AI in Energy Transitions

The Netherlands Environmental Assessment Agency (PBL)

Grey Swans lecture, 17 June 2025

Professor Charlie Wilson

Environmental Change Institute, University of Oxford

iDODDLE

The Impacts of Digitalised Daily Life on Climate Change

Environmental *Change* Institute

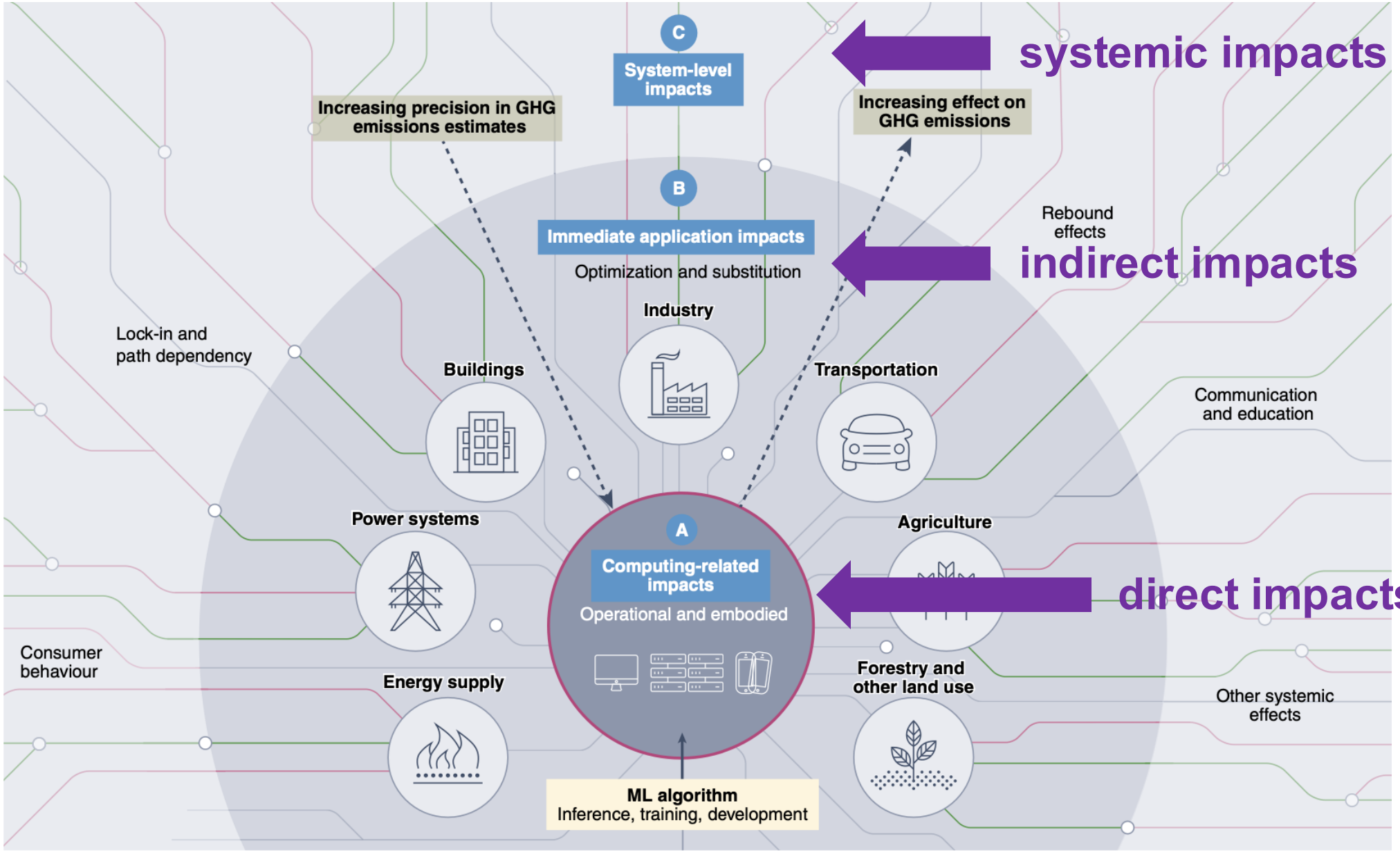
eci

UNIVERSITY OF OXFORD

erc European Research Council

Consolidator Grant #101003083

AI impact on energy transition is diffuse (AI = GPT!)



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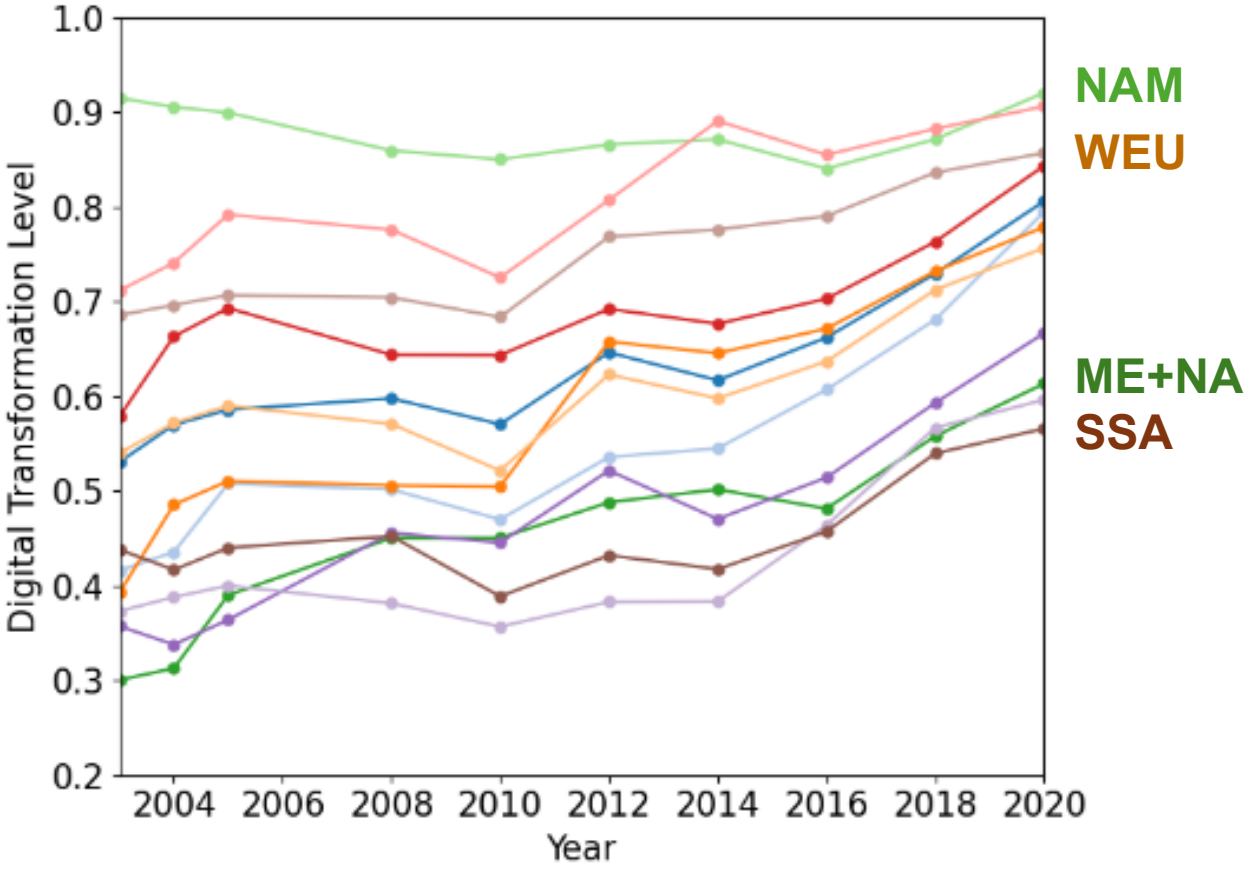
AI in energy transitions – outline of talk.

1. Digital transformation in the SSPs.
2. AI & data centres: *direct* impacts on energy.
3. AI use cases: *indirect* impacts on energy.
4. AI *systemic* impacts on energy transitions.

Projecting digital transformation in global scenarios.

***historical*: E-Gov Development Index**



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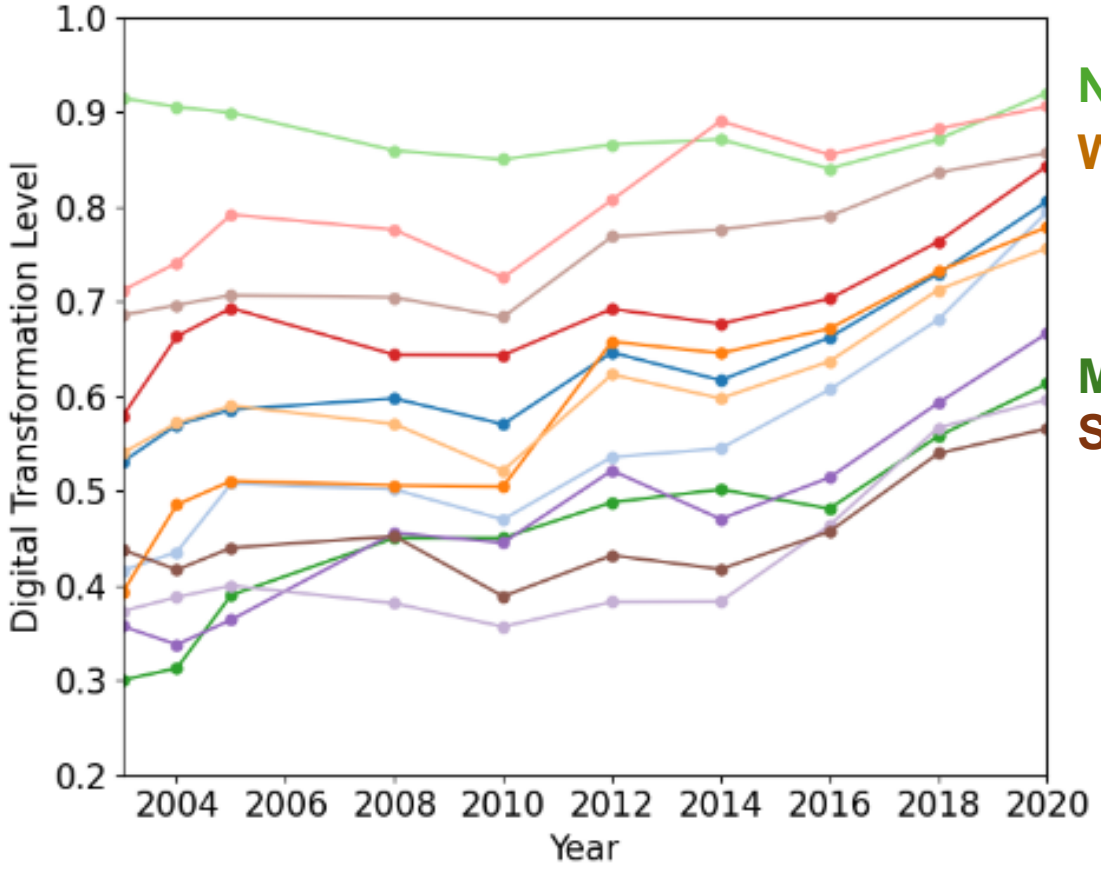
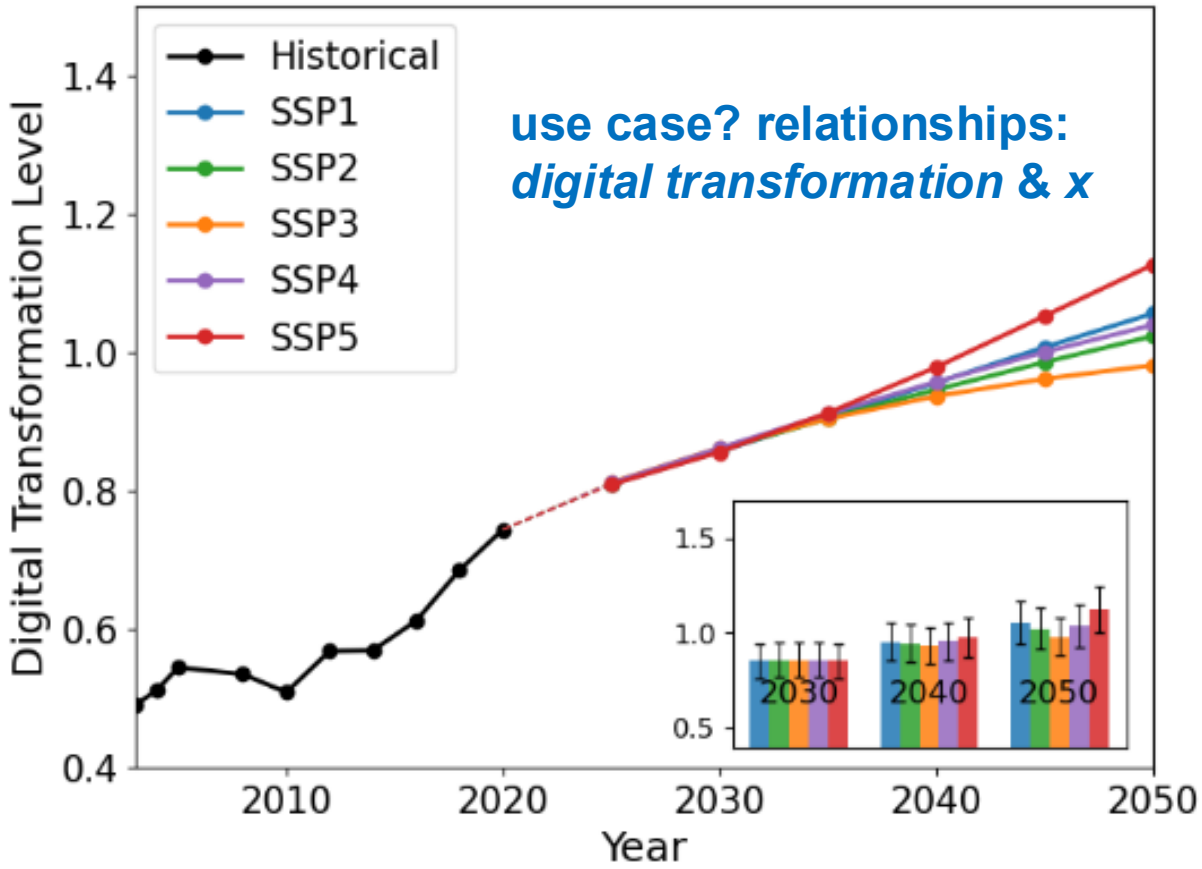


