International Energy Agency

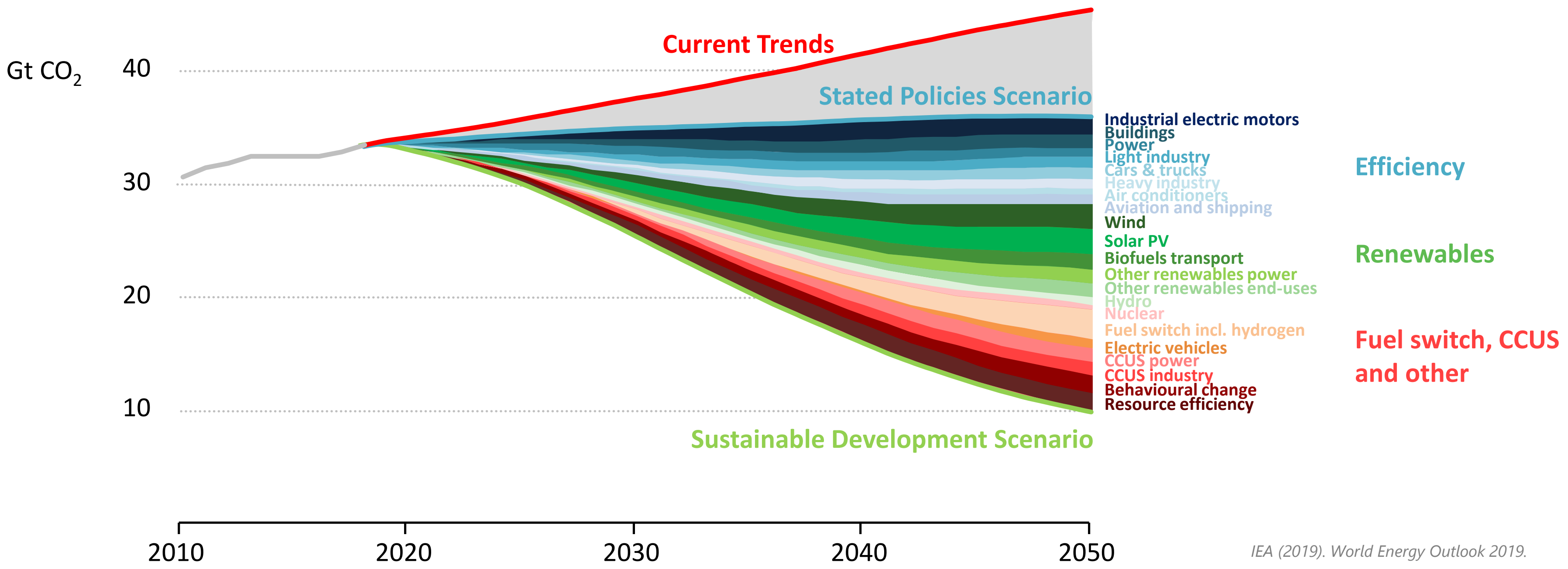
Digital technologies, energy, and climate

George Kamiya, Strategic Initiatives Office

11 December 2019

No single or simple solutions to reach sustainable energy goals

Energy-related CO2 emissions and reductions in the Sustainable Development Scenario by source



IEA (2019). World Energy Outlook 2019.

A host of policies and technologies will be needed across every sector to keep climate targets within reach, and further technology innovation will be essential to aid the pursuit of a 1.5°C stabilisation

Tracking progress of technologies and sectors – www.iea.org/tcep

Power

- Renewable power
  - Solar PV
  - Onshore wind
  - Offshore wind
  - Hydropower
  - Bioenergy
  - Geothermal
  - CSP
  - Ocean
- Nuclear power
- Gas-fired power
- Coal-fired power
- CCUS in power

Industry

- Chemicals
- Iron and steel
- Cement
- Pulp and paper
- Aluminium
- CCUS in industry & transformation

Transport

- Electric vehicles
- Fuel economy
- Trucks & buses
- Transport biofuels
- Aviation
- Shipping
- Rail

Buildings

- Building envelopes
- Heating
- Heat pumps
- Cooling
- Lighting
- Appliances & equipment
- Data centres and networks

Fuel supply

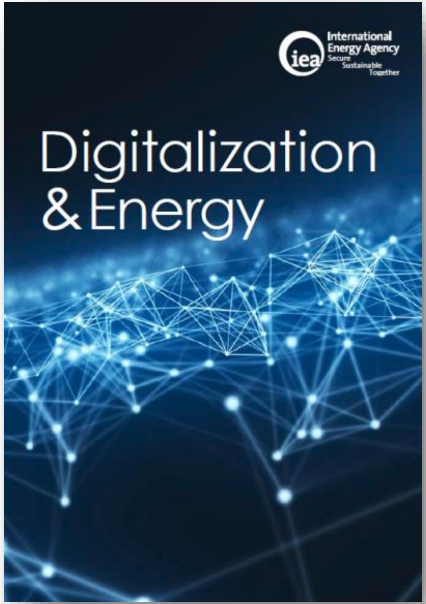
- Methane emissions from oil and gas
- Flaring emissions

Energy integration

- Energy storage
- Hydrogen
- Smart grids
- Demand response

IEA (2019). Tracking Clean Energy Progress. www.iea.org/tcep.

Digitalization & Energy

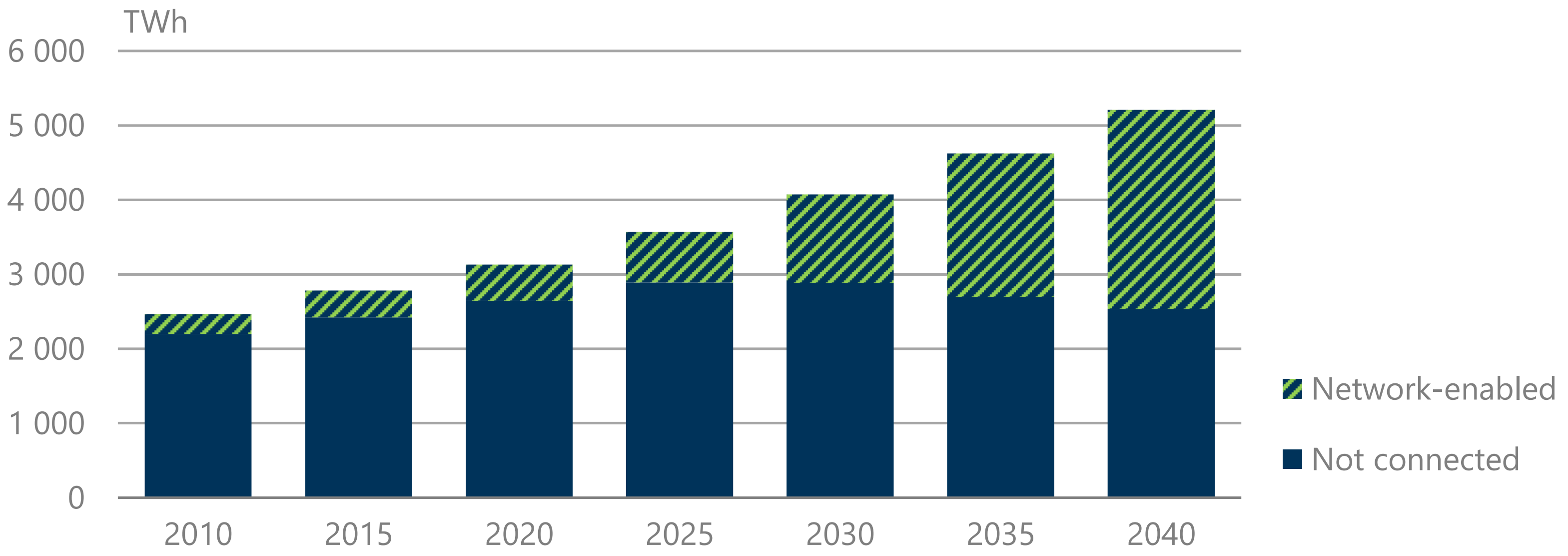


www.iea.org/digital

1. **Introduction**: A new era of digitalization in energy?
2. **Energy demand**: transport, buildings, and industries
3. **Energy supply**: oil and gas, coal, and power
4. **System-wide impacts**: from energy silos to digitally-interconnected systems
5. **Energy use** by digital technologies
6. **Cross-cutting risks:** cyber security, privacy, and economic disruption
7. **Policy**, including no-regrets recommendations

