

The Age of Power

How an electric revolution in information and energy is redefining power

16 September 2026

Daan Walter, Sam Butler-Sloss,
Kingsmill Bond, Antoine Issac

Executive Summary

The race of the 21st century is the race to master the electron

- ◆ **The world runs on two foundations: energy and information.** Energy does work; information directs it. The digital revolution shifted information onto electrons; the electrotech revolution is shifting energy onto electrons as well.
- ◆ **The electrification of information.** Over 99% of the world's storage and communication is already digital, and so runs on electrons. Now, with AI, thinking itself is moving onto electrons too.
- ◆ **The electrification of energy.** Electricity already overtook oil as the largest source of useful energy in 2007. Since then, renewables have made electrons cheap, digitalisation and AI have made them smart, and batteries have made them mobile. The combination is speeding up electrification.
- ◆ **The two revolutions have far more in common than conventional wisdom holds.** They share a history, a physics, a supply chain, a geography and the same scaling laws. They have even been built by the same people, from Robin Zeng to Greg Jackson.
- ◆ **One shared tech stack makes two revolutions turn the same flywheel.** Five components – chips, batteries, power electronics, motors and sensors – sit inside the machines of both revolutions, so each purchase of one makes the others cheaper. The smartphone made the battery cheap enough for the car; the car made it cheap enough for the grid. Since 1990, their combined cost has fallen by 99%.
- ◆ **Each revolution now needs the other.** AI's limits are increasingly electrical. It needs power and grid connections, fast. And physical AI needs economy-wide electrification, since it demands far greater precision and responsiveness than fossil fuels can offer. Likewise, electrotech's limits are increasingly in coordination: smoothing a variable, distributed supply, flexing an idle demand, and optimising an underutilised grid – a challenge infotech helps address.
- ◆ **Together, they can collapse costs.** Move a household onto electrotech, then optimise its usage, and running costs fall by up to 80%. Electrify motion and automate driving, and freight and taxi costs fall by up to 70%. Combine electrification with advanced automation, and manufacturing costs fall by 40–70%.
- ◆ **Few countries fuse the two revolutions together.** Most are pursuing one revolution alone, or both apart. The US leads in AI but lags in electrotech; Europe leads in renewables but lags in electrification and has little AI. The standout exception is China: since 2010 it has more than doubled its electricity supply, taken EVs from zero to over 60% of new car sales, and built the world's largest robot fleet and the second-largest AI data centre fleet.
- ◆ **The shape of things to come.** Growth this decade, disruption in the 2030s, then a new world.
- ◆ **This decade: growth amid friction.** Electrotech and infotech costs will keep falling, performance will keep improving and deployment will keep rising. Bottlenecks, bubbles and backlash are all but guaranteed, but will not be enough to hold back the tide of change.
- ◆ **The 2030s: disruption to four sources of power.** Energy shifts from molecules to electrons; industry from incumbents to innovators; geopolitics from geology to technology; defence from concentration towards swarms. Small and fast beats big and heavy, as size moves from a shield to a burden.
- ◆ **The long term: a new electric world.** Electric energy and intelligence promise decentralisation, faster decarbonisation, greater sovereignty and new-found abundance. But they could also concentrate manufacturing, put dangerous intelligence in every pocket, and entrench autarky. A world of ubiquitous energy and intelligence may be richer and cleverer – but not necessarily wiser.
- ◆ **The electron is now the foundation of power itself.** Success rests on securing cheap electricity and capital, using these new tools to build energy and digital sovereignty, and taking a stake in the electro-industrial base.

Contents

01 Two interlinked revolutions

The electrification of information and energy

02 The electric rise

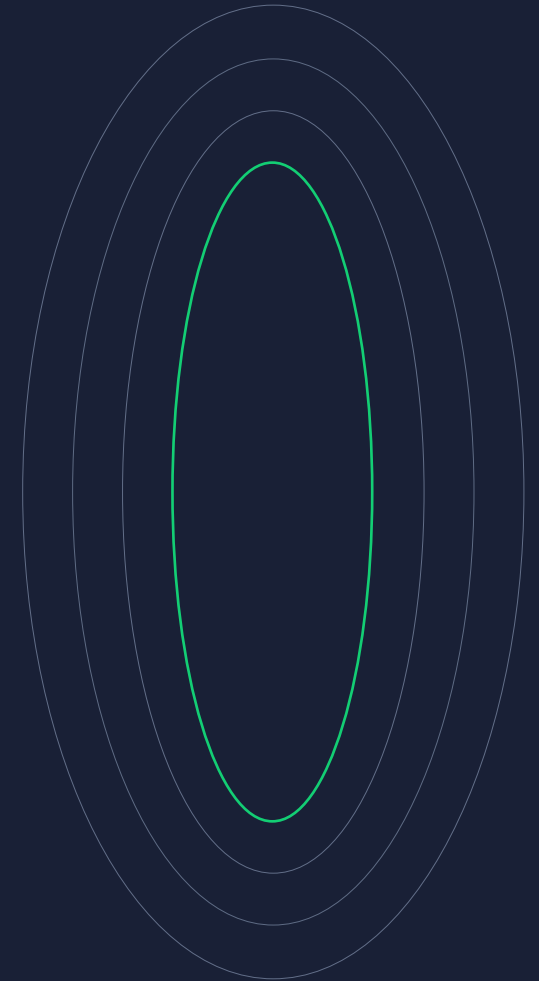
The rise of infotech and electrotech

03 The shape of things to come

The implications of the two revolutions converging

04 Seizing the opportunity

Navigating the incoming electric disruption



The electrification of information and energy

01

A shared history

For nearly 200 years, from the telegraph to electricity to the internet, we have seen interlinked stories of rapid growth in infotech and electrotech. Each has built off the other.

02

A shared supply chain

Both areas rely on similar electro-minerals for most of their materials. They share the same five core components of chips, sensors, power electronics, batteries and electric motors.

03

The same people and places

They are largely developed and manufactured by the same groups of entrepreneurs (Elon Musk, Greg Jackson, Robin Zeng) in the same places (Eastern China, Northern Europe, coastal US).

04

The same physics and economics

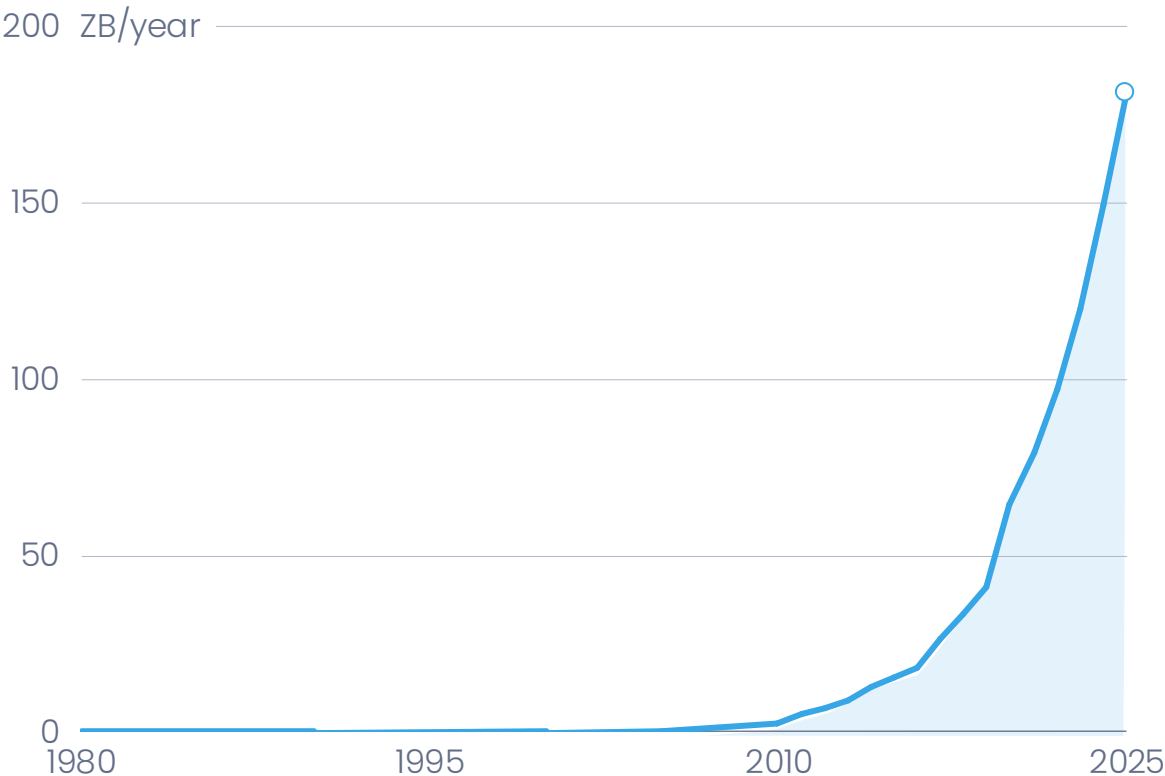
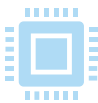
They both harness the same scientific breakthroughs in electromagnetism, and are powered by small modular technologies which have seen their combined costs fall since 1990 by 99%. Each fall in costs opens up a new area of growth.

The world is living through an information and energy revolution

Conventional thinking still treats them as two separate stories

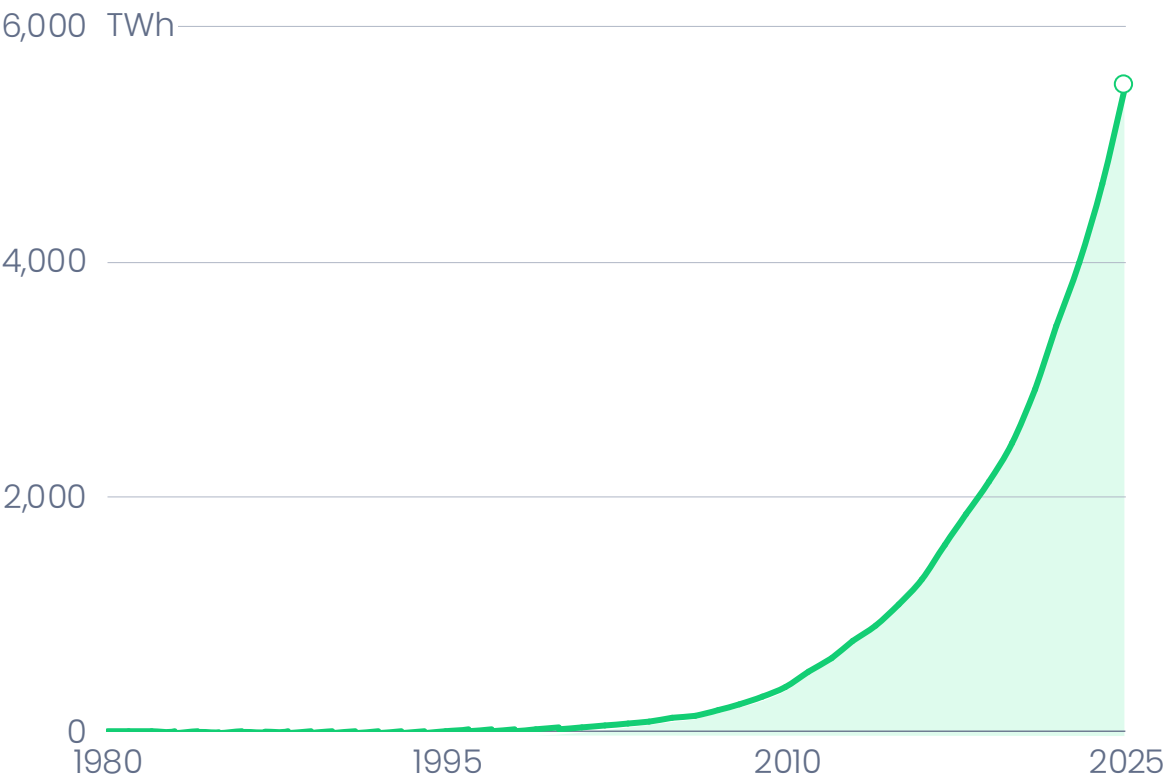
The infotech revolution

Example: data created worldwide



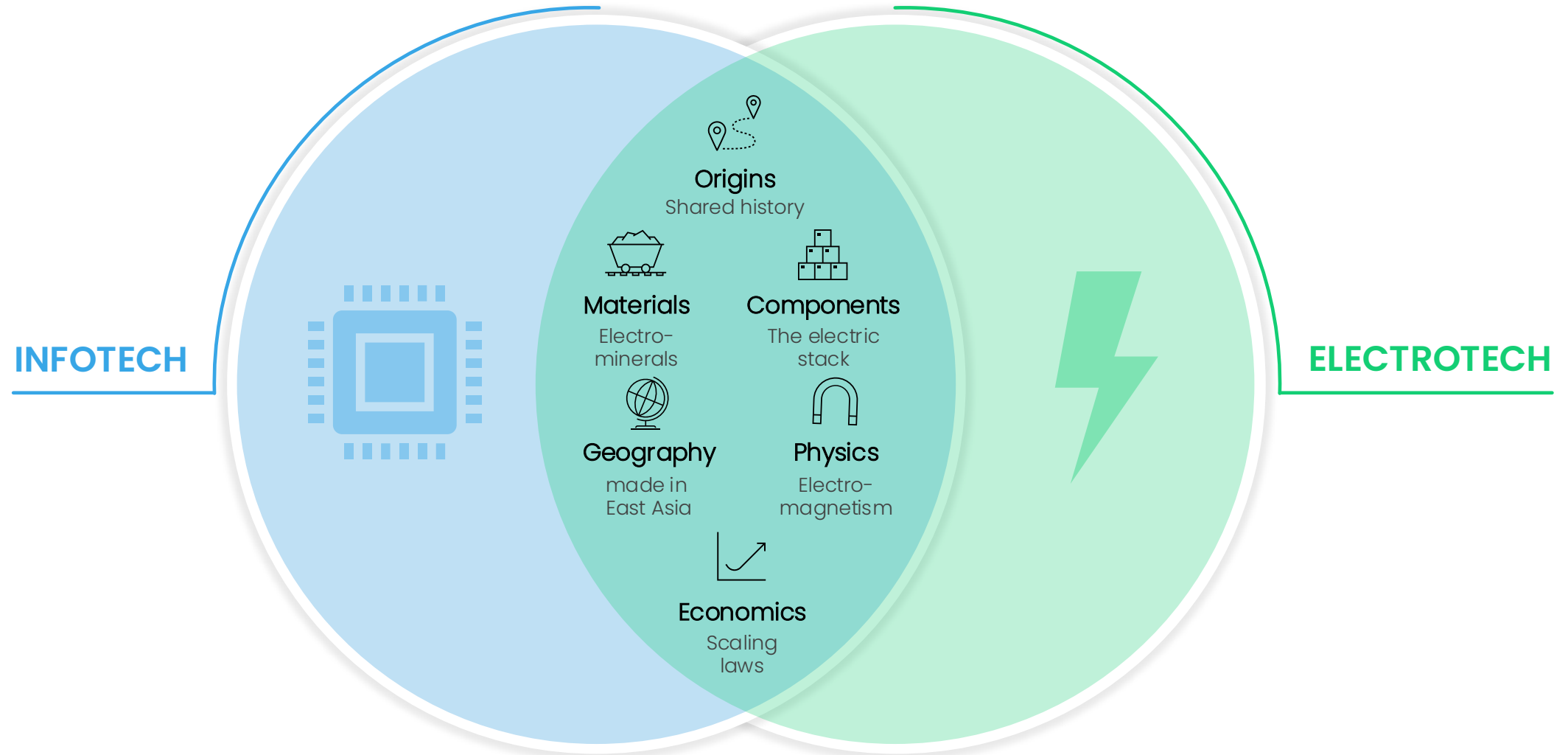
The electrotech revolution

Example: solar and wind generation worldwide



The two revolutions are deeply interlinked

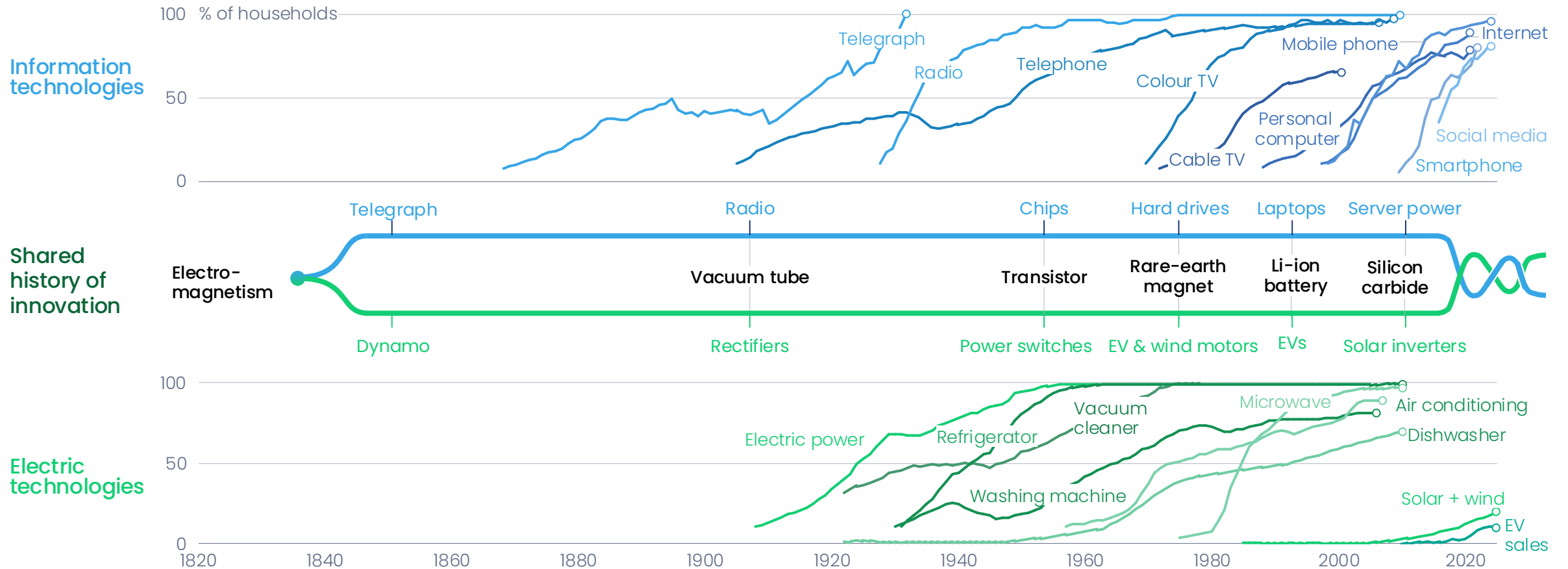
Sharing origins, materials, components, geography, physics and economics



A shared history

From the vacuum tube, to transistors, to Li-ion batteries, infotech and electrotech developed together

Infotech and electrotech adoption, US



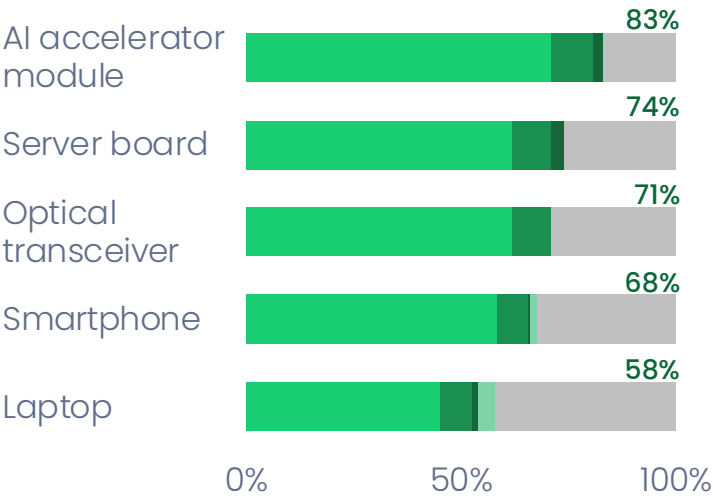
Made of the same minerals

Infotech and electrotech are both largely made from electro-minerals

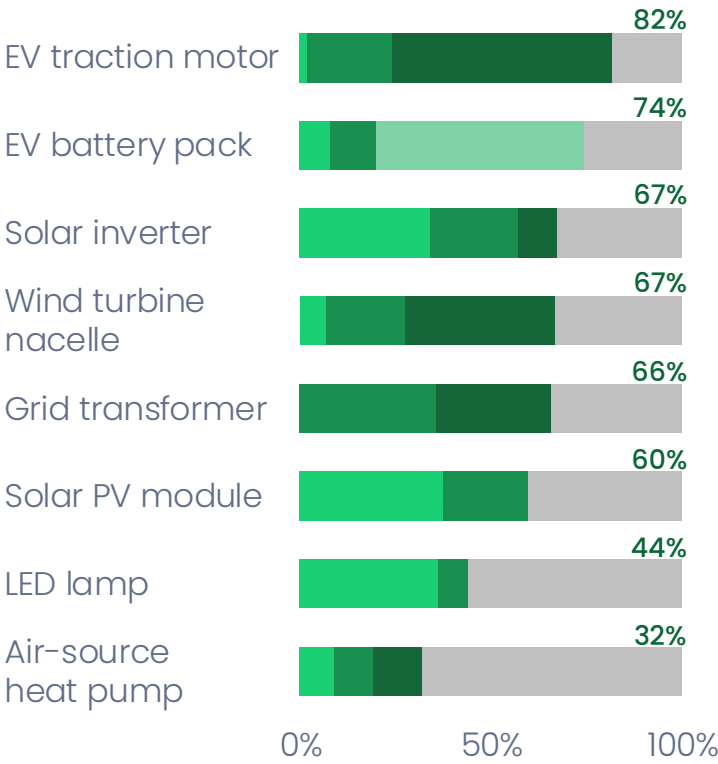
Bill of materials by value

Share of unit material cost, %

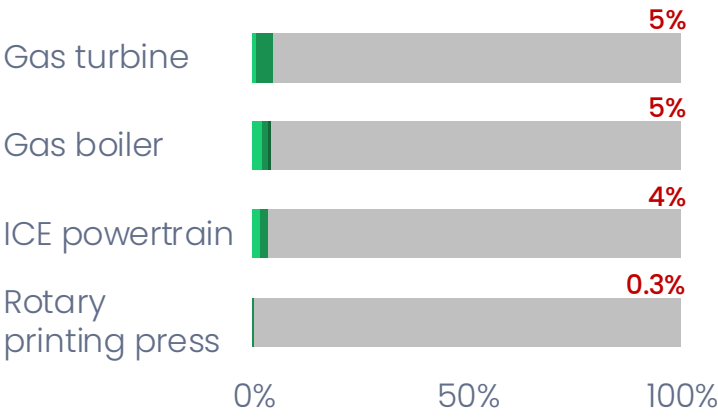
Information technology



Electrotech



The machines they replace

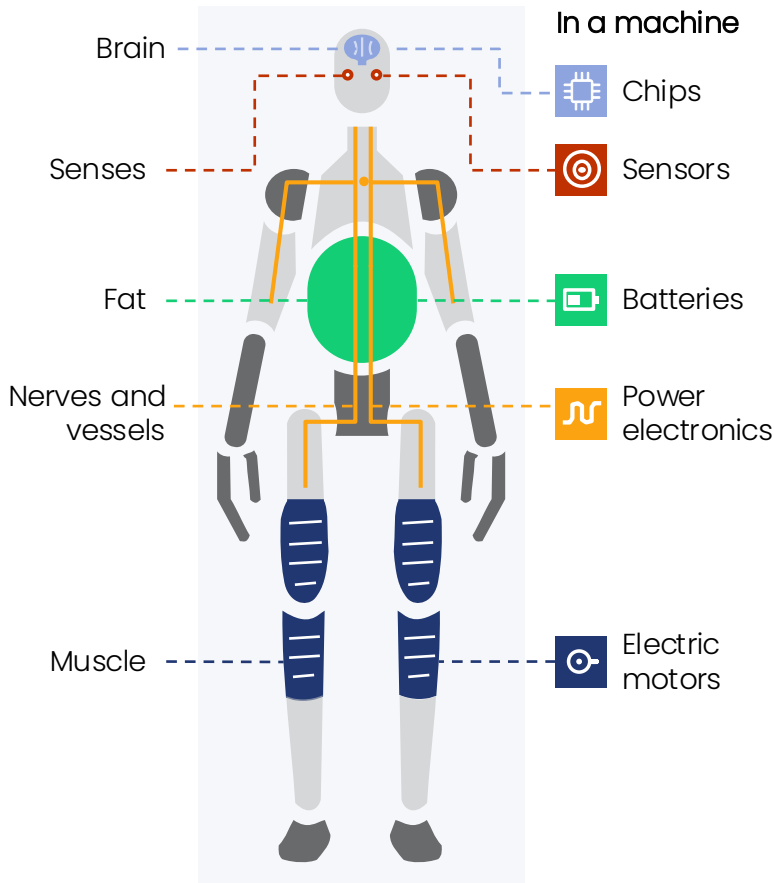


The same component tech stack

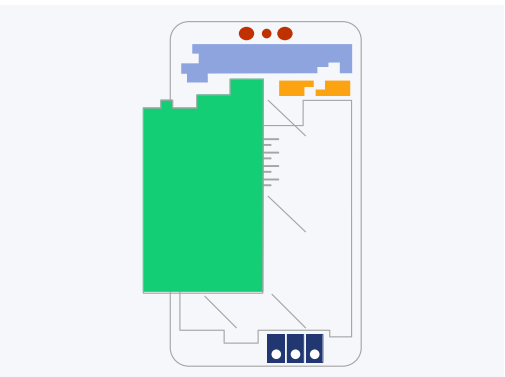
Infotech and electrotech both build on chips, sensors, power electronics, batteries and motors

Chips Sensors Power electronics Batteries Electric motors

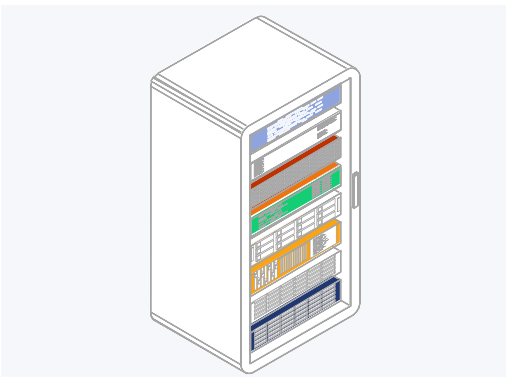
The humanoid body



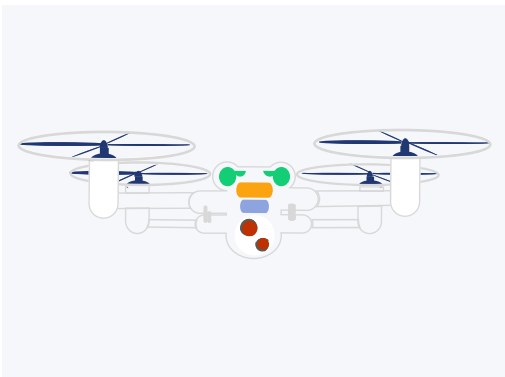
Smartphone



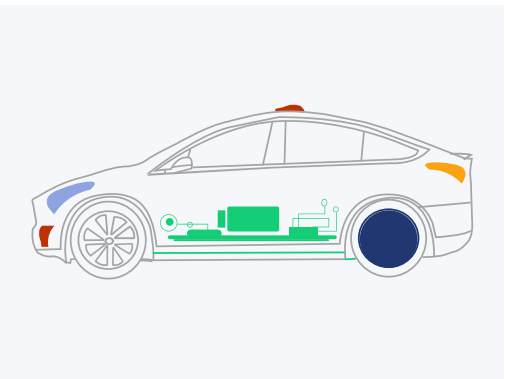
AI server



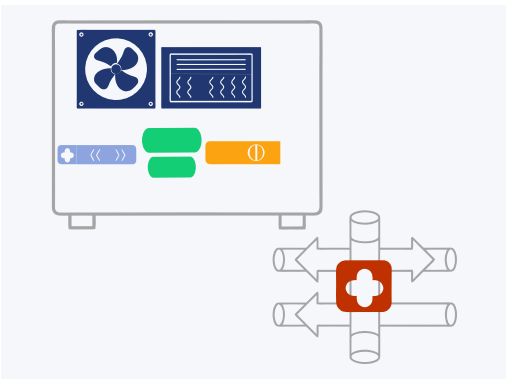
Drone



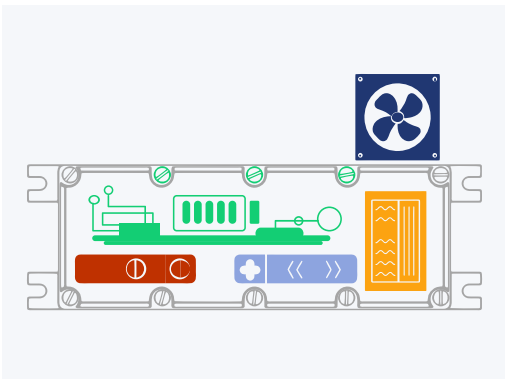
Electric car



Heat pump

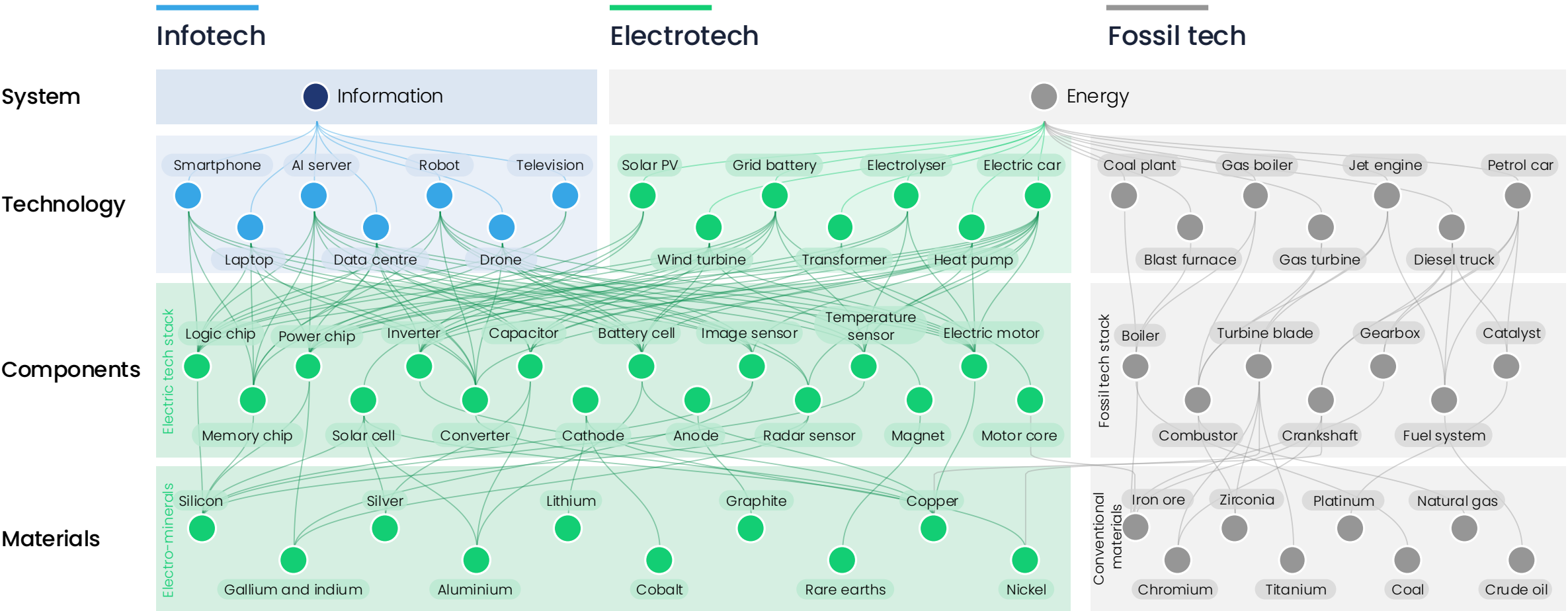


Grid battery



A shared supply chain

Infotech supply chains are much more interlinked with electrotech than the fossil system

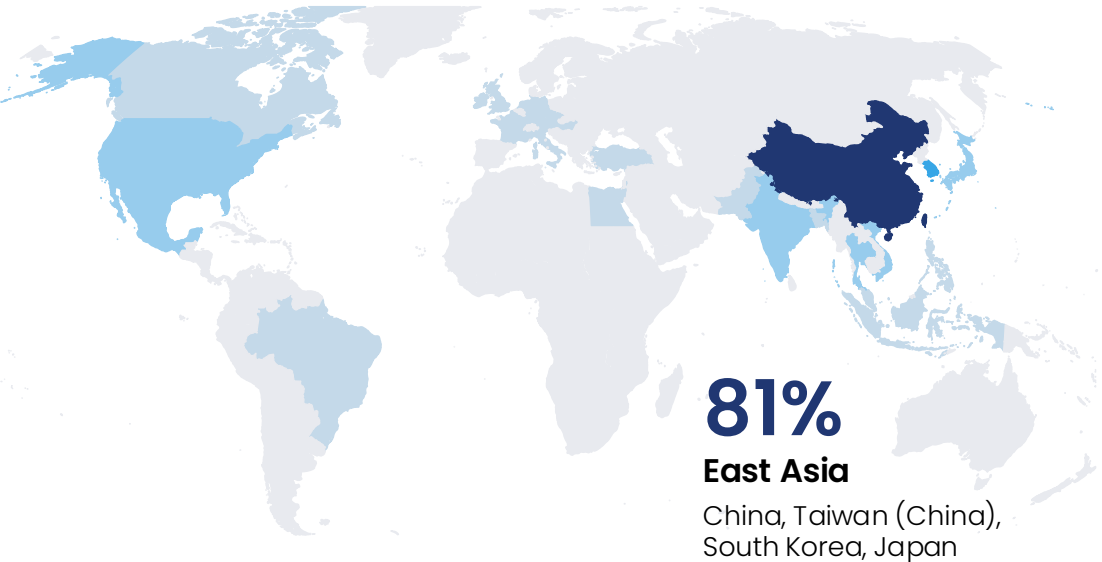


Made in the same places

The infotech manufacturing hotspots in the world are also the electrotech hotspots

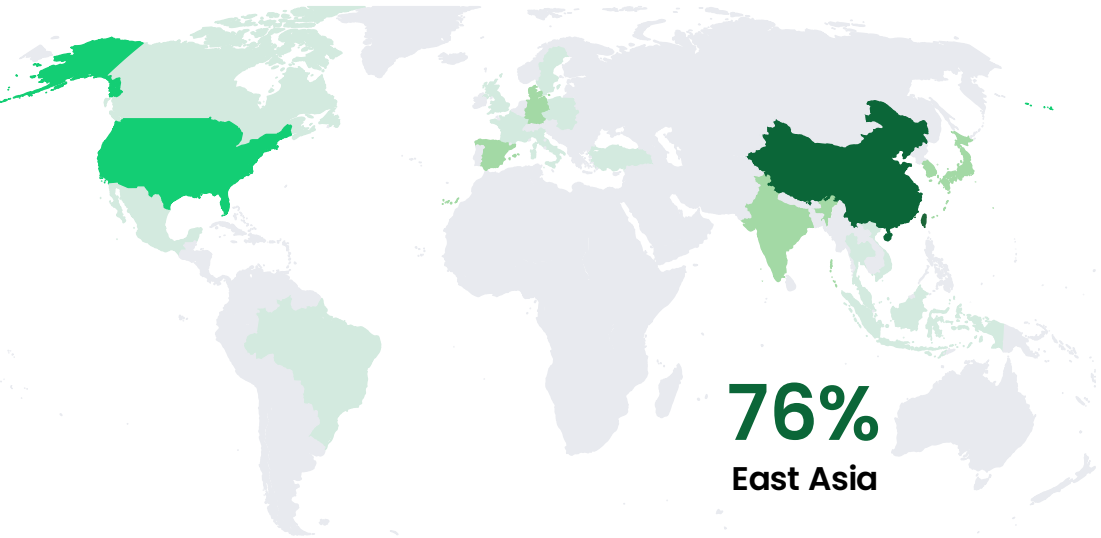
Digital hardware manufacturing

Equal-weighted composite selected infotech,
% of world capacity, 2024–25



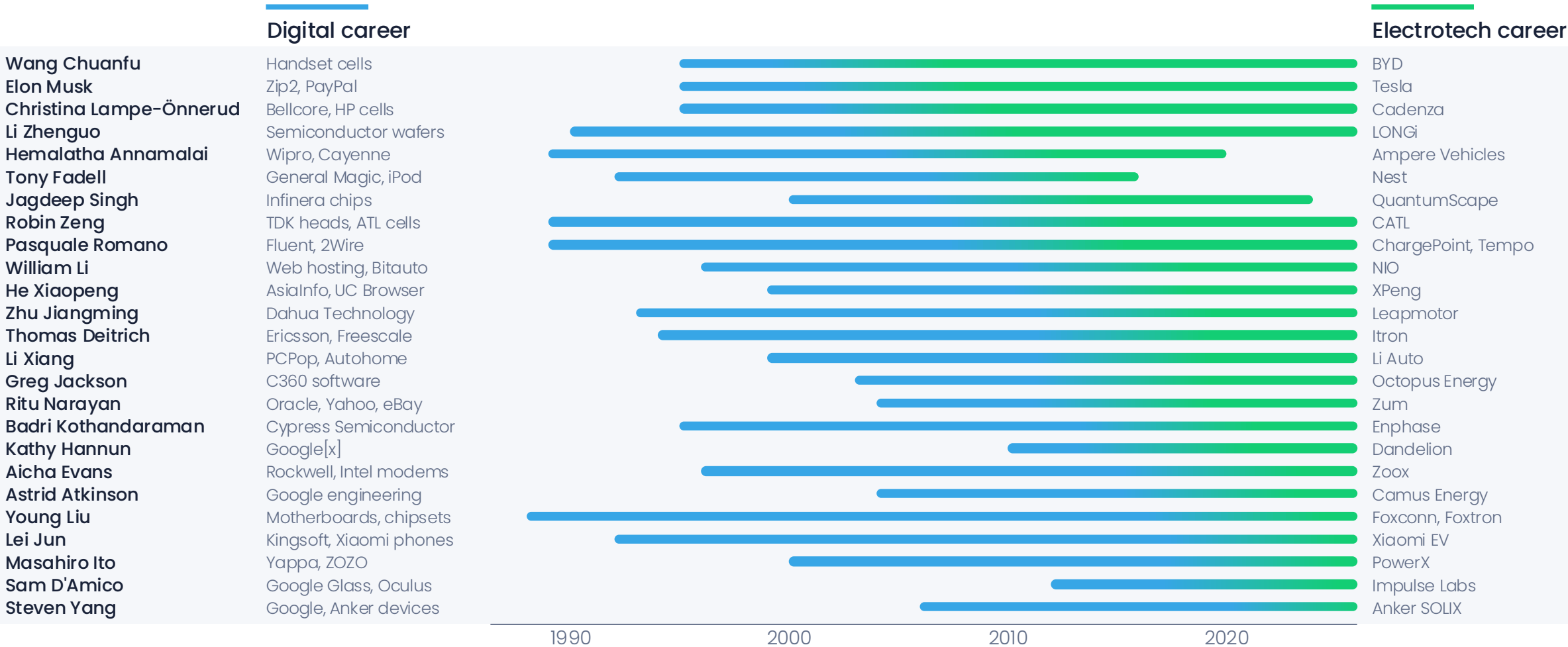
Electrotech hardware manufacturing

Equal-weighted composite selected electrotech,
% of world capacity, 2024



Built by the same people

Many electrotech entrepreneurs started in infotech

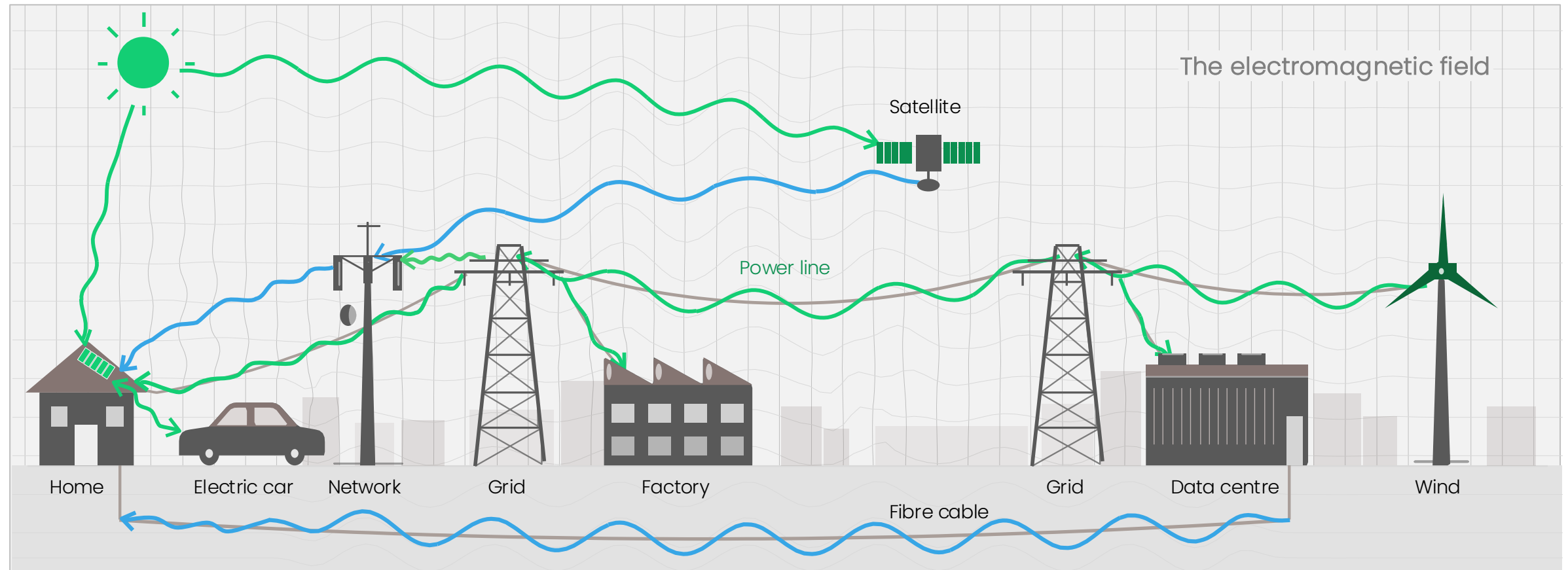


Shared underlying physics

Infotech and electrotech both use the electromagnetic field to transfer energy and information

 **Energy** waves that transport energy

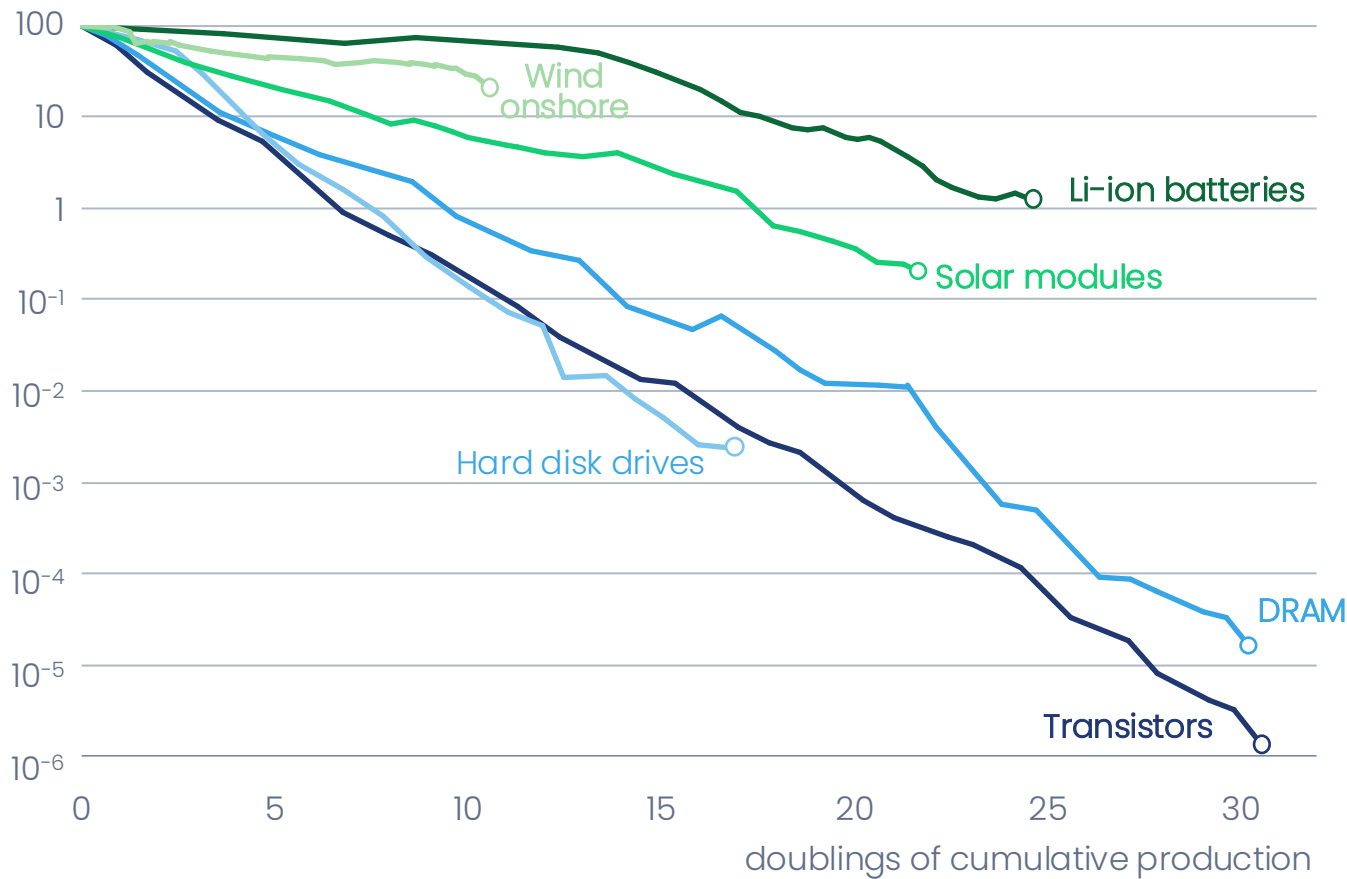
 **Information** waves that transport information



