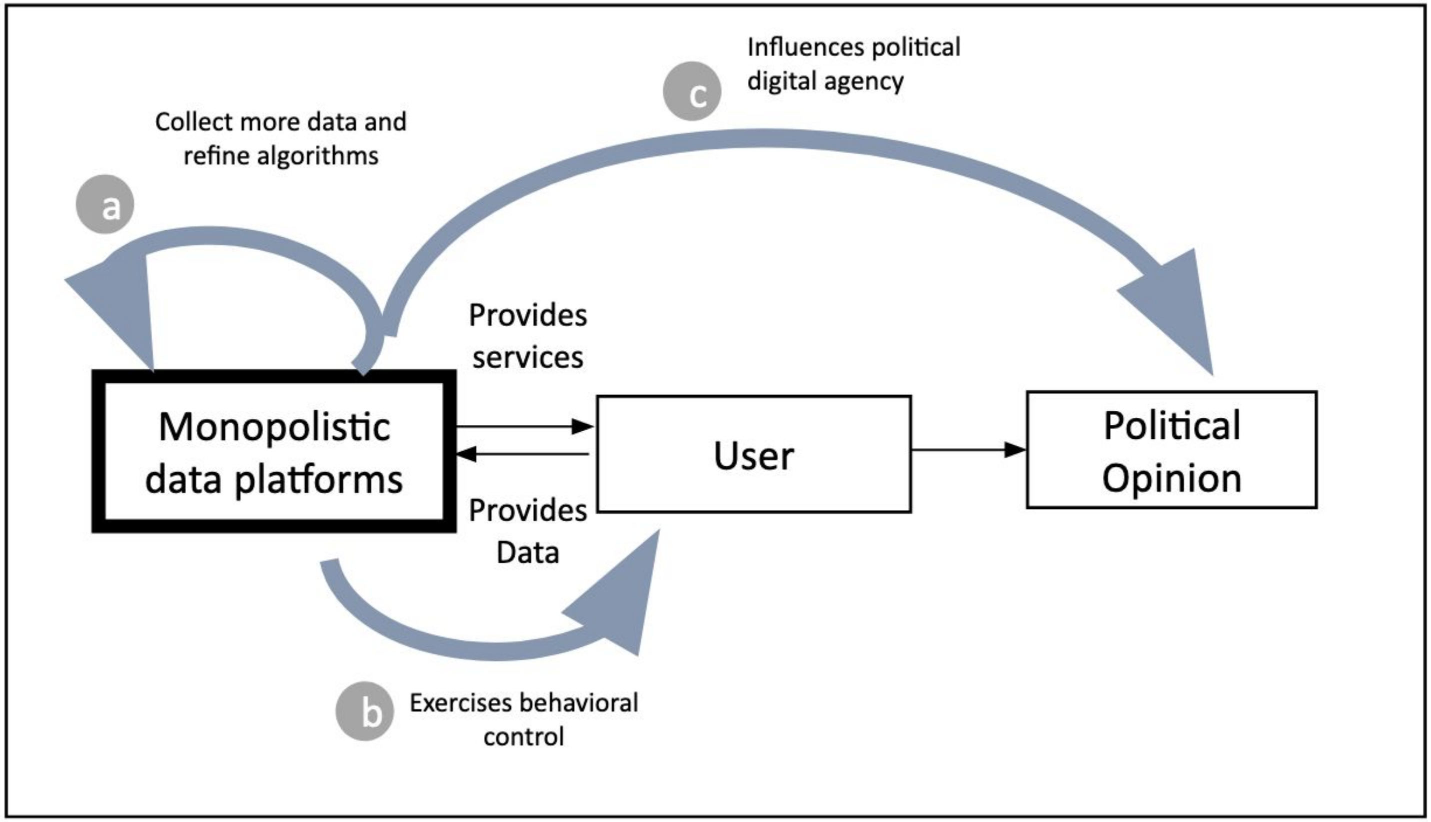
- Mining operations servicing the ICT sector are associated with forced labor, including child labor, excessive working hours, low wages, lack of social protection, discrimination against migrant workers, humiliating disciplinary actions and (sexual) violence