Rapid growth of the IoT and connected devices

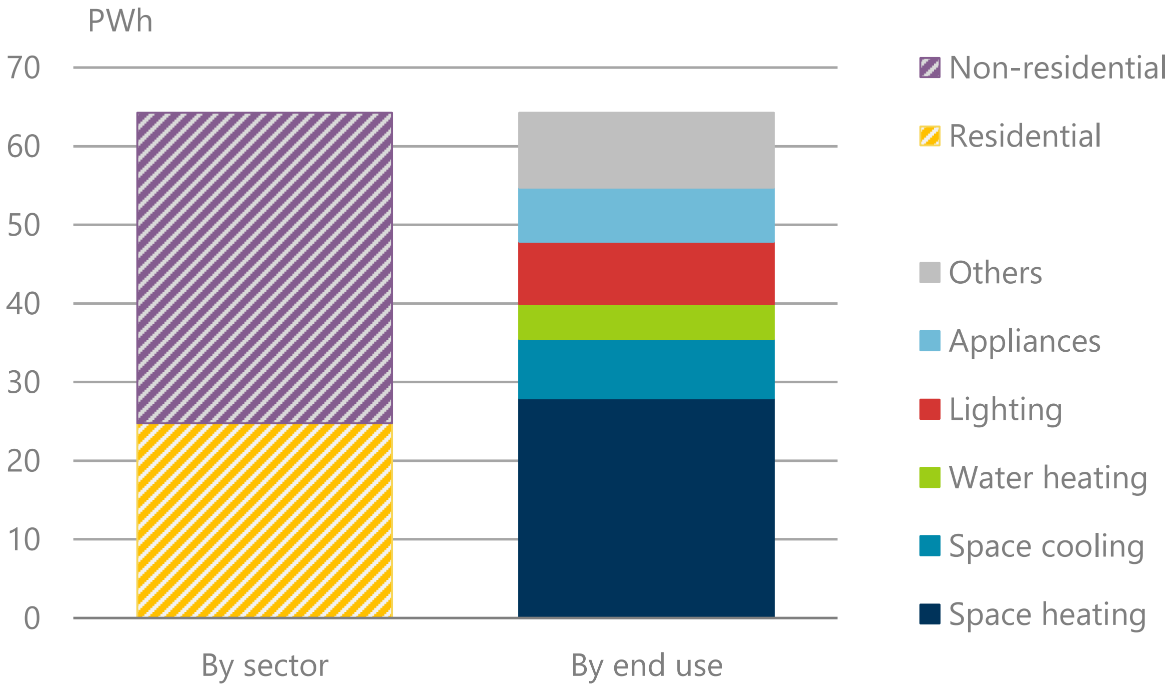
Household electricity consumption of appliances and other small plug loads



IEA analysis

The growth in network-enabled devices presents opportunities for smart demand response but also increases needs for standby power

Buildings

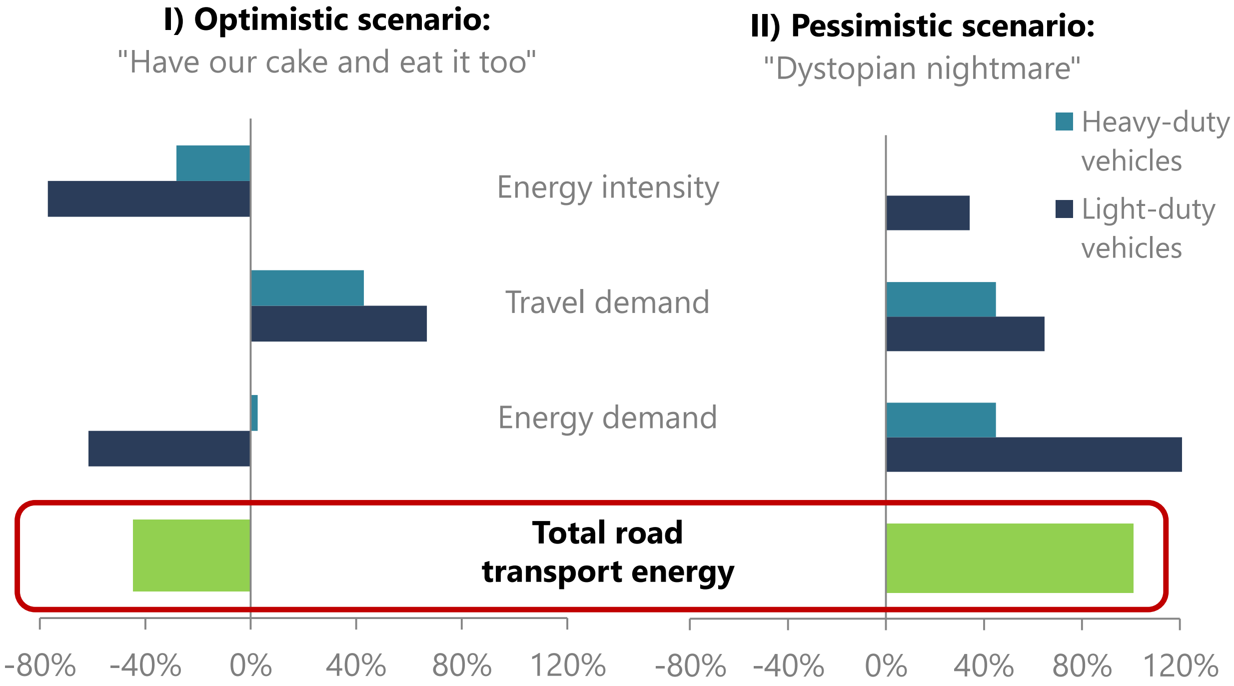


IEA (2017). Digitalization & Energy.

Widespread deployment of smart building controls could reduce energy use by 10% to 2040

Transport

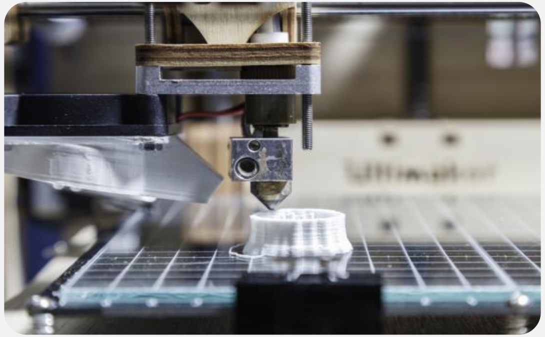
- Automation, connectivity, sharing, and electrification (ACES) to dramatically reshape mobility
- Impacts on energy demand difficult to predict