NAM
WEU

ME+NA
SSA

***future*: SSP storyline consistent projections**



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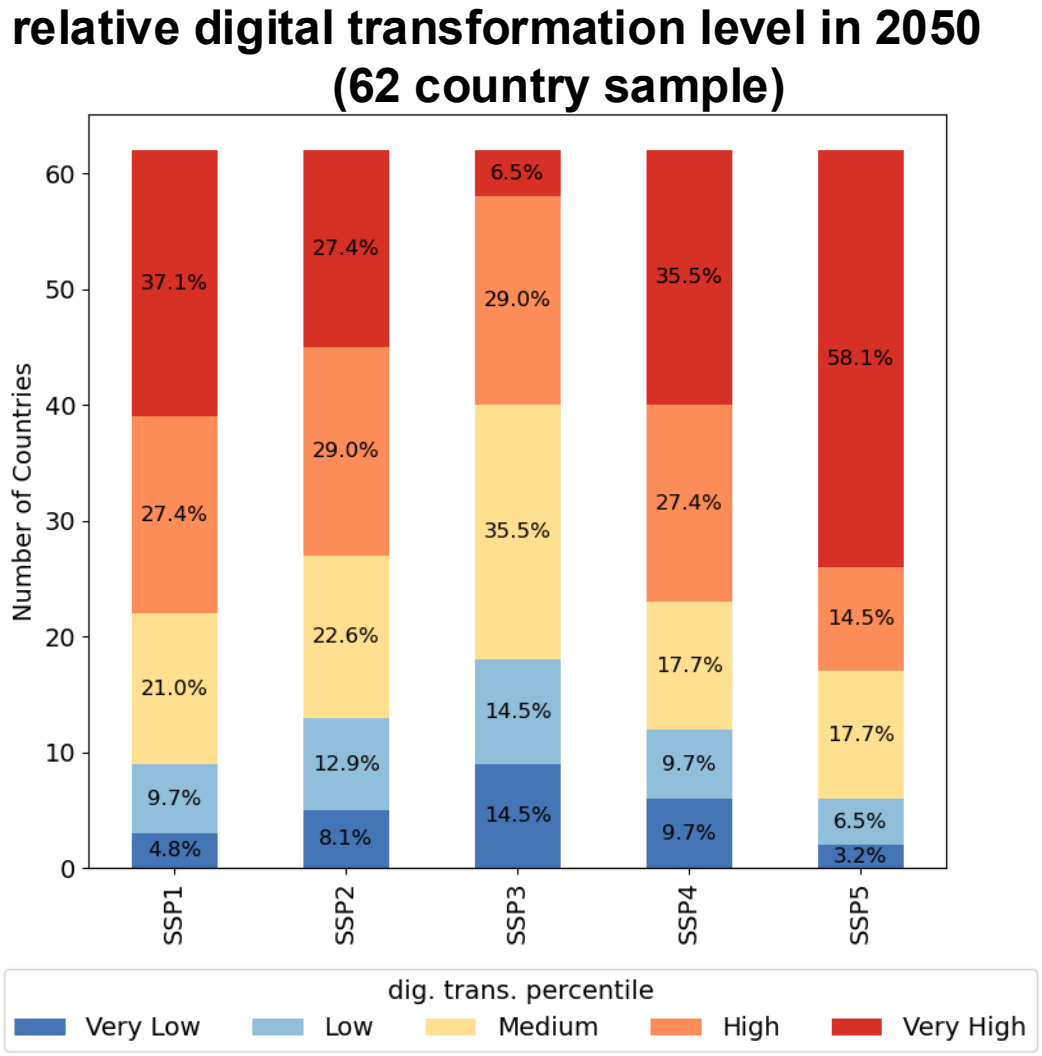
Future digital divide compounds inequality in some SSPs.



62 countries extrapolated to global:

<u>under SSP3 assumptions by 2050</u>,

very low to low digital transformation for

47% of all countries
35% of total population (3.5 billion people)

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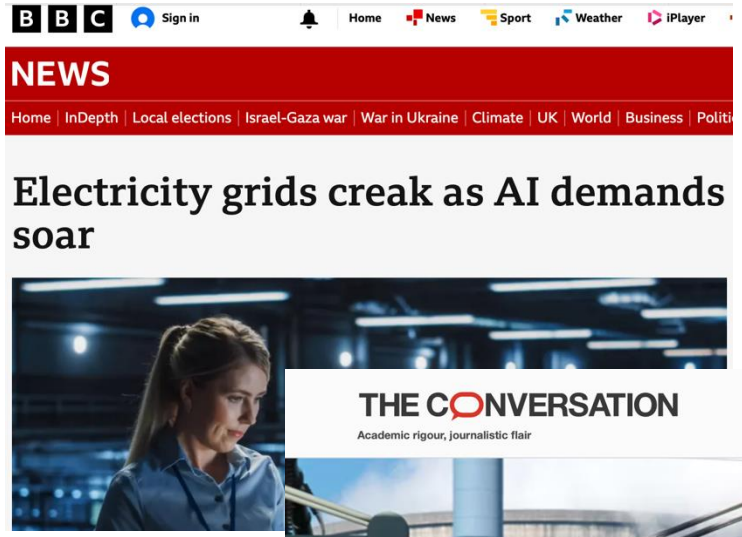
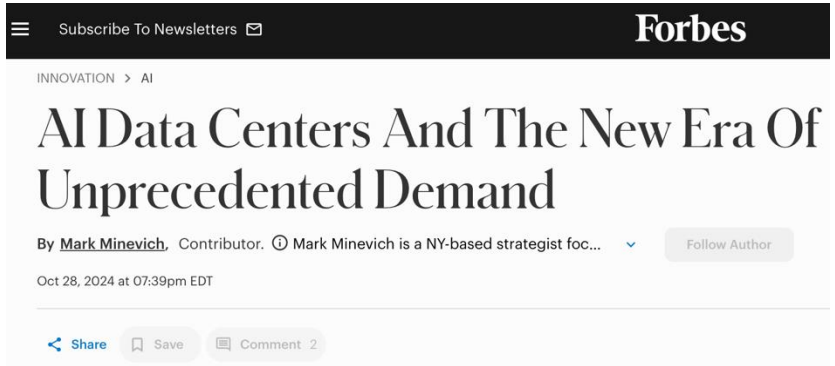
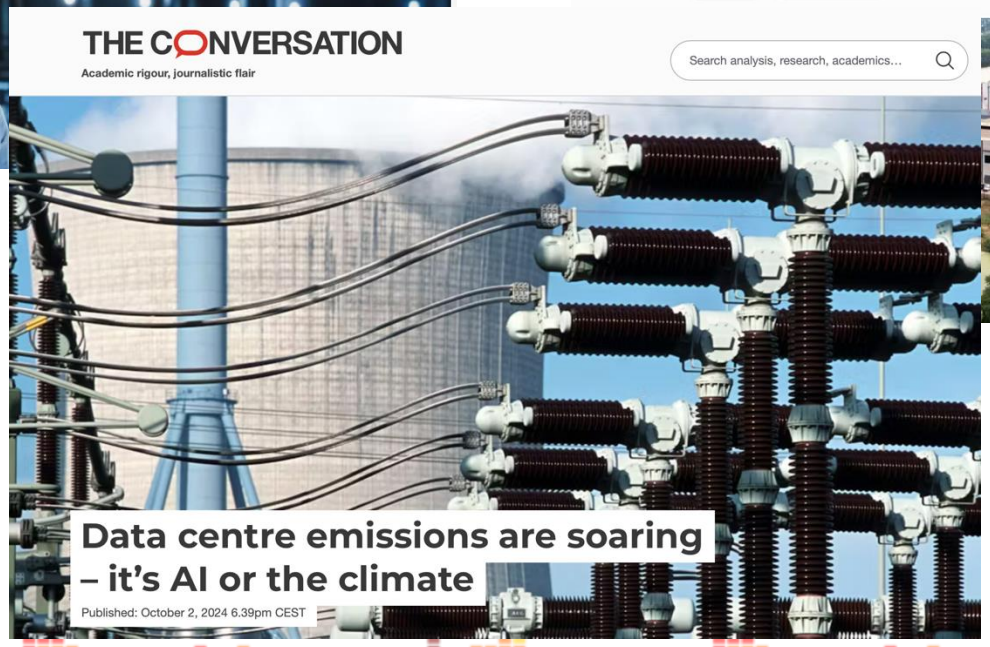
AI impact on energy & climate = data centres?