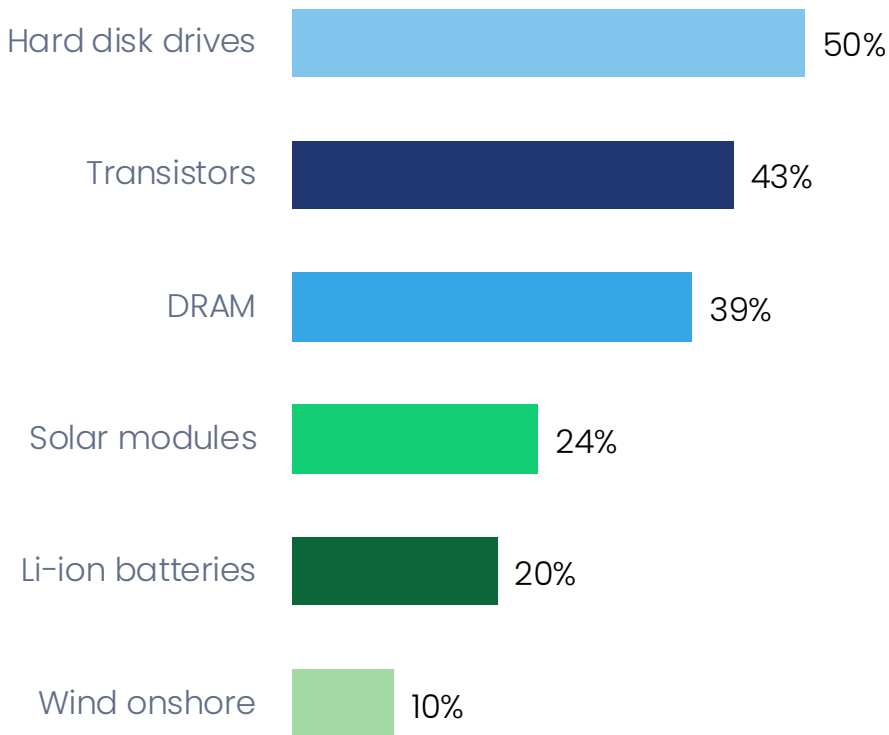
Shared economics of learning

Infotech and electrotech costs fall rapidly because they are small and modular

Cost index, start=100, log scale



Learning rate: cost decline per doubling of uptake

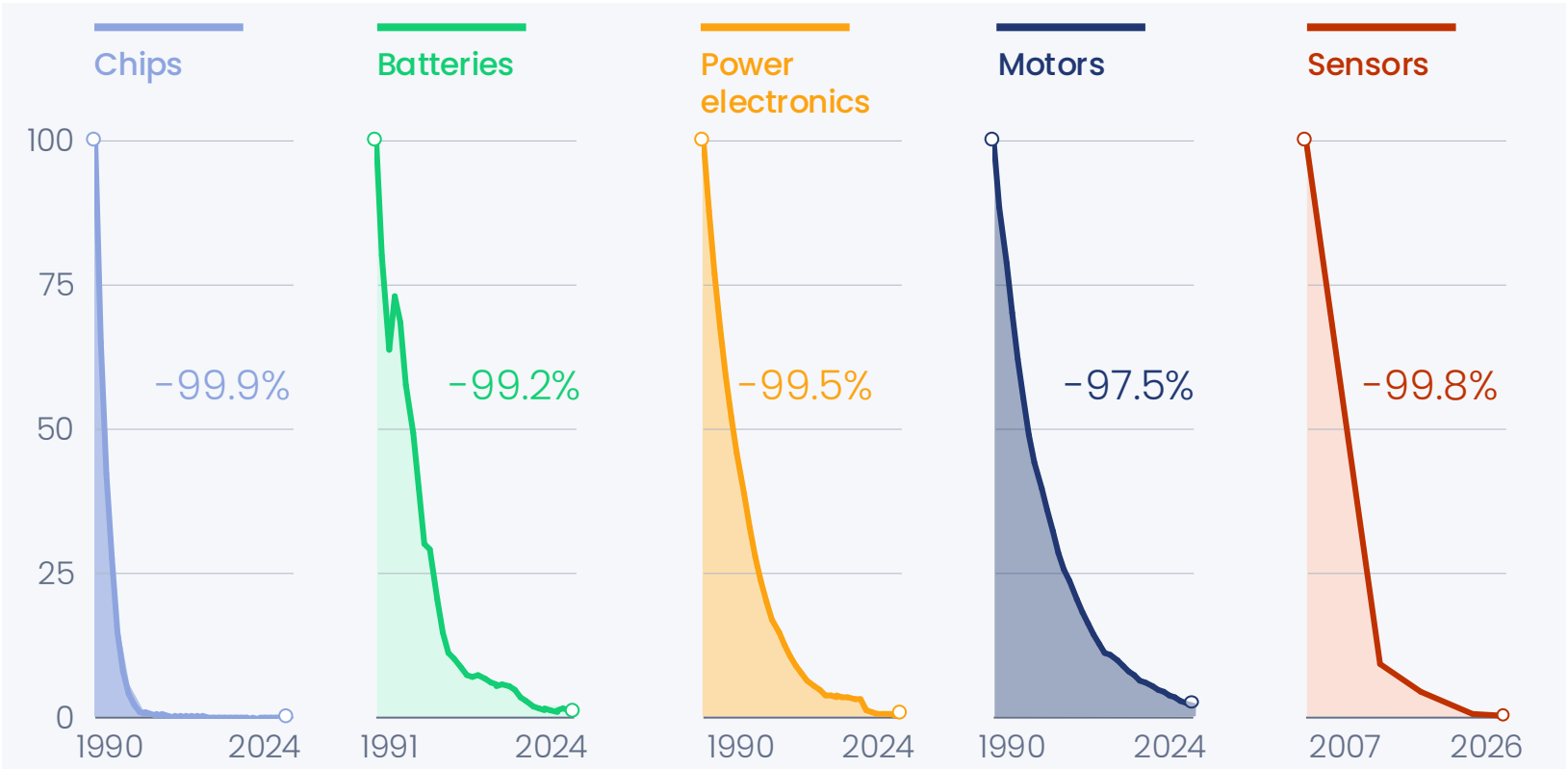


One tech stack, one flywheel, two revolutions

Infotech and electrotech push each other's costs down and capabilities up

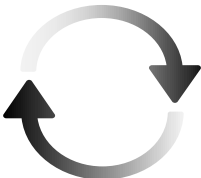
The electric component stack

Price, first year = 100



Lower prices for each

Lower prices reduce final cost of infotech and electrotech, boosting sales



More collective volume

Both infotech and electrotech drive up demand and therefore scale up supply, lowering production cost

Example electrotech and infotech using the five components



Laptop & PC



Smartphone



AI server



Solar system



Electric car



Grid battery

Contents

01 Two interlinked revolutions

The electrification of information and energy

02 The electric rise

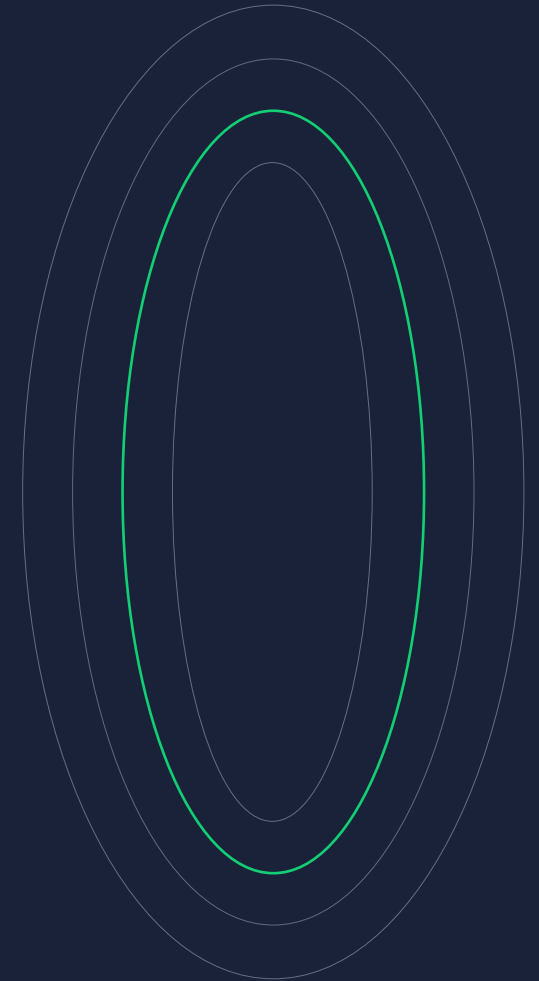
The rise of infotech and electrotech

03 The shape of things to come

The implications of the two revolutions converging

04 Seizing the opportunity

Navigating the incoming electric disruption



The rise of infotech and electrotech

01

Information is rapidly electrifying

Electrifying information systems drove a boom in memory and communications. Reasoning is next, yet its rapid growth is already hitting limits: it needs more electricity, faster connections and more end-use sectors to deploy in. Electrotech supplies all three.

02

Energy is rapidly electrifying

Electrotech is transforming how electricity is supplied, connected and used – and getting cheaper as it scales. Its constraint is no longer cost but coordination: matching variable, distributed resources across the system. Infotech eases that, through smart meters, digital grids and real-time control of billions of devices.

03

Combining the two drives fast change

Deployed together, electrotech and infotech can cut transport costs by up to 70%, household energy running costs by up to 80% and manufacturing costs by 40–70%. Progress in each raises the ceiling for the other.

04

Few countries are pursuing both

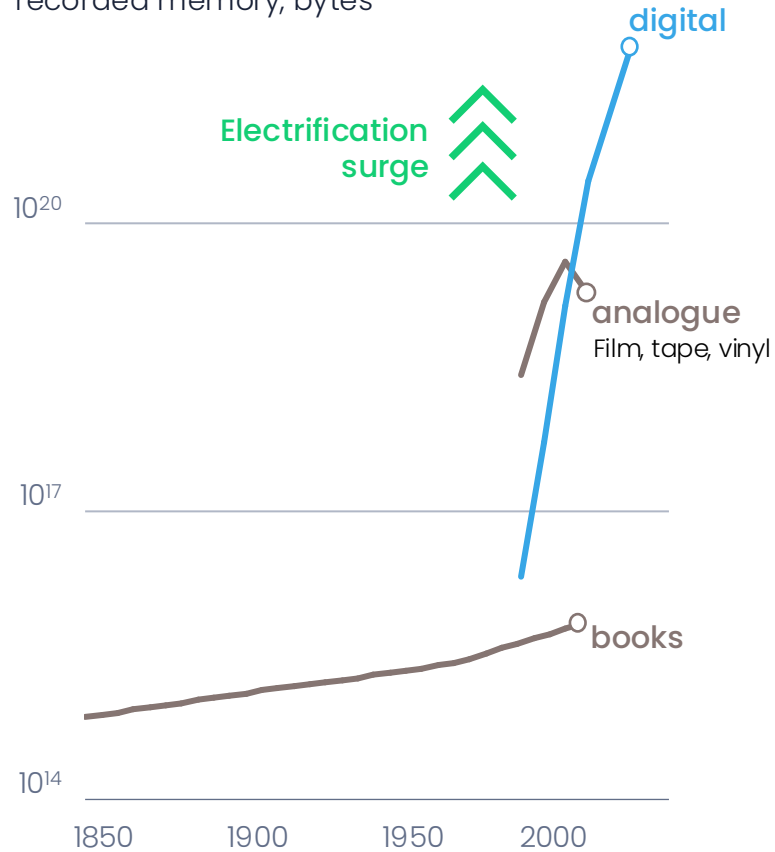
The US is focused on the frontier of infotech: AI. Europe is focused on renewables. Only China is pushing both, aiming to lead in electrification and automation at the same time.

The electric leap in information systems

By going electric, memory, communication and reasoning surged in capabilities and use

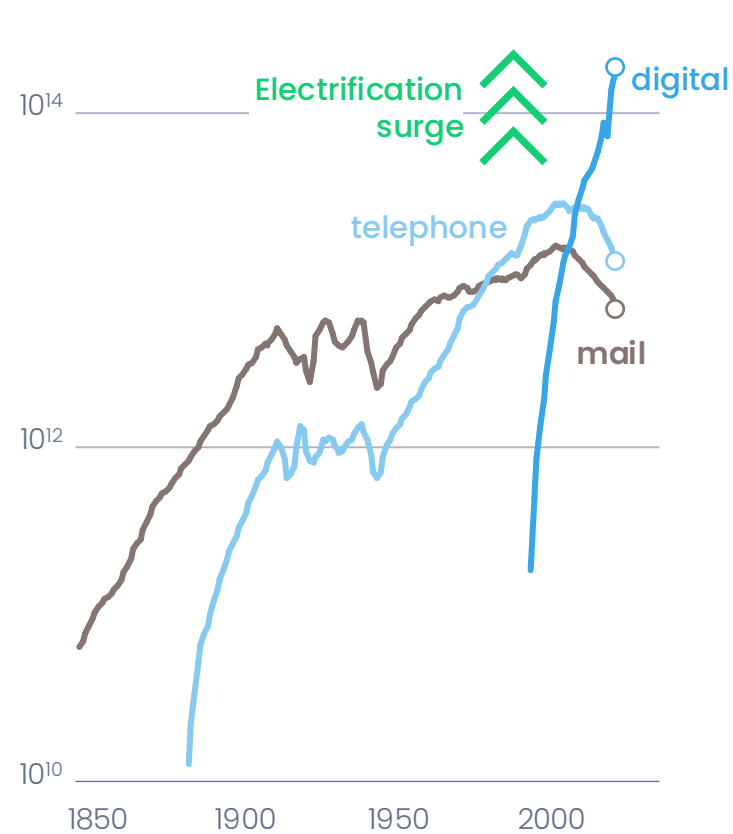
Memory

recorded memory, bytes



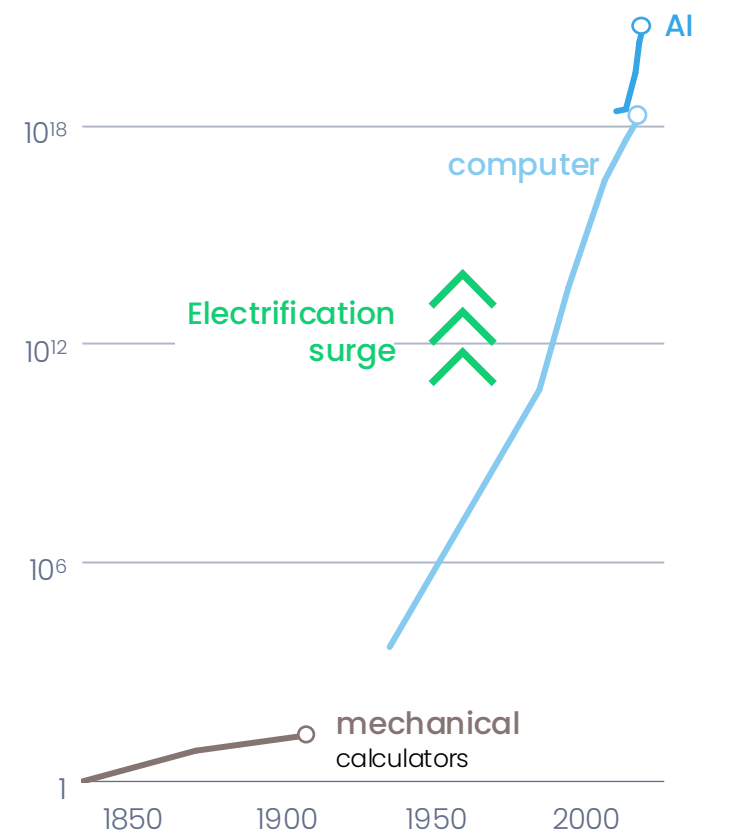
Communication

bytes of messages sent per year, Germany



Reasoning

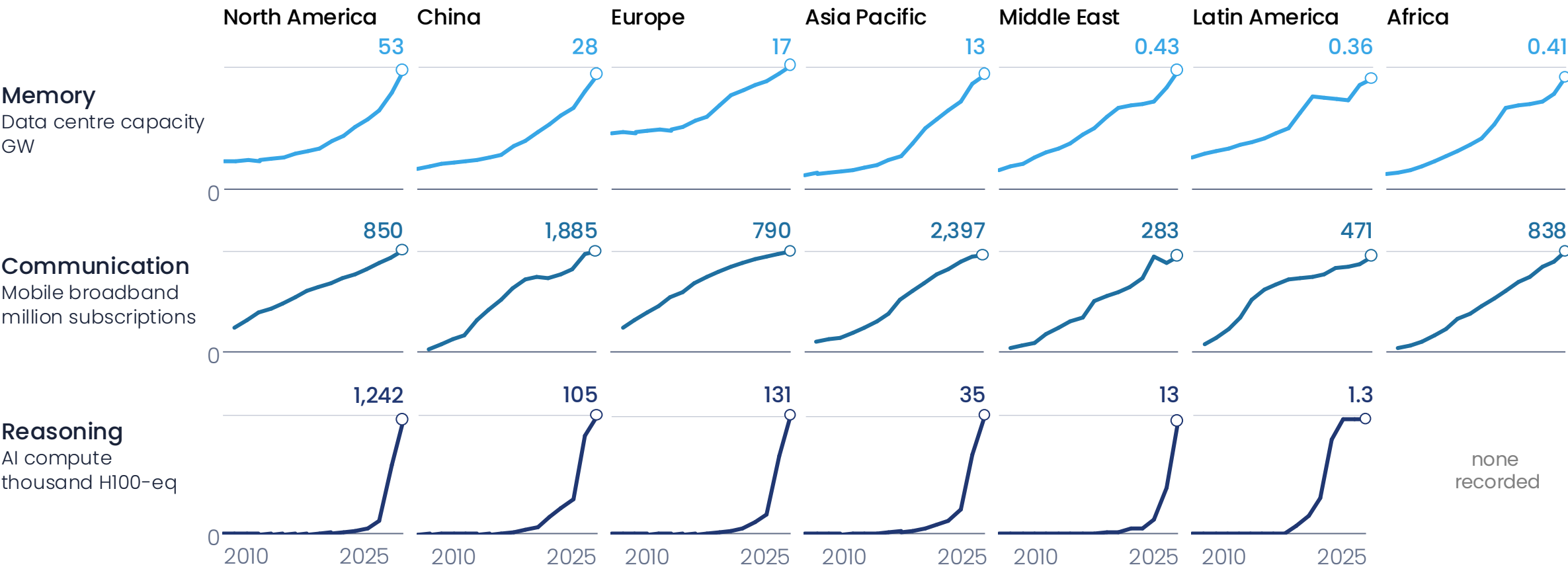
most powerful machine, operations per second



Infotech has gone around the world

Steep growth in every region

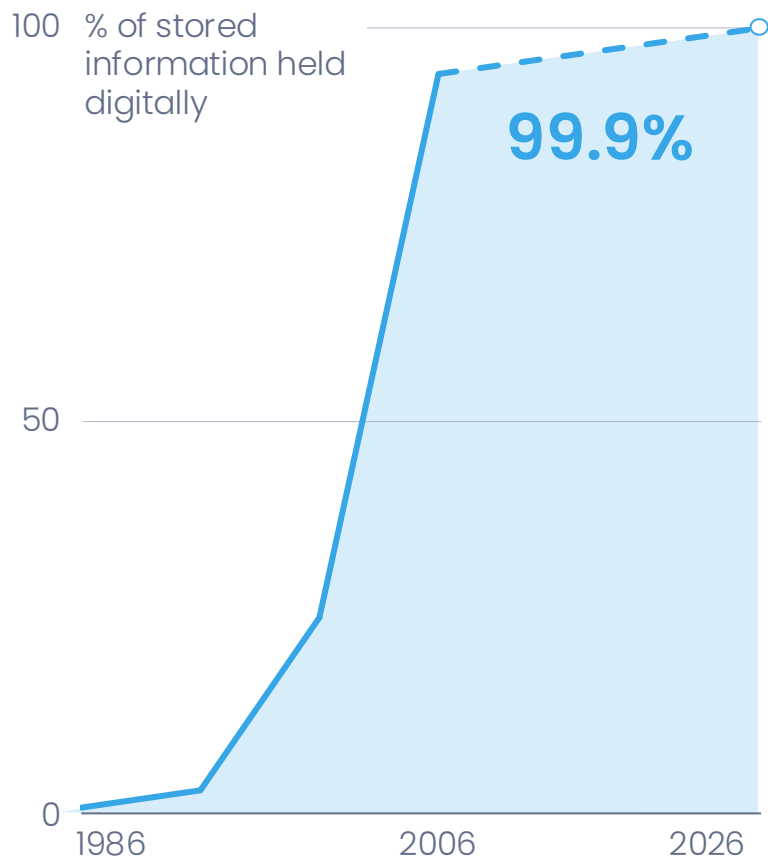
Rise of infotech by region, 2010-2025



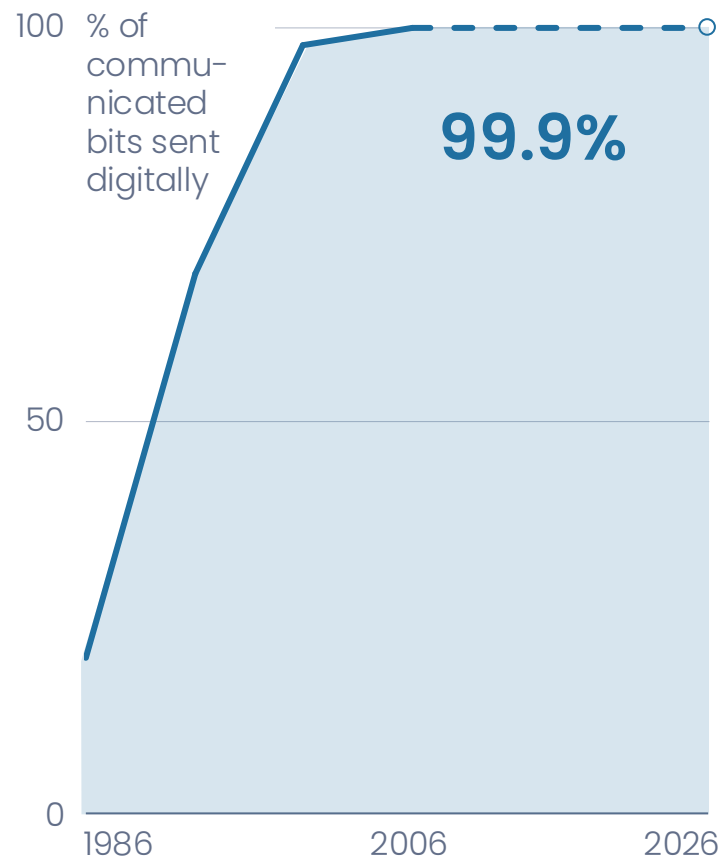
Memory, communication, and now reasoning

Memory and communication are already electrified; reasoning is just starting

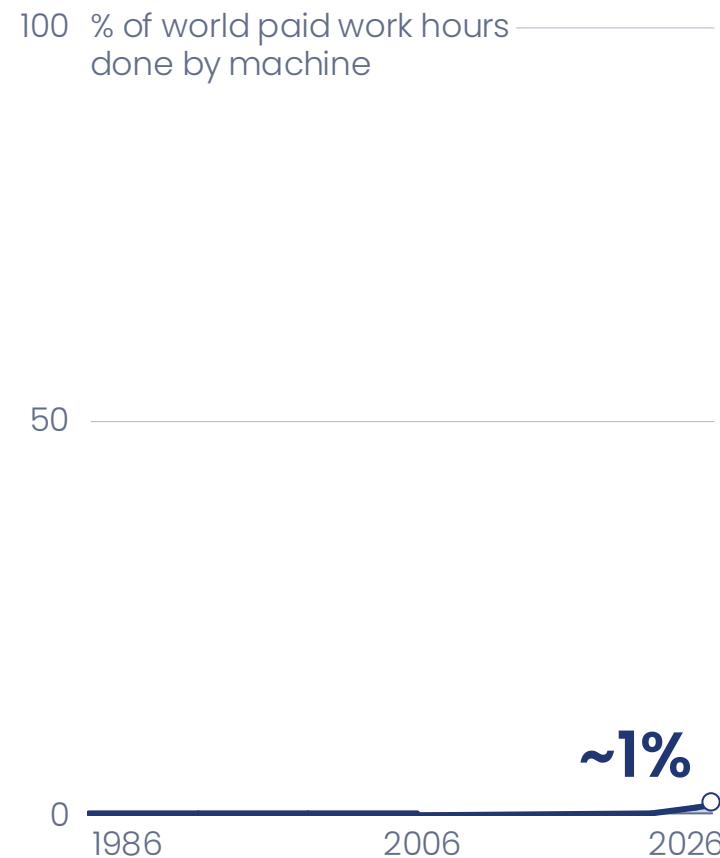
Memory



Communication



Reasoning



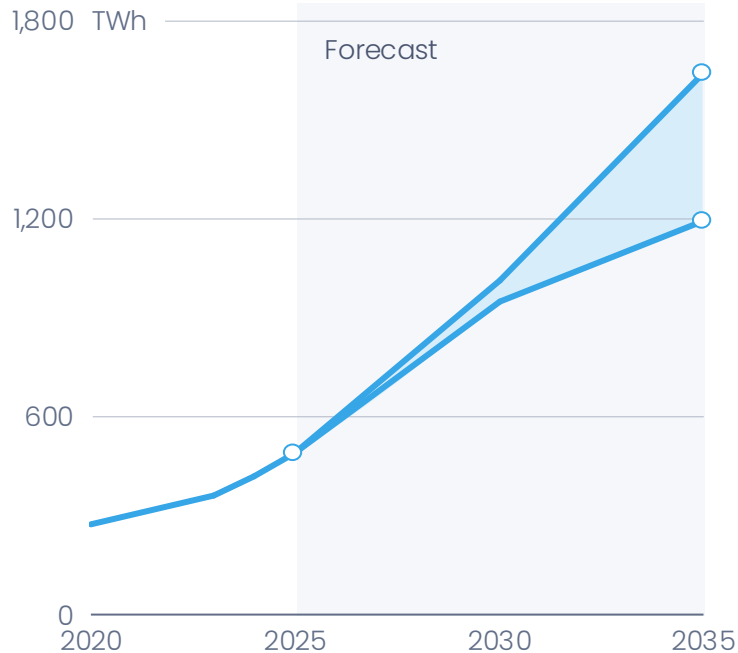
Infotech's frontier is hitting energy ceilings

AI needs more electricity, faster connections and more end-use applications

Supply

AI, and physical AI like robotics, needs a lot of power, **faster than conventional electricity tech is used to scaling**

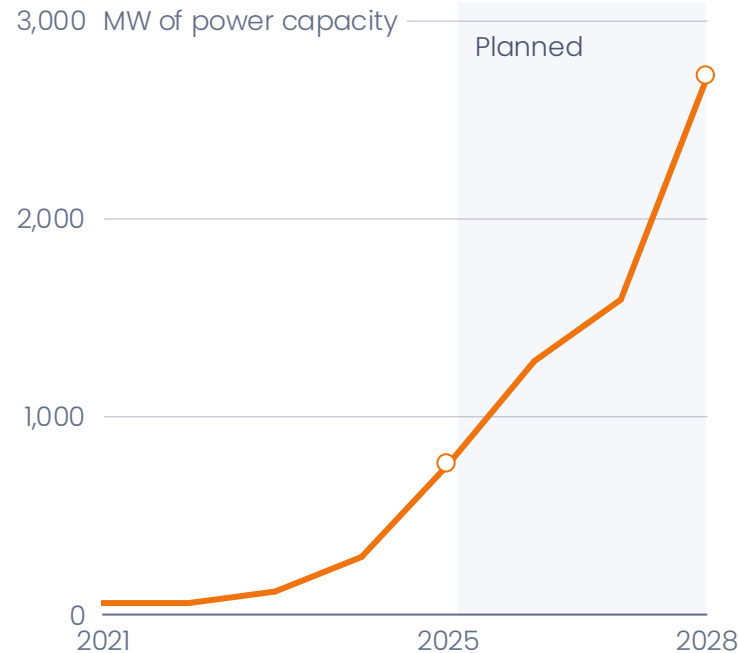
World data centre electricity demand



Connection

Loads are getting bigger; data centres and automated factories **need ever bigger connections the old grid struggles to build**

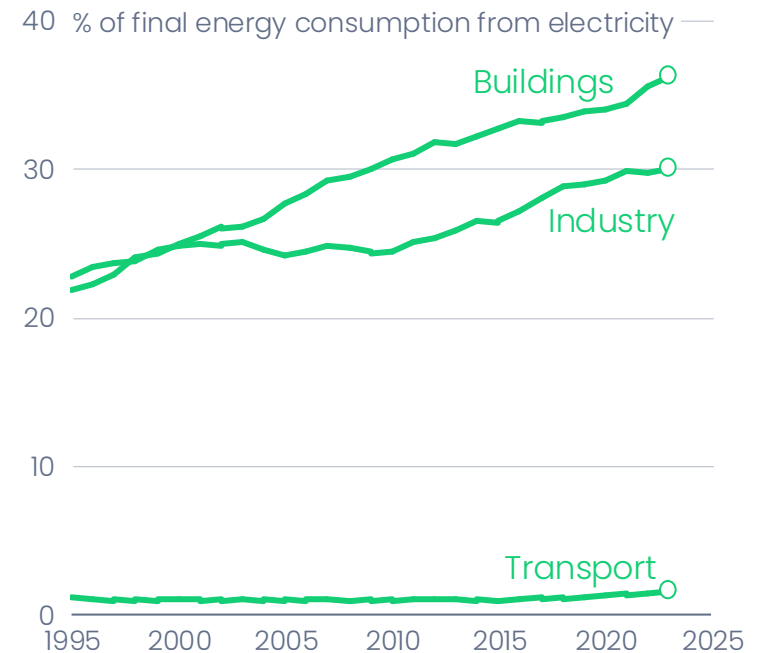
Size of largest data centres



Demand

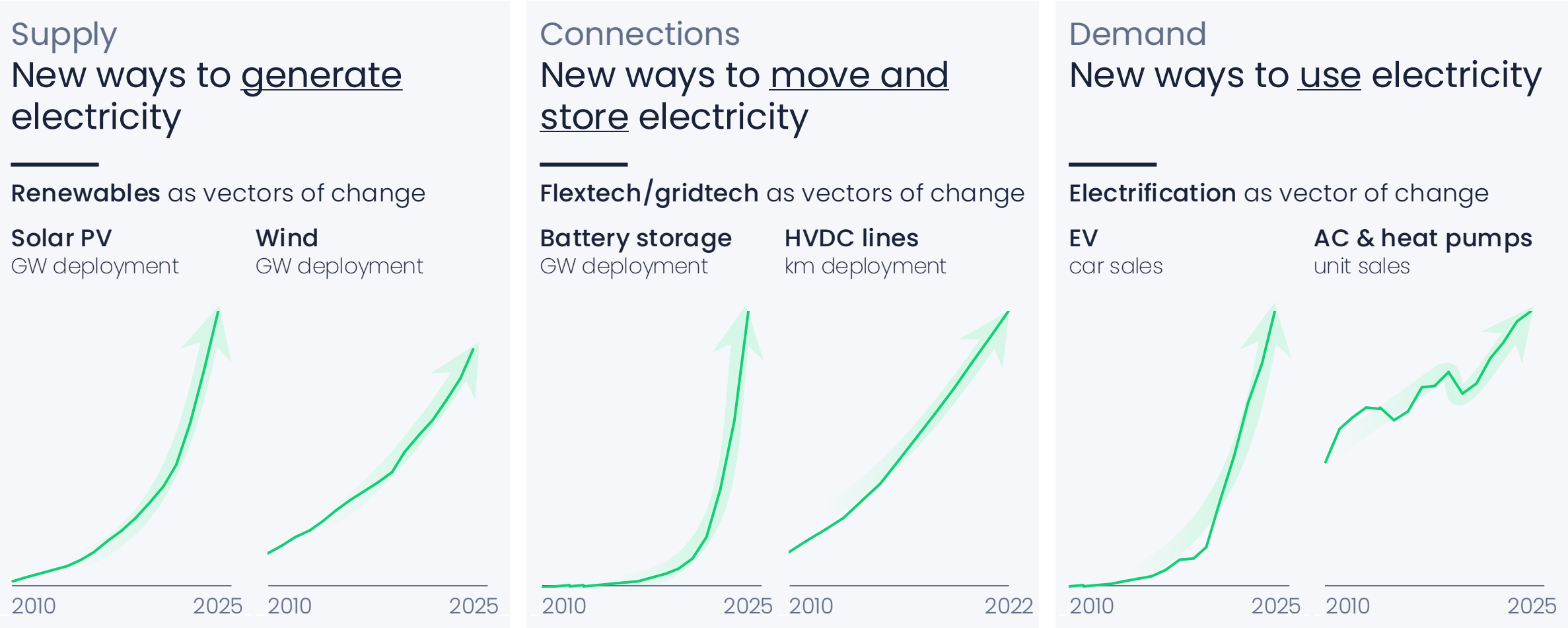
AI needs new markets to earn its returns; a huge potential market is physical AI, but that **needs faster uptake of electric tech that can be made smart**

Share of economy electrified



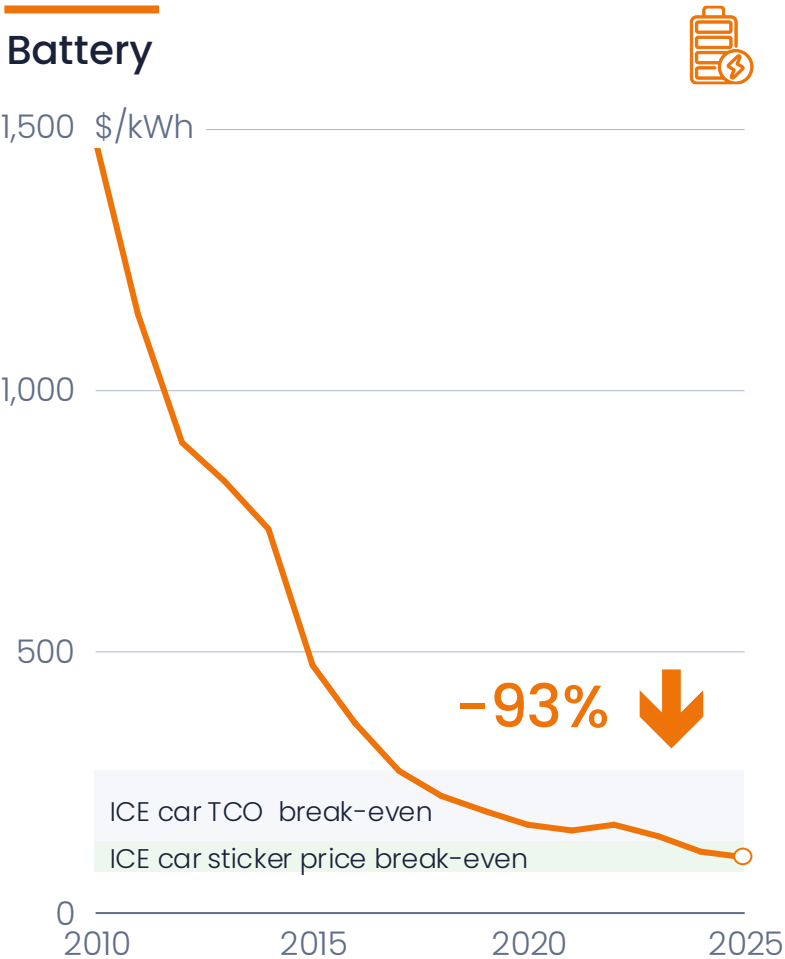
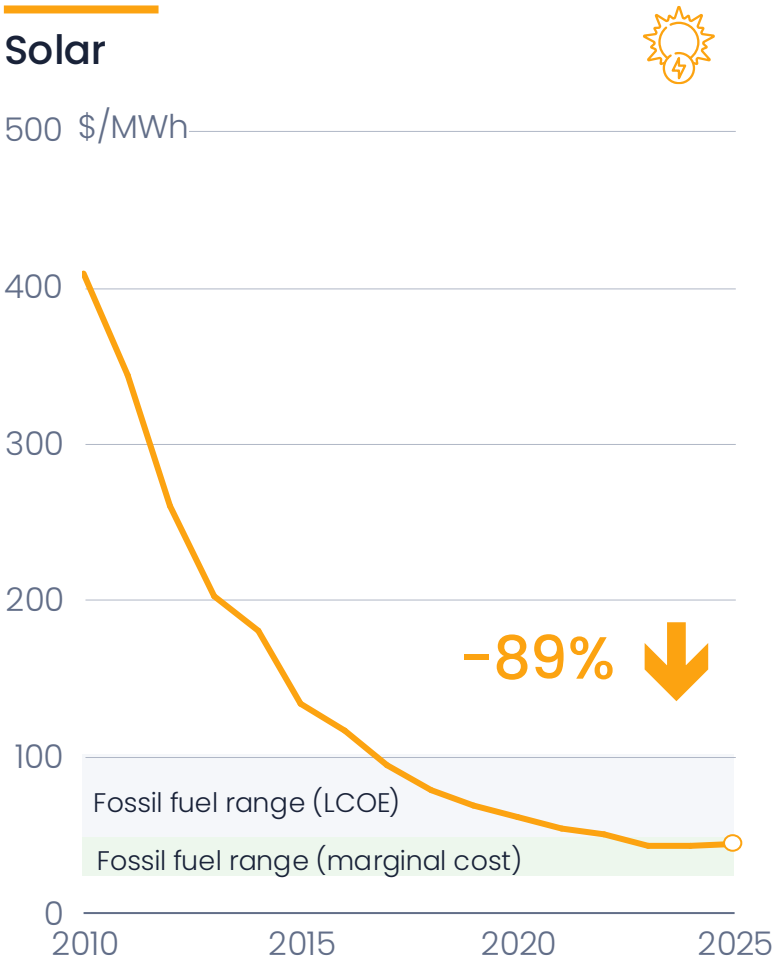
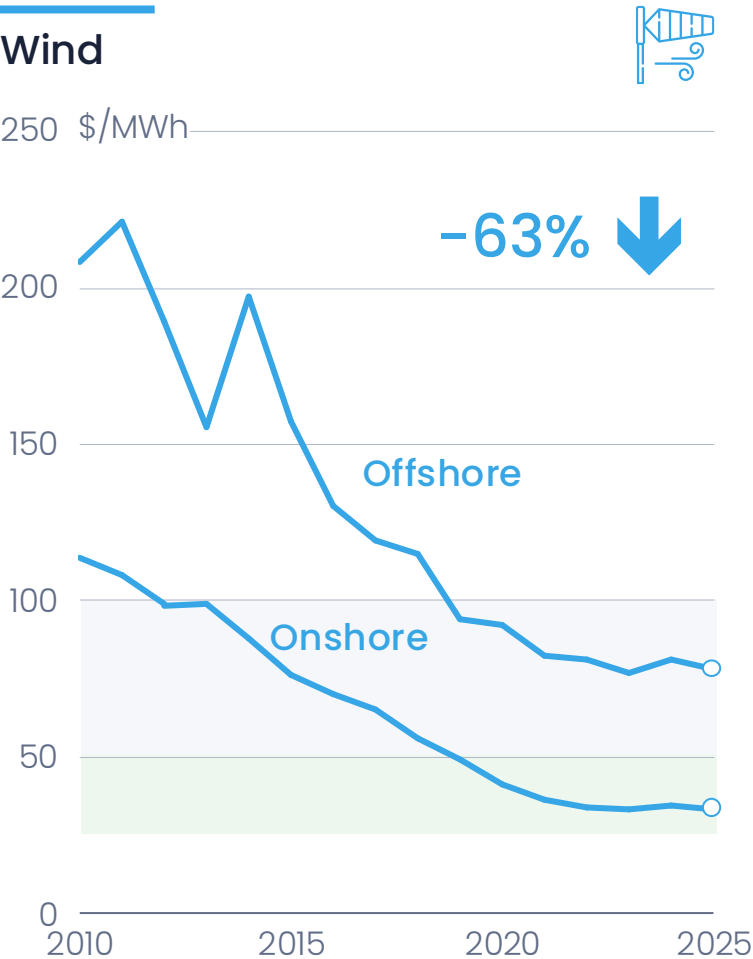
Enter the electrotech revolution

New, electric technologies revolutionise the supply, connection and demand of energy



Electrotech has become cheap

After decades of cost innovation, electrotech is now cheaper than other energy tech

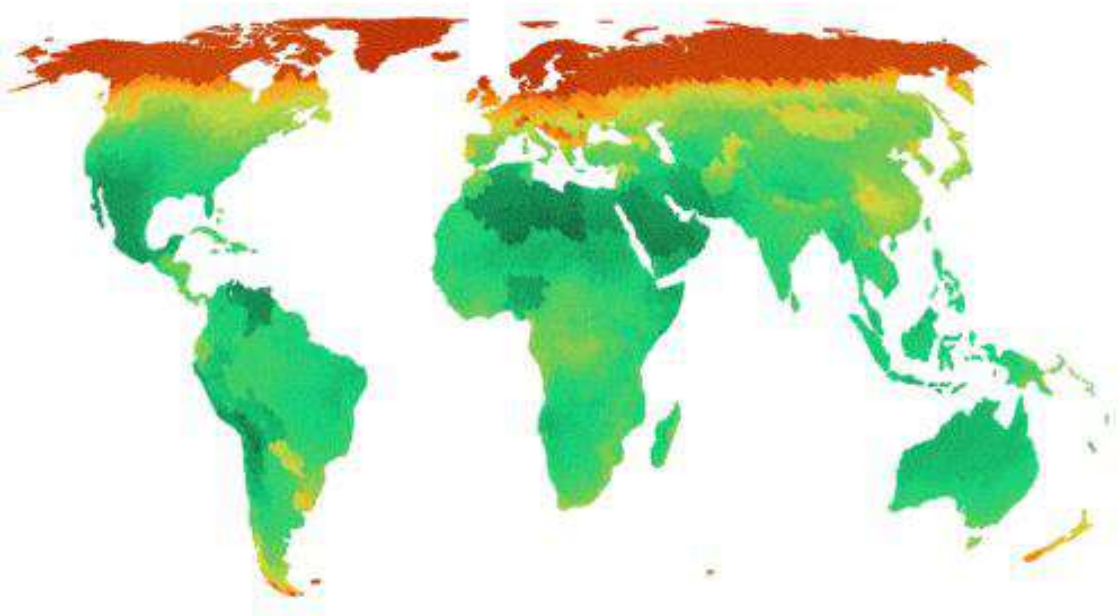


Firm renewables are here

Some 75% of the planet can get firm solar + battery + backup supply for under \$100/MWh

Solar, battery and backup LCOE across the world, 2026

Cheapest 100%-uptime system

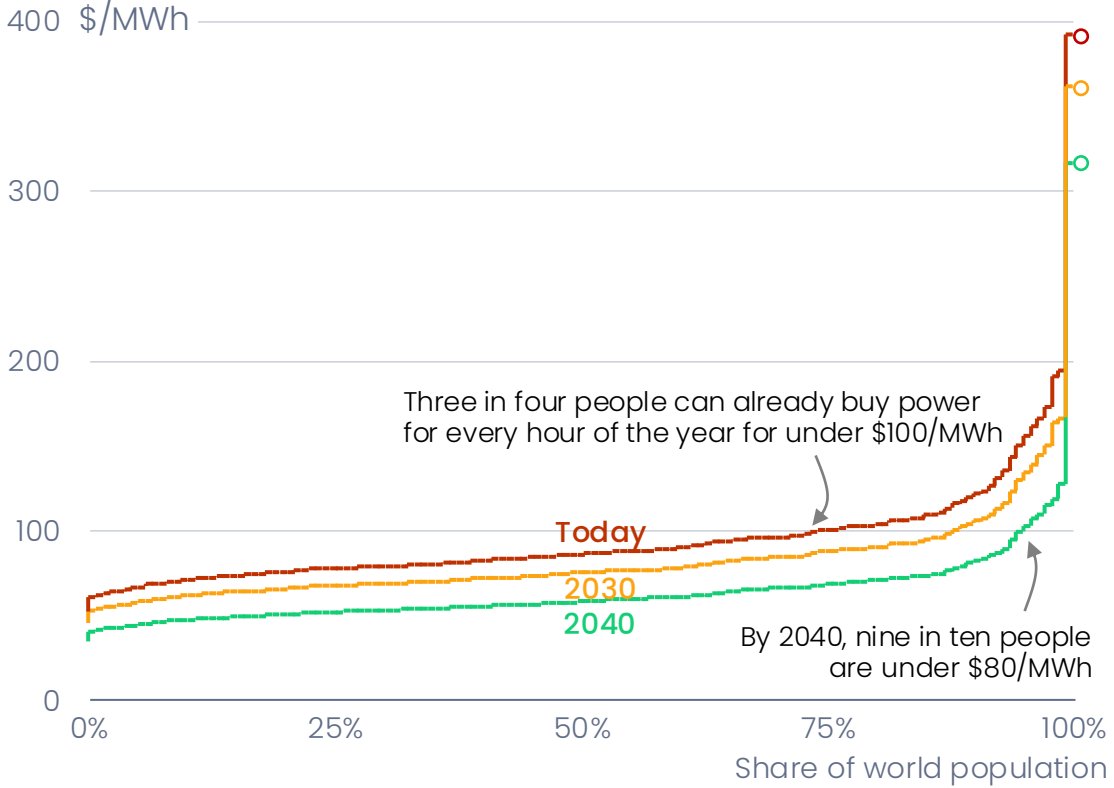


LCOE for 100% uptime; of which 80%+ solar + battery share

\$50/MWh \$125/MWh \$200/MWh and up

Share of population by 24/7 power cost

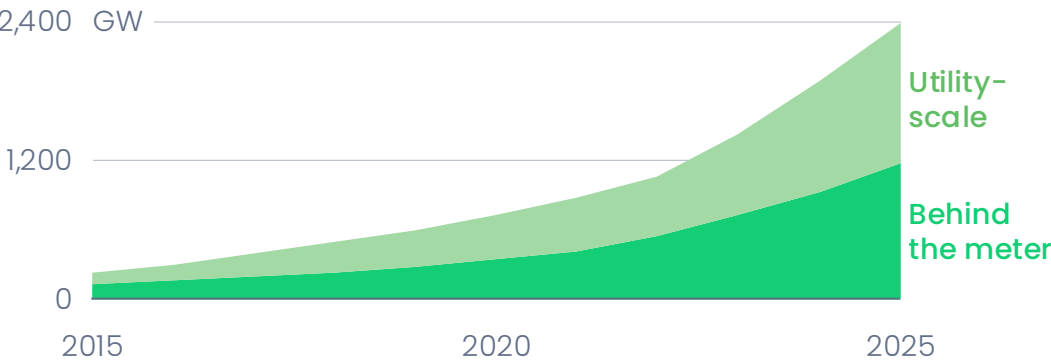
Cumulative, cheapest region first



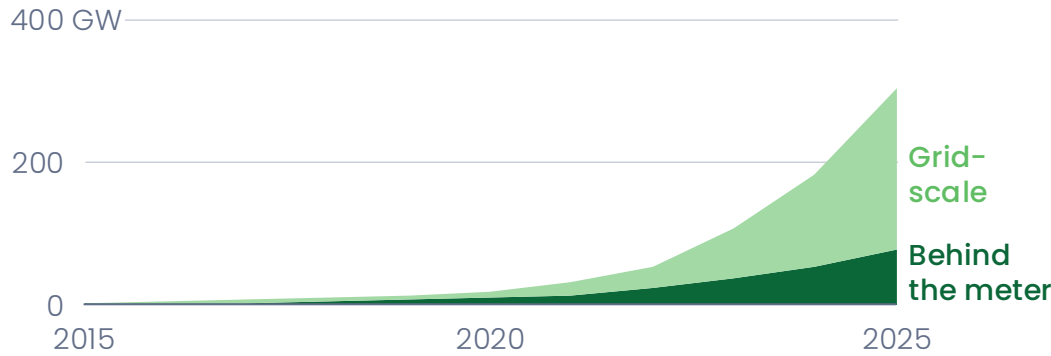
Electrotech is decentralising energy supply

