Digitalisation and Energy Demand

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What % of UK household's* electricity usage

is for **consumer electronics**

(TV, laptop, phone, games consoles, etc.)?

*homes without electric heating

End use	Percentage of electricity
Cold appliances (fridges, freezers)	16%
Wet appliances (washing machines, dishwashers etc)	21%
Cooking (ovens, microwaves etc)	14%
Lighting (lamps and lights)	15%
Consumer electronics (TV, laptop, phone, games consoles etc)	14%
ICT and unknown	7% and 14%

https://www.ovoenergy.com/guides/energy-guides/how-much-electricity-does-a-home-use

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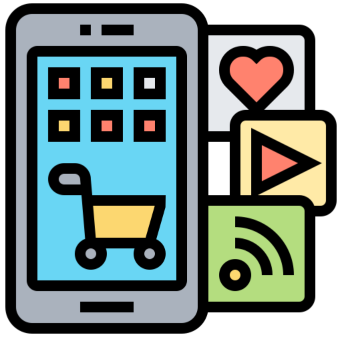
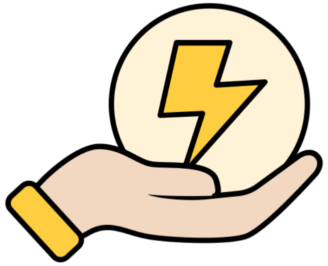
Outline



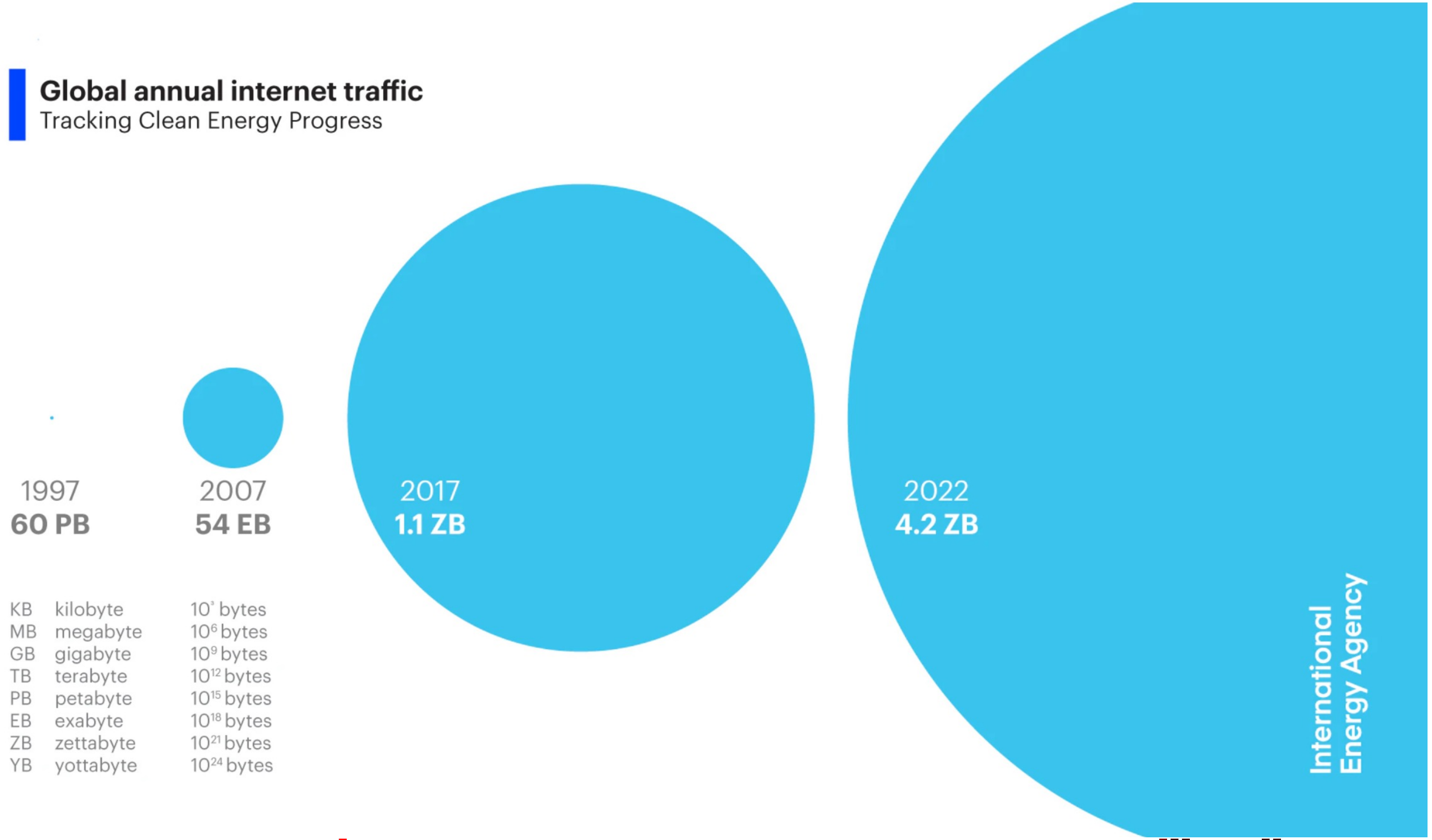
Digital transformation

Social transformation

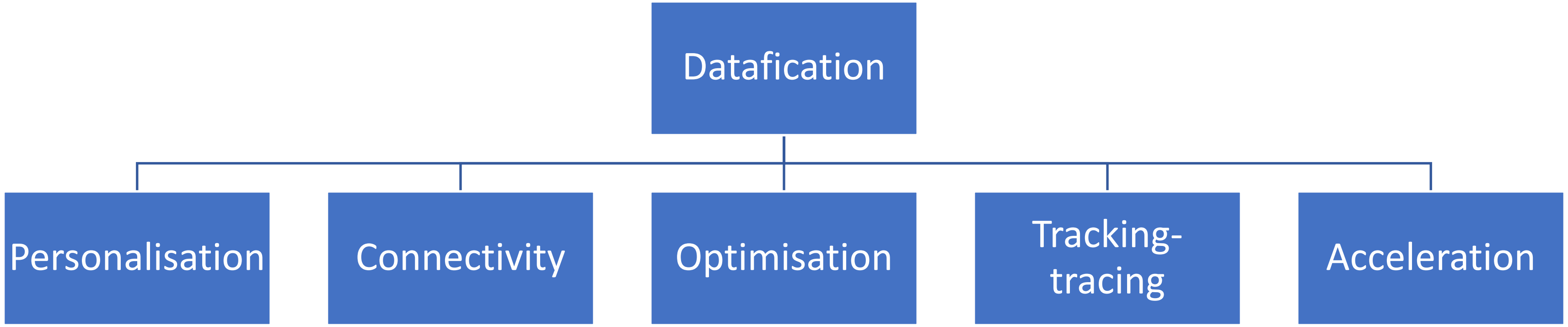


Energy demand

Volume of data traffic worldwide grows exponentially



Data enables digital transformation



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Access-based economy – from ownership to usership

Ciulli, F., & Kolk, A. (2018). Incumbents and business model innovation for the sharing economy: Implications for sustainability. *Journal of Cleaner Production, 214* https://doi.org/10.1016/j.jclepro.2018.12.295

Laukkanen, M., & Tura, N. (2020). The potential of sharing economy business models for sustainable value creation. *Journal of Cleaner Production*, *253*. https://doi.org/10.1016/j.jclepro.2020.120004

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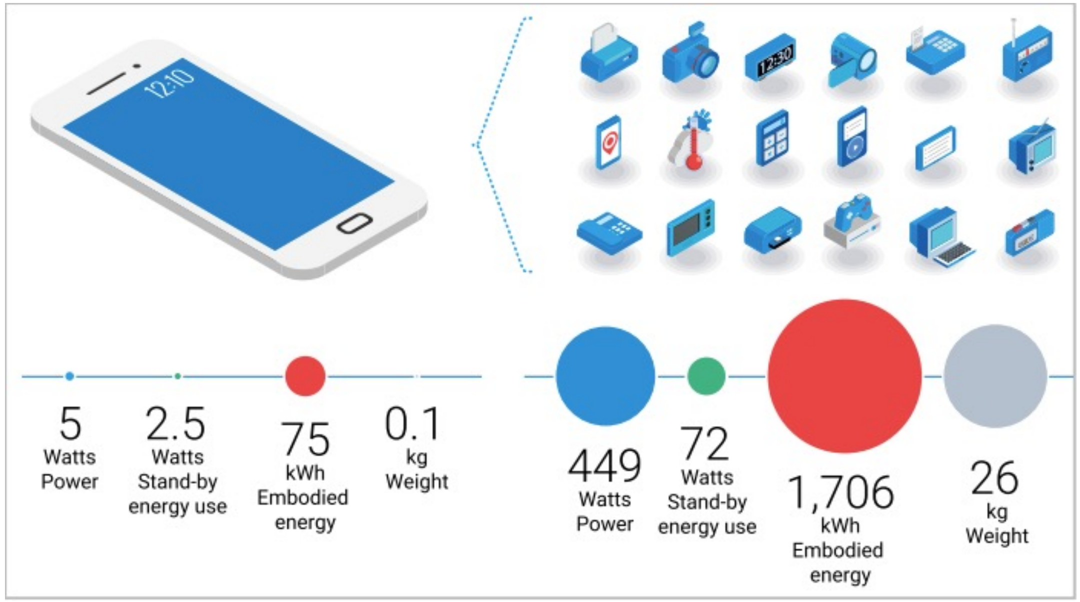
Dematerialisation – from physical to digital



Court, V., & Sorrell, S. (2020). Digitalisation of goods: A systematic review of the determinants and magnitude of the impacts on energy consumption. *Environmental Research Letters*, *15*(4). https://doi.org/10.1088/1748-9326/ab6788

Grubler, A., et al. (2018). A Low Energy Demand Scenario for Meeting the 1.5oC Target and Sustainable Development Goals without Negative Emission Technologies. Nature Energy, 3. p. 515-527.