Consumption

- In developed world 87% have access to internet, in developing world 19%

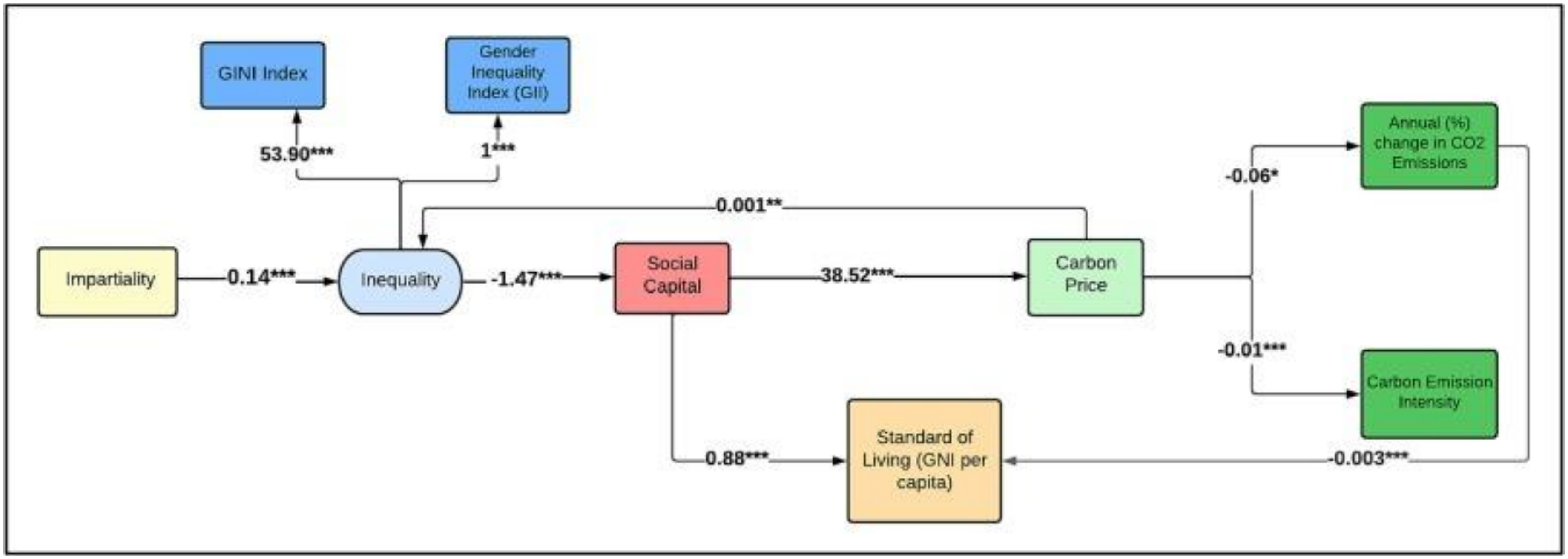
Creutzig et al, Digitalization and the Anthropocene, Ann. Rev. Env. Res. 2022

Political agency: substantial potential but economics of attention and emotion destabilize democracies



