PUBLIC IMPROVEMENTS COMMITTEE

AGENDA

Council Chambers
3760 Darrow Rd.
Stow, OH

NOVEMBER 5, 2026

TIME: 5:45 P.M.

Committee Members: Matt Riehl, Chair; Kelly Coffey, Vice-Chair; John Baranek and Mario Fiocca

The meeting will begin immediately after the Planning Committee meeting.

Meeting will be Live Streamed and Archived on the City Council webpage
https://stowohio.gov/244/City-Council and You Tube
https://www.youtube.com/@CityofStowOhio/streams

1. **Call to Order**

2. **Roll Call**

3. **Approval of Minutes**

   a. Approval of September 10, 2026 Minutes
   2026-09-10 Public Improvements Committee Minutes - DRAFT.pdf

   b. Approval of September 24, 2026 Minutes
   2026-09-24 Public Improvements Committee Minutes - DRAFT.pdf

4. **Service Director's Report**

5. **Consideration of Business Items**

   a. Presentation: Command Consulting
   Requested by Environmental Commission.
   The main points are:
   1. Electrification is THE emissions reduction strategy for municipalities
   2. Resiliency requirements => oversized systems which offer revenue and savings
   3. This is an opportunity, not a cost; there is an ROI, no grant is needed to act now
   4. Next step is to see what is possible in Stow via affordable feasibility study ($25k)
   Municipal Electrification Value Stacking - Stow OH 11 05 26.pdf
   Slidedeck-The-Electrotech-Revolution-PDF - Ember Sep 2025.pdf

6. **Public Comment Period**

7. **Adjournment**

ALL PERSONS WITH DISABILITIES:
The City of Stow will make the transition of all city business accessible via any reasonable accommodation. Please contact the Clerk of Council or Commission Secretary 48 hours in advance for the necessary arrangements.

PLEASE TURN OFF ALL CELL PHONES BEFORE THE MEETING

(Agendas, Minutes, Packets and Legislation posted at www.stowohio.gov)

Minutes of the Public Improvements Committee held on Thursday, September 10, 2026, 6:27 pm

Call to Order

Roll Call

Council Members Present:	Matt Riehl, Kelly Coffey, Mario Fiocca, and John Baranek
Council Members Absent:	None.
City Officials Present:	Kyle Herman, Cyle Feldman, Kim Young, John Pribonic, Nick Wren, Kelly Toppin, Drew Reilly, Mike Jones, Heather Prusha, Mike Lang Jr., and Sonya Mottram

Approval of Minutes

- Approval of Minutes from August 6, 2026

2026-08-06 Public Improvements Committee - Draft.pdf

Motion made by John Baranek, seconded by Kelly Coffey, to approve. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

Service Director's Report / Chief of Staff Report

Mr. Wren had nothing to report.

Consideration of Business Items

- 2026-137 AN ORDINANCE AMENDING CERTAIN SECTIONS OF C.O.S., PARTICULARLY TO 921 C.O.S, ENTITLED "WATER SYSTEM FEES AND USER CHARGES," TO INCREASE CERTAIN WATER RATE FEES FOR USERS OF THE CITY OF STOW'S WATER SYSTEM

2026-137 Ch. 921 - 921.03 User Charges - Water Rates.pdf

Mr. Toppin explained that the water-rate study had been requested in 2024 and completed in 2025, but the previous council had rejected its recommended increase. He said the water operating and capital funds were meant to be self-sustaining, so he had presented four alternative rate options, along with the original consultant proposal. He noted that every option involved increases over the next four years

because the earlier decision had delayed the plan by a year, and he left the choice to the council.

Mrs. Coffey said she appreciated that Mr. Toppin's proposal was clearer and lower than the consultant's, estimating a 40% increase rather than 50%. She suggested itemizing the administration fee on residents' bills and keeping increases as low as possible. Rather than a four-year plan, she preferred a two-year plan that applied roughly half the proposed increases, then reassess at a later date. Based on Mrs. Coffey's calculations, that approach could bring in about $800,000 more for capital and $700,000 more for operations, which she felt could cover the funds' average historical deficits while helping limit residents' costs.

Mr. Toppin asked Jeff Smithm water supervisor, to describe upcoming water-system projects. Mr. Smith said the city planned a meter-replacement program estimated at $4.1 million, a second water tower expected to cost $15–20 million, and water-main replacements. Mayor Pribonic asked about routine upgrades and the longer-term plan. Mr. Smith replied that he had mapped out work over roughly 10 years to replace the city's 1956 water lines, at an estimated cost of $14 million. Mrs. Coffey asked how many smart meters had already been replaced and what the program would cost. Mr. Smith said nearly 2,000 had been replaced in five years, and the next phase would replace a little over 10,000 meters in 12-16 months, confirming the $4.1 million estimate. Mr. Toppin said the city planned to seek 0% OPWC financing over 20 years for the meters, while Mr. Smith said they would also seek OPWC financing over 30 years for the tower.

Mr. Feldman noted that the meter, water-tower, and water-main projects totaled about $35.1 million, and said the city needed to invest in its water system. He asked whether Mrs. Coffey's proposal adjusted the administration and volume-rate increases, and whether the water-improvement fee was included. Mr. Toppin clarified that the "50-cent accelerator" added 50 cents to both the administration fee and volume rate, while the water-improvement fee would also rise by $2 each year. Mr. Feldman confirmed that this meant a $3 monthly increase; Mr. Toppin agreed and said that amounted to $36 per year, or $144 per resident over four years. Mr. Feldman asked how many water-main breaks the city had experienced. Mr. Smith said there had been 36 so far that year and 98 the previous year. Mr. Feldman confirmed that the city's own staff handled the repairs, and Smith agreed.

Mr. Riehl said the council would not resolve the water-rate issue that evening or make a rushed decision at the third reading. He asked members who wanted to propose a solution to submit it to the clerk by the following Thursday, so the proposals could be reviewed at the next Public Improvements meeting.

Mayor Pribonic asked about the life expectancy of the older water pipes. Mr. Smith said the proposed $14 million in replacements would move the system from the 1956 pipes to 1960, and estimated cast-iron pipes had a life expectancy of about 63 years. He continued by saying that replacing all cast-iron pipes would cost roughly $80 million and cover 29% of the system. Mr. Riehl added that Akron and Summit County had previously owned and operated the system before Stow reclaimed the rights in the late 1990s. Mr. Feldman then asked whether the proposed rate increases would affect seniors on fixed incomes. Mr. Reilly said eligible seniors could apply for the discount program, which the proposal would increase from 10% to 15%; Mr. Toppin confirmed that they would need to apply. Mr. Feldman said he had raised the issue because it was important to consider.

Ordinance 2026-137 remained in committee.

- 2026-139 AN ORDINANCE AUTHORIZING THE MAYOR TO MAKE AND ENTER INTO A CONTRACT WITH GARDINER SERVICE CO FOR HVAC

REPLACEMENT AT VARIOUS CITY BUILDINGS, WITHOUT THE NECESSITY OF PUBLIC BIDS AND DECLARING AN EMERGENCY

2026-139 PI Gardiner - BOC Memo.pdf

2026-139 Gardiner Service Co - various HVAC replacements.pdf

Mr. Wren explained that the proposed HVAC work would replace two City Hall atrium units dating to 1986, a 20-ton Community Center unit from 1992, and the Safety Building's 1994 boilers, whose parts had become obsolete, and which provided the building's only heat source. He also said the Fox Den Golf Course replacement would double heating and cooling capacity and noted the clubhouse had reached 86 degrees on summer days.

Motion made by John Baranek, seconded by Mario Fiocca, to forward to this evening's regular council meeting. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

- 2026-145 AN ORDINANCE AUTHORIZING THE MAYOR TO MAKE AND ENTER INTO A CONTRACT WITH GUNTON CORPORATION dba PELLA WINDOWS & DOORS FOR WINDOW REPLACEMENT AT THE SAFETY BUILDING, WITHOUT THE NECESSITY OF PUBLIC BIDS AND DECLARING AN EMERGENCY

2026-145 PI Gunton - BOC Memo.pdf

2026-145 Gunton Corp - Safety Center windows.pdf

Mr. Wren stated this was to replace the windows at the Safety Center which were installed in 1994 with new Pella windows. This item was on the 2026 capital improvement plan.

Motion made by Kelly Coffey, seconded by Mario Fiocca, to forward to this evening's regular council meeting. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

- 2026-148 AN ORDINANCE AUTHORIZING THE MAYOR TO MAKE AND ENTER INTO AN INTERGOVERNMENTAL AGREEMENT WITH THE CITY OF AKRON AND VILLAGE OF SILVER LAKE FOR CERTAIN WATER SERVICES AND DECLARING AN EMERGENCY

Mr. Reilly explained that the City of Silver Lake wanted to switch its water source to Akron, requiring the water to pass through Stow's lines. He continued to say under the proposed agreement, Stow would receive a 10% credit for water flowing through its system. He said the arrangement would not complicate or burden Stow's system and was similar to existing agreements with other areas. Mr. Baranek asked if there was a meter. Mrs. Coffey asked if there would be new water lines. Mr. Smith answered by stating all cost would be paid by Silver Lake to add a meter and any water line upgrades.

Motion made by John Baranek, seconded by Mario Fiocca, to forward to this evening's regular council meeting. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

Public Comment Period

2026-148 Akron-Silver Lake-Stow Water Contract.pdf

There was no public comment this evening.