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car clubs
'taxi-bus'
ride-share
P2P cars
bike-share
MaaS
virtual travel
online food hubs
recipe boxes
11th hour apps
P2P food sharing
diet gamification
food pairing
food redistribution
P2P goods
smart lighting
internet of things
smart appliances
smart heating
smart homes
energy management
PV + storage
P2P electricity
vehicle-to-grid
disaggregated feedback
demand response
time-of-use pricing
energy service co.s

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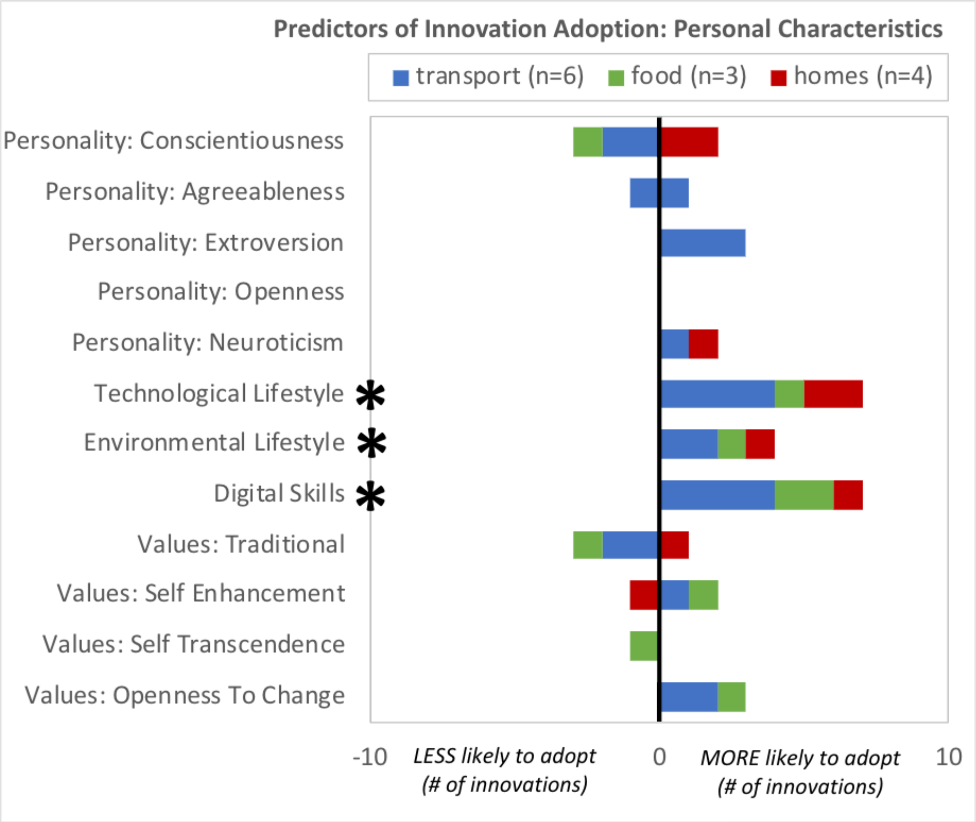
Technology adoption is not a given



Wilson, C., Andrews, B., & Vrain, E. (2022). *Consumer uptake of digital low-carbon innovations*.

Depends on…

- Skills
- Access
- Literacy
- Culture
- Attitudes
- Socioeconomic

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Digital transformation is a social process

Individual responses resulting in…

- Learning
- Adapting
- Shaping
- Rejecting

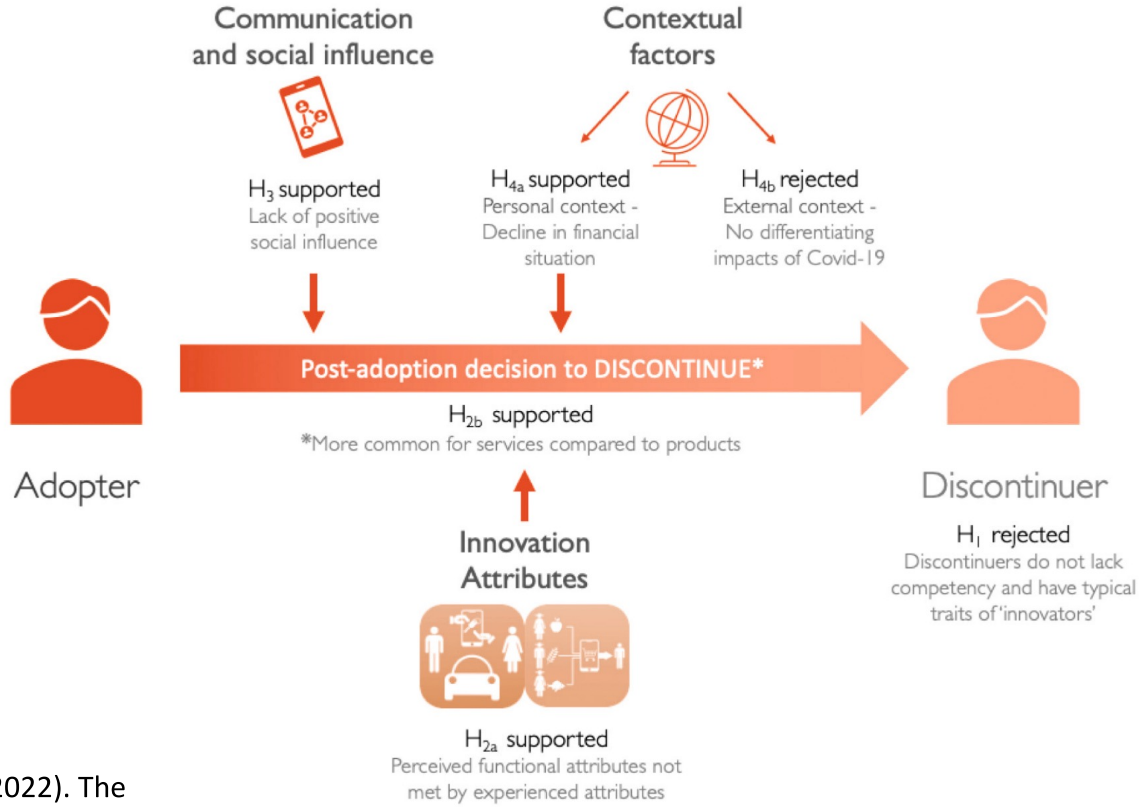
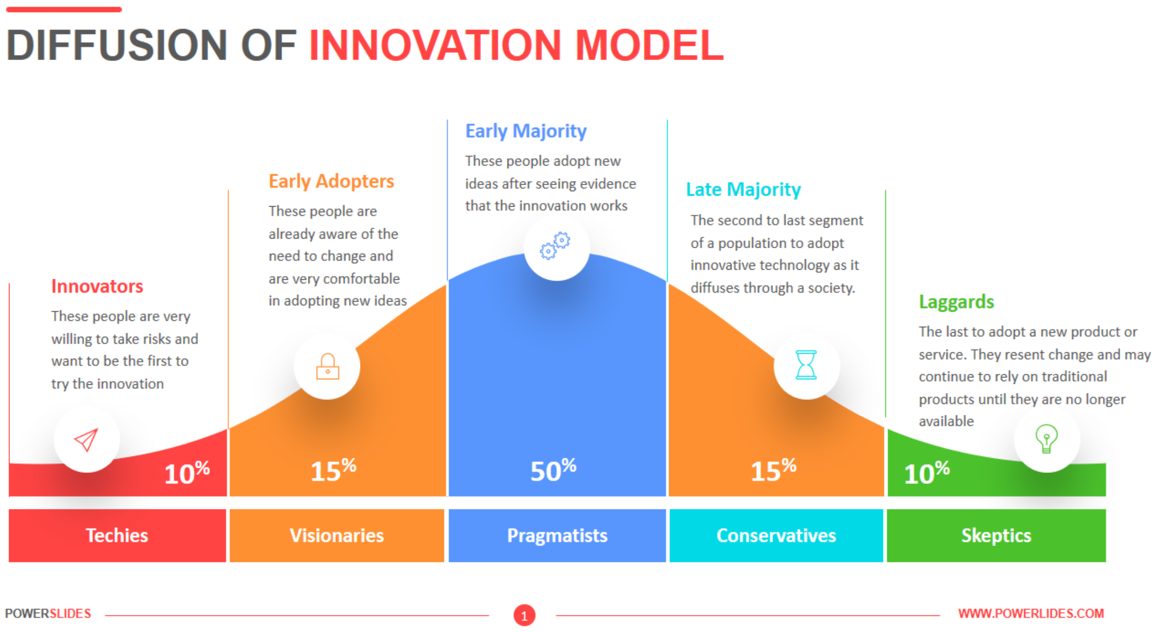


Fig. 5. Summary of key findings of our discontinuance framework.