Half of global solar is behind the meter; rooftop solar and batteries are already 12% of global capacity

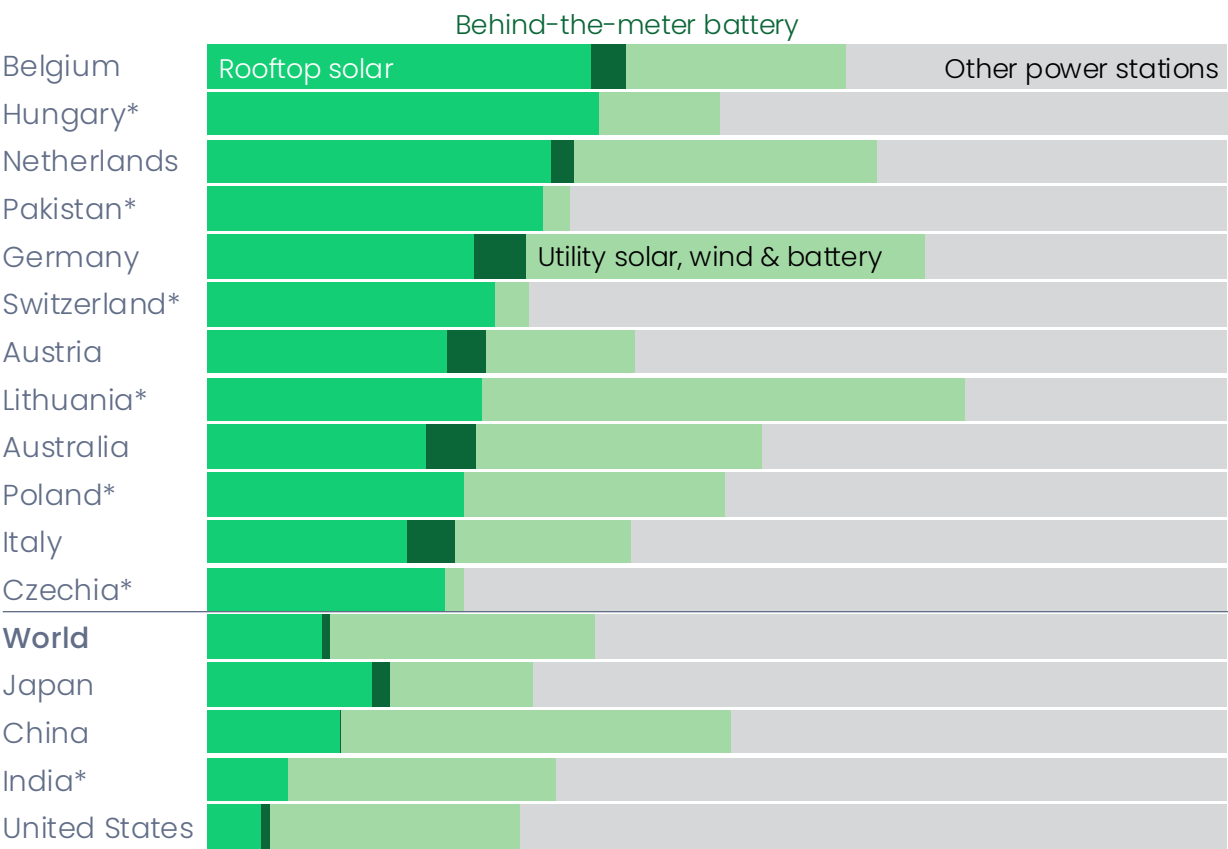
Solar capacity, global



Battery capacity, global

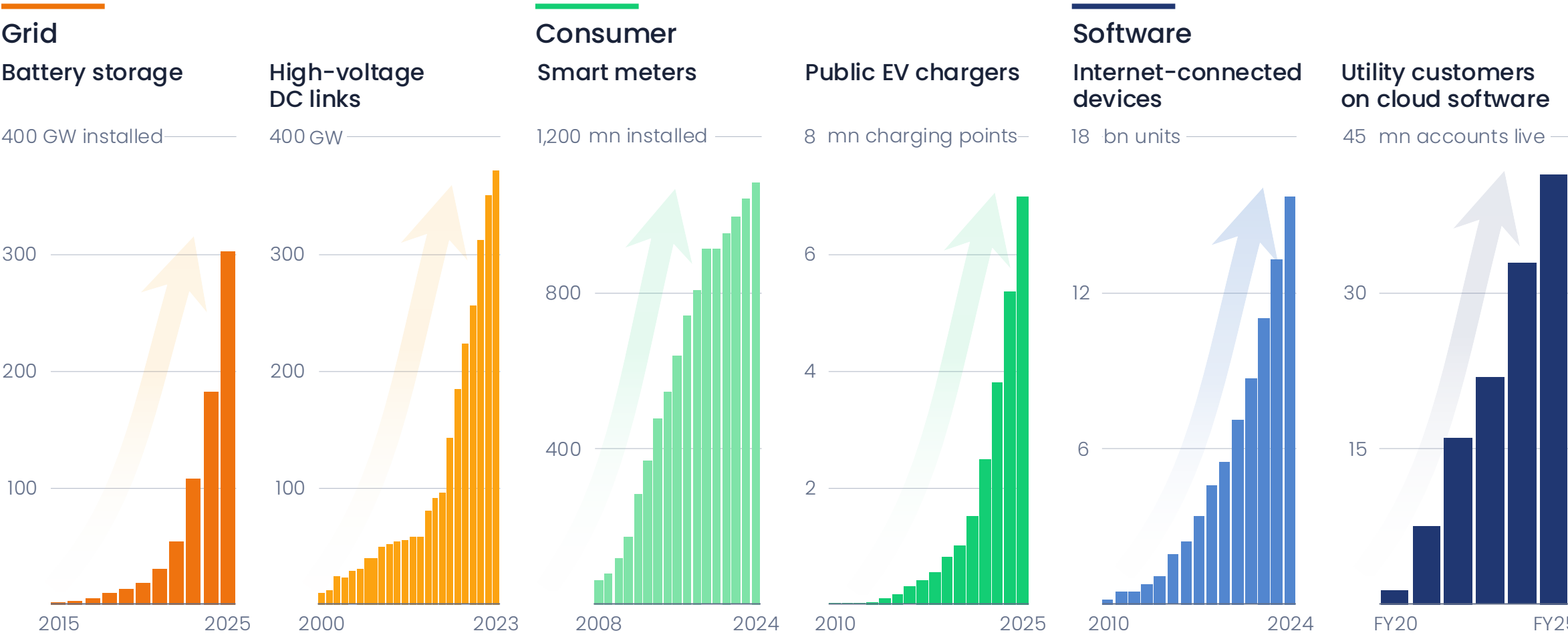


Total installed capacity by country
2025



New connection infrastructure is coming online fast

Storage, smart grids, flexible demand and the software tying it together



The connection opportunity is huge

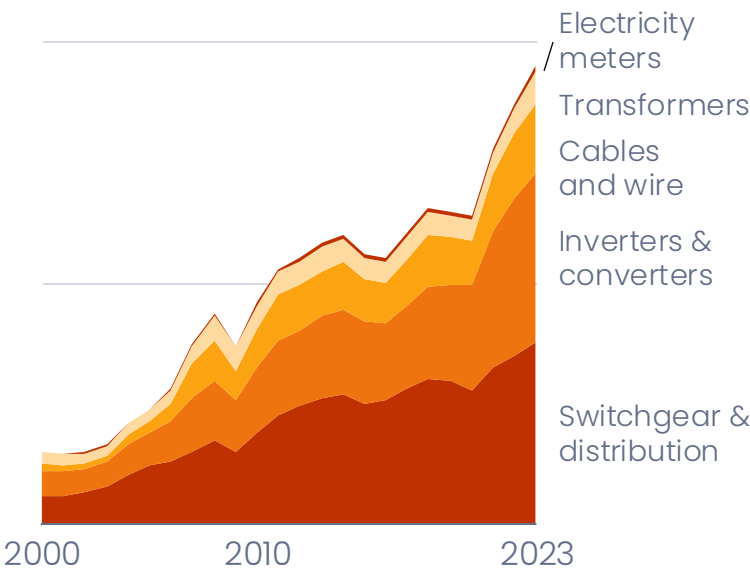
The trade in connection technologies is three times larger than solar panels

Cross-bloc exports of electrotech

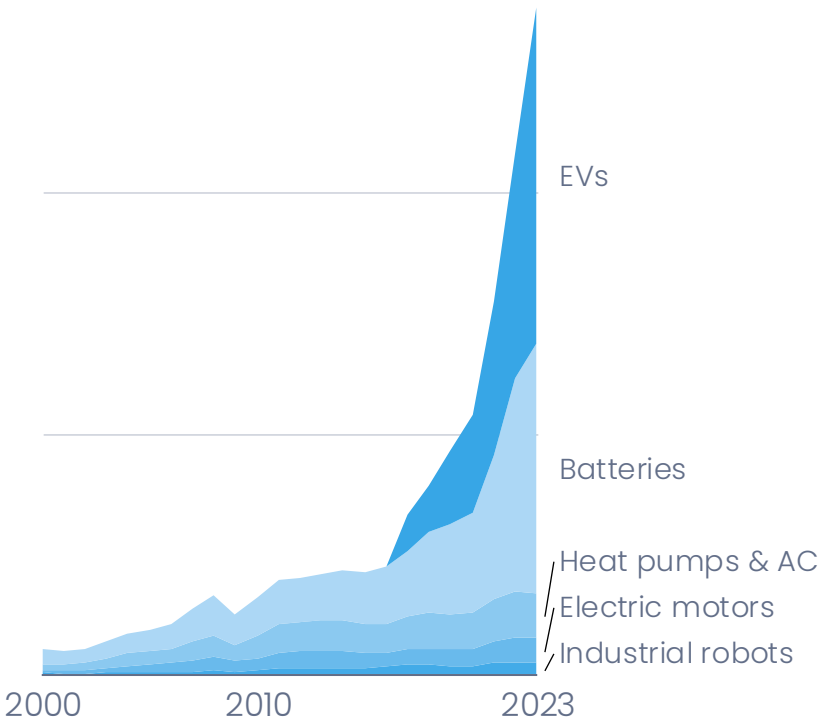
Supply tech



Connection tech



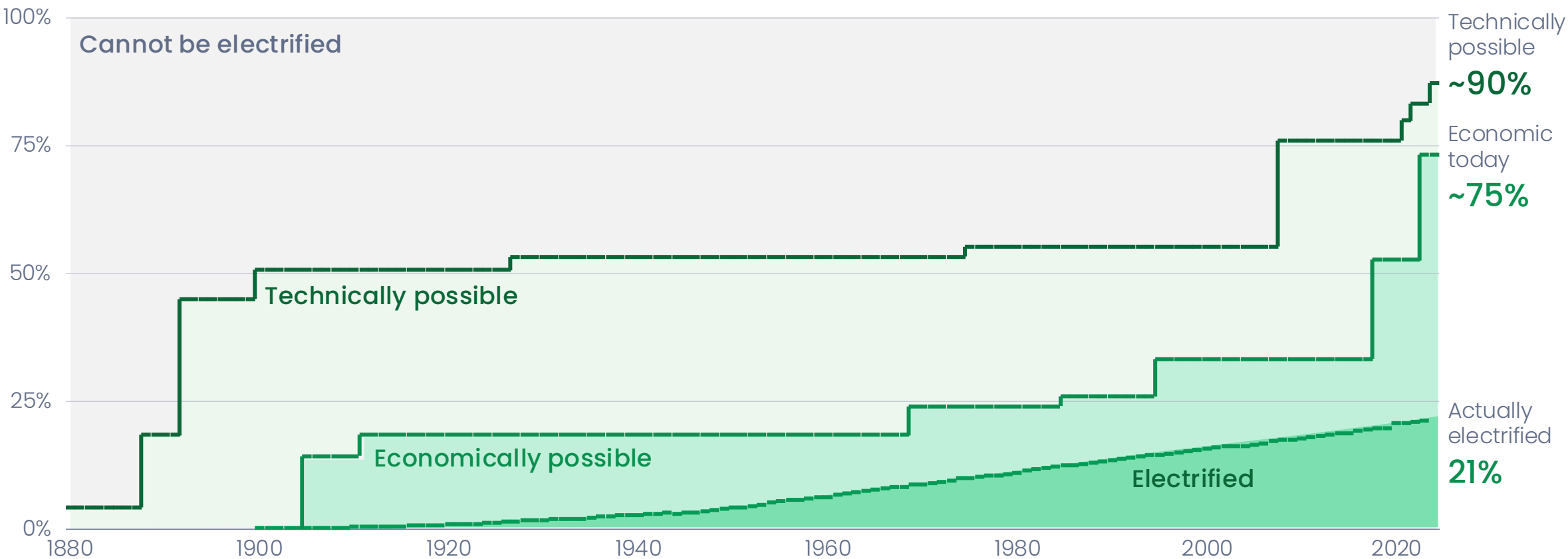
Demand tech



The long march of electrification

Three quarters of final energy demand can be electrified economically

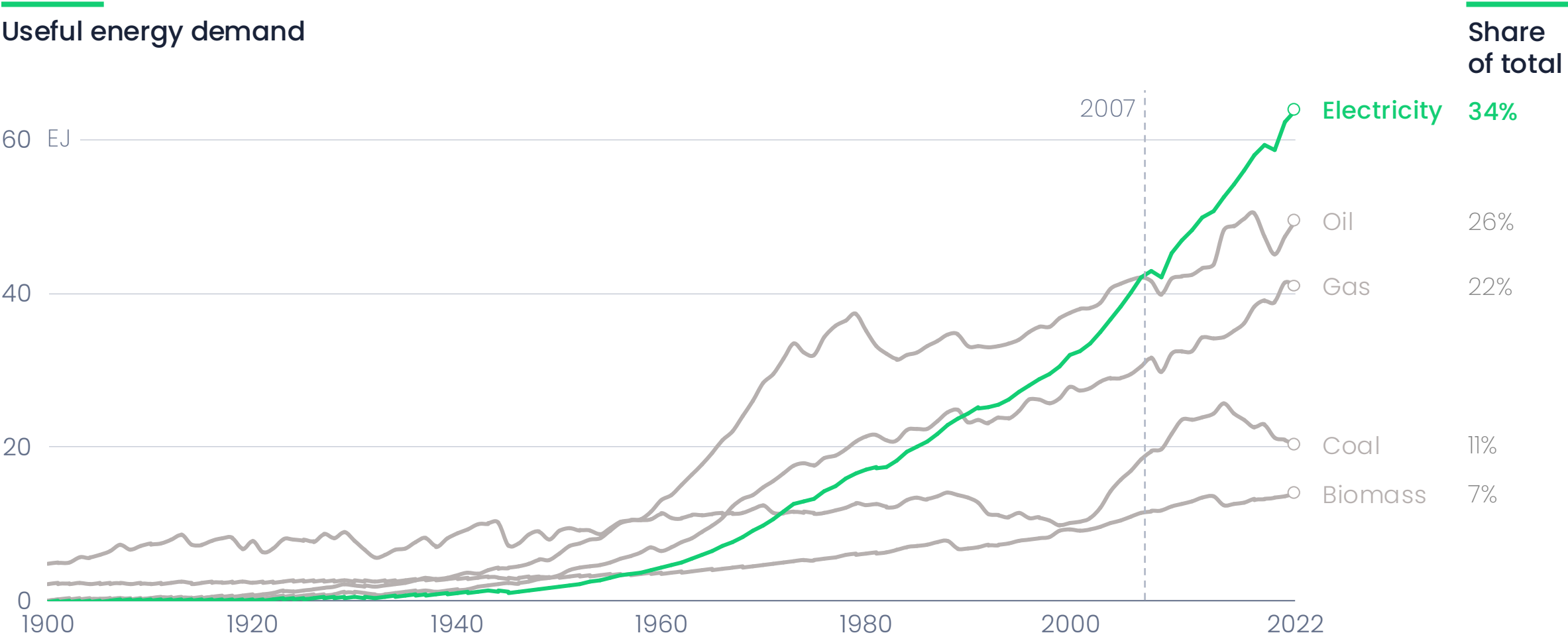
Share of final energy



In useful terms, electricity already dominates

Electricity overtook oil in 2007 and is now the largest source of useful energy demand

Useful energy demand

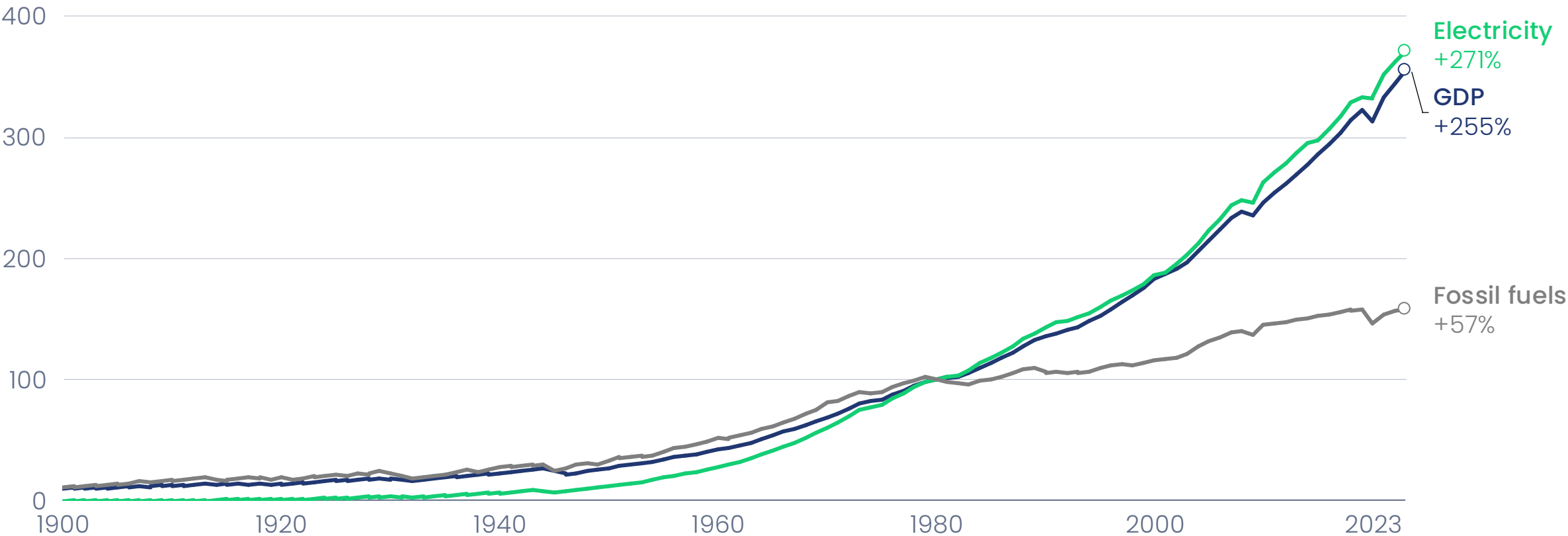


Electricity is the foundation of modern growth

GDP growth decoupled from final fossil energy consumption in the 1980s

World GDP, electricity and fossil fuels in final energy

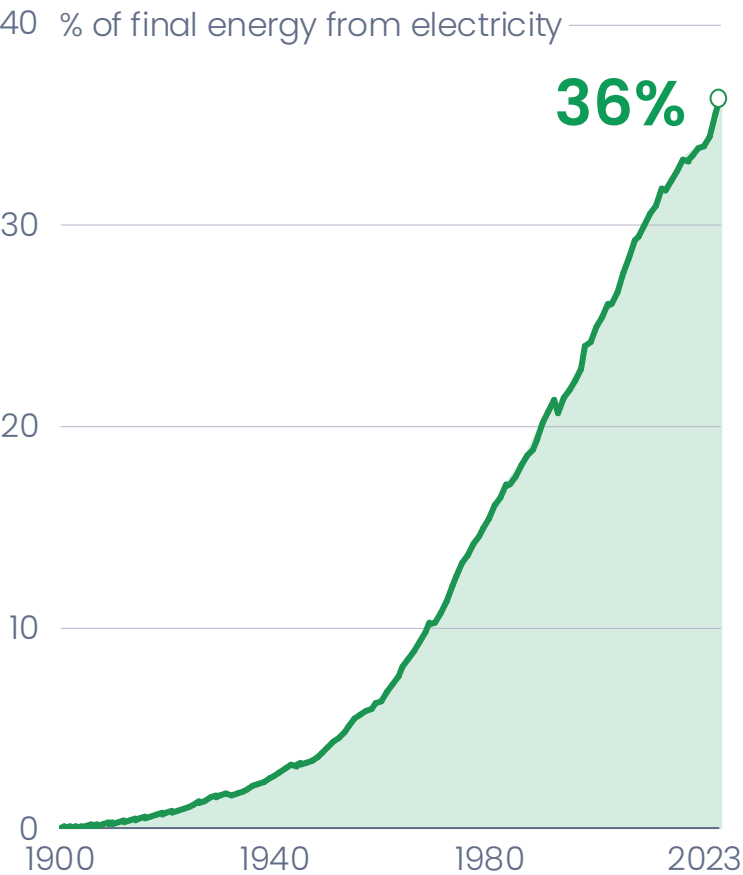
Index, 1980 = 100. Final energy, non-energy use excluded



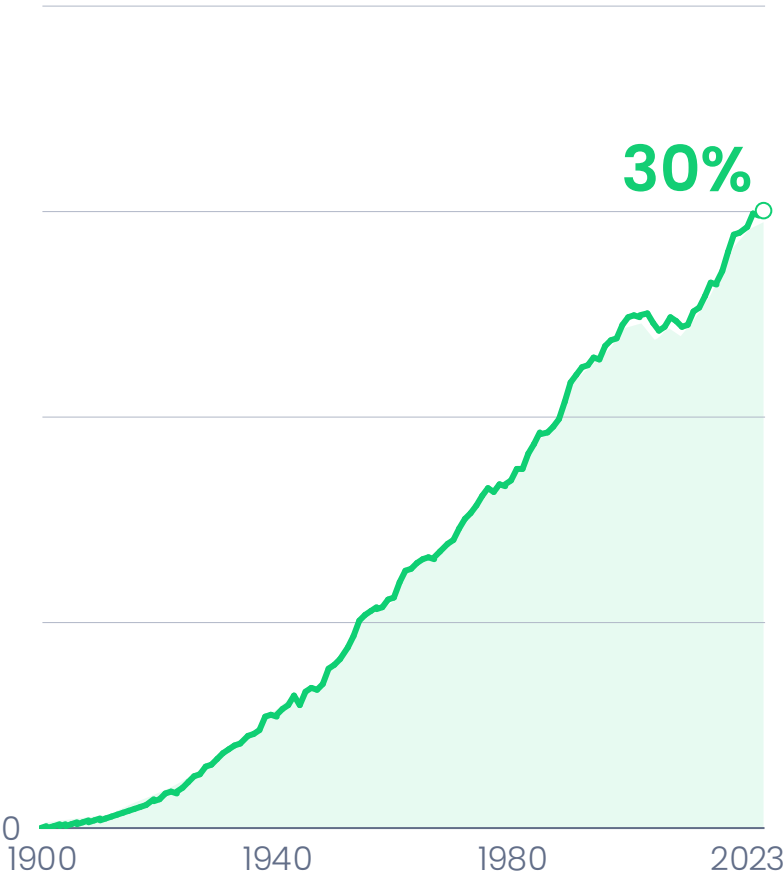
Steady electrification in buildings and industry

Yet transport barely moved and is still just 1.5% electrified

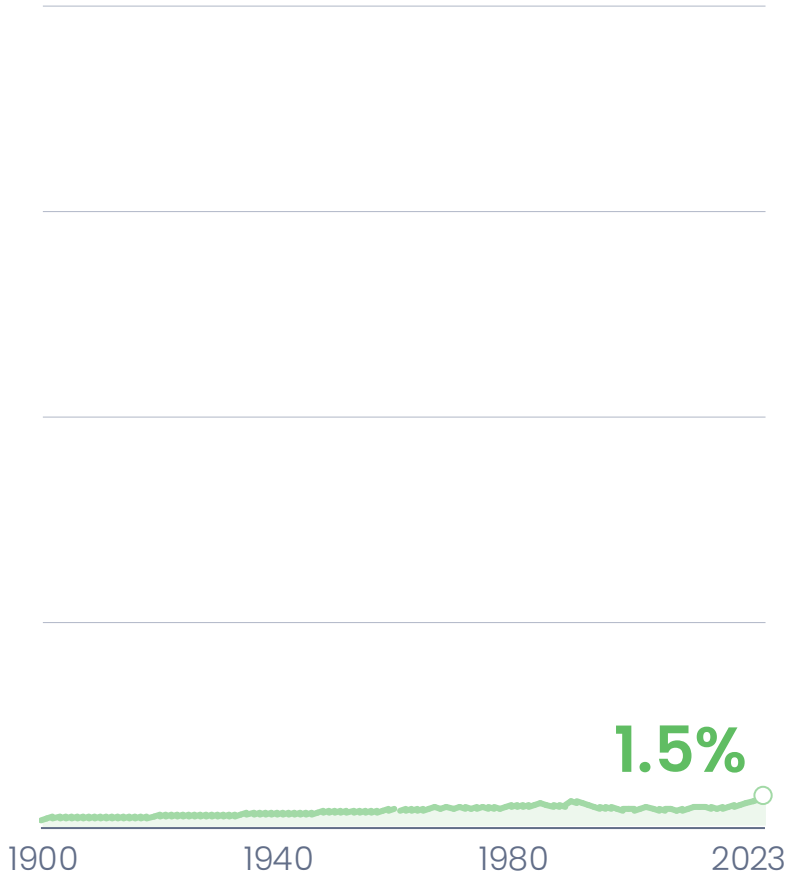
Buildings



Industry

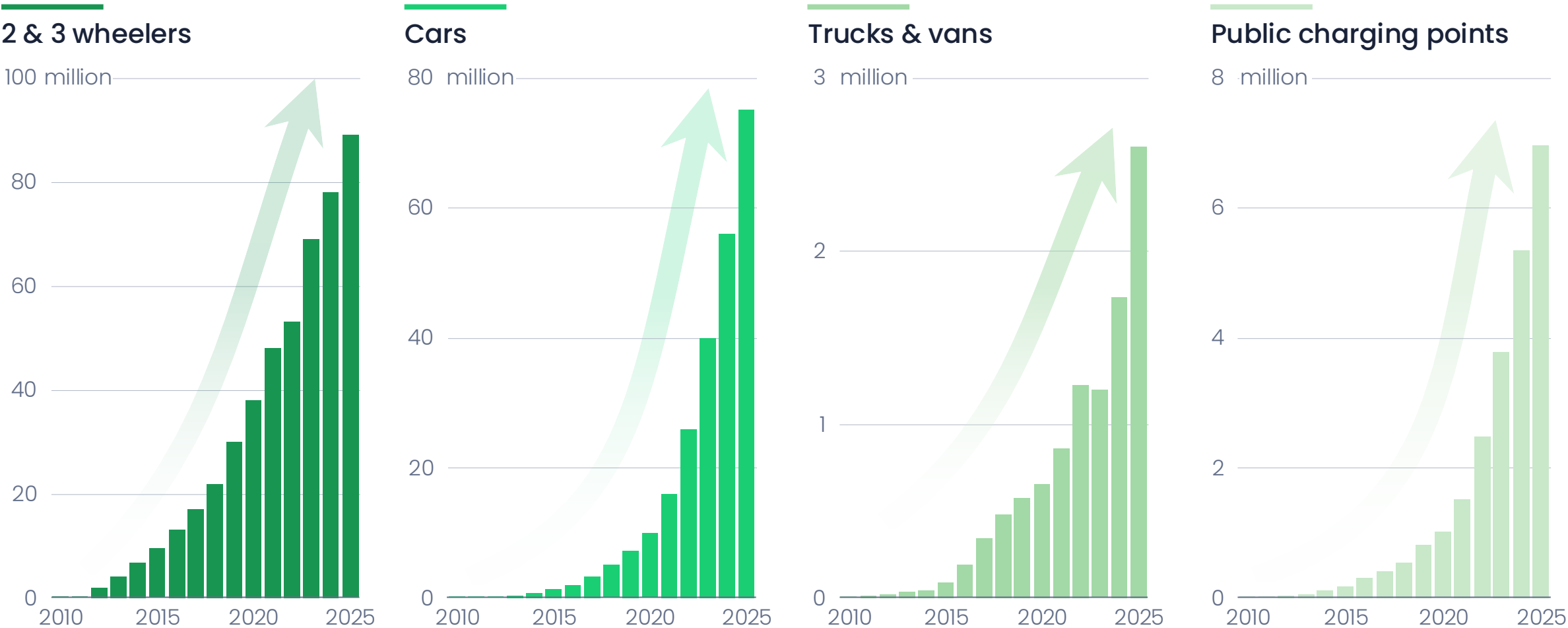


Transport



Now transport is joining the electrification party

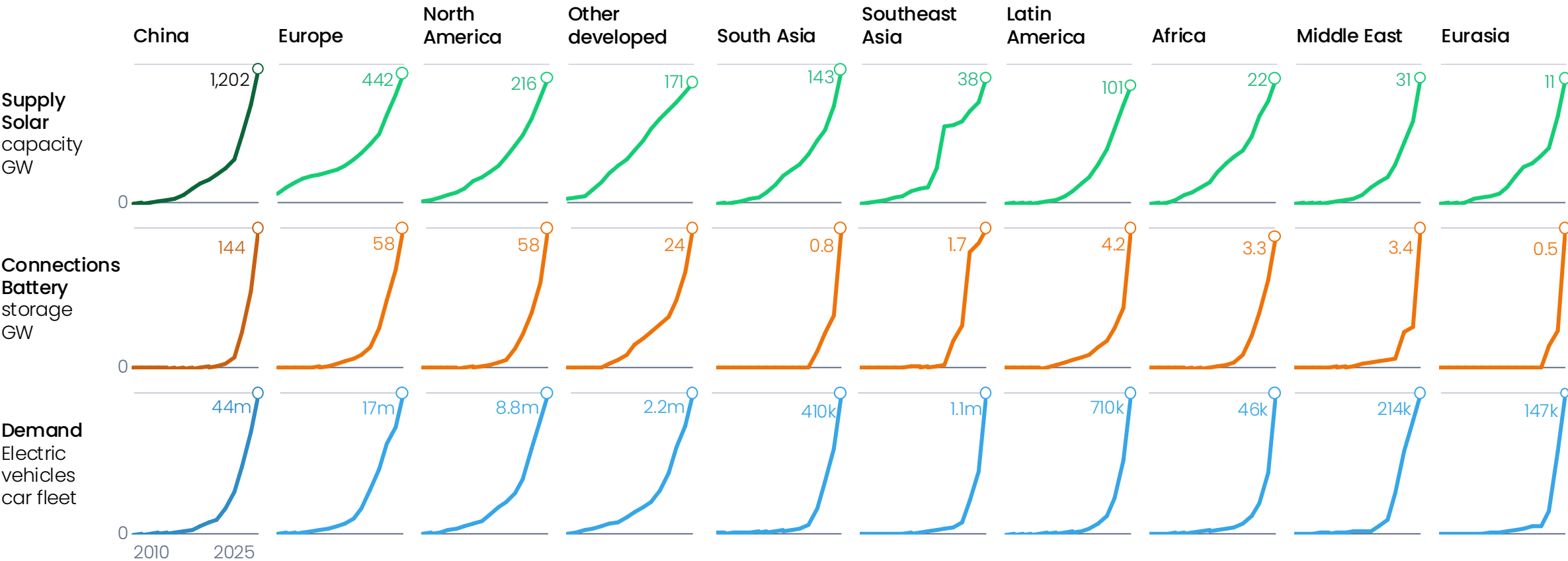
Electric mobility is growing exponentially across vehicle sizes



The rise of electrotech is global

China and solar may grab the headlines, but the story is much broader

Regional electrotech adoption, 2010–2025



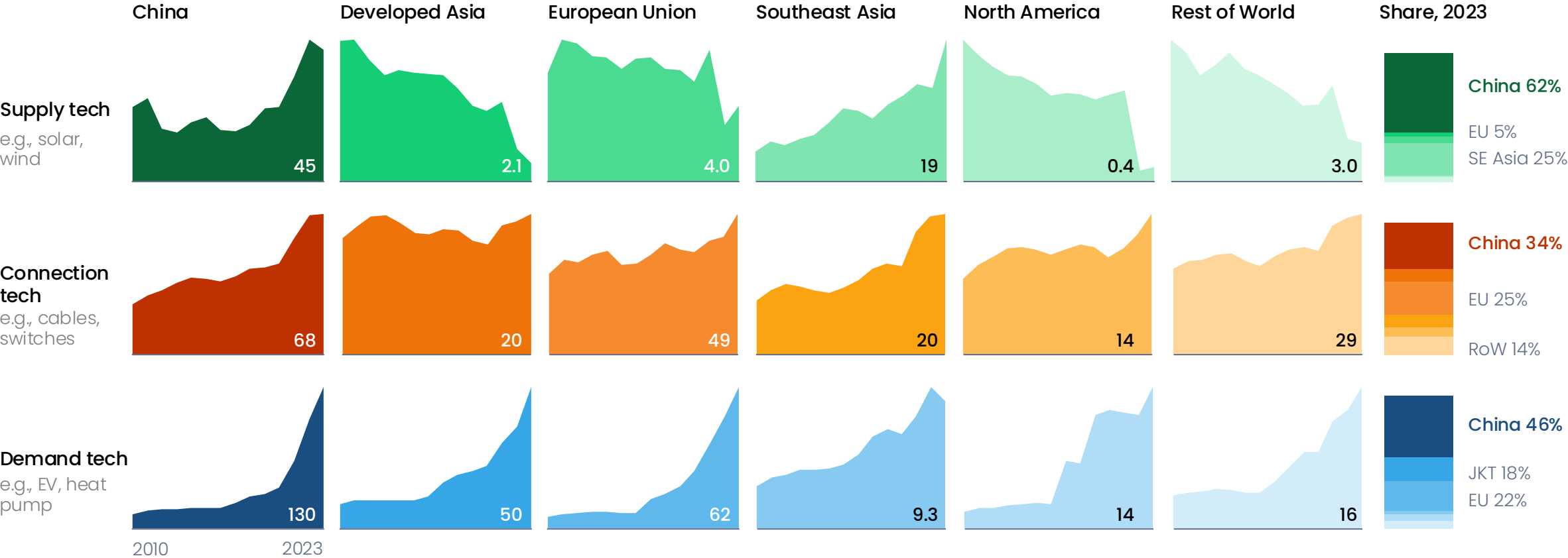


A global race to make electrotech

New opportunities and niches are opening all over the world



Cross-bloc electrotech exports by bloc, US\$ billion, 2010-2023



Electrotech's frontier is hitting information ceilings

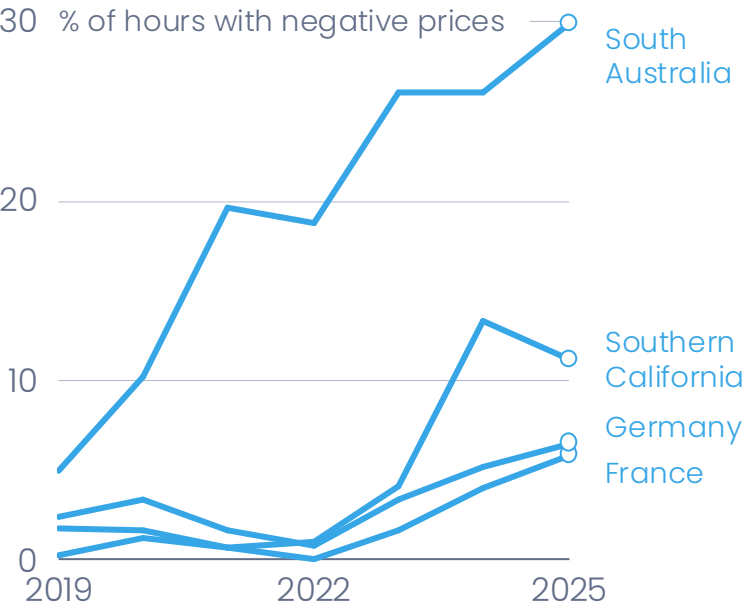
Growth in frontrunner countries is inhibited by poorly coordinated supply, grids and demand

Supply

Negative prices and rising curtailment hurt project finance: **not because there is too much supply, but because nothing coordinates it with demand and storage.**

Negative prices

Selected markets

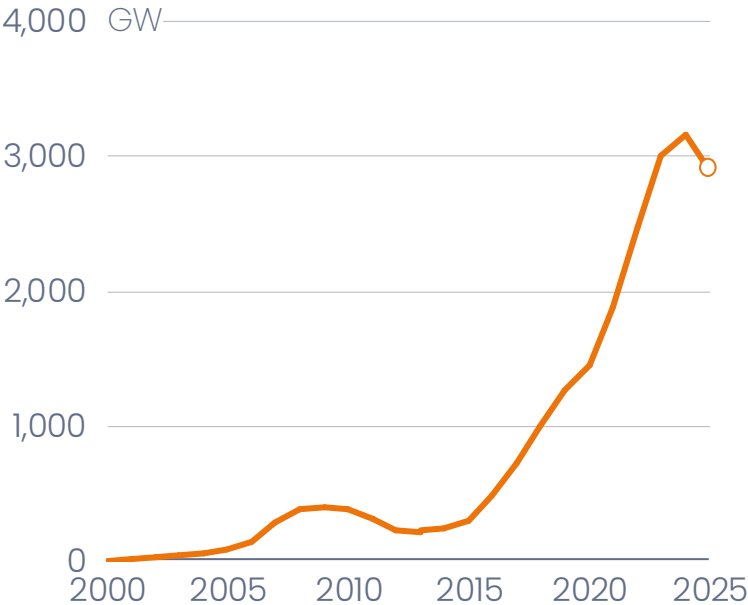


Connections

Queues lengthen as **permitting and integration modelling drag on, while line capacity is not set dynamically but fixed based on the worst day of the decade.**

Connection queue

Global

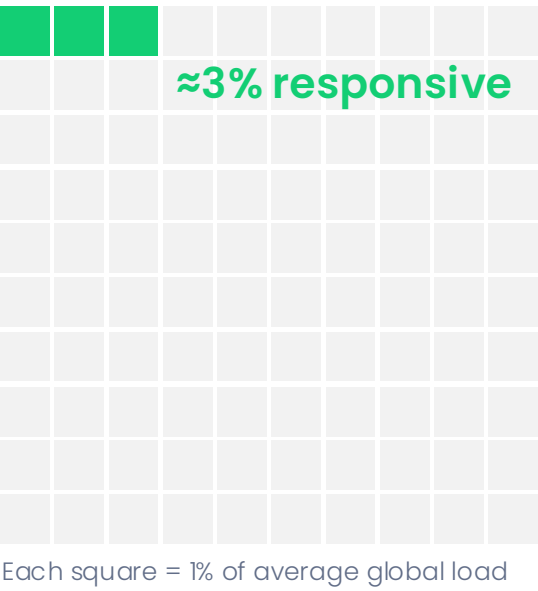


Demand

Much electrotech could **run flexibly on cheaper power, but without a price signal or controls it doesn't**, and forgoes that additional competitiveness.

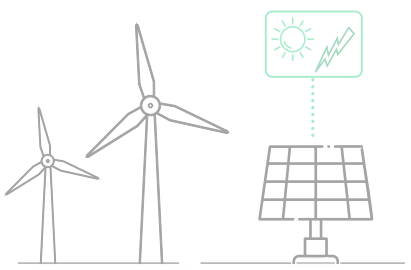
Flexible demand

Responsive capacity vs average load, 2024



Infotech offers a new suite of solutions to electrotech

Across supply, grids, storage and flex, demand and even manufacturing and finance



Supply

What digital changes

Variable output becomes predictable enough to schedule

Examples in operation today



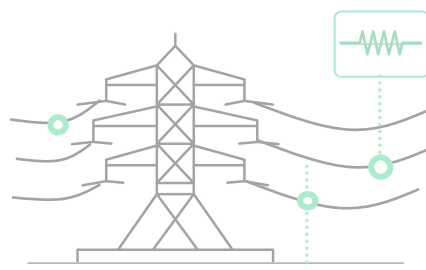
Wind and solar forecasting



Grid-forming inverters



Drone inspection of the fleet



Grid

Existing wires carry more, and faults are found before they spread



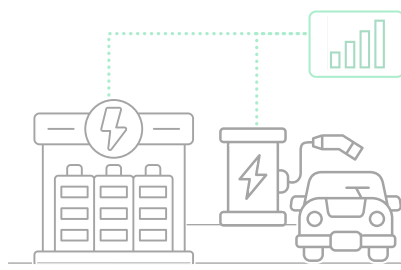
Dynamic line rating



Automated grid connection studies



Wildfire and fault prediction



Storage and flexibility

Millions of small assets run as one dispatchable machine



Algorithmic battery trading



Virtual power plants



Smart EV charging



Demand

Demand can be shifted to match supply



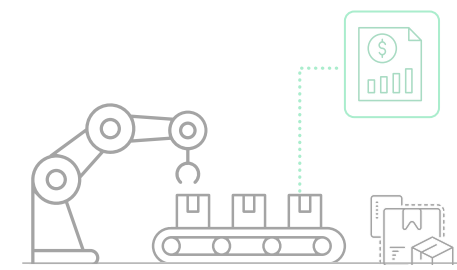
Data centre cooling and load shifting



Industrial process optimisation



Building energy management



Manufacturing and finance

Kit gets cheaper to build, and credit reaches the unbanked



Gigafactory robotics



AI materials discovery



Pay-as-you-go solar credit

The ceiling of the possible is high and rising

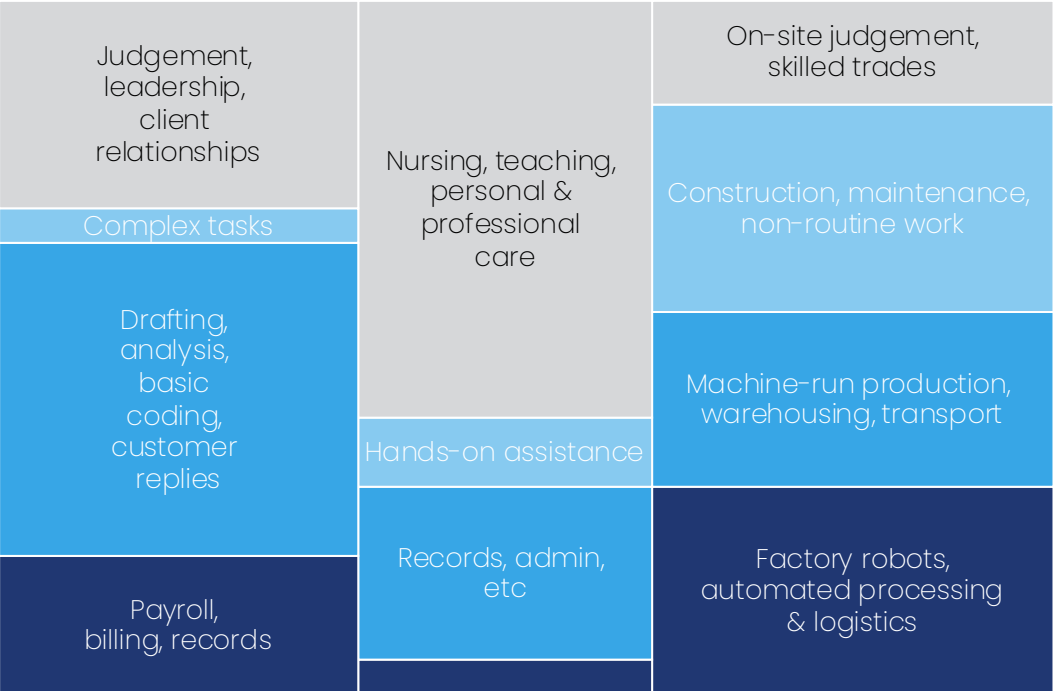
More and more can be electrified and automated, with each enabling the other

ILLUSTRATIVE

Share of global value-add by task and automation penetration, %

2025

- Low automation potential
- Possible to enhance with automation
- Hard to automate
- Already automated



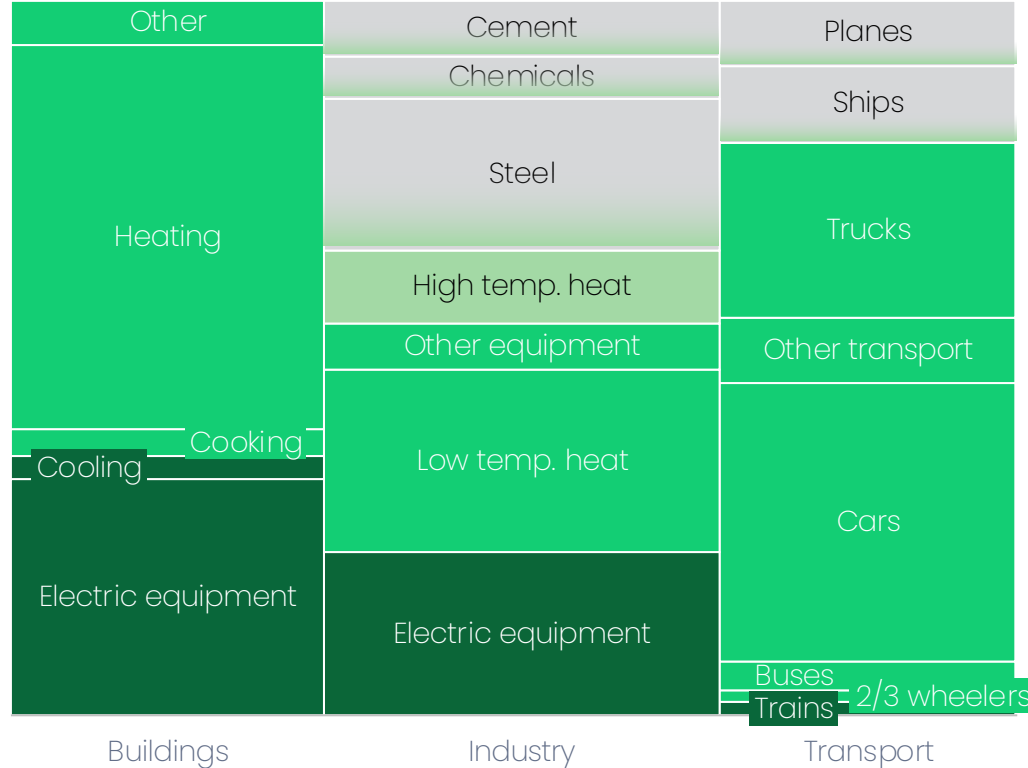
Electrification is cheaper when combined with automation