Adjournment

Motion made by Kelly Coffey, seconded by Mario Fiocca, to adjourn. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

The meeting adjourned at 6:52 pm.

Clerk

Chairman

Minutes of the Public Improvements Committee held on Thursday, September 24, 2026, 6:20 pm

Call to Order

Roll Call

Council Members Present:	Matt Riehl, Kelly Coffey, Mario Fiocca, and John Baranek
Council Members Absent:	None.
City Officials Present:	Kyle Herman, Cyle Feldman, Kim Young, John Pribonic, Kelly Toppin, Angela Revay, Drew Reilly, Jim McCleary, Bryan Snavely, Mike Lang Jr., Don Brooker, Peter Wearstler, Steve Hooten, and Sonya Mottram

Approval of Minutes

- Approval of August 6, 2026 Minutes

  Motion made by Mario Fiocca, seconded by Kelly Coffey, to approve Approval of August 6, 2026 Minutes. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

Service Director's Report

Mr. Brooker who attended on behalf of Mr. Wren. Mr. Brooker had nothing to report this evening.

Consideration of Business Items

- Discussion: The Summit County Department of Sanitary Sewer Services Project Q-452 Pump Station No. 19 Relocation (Wyoga Lake)

  2026-09-24 Summit County Department of Sanitary Sewer Services Project Q-452.pdf

  Ms. Young said resident Michael Sermersham had raised the long-running Pump Station 19 issue with her the previous summer. She noted that the project dated back to 2015, was mostly the county's responsibility, and could pose a serious risk to the neighborhood and Wyoga Lake. She had contacted county officials and invited the resident and county representatives to provide an update.
  Mr. Micheal Sermersham, 783 Hampshire Rd, said he understood that the Pump

Station 19 replacement project had begun in 2015. The pump failed in 2023, and the county responded with round-the-clock trucks to prevent sewage from backing up into homes, though one resident's home was affected. He said a contractor had rebuilt the pump using salvaged parts that were difficult to obtain. Although neighbors had signed easements and he had received compensation, he had seen no progress in 2023 or 2025. He urged the city and county to make the project a priority, citing the risk of sewage entering homes and Wyoga Lake and flowing downstream.

Ross Nicholson introduced himself as Deputy Director of Engineering for Sanitary Sewer Services and introduced Jacob Morrison as the Q452 project engineer. He said the project was making progress and apologized for the delays, which he attributed to COVID-19 and repeated staff turnover among both the consultant and the county.

Mr. Morrison said he had been the project manager since June of the previous year. The county had ended its contract with the former design consultant because the work was progressing too slowly, and it had nearly finalized an agreement with a new consultant. They had met that day to review the scope and complete the remaining design work. Mr. Morrison hoped to finish the design by the end of the year, submit it for Stow and EPA permits early the following year, and begin construction in the third quarter after bidding. Mr. Morrison said the project would need reviews from Stow's engineering, building, fire, and roads departments, as well as EPA approval. Mr. McCleary clarified that engineering, building, and fire would review the permits. Mr. Morrison said the county hoped to submit the design for permits early the following year; earlier permits had expired after COVID-related delays. Ms. Young emphasized residents' frustration and concern about another failure. The county said the 61-year-old station had two working pumps, providing backup if one failed. Mr. Sermersham praised the county's response and monitoring but urged officials to prioritize the replacement, noting the costs and risks of relying on emergency measures. Mr. Baranek asked the city to remain attentive to the issue and move the project through its process as quickly as possible.

- 2026-137 AN ORDINANCE AMENDING CERTAIN SECTIONS OF C.O.S., PARTICULARLY TO 921 C.O.S, ENTITLED "WATER SYSTEM FEES AND USER CHARGES," TO INCREASE CERTAIN WATER RATE FEES FOR USERS OF THE CITY OF STOW'S WATER SYSTEM

2026-137 Ch. 921 - 921.03 User Charges - Water Rates.pdf

2026-137 V2 Ch. 921 Water Increase - Coffey Proposal.pdf

2026-137 V3 Ch. 921 Water Increase - Feldman Recommendation.pdf

Mr. Riehl introduced the water-rate proposals. He noted that the finance director had presented an initial proposal at the previous meeting and that council members had submitted two more, from Councilwoman Kelly Coffey and Councilman Cyle Feldman. He hoped the committee could advance a proposal to City Council for consideration and a vote. Mr. Toppin stated that he had nothing new to add to his recommendation from last meeting.

Mrs. Coffey proposed applying the administration's 25-cent accelerator over two years instead of four. She estimated that a $4 increase would generate about $800,000 in additional capital revenue—enough to cover the average capital deficit and help fund smart meters and water-line work. She said the operating-revenue impact depended on water usage but was expected to cover the roughly $200,000

operating deficit. The increase would raise the bill by about 20% over two years, or approximately 10% per year. Mrs. Coffey said she did not want to charge residents in advance for a water tower before the city had discussed or committed to it. Mrs. ReVay cautioned that a tower was likely needed within five years and had been estimated at $18 million, so future water needs should be considered when setting rates. Mrs. Coffey agreed and said the city could reassess rates in two years if it chose her proposal.

Mr. Feldman said he had tried to balance the city's infrastructure needs with residents' ability to afford higher bills. He noted that the last water-rate increase had been in 2011, and cited aging water lines, frequent main breaks, and the planned replacement of water meters. After considering several options, he proposed a 38-cent increase, which he estimated would add $2.76 per month or $33.12 per year, an amount some residents he had spoken with considered reasonable. Mr. Baranek said the city's fixed water rates had not increased since 2005, aside from pass-through increases in Akron's water-supply charges, leaving the city behind on costs. He supported Mr. Feldman's proposal because it phased in increases over four years and could be revisited by Council. He also noted that new meters might increase revenue by more accurately recording water use.

Mrs. Coffey said smart meters could bring in additional revenue. She cited information from Mr. Smith that 14 million gallons of water were unaccounted for and said smart caps on hydrants could help address the loss, potentially adding about $800,000 in revenue. She argued for a slower rate increase so the city could review the results first. She also said Mr. Feldman's proposal would raise her bill from $40 to $60, a 50% increase.

Ms. Young said she did not want the city to keep postponing difficult decisions. She argued that because water rates had not increased since 2011, a rate increase was warranted, especially given water main problems and the operating-budget deficit. She said she had favored Mr. Toppin's proposal and supported Mr. Feldman's proposal as well.

There was no motion to forward the Finance Department's proposal to City Council agenda.

Motion made by Kelly Coffey, seconded by Mario Fiocca, to forward to this evening's regular council meeting Version 2, Kelly Coffey's proposal for rate increases. Vote – Yeas: Kelly Coffey, Mario Fiocca. Nays: Matt Riehl, John Baranek. Motion failed.

Motion made by John Baranek, seconded by Matt Riehl, to forward to this evening's regular council meeting Version 3, Cyle Feldman's proposal for rate increases. Vote – Yeas: Matt Riehl, Mario Fiocca, John Baranek. Nays: Kelly Coffey. Motion carried.

Mr. Riehl stated that Version 3 would move forward to the Council agenda.

Public Comment Period

There was no public comment this evening.

Adjournment

Motion made by Kelly Coffey, seconded by Mario Fiocca, to adjourn. Vote – Yeas: Matt Riehl, Kelly Coffey, Mario Fiocca, John Baranek. Nays: None. Motion carried unanimously.

The meeting adjourned at 6:48 PM.

Clerk

Chairman

City of Stow
Tradition Centered. Future Focused.

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Electrification in Stow, Ohio

The value stack from resilient operations and infrastructure

Michael Benson, MPA

Public Safety for 30 years

Electrification for 9 years

Environmental Commission -> Electrification

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Emissions Reduction

- What to do?
- Where to start?
- How to pay for it?



Electrification Strategy

- First, use less energy (Efficiency)
- Switch to electric with what you control:
  - Building systems
  - Transportation
  - Tools
  - Equipment

Municipal electrification is unique

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Your city requires resiliency

- Mission-Critical
- More than a backup
- Oversized for your worst day plus
- Smart, proactive
- Small, local systems (microgrids)
- Hubs for disaster support



Microgrids

- Designed specifically for you
- Based on your infrastructure
- Energy storage and controls
- Allows for clean energy sources
- Rooftops and parking lots
- Paired with legacy equipment



Resiliency, something to bank on

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Economics



- “Free” energy sources
- Efficiency = money
- Storage is energy time machine



  - Arbitrage (buy low sell high)
  - Hedge against increasing costs
- Microgrid sized for your worst day and available everyday



  - Virtual Power Plant grid services (PJM)
  - Cheapest energy source by situation

Financing

Other People’s Money (OPM)



- Limit capital expense
- Energy as a Service (EaaS - PPA)
- Energy Savings Performance (ESPC)

Traditional Finance



- ROI at government pace

Valuing the project:

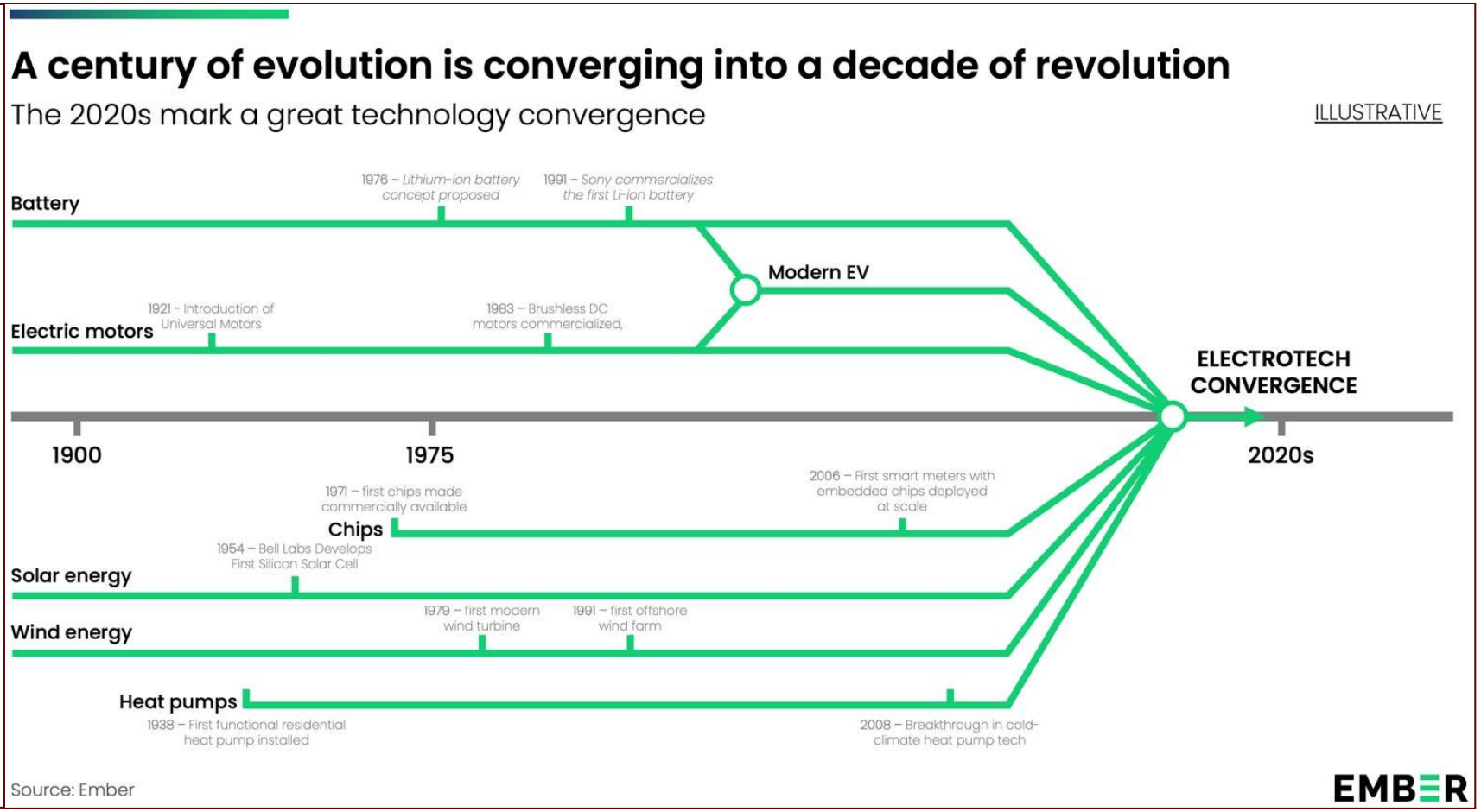
- Add up the avoided costs
- Include the value of resiliency
- An investment, not a cost

It is time for “Electric First”

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Buying Electric

- Now cheapest & best
- Equipment & tools
- Appliances, HVAC, Geothermal
- Vehicles (seriously)
  - Better, faster, cheaper
  - Total Cost of Ownership
- Risk avoidance, stranded assets



Electrification Feasibility Study is the next step

COMMAND CONSULTING, L.L.C
SOLUTIONS THAT WORK

Michael Benson, MPA

Co-Owner, Command Consulting LLC

330.620.2048

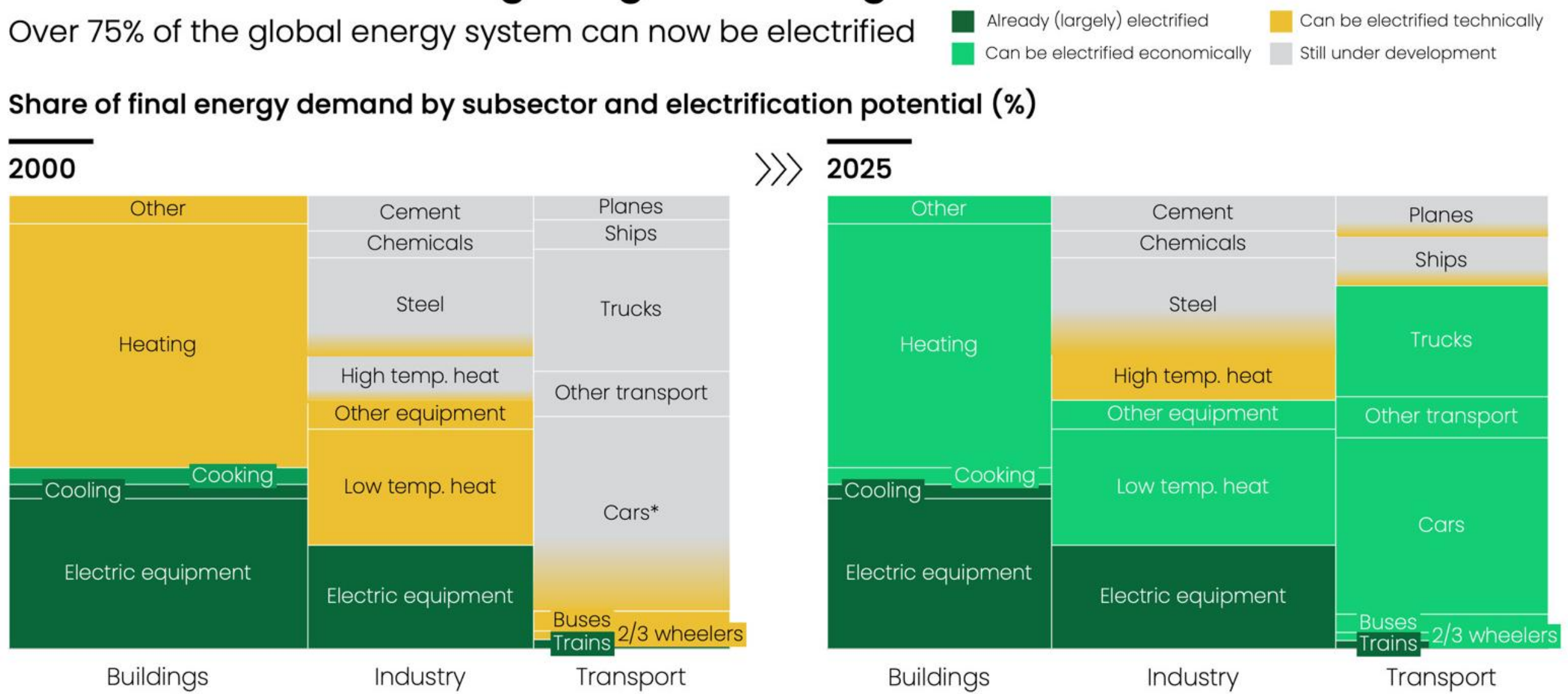
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linkedin.com/in/michael-benson-mpa

The electrification ceiling is high and rising

Over 75% of the global energy system can now be electrified



Sources: IIASA; IEA; BNEF; Ember analysis • Note: excluding feedstock *Technologies available for subset of total end-use with a clear path to expansion

This is a technology revolution in energy

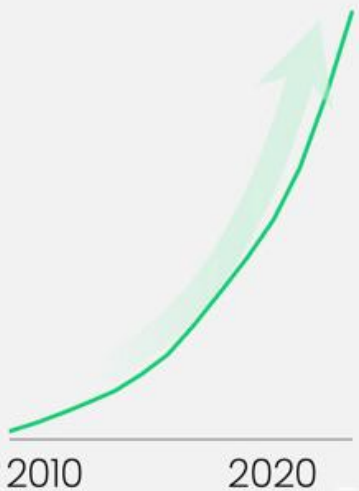
Electrotech is technology that revolutionises the supply, connection and demand of electricity

Supply

New ways to generate electricity

Renewables as vectors of change

Solar PV
deployment (GW)



Wind
deployment (GW)



Connections

New ways to transport and store electricity

Flextech/gridtech as vectors of change

Battery storage
deployment



HVDC lines
deployment (km)