https://www.datacentermap.com/the-netherlands/

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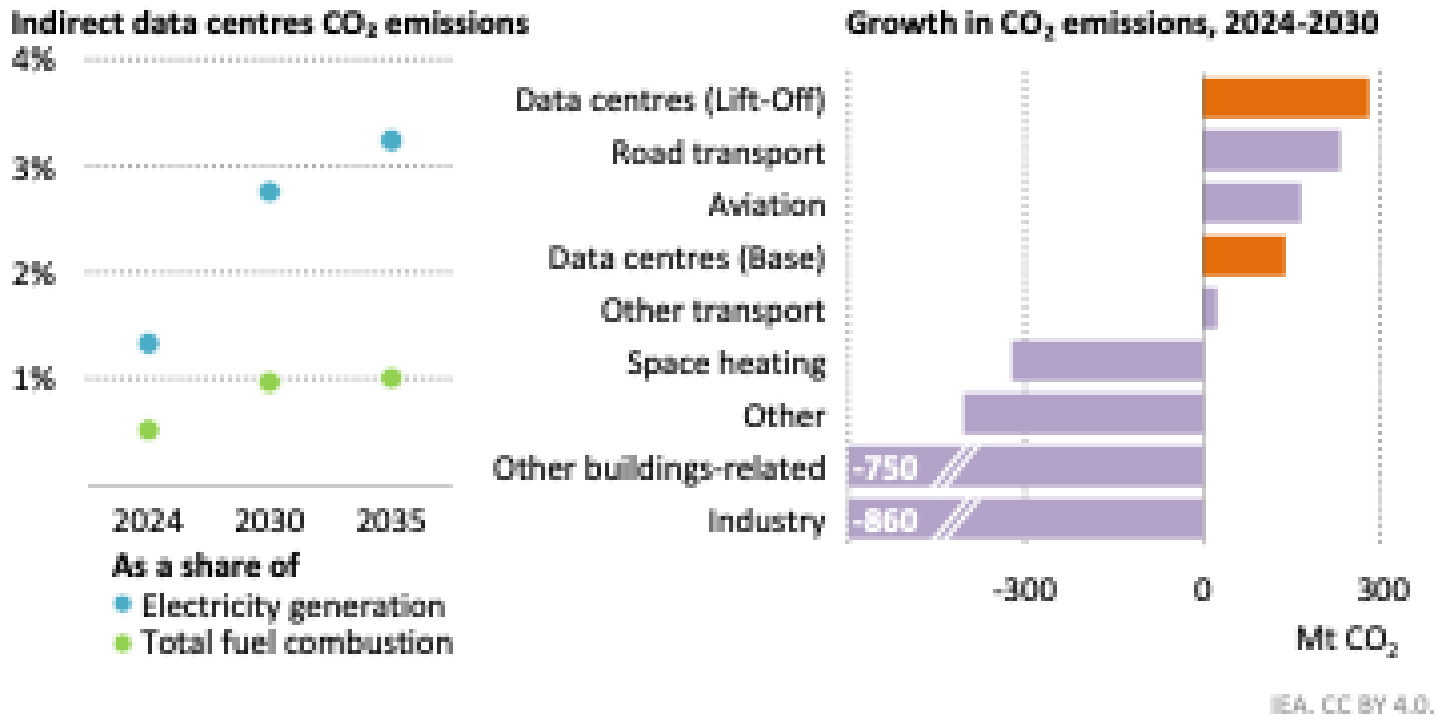
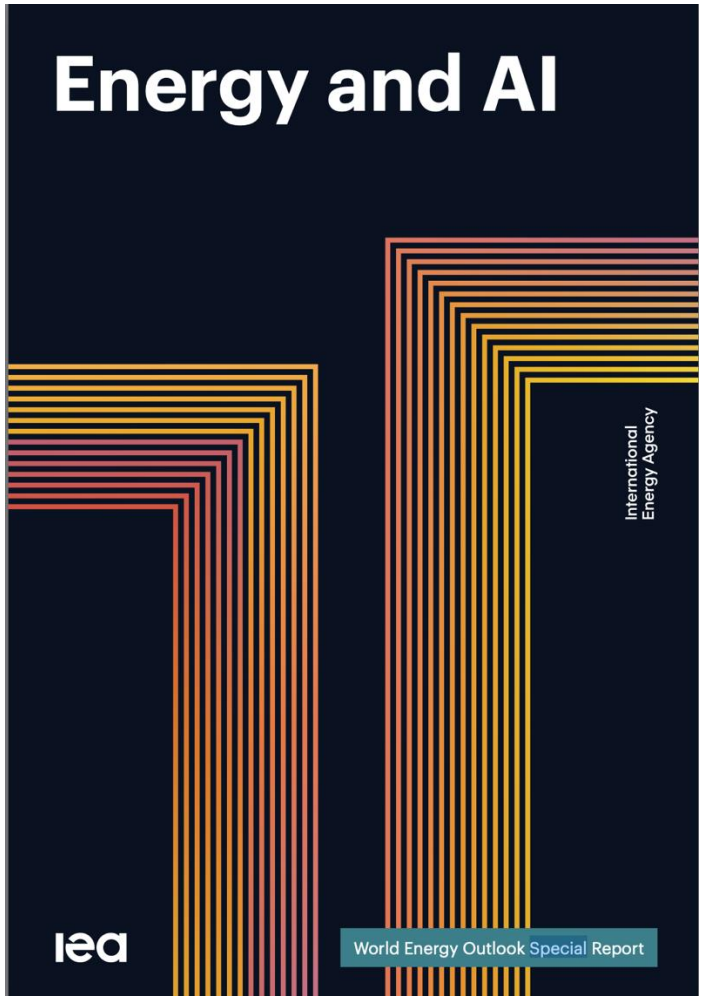
Energy-hungry AI data centres projected to scale rapidly.

Figure 5.28 ▷ Indirect data centres CO_2 emissions and CO_2 emissions growth by sector (not considering AI impacts), 2024-2030



Data centres are on track to be responsible for 3% of electricity generation and 1% of total combustion emissions by 2030; they are among the few sectors that show growth to 2030



IEA. 2025. Energy and AI.
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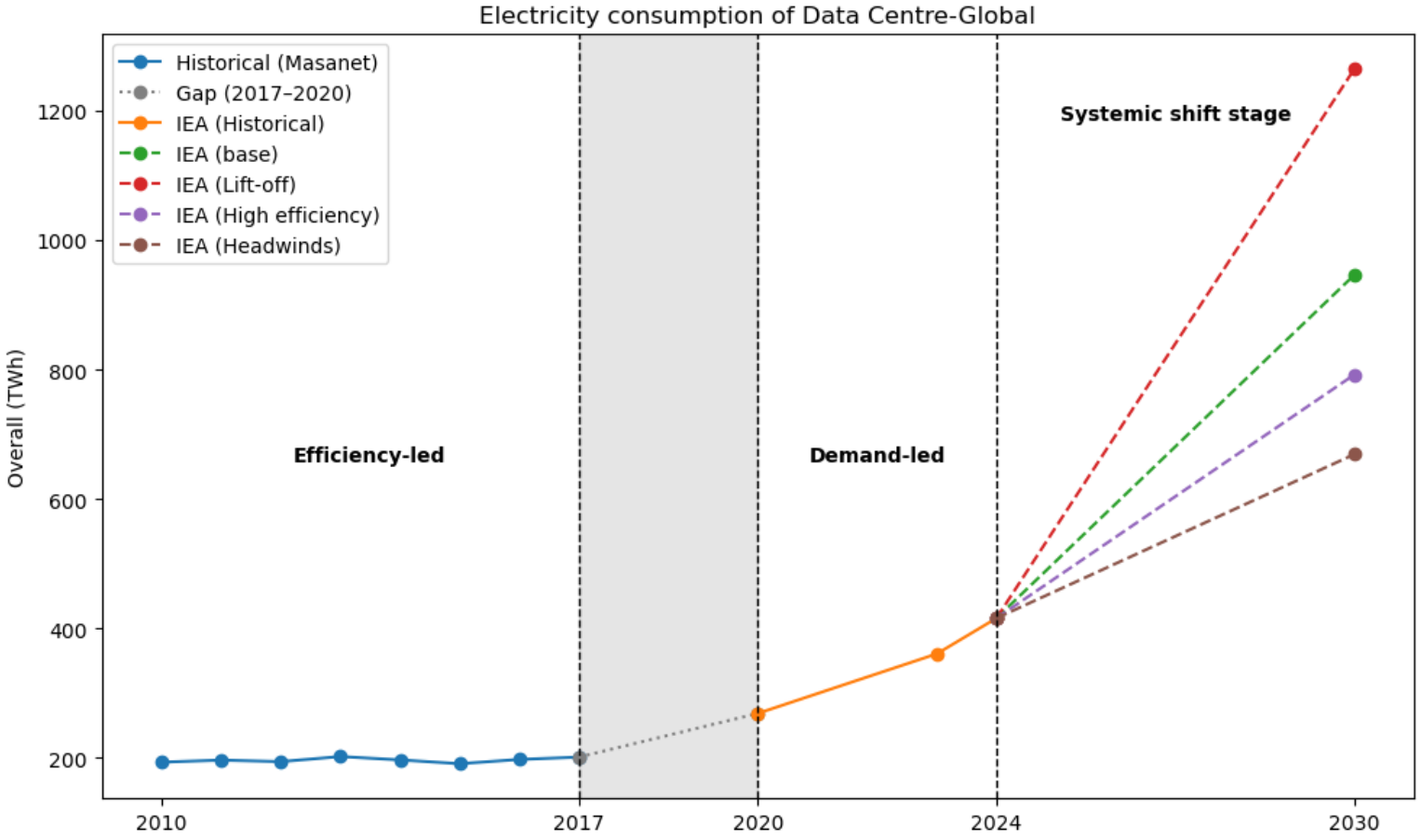

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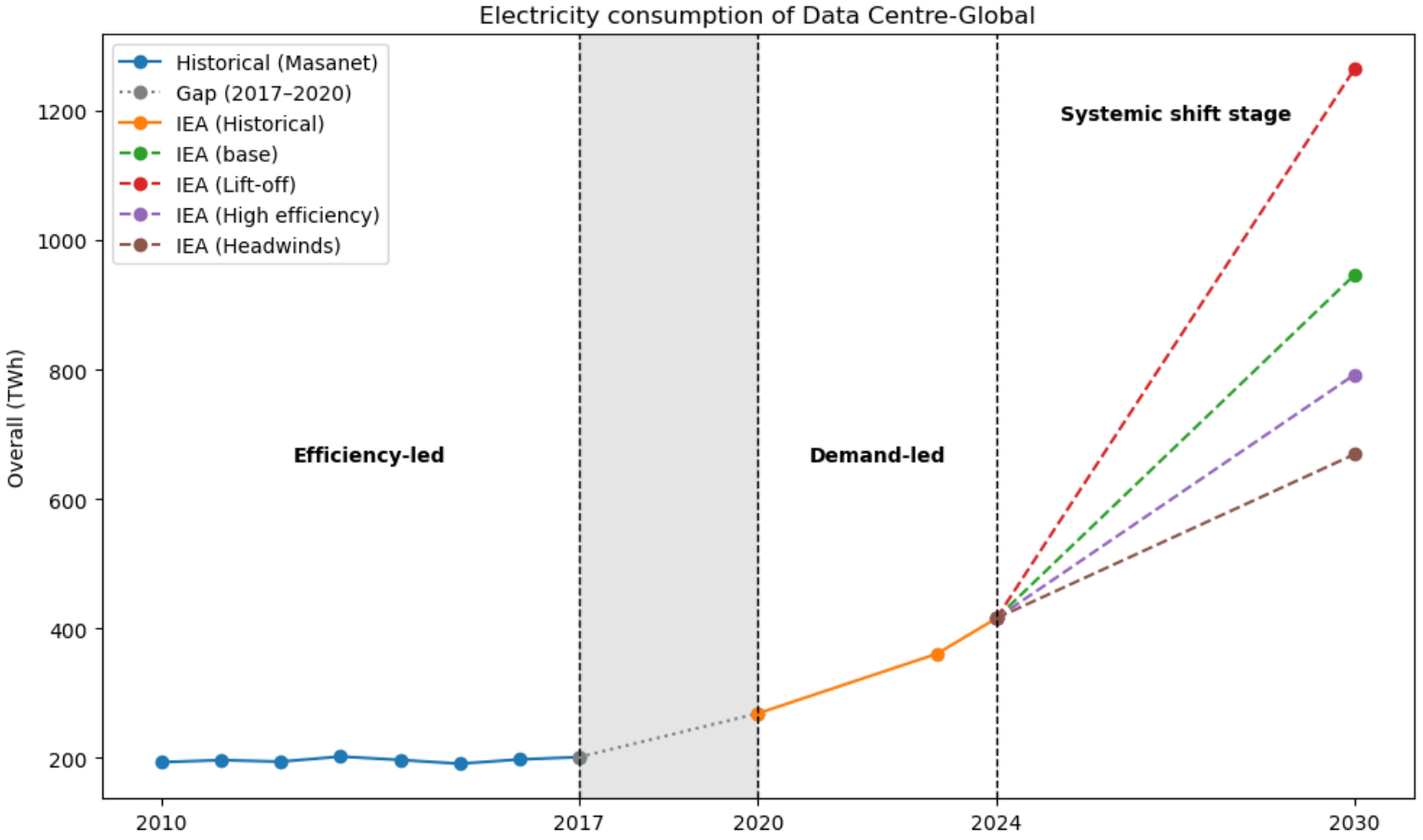

***Global* growth <–> *local* constraints**

- grid connections, network capacity
- available (low carbon) power
- permitting & build timelines (SMRs!)
- latency, proximity to demand centres

+ Lovins (2025): risk of 12x overbuild

Wilson, C., Fan, Y. V., & Amanta, F. (2025). *Oxford Energy Forum*, *Artificial Intelligence and its Implications for Electricity System*(145), 10–15. https://www.oxfordenergy.org/publications/artificial-intelligence-and-its-implications-for-electricity-systems-issue-145/