Automation of many physical tasks requires their electrification

Share of global final energy demand by subsector and electrification potential, %

2025

- Already electrified
- Economically possible
- Technically possible
- Not yet possible



A marriage of necessity

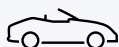
Infotech and electrotech need each other's timing, precision and ability to deal with complexity

Infotech
needs
electrotech

Timing

Autonomous EV

Chip needs to pass on **100+ control** commands per second



3/s

ICE engine max response time

Required

200/s

EV motor response time



No self-driving with a gasoline car

Electrotech
needs
infotech

Battery fast charging

Fast charging requires retuning ingoing current up to **1,000 times per second**



0/s

Analogue plug

Required

1,000x /s

Chip controlled charging



No fast charging without a chip

Precision

Automated welding

System can target **dozens of spots to weld per cm** or more



<1/cm

Gas torch — flame spreads heat

Required

50/cm

Electric coil



No robotic precision welding with gas

Wind turbine rotation

Peak yield requires the nacelle to track wind direction **dozens of times per day**



0/day

Static blades

Required

100/day

Sensors + chip steered



No optimal wind yield without software

Complexity

Sorting & distribution

Automated fulfilment requires dense automated fleets; **100s per acre**



<20/acre

Diesel fork-lifts

Required

600/acre

Electric robots



No automated warehouse on diesel

Distributed generation

Distributed solar and battery requires managing **1,000s of assets in sync**



200 assets

Typical human control room max

Required

100,000+ assets

AI VPP automated dispatch



No smart DERs without AI

The dual revolution in transport

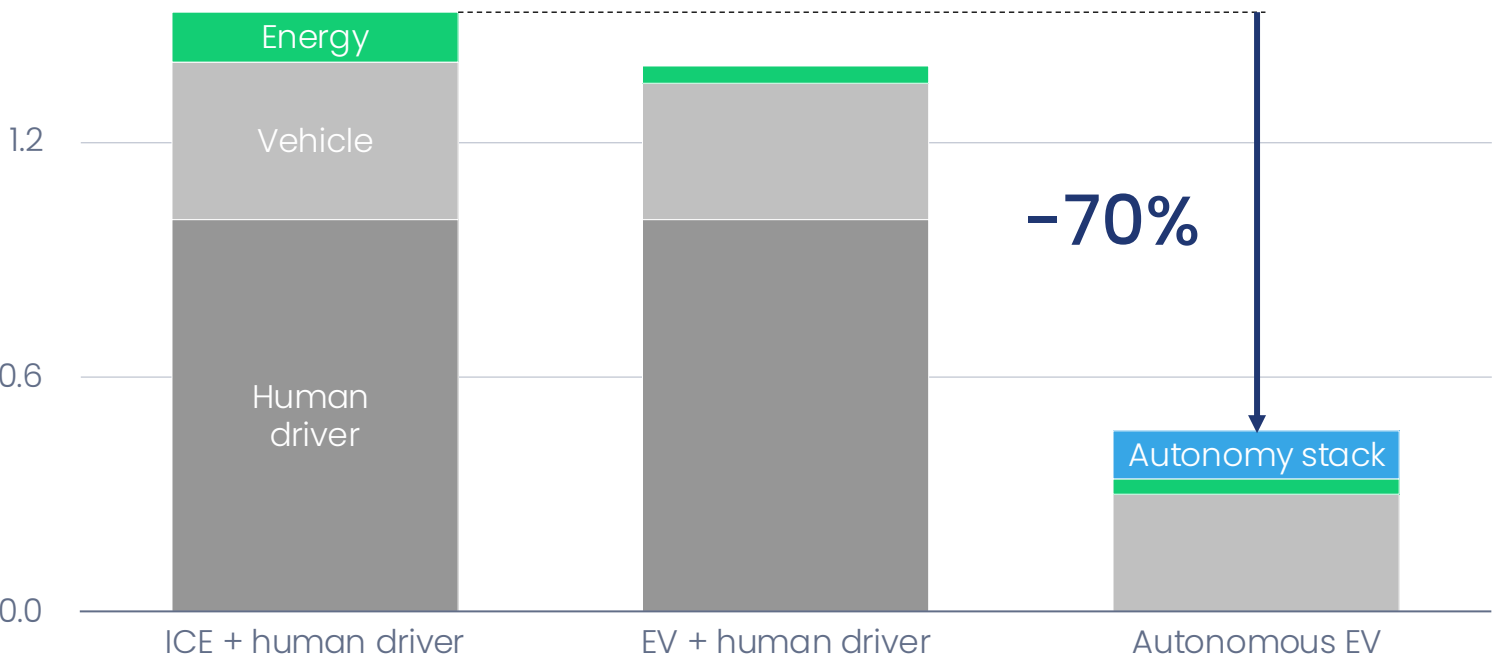
New infotech and electrotech can drive down transport cost by as much as 70%

Cost per mile driving

US city, 2026 – stylised build-up for ride-hailing service

INDICATIVE

1.8 \$ per vehicle-mile



Other advantages

94%

fewer serious-injury crashes

Note: 1.2 million people a year die on the roads

385,000

deaths a year from exhaust fumes

Can be reduced to zero with EVs

95%

of the day a car sits parked

Autonomous fleets liberate valuable space

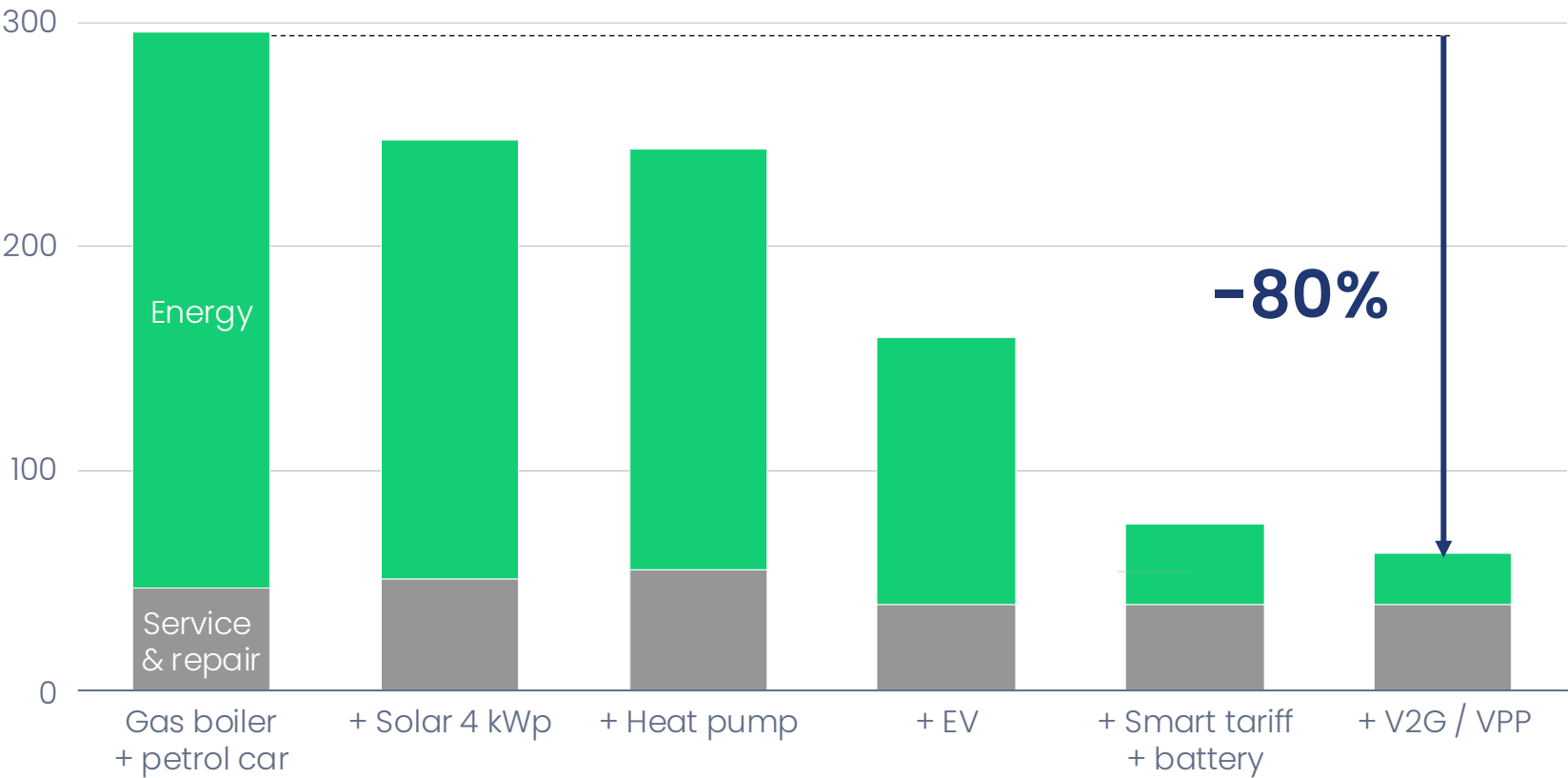
The dual revolution for households

New infotech and electrotech can drive down household bills by as much as 80%

Monthly energy-related bills for a household in the UK

£ per month at 2026 UK prices

INDICATIVE



Other advantages

13%
of childhood asthma attributable to gas cooking in the US
Can be avoided with electric stoves

3 million
homes overheat with no way to cool in England
Heat pumps can heat and cool

75%
of charging happens at home or the workplace
So no more trips to the gas station needed

The dual revolution in industry

New infotech and electrotech can drive down manufacturing costs by 40 to 70%

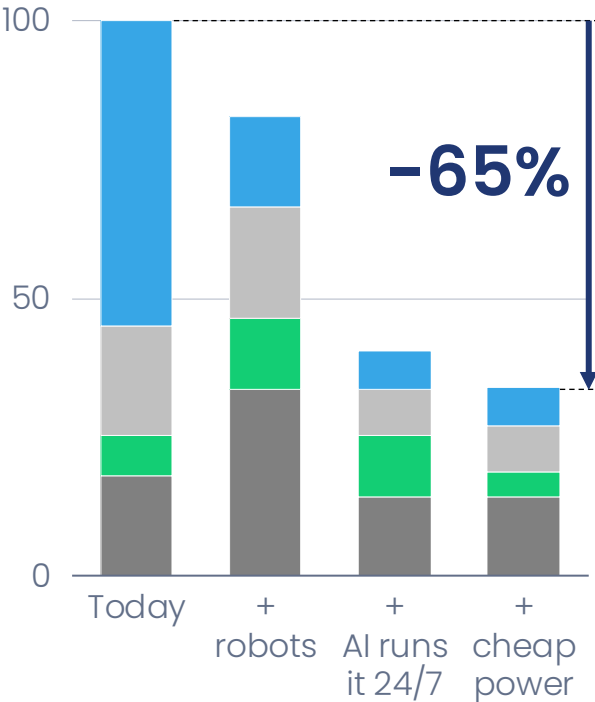
Cost of turning materials into product

Cost per good unit, index: today = 100, purchased materials excluded

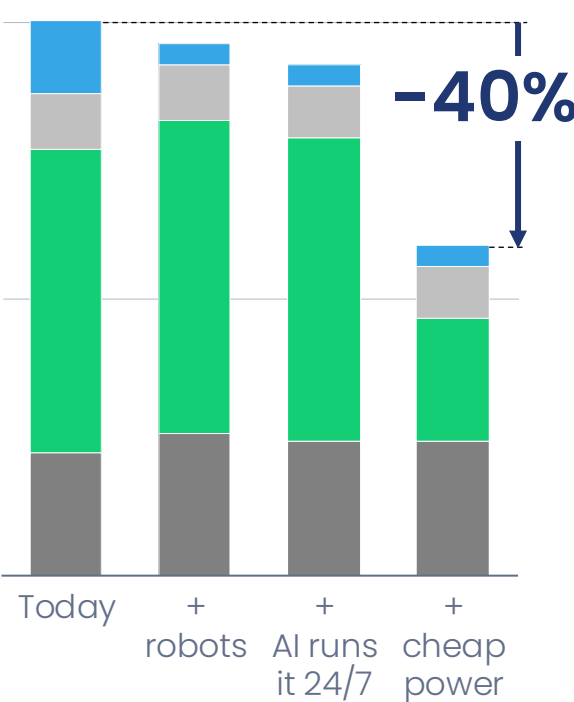
INDICATIVE

Capital Energy Overhead Labour

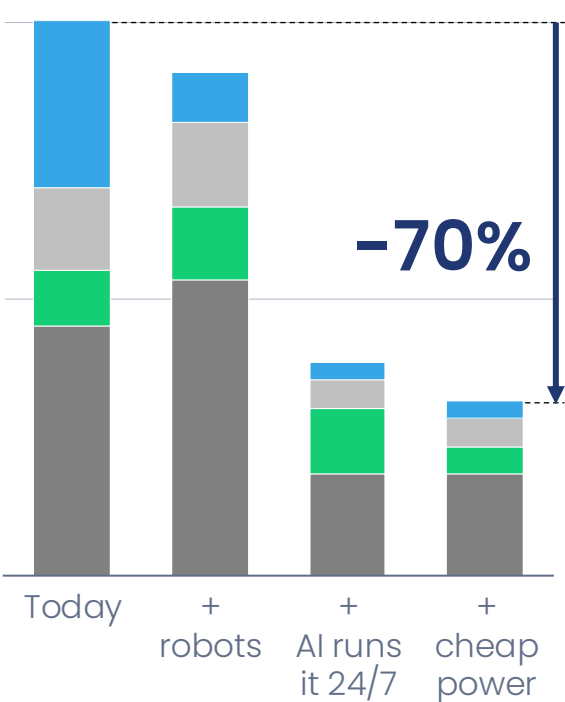
Labour-intensive



Energy-intensive



Capital-intensive



Other advantages

99%
of defects caught by machine vision
a typical human inspector catches 80%

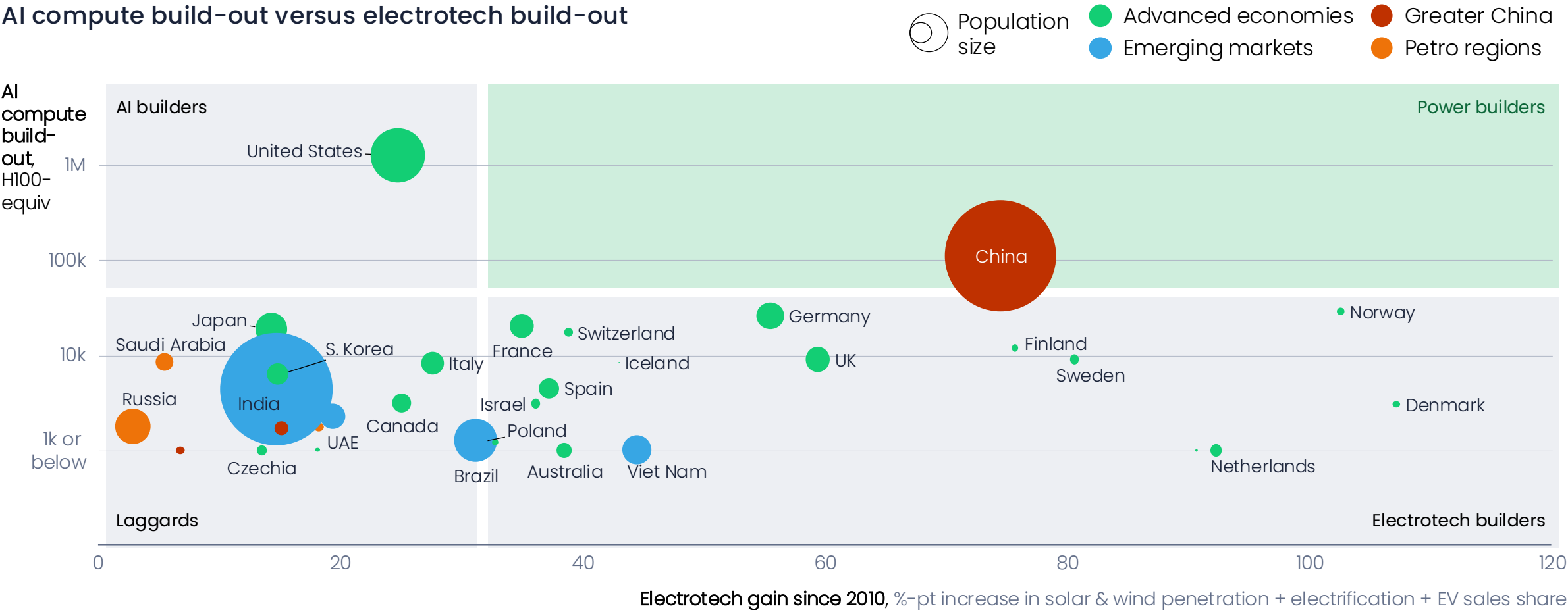
-40%
unplanned downtime
AI predictive maintenance

+20%
machine life
so the capital spreads further still

Few countries are pursuing both revolutions

China is leading the way pushing the envelope on both electrotech and AI

AI compute build-out versus electrotech build-out

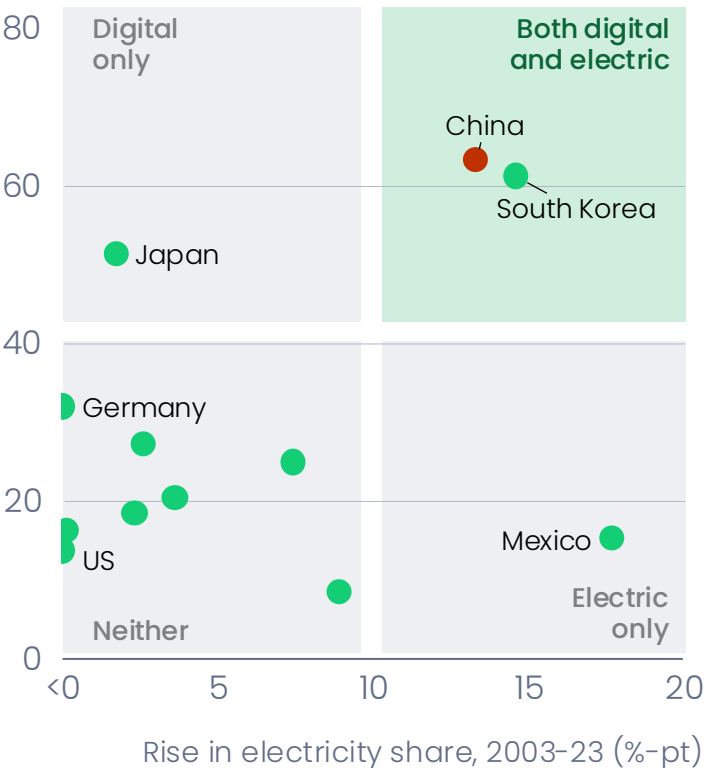


Few countries are both electrifying and digitising

Only China does so consistently across sectors

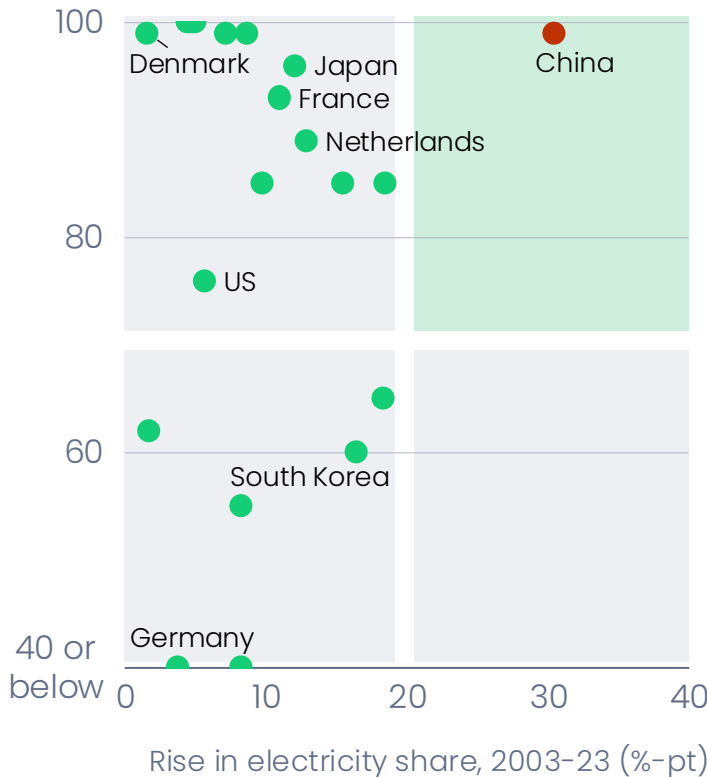
Industry: robots

Robots installed per \$bn of value added



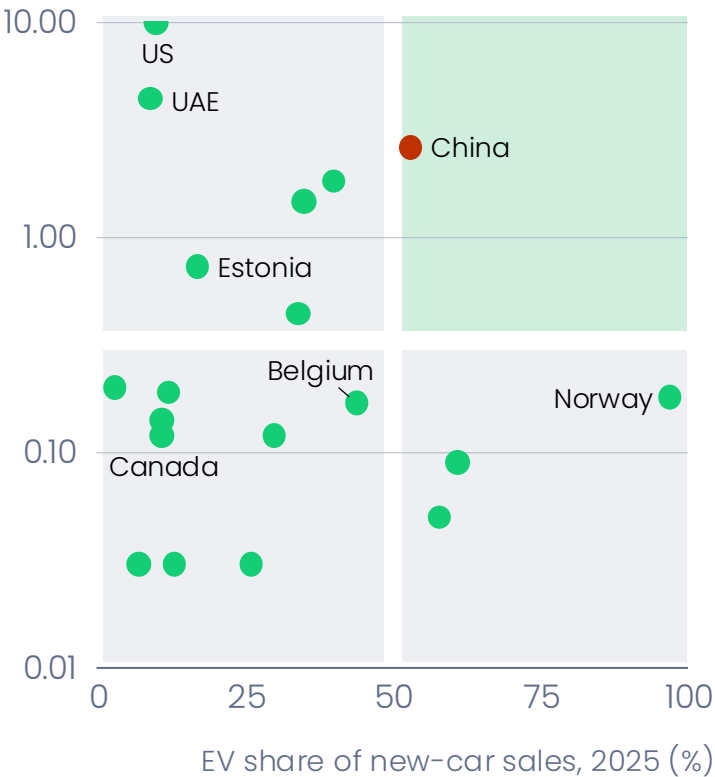
Buildings: smart meters

Smart meters, % of metering points



Mobility: autonomy

Autonomous vehicles per million people, log scale

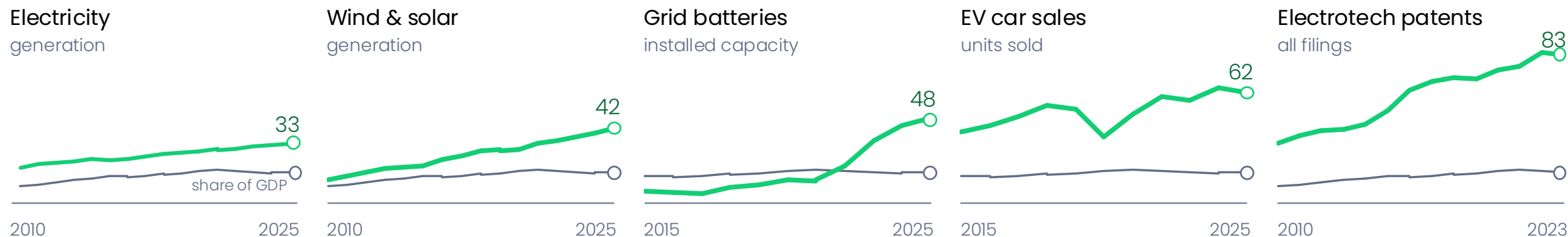


China has an outsized influence on both revolutions

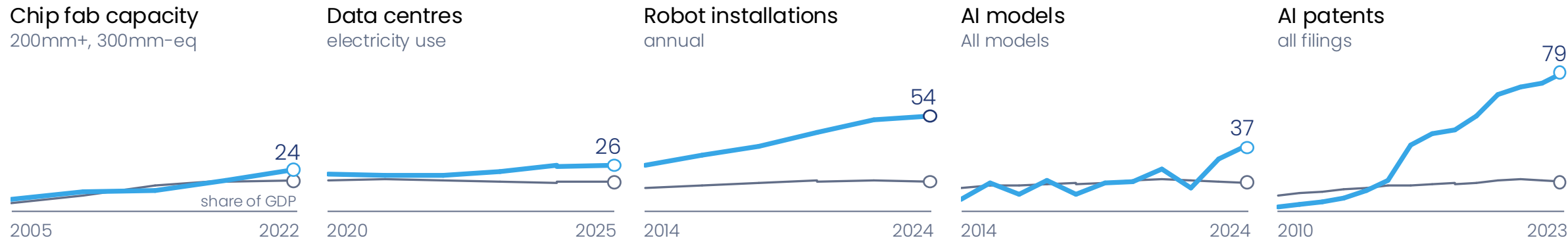
It is a powerhouse of electrotech and infotech

China's share of the world total vs its share of world GDP, %

Electrotech



Infotech



Contents

01 Two interlinked revolutions

The electrification of information and energy

02 The electric rise

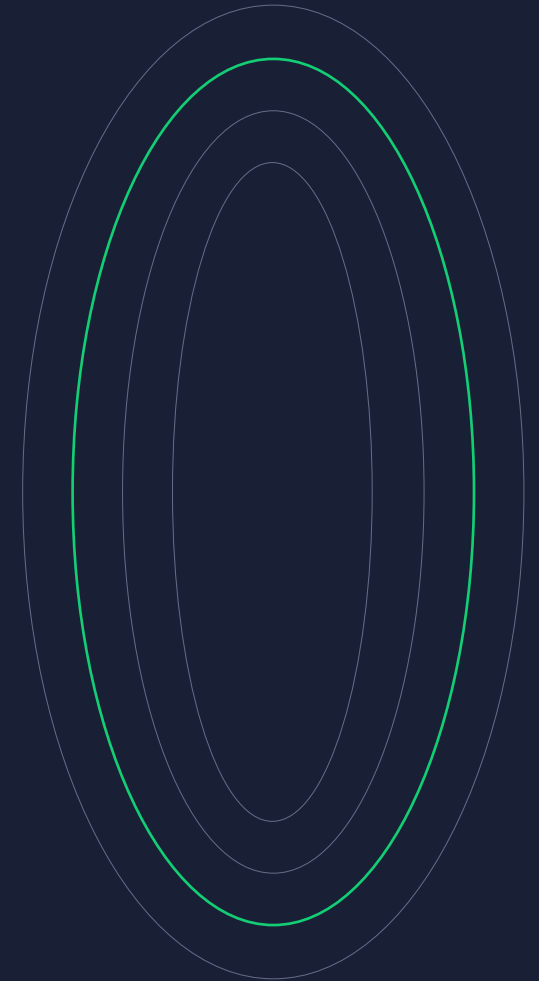
The rise of infotech and electrotech

03 The shape of things to come

The implications of the two revolutions converging

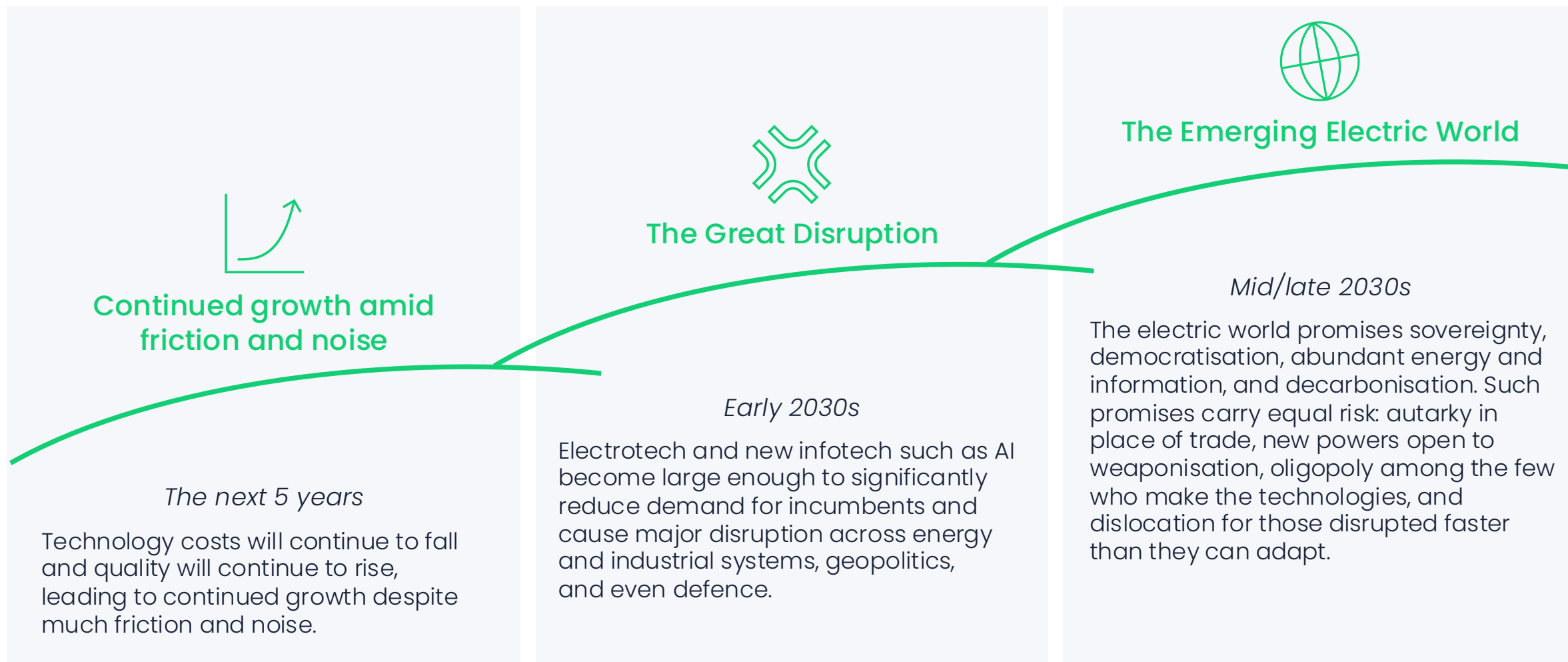
04 Seizing the opportunity

Navigating the incoming electric disruption



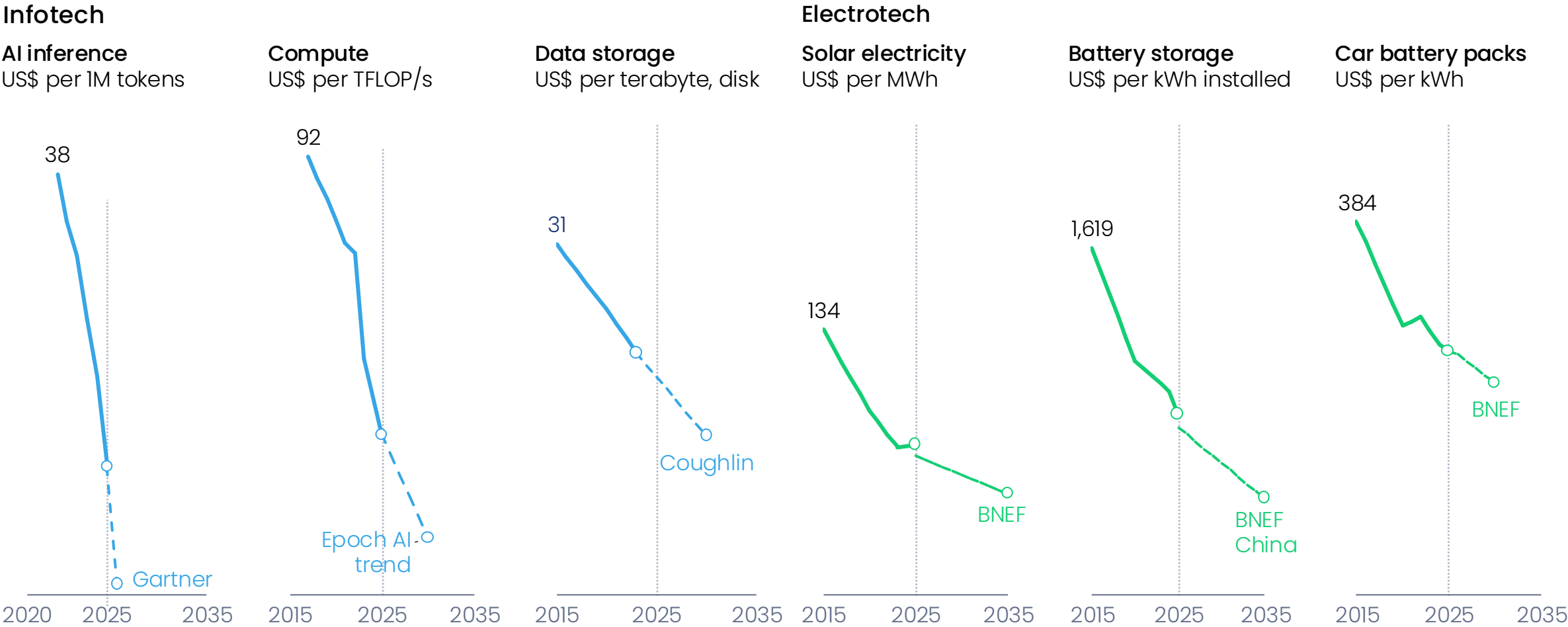
The shape of things to come

The implications of the two revolutions across three time horizons



Costs will continue to fall

What is cheap today will be irresistible by 2030

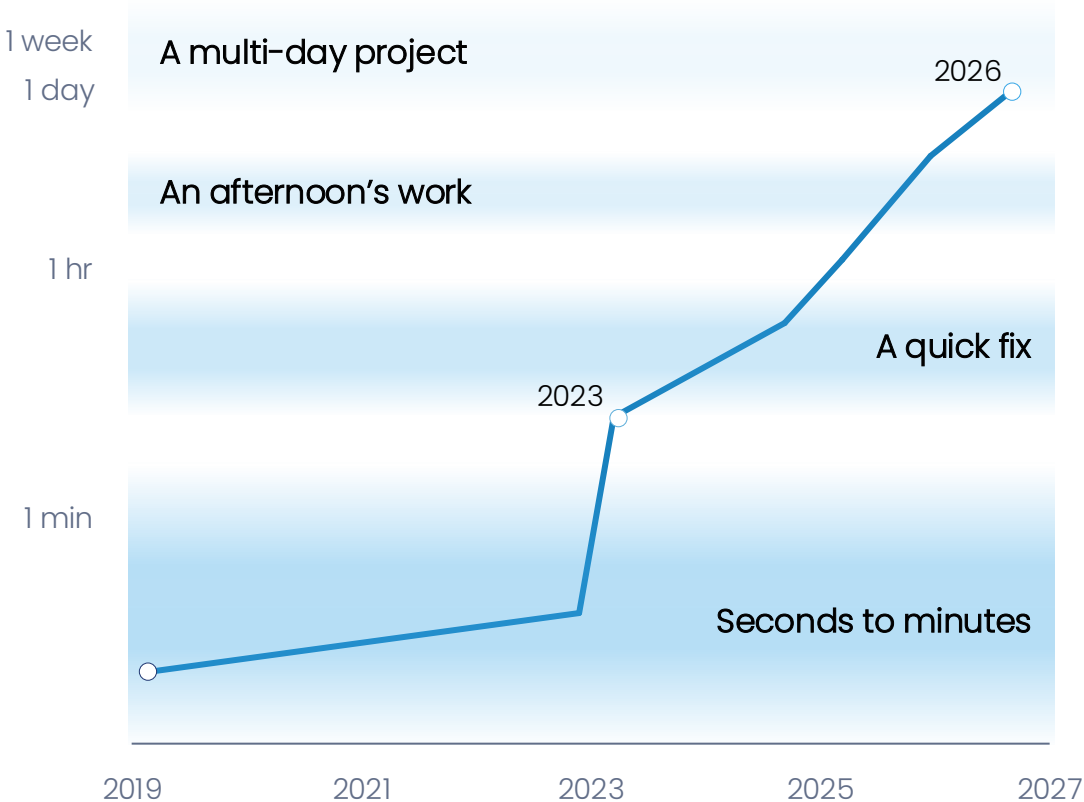


So change spreads from one market to the next

As infotech and electrotech improve, so they open up new markets

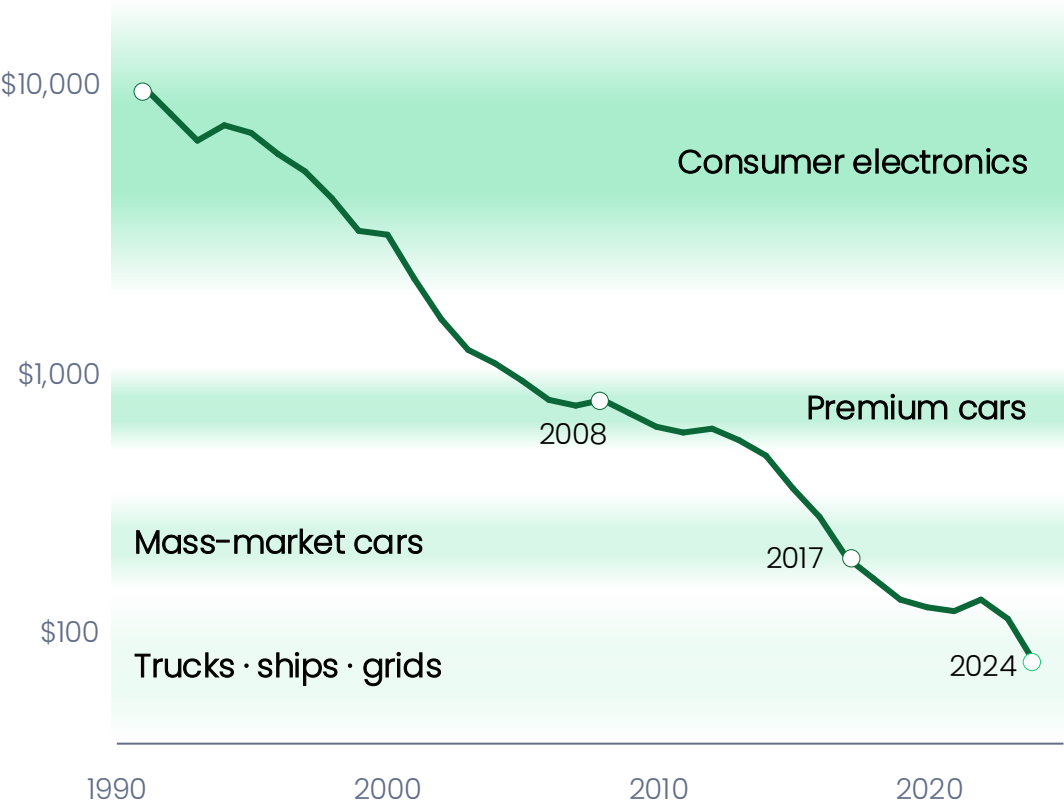
AI uses by capability

Length of a human software task matched half the time (METR)



Battery uses by price

Li-ion cell, constant 2024 US\$ per kWh

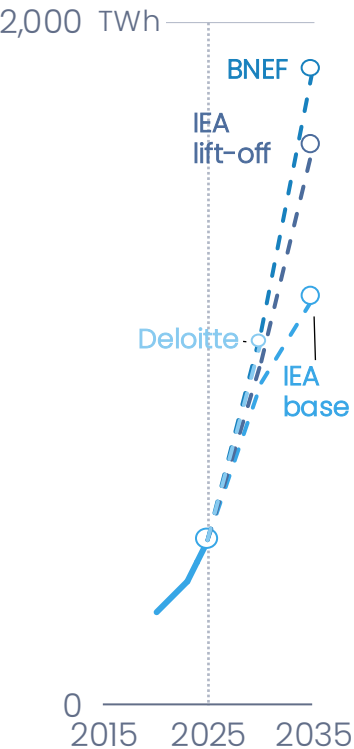


So rapid growth will continue

It is just a question of fast or *faster* growth

Infotech

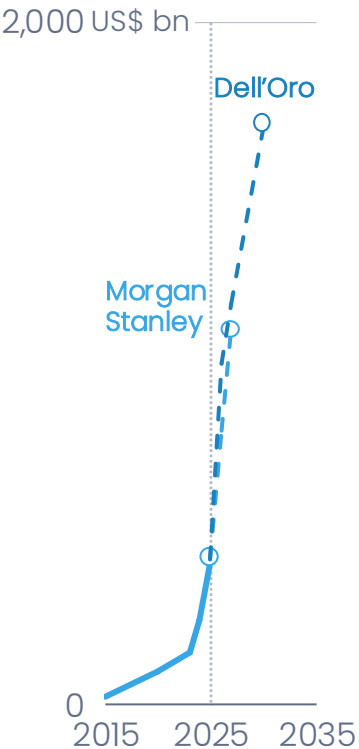
Data centre electricity demand



Semiconductor sales

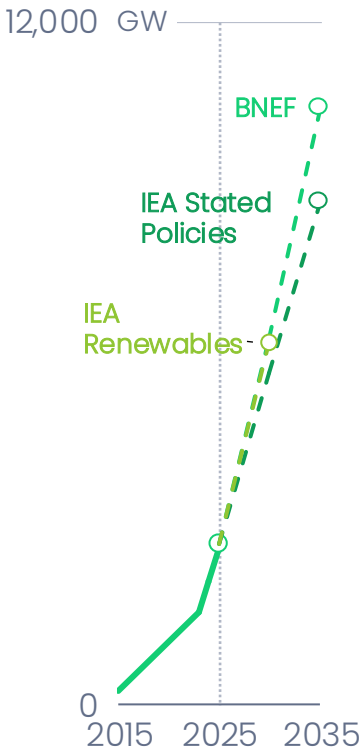


Data centre capex

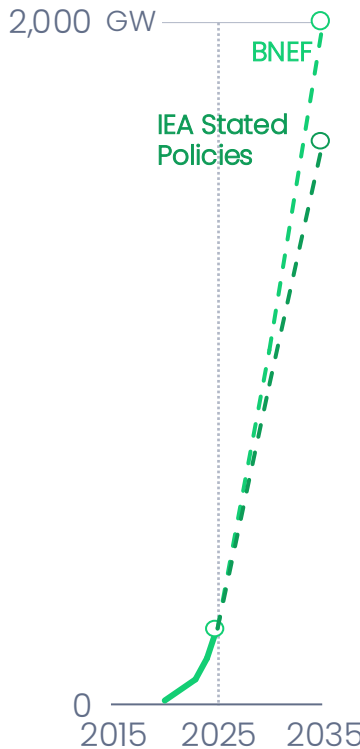


Electrotech

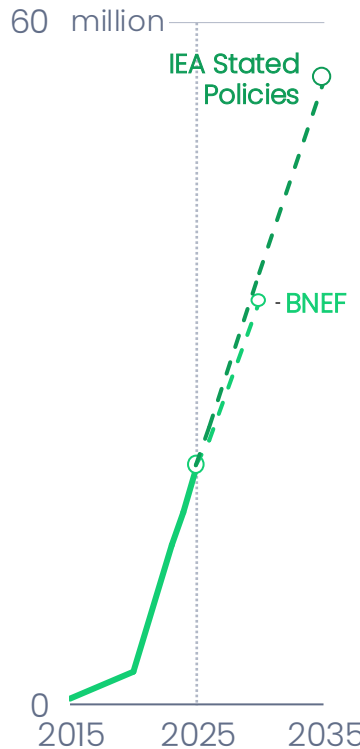
Solar installed base



Battery storage on the grid



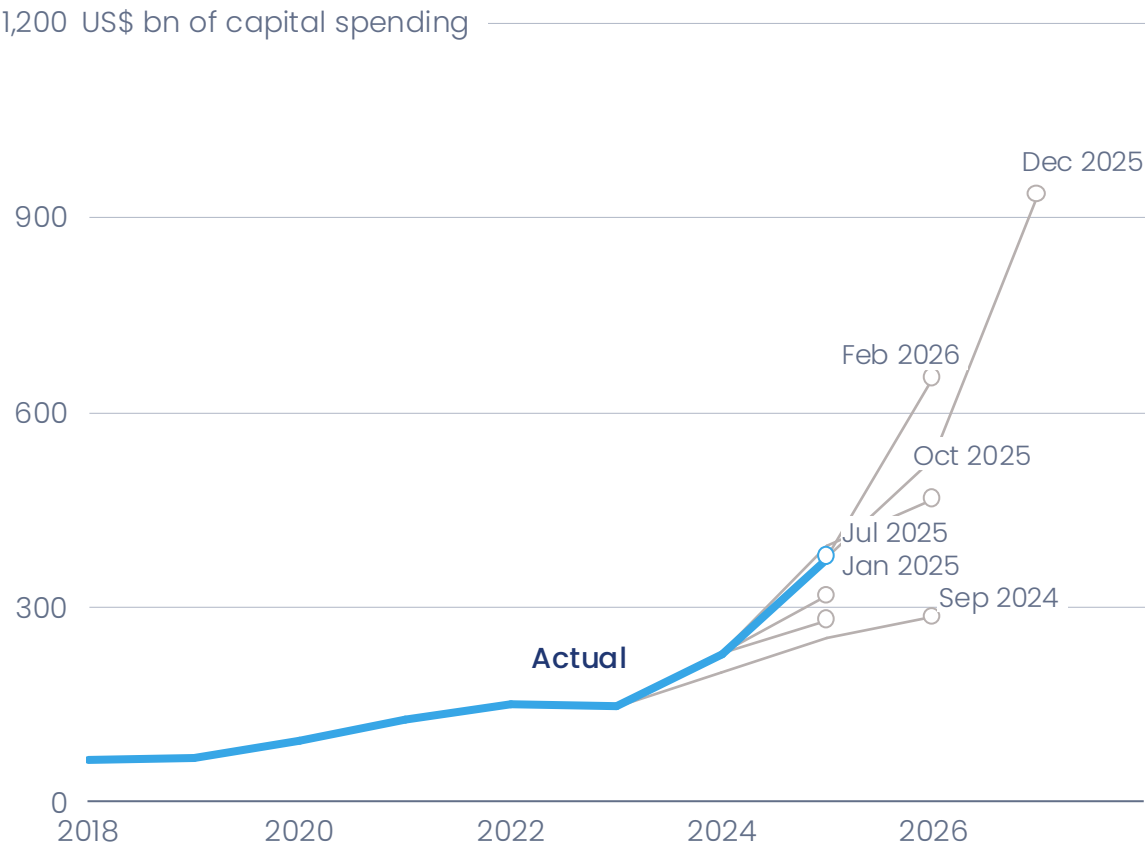
Electric cars sold each year



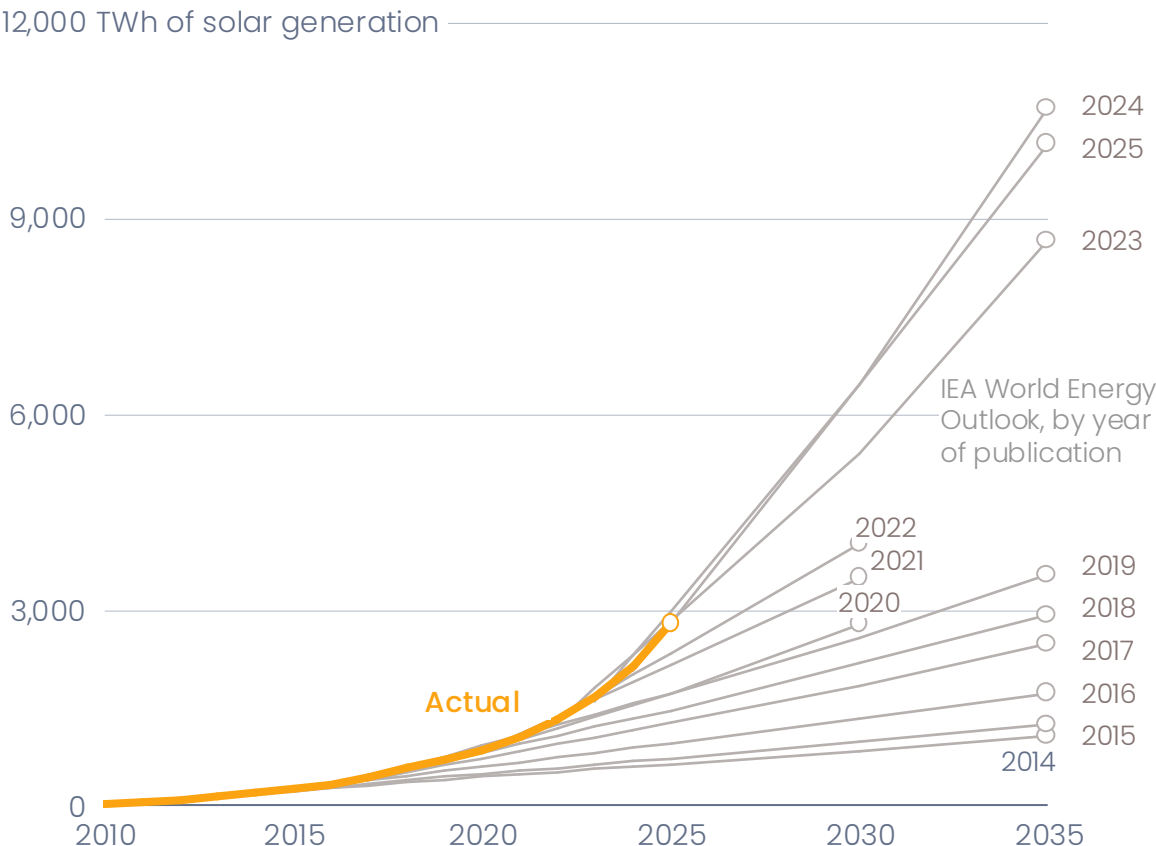
Change will happen faster than expected

Forecasters have structurally underestimated how fast change can happen

AI capex: Analyst outlooks vs reality



Solar generation: IEA outlooks vs reality

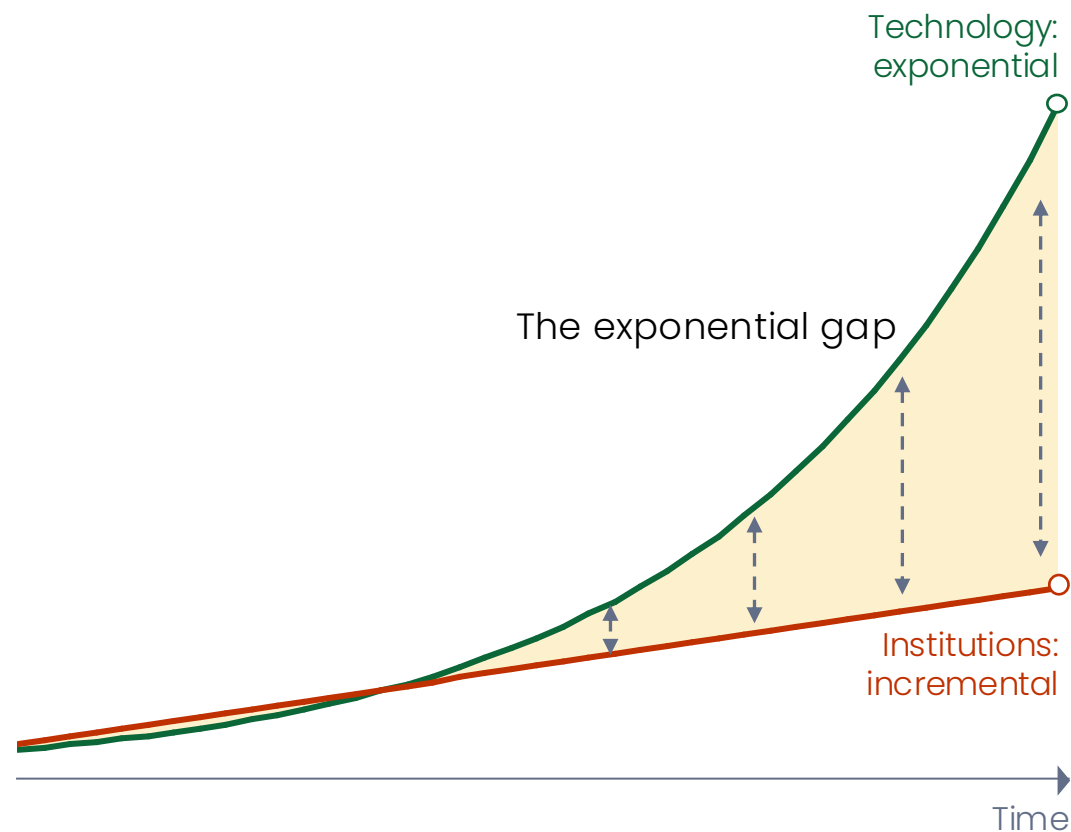


The exponential gap will widen

Institutions will struggle to keep up with the pace of change; not all will succeed