Demand

New ways to use electricity

Electrification as vector of change

EV
sales



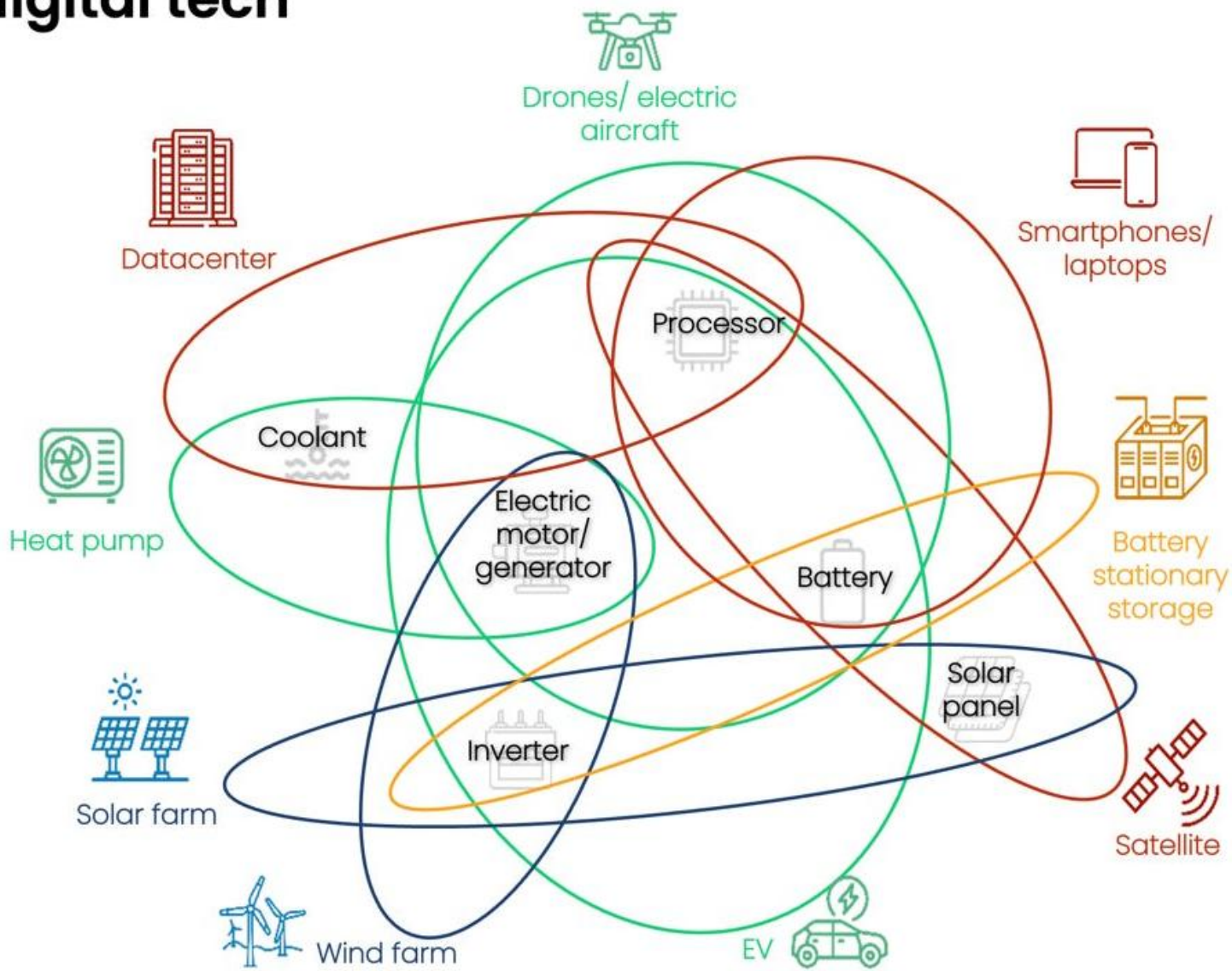
Heat pumps
sales



Sources: Ember, IEA, RMI, Thunder Said

Electrotech is the child of digital tech

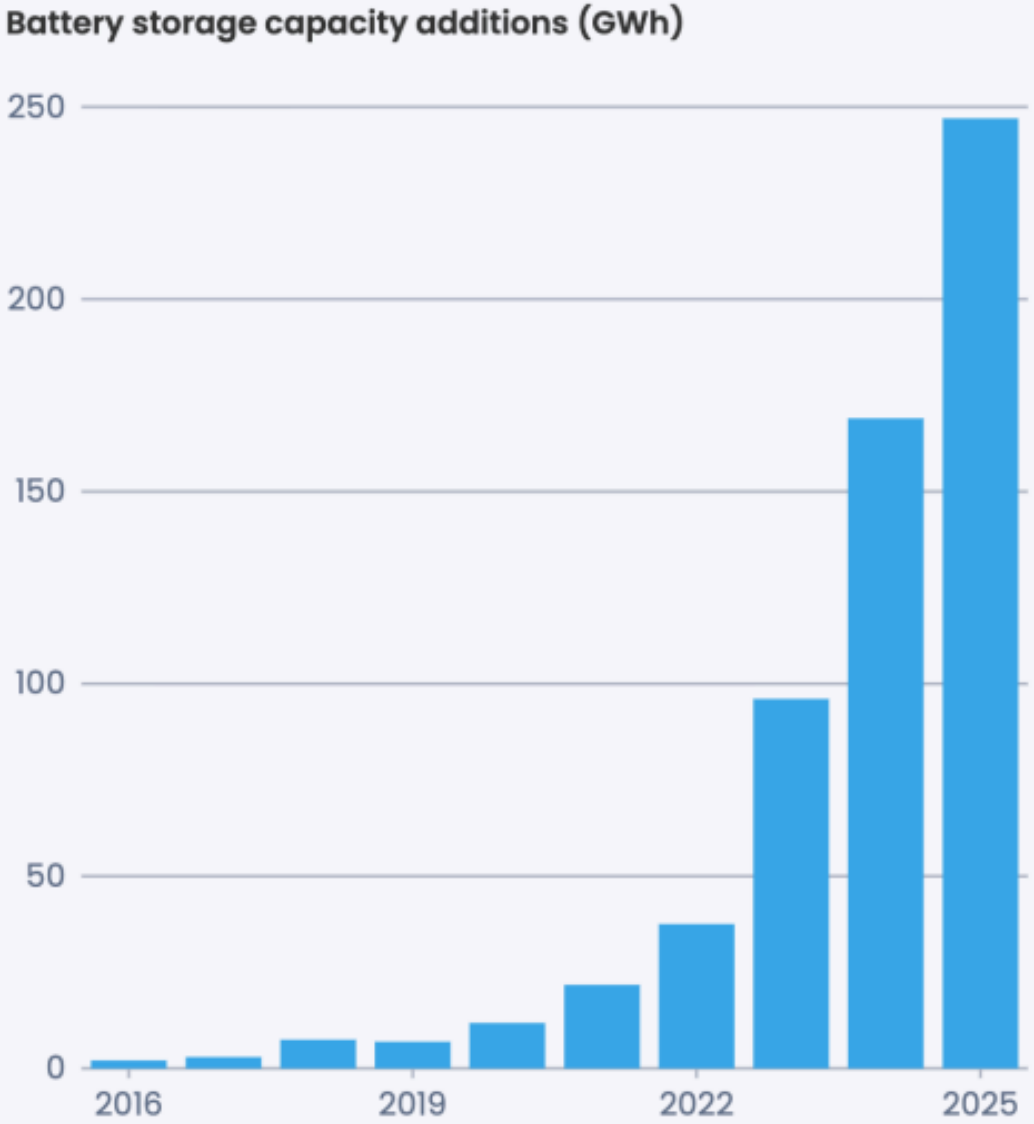
Electrotech is made of the same components as digital tech, and inherits its momentum



Source: Ember analysis

Battery prices continued their free fall in 2025 while installations are surging





Source: BloombergNEF • Volume-weighted average prices in 2025 real USD
2025 capacity additions are projected

EMBER

EMBER

The Electrotech Revolution

The shape of things to come



Daan Walter
Sam Butler-Sloss
Kingsmill Bond, CFA

September, 2025

The Age of Electrotech

Humanity is graduating from burning fossil commodities to harnessing manufactured technologies—from hunting scarce fossils to farming the inexhaustible sun, from consuming Earth's resources to merely borrowing them.

This isn't a marginal climate substitution. It's an energy revolution.

The magnetic centre is the electron: we are revolutionising how we generate, use, and connect electrons. Solar and wind are conquering electricity supply. EVs, heat pumps, and AI are electrifying major new uses. Batteries and digitalisation are connecting supply and demand.

Three reinforcing shifts. One energy revolution. The electrotech revolution.

At its core, this revolution is driven by physics, economics, and geopolitics. After all, the arc of energy history bends towards solutions that are leaner, cheaper and more secure.

Short-terms setbacks matter, but fundamentals matter more. And the fundamentals are stacked in electrotech's favour.

Physics. Electrotech makes a mockery of setting fossils on fire and losing two-thirds of the energy to heat. Electrotech is three times as efficient.

Economics. Technologies get cheaper with scale. Commodities get more expensive the deeper you dig.

Geopolitics. Three quarters of the world is dependent on fossil imports. 92% of countries have renewables potential over 10x their current demand.

Electrotech has grown exponentially for decades. The difference today is that it's too cheap to contain and too big to ignore. If current exponentials hold for five more years, global fossil demand will fall off its plateau.

Welcome to the Age of Electrotech.