Vrain, E., Wilson, C., & Andrews, B. (2022). The discontinuance of low carbon digital products and services. Technological Forecasting & Social Change 185.

Societal response to technology is uncertain

- Changing activity patterns
  - Teleworking
  - Mobility
- Changing consumption patterns
  - E-retail
  - Circular economy
- Changing social norms
  - Sharing economy
- Social construction of technology



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Energy impacts on three levels…

- Direct
- Indirect
- Systemic

Horner, N. C., Shehabi, A., & Azevedo, I. L. (2016). Known unknowns: indirect energy effects of information and communication technology. *Environmental Research Letters*, *11*(10), 103001-. https://doi.org/10.1088/1748-9326/11/10/103001

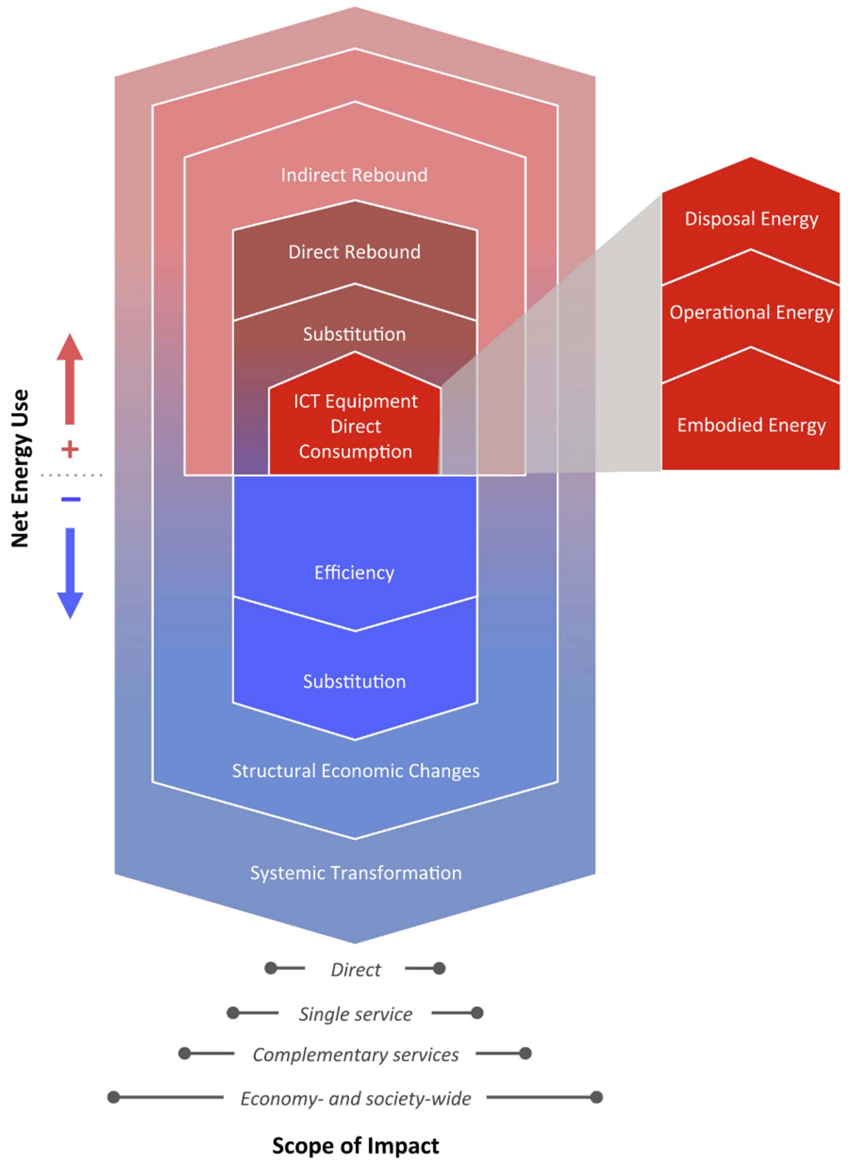

Figure 2. Taxonomy of ICT energy effects. Red effects increase energy use, blue effects decrease energy use, and shading intensity decreases as effect scope increases. (Effect magnitudes are only illustrative and not to scale.)

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technology perspective	direct impacts		embodied energy	+
			operational energy	+
			disposal energy	+
user perspective	indirect impacts	single service	efficiency or optimisation	-
			substitution	+/-
			direct rebound	+
system perspective		complementary services	indirect rebound	+/-
		economy-wide	economy-wide rebound	+/-
		society-wide	transformational change	+/-

Court, V. & S. Sorrell (2020). “Digitalisation of goods: a systematic review of the determinants and magnitude of the impacts on energy consumption“. *Environmental Research Letters* 15(4): 043001.

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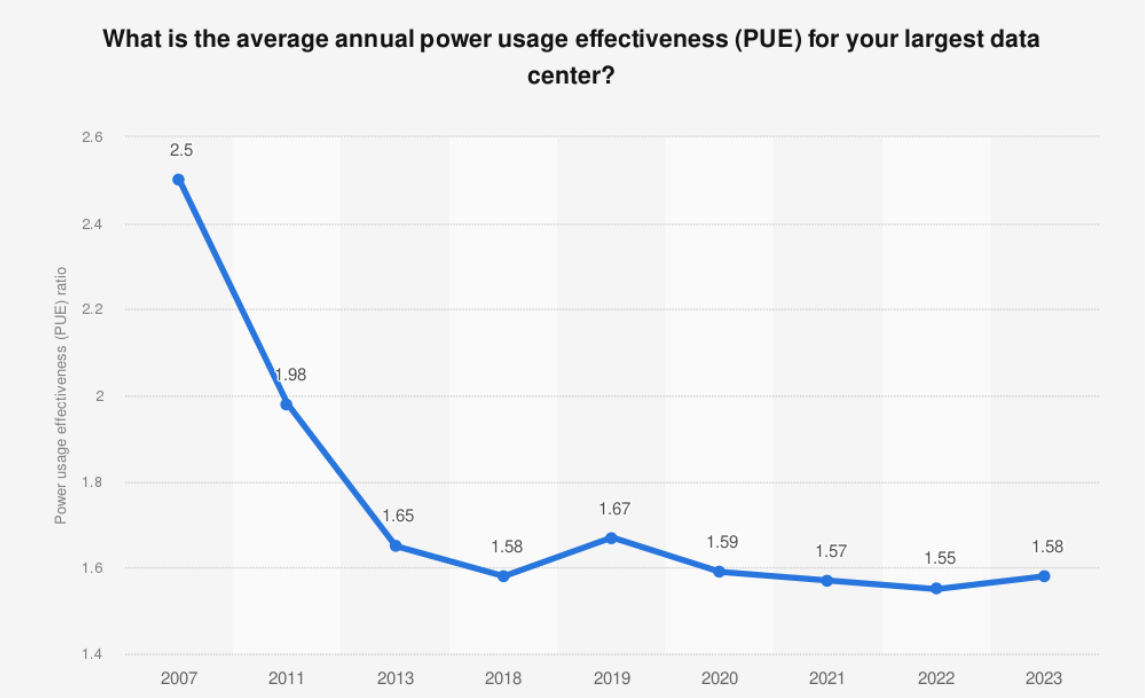
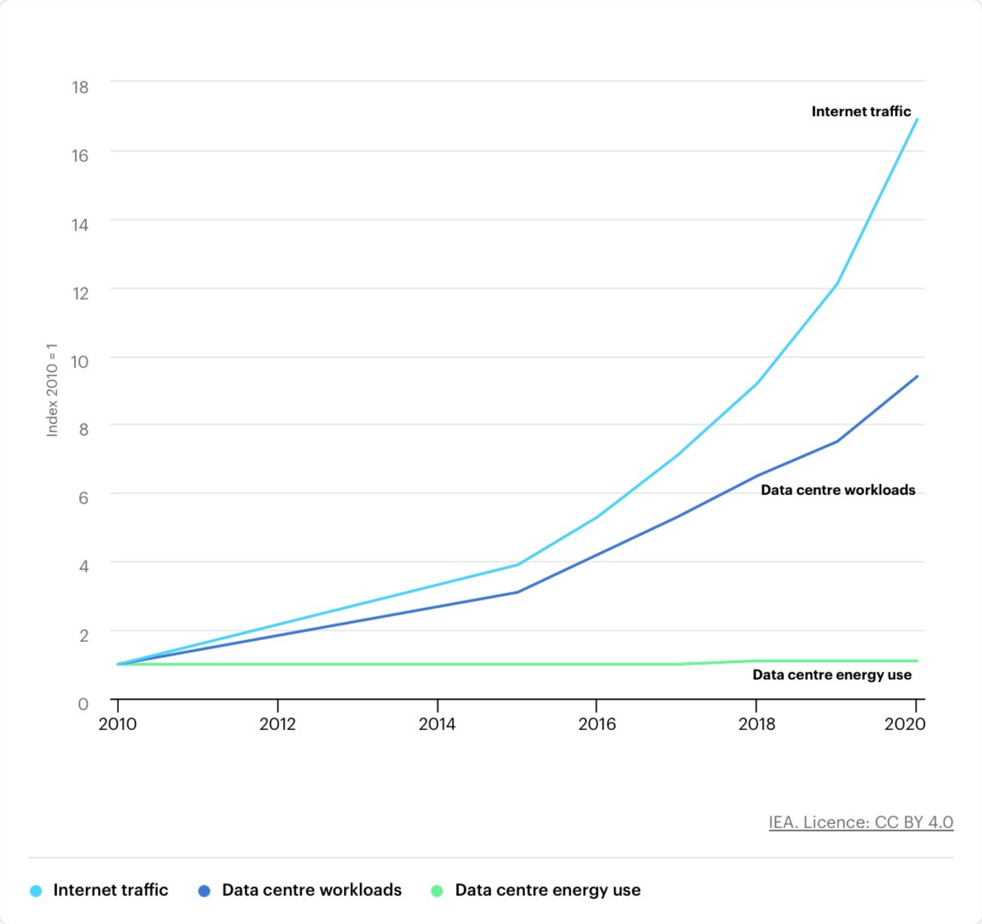
Direct: ICT infrastructure



