THE OXFORD INSTITUTE FOR ENERGY STUDIES

# Artificial Intelligence and the Energy Transition

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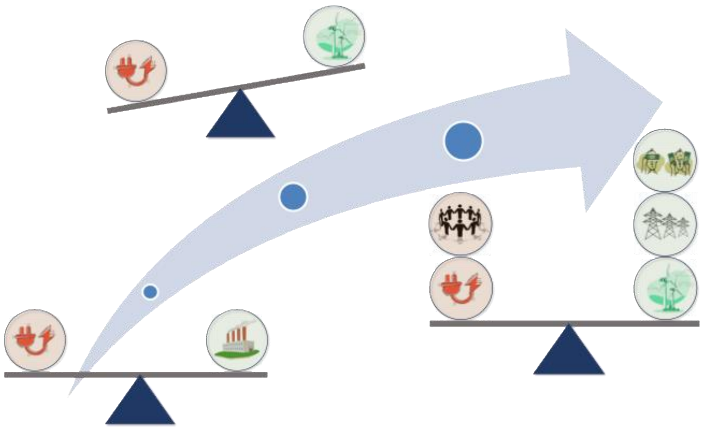
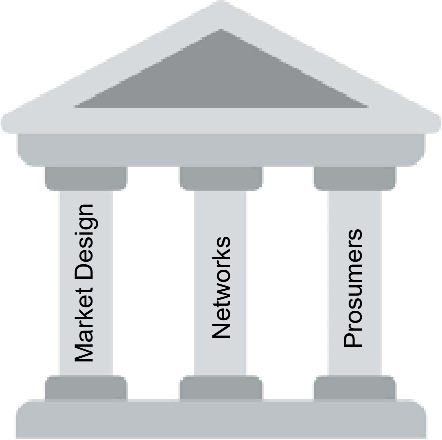
# Oxford Institute for Energy Studies – who we are and what we do

**Academic research on strategic and commercial energy themes, structured across seven main programmes:**

1. Oil research programme, 2. Natural gas research programme,
**3. Electricity research programme, 4.** China energy research programme,
5. Hydrogen research programme, 6. Carbon management programme,
7. The energy transition






*Electricity Programme*: Work towards Decarbonised, Decentralised and Digitalised Electricity Systems

- Market design and integration of renewable energy resources
- Electricity networks and decarbonisation of economy
- Distributed energy resources, demand side flexibility and consumer participation

# Oxford Energy Forum 145

- OEF on Artificial Intelligence and Its Implications for Electricity Systems
- The issue has 14 contributions from authors from academia, industry, and think tanks that examine
  - how AI and electricity systems are becoming increasingly intertwined
  - presenting both challenges and opportunities for the global energy transition

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ARTIFICIAL INTELLIGENCE AND ITS IMPLICATIONS FOR ELECTRICITY SYSTEMS