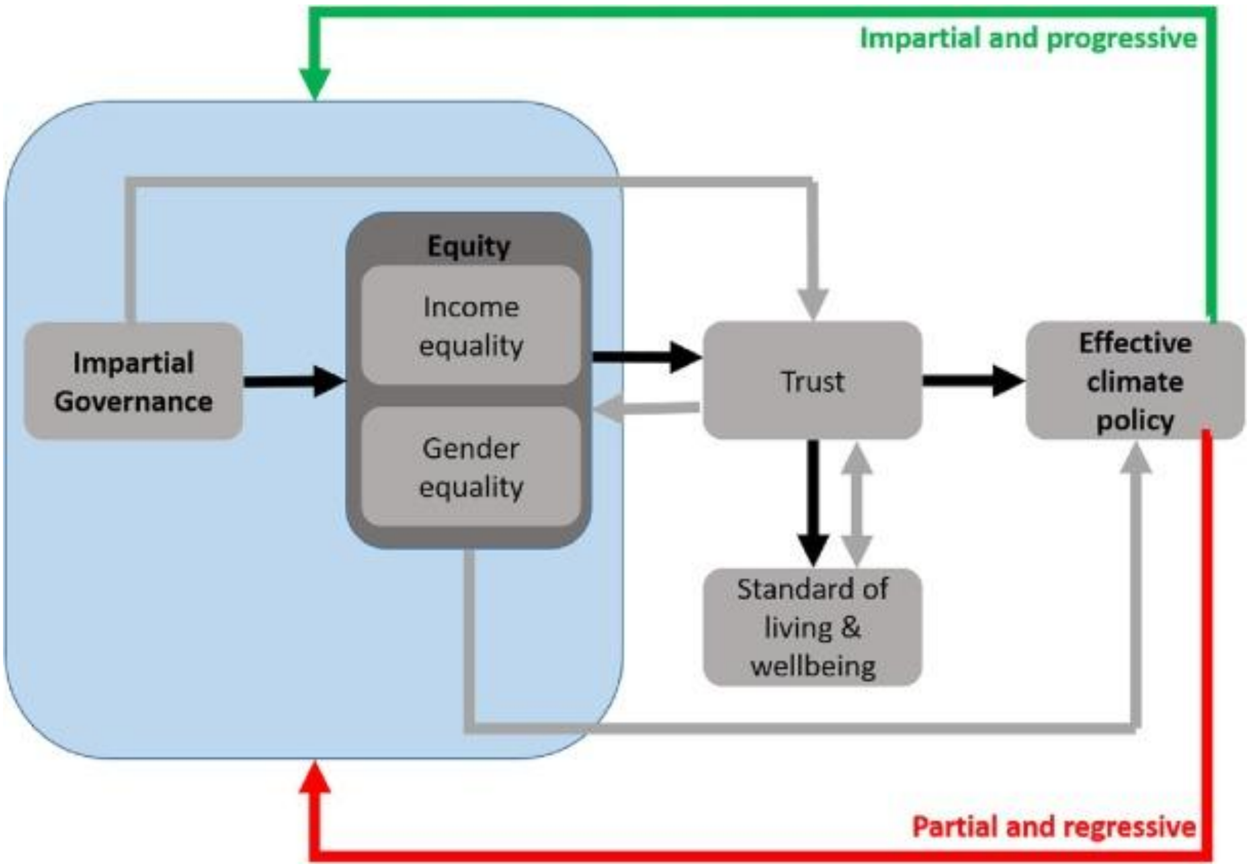
Creutzig et al, Digitalization and the Anthropocene, Ann. Rev. Env. Res. 2022

A structural equation model applied on nation-level data demonstrates that impartial governance fosters social capital and thus climate policies



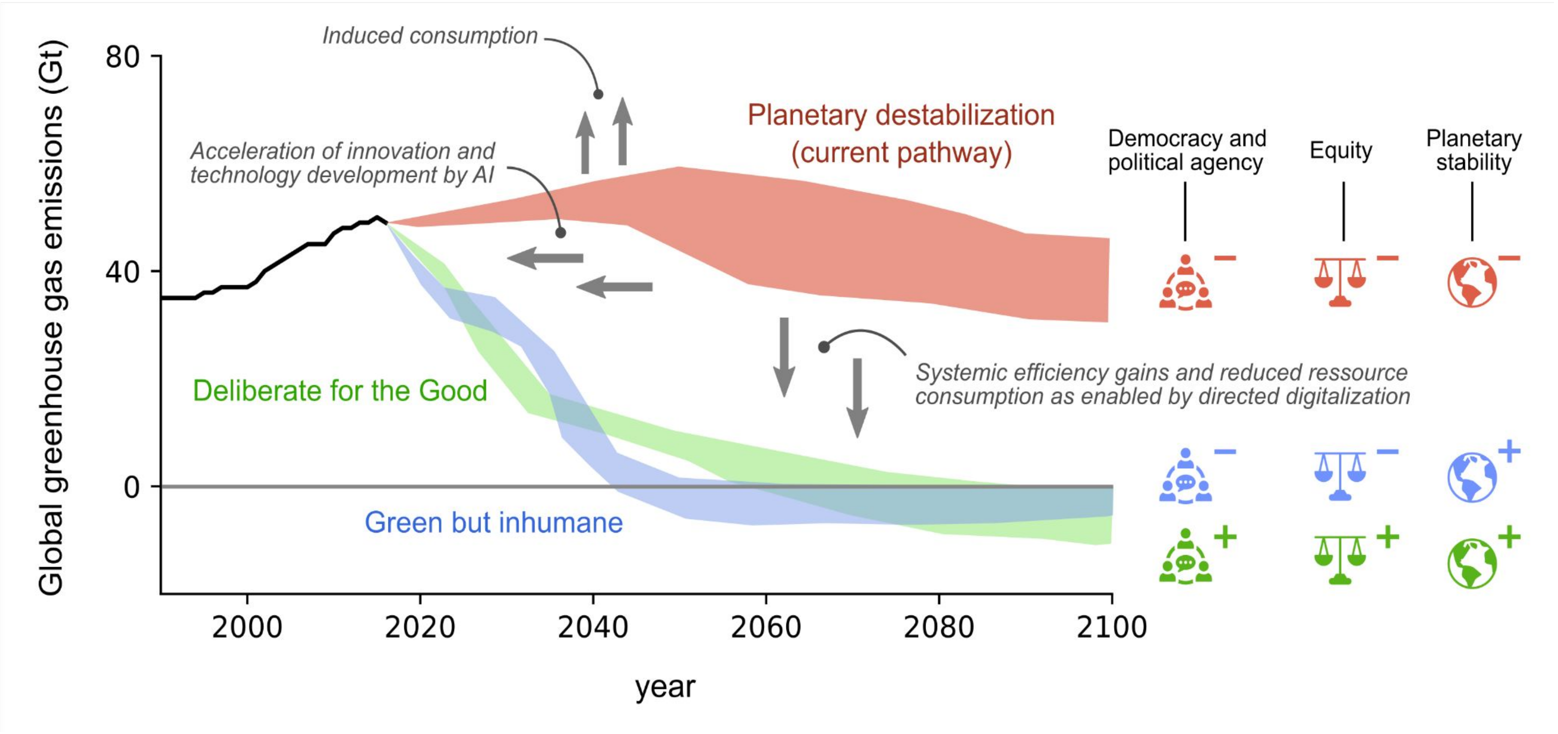
Creutzig et al. 2023 Global Environmental Change