Exponential technologies vs linear institutions

Change over time



Examples of places the gap already bites

	Technology can	Institutions still...
 Flexible connections	Accept interruption for a handful of peak hours	Plan every connection as if it needs firm power 24/7
 Grid capacity	Unlock major capacity from existing wires with sensors + GETs	Default to building new lines through years-long approval processes
 Connection speed	Build solar + batteries in months	Take 5+ years to connect them to the grid
 Distributed flexibility	Coordinate millions of EVs, batteries and heat pumps in real time	Run markets designed around a handful of large power stations
 Multi-use storage	Switch instantly between load, generation and grid support	Force batteries into regulatory boxes built for either consumers or generators
 Electrification	Deliver ~3× more useful energy from each unit of energy	Tax electricity more heavily than the fossil fuels it replaces

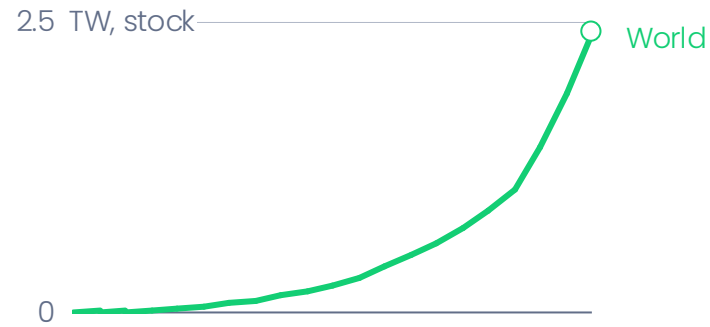
Locally bumpy but globally smooth

Countries will face setbacks and breakthroughs even as global growth continues steadily

The world climbs without a break

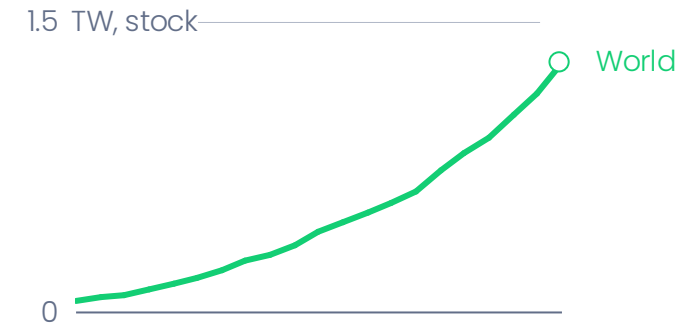
Solar PV

installed capacity



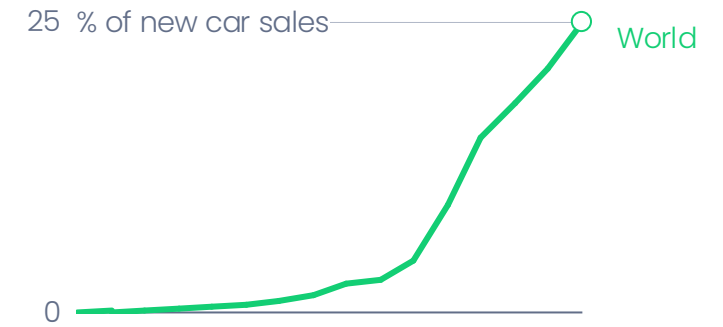
Wind

installed capacity

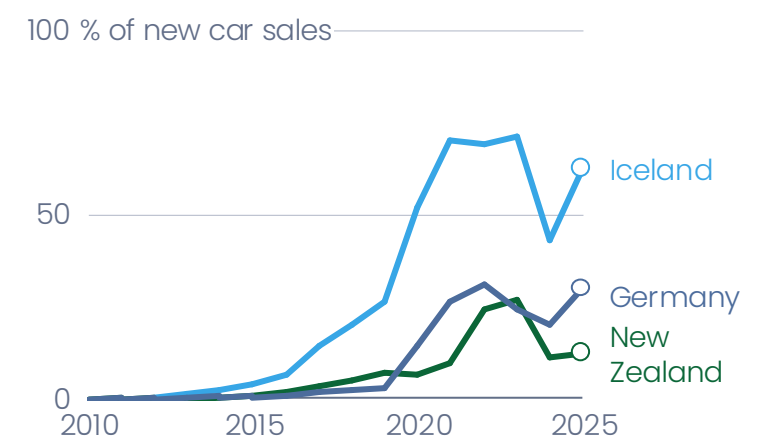
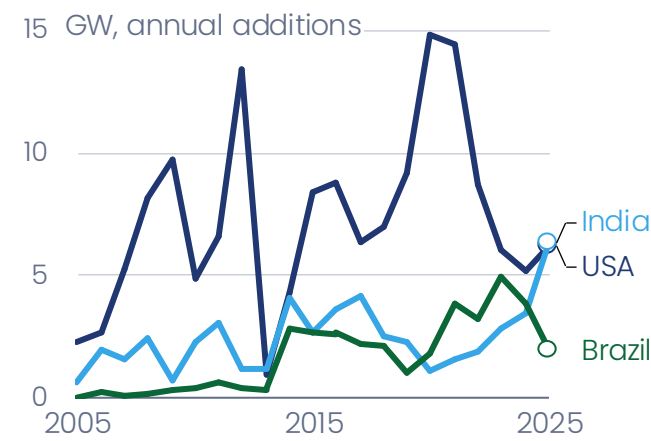
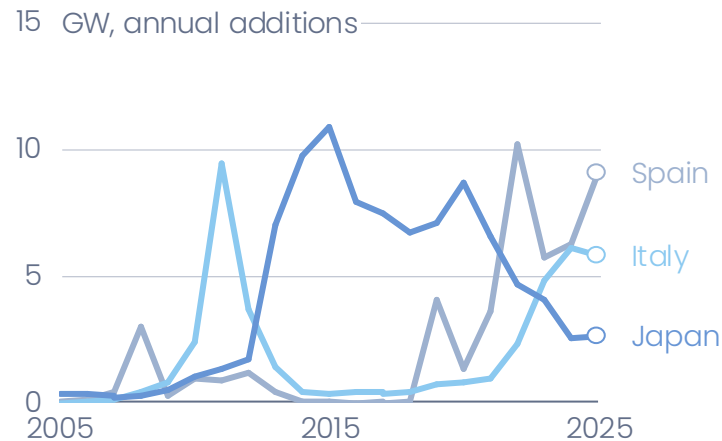


Electric cars

share of new car sales



Countries can experience ups and downs



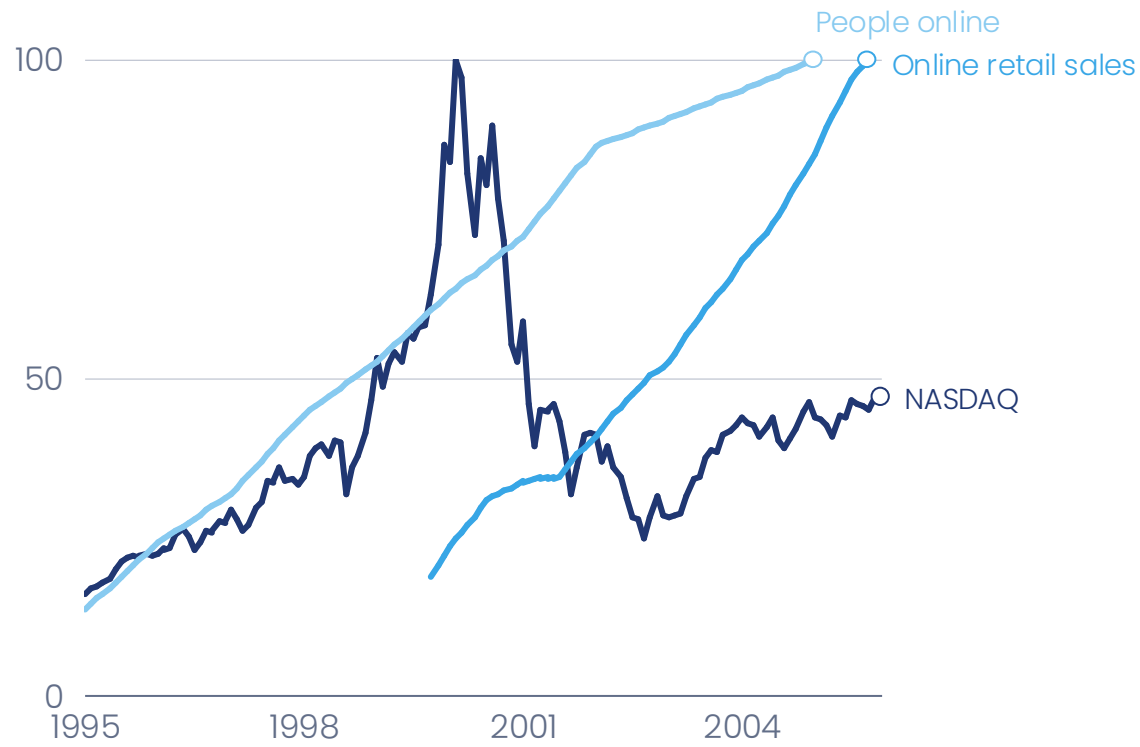
Bubbles often form and pop in times of rapid transition

But superior technologies tend to keep growing regardless

Two revolutions, two bubbles, two continued technology trends

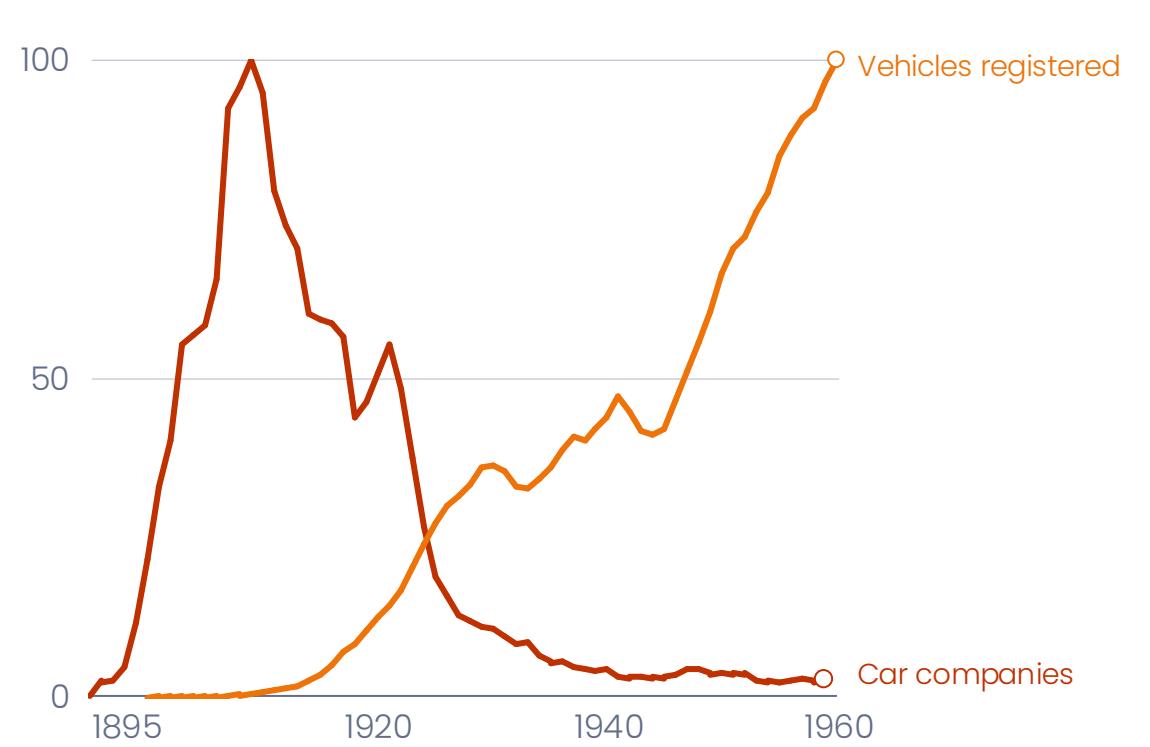
The dotcom crash

United States, 1995–2005, 100 = peak



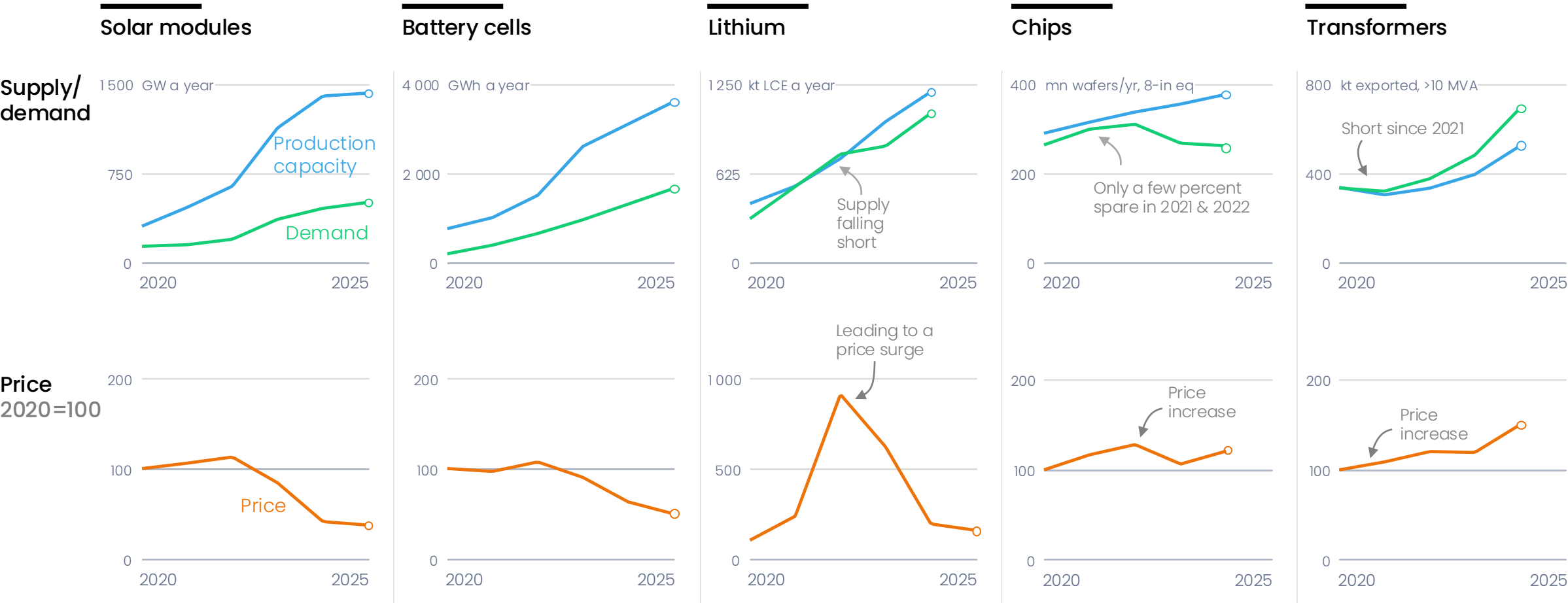
The car shakeout

United States, 1895–1960, 100 = peak



Bottlenecks are inevitable but transitory

Prices spike in those parts of the supply chain that don't build ahead of the demand surge



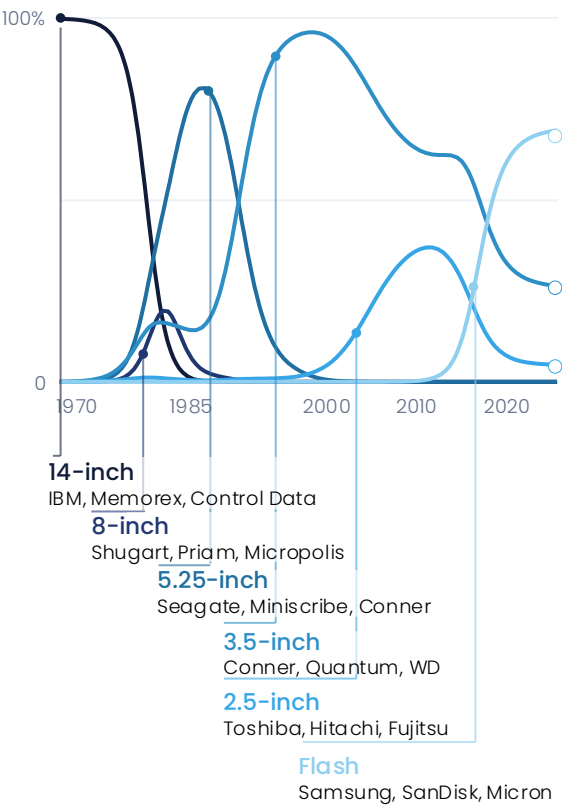
Revolutions also devour their own children

Every generation is won by new firms – today’s behemoths can always be tomorrow’s bankruptcies

Infotech

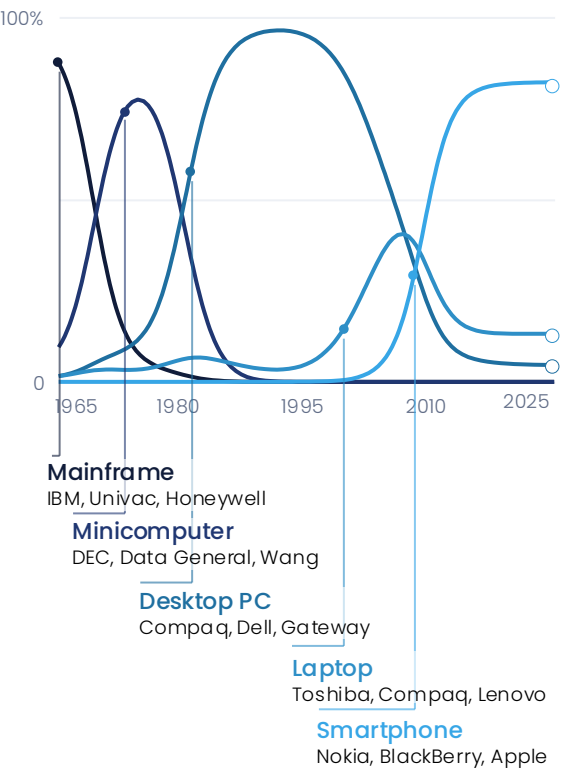
Hard-disk drives

by form factor · % of drives shipped



Computers

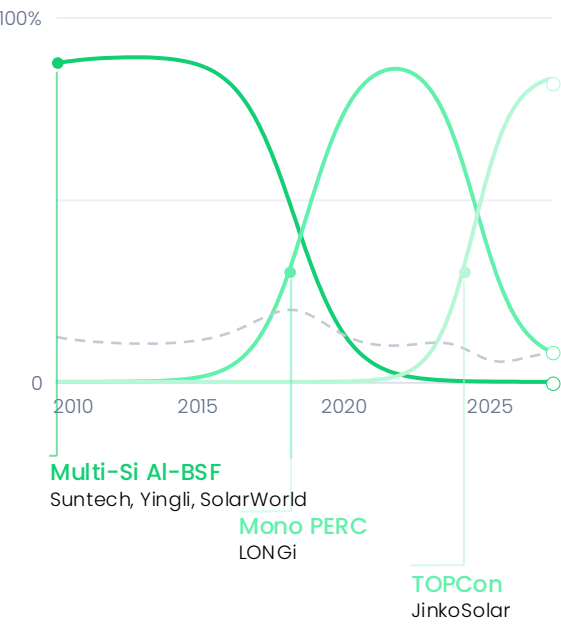
by category · % of units shipped



Electrotech

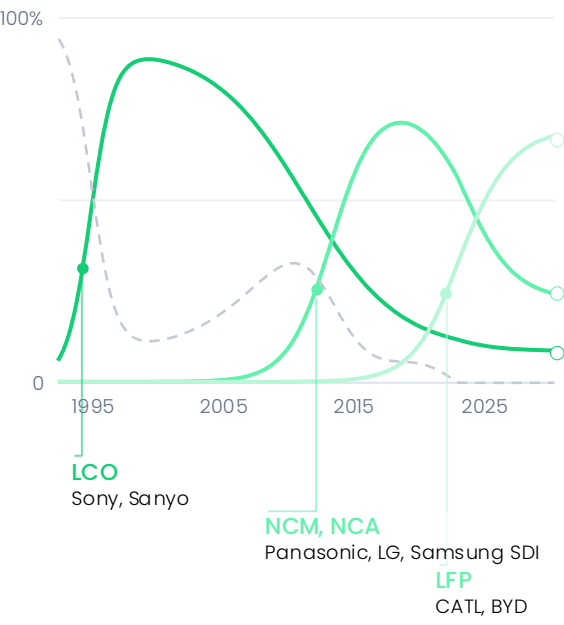
Solar cells

by architecture · % of cell production



Lithium-ion cells

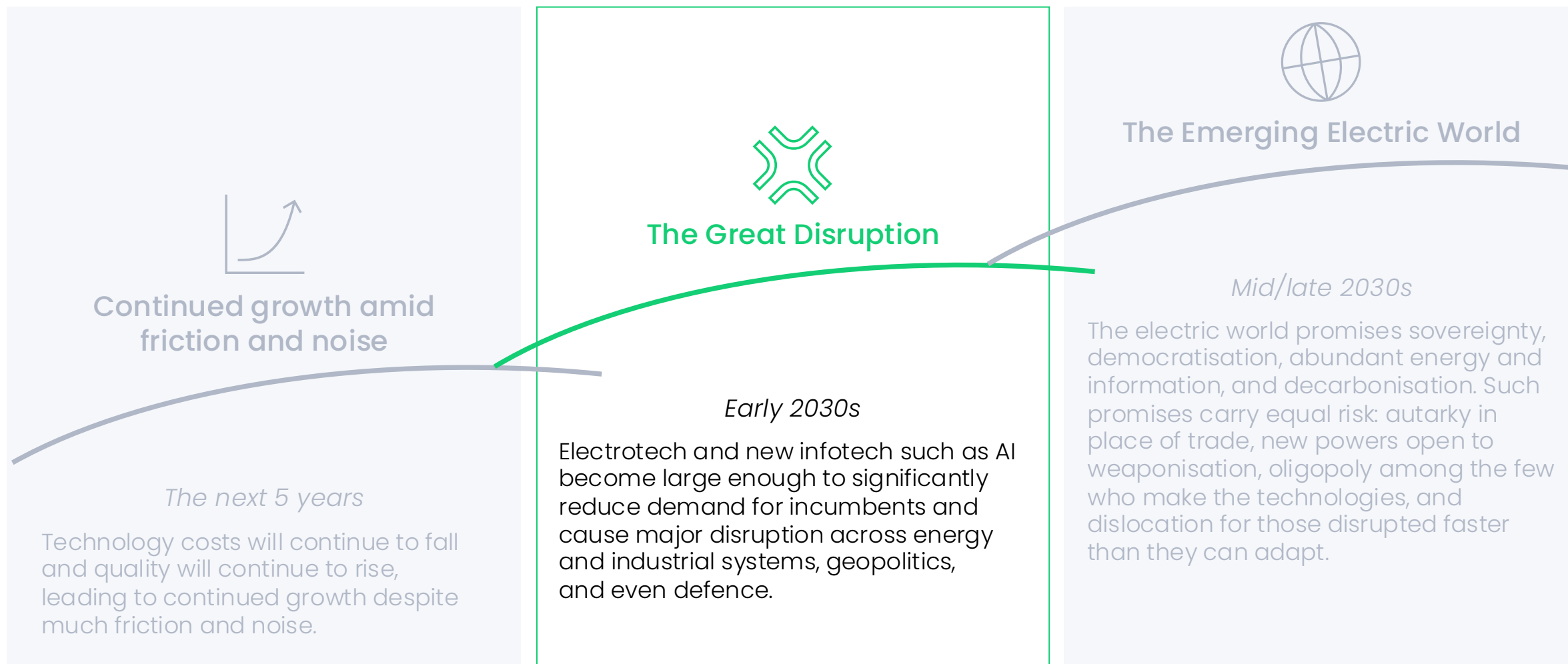
by chemistry · % of cells made



INDICATIVE

The shape of things to come

The implications of the two revolutions across three time horizons

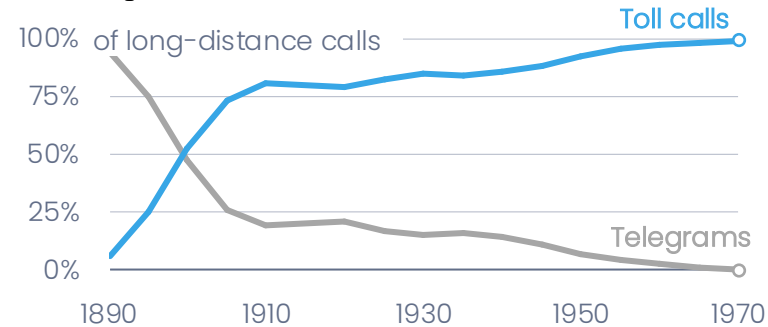


In with the new, out with the old

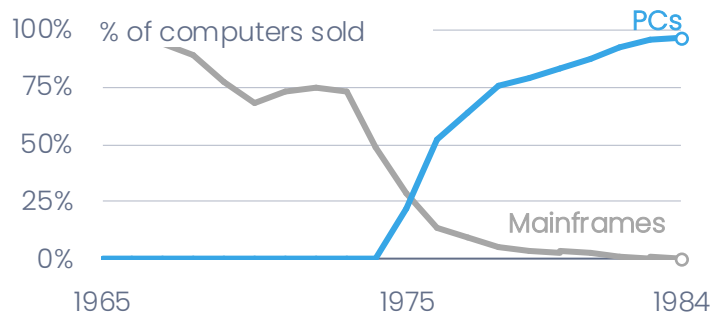
Throughout history, as the new renders the old obsolete, the old can lose market share rapidly

Information

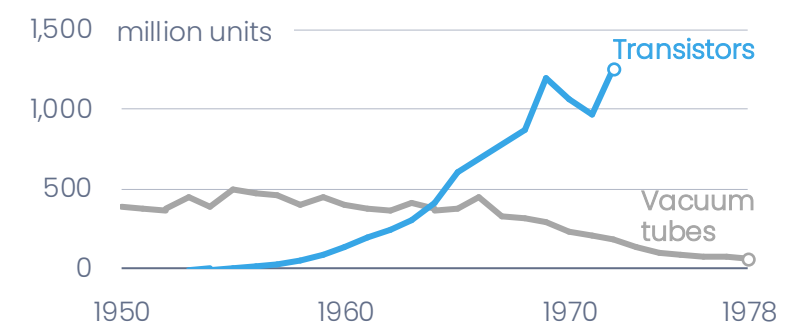
Messages



Computers

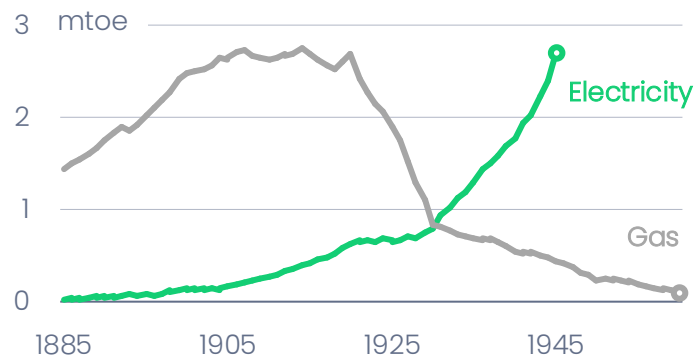


Electronics

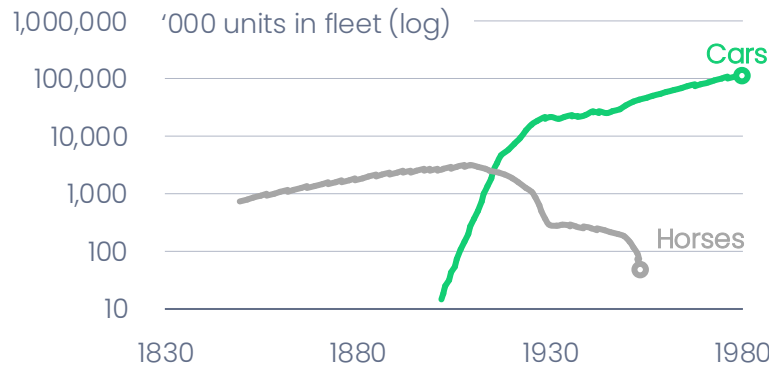


Energy

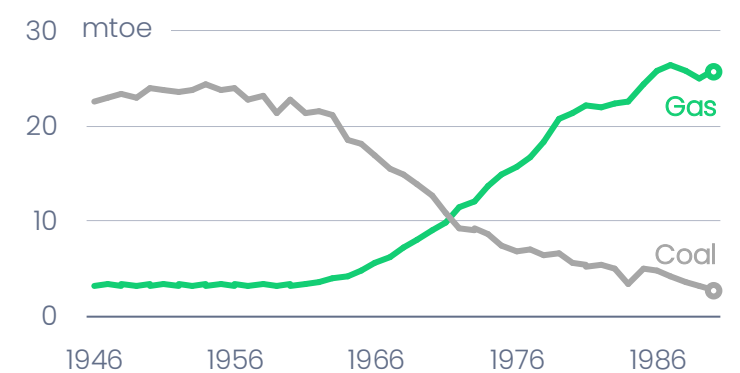
Lighting: Gas to electricity



Land transport: Horses to cars

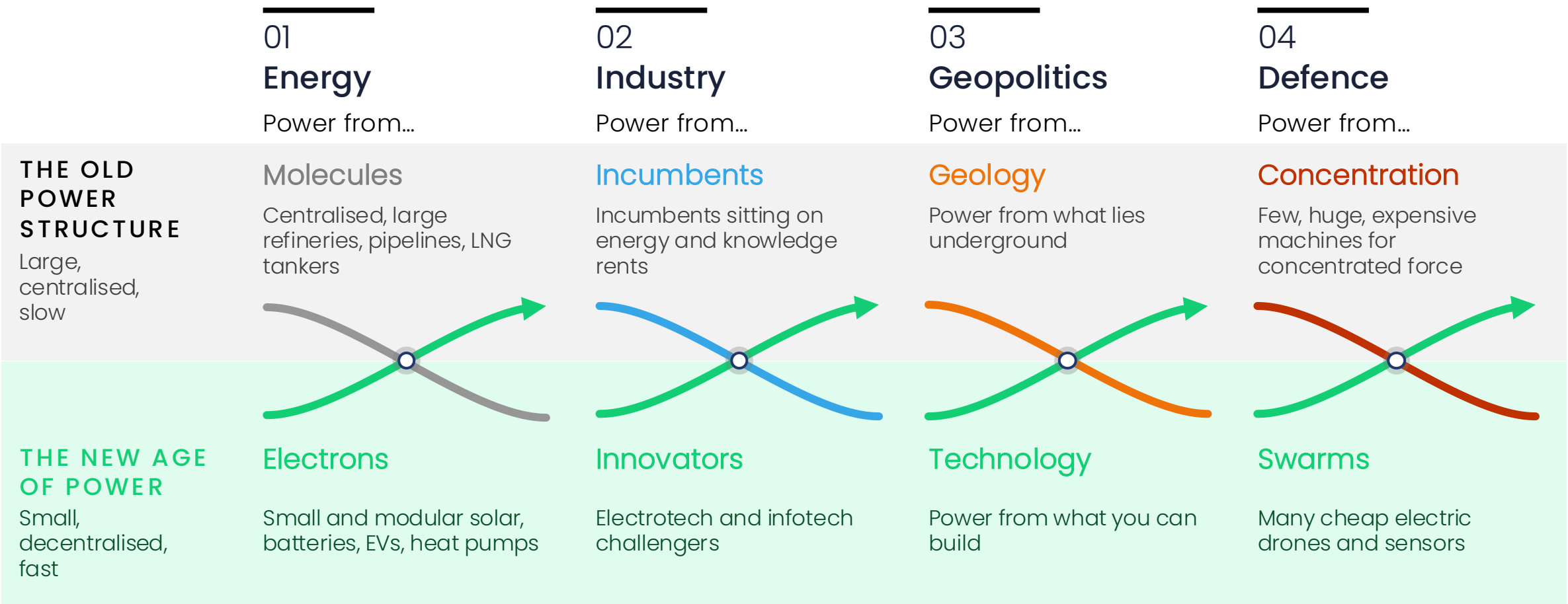


Heat: Coal to gas



Four disruptions will reshape global power

The old order of slow, centralised power gets disrupted by small, fast, decentralised technologies



Fossil decline has started to set in across the world

As electrotech scales, fossil fuel demand has peaked in large parts of the world

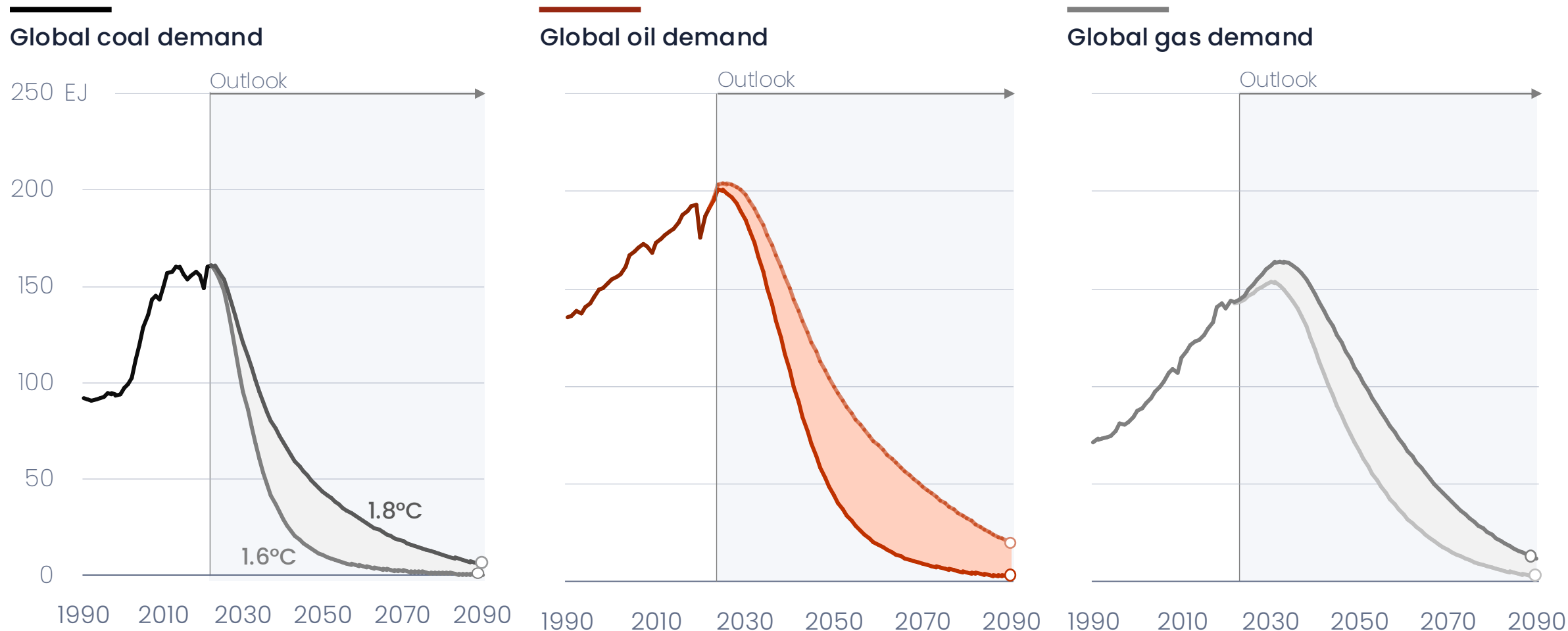
Regional fossil fuel shares, since 1990



Sources: Ember; IEA; Ember analysis. • Note: final energy excludes non-energy use. World peaks summed by country, measured by total electricity and final energy demand respectively. Other developed includes Australia, Japan, New Zealand, Singapore and South Korea.