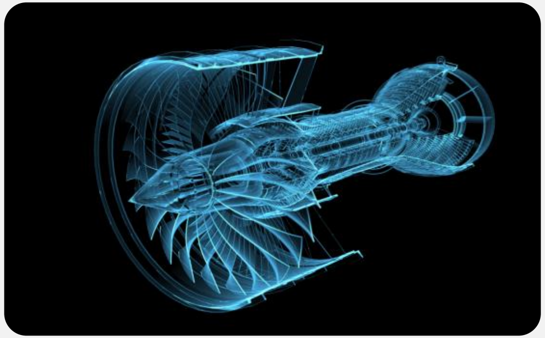


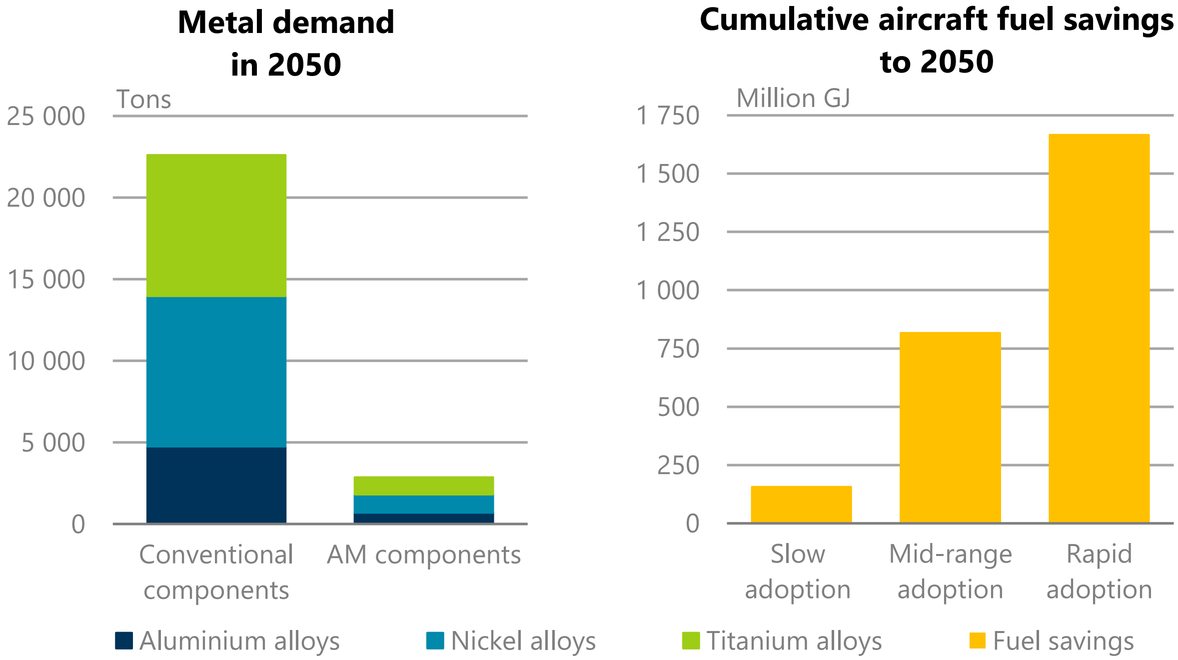
Wadud, MacKenzie and Leiby (2016), "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles".

Road transport energy demand could halve or double from automation and connectivity depending on how technology, behavior, and policy evolve

Industry







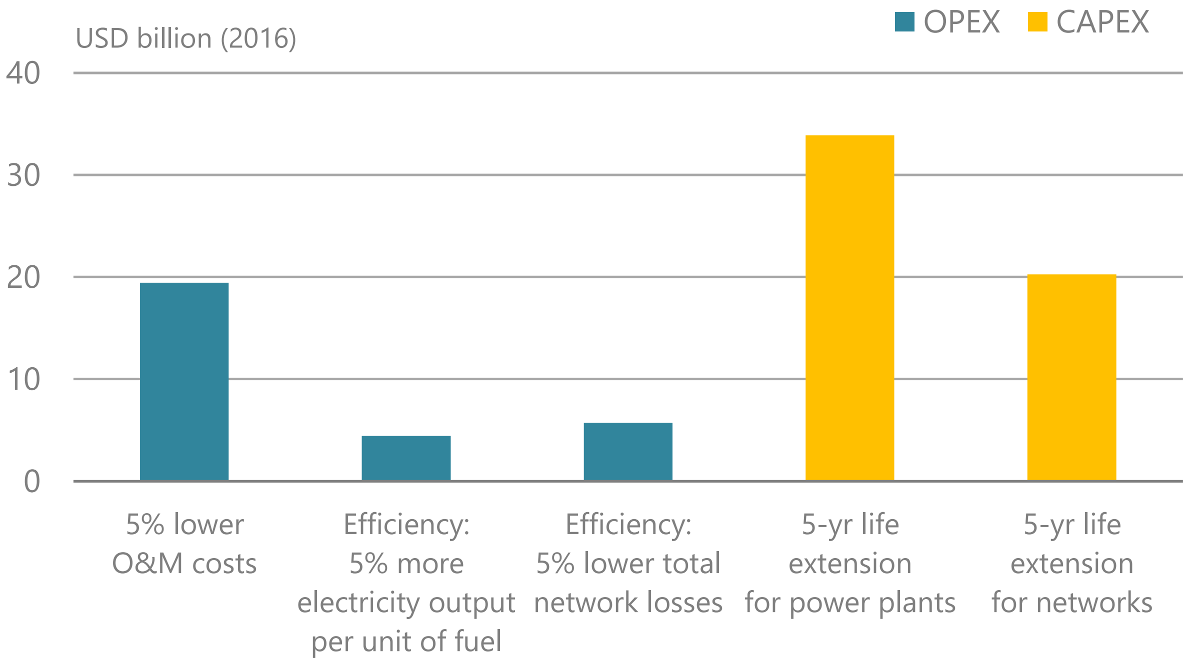
Huang et al. (2016). Energy and emissions saving potential of additive manufacturing: the case of lightweight aircraft components. Journal of Cleaner Production

Energy use can be incrementally reduced at the plant level but widespread use of 3D printing, AI and robotics could herald transformative changes

Electricity generation and networks

Power

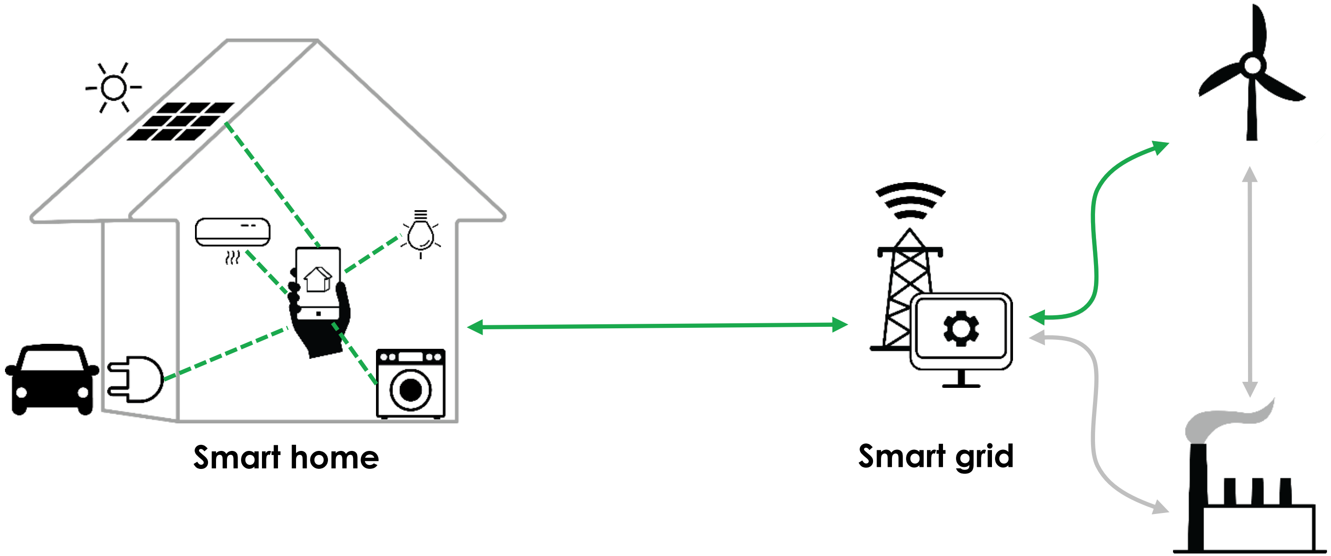
- Power plants and electricity networks could see reduced O&M costs, extended life time, improved efficiencies and enhanced stability



IEA (2017). Digitalization & Energy.