Design of climate policies can contribute to a virtuous cycle



Creutzig et al. 2023 Global Environmental Change

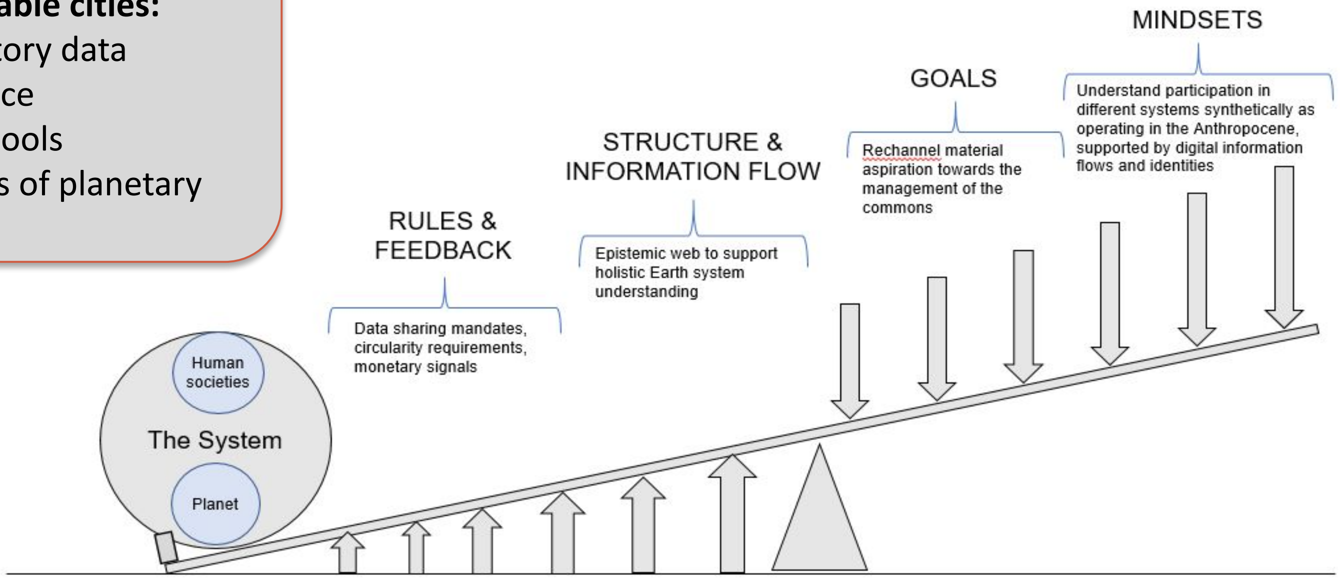
Three pathways of digitalization in the Anthropocene