Sources
Uptime Institute; Upsite Technologies

Additional Information:
Worldwide; 2007 to 2023; Data center owners and operators



Sources
Based on Cisco (2015), The History and Future of Internet Traffic; Cisco (2018), Cisco Global Cloud Index; Cisco (2019b), Cisco Visual Networking Index; Masanet et al. (2020), Recalibrating global data center energy-use estimates; TeleGeography (2021), Global Internet Geography.

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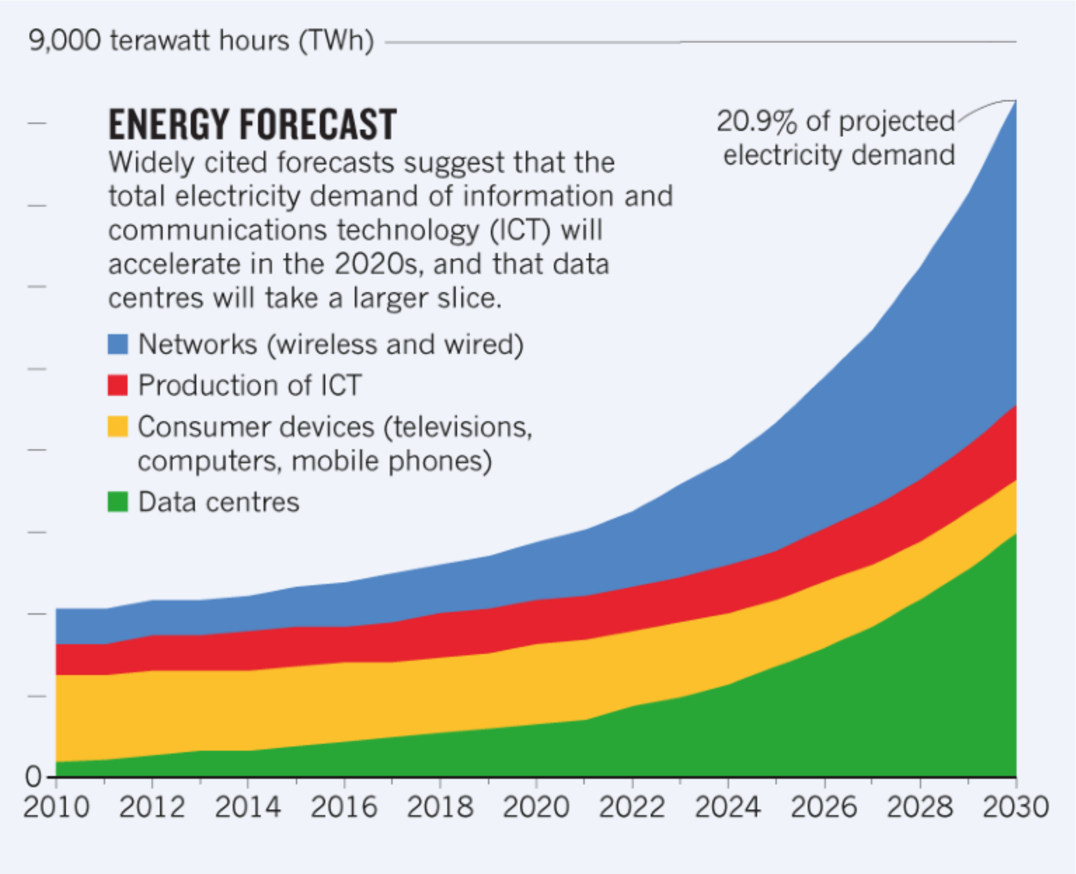
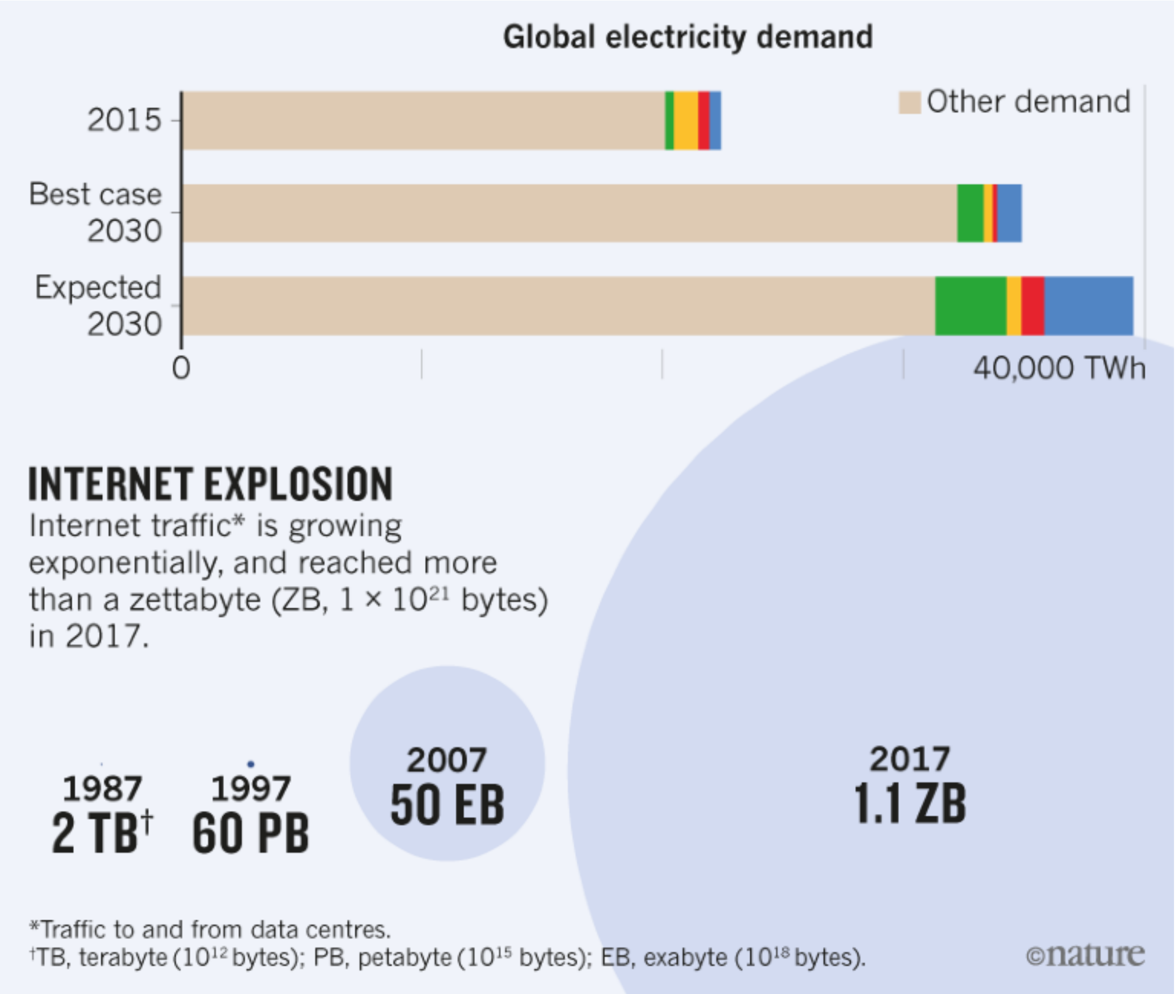


The chart above is an 'expected case' projection from Anders Andrae, a specialist in sustainable ICT. In his 'best case' scenario, ICT grows to only 8% of total electricity demand by 2030, rather than to 21%.