Digitalization could save around USD 80 billion per year, or about 5% of total annual power generation costs

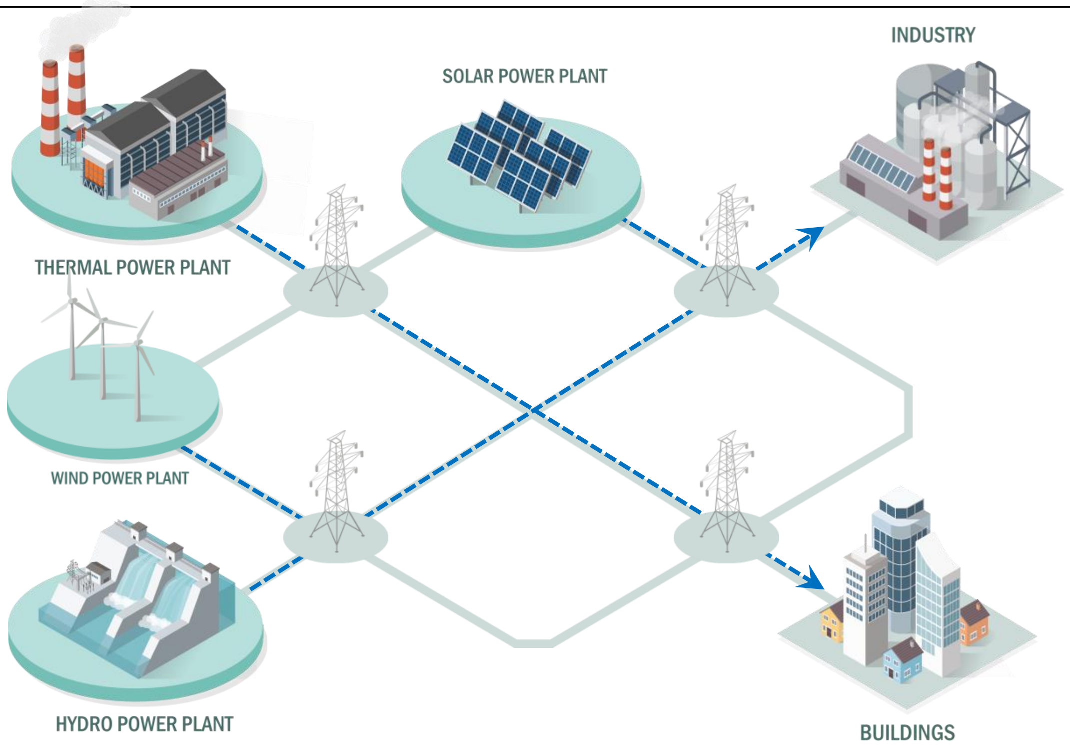
Digitalisation: From end-use to system efficiency



IEA (2019). Energy Efficiency Market Report.

Traditional efficiency policy addresses devices individually. Digitalisation, with the right policies, enables a progression to optimising the efficiency of the whole energy system.

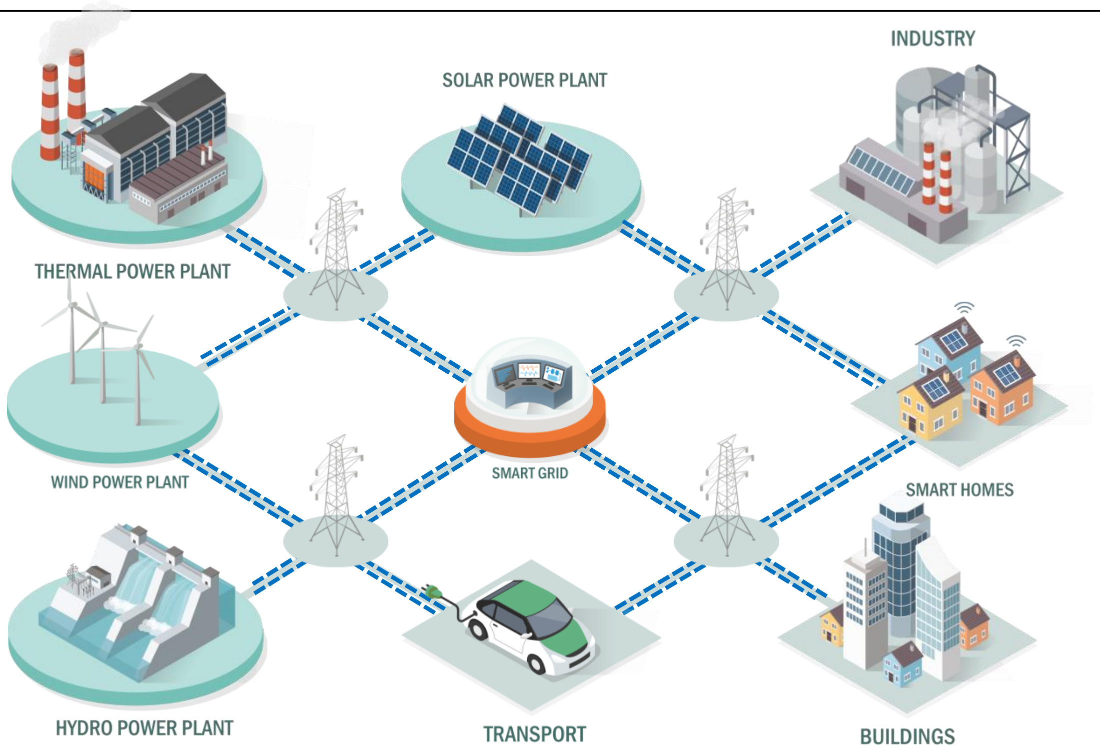
The digital transformation of the energy system



IEA (2017). Digitalization & Energy.

Pre-digital energy systems are defined by unidirectional flows and distinct roles

The digital transformation of the energy system

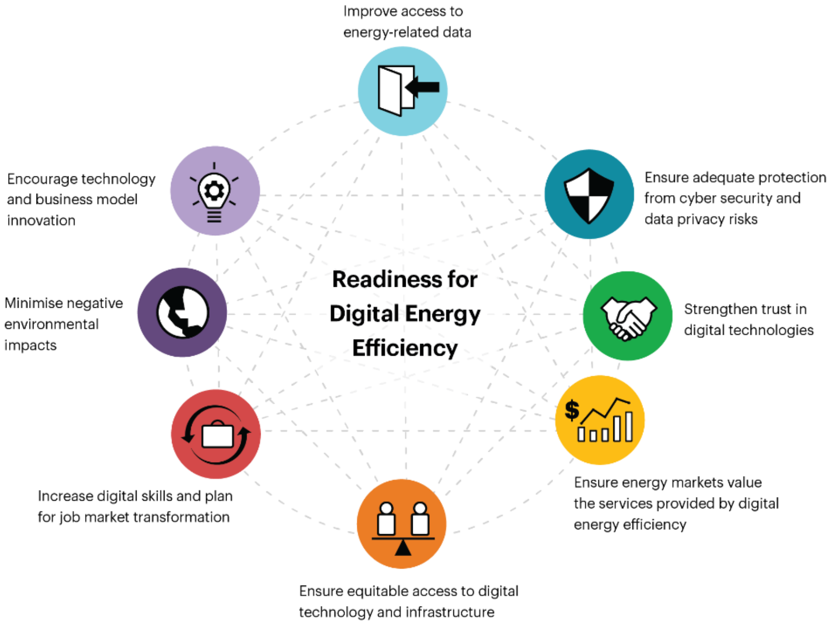


IEA (2017). Digitalization & Energy.