Creutzig et al, Digitalization and the Anthropocene, Ann. Rev. Env. Res. 2022

Key leverage points

Apply to smart conscious sustainable cities:
- Participatory data governance
- Big data tools
- Conscious of planetary stability



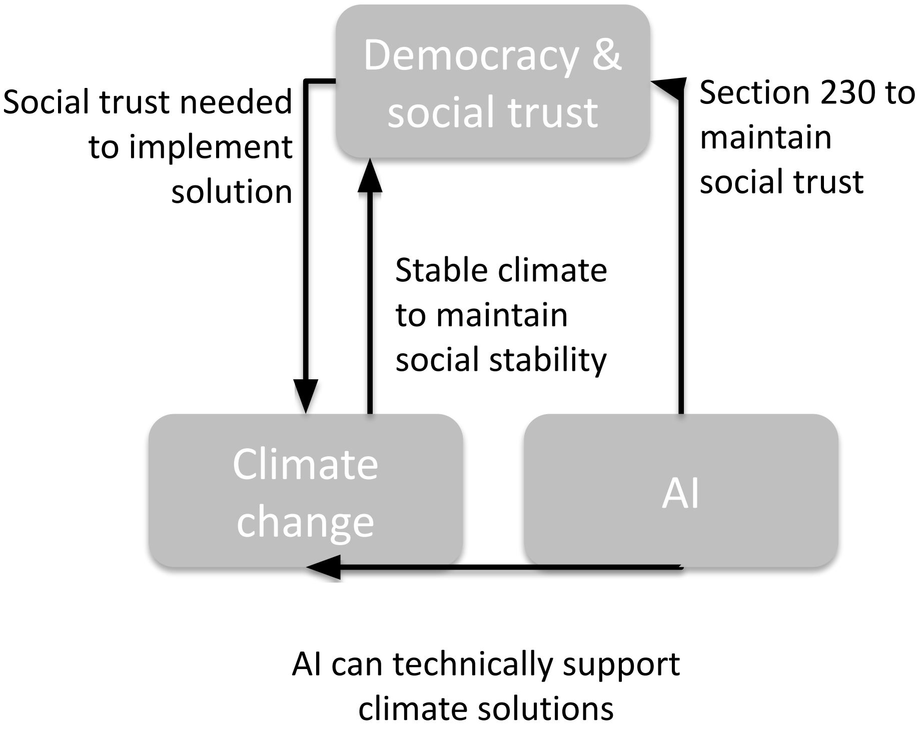
Summary:
- Digitalization part of planetary dynamics of the Anthropocene, via environmental, social and political channels (co-evolution)
- Set appropriate goals, developing balanced epistemic web, and apply new rules via public policy