Jones, N. (2018). The Information Factories. *Nature (London)*, *561*(7722), 163–166. https://doi.org/10.1038/d41586-018-06610-y

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Direct: AI training

Environmental Impact of Select Machine Learning Models, 2022

Source: Luccioni et al., 2022 | Table: 2023 AI Index Report

Model	Number of Parameters	Datacenter PUE	Grid Carbon Intensity	Power Consumption	C02 Equivalent Emissions	C02 Equivalent Emissions x PUE
Gopher	280B	1.08	330 gC02eq/kWh	1,066 MWh	352 tonnes	380 tonnes
BLOOM	176B	1.20	57 gC02eq/kWh	433 MWh	25 tonnes	30 tonnes
GPT-3	175B	1.10	429 gC02eq/kWh	1,287 MWh	502 tonnes	552 tonnes
OPT	175B	1.09	231 gC02eq/kWh	324 MWh	70 tonnes	76.3 tonnes

Nestor Maslej, Loredana Fattorini, Erik Brynjolfsson, John Etchemendy, Katrina Ligett, Terah Lyons, James Manyika, Helen Ngo, Juan Carlos Niebles, Vanessa Parli, Yoav Shoham, Russell Wald, Jack Clark, and Raymond Perrault, “The AI Index 2023 Annual Report,” AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA, April 2023.

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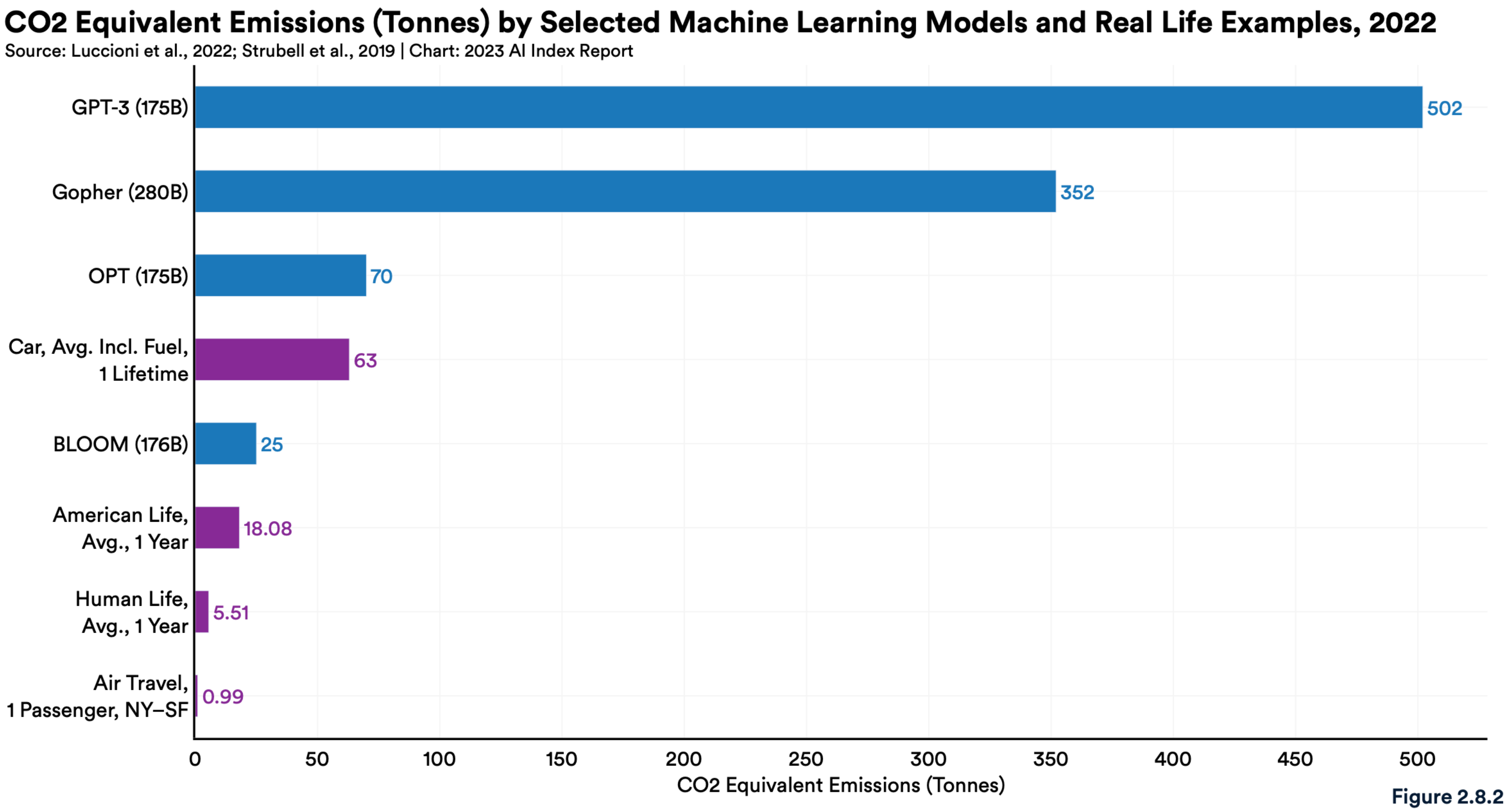

Figure 2.8.2

Nestor Maslej, Loredana Fattorini, Erik Brynjolfsson, John Etchemendy, Katrina Ligett, Terah Lyons, James Manyika, Helen Ngo, Juan Carlos Niebles, Vanessa Parli, Yoav Shoham, Russell Wald, Jack Clark, and Raymond Perrault, “The AI Index 2023 Annual Report,” AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA, April 2023.

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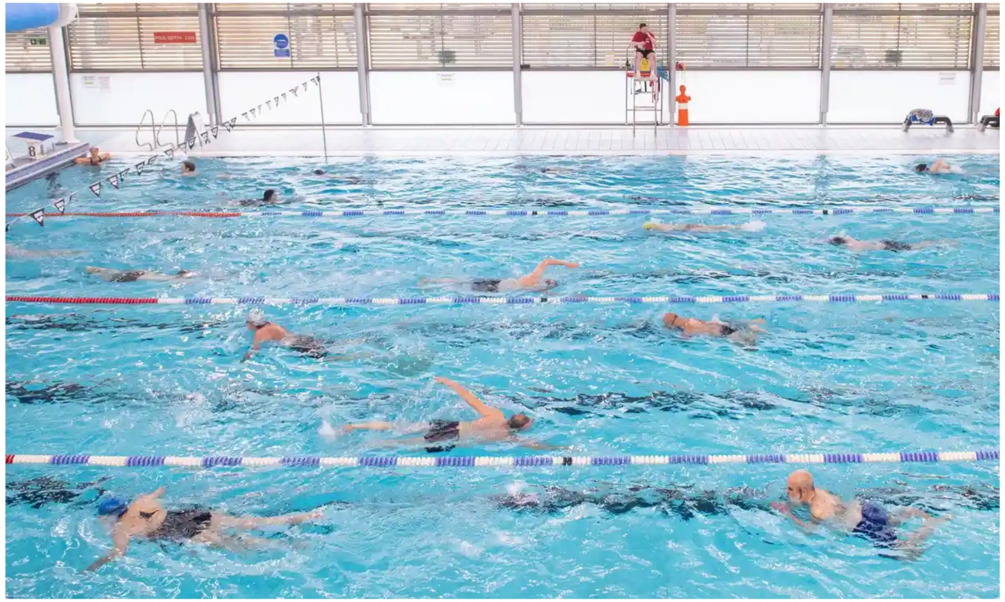
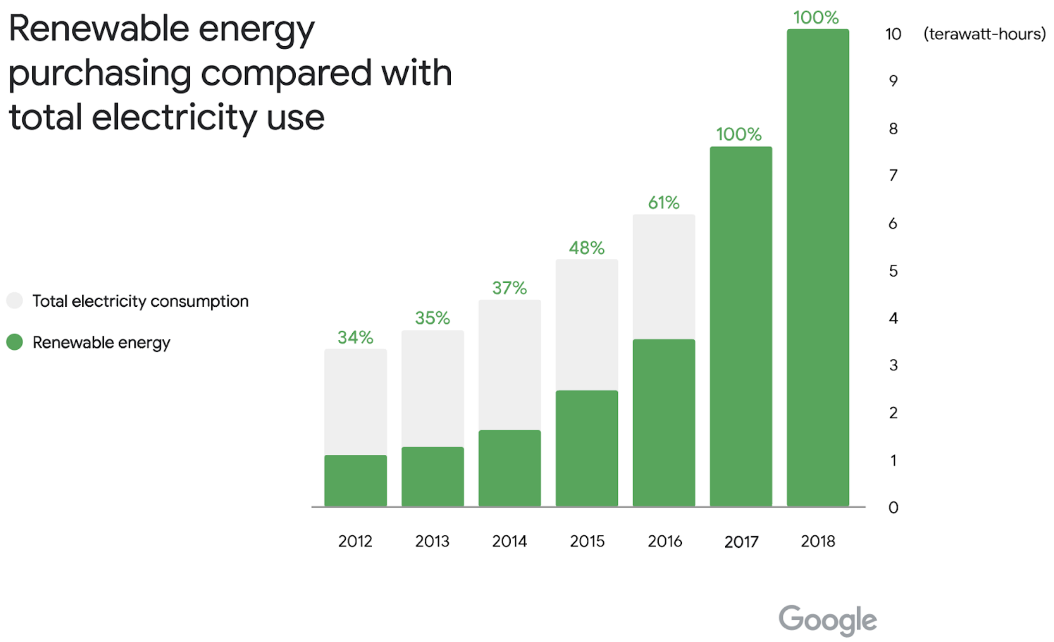
Companies are investing on green data centres

Energy from data centres could heat UK swimming pools after green investment

Octopus Energy invests in scheme which recycles heat from computer data processing centres