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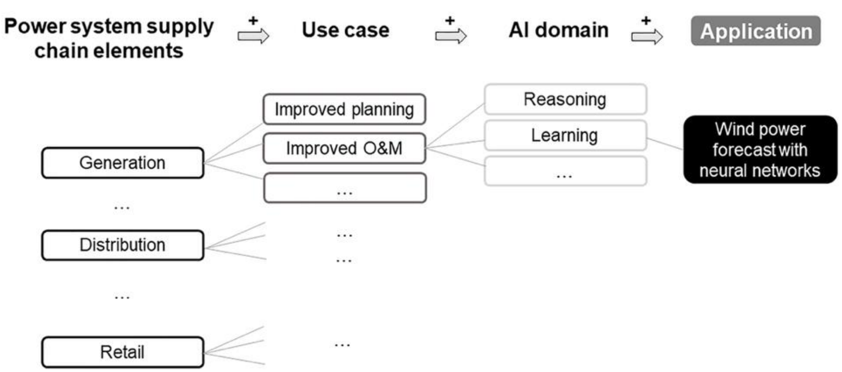
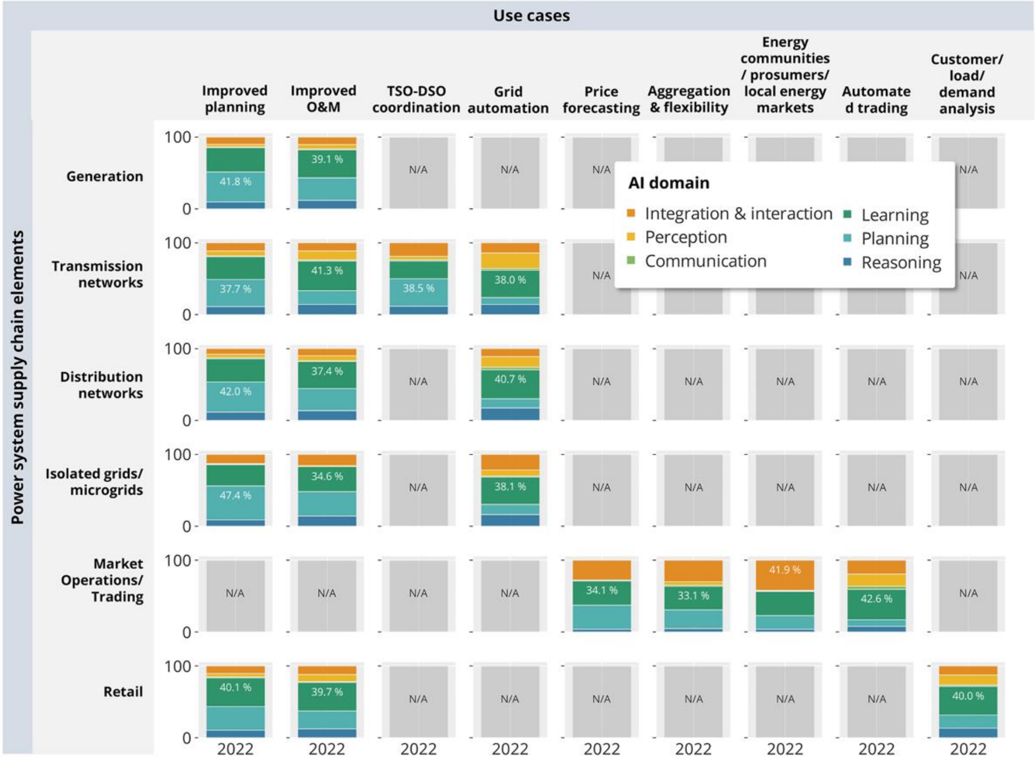
# AI & Energy Transition – Some High-Level Messages

- AI fundamentally transforms energy system operations by, e.g., enabling aggregation of decentralised assets and enhancing cross-sector coordination capabilities
- AI is one of the main drivers of electricity demand growth
- Measures to mitigate AI’s direct impacts on electricity systems
- Introduction of AI’s indirect impacts and their effect on the energy transition

# Use of AI in Power Systems

- AI applications reduce costs for investments in generation by $1.3 trillion, for better component utilisation by $188 billion and overall power system costs by 6-13% through AI-enabled control systems
- AI applications to power systems may be categorised:



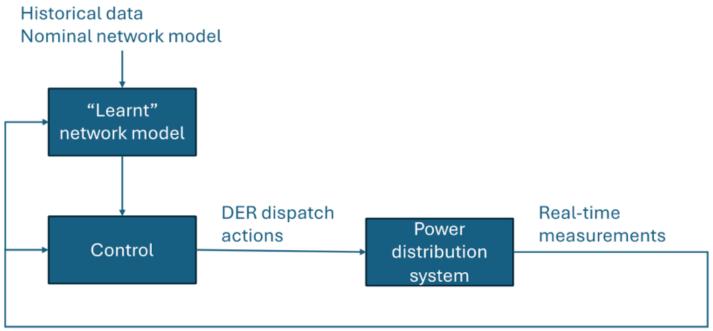




World Economic Forum, 2021; Energy and AI, “Reviewing 40 years of artificial intelligence applied to power systems – A taxonomic perspective”, 2024.