Pre-digital energy systems are defined by unidirectional flows and distinct roles, digital technologies enable a multi-directional and highly integrated energy system

Digitalisation requires policy action

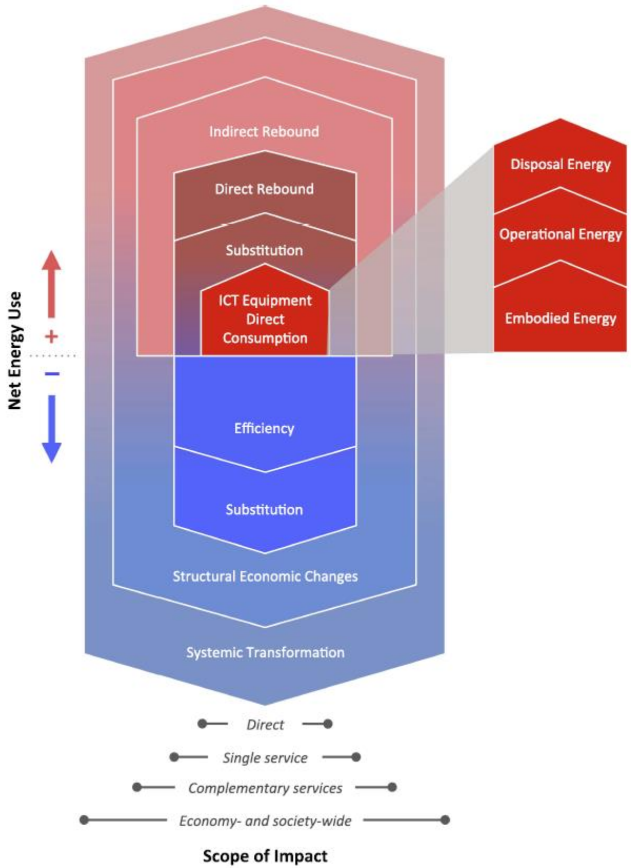
Policy principles comprising the Readiness for Digital Energy Efficiency framework



IEA (2019). Energy Efficiency Market Report.

Policy makers must engage with a range of challenging issues if the world is to harness digitalisation for greater energy efficiency

Direct and indirect effects of ICT



Taxonomy described in this paper		
Effect	**Scope**	**GPS System Example**
Embodied energy	Direct	Energy to produce a GPS system
Operational energy		Energy to operate a GPS system
Disposal energy		Energy to dispose of a GPS system at end-of-life
Efficiency	Indirect: Single-service	More efficient traffic flow due to GPS-enhanced routing
Substitution		Replacement of paper-based maps
Direct rebound		More travel due to lower cost of traffic congestion
Indirect rebound	Indirect: Comple-mentary services	Energy consumed during time saved by more efficient travel
Economy-wide rebound (Structural change)	Indirect: Economy-wide	GPS enables autonomous vehicles and causes growth of intelligent transportation system manufacturing
Systemic Transformation	Indirect: Society-wide	Autonomous vehicles alter patterns in where people choose to live and work

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.

ICT energy use

Support us →

The Guardian

News | Opinion | Sport | Culture | Lifestyle

Guardian Environment Network

‘Tsunami of data’ could consume one fifth of global electricity by 2025

Billions of internet-connected devices could produce 3.5% of global emissions within 10 years and 14% by 2040, according to new research, reports Climate Home News

Climate Home News, part of the Guardian Environment Network

Mon 11 Dec 2017 08.27 EST

1 year old

The communications industry could use 20% of all the world’s electricity by 2025, hampering attempts to meet climate change targets and straining grids as demand by power-hungry server farms storing digital data from billions of smartphones, tablets and internet-connected devices grows exponentially.

Why Energy Is A Big And Rapidly Growing Problem For Data Centers

Forbes

Radoslav Danilak Forbes Councils Member
Forbes Technology Council COUNCIL POST | Paid Program
Innovation

POST WRITTEN BY

Radoslav Danilak

U.S. data centers use more than 90 billion kilowatt-hours of electricity a year, requiring roughly 34 giant (500-megawatt) coal-powered plants. Global data centers used roughly 416 terawatts (4.16×10^{14} watts) (or about 3% of the total electricity) last year, nearly 40% more than the entire United Kingdom. And this consumption will double every four years.

Are data centres still big energy guzzlers?

Share 6 | Tweet

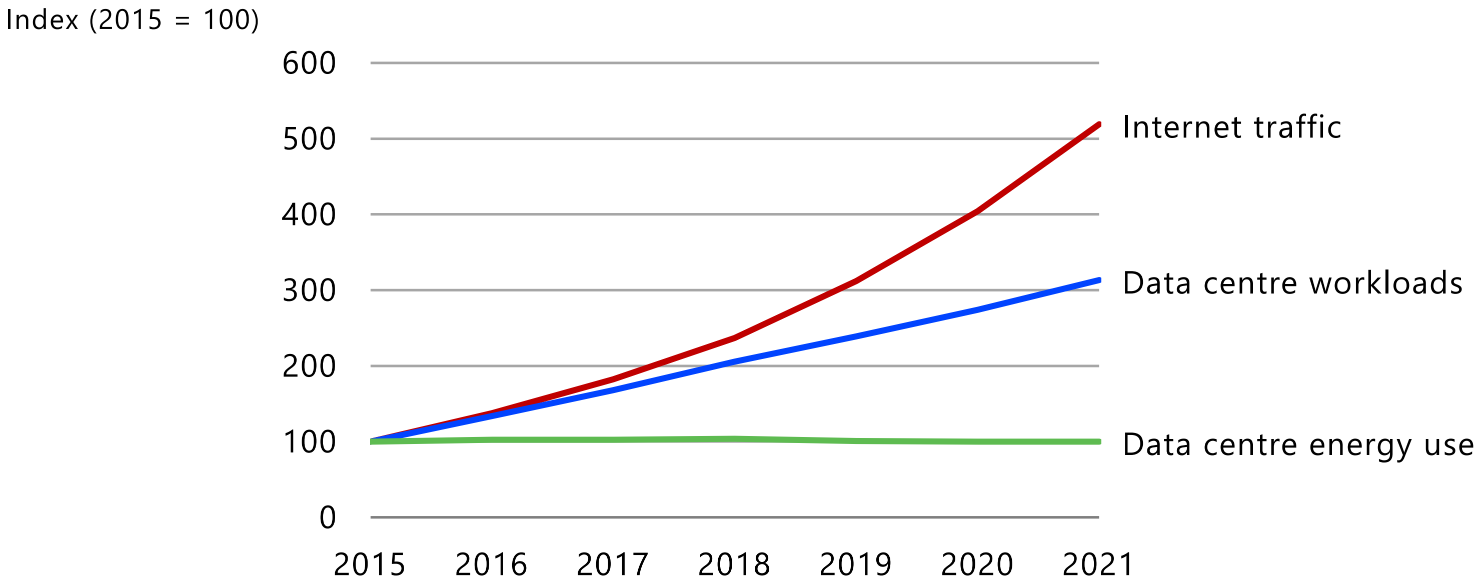
Poppy Johnston | 8 August 2019

Data centres consume 3 per cent of the world’s energy so it’s fortunate these buildings are becoming increasingly energy efficient. Sadly these efficiency gains might disappear when the world’s appetite for data is expected to accelerate with the proliferation of artificial intelligence and autonomous cars.