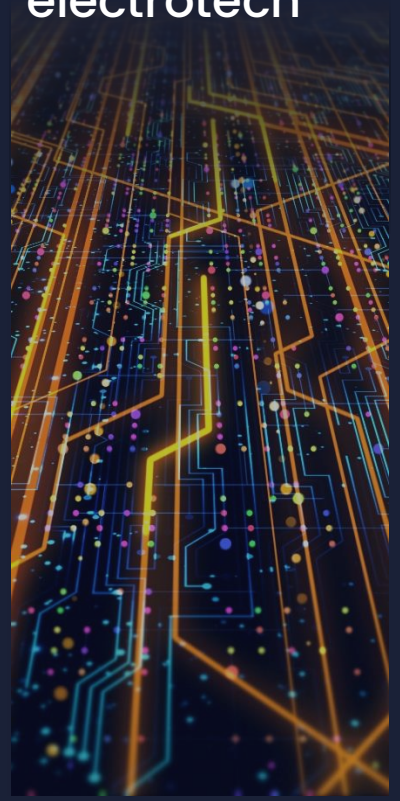
Daan Walter, Sam Butler-Sloss, Kingsmill Bond

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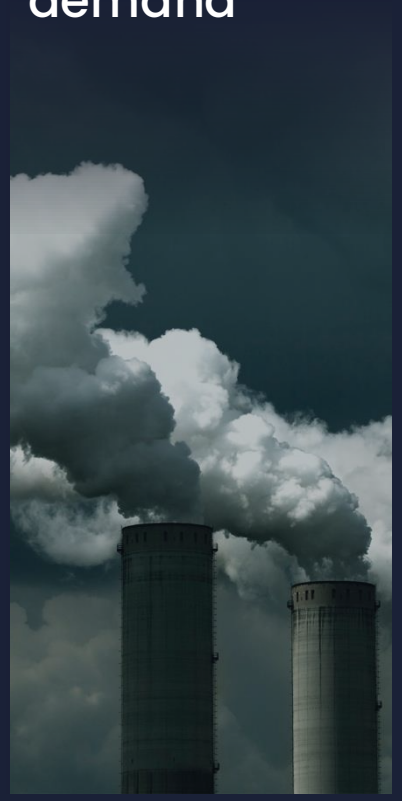
1 A new perspective



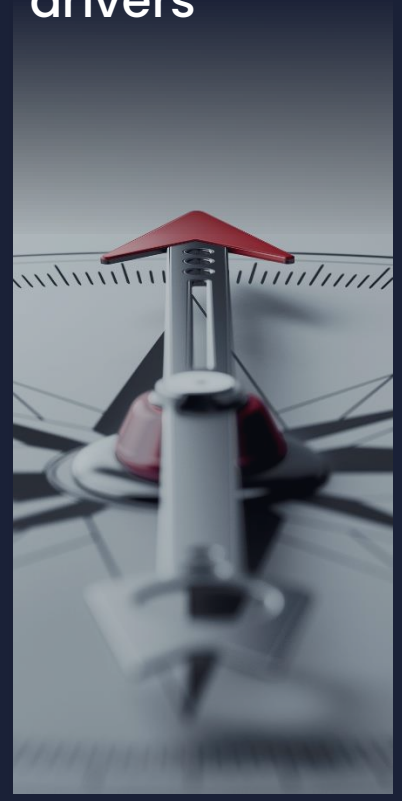
2 The rise of electrotech



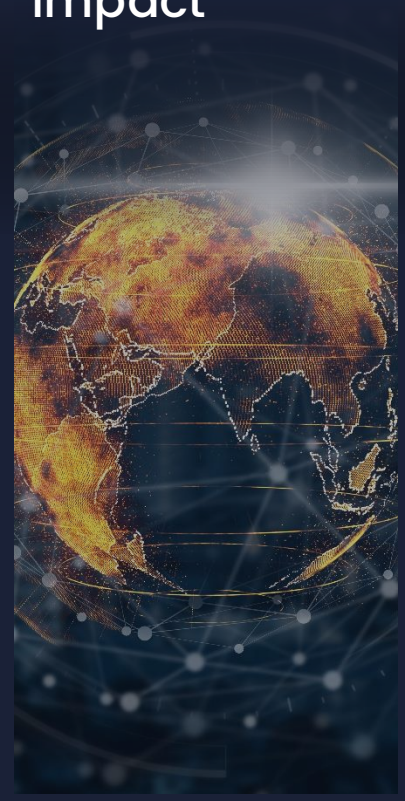
3 Peak fossil demand



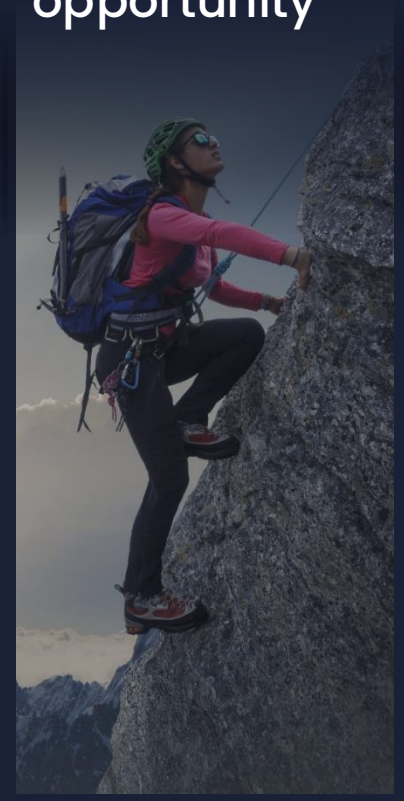
4 Fundamental drivers



5 Profound impact



6 Seize the opportunity



Chapter 1
A New Perspective: The Electrotech Revolution

01

Electrotech is a better way to explain reality

Most of the debate on the future of energy is between fossil gradualists and net zero advocates. We propose a third approach — the electrotech revolution — which better explains the extraordinary changes taking place in the energy system today.

02

Electrotech is electricity technology

Electrotech describes exponential energy technologies revolutionising how we generate, connect and use electrons – technologies enjoying learning curves and rapid growth, such as solar, wind, batteries, and digital solutions.

03

Electrotech releases 100x more energy

Electrotech enables us to harness the sun's enormous energy resources. The sun supplies Earth with as much energy every five days as all fossil fuel reserves combined. This makes possible a new energy era.

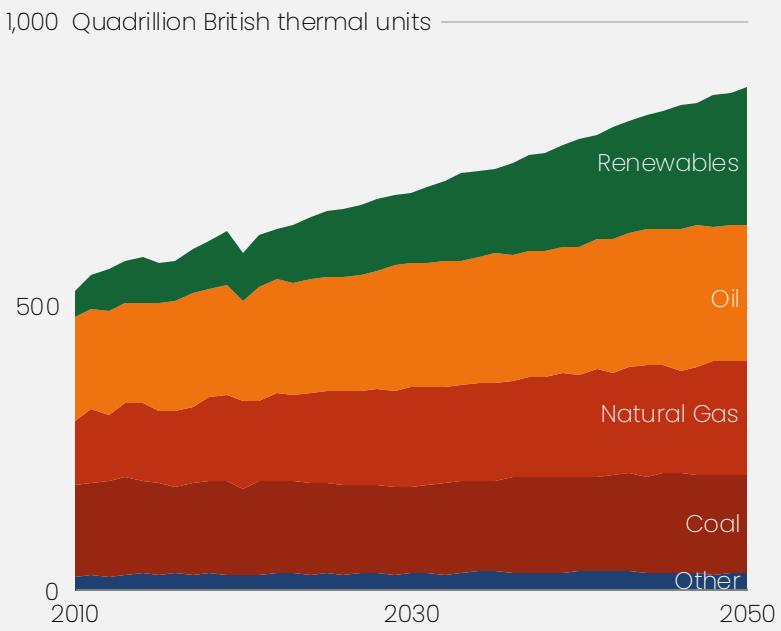
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Two views on energy dominate the conversation. We propose a third

The dominant energy views in the energy debate today

The incumbent energy view, centred on fossil fuels, slow change and business-as-usual

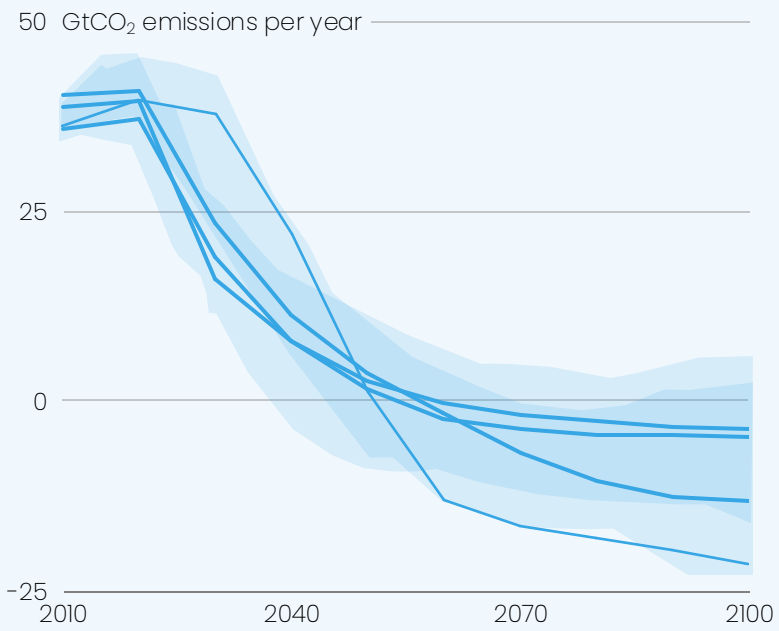
EIA – Primary energy supply



Source: Energy information Administration

The climate view, centred on emissions, policy targets and the moral obligation to fix climate change