# Transform Data into Actions

- Integration of DERs comes with many benefits; for example, it can improve reliability, decrease operating costs, reduce resource adequacy goals, and aid grid decarbonization

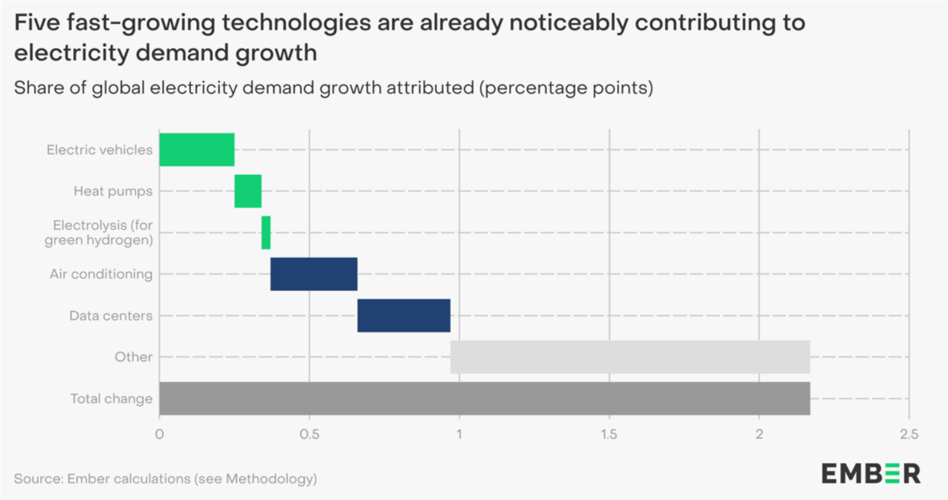

- Deployment of advanced metering infrastructure and communication systems has enabled unprecedented access to real-time operational data
- A key idea in adaptive control methods is to use learning-based techniques and approximate the network model using real-time measurements
- Future control room will look a lot different than today's control room



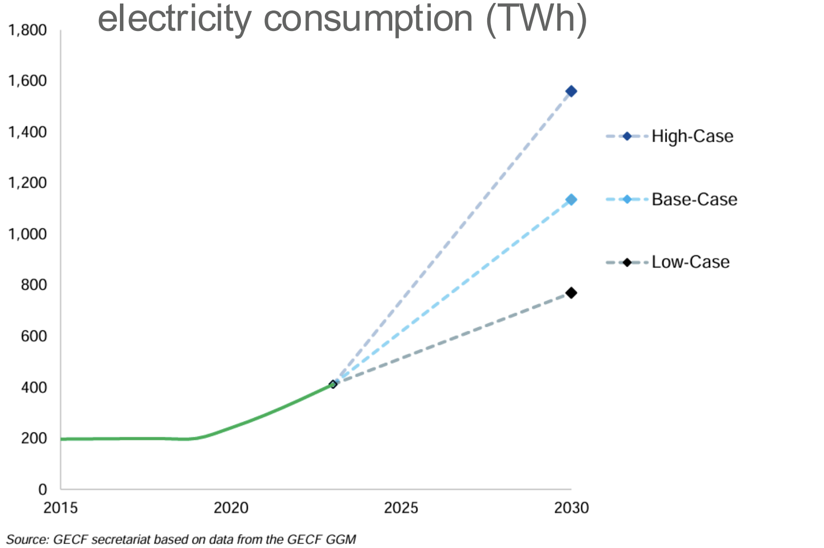

Apostolopoulou et al. "Learning For Control Of Distributed Energy Resources: Enabling Smarter Grid Management"
https://www.nrel.com/

# AI Direct Energy Needs - Future Energy Demand

- Forecasts suggest electricity demand for AI will increase between three and six times by 2030