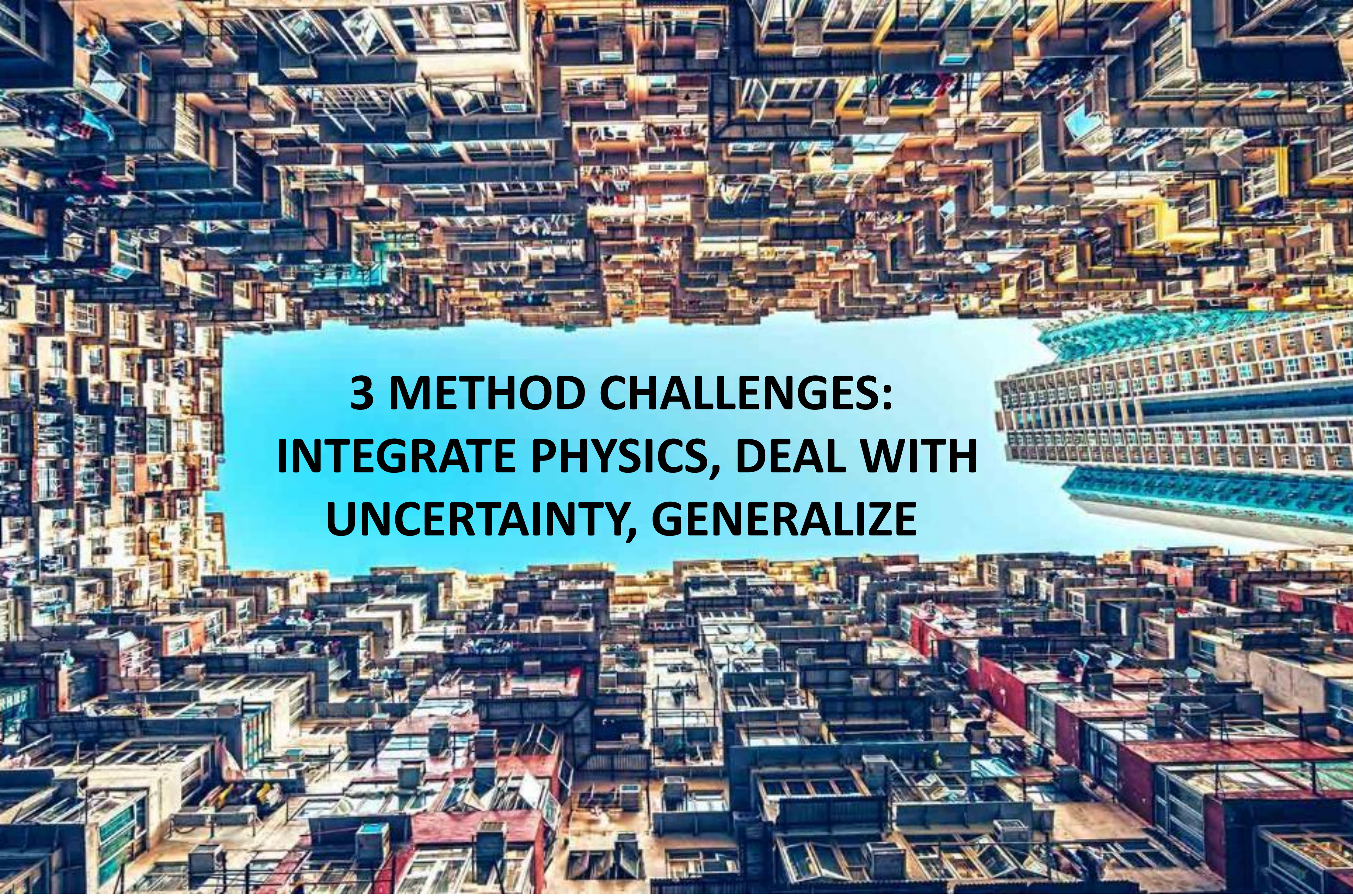
Three-tiered architecture of AI for climate change mitigation

Governance	**Avoid** run-away consumption pathways Direct **improved** energy technologies Direct enabling tools to **shift** & accelerate mitigation
Pathways	**Implement** efficient energy end use technologies, such as shared mobility systems, highly accessible cities, and renewable energy grid integration
Tools	**Develop** AI-based tools for agile climate governance, low-carbon urban planning that accelerate energy conversation and climate mitigation efforts