IPCC – Pathways to net zero emissions

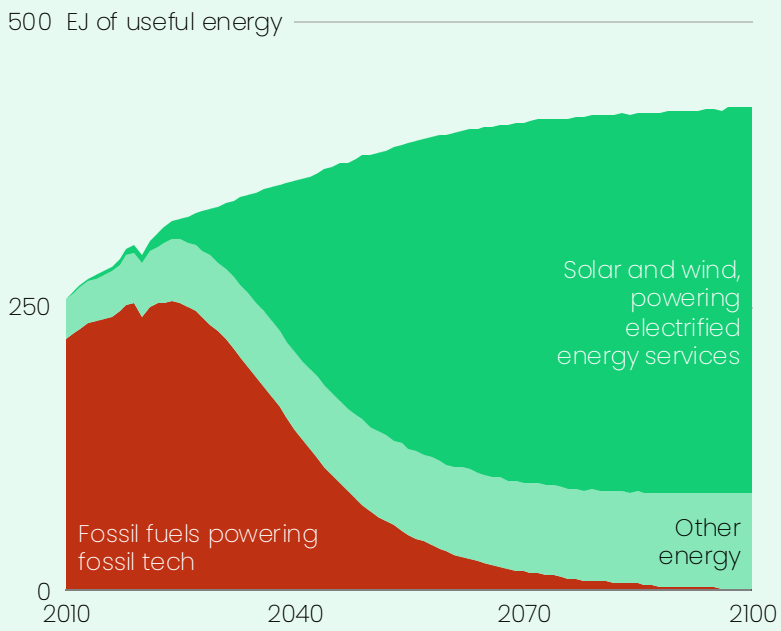


Source: Intergovernmental Panel on Climate Change (IPCC)

A third way: the electrotech view

The new electrotech view, centred on growth and innovation

Rystad – Global useful energy demand



Source: Rystad Energy

This is a technology revolution in energy

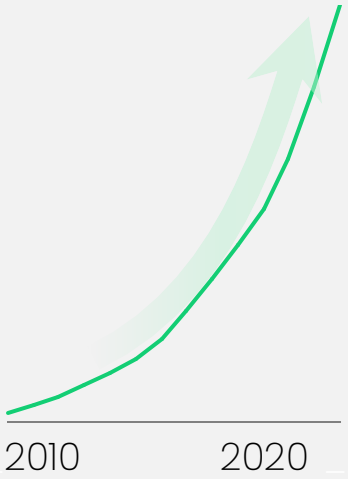
Electrotech is technology that revolutionises the supply, connection and demand of electricity

Supply

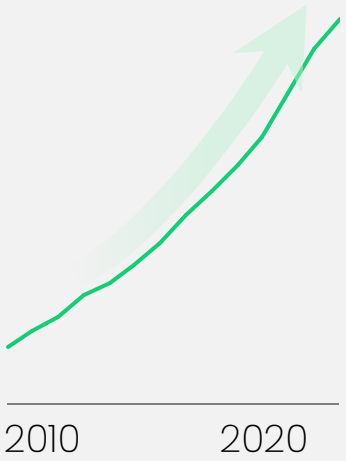
New ways to generate electricity

Renewables as vectors of change

Solar PV
deployment (GW)



Wind
deployment (GW)

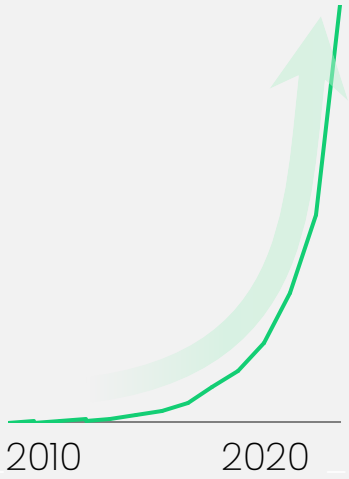


Connections

New ways to transport and store electricity

Flextech/gridtech as vectors of change

Battery storage
deployment



HVDC lines
deployment (km)