The growth of electrotech means the decline of fossil fuels

The process is bumpy, but fossils will be in clear decline by the early 2030s

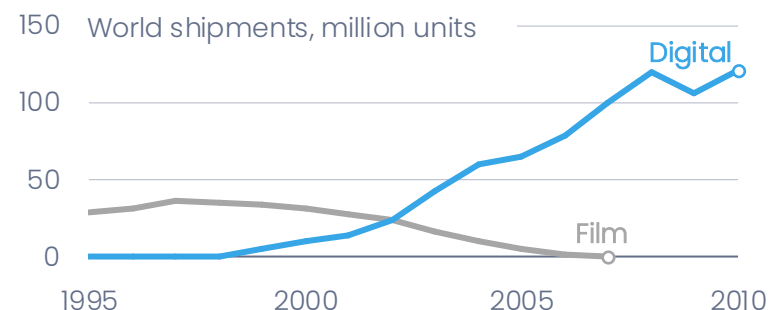


Innovative infotech and electrotech are already displacing incumbents

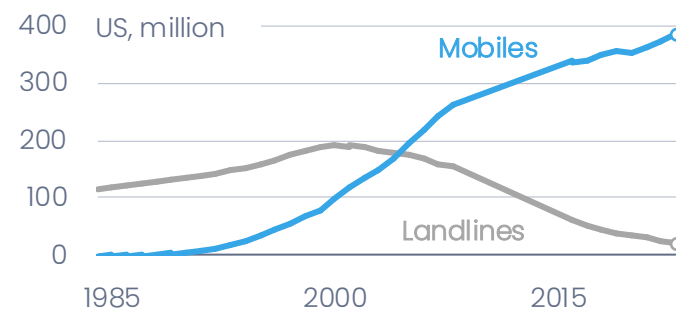
As with digital cameras and mobile phones, now with AI and electrotech

Information

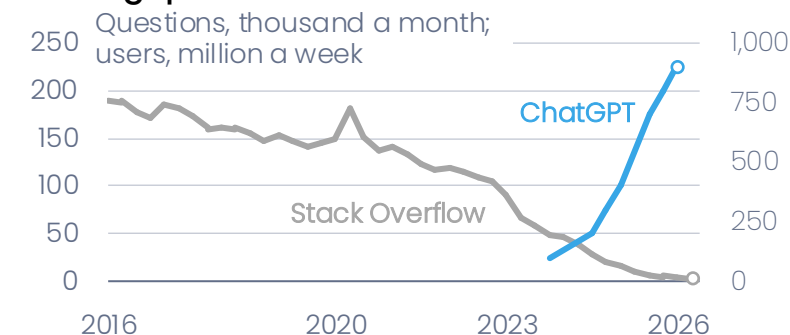
Cameras



Phones

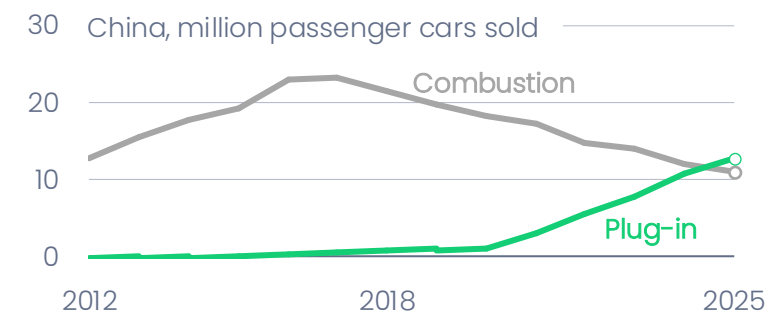


Coding questions and answers

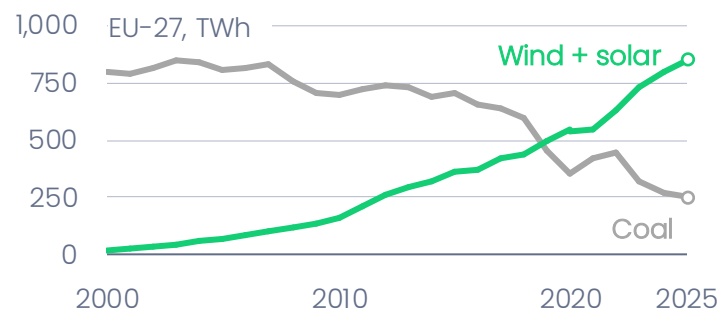


Energy

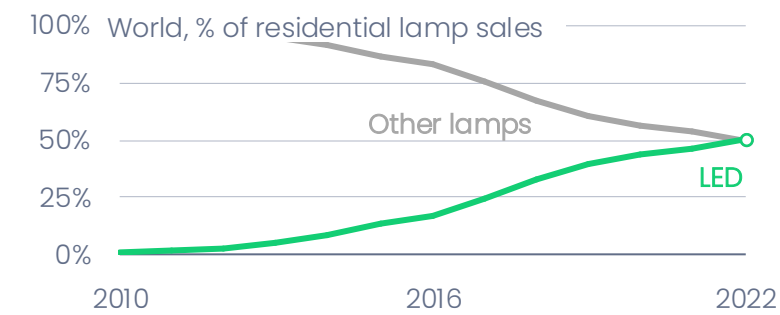
Cars



Electricity



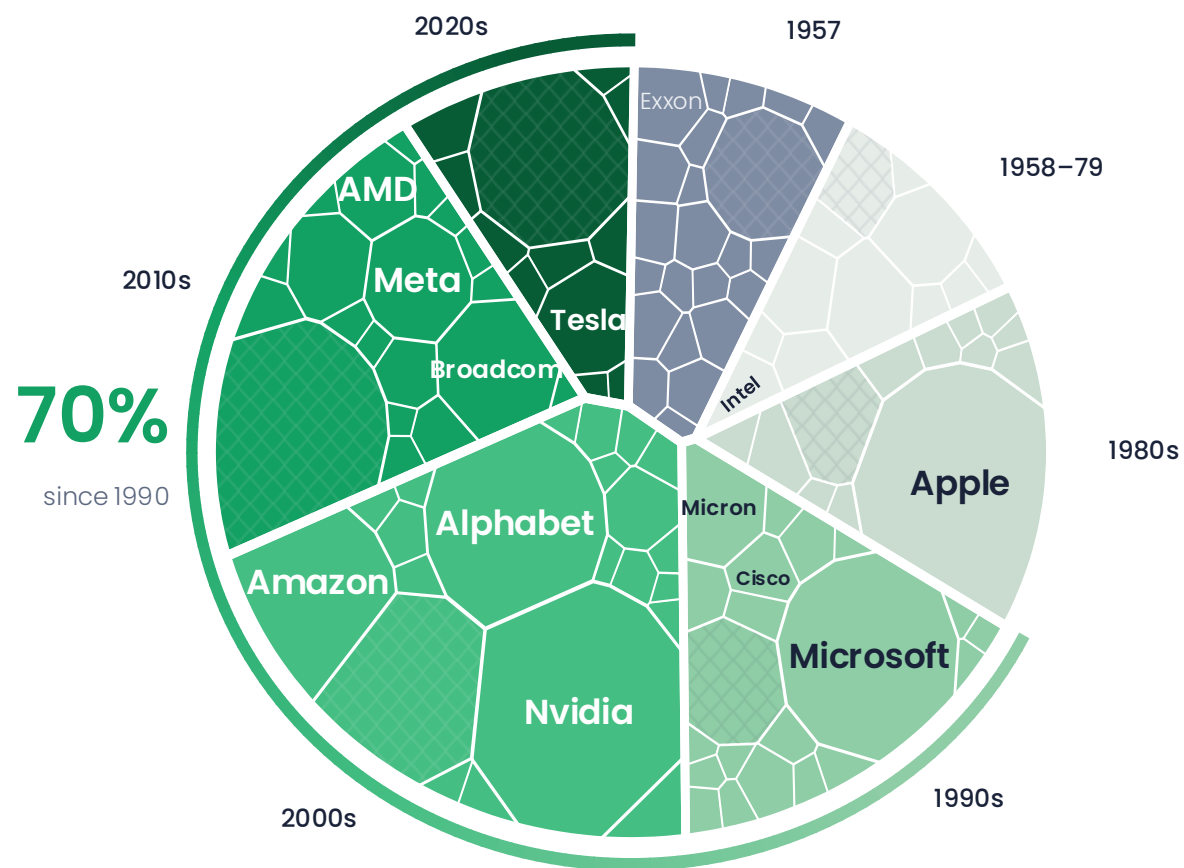
Lighting



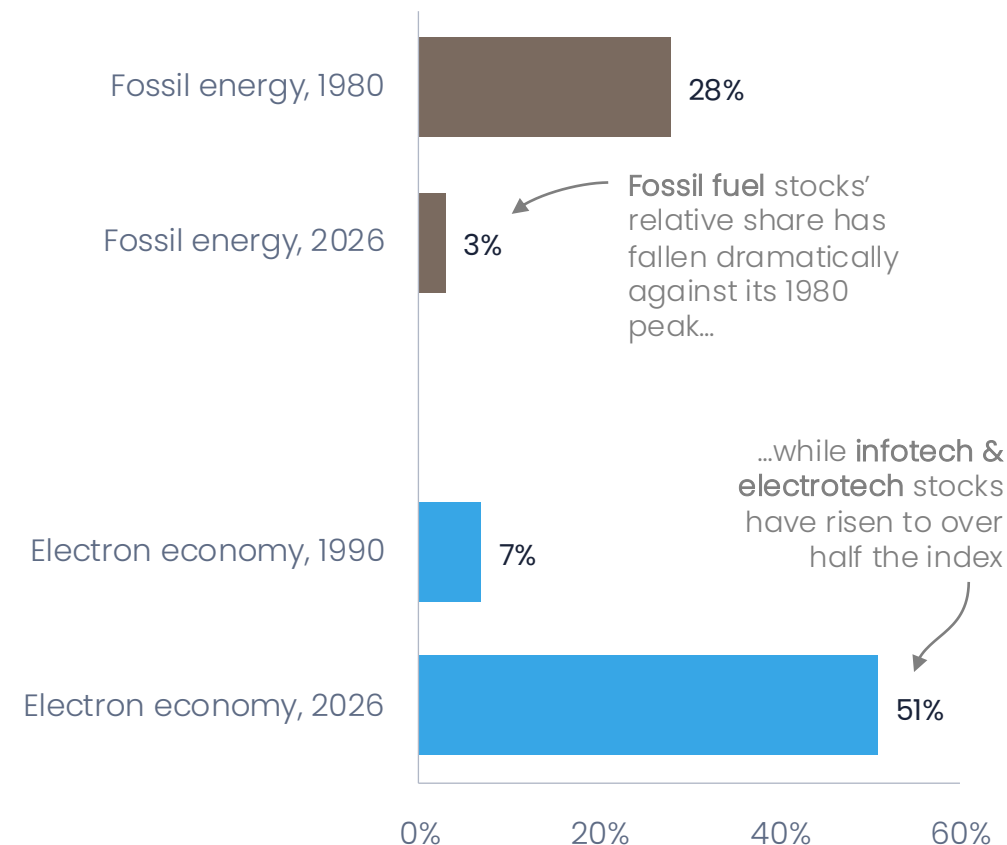
Technology revolutions drive vast new value pools

The S&P 500 is already majority infotech and electrotech companies; this will only accelerate

Share of S&P 500 by time of joining



Share of index market value

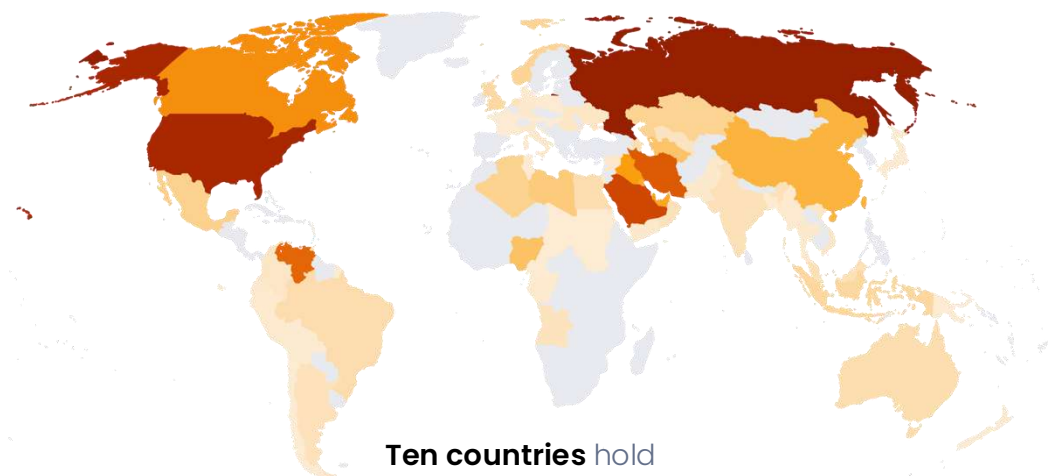


Electrotech will curb the power of the petrostates

Ten countries hold three-quarters of the oil and gas; nearly every country has enough sun and wind

Geology concentrates power

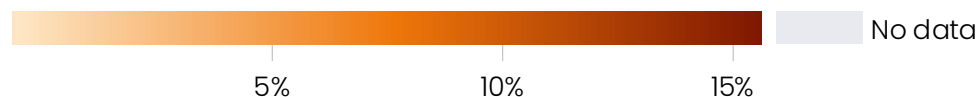
Oil and gas ever extracted plus proved reserves, % of world



Ten countries hold

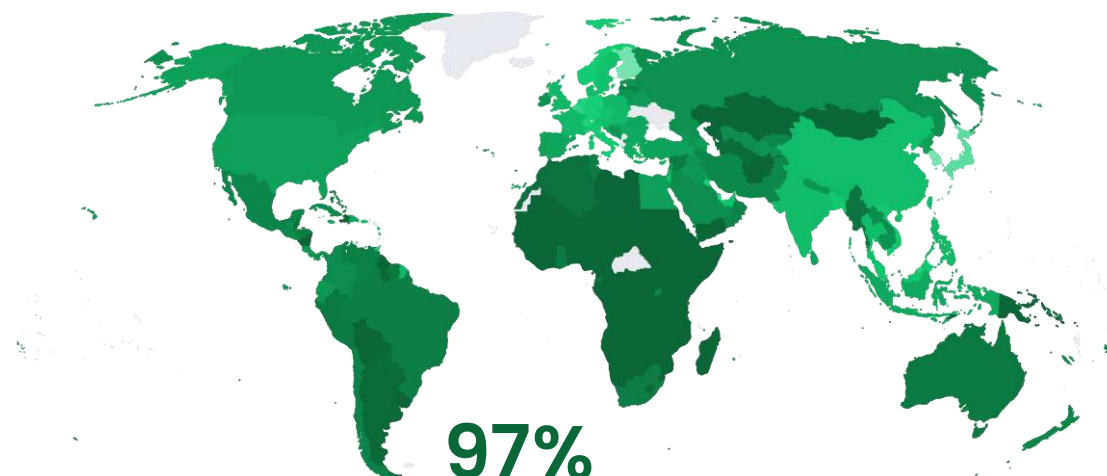
73%

of all the oil and gas
ever found



Electrotech spreads it

Domestic wind and solar potential as a multiple of electricity demand, log scale



97%

of the world's people

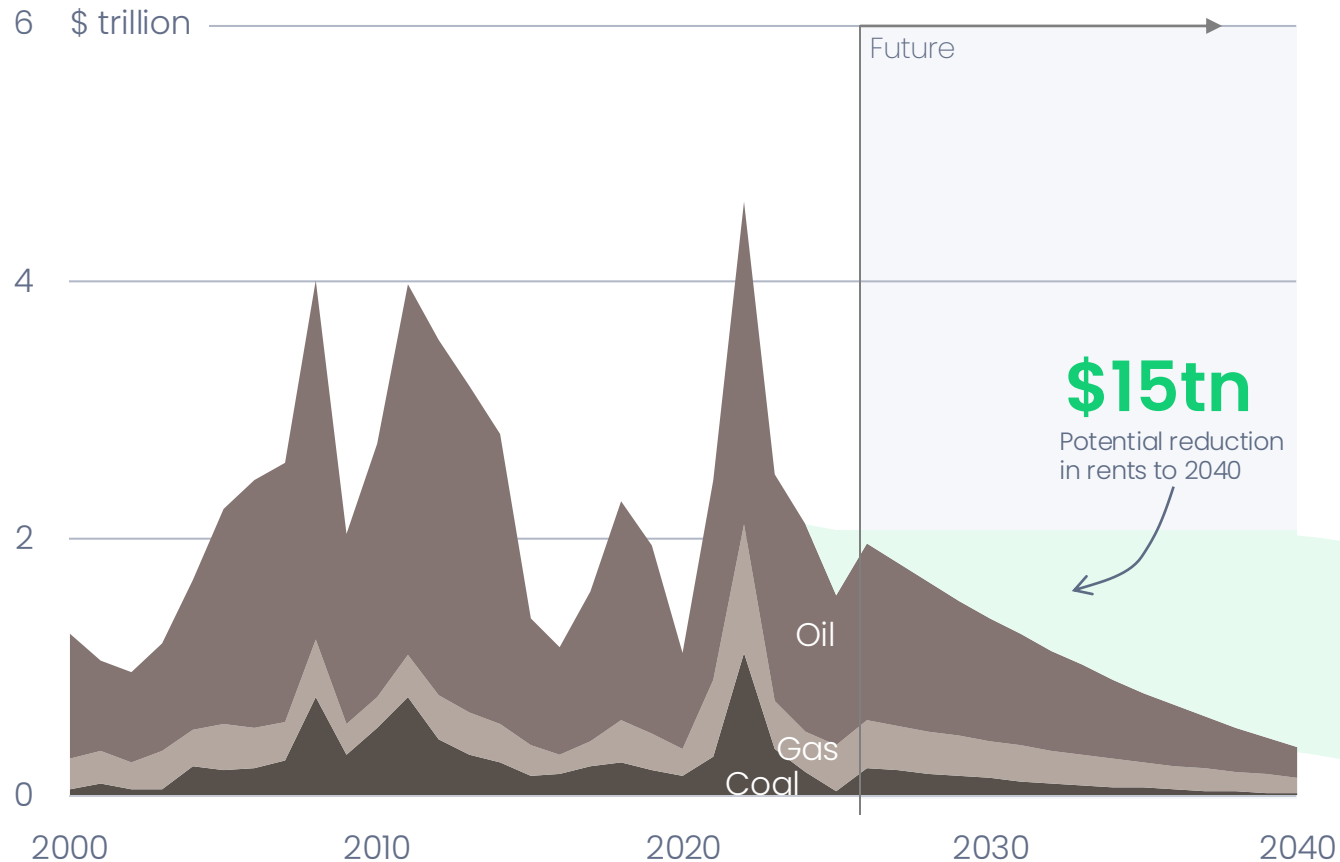
live in a country with solar and wind
potential of over ten times its current
electricity demand



Fossil rents will be redistributed

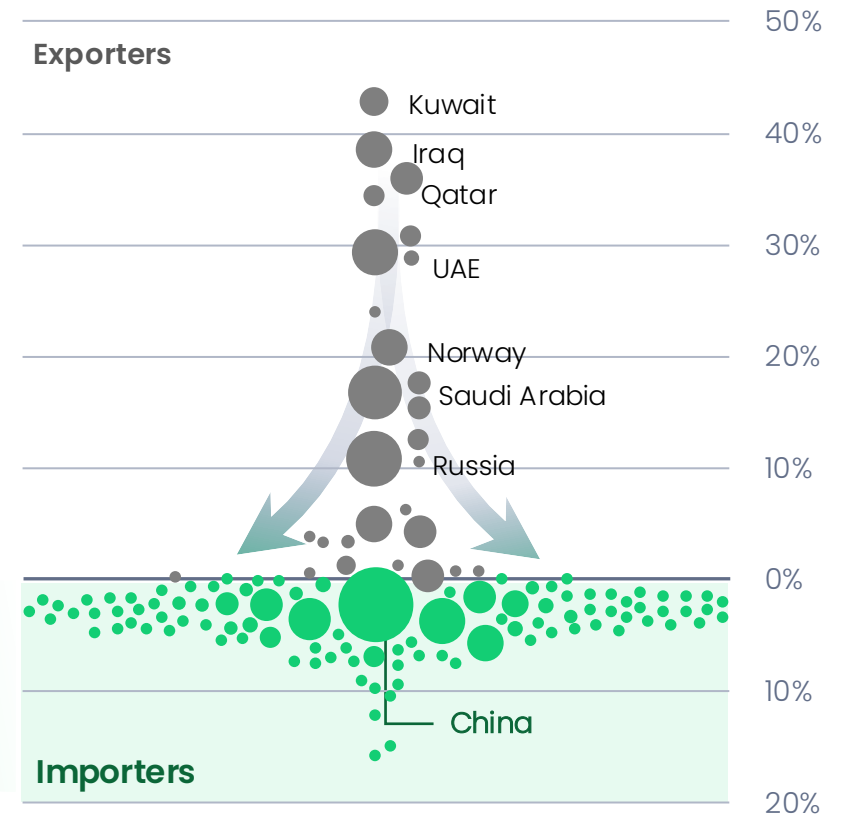
Up to \$15 trillion could shift from producers to consumers by 2040

World fossil fuel rents



Today's exporters and importers

Net fossil trade, % of GDP, 2024; marker area = \$bn

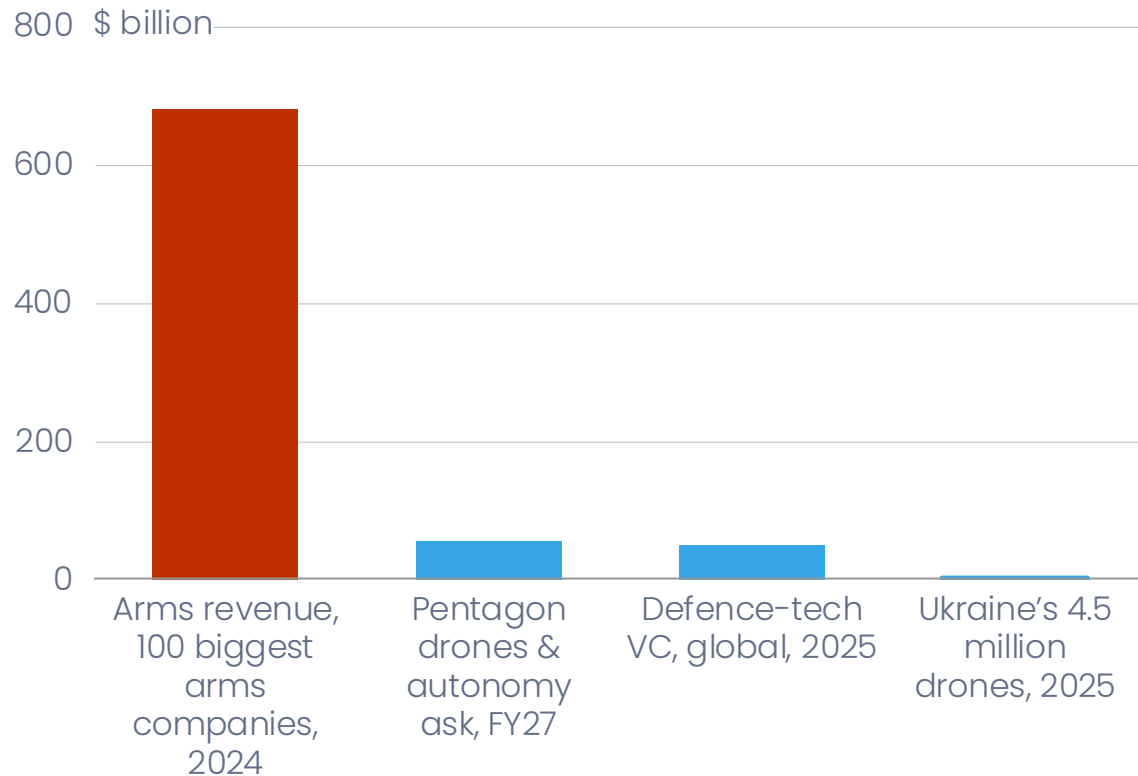


The next stranded assets are defence assets

Expensive large equipment is losing against small cheaper electric defence tech

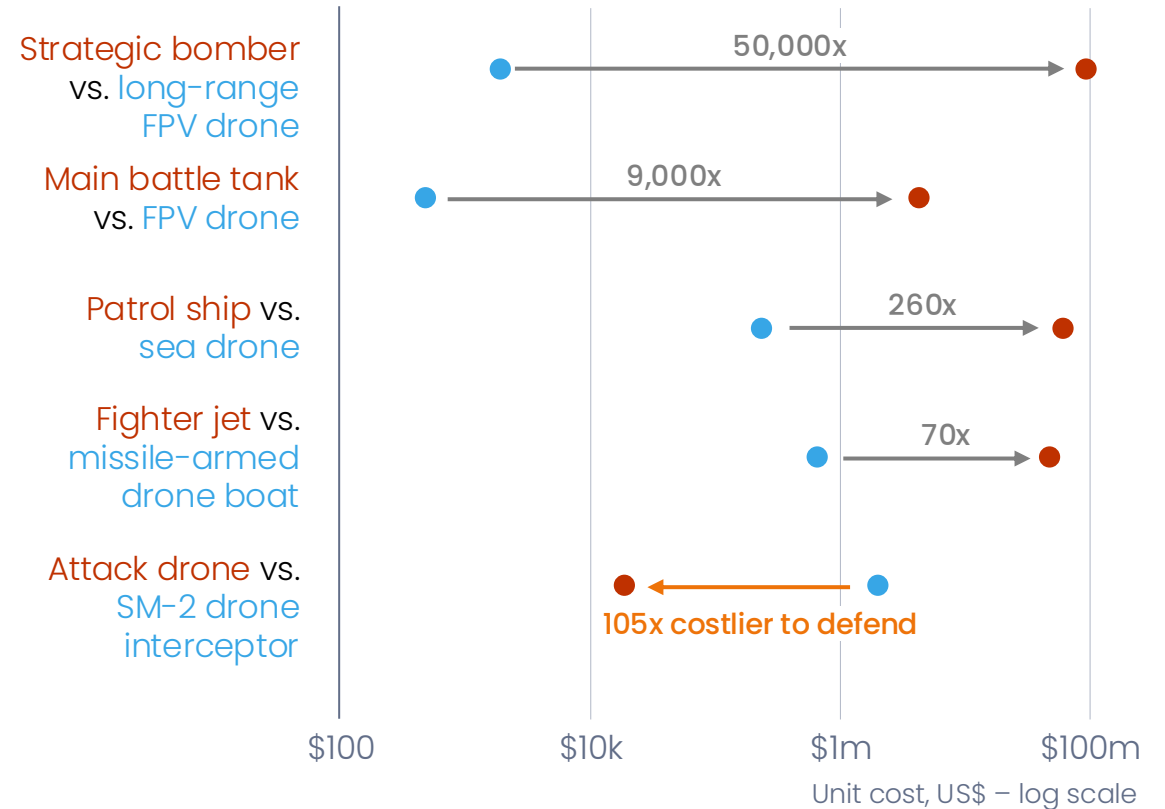
Defence money: the old guard dwarfs the challengers

Annual arms industry revenue vs spending on drones and autonomy



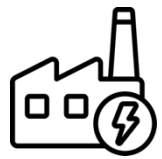
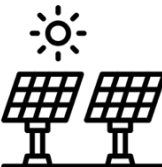
Asymmetric warfare: cheap drones, expensive targets

The cost of the **target** versus the **attacking equipment**



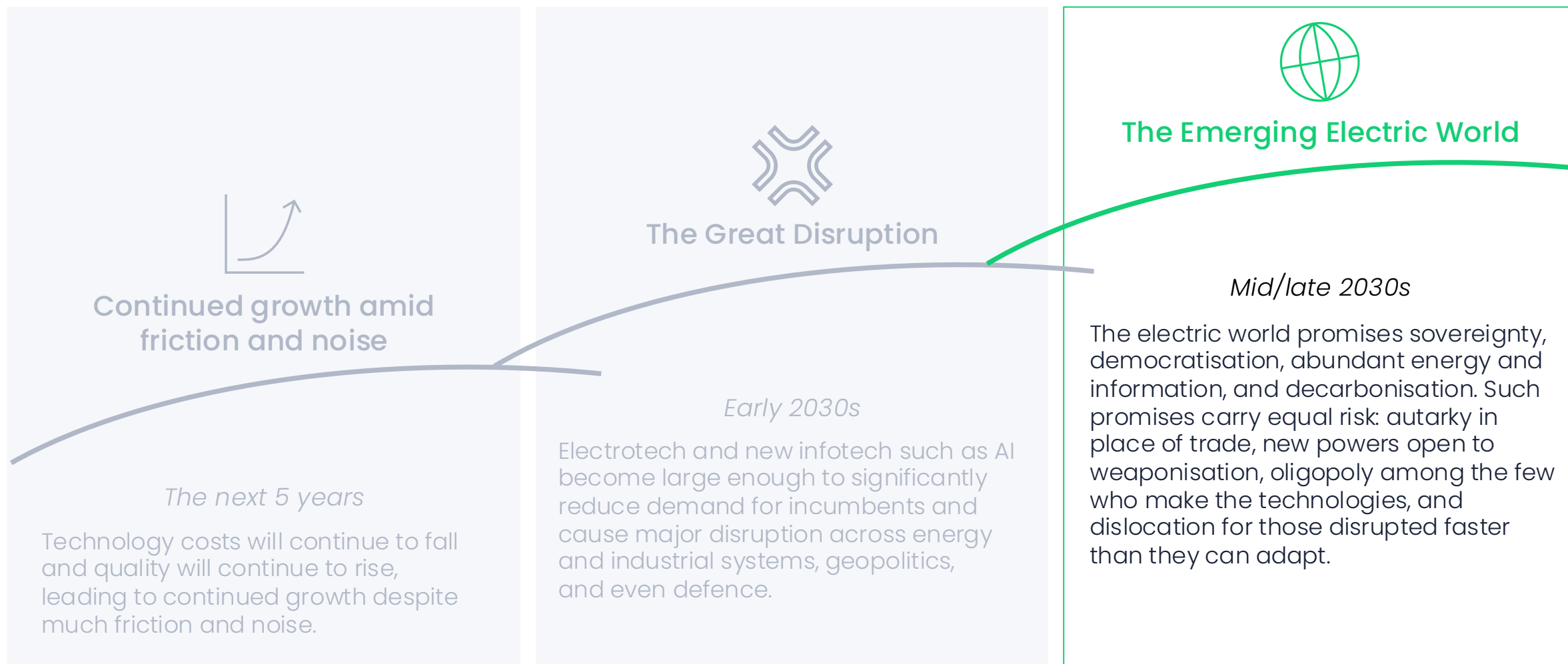
DERfence

Distributed Energy Resources (DER) better insulate energy infrastructure from modern warfare

		Cost	Energy throughput per year	Time to repair after major strike
 1 well-aimed attack drone of \$500-\$5k can take offline...	 1 refinery	\$7bn	150 TWh/y	6-18 months
	or			
	 1 gas power plant, 600 MW	\$600mn	3 TWh/y	12-36 months
	or			
	 1 solar farm, 20 MW	\$30mn	42 GWh/y	1-6 months
	or			
	 1 DER solar system	\$5k	5 MWh/y	<1 month

The shape of things to come

The implications of the two revolutions across three time horizons

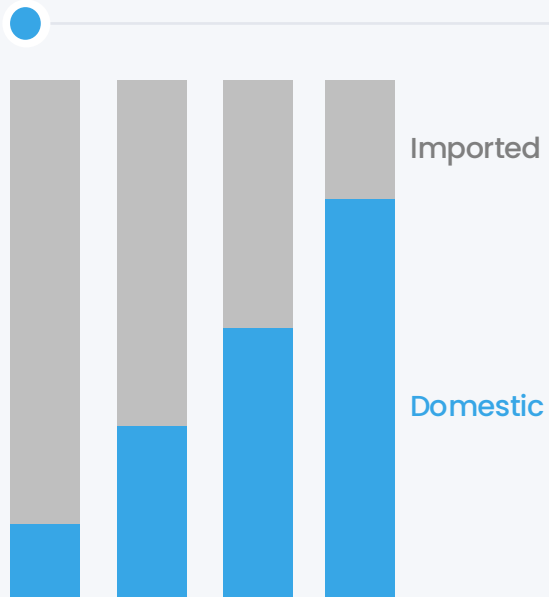


The four promises of infotech and electrotech

01

Sovereignty

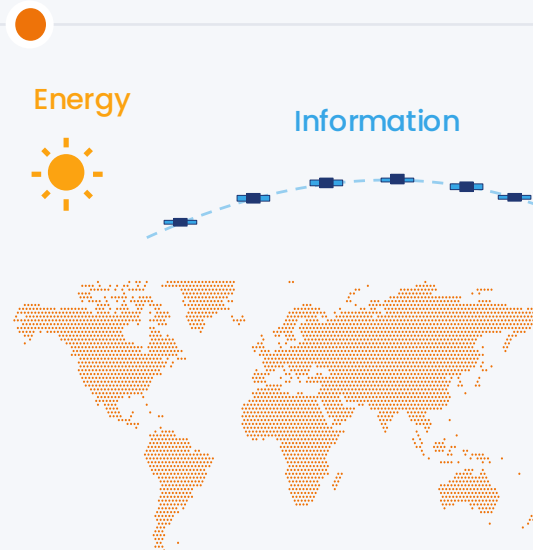
Domestically run information and energy systems



02

Democratisation

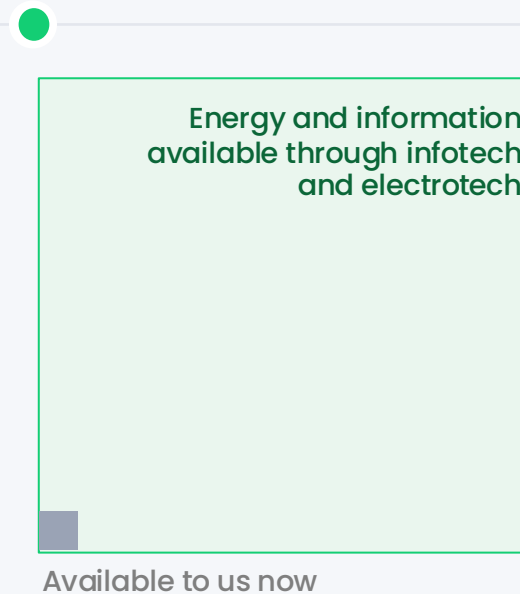
Energy on your roof, intelligence in your pocket



03

Abundance

Access to orders of magnitude more energy and information



04

Decarbonisation

Fast decline in global emissions and a stable climate

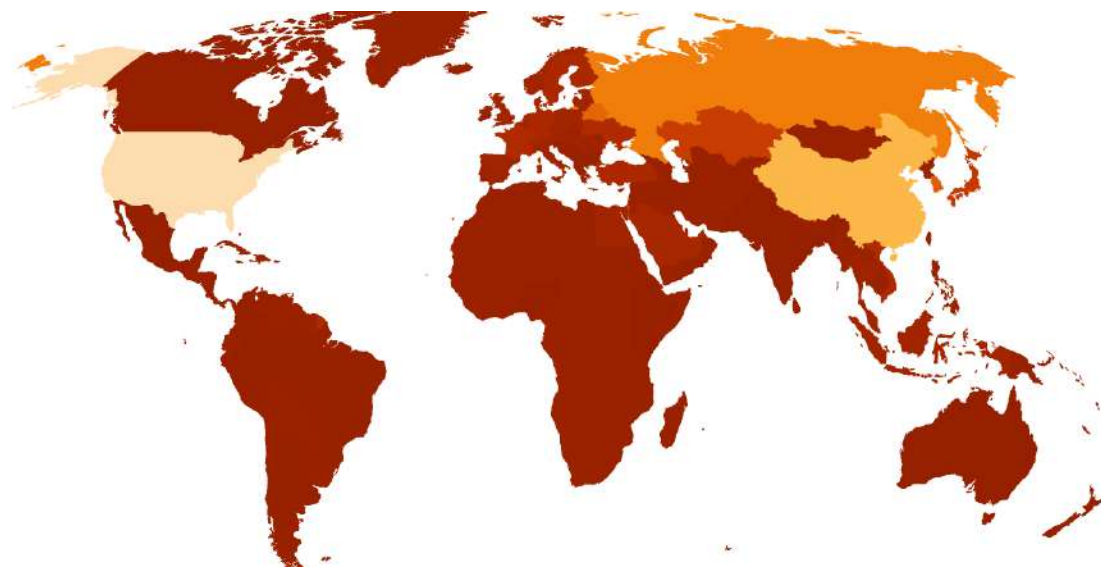


We live in a world of centralised dependence

Most of the world runs on foreign clouds and imported energy – sovereignty in both is rare

Foreign cloud dependence

Cloud infrastructure run on foreign providers, %



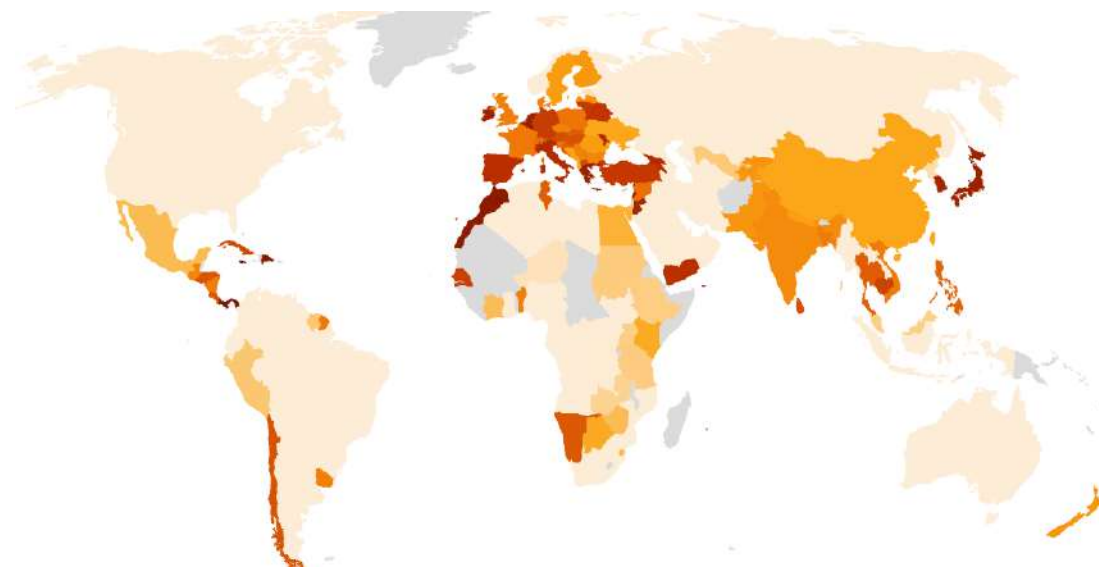
78% of the world's people live in countries more than 20% reliant on foreign clouds

Dependence, %

0	25	50	75	100	no data
---	----	----	----	-----	---------

Energy import dependence

Net energy imports, % of total energy supply



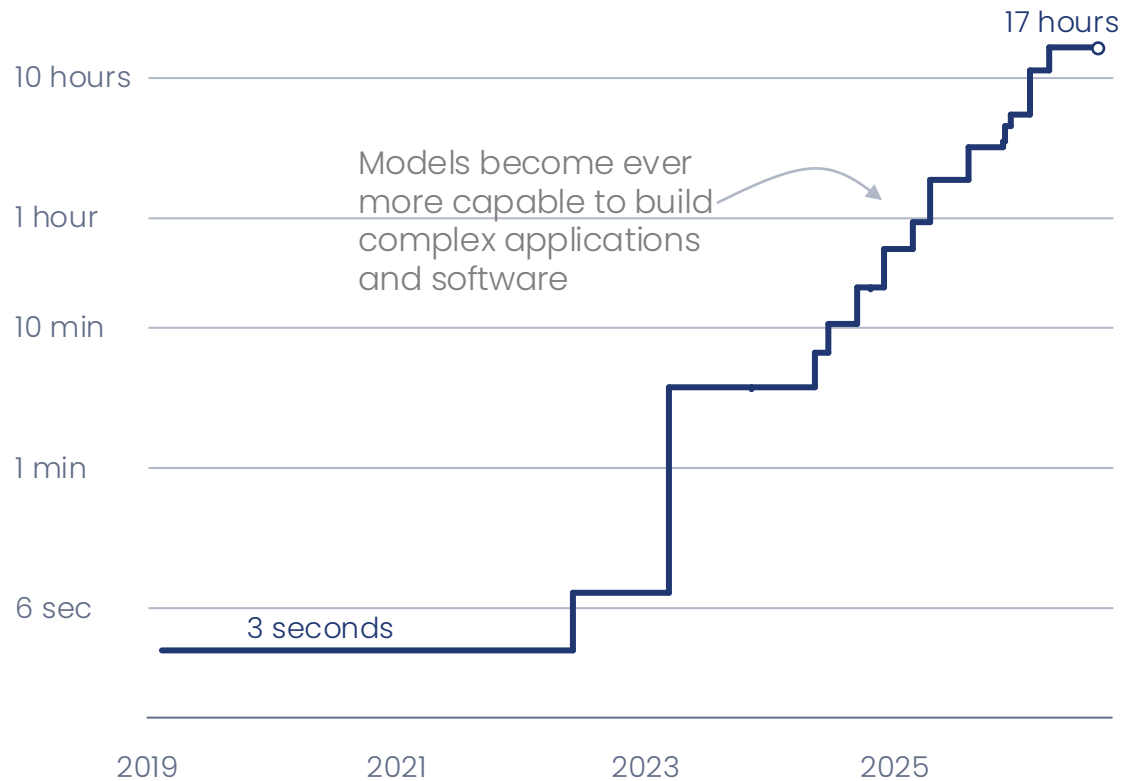
71% of the world's people live in countries that are net energy importers

AI lowers the barrier to building sovereign software

Powerful AI weakens software monopolies. Open-weight AI weakens AI monopolies too

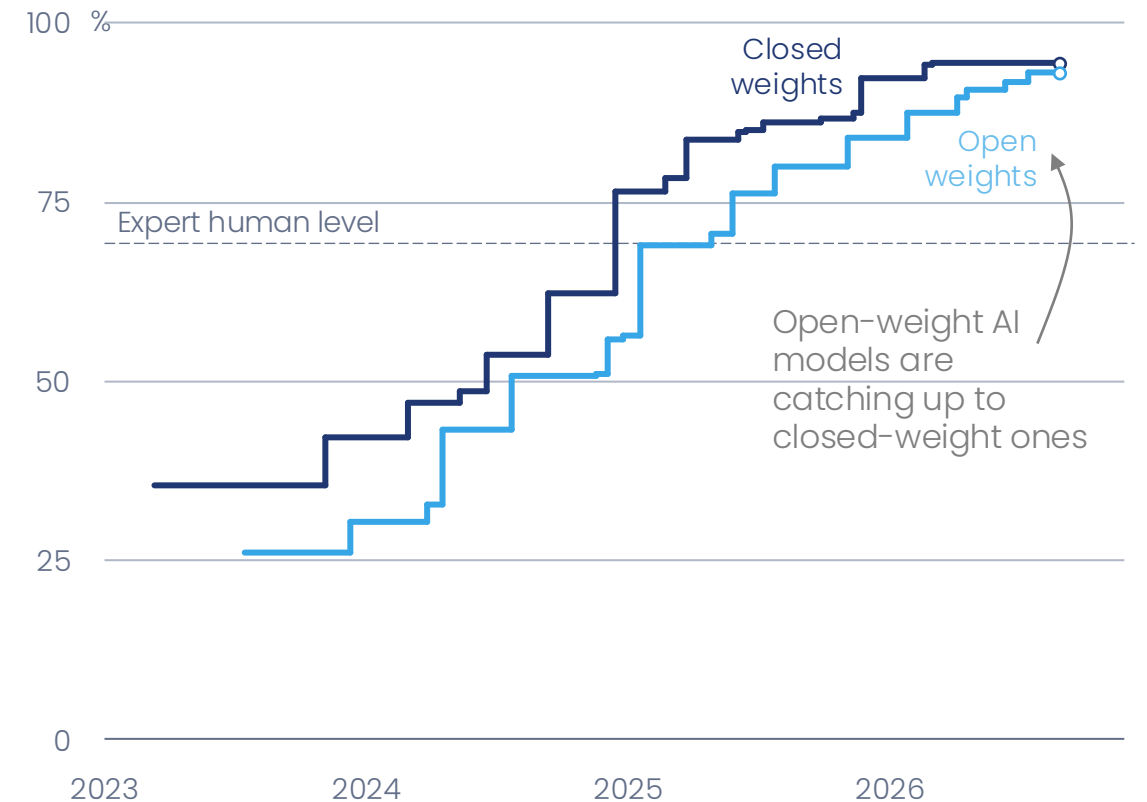
Length of software task AI completes unaided

Human work time per task, 50% success rate, log scale



AI model capability

% of expert-level science questions answered correctly



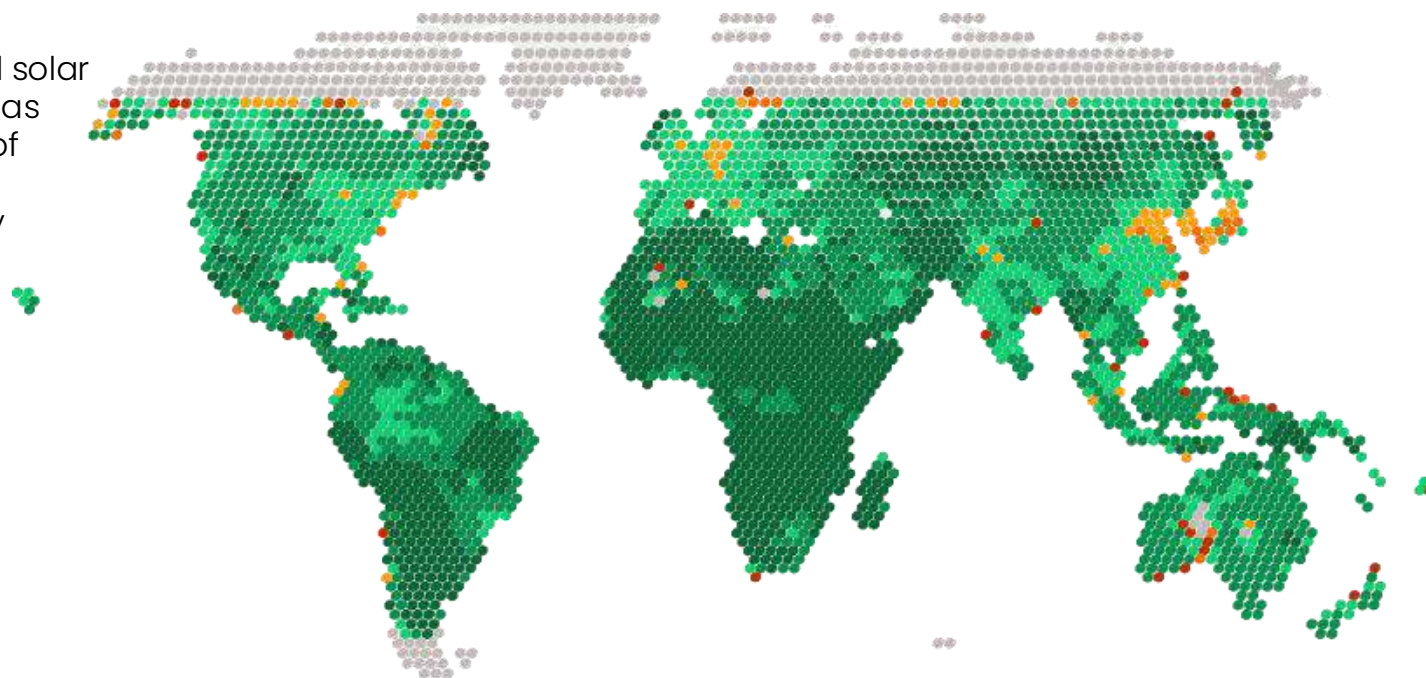
Every region in the world can be energy independent with electrotech

Domestic renewable energy is abundant, and most of the economy can be electrified to run on it

Renewable resources as a multiple of current electricity demand

Supply

Wind and solar potential as multiple of current electricity demand

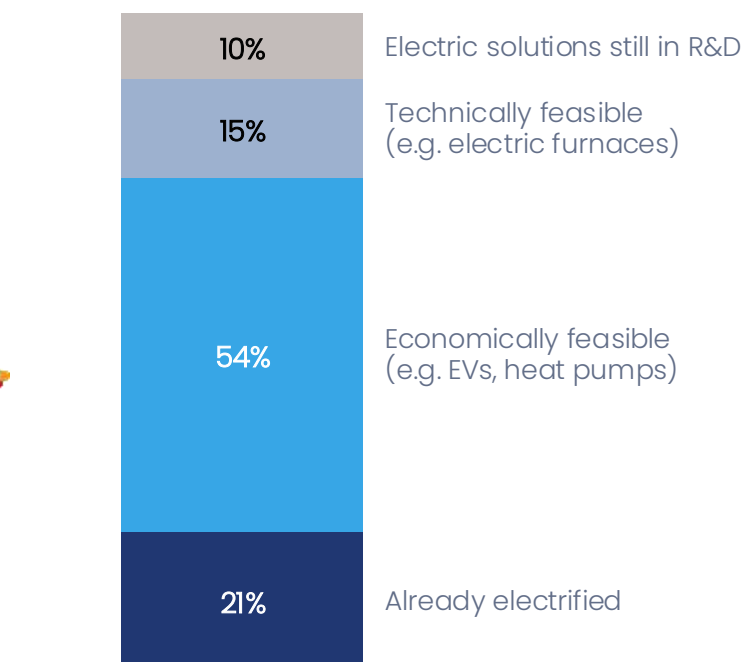


Multiple

■ <1x
 ■ 1-3x
 ■ 3-10x
 ■ 10-100x
 ■ 100-1000x
 ■ >1000x
 ■ No data

Demand

Share of world final energy, 2025

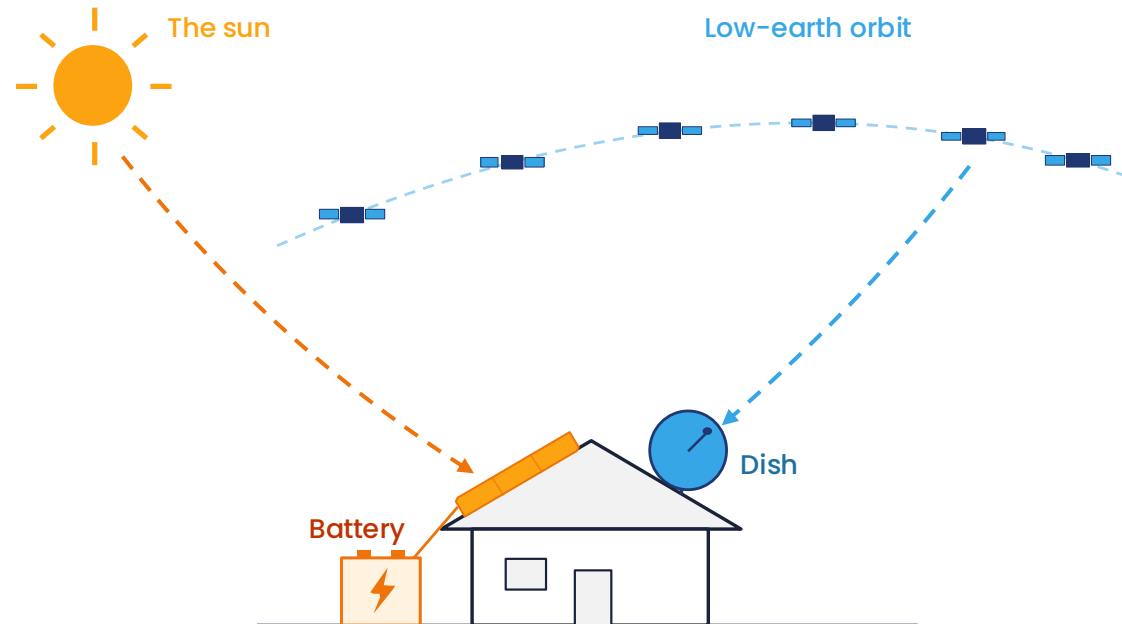


Energy and information will become ubiquitous

Electricity from the sun and data from orbit

Both fall from the sky

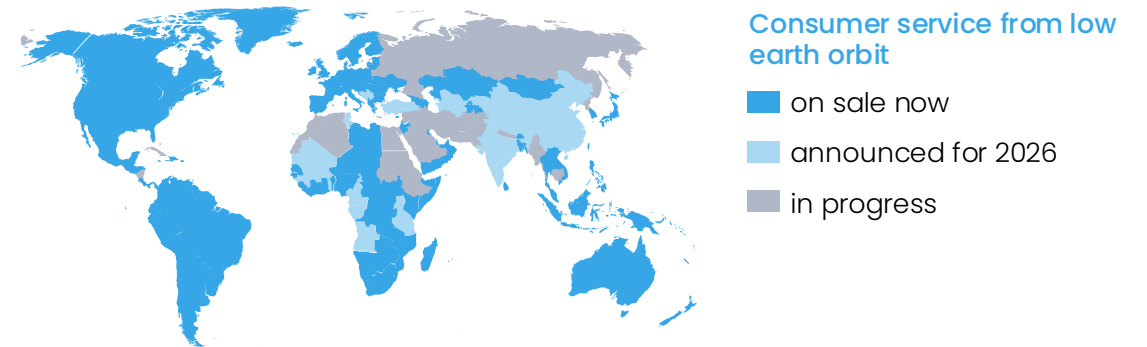
Sunlight to a panel and battery; low orbit to a dish and terminal