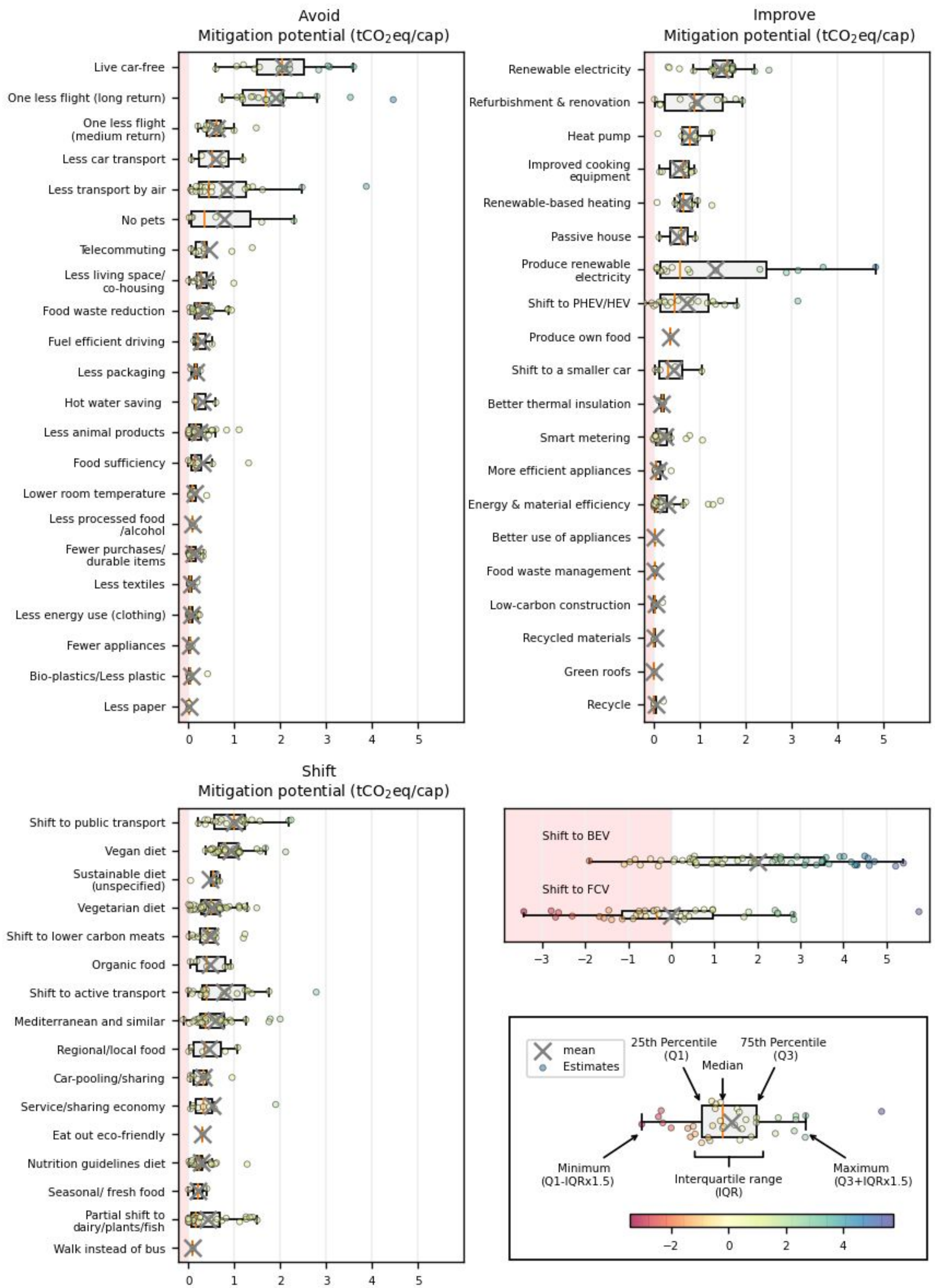
Are the AI and climate issues connected?

- Policy-wise: NO
  - Climate: carbon tax, phase out fossils, etc.
  - AI: Section 230, DMA, etc
- Technically: YES
  - AI can provide efficient climate solutions
- Conceptually: YES





3 METHOD CHALLENGES: INTEGRATE PHYSICS, DEAL WITH UNCERTAINTY, GENERALIZE



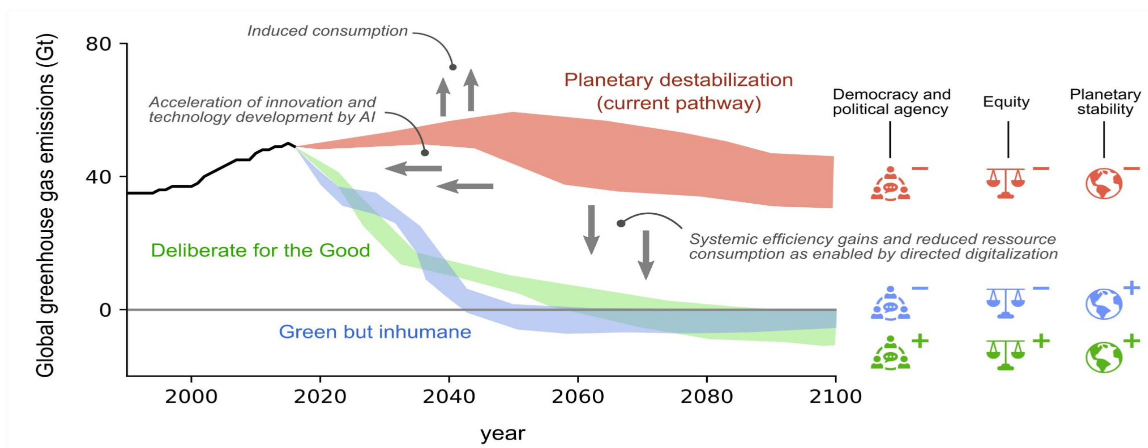
Consumption options categorized into avoid-shift-improve, with major potential in mobility