Deep Green has already piloted using energy from computer data processing centres to heat swimming pools. Photograph: Dominic Lipinski/PA



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Indirect effects are larger in magnitude and scale, but also uncertainty

- Substitution
  - Teleworking replacing work commute
- Efficiency
  - Smart home technology
- Rebound

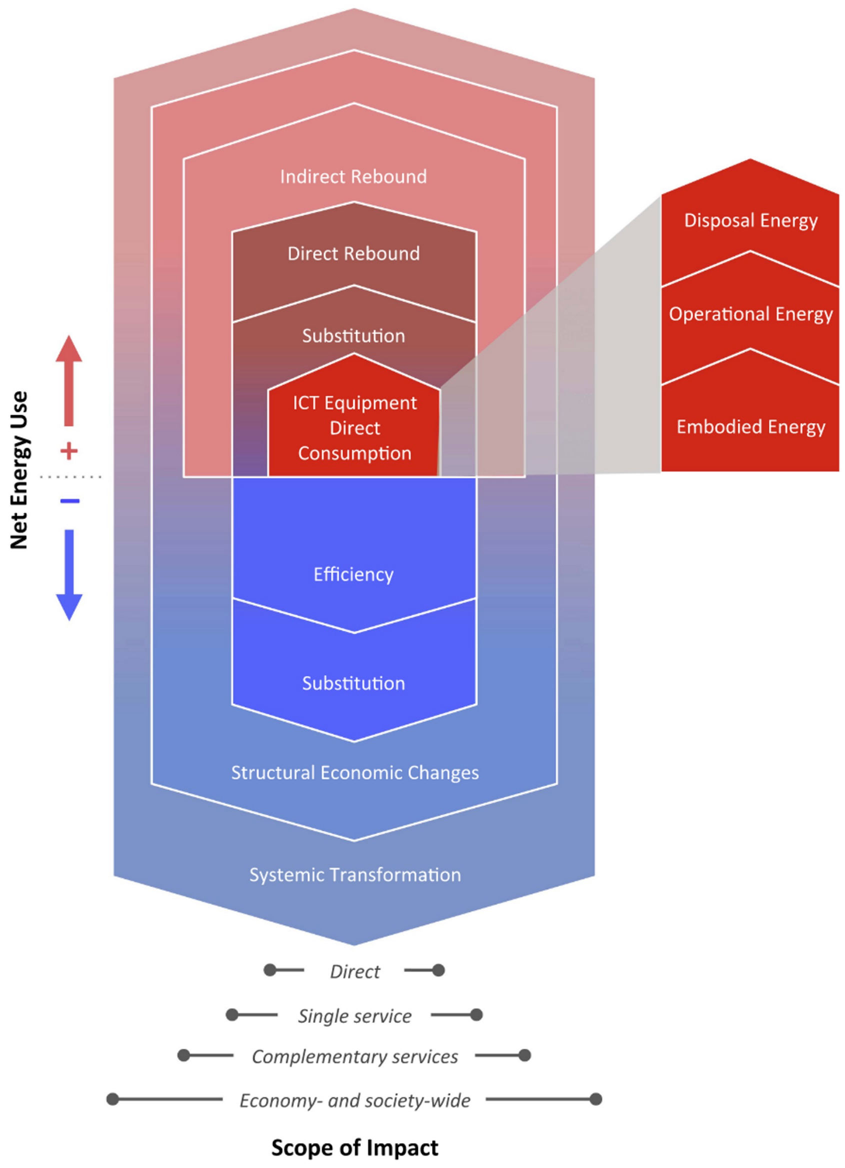

Figure 2. Taxonomy of ICT energy effects. Red effects increase energy use, blue effects decrease energy use, and shading intensity decreases as effect scope increases. (Effect magnitudes are only illustrative and not to scale.)

Rebound effect

- **Direct rebound:** as prices fall, consumption/activity increase
- **Indirect rebound:** cross-price elasticity of demand for other products and services
- **Time rebound:** time saving leads to additional activities
- **Economy-wide rebound:** macroeconomic adjustments
- **Psychology rebound:** diffusion of responsibility, moral licensing

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Rebound effect – smart home

- Energy consumption need to be reduced by at least **6%** for the production and use of smart heating to be environmentally beneficial
- Households purchase and use **additional smart devices** to increase controllability and comfort, rather than reduce energy demand

Lange S, Frick V, Gossen M, Pohl J, Rohde F and Santarius T (2023) The induction effect: why the rebound effect is only half the story of technology's failure to achieve sustainability. Front. Sustain. 4:1178089. doi: 10.3389/frsus.2023.1178089

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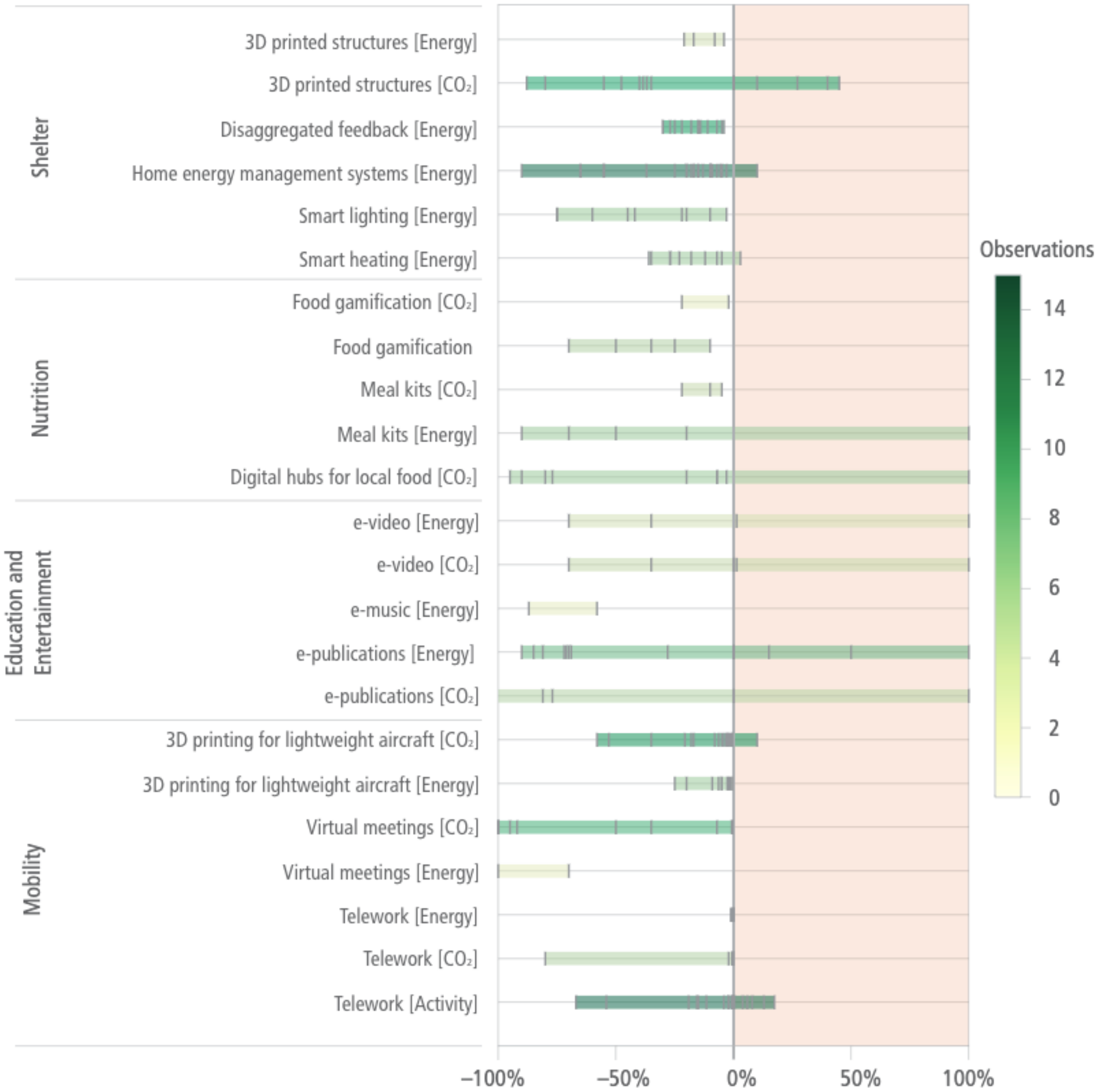
End-user-oriented digitalisation solutions have **mitigation potentials**, but also **risks of increased emissions** due to inefficient substitutions, induced demand, and rebound effects.



Creutzig, F., J. et al. (2022) Demand, services and social aspects of mitigation. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.007.