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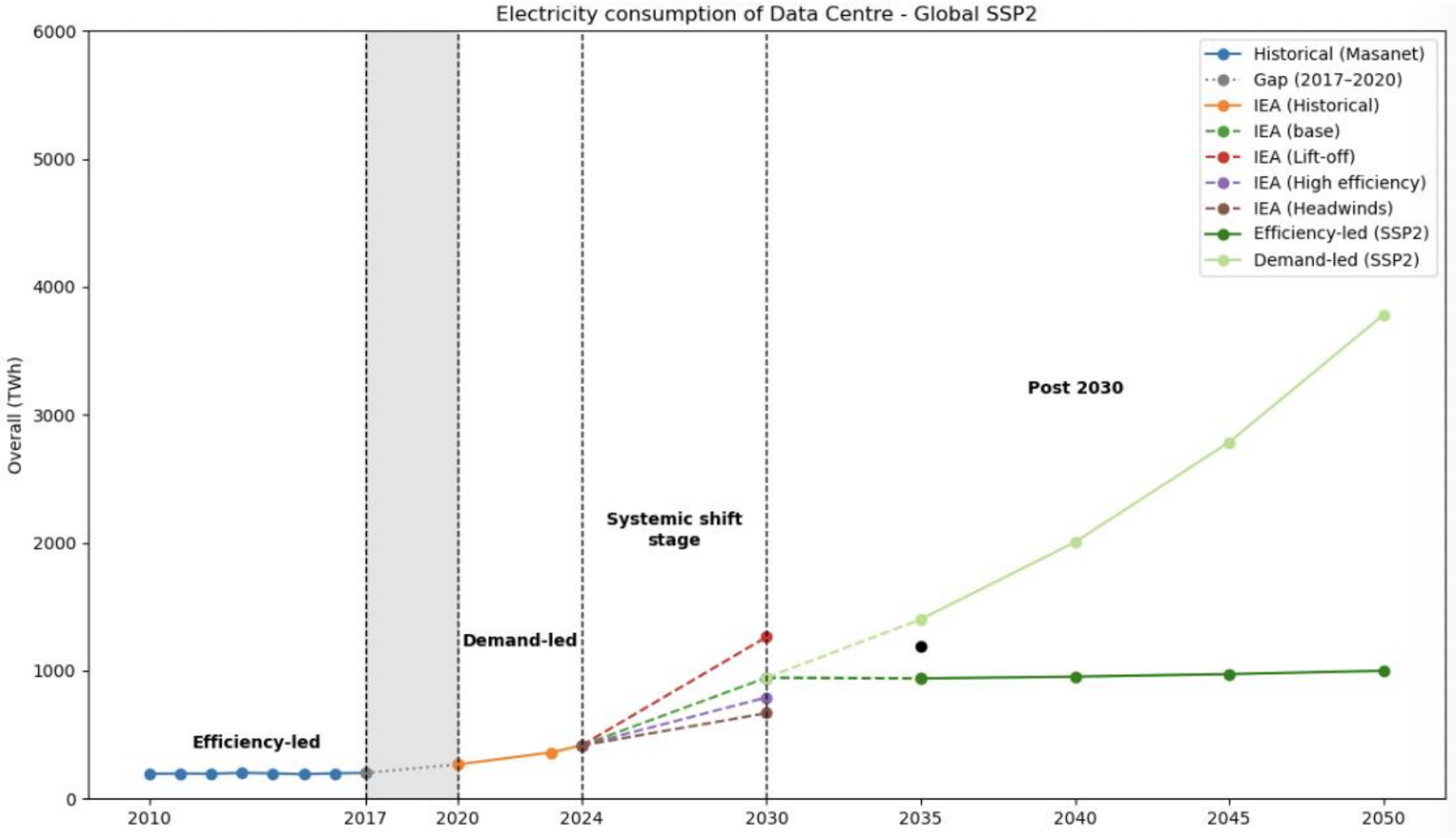
Long-term data centre energy footprints? Very uncertain.



SSP consistent projections

calibrated to elasticity of ***data centre energy demand*** with respect to ***digital transformation***

observed historically

(shown here: SSP2)

Yee Van Fan analysis.
https://idoddle.org/new-iea-report-on-ai-and-energy/

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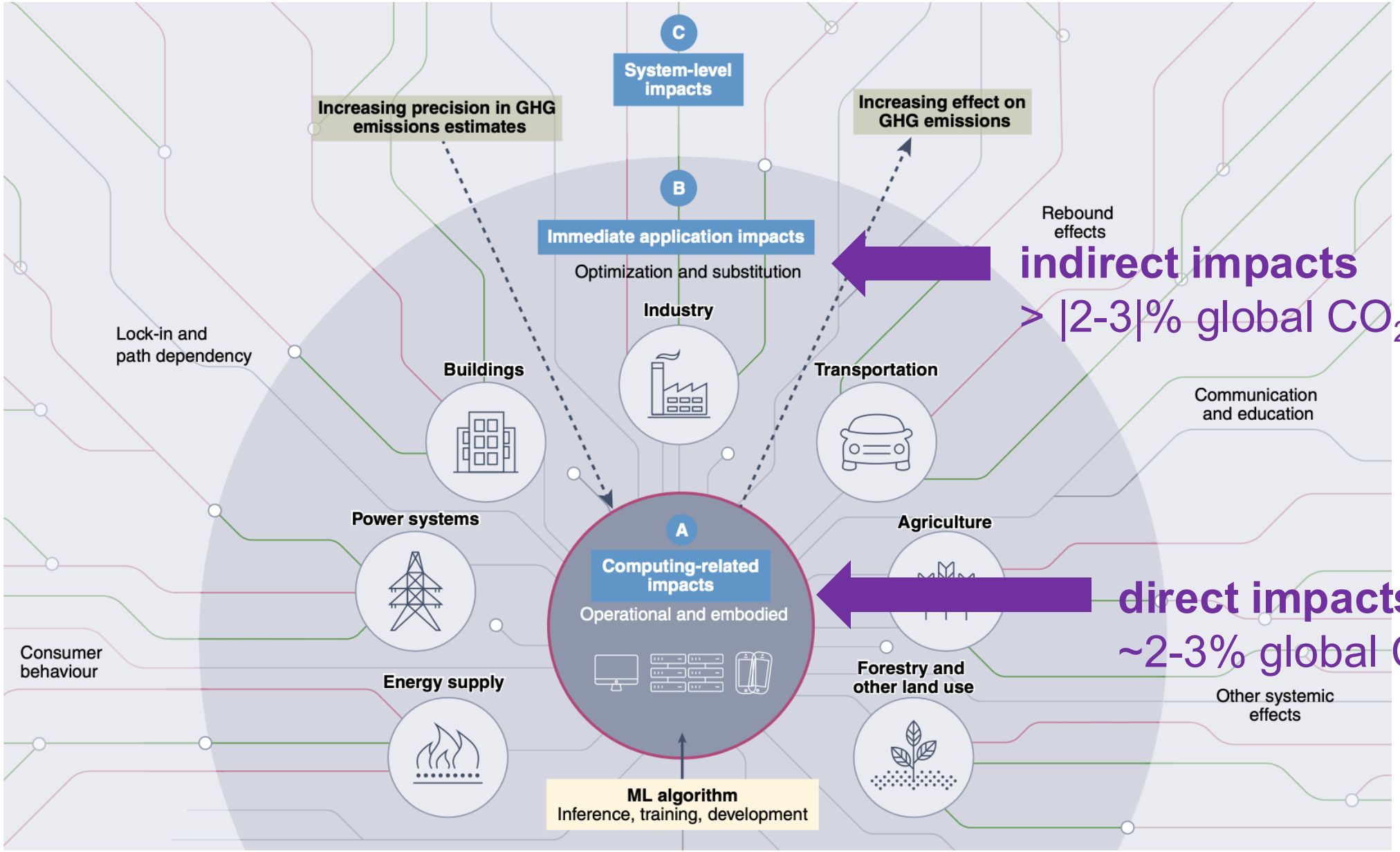

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Many examples of climate-beneficial AI use cases.

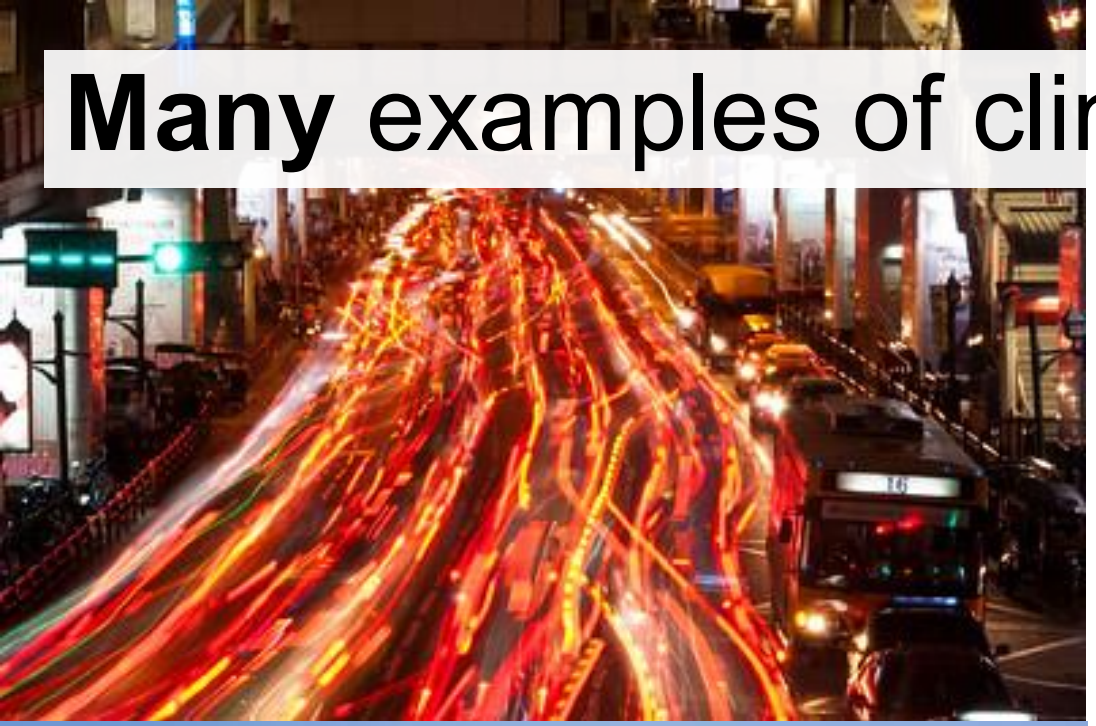


Photo: Fischer @Flickr. CC BY-SA 2.0

Photo: Rice in HD @Unsplash.

Photo: EWEA @Flickr. CC BY-NC-ND 2.0

Photo: Nicholas Picard @Unsplash.

Many examples of climate-beneficial AI use cases.