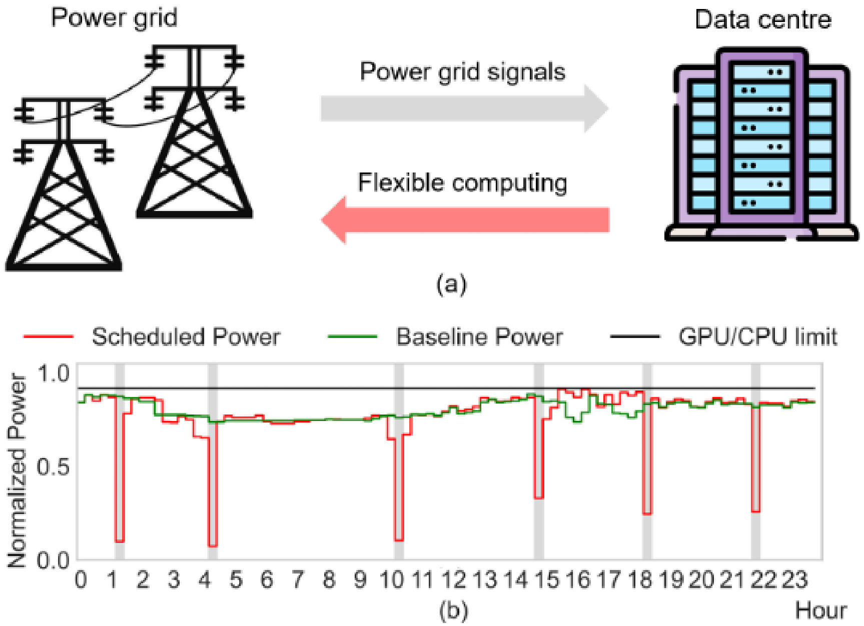

Forecast for global data centre and AI electricity consumption (TWh)




- There is a geopolitical arms race to develop AI, with the UK and the EU committing to massive investments to catch up with the US and China
- Hardware advancements, algorithmic optimisation and open-source models help in decreasing AI energy demand
- Due to a variety of technical and economic factors, it is quite uncertain how much electricity demand will grow and where

# Mitigation of Data Centres Direct Energy Needs

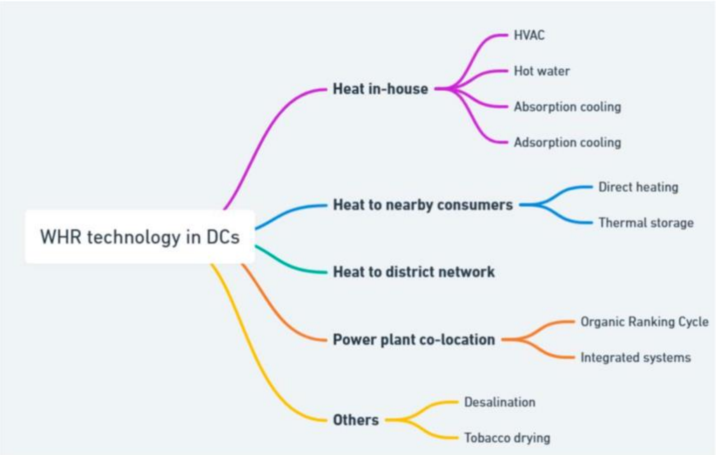
- *Economies of scale*: Large data centres can optimise hardware utilisation by running AI workloads on densely packed, high-efficiency servers, reducing energy waste. Load balancing across server networks enables computing services to be used efficiently
- *Policy and market incentives*. Enforcement of energy-efficiency standards and implementing carbon pricing; green computing financial support
- *Energy management systems*. Some data centres can leverage renewable energy integration and energy storage, reducing dependency on expensive peak-hour electricity; strategies for flexible AI electricity demand
- *Infrastructure efficiency*: Data centres can benefit from efficient cooling, waste heat recovery methods