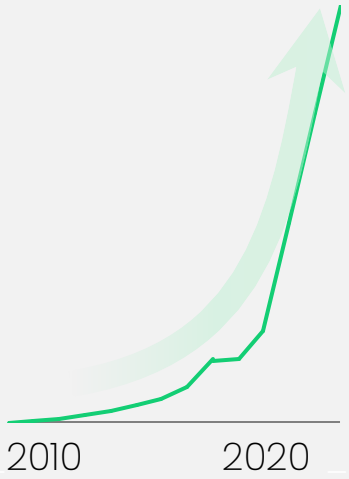


Demand

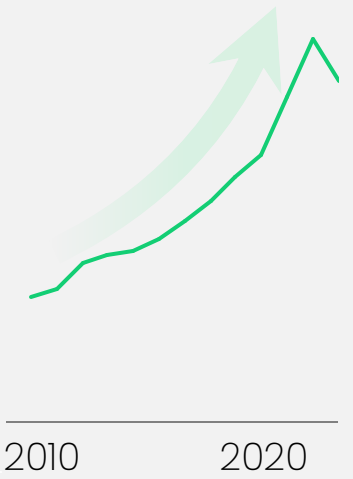
New ways to use electricity

Electrification as vector of change

EV
sales



Heat pumps
sales

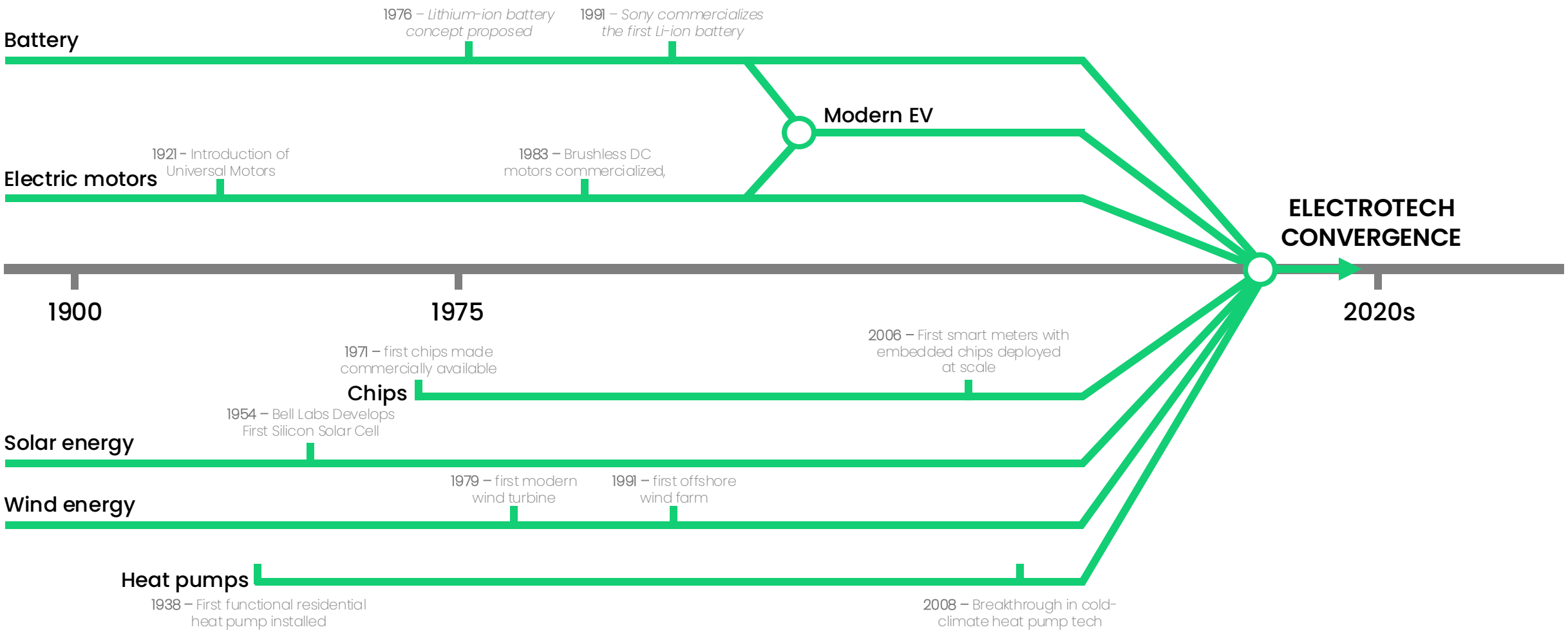


Sources: Ember, IEA, RMI, Thunder Said

A century of evolution is converging into a decade of revolution

The 2020s mark a great technology convergence

ILLUSTRATIVE



Source: Ember

This is the age of electrotech

It is the latest in a long line of technology shifts



Industrial Revolution
1st wave

Iron
Waterpower
Mechanisation



Age of steam and rail
2nd wave

Steam engines
Steam power
Rail



Age of steel and electricity
3rd wave

Electricity
Steel
Heavy engineering



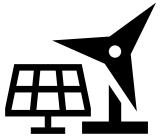
Age of oil and mass production
4th wave

Mass-produced automobiles
Cheap oil
Petrochem



Digital Age
5th wave

Information technologies
Telecoms
Software



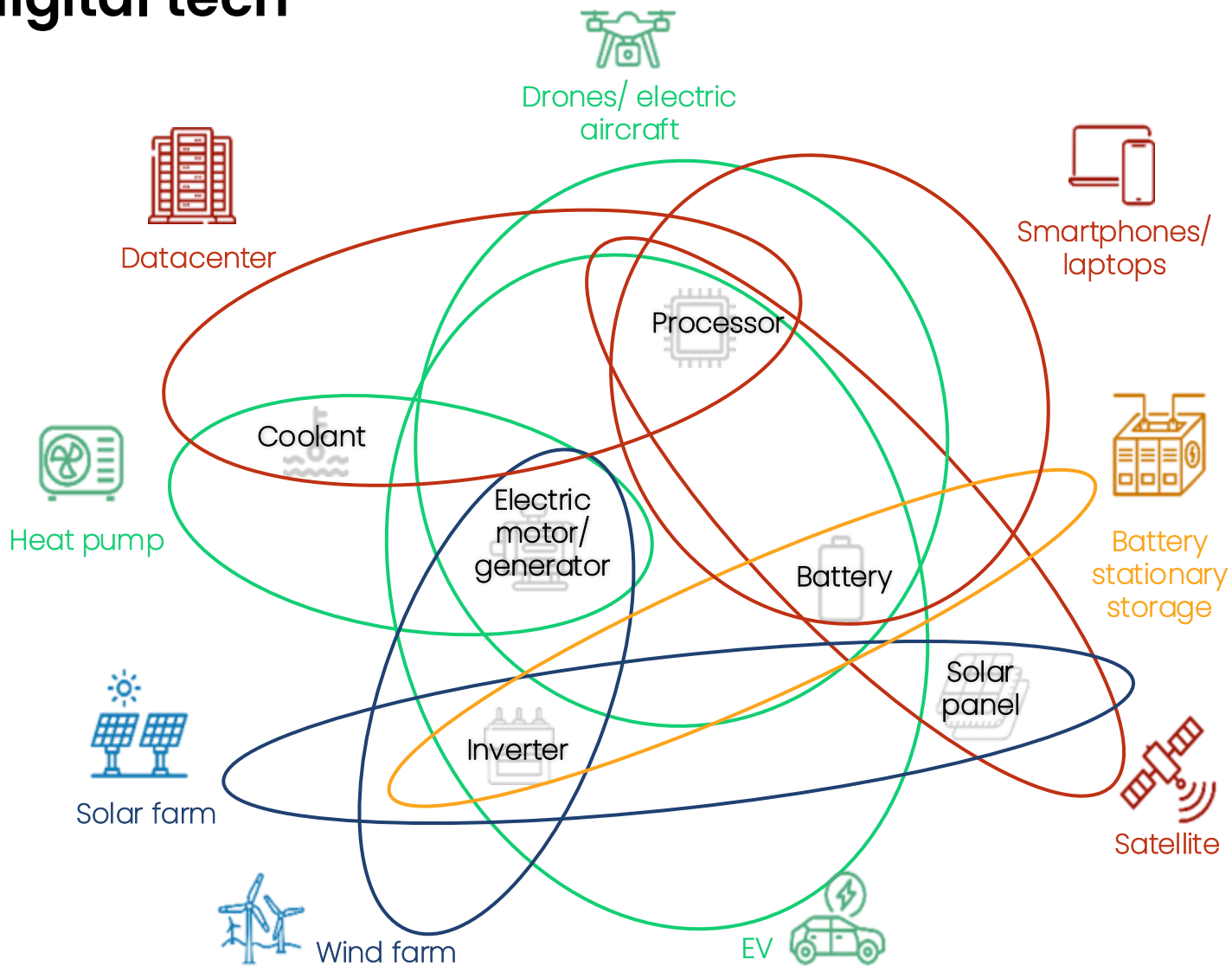
Electrotech Age
6th wave

Renewable energy
Electrification
AI

Sources: Carlota Perez (first five waves), Ember Futures (6th wave)

Electrotech is the child of digital tech

Electrotech is made of the same components as digital tech, and inherits its momentum

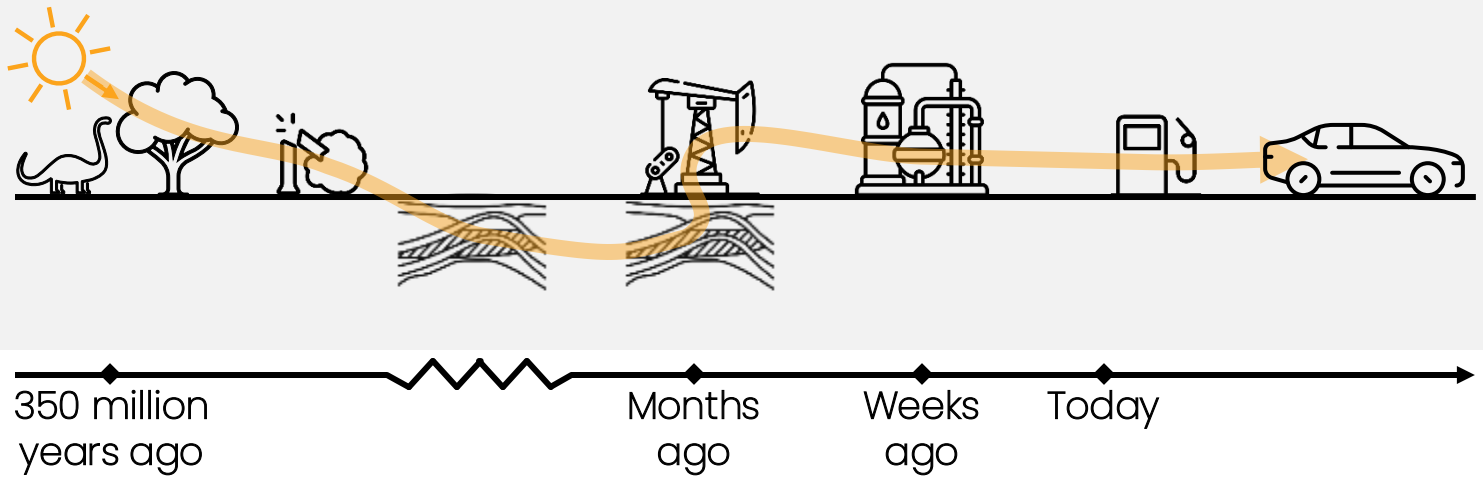


Source: Ember analysis

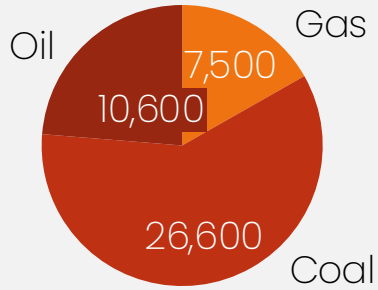
From burning old sunshine to using it real-time

The sun supplies more energy to Earth every 5 days than all fossil fuel reserves

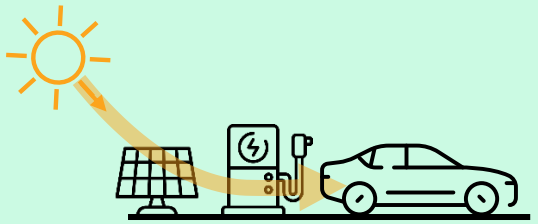
Fossil fuels



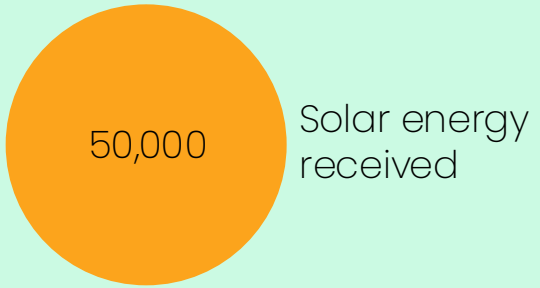
Total terrestrial energy reserves for the rest of time, current estimates, global, EJ