iea

ICT energy use: service demand growth vs. efficiency

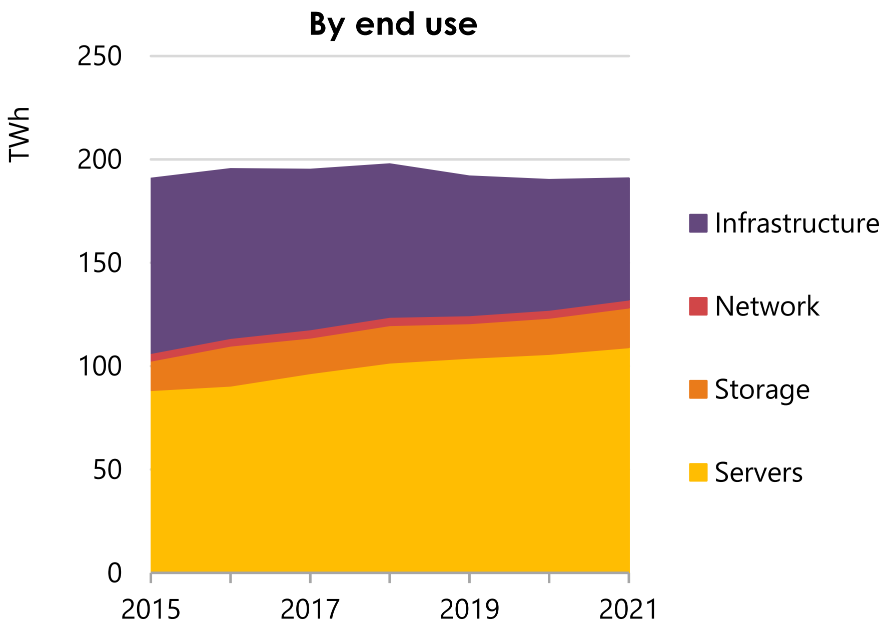
Global trends in internet traffic, data centre workloads and data centre energy use

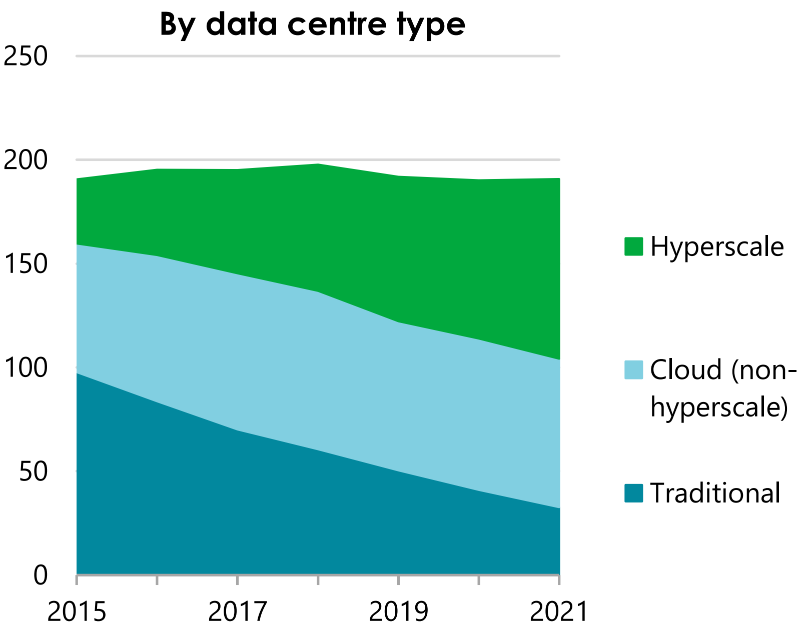


IEA (2019). Tracking Clean Energy Progress: Data centres and networks; Cisco (2018). Global Cloud Index.

Global internet traffic has tripled since 2015, but data centre energy use remains flat

ICT energy use: data centres



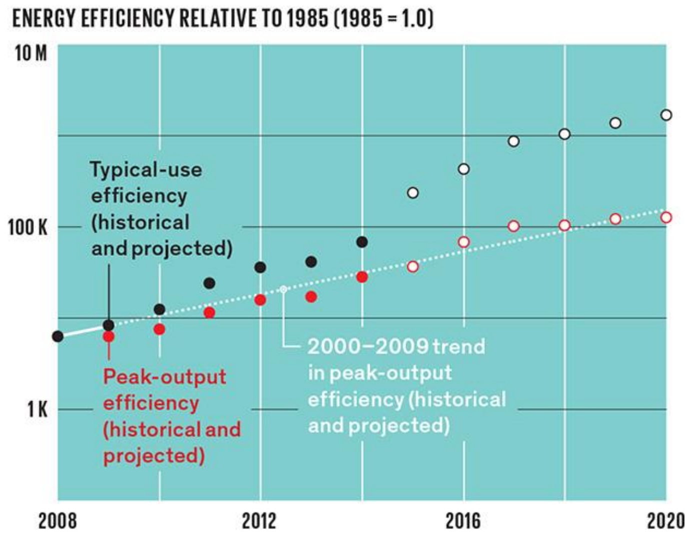


IEA (2019). Tracking Clean Energy Progress: Data centres and data transmission networks.

Strong efficiency improvements and a shift to hyperscale data centres have helped to keep global data centre energy demand flat