Robinson et al. "The AI Arms Race and Electricity Needs"; https://eng.ox.ac.uk/

# From Waste To Warmth: Data Centre Heat Recovery

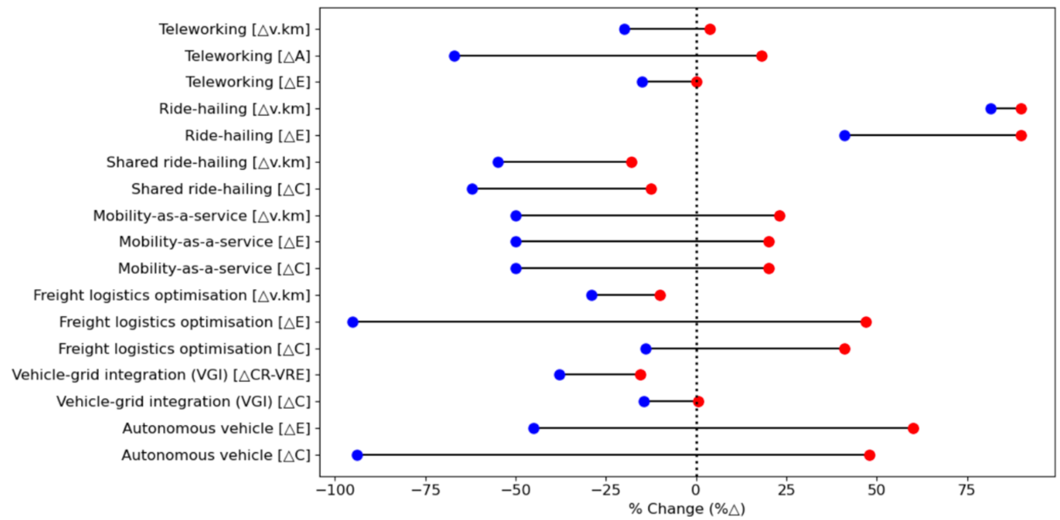
- Data centres convert nearly all their electricity into heat; information technology equipment accounts for 44% and cooling 40% of total electricity consumption
- Waste heat recovery (WHR) projects often face significant technical and economic barriers, making their implementation challenging or unsustainable
- Successful WHR projects are in jurisdictions where clear policies and incentives for heat recovery, alongside extensive district heating infrastructure, are in place
- Effective heat reuse is not just a technological challenge but a systemic one requiring alignment of technical feasibility, economic incentives, regulatory support, and infrastructure readiness
- There is a need for a holistic approach to heat sector decarbonisation strategies and data centre expansion




Apostolopoulou et al. "From waste to warmth: what determines the success of data centre heat recovery?

# AI Indirect Impacts on Climate Change

- Indirect impacts are from the energy consumed or saved by the AI applications; their magnitude is considerably larger than its direct energy footprint
- AI applications are a double-edged sword for energy. By reducing the time, cost, effort, or friction of a wide range of activities, AI drives up or induces demand for those activities. Most AI applications either reduces energy or GHG emissions depending on on rebound effects and whether they can be managed
- Autonomous vehicles can halve demand by optimized routing, driving and occupancy or double it by increases in vehicle trips and distances
- Indirect impacts are currently left to energy or climate policies in the many different AI application domains; however, these should be mitigated by AI governance




Wilson, C., et al. (2024), Evidence Synthesis of Indirect Impacts of Digitalisation on Energy and Emissions, 2024 10th International Conference on ICT for Sustainability; Wilson et al. “AI’s indirect impacts on climate outweigh concerns over its direct energy footprint”

# AI & Energy Transition - Key takeaways

- AI-enabled future power system operations will be very different to current ones and will support decentralised, decarbonised, and digitalised electricity systems
- There is a need to incentivise flexibility from data centres to promote a synergetic relationship with electricity systems
- Plan for data centre expansion and heat sector decarbonization in tandem
- Measurement and regulation of the indirect impacts of AI are imperative to support the energy transition

# Thank you!

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## Questions