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Breakout group (10 groups)

- Behaviour change and energy implications (indirect – positive, negative) in case studies:
  - Ride-hailing
  - Video conferencing
  - Autonomous vehicle
  - Meal kits
  - Online shopping

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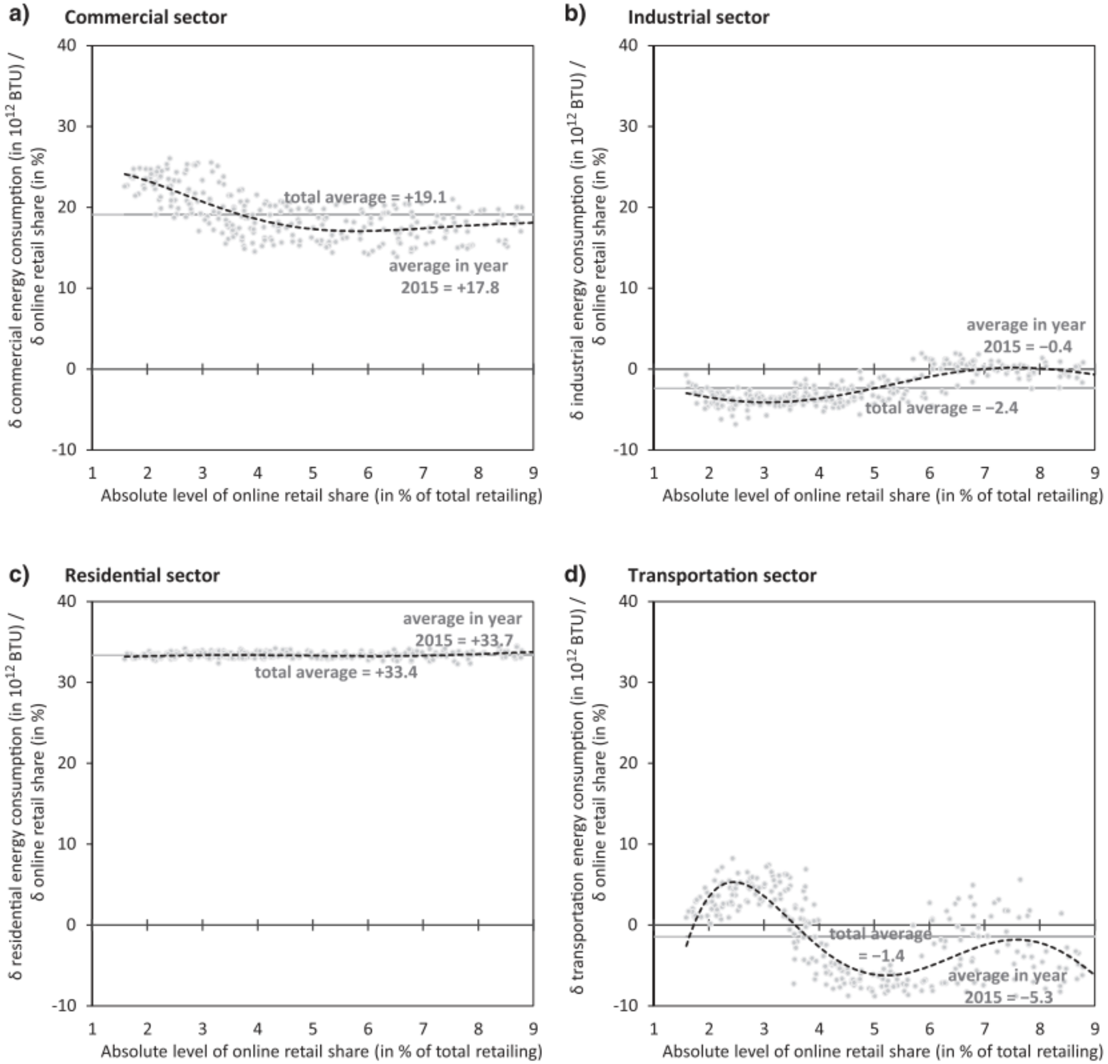
Systemic effects – structural economic changes



Dost, F. & Maier, E. (2017). E-commerce effects on energy consumption: A multi-year ecosystem-level assessment. *Journal of Industrial Ecology,* 22(4). https://doi.org/10.1111/jiec.12639

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Systemic effects – society-wide changes

Job loss,
digital exclusion

Increasing inequality

Reducing trust

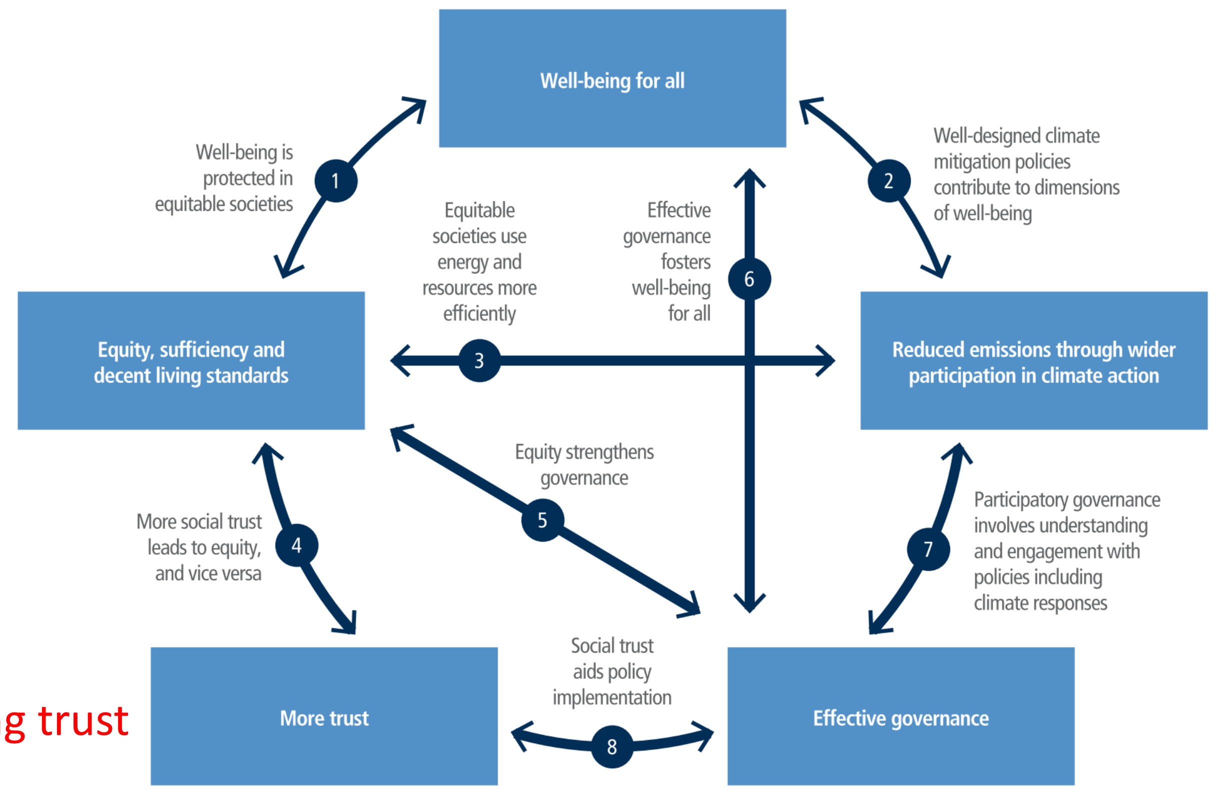


Figure 5.5 | Well-being, equity, trust, governance and climate mitigation: positive feedbacks. Well-being for all, increasingly seen as the main goal of sustainable economies, reinforces emissions reductions through a network of positive feedbacks linking effective governance, social trust, equity, participation and sufficiency. This diagram depicts relationships noted in this chapter text and explained further in the Social Science Primer (Chapter 5 Supplementary Material I). The width of the arrows corresponds to the level of confidence and degree of evidence from recent social sciences literature.

Creutzig, F., J. et al. (2022) Demand, services and social aspects of mitigation. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.007.

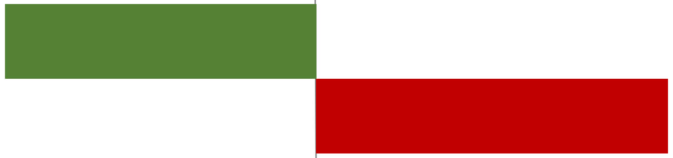
Transport sector: high impact digital applications

- teleworking
- on-demand mobility services
- autonomous vehicles
- also:
  - smart charging, vehicle-to-grid
  - freight logistics

Δ in energy or GHGs

less activity	displaced or (much) more activity
integrated systems	cannibalised public transport
higher occupancy, sharing	single occupancy, deadheading

-Δ > 40%



+Δ > 50%

best case | *worst case*

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Buildings sector: high impact digital applications

- smart building controls & energy management systems
- flexible, responsive demand

also:
- sharing economies (goods, floor area)
- building information modelling
- digital construction (inc. 3D printing)
- real-time data enabling performance contracting

Δ in energy or GHGs	
energy optimisation	comfort-seeking
distributed generation	device proliferation
grid integration	limited flexibility (exc. large users)

-Δ > 10-20%

+Δ < 5-10%

best case *worst case*

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Industry sector: high impact digital applications

- process control, efficiency & automation
- additive manufacturing (3d printing)
- demand response
- also:
  - digital twins for prototyping
  - continuous performance monitoring