How AI can advance climate action

Distilling raw data into actionable information

Improving operational efficiency

Forecasting

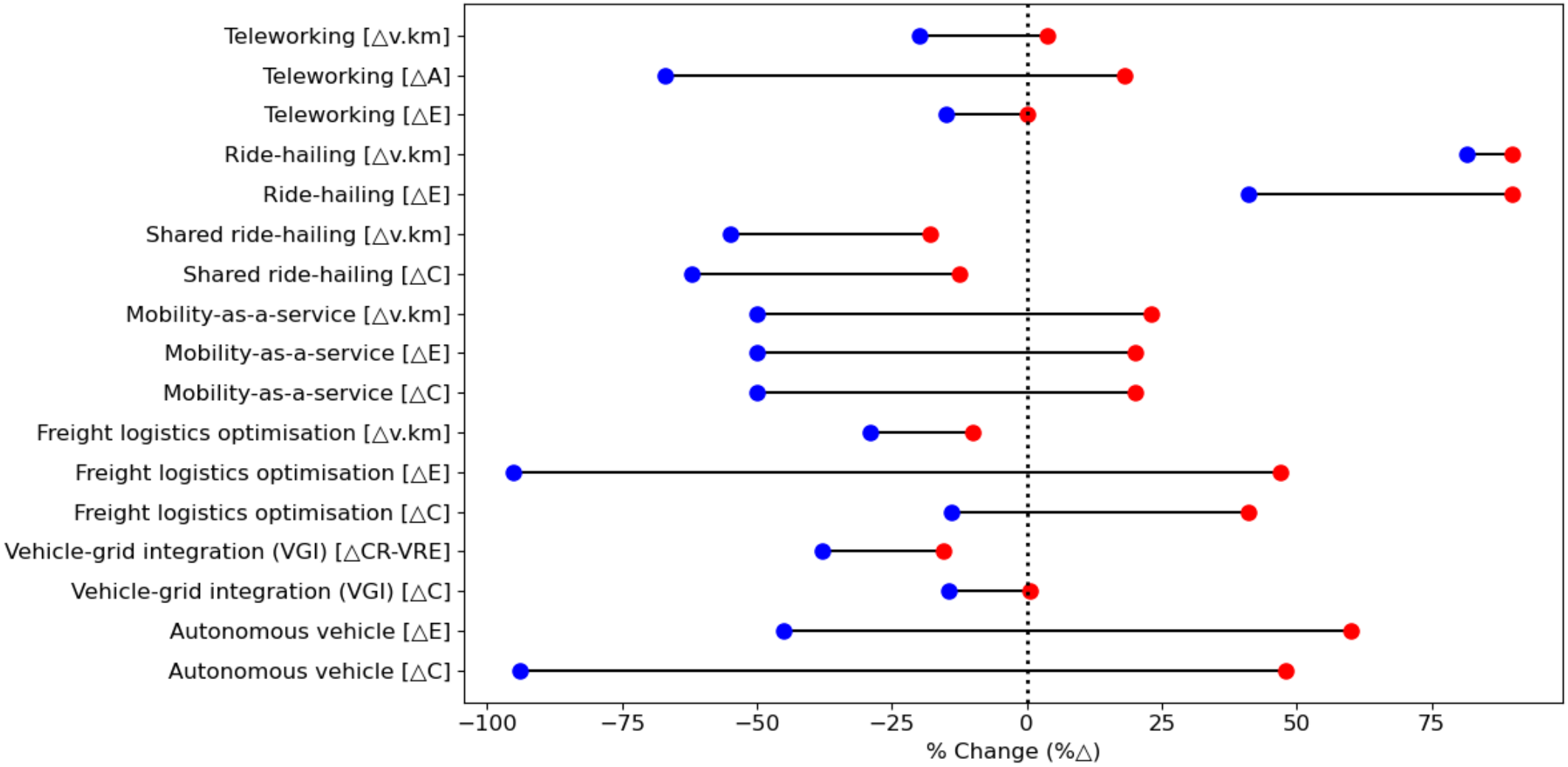
Speeding up time-intensive simulations

Accelerating scientific discovery

Rolnick, D. et al. (2022). "Tackling Climate Change with Machine Learning." *ACM Comput. Surv.* 55(2): Article 42. doi.org/10.1145/3485128

Slide by David Rolnick (McGill & Climate Change AI), presented at the Workshop on Digital & Climate Futures. 13-14 May, IIASA, Austria.

AI use cases: double-edged swords for energy.



Wilson, C., Agnew, M., Amanta, F., Fan, Y. V., Kumar, P., & Seger, M. (2024). Evidence Synthesis of Indirect Impacts of Digitalisation on Energy and Emissions. ICT4S 2024 Conference Proceedings. pp116–127. https://doi.org/10.1109/ICT4S64576.2024.00021

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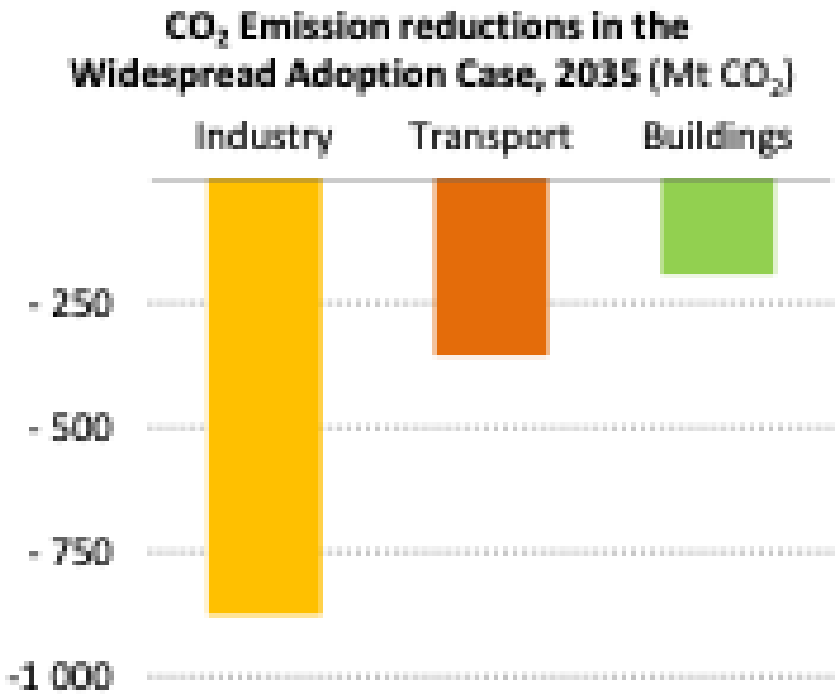


Fig 5.30. *Indirect* emission reduction in end-use sectors in the Widespread Adoption Case in 2035.

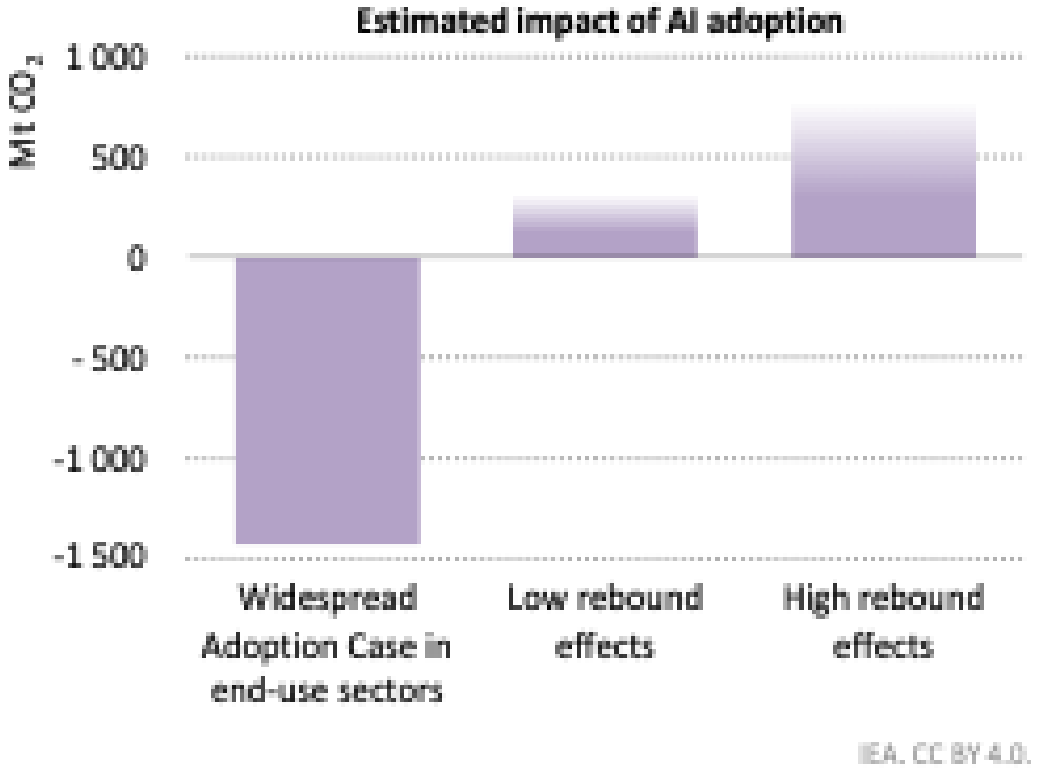


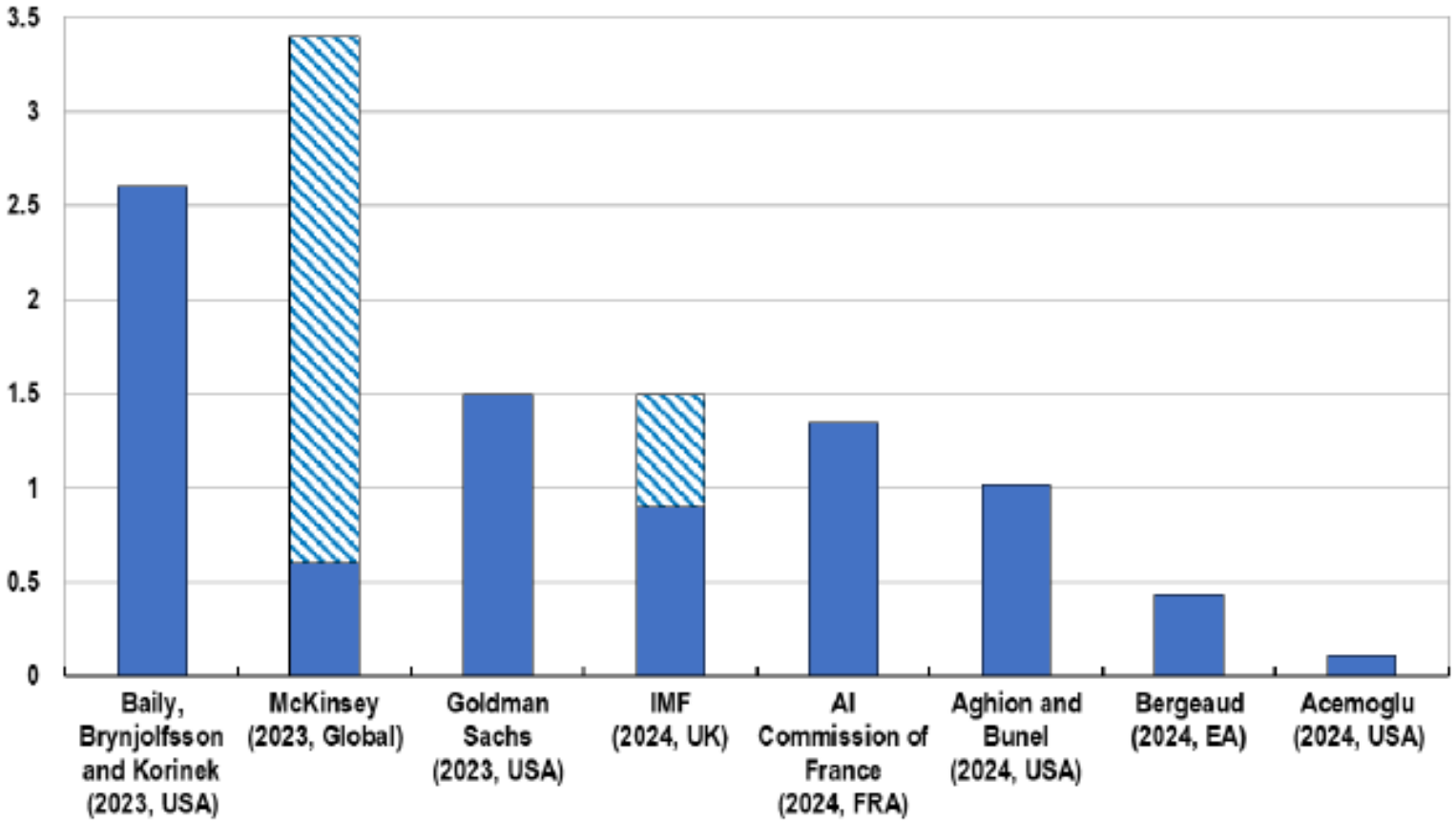
Fig 5.31. An *exploratory analysis* of AI impacts on emissions in 2035.

IEA. 2025. Energy and AI. Paris, France: International Energy Agency (IEA).

AI indirect impact on energy via productivity & growth.