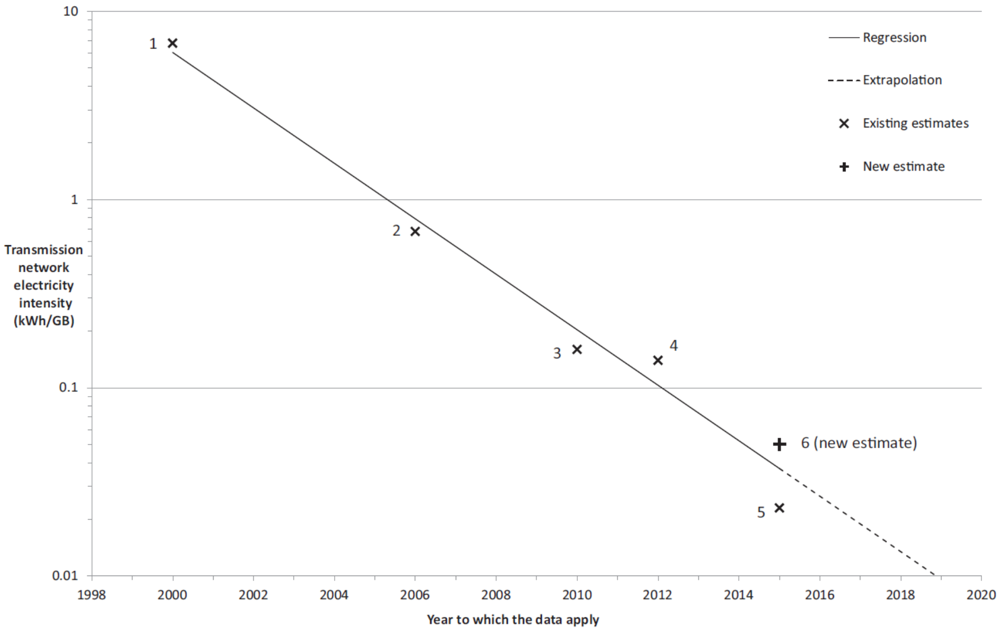
ICT energy use: efficiency trends

Computing



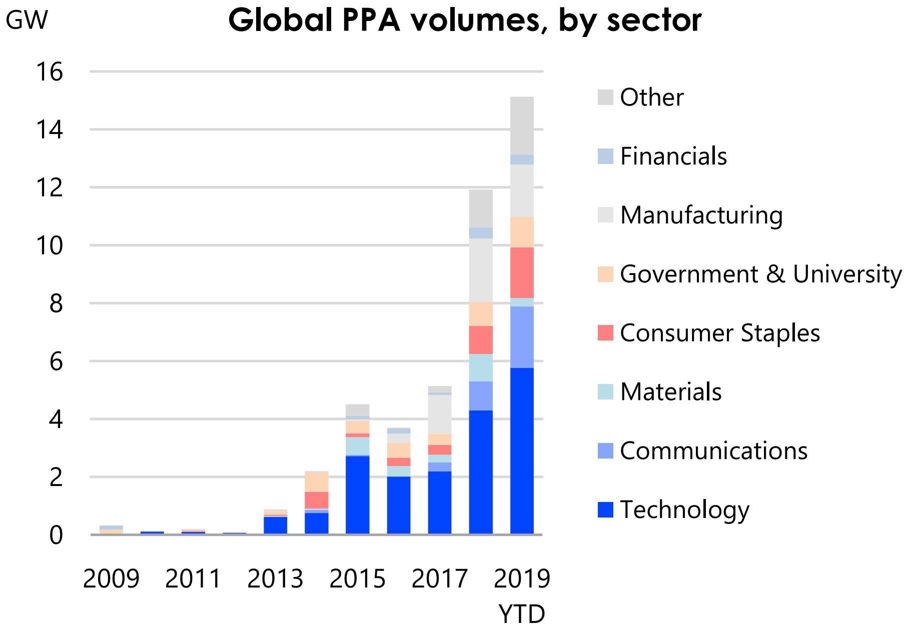
Koomey, J. and S. Naffziger (2015), "Moore's Law Might Be Slowing Down, But Not Energy Efficiency", *IEEE Spectrum*.

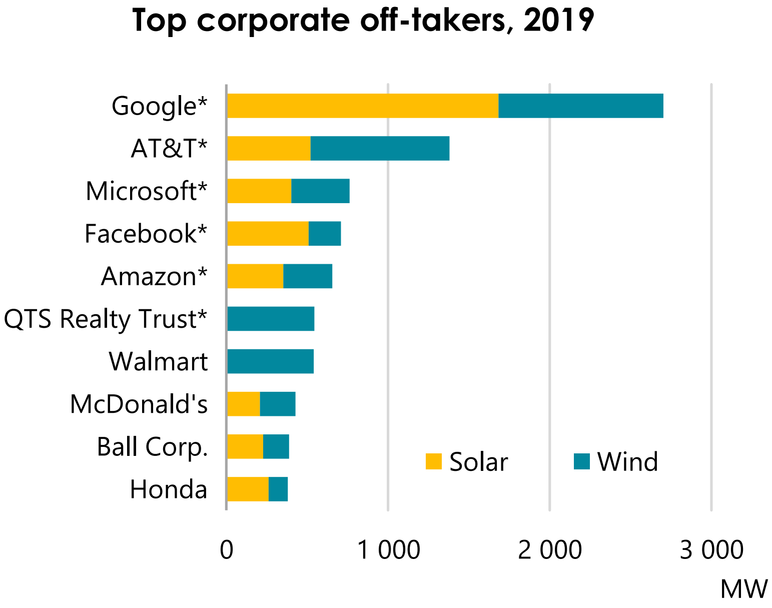
Data transmission



Aslan, J., Mayers, K., Koomey, J. G., & France, C. (2018). Electricity intensity of Internet data transmission: Untangling the estimates. Journal of Industrial Ecology, 22(4), 785-798.

ICT energy use: renewable energy

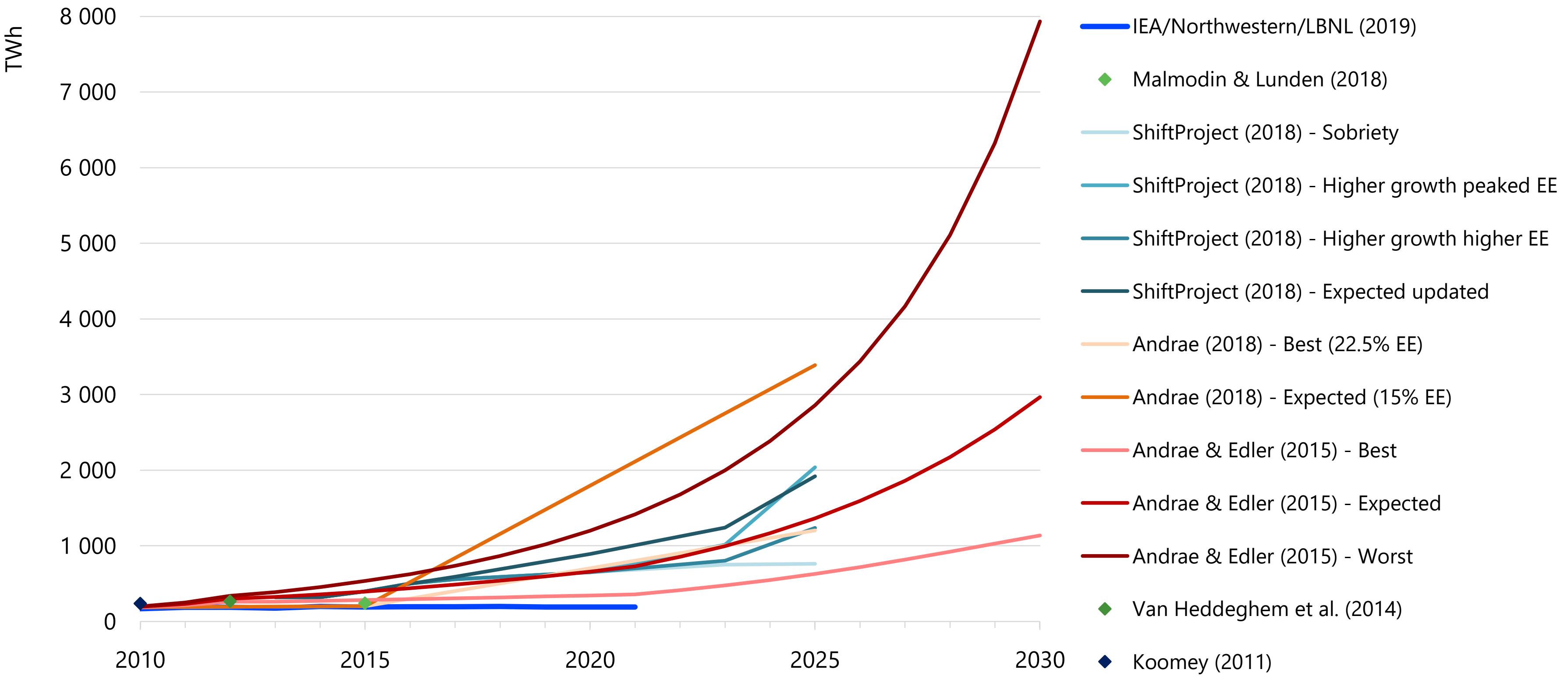




Notes: * denotes ICT company. 2019 data as of November 2019.
Source: BloombergNEF (2019), Corporate PPA Deal Tracker November 2019.