Solar irradiation



Satellite broadband availability



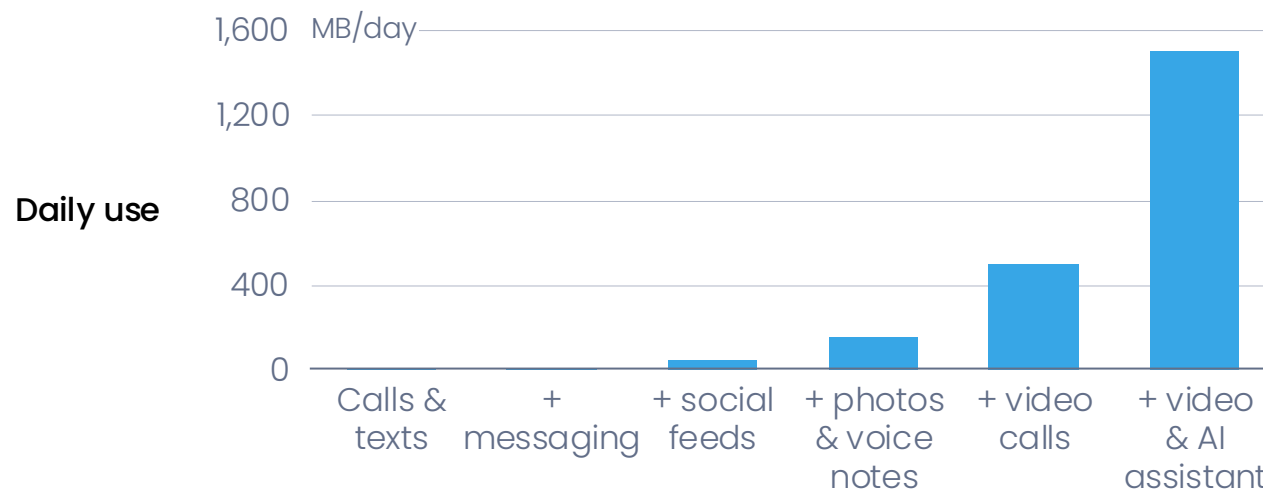
Emerging markets have a new development tool

Small and modular technology allows for development steps within reach through savings or pay-as-you-go

Information ladder

each square is 1 GB a month

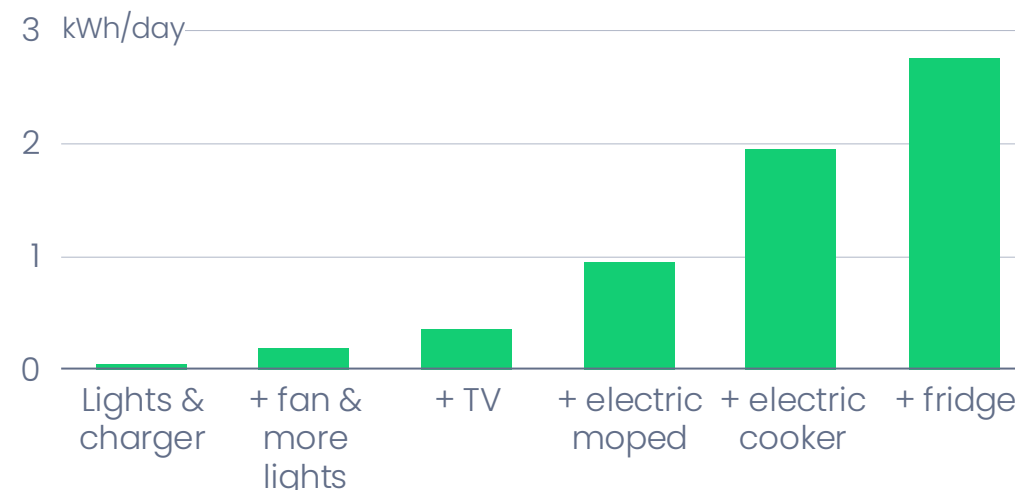
Purchased	Phone						
Network	2G	3G	3G	4G	4G	4G	4G
Data							
Cost per rung	+\$40	+\$1	+\$6	+\$20	+\$60	+\$180	+\$180



Electricity ladder

each panel 100 W, each cell 250 Wh

Solar						
Battery						
	+\$20	+\$50	+\$50	+\$80	+\$160	+\$180

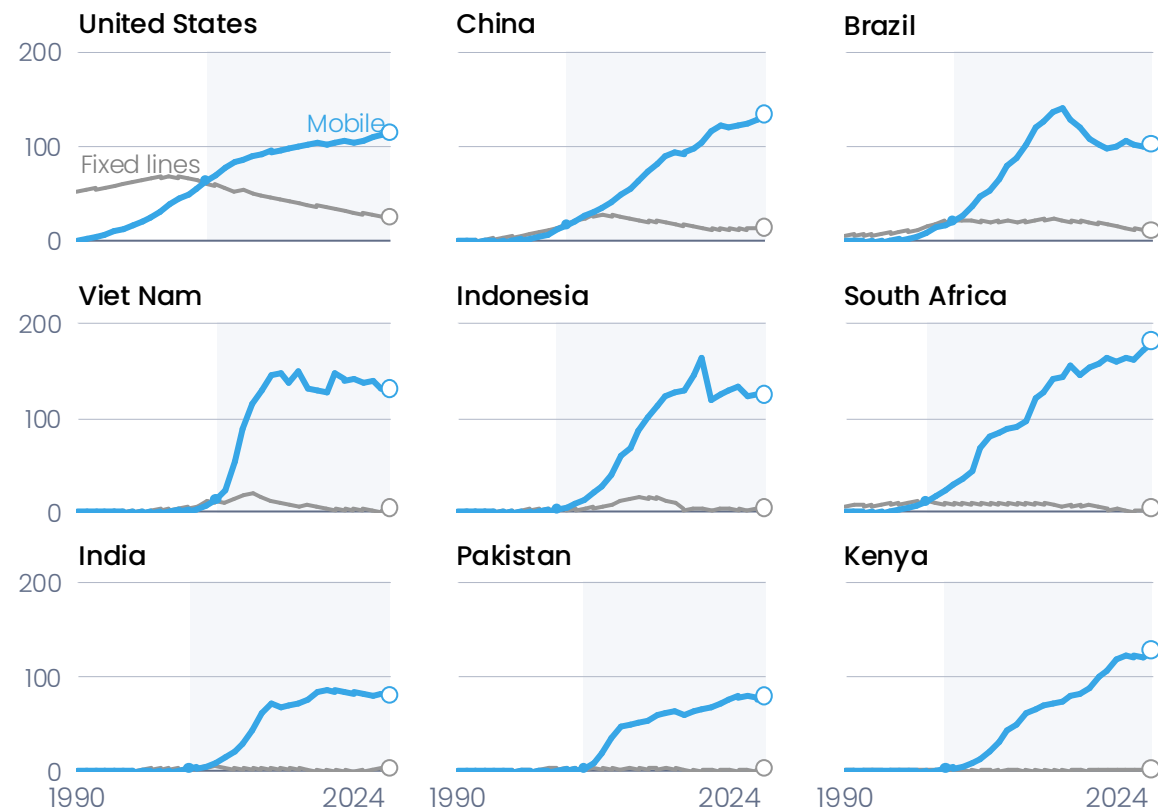


So emerging markets can leapfrog direct to better solutions

As with mobile phones, so with solar

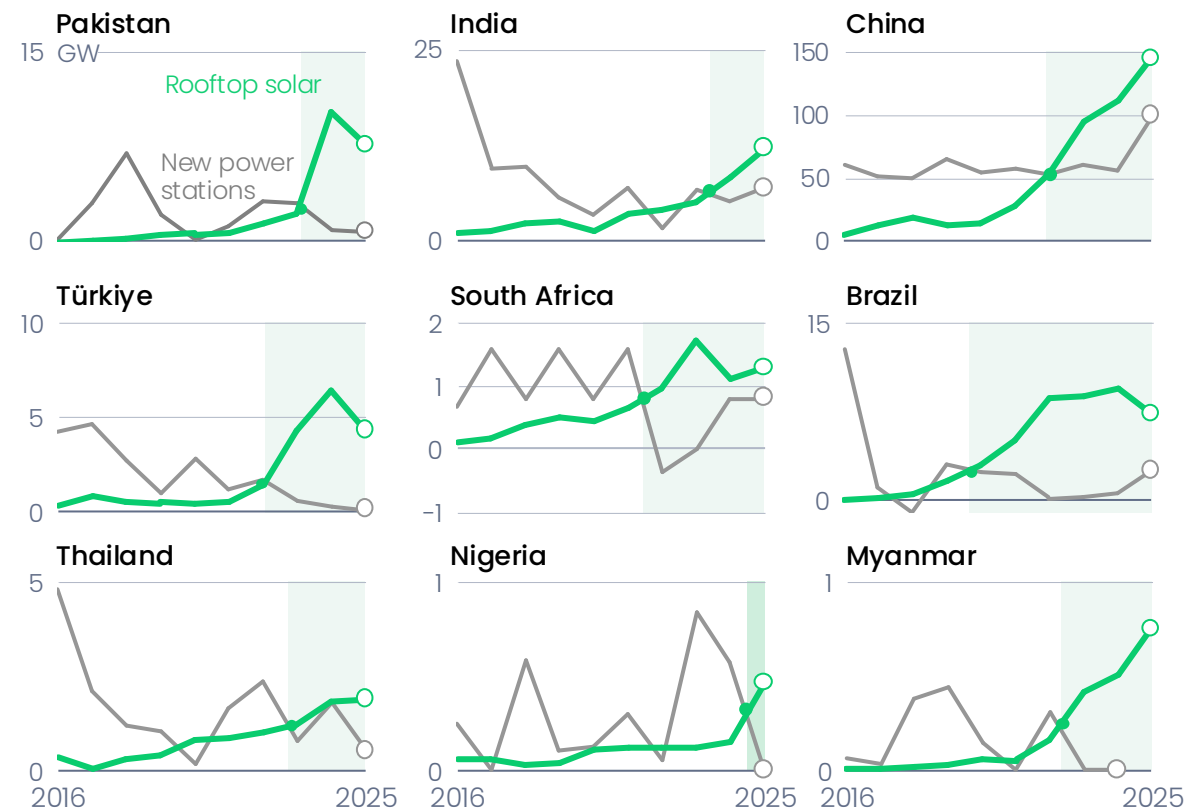
Mobile overtakes fixed lines

Subscriptions per 100 people



Rooftops overtake power stations in what gets built

Net GW added each year

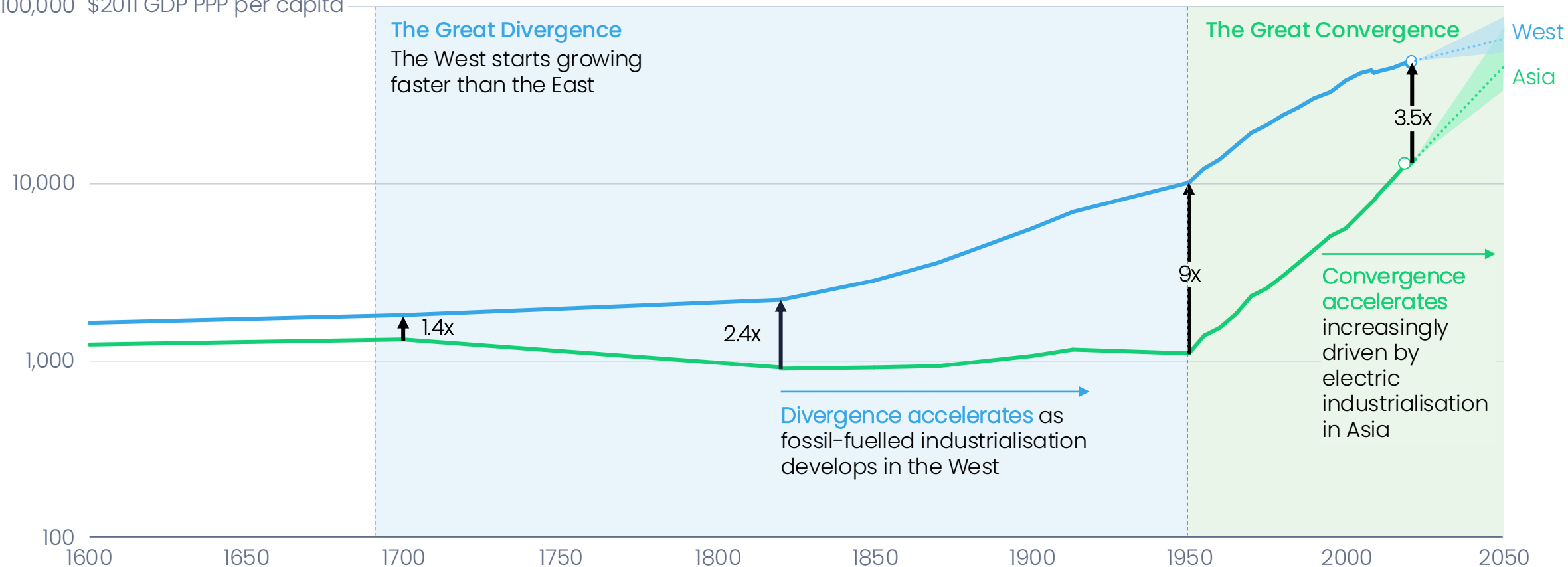


The dual revolution accelerates the Great Convergence

Fossil fuels drove the West's divergence; electrotech and infotech help drive Asia's convergence

GDP per capita, the West versus Asia, 1600–2050

100,000 \$2011 GDP PPP per capita



Infotech and electrotech open up new abundance

Energy and information in orders of magnitude more than the analogue, fossil system

ILLUSTRATIVE

Information

Primary information available per person

The analogue,
fossil system

Information available through newspaper
& local library, 25 gigabytes of text

The digital,
electric
system

Information on the
Internet available to all:
100 million gigabytes

Energy

Primary energy available per person

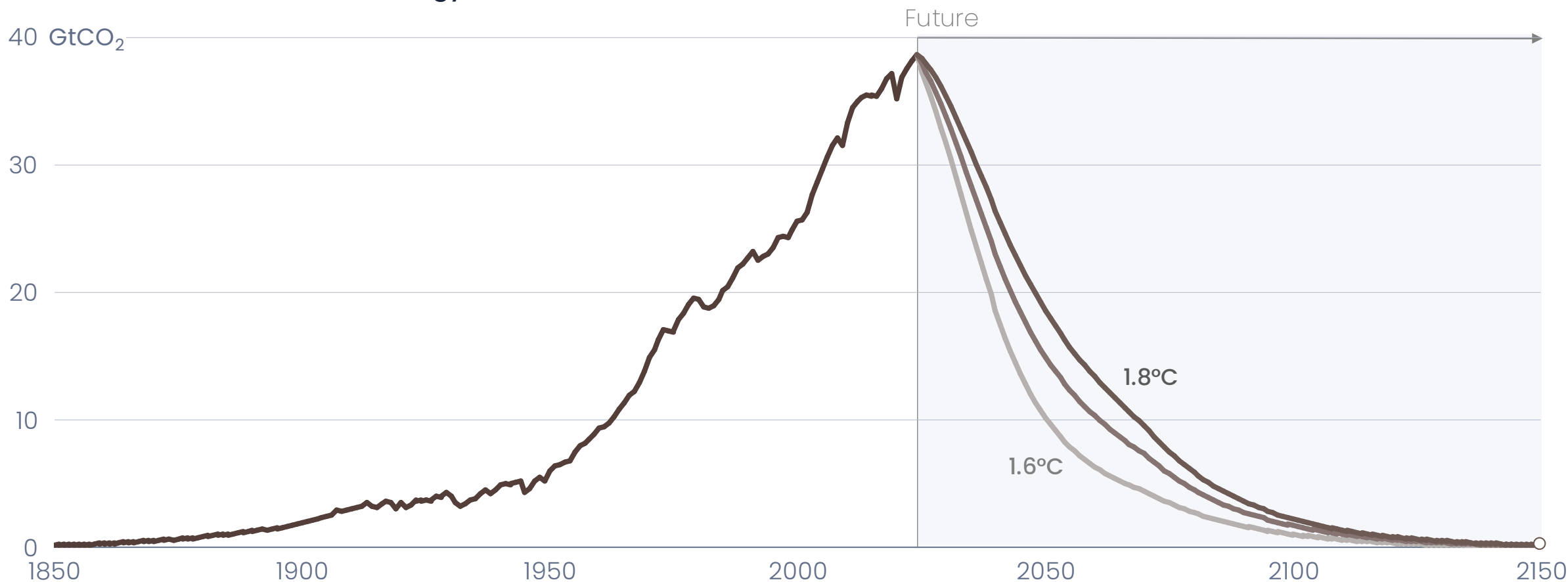
Fossil extraction per person
17.5 MWh a year

Solar and wind
potential per person:
790 MWh a year

Electrotech uptake will lower emissions

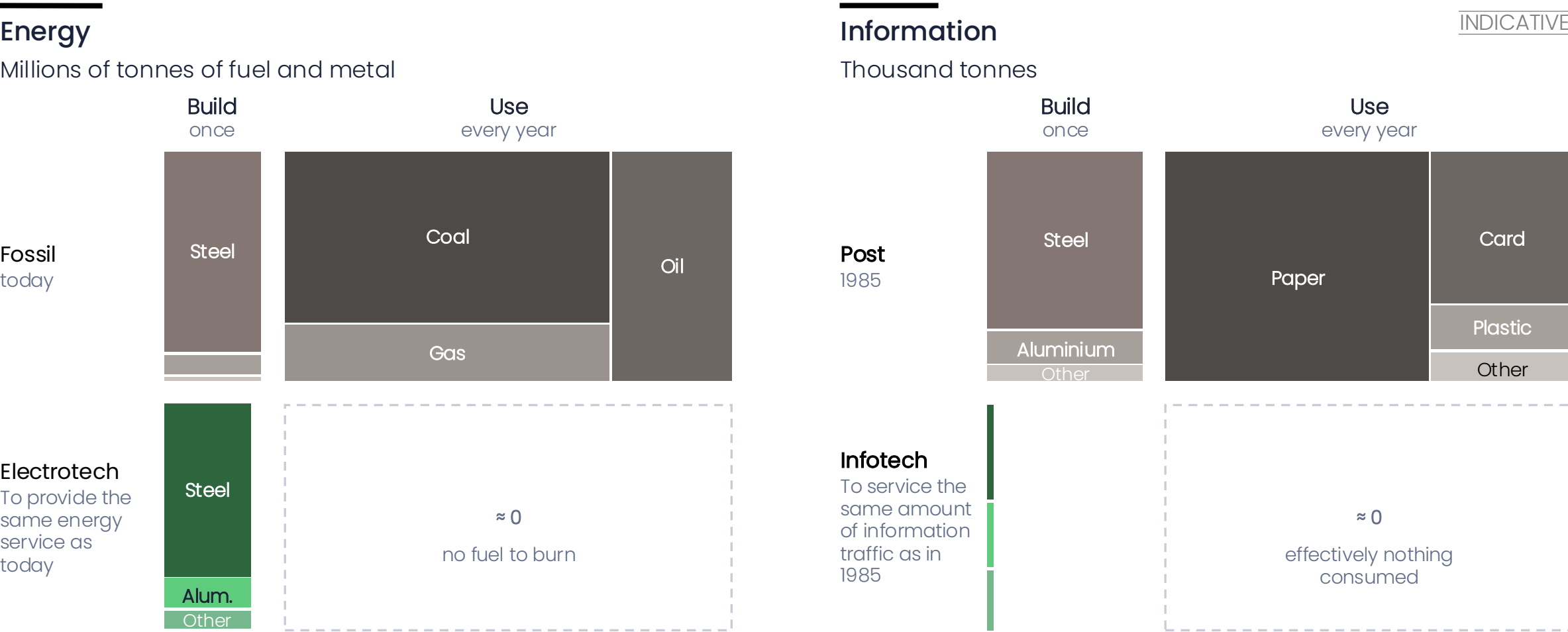
And infotech will help speed up electrotech's rise

Global CO₂ emissions from energy



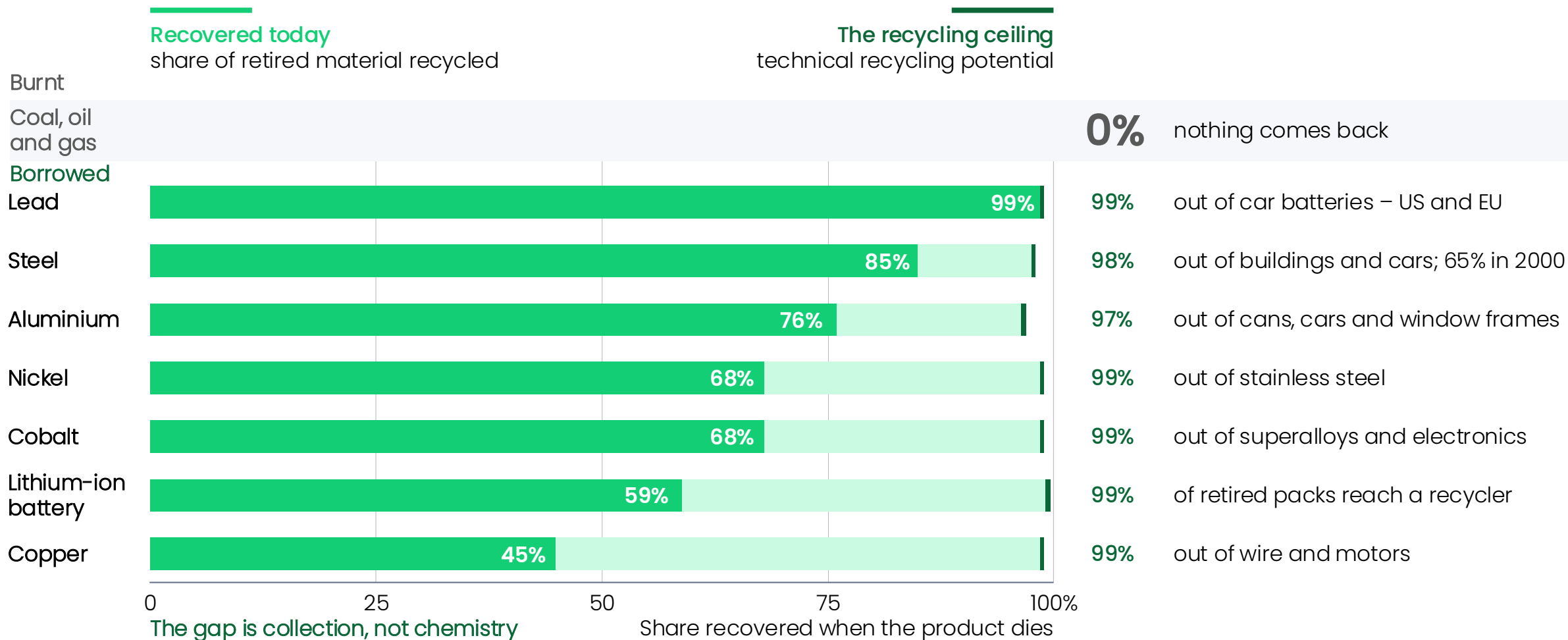
Dematerialisation

Infotech & electrotech need almost no materials to run, and no more than the old system to build



Borrowing, not burning

Materials used to build technologies can be recycled



Every promise carries a risk

The same forces that empower can also endanger

The promise



Sovereignty

Domestic supply, beyond the reach of cartels



Democratisation

Cheap energy and intelligence in billions of hands



Abundance

Plentiful energy and information



Decarbonisation

A rapidly decarbonising world consuming fewer virgin materials

Risks



Autarky

Each country looks inward, prioritising energy and technology self-sufficiency over open trade



Weaponisation

Formidable intelligence in everyone's hands raises new risks, in cybersecurity and beyond



Oligopoly

Production is concentrated in a few firms even as consumption spreads across the many



Destabilisation

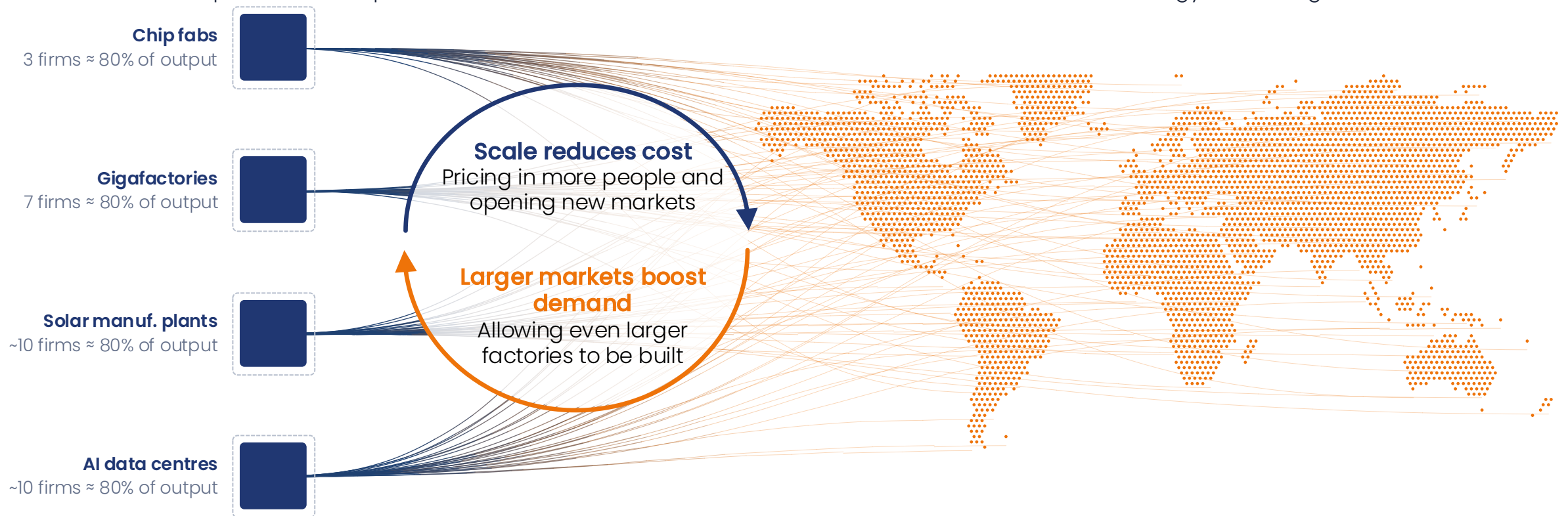
Rapid decarbonisation can strand industries, jobs, regions and national revenues faster than they can adjust

There is a paradox at the heart of the Age of Power

A great democratisation of use is made possible by great centralisation of production

The great centralisation

Vast factories and plants, in a few places



Contents

01 Two interlinked revolutions

The electrification of information and energy

02 The electric rise

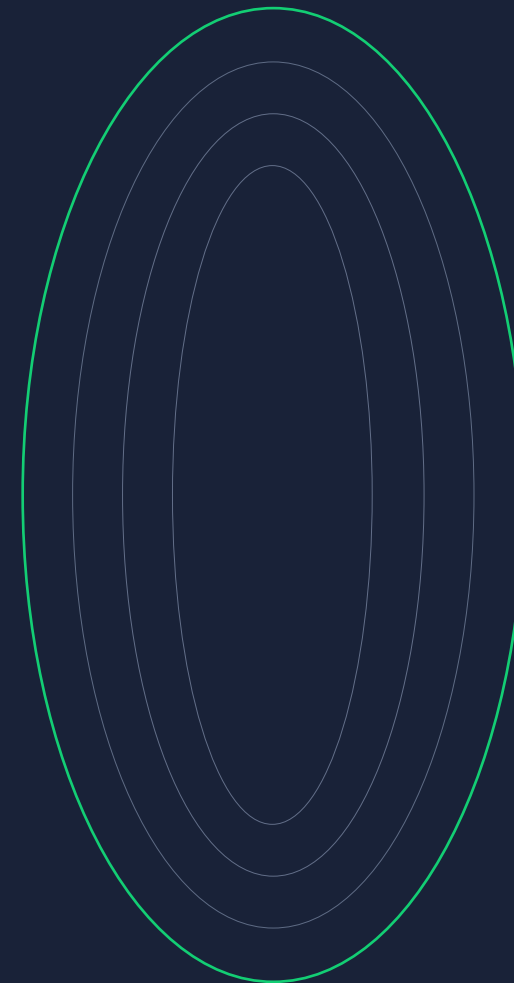
The rise of infotech and electrotech

03 The shape of things to come

The implications of the two revolutions converging

04 Seizing the opportunity

Navigating the incoming electric disruption



Navigating the incoming electric disruption

01

Build an integrated strategy

Every country needs a joint strategy for electrotech and infotech. Within electrotech that means renewables and electrification; within infotech, data centres and physical AI.

02

Make agility your advantage

Information and energy systems are changing faster than ever. Regulation and incentives need to move just as fast, or institutions will become the bottleneck.

03

Lower the two costs that matter

This is an electric and capital intensive revolution. Those who want to succeed need to drive down both electricity prices and the cost of capital.

04

Build the electric stack and shield

Countries need to build the electric tech stack and find the niches where they can hold leverage. That same base can become an electro shield for sovereignty and security.

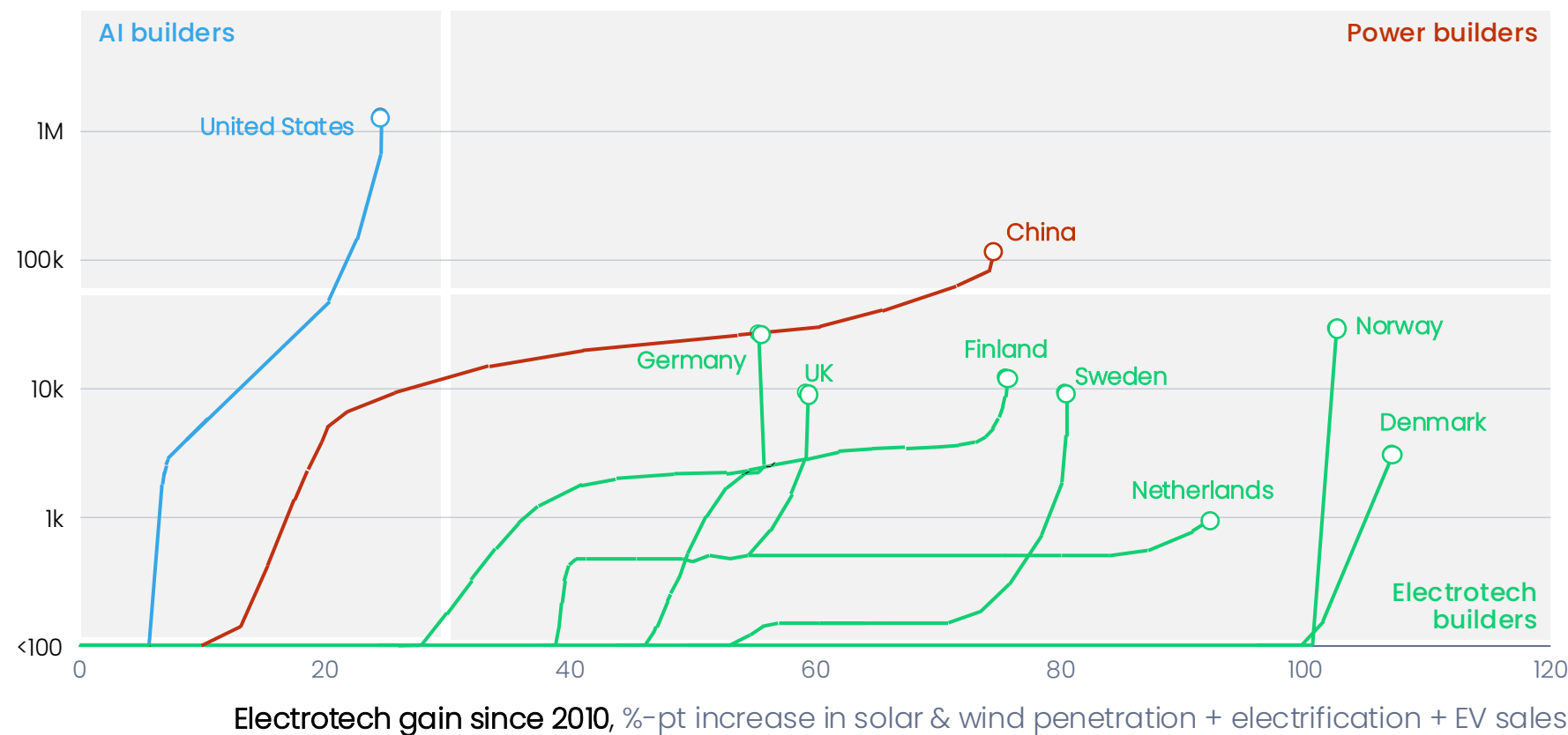
Build an integrated strategy for electrotech and infotech

To win at either, countries need to play at the frontier of both

Two macro races: AI and electrotech build-out, line shows 2010-2025

AI compute build-out, H100-equiv

NON-EXHAUSTIVE



AI builders without electrotech
AI gets built but escalates prices as it hits the wall of an old power system that cannot scale fast enough, and physical end-use markets not ready to implement AI

Electrotech builders with limited AI
Renewables and flexible demand hit an integration wall: they need far more coordination than old electricity control systems can deliver.

Power builders
Scaling electrotech and AI together lets each feed off the other, accelerating growth in both.

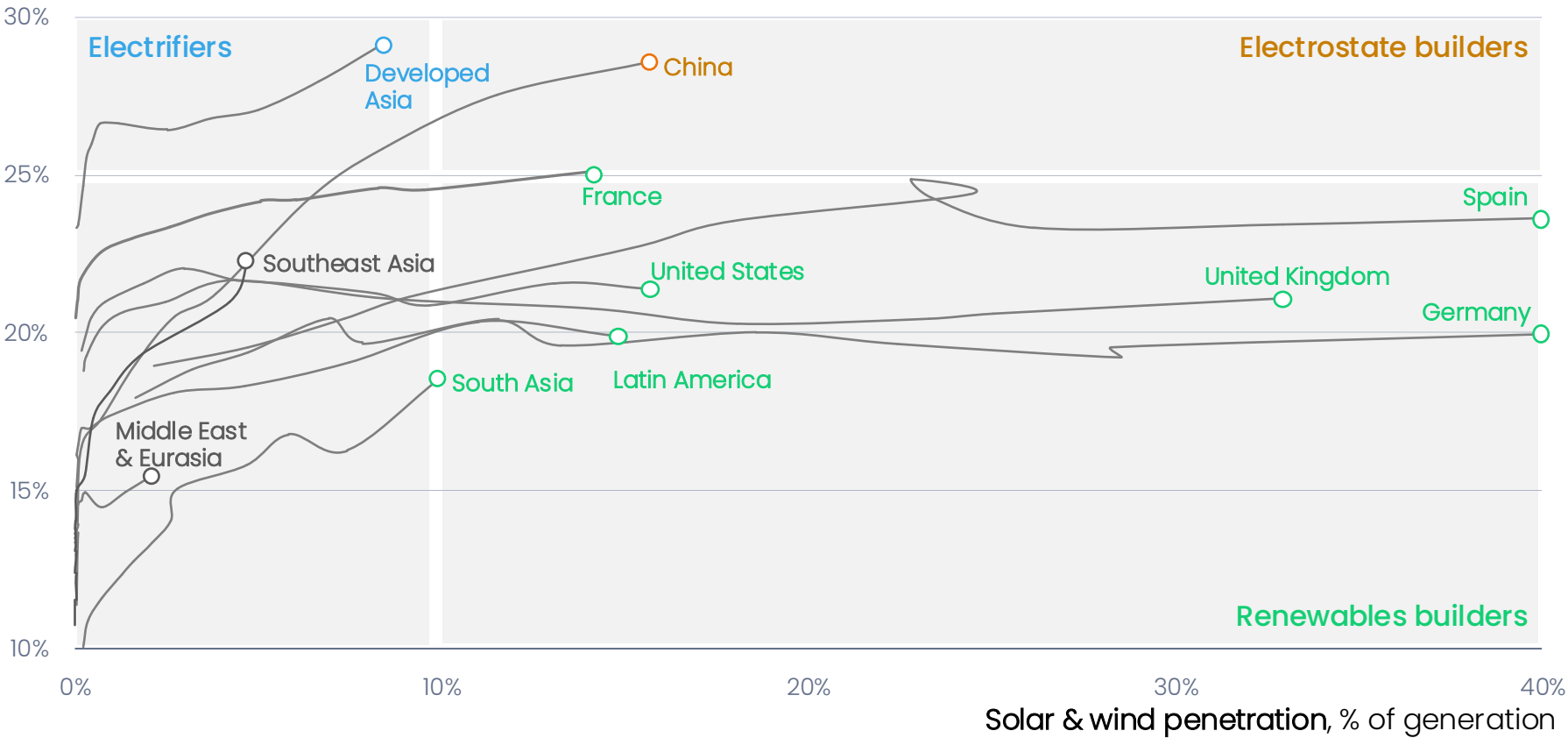
Run both electrotech races

Many countries are focused on building renewables; few are electrifying

Two electrotech races: electrification and solar & wind, line shows 2000 to 2023

Electrification, % of final energy from electricity

NON-EXHAUSTIVE



- Electrifiers**
Electrifiers eventually hit a wall: old electricity supply tech cannot scale fast enough, and for most countries it means more imports and less security.
- Renewables builders**
Renewables scale fast but only reach the 20-30% of demand that is electrified. And little conventional electricity demand is flexible, making deep wind and solar penetration harder still.
- Electrostate builders**
Building the renewables and putting this new energy to work in the economy by electrifying at the same time

Physical AI will draw far more power than data centres

Data centres are only the start of a major electrification wave AI helps unlock

Electricity demand for data centres/"physical AI", end of 2030s, indicative scenario

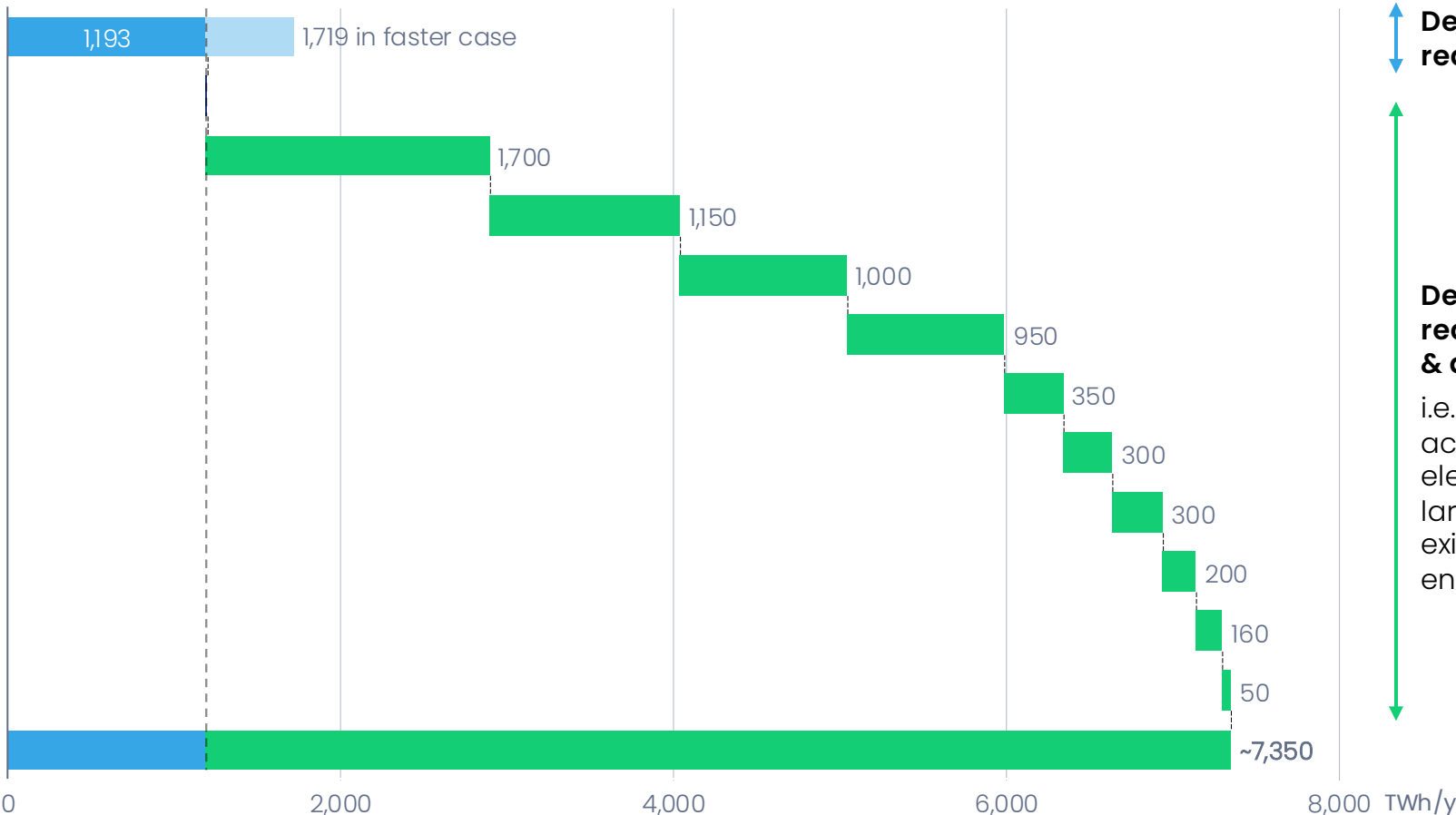
NON-EXHAUSTIVE

Data centres
IEA base case

Physical AI

- Lights-out electrified factories
a tenth of factory fuel, plus 23 million robot arms
- Driverless electric trucking
a third of truck travel
- Robotaxis and autonomous cars
a third of car travel, plus a quarter running empty
- Humanoid robots
100 million, at 1.2 kW for 20 hours a day
- Electric construction/mining machines
the whole fleet electrified and automated
- Autonomous farm machinery
half of farm diesel
- Delivery vans and pavement robots
half of van travel goes robotic
- Warehouses, ports and logistics robots
50 million mobile robots
- Autonomous electric buses and shuttles
half of bus travel
- Drones and autonomous aviation
100 billion parcel drops, half a billion air-taxi flights

Total



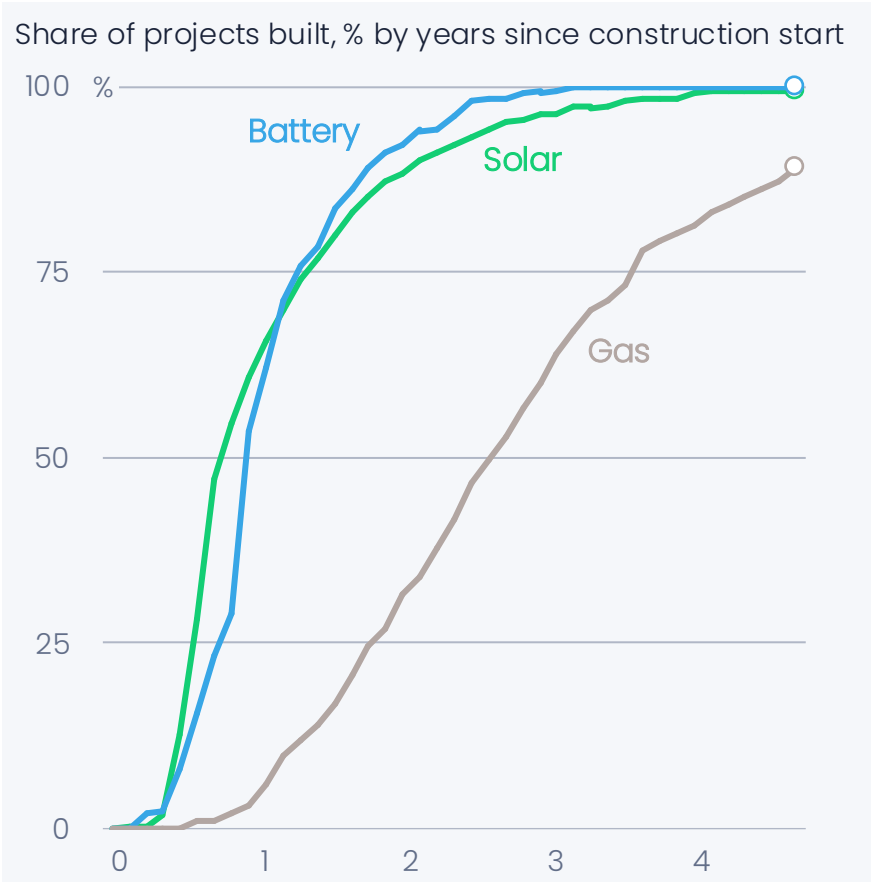
Demand for reasoning only

Demand for reasoning & action
i.e. enabled/accelerated electrification – largely displacing existing fossil energy demand

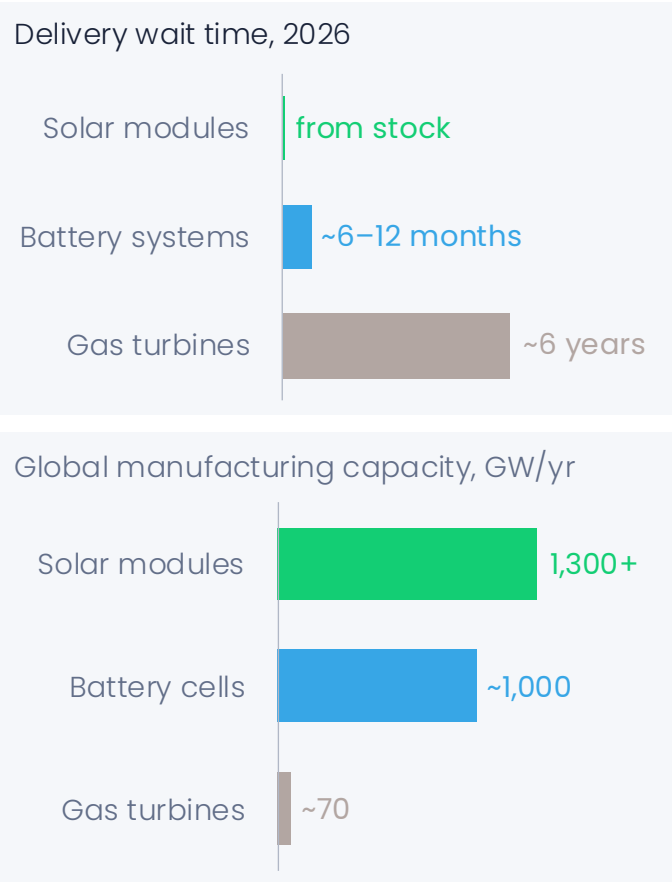
Gas is only a band-aid answer to AI's need for power