Based on Ivanova et al 2020; figure design by Max Callaghan

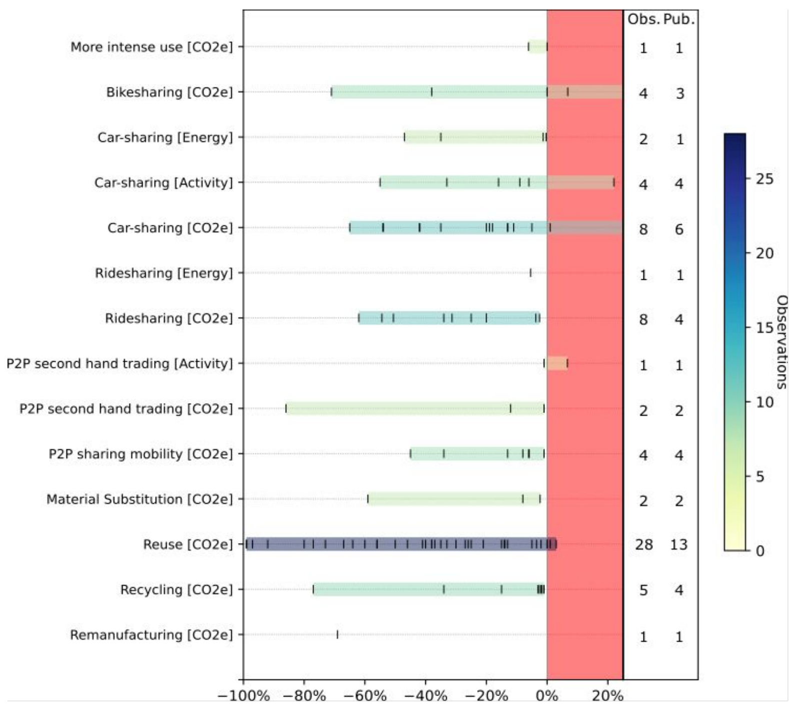
AI governance for climate change mitigation: the urban example

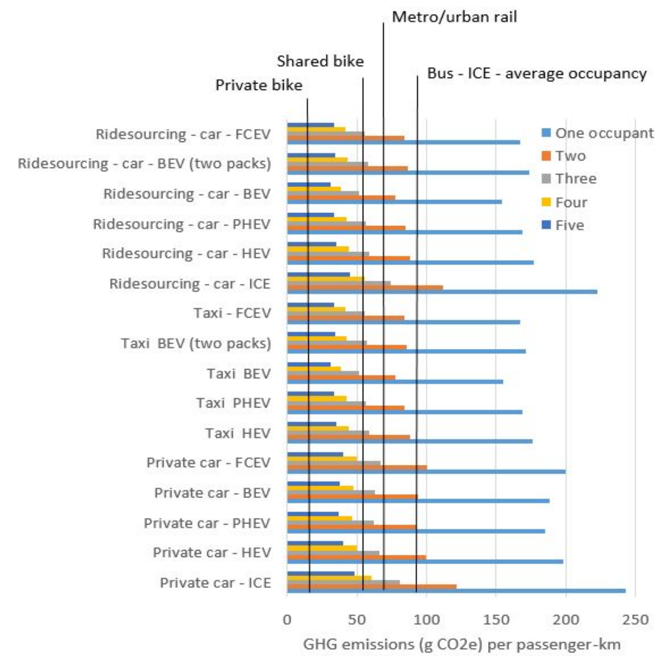
Make use of agile AI-based urban planning systems to:

- Avoid high energy consumption induced by inefficient urban planning and urban sprawl
- Improve energy efficient mobility services and housing use to reduce GHG emissions
- Shift and accelerate mitigation pathways by accelerating planning processes and rapidly adapt (street) infrastructures



In particular by sharing material stock and vehicles (occupancy)





Synthesis by Nico Heeren, Eric Masanet and Alessandro Sanchez Pereira; right panel based on ITF, 2020