Figure 1. AI's predicted macro-level productivity gains vary substantially across studies

Predicted increase in annual labour productivity growth over a 10-year horizon due to AI (in percentage points)



Filippucci, F., Gal, P., & Schief, M. (2024). Miracle or Myth? Assessing the macroeconomic productivity gains from Artificial Intelligence. OECD Artificial Intelligence Papers. DOI: 10.1787/b524a072-en

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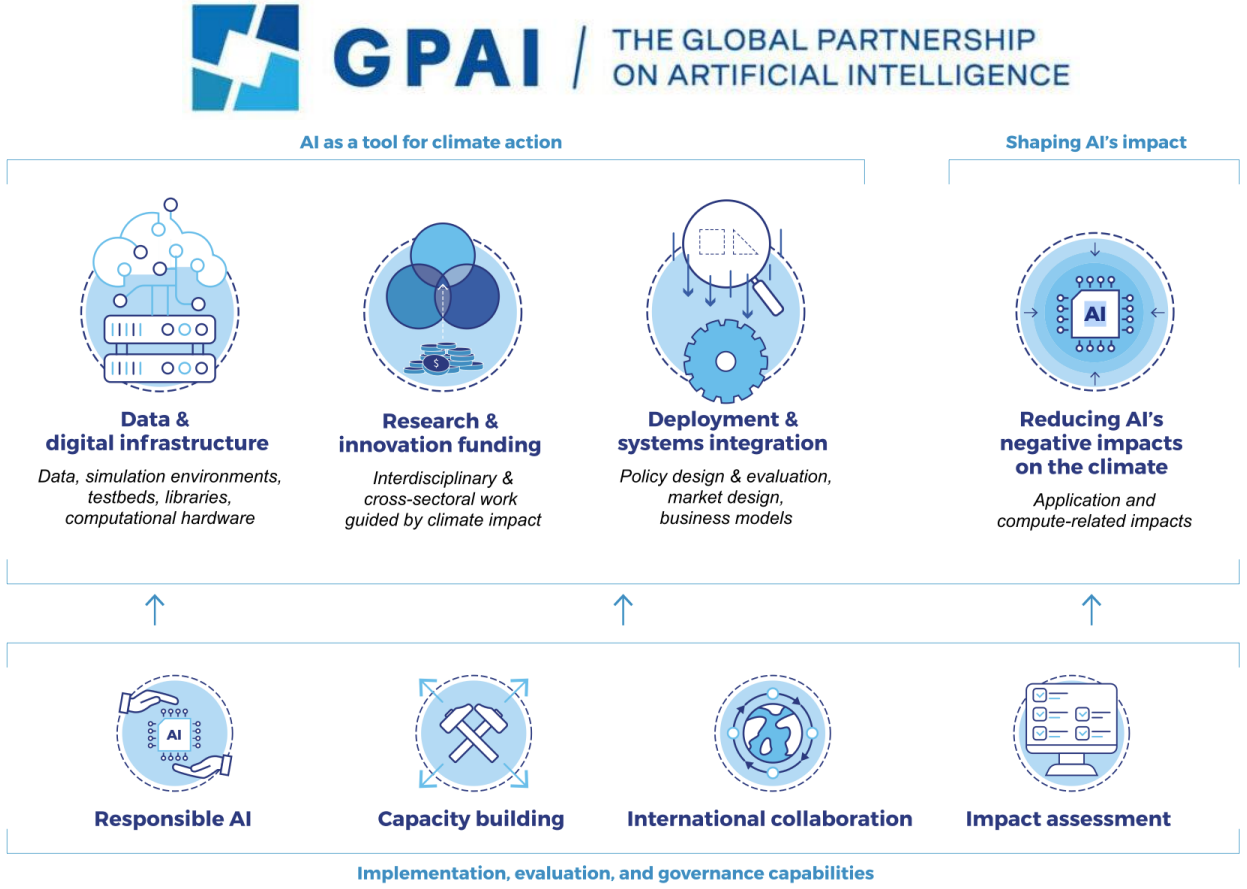
Data centres aside, the AI-energy transition narrative is framed about opportunity.



Areas of action for governments in supporting the responsible use of AI in the context of climate change

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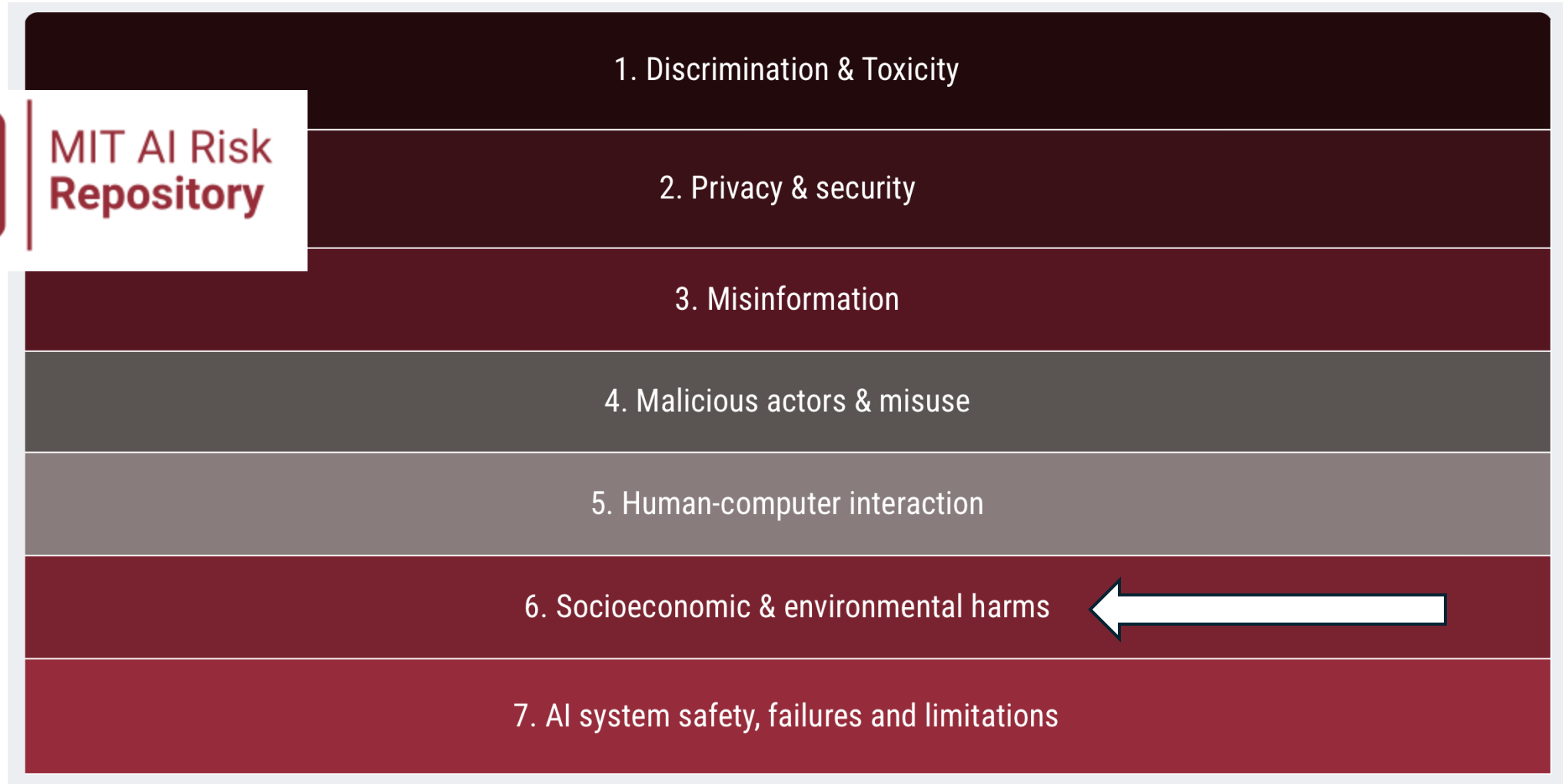
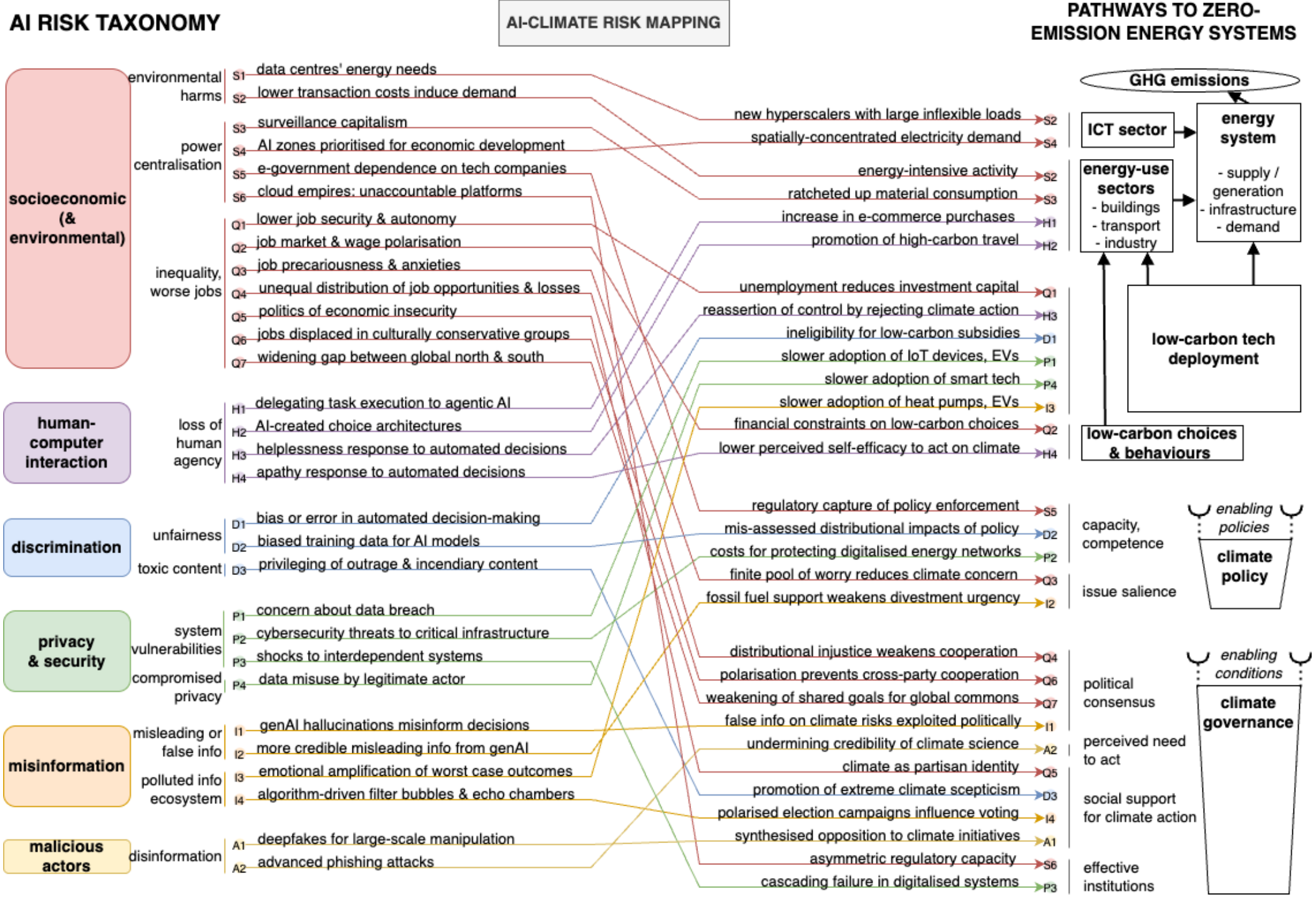
We mapped 30 AI risks for zero-emission energy (including climate policy & governance).