ICT companies are leaders in corporate renewable energy procurement, and further efforts to match for time and location can reduce environmental impacts of data centres further

Comparing global energy use estimates for data centres



Global electricity demand in 2030 in the IEA NPS: ~30,000 TWh

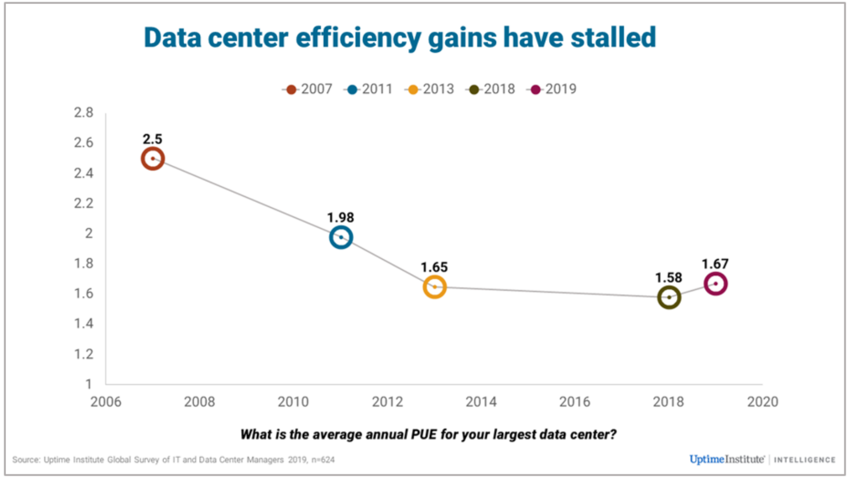
Questions for longer-term outlooks

- Continued slowdown in IT efficiency (Koomey's Law) and long-term limits to efficiency?
- Slowdown in PUE improvement?
- Limits to shifting to hyperscale?
- Emerging demands and services: AI/ML, blockchain, 5G, AR/VR, connected and automated vehicles, rebound effects, etc.

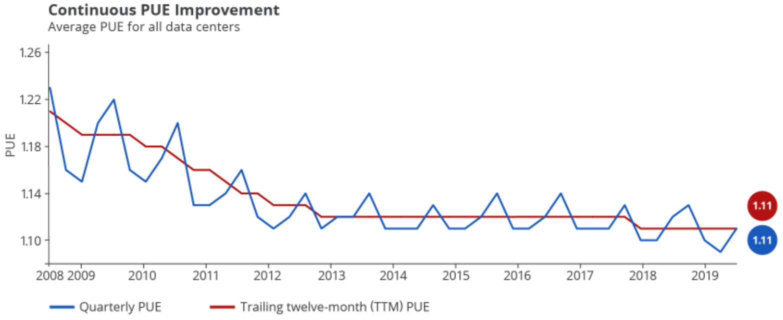
Consumption	CO_2e (lbs)
Air travel, 1 passenger, NY↔SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car, avg incl. fuel, 1 lifetime	126,000
Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experimentation	78,468
Transformer (big)	192
w/ neural architecture search	626,155

Table 1: Estimated CO_2 emissions from training common NLP models, compared to familiar consumption.[1]

Strubell et al. (2019). Energy and Policy Considerations for Deep Learning in NLP.

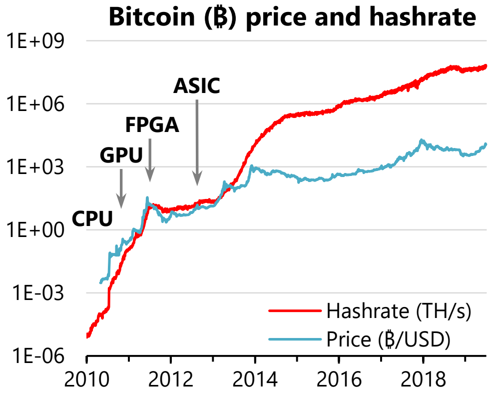


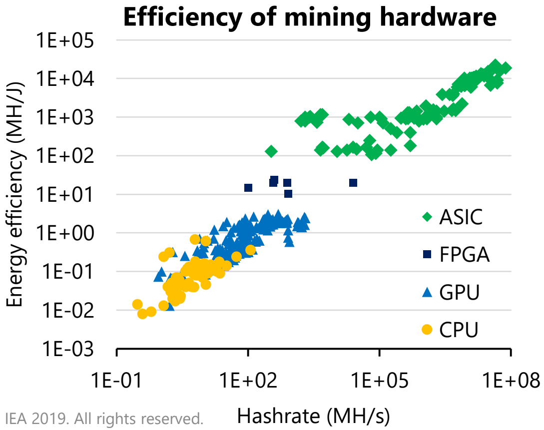
Uptime Institute (2019). Is PUE actually going up? https://journal.uptimeinstitute.com/is-pue-actually-going-up/.

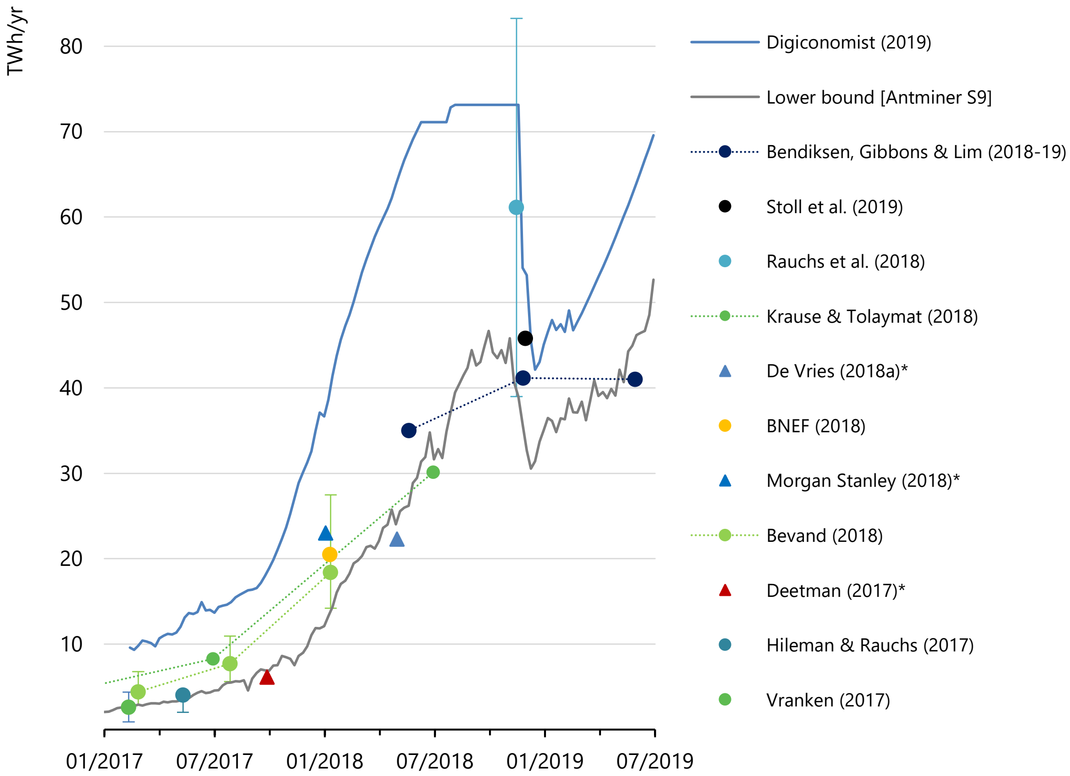


Google (2019), Data Centres: Efficiency, https://www.google.com/about/datacenters/efficiency/.

Bitcoin mining: ~45 TWh in 2018; ~30 TWh in 2019-H1







IEA (2019). Bitcoin energy use: mined the gap.

Further reading

- IEA reports:
  - Digitalization & Energy. www.iea.org/digital.
  - Tracking Clean Energy Progress. www.iea.org/tcep.
  - Energy Efficiency Market Report 2019. www.iea.org/reports/energy-efficiency-2019.

- Climate Change AI; Tackling Climate Change with Machine Learning. www.climatechange.ai/.
- Horner et al. (2017). Known unknowns: indirect energy effects of information and communication technology. iopscience.iop.org/article/10.1088/1748-9326/11/10/103001.
- Shehabi et al. (2016). United States Data Center Energy Usage Report. eta.lbl.gov/publications/united-states-data-center-energy.
- Malmodin & Lunden (2018). The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015. www.mdpi.com/2071-1050/10/9/3027.

George Kamiya
Strategic Initiatives Office

george.kamiya@iea.org
linkedin.com/in/georgekamiya/
@GeorgeKamiya