Gas is slower to build, sold out for years and no longer cheaper than firm renewables

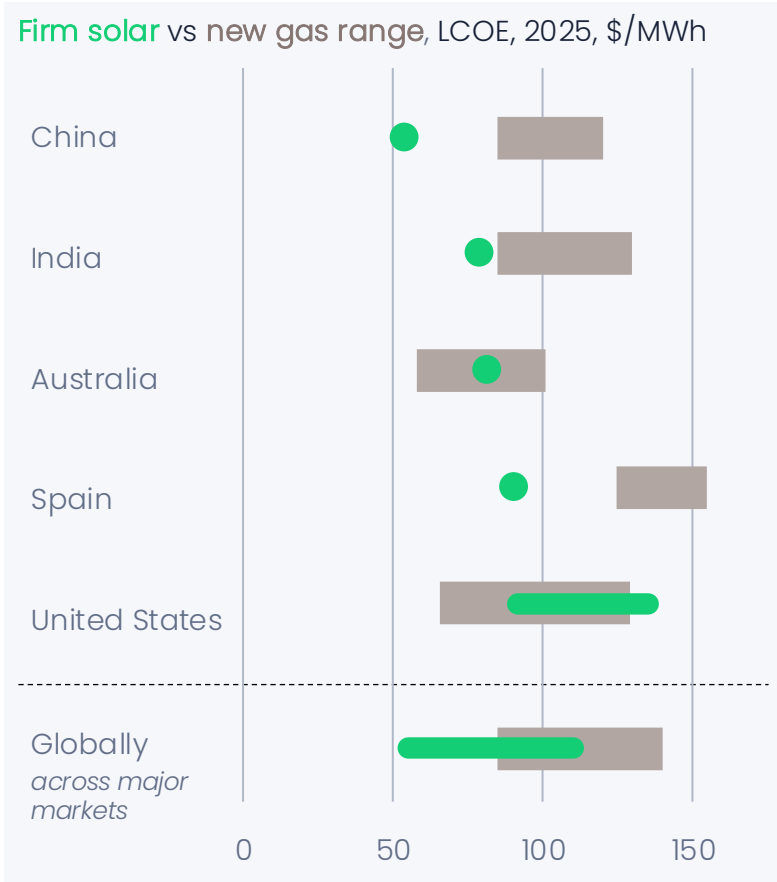
Too slow



Sold out



No longer cheaper



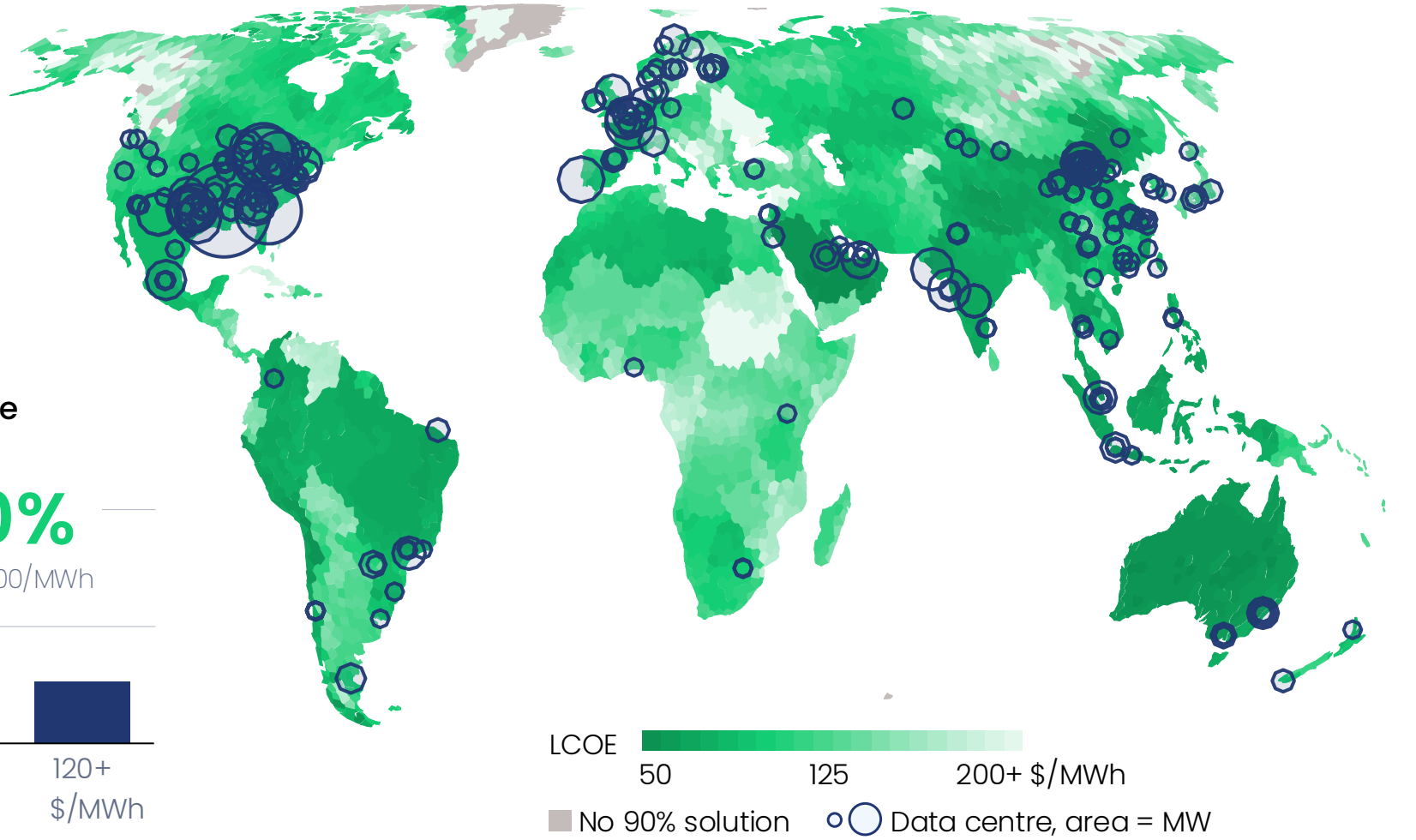
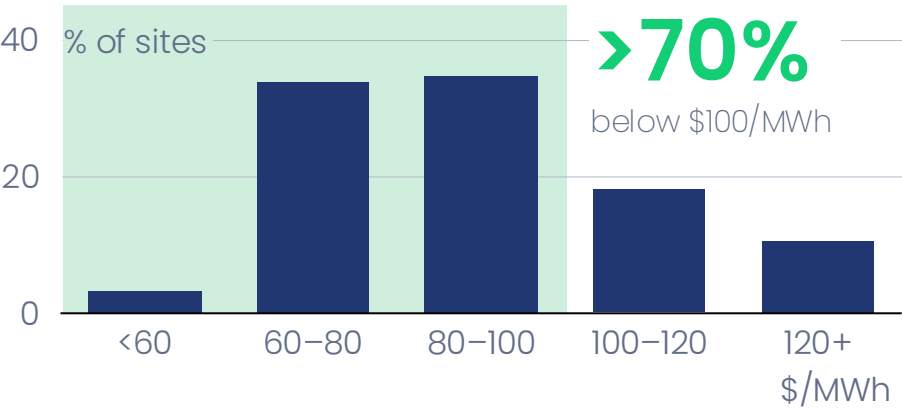
AI can run on renewables

Renewables can now be firmed cheaply; and they're more abundant than any other energy source

Cost of firm renewables vs AI data centre capacity

Least-cost 24/7 power from solar, wind, batteries and backup, with >90% of electricity from solar and wind

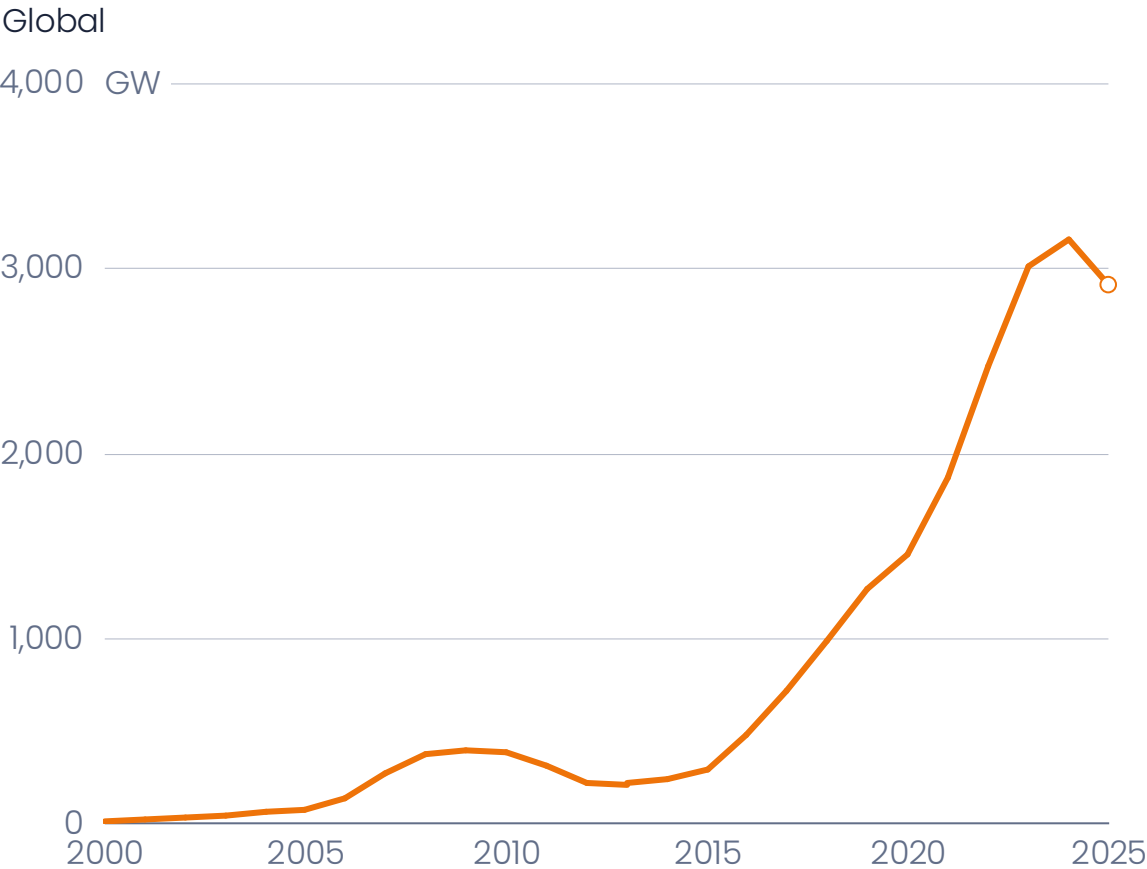
Data centre capacity by firm renewable power cost



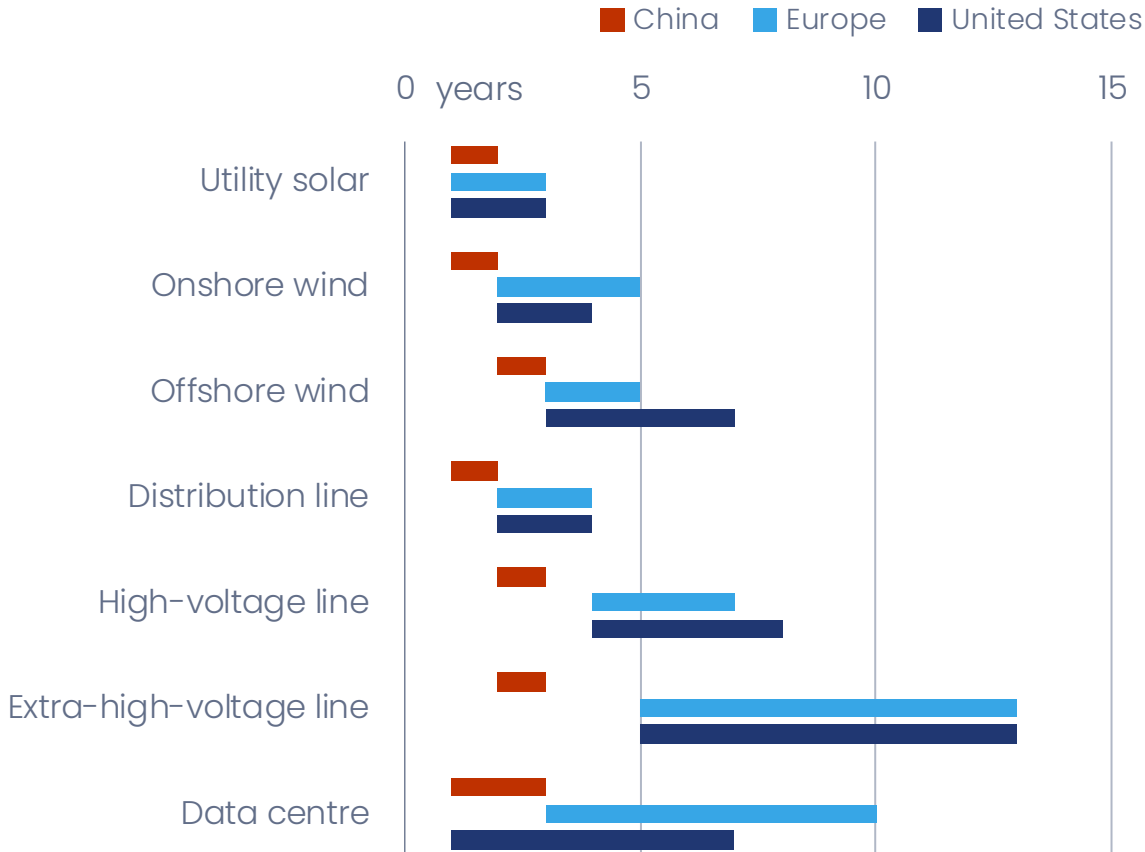
Move fast and break up the old regulatory structures

Regulation is a key differentiator between nations. If you don't change, your competition will

Connection queue



Typical project delivery time

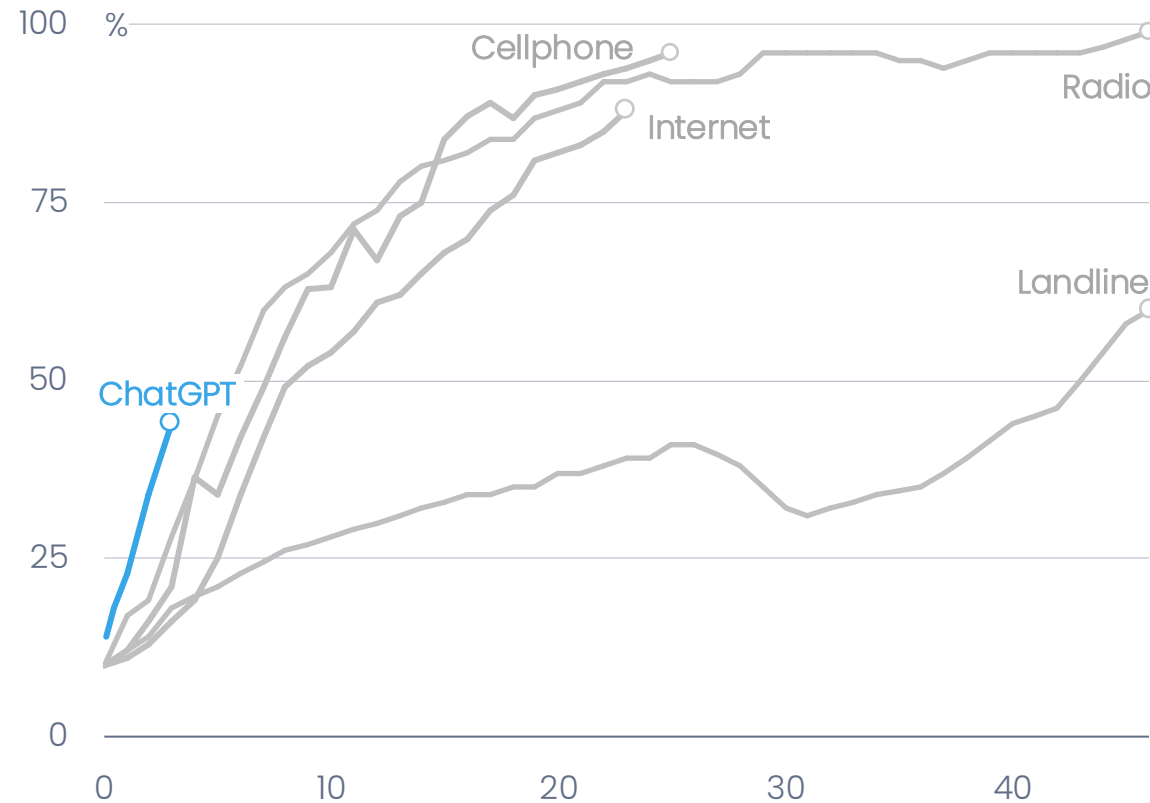


Agility is power

Change is happening at unprecedented levels and only the agile will survive

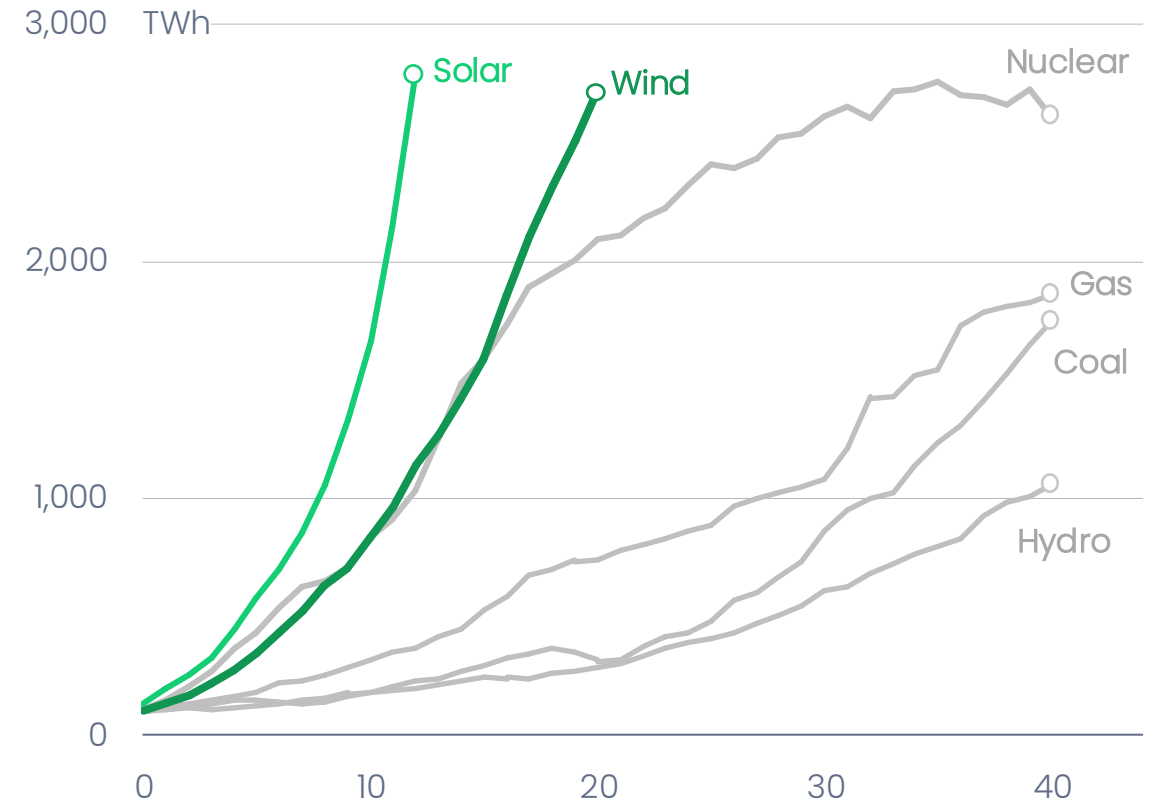
Information technology

Share of US households, by years since reaching 10%



Electricity technology

Global generation, by years since passing 100 TWh

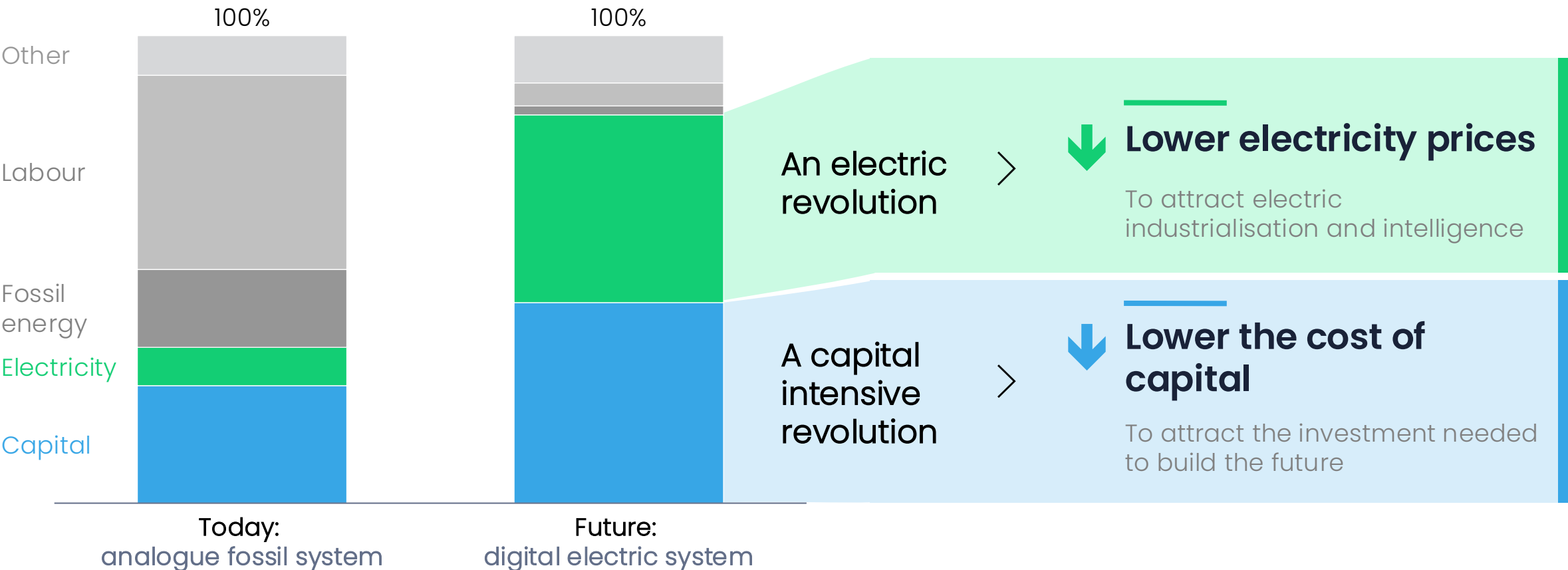


This is an electric and capital intensive revolution

And so the two main macro drivers to focus on are electricity price and cost of capital

ILLUSTRATIVE

Industrial cost structure changes – indicative



How to enable growth

Driving down electricity prices and cost of capital requires concerted effort

Core objectives

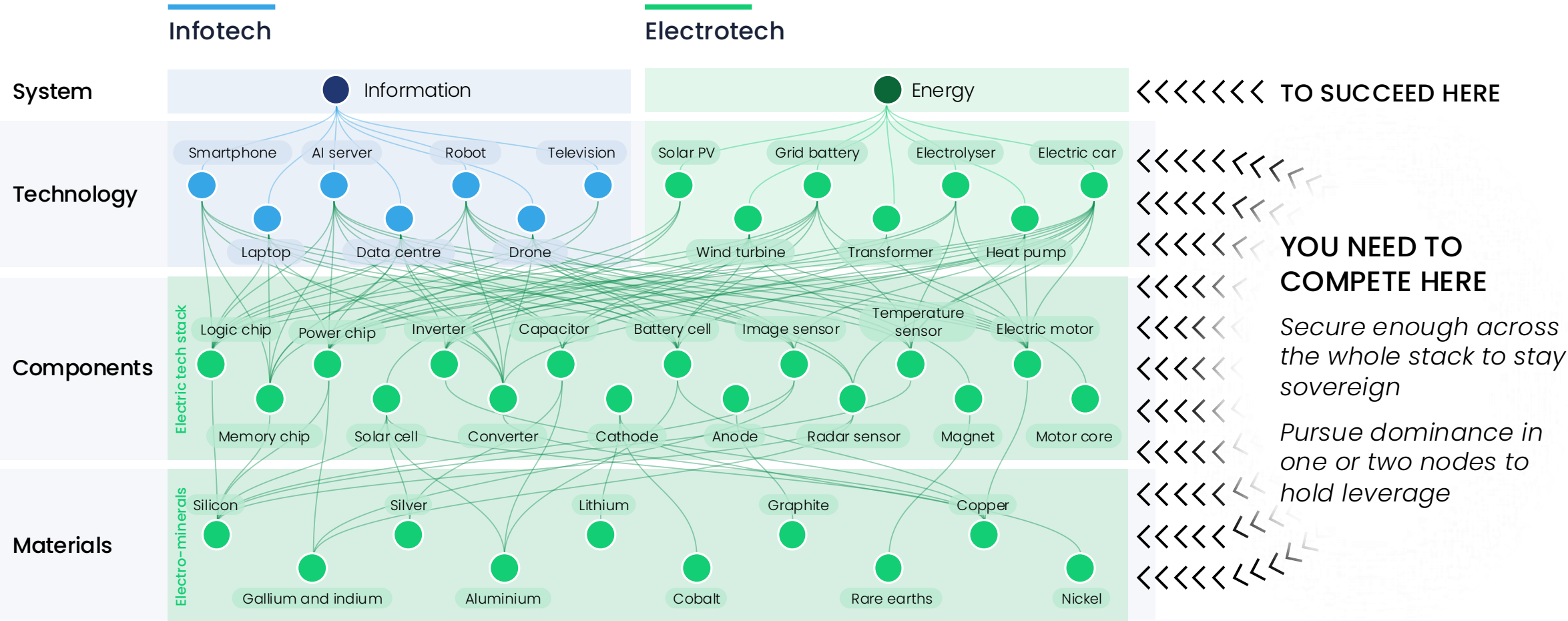
↓ Lower
electricity
prices

↓ Lower
the cost of
capital

01	Permit fast and predictably	Less delay, less project risk
02	Expand and modernise grids	More capacity from new wires and smarter networks
03	Stop overtaxing electricity	Let cheap electrons compete fairly
04	Keep market rules stable	Lower uncertainty, lower WACC
05	Use competition aggressively	Drive down equipment and power costs
06	Reduce macro and currency risk	E.g. electrification cuts fossil imports and can strengthen the currency
07	Extend the investment horizon	Avoid the pitfall of investing for the next quarter or next election; invest decadal

Build an electro-industrial base

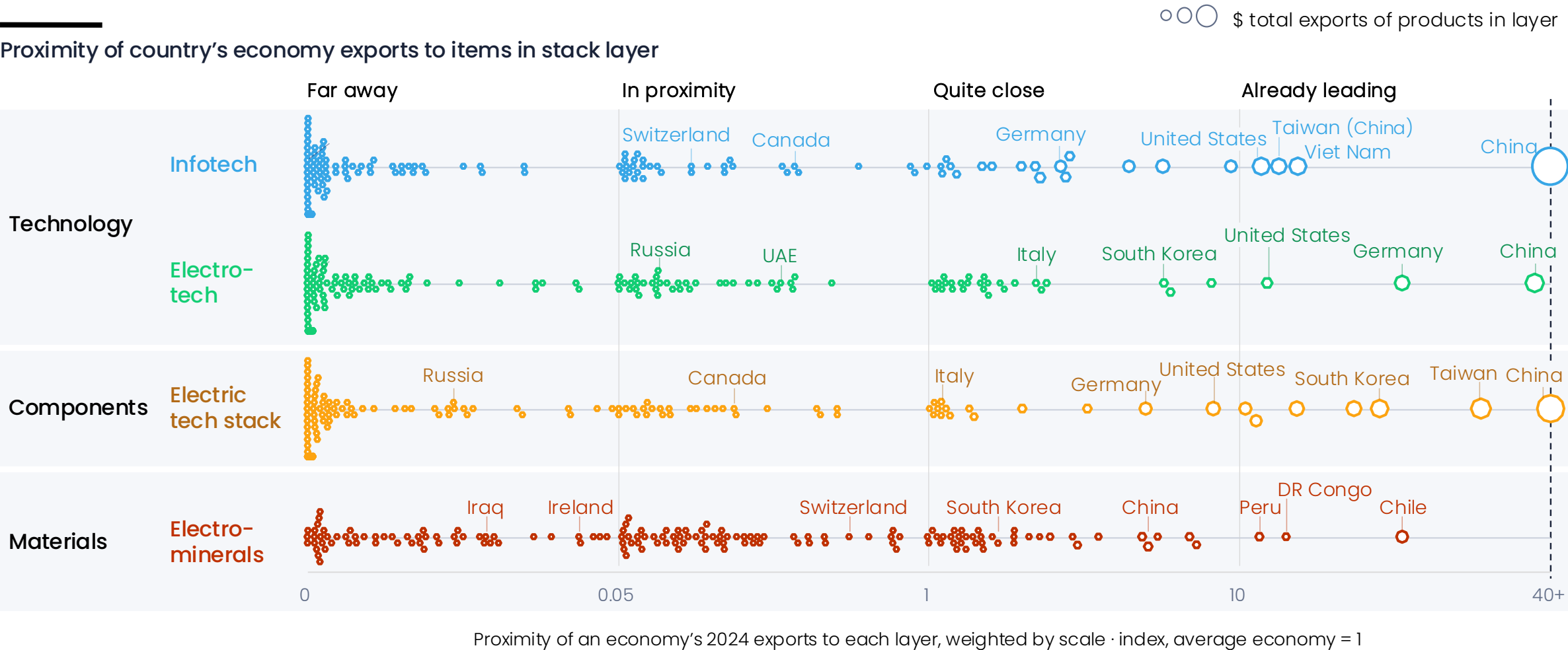
To win the future of information and energy systems, you need to build their industrial base



Find your niche

Each country needs to find a role in the new systems of energy and information

Proximity of country's economy exports to items in stack layer



Construct an electro shield

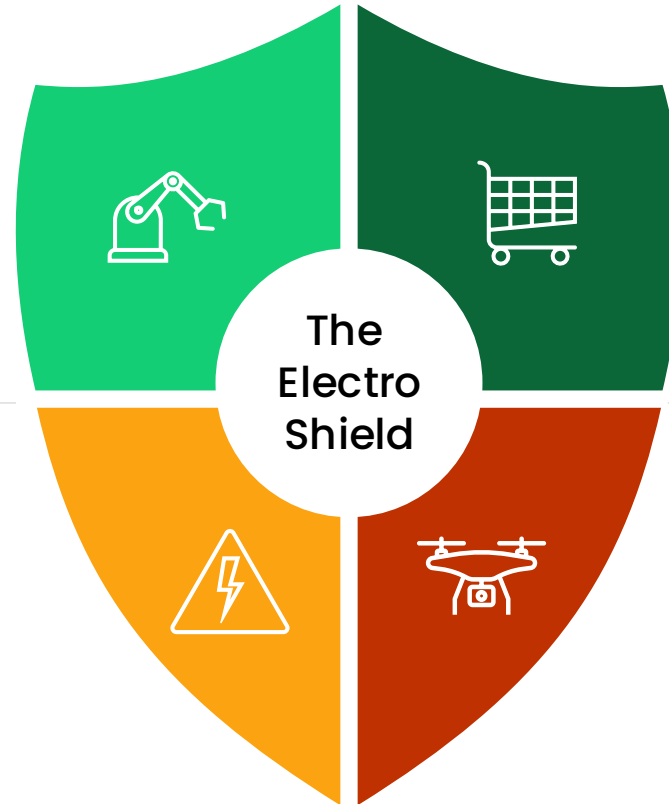
In the age of power, electrotech allows countries to gain sovereignty in four ways

Supply chain criticality

Control the industrial base behind the electric and digital economy

Energy security

Run the economy on domestically generated electricity, not imported fuels



Market access

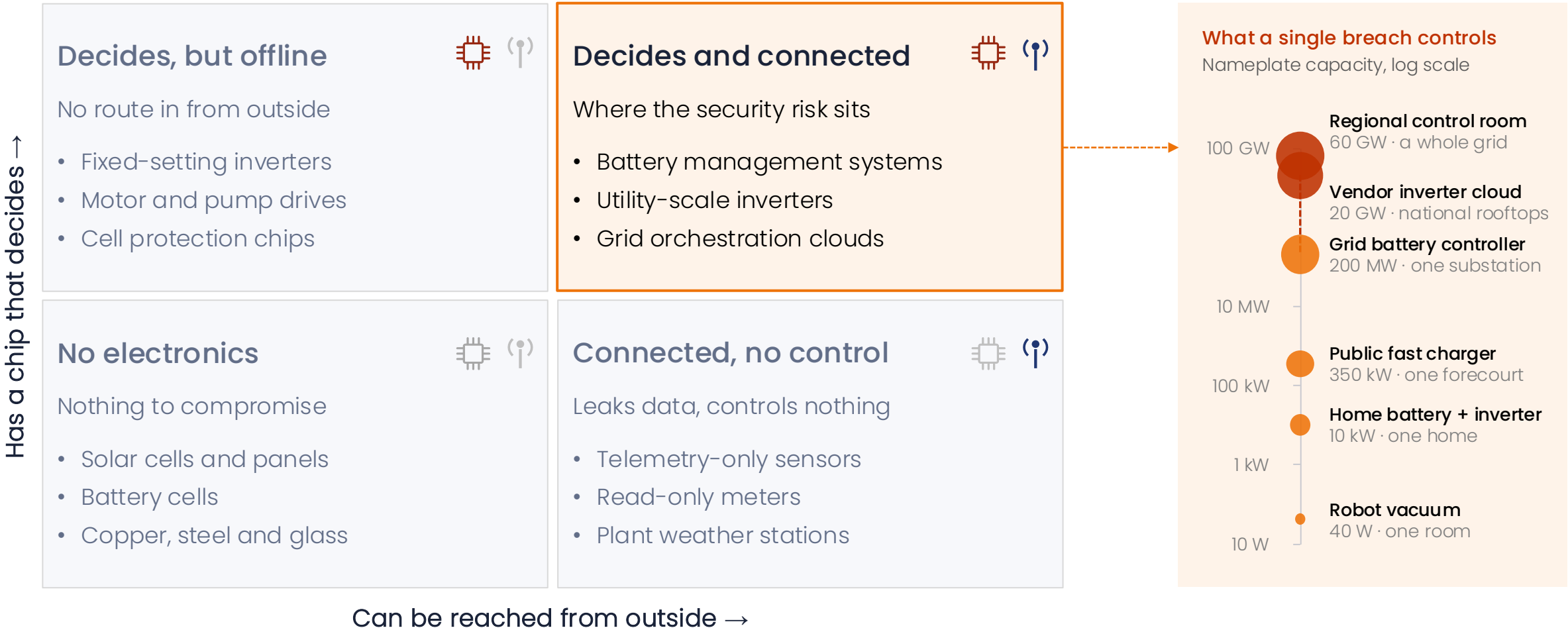
Use demand, standards and scale to shape global markets, from chips to electric vehicles

Defence readiness

Build dual-use capabilities needed for modern security, from drones to AI

Focus on the brain not the brick

Only a small share of infotech and electrotech imports poses a real security risk

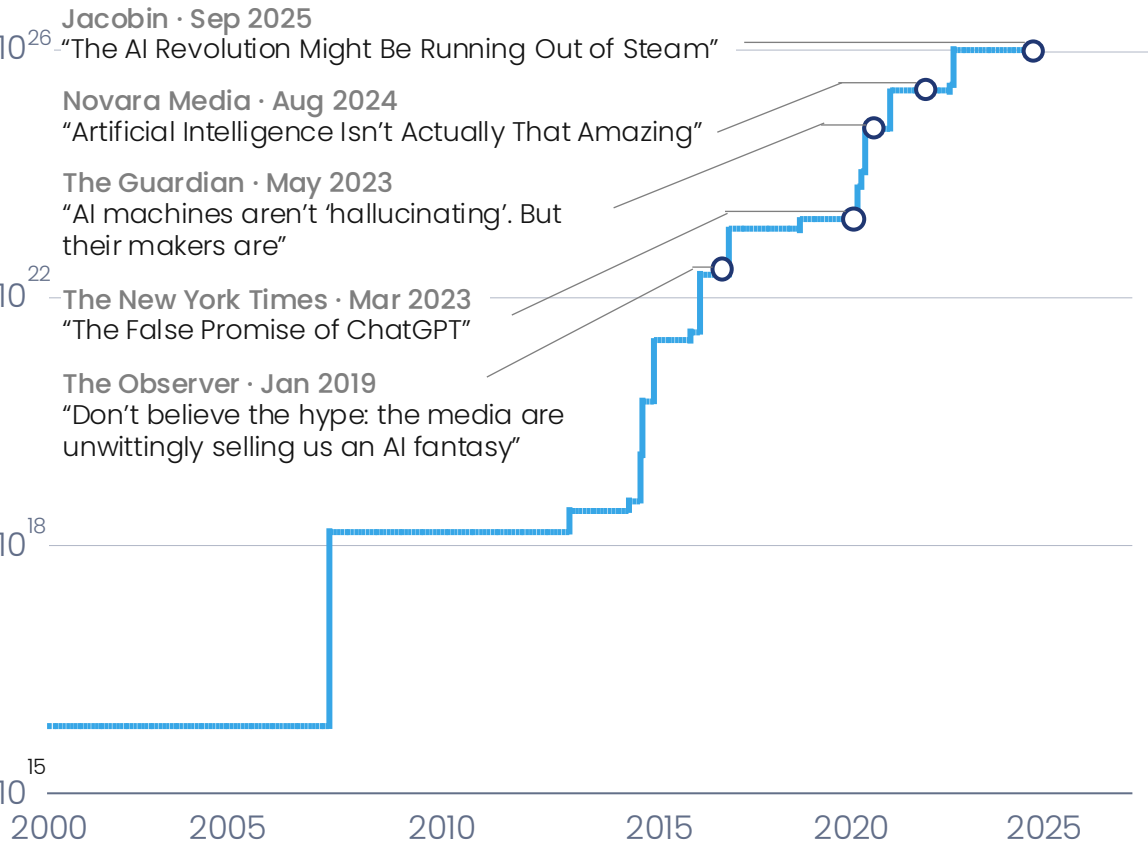


Don't get distracted by the culture wars

Many proponents of AI are against electrotech, and vice versa; the reality is they are deeply linked

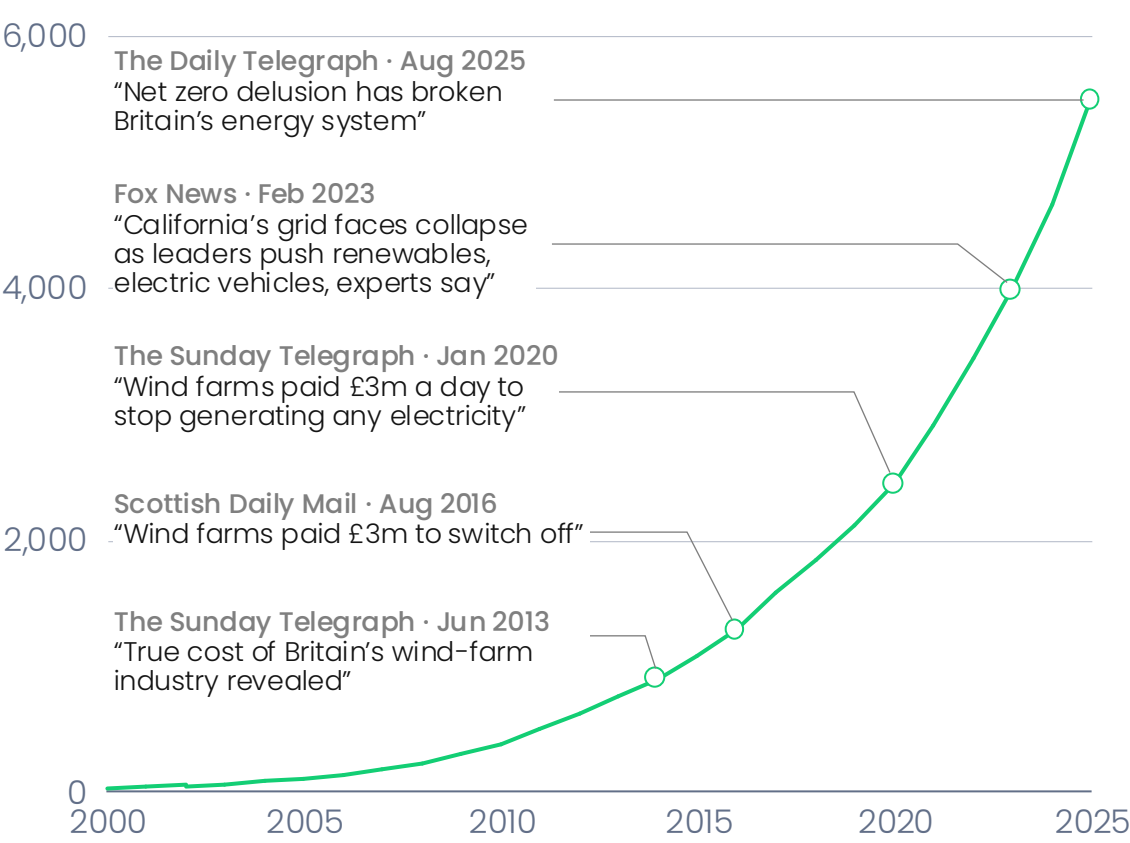
Training compute of the largest AI model, 2000–2025

FLOP, log scale



Global solar and wind generation, 2000–2025

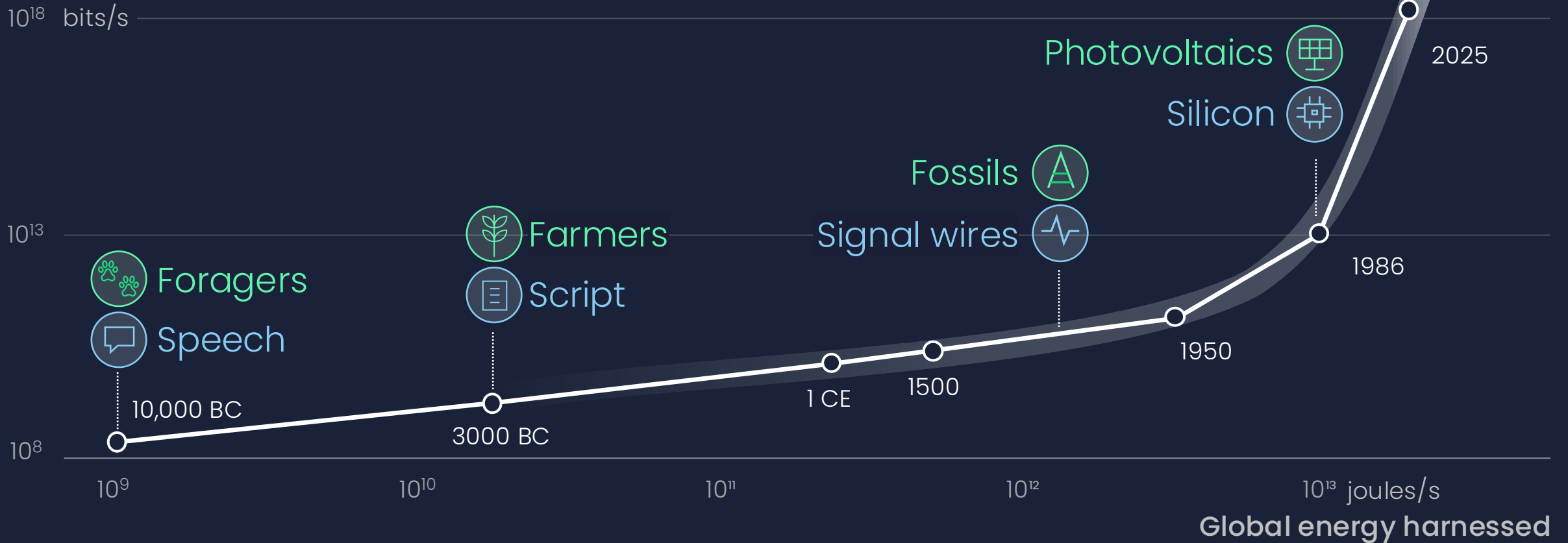
TWh



This is a major moment in human history

Abundance is arriving. Whether it is used well is up to us.

Global information transferred



About Ember

Ember is an independent global energy think tank that aims to accelerate the clean energy transition with data and policy. Its vision is a world with a safe climate, powered by a clean, electrified energy system for all.

The Team



Kingsmill Bond
Director



Daan Walter
Principal



Sam Butler-Sloss
Research
Manager



Jardine Wall
Partnerships
Manager



Antoine Issac
Analyst

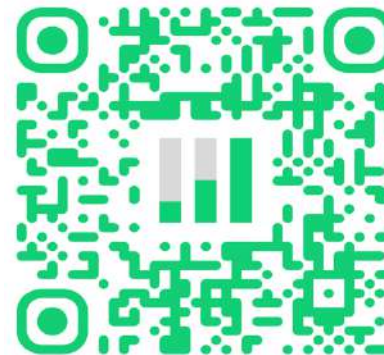
About Ember Futures

Ember Futures is a new research initiative established to help leaders navigate the rise of electrotech and what it means for energy, financial markets and geopolitics.

With thanks to

Amory Lovins, Ardhi Arsala Rahmani, Bill McKibben, Biqing Yang, Bruce Douglas, Bryony Worthington, Caroline Cook, Chris Nelder, Dave Jones, Dimitri Zenghelis, Emily Nurse, Francisco Laverón, Hannah Broadbent, Hannah Ritchie, Harry Benham, Harry Krejsa, Jules Kortenhorst, Mark Campanale, Michael Collins, Mike Hemsley, Phil MacDonald, Phoebe Benich, Rashmi Mishra, Rini Sucahyo, Simon Sharpe, Thijs Van de Graaf, Thomas Kwan, Tim Buckley, Vincent Petit.

Sign up to our research on Substack



Sign up [here](#)