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AI-CLIMATE RISK MAPPING
PATHWAYS TO ZERO-EMISSION ENERGY SYSTEMS
socioeconomic (& environmental)
environmental harms
power centralisation
inequality, worse jobs
human-computer interaction
loss of human agency
discrimination
unfairness
toxic content
privacy & security
system vulnerabilities
compromised privacy
misinformation
misleading or false info
polluted info ecosystem
malicious actors
disinformation
S1 data centres' energy needs
S2 lower transaction costs induce demand
S3 surveillance capitalism
S4 AI zones prioritised for economic development
S5 e-government dependence on tech companies
S6 cloud empires: unaccountable platforms
Q1 lower job security & autonomy
Q2 job market & wage polarisation
Q3 job precariousness & anxieties
Q4 unequal distribution of job opportunities & losses
Q5 politics of economic insecurity
Q6 jobs displaced in culturally conservative groups
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H1 delegating task execution to agentic AI
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P1 concern about data breach
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I1 genAI hallucinations misinform decisions
I2 more credible misleading info from genAI
I3 emotional amplification of worst case outcomes
I4 algorithm-driven filter bubbles & echo chambers
A1 deepfakes for large-scale manipulation
A2 advanced phishing attacks
new hyperscalers with large inflexible loads S2
spatially-concentrated electricity demand S4
energy-intensive activity S2
ratcheted up material consumption S3
increase in e-commerce purchases H1
promotion of high-carbon travel H2
unemployment reduces investment capital Q1
reassertion of control by rejecting climate action H3
ineligibility for low-carbon subsidies D1
slower adoption of IoT devices, EVs P1
slower adoption of smart tech P4
slower adoption of heat pumps, EVs I3
financial constraints on low-carbon choices Q2
lower perceived self-efficacy to act on climate H4
regulatory capture of policy enforcement S5
mis-assessed distributional impacts of policy D2
costs for protecting digitalised energy networks P2
finite pool of worry reduces climate concern Q3
fossil fuel support weakens divestment urgency I2
distributional injustice weakens cooperation Q4
polarisation prevents cross-party cooperation Q6
weakening of shared goals for global commons Q7
false info on climate risks exploited politically I1
undermining credibility of climate science A2
climate as partisan identity Q5
promotion of extreme climate scepticism D3
polarised election campaigns influence voting I4
synthesised opposition to climate initiatives A1
asymmetric regulatory capacity S6
cascading failure in digitalised systems P3
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- infrastructure
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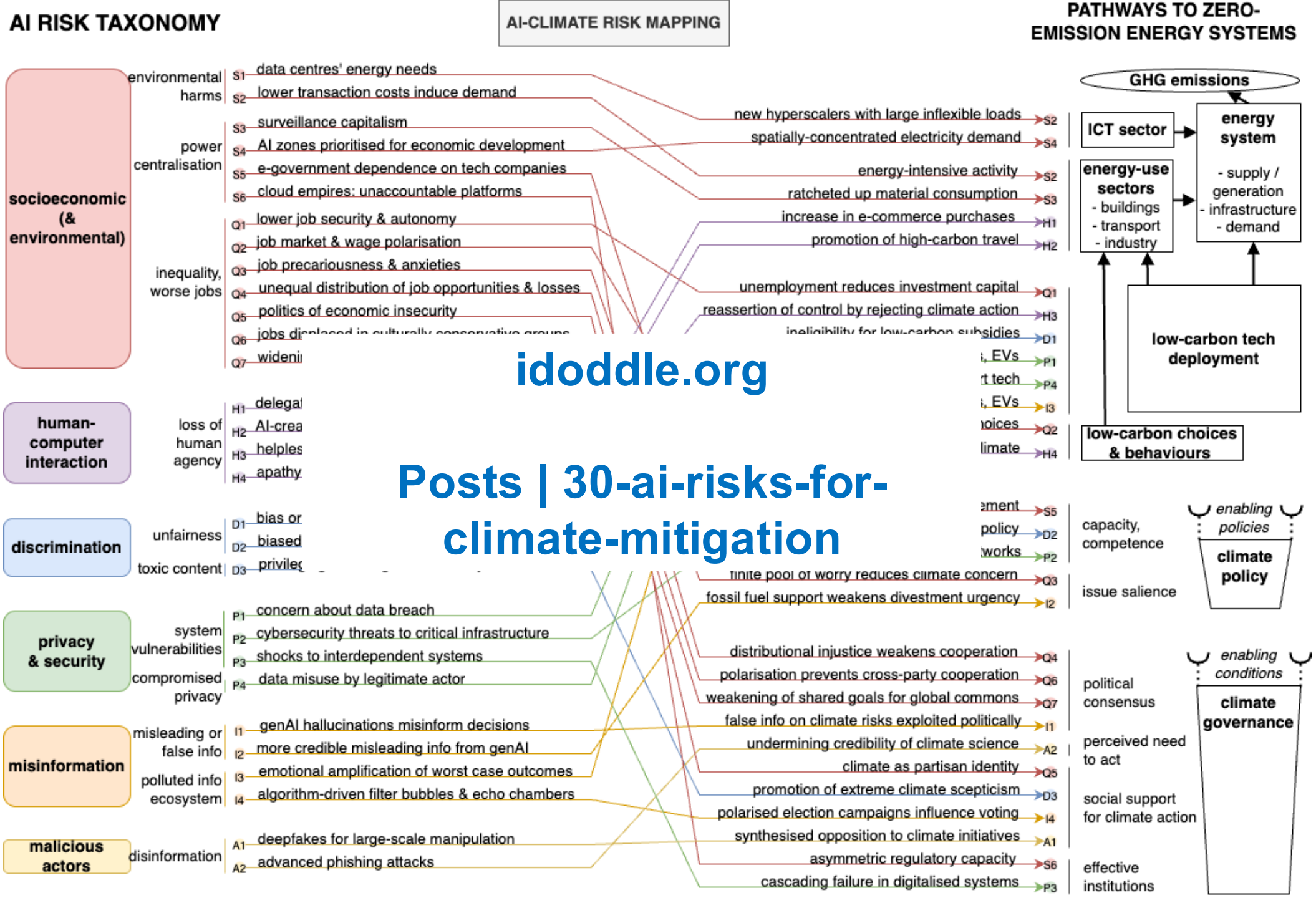
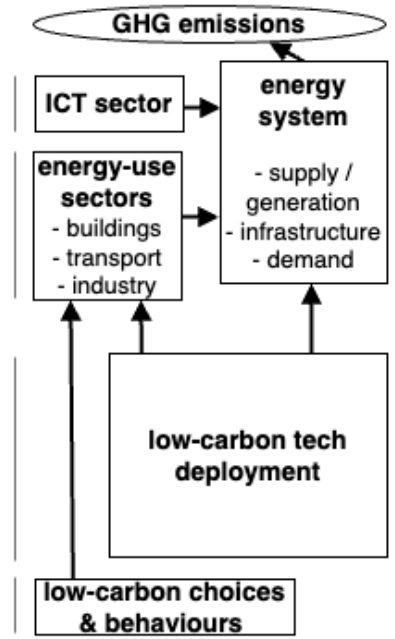
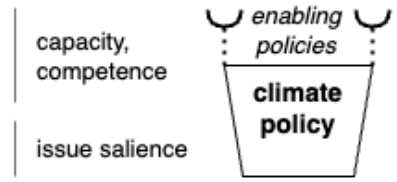


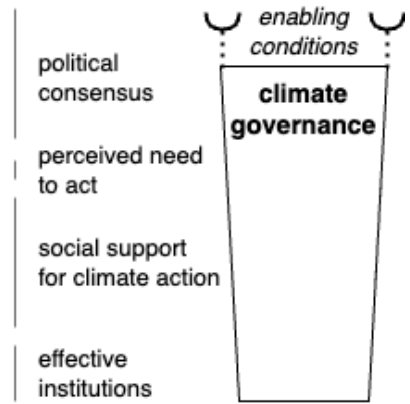
AI RISK TAXONOMY

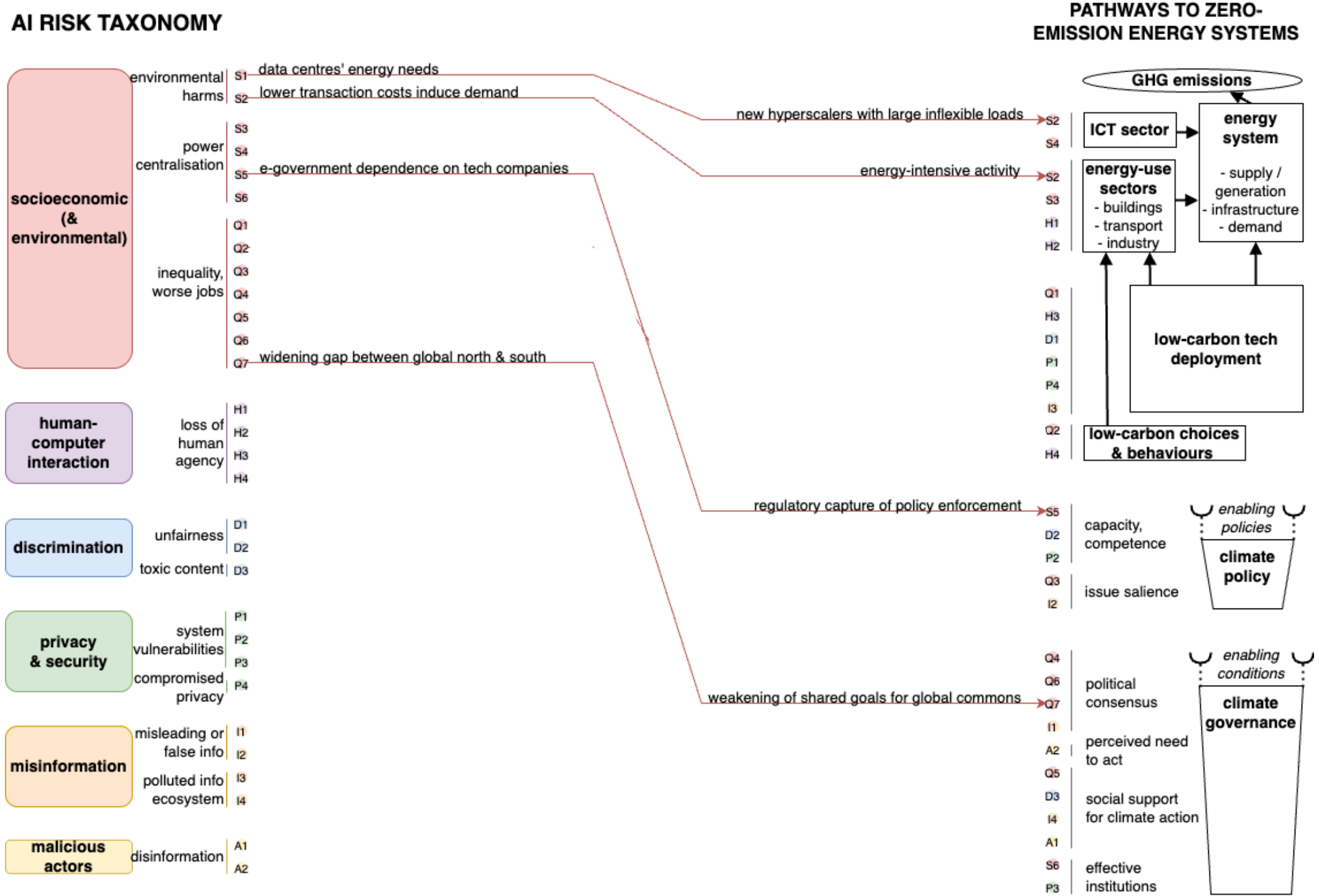
- **socioeconomic (& environmental)**
  - environmental harms
  - power centralisation
  - inequality, worse jobs
- **human-computer interaction**
  - loss of human agency
- **discrimination**
  - unfairness
  - toxic content
- **privacy & security**
  - system vulnerabilities
  - compromised privacy
- **misinformation**
  - misleading or false info
  - polluted info ecosystem
- **malicious actors**
  - disinformation