Δ in energy or GHGs

best case	worst case
process efficiencies	limited uptake, skills gap
shift from products to services	growth > efficiency (esp. low income)
(new jobs)	(job losses)
-Δ < 5-15%	+Δ > + 5%

large subsectoral variability

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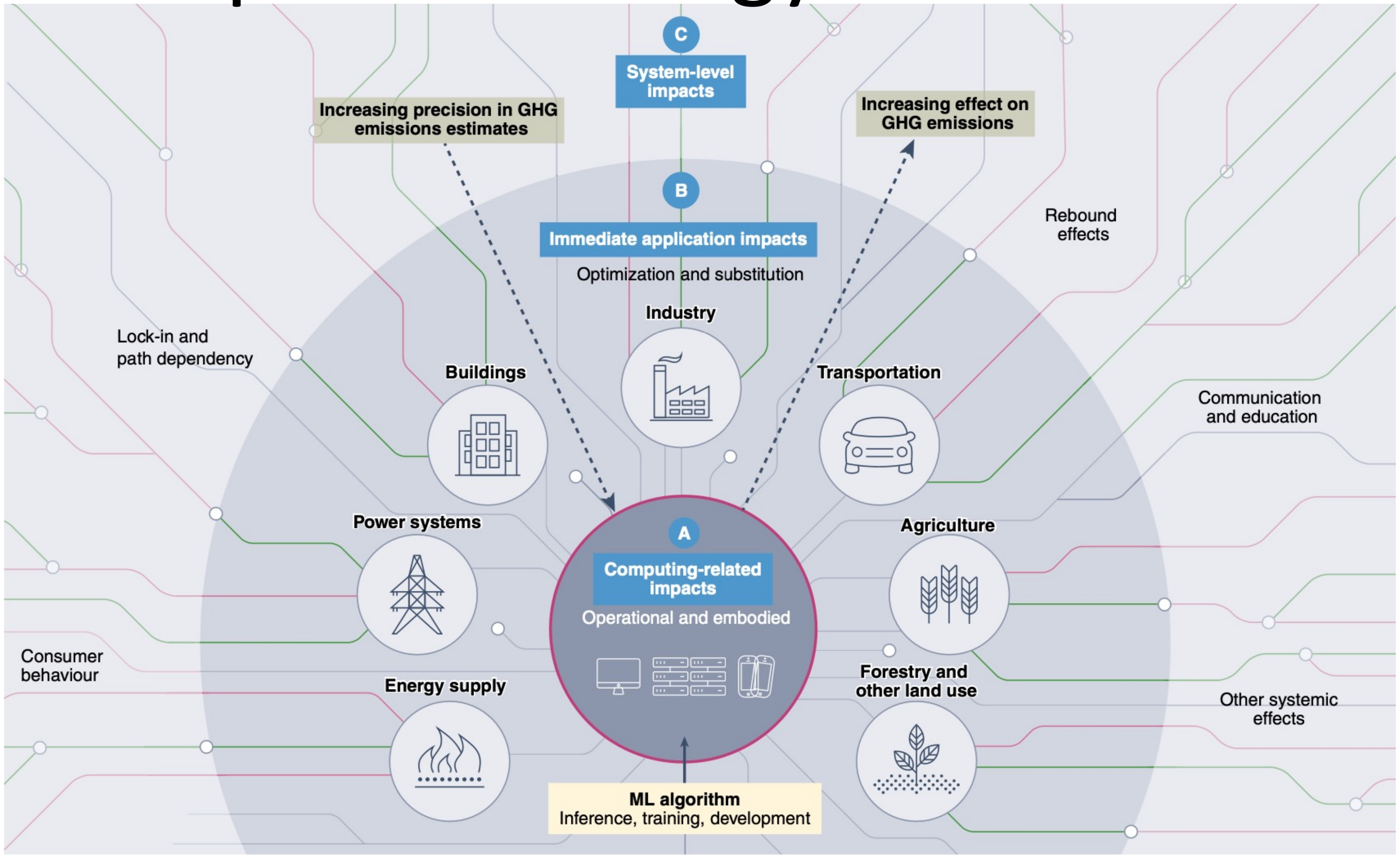
AI impact on energy & emissions



Kaack et al. (2022). "Aligning artificial intelligence with climate change mitigation." Nature Climate Change. doi.org/10.1038/s41558-022-01377-7

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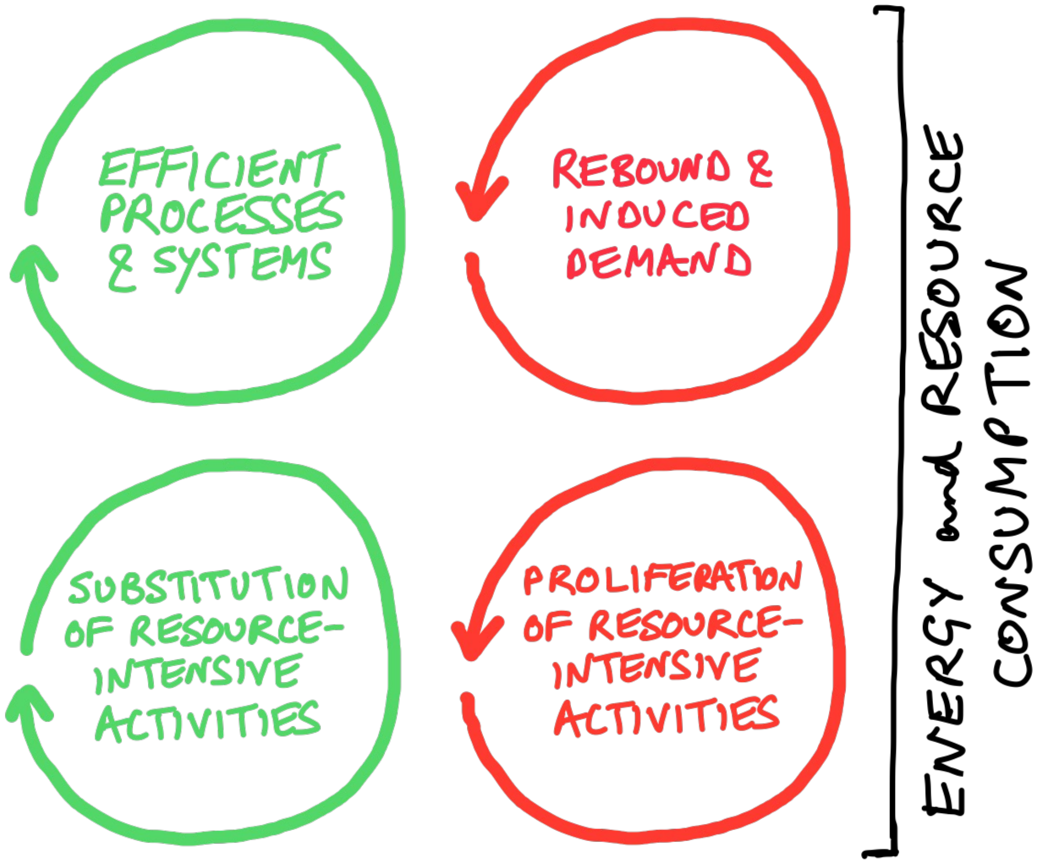
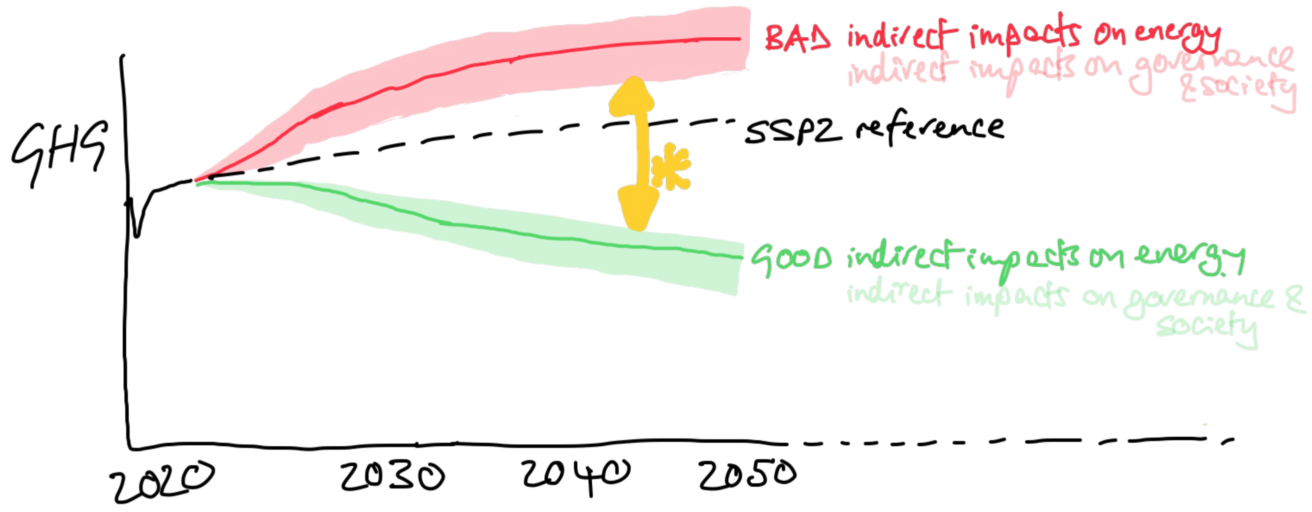
DIGITALISATION DYNAMICS both HELP and HINDER



THE DIGITALIZATION WILDCARD FOR MITIGATION



*** policy response**

(1) generic enablers: access, skills, data, trust

(2) specific climate policy for digitalisation?

Thank you for listening!

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