PATHWAYS TO ZERO-EMISSION ENERGY SYSTEMS





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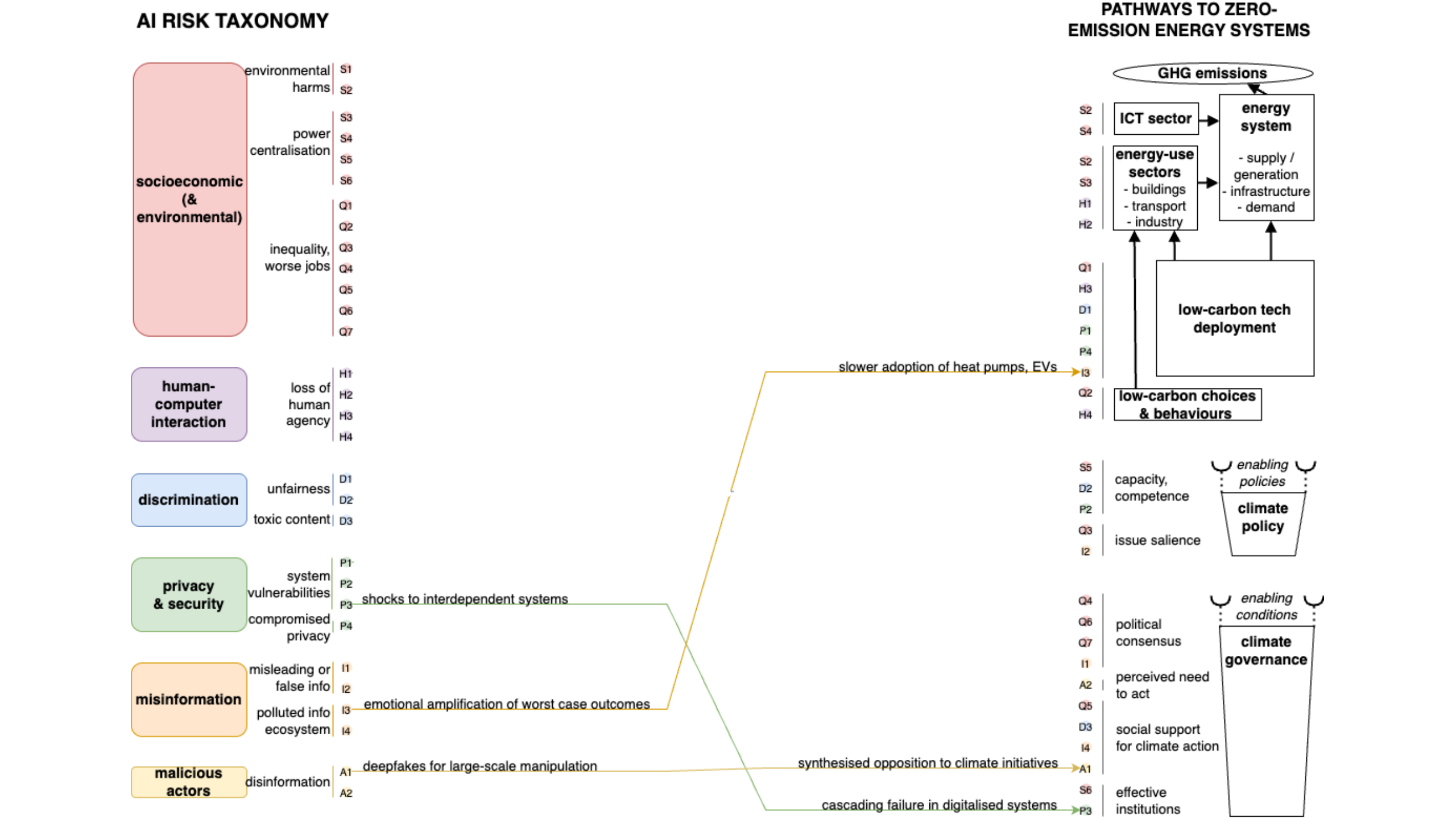
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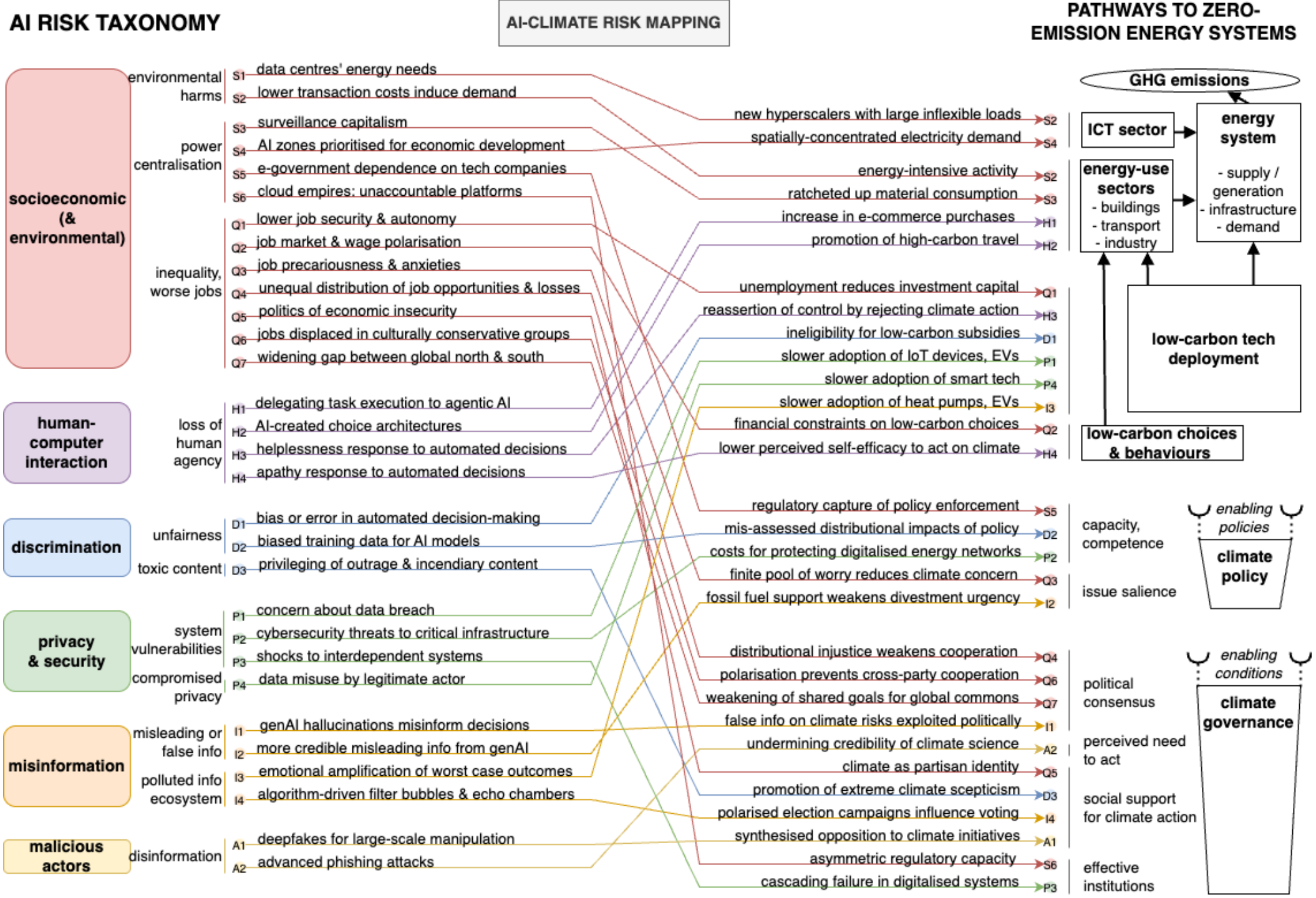
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A1 deepfakes for large-scale manipulation
A2 advanced phishing attacks
new hyperscalers with large inflexible loads S2
spatially-concentrated electricity demand S4
energy-intensive activity S2
ratcheted up material consumption S3
increase in e-commerce purchases H1
promotion of high-carbon travel H2
unemployment reduces investment capital Q1
reassertion of control by rejecting climate action H3
ineligibility for low-carbon subsidies D1
slower adoption of IoT devices, EVs P1
slower adoption of smart tech P4
slower adoption of heat pumps, EVs I3
financial constraints on low-carbon choices Q2
lower perceived self-efficacy to act on climate H4
regulatory capture of policy enforcement S5
mis-assessed distributional impacts of policy D2
costs for protecting digitalised energy networks P2
finite pool of worry reduces climate concern Q3
fossil fuel support weakens divestment urgency I2
distributional injustice weakens cooperation Q4
polarisation prevents cross-party cooperation Q6
weakening of shared goals for global commons Q7
false info on climate risks exploited politically I1
undermining credibility of climate science A2
climate as partisan identity Q5
promotion of extreme climate scepticism D3
polarised election campaigns influence voting I4
synthesised opposition to climate initiatives A1
asymmetric regulatory capacity S6
cascading failure in digitalised systems P3
GHG emissions
ICT sector
energy system
- supply / generation
- infrastructure
- demand
energy-use sectors
- buildings
- transport
- industry
low-carbon tech deployment
low-carbon choices & behaviours
enabling policies
capacity, competence
issue salience
climate policy
enabling conditions
political consensus
perceived need to act
social support for climate action
effective institutions
climate governance

AI RISK TAXONOMY

AI-CLIMATE RISK MAPPING

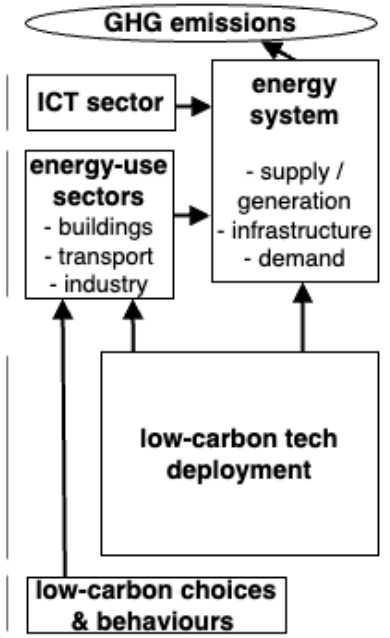
PATHWAYS TO ZERO-EMISSION ENERGY SYSTEMS

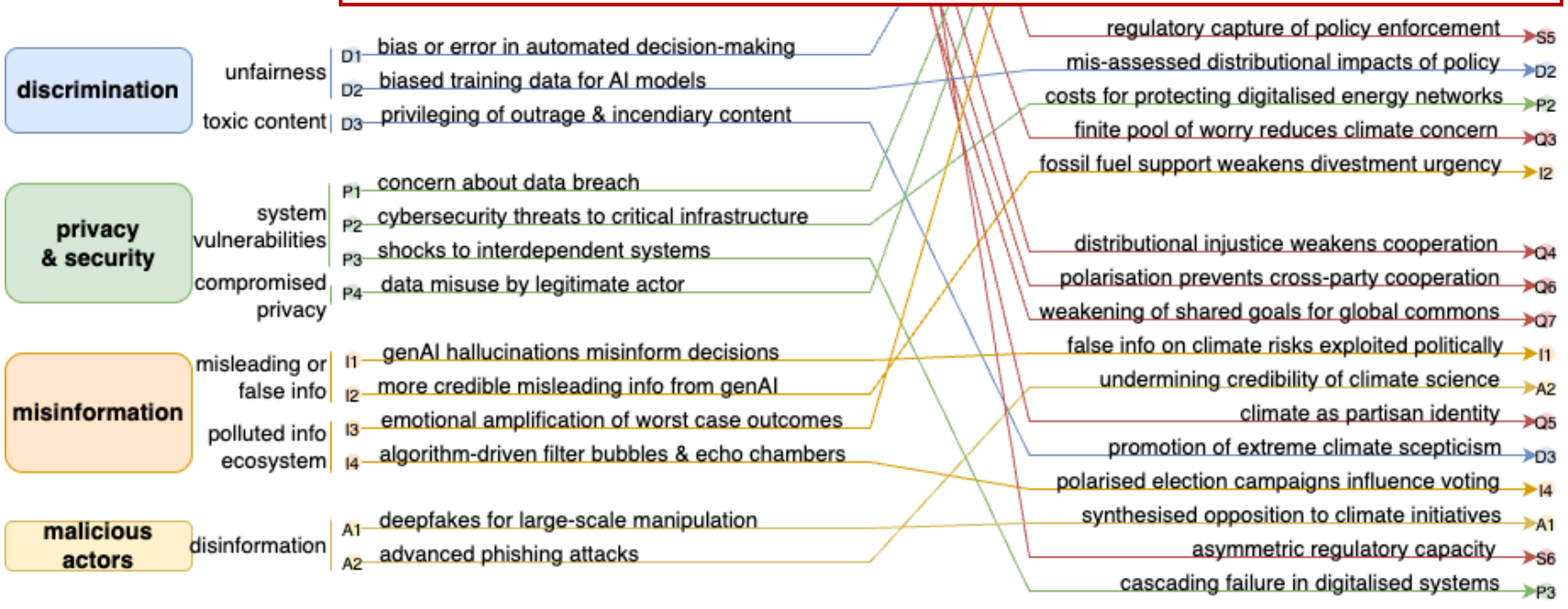
AI risks for climate policy & governance

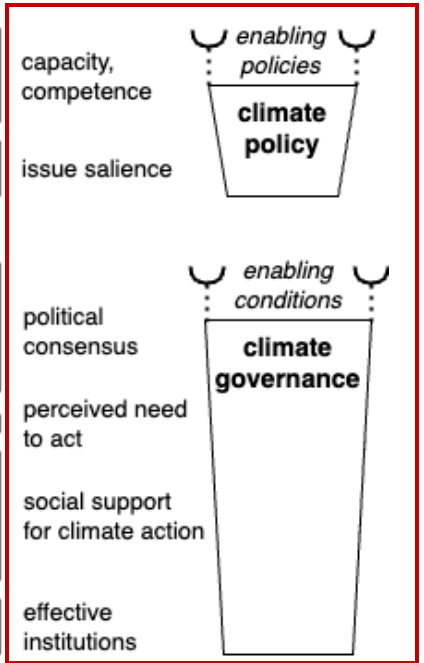
are not explicit in

AI ethics & governance frameworks (e.g. EU AI Act)

AI-energy transition analyses & pathways (e.g. IEA)







AI in energy transitions (+ analytical challenges).

1. Digital transformation in the SSPs.
   - empirical relationships with energy transition factors

2. AI & data centres: *direct* impacts on energy.
   - global vs. local dynamics, geographic dispersion

3. AI use cases: *indirect* impacts on energy.
   - standardised assessments, generalisability

4. AI *systemic* impacts on energy transitions.
   - macro productivity, risks to climate policy & governance

AI in Energy Transitions

The Netherlands Environmental Assessment Agency (PBL)

Grey Swans lecture, 17 June 2025

Professor Charlie Wilson

Environmental Change Institute, University of Oxford

iDODDLE

The Impacts of Digitalised Daily Life on Climate Change

Environmental *Change* Institute

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