Electrotech – solar



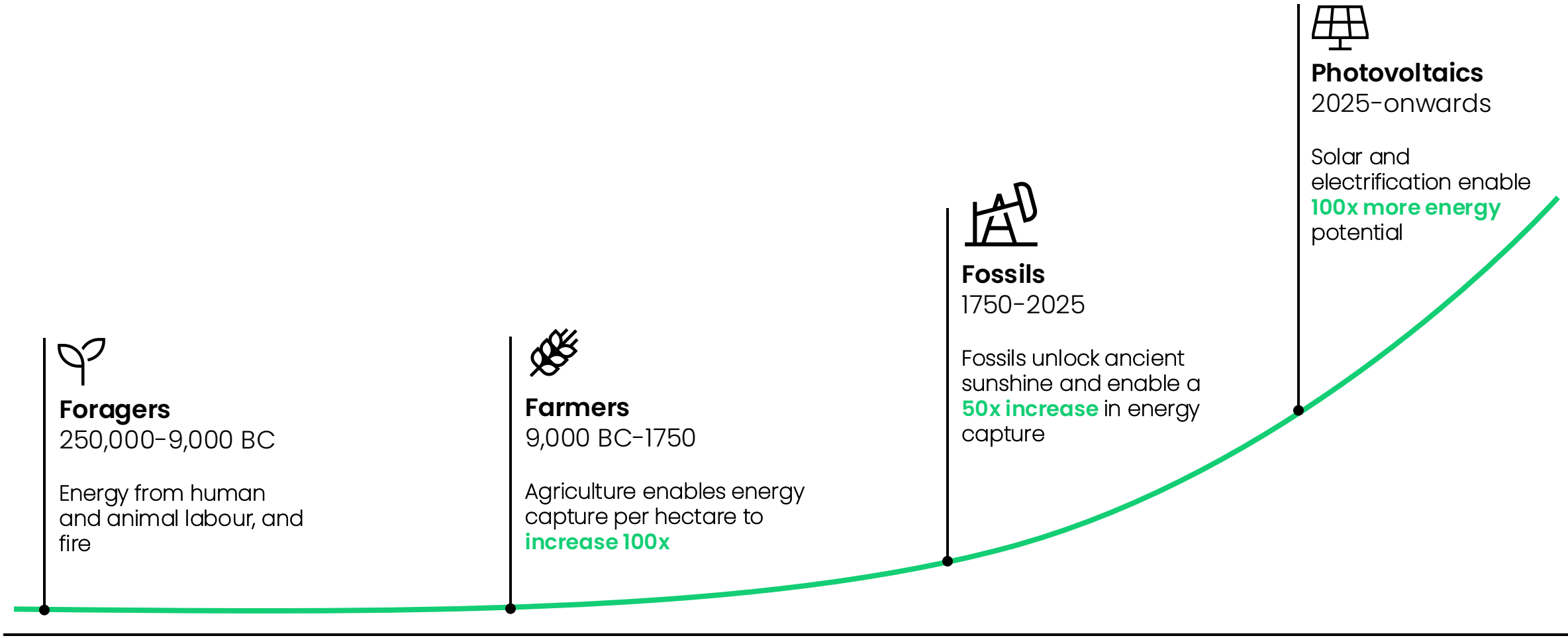
Solar energy received from the sun every 5 days, EJ



Sources: EI; Ember analysis. Note this is all solar energy received by the earth. We only need to extract a small fraction of it.

Foragers, Farmers, Fossils, Photovoltaics

Electrotech enables another 100x leap in energy abundance



Sources: Ian Morris: Foragers, Farmers and Fossil fuels; Carbon Tracker: The Sky's the limit; Ember framing.

Chapter 2
The rise of electrotech

01

Electrotech costs have fallen fast

Electrotech costs have been falling for decades on established learning curves of around 20% for every doubling in deployment. They now challenge fossil fuels on cost, with Dolphin EVs retailing in China below $10,000 and solar-plus-storage in India at $40 per MWh. As a result, capital is shifting, and two-thirds of energy expenditure is going into electrotech.

02

Growth has been exponential

Key electrotech technologies have enjoyed exponential growth. We see this for generation (solar and wind), connections (batteries and software) and usage (EV and heat pumps). Change is led by China, and is now cascading into the emerging markets. ASEAN, for example, leapfrogged the US in electrification in 2023.

03

The ceiling of the possible is high above us

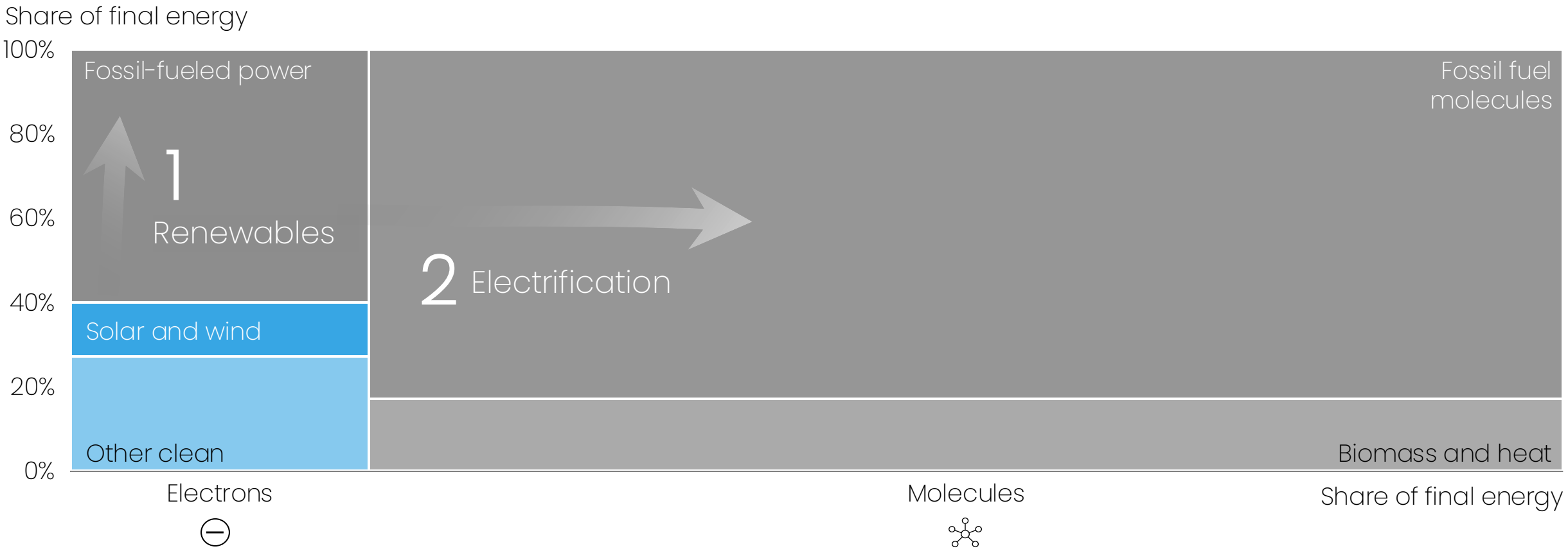
We already know how to get solar and wind to 70-80% of generation at a cost comparable with fossil fuels and how to electrify around 75% of end demand. So we can more than triple renewables and electrification.

>> Return to Table of Contents

The two vectors of the energy transition

Renewables replace fossil electricity; electrification replaces fossil molecules

Global final energy demand in 2023

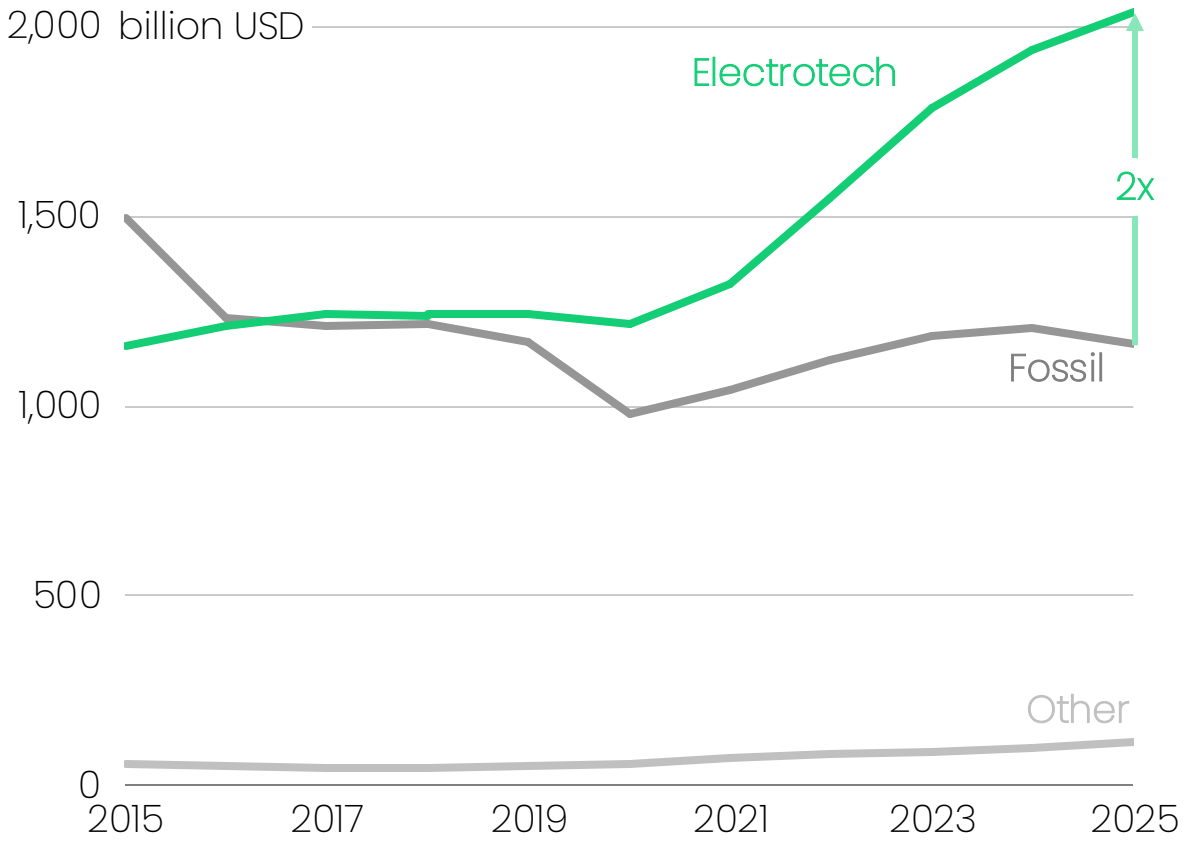


Sources: IEA WEO 2024; Ember analysis. Other clean electrons are mainly nuclear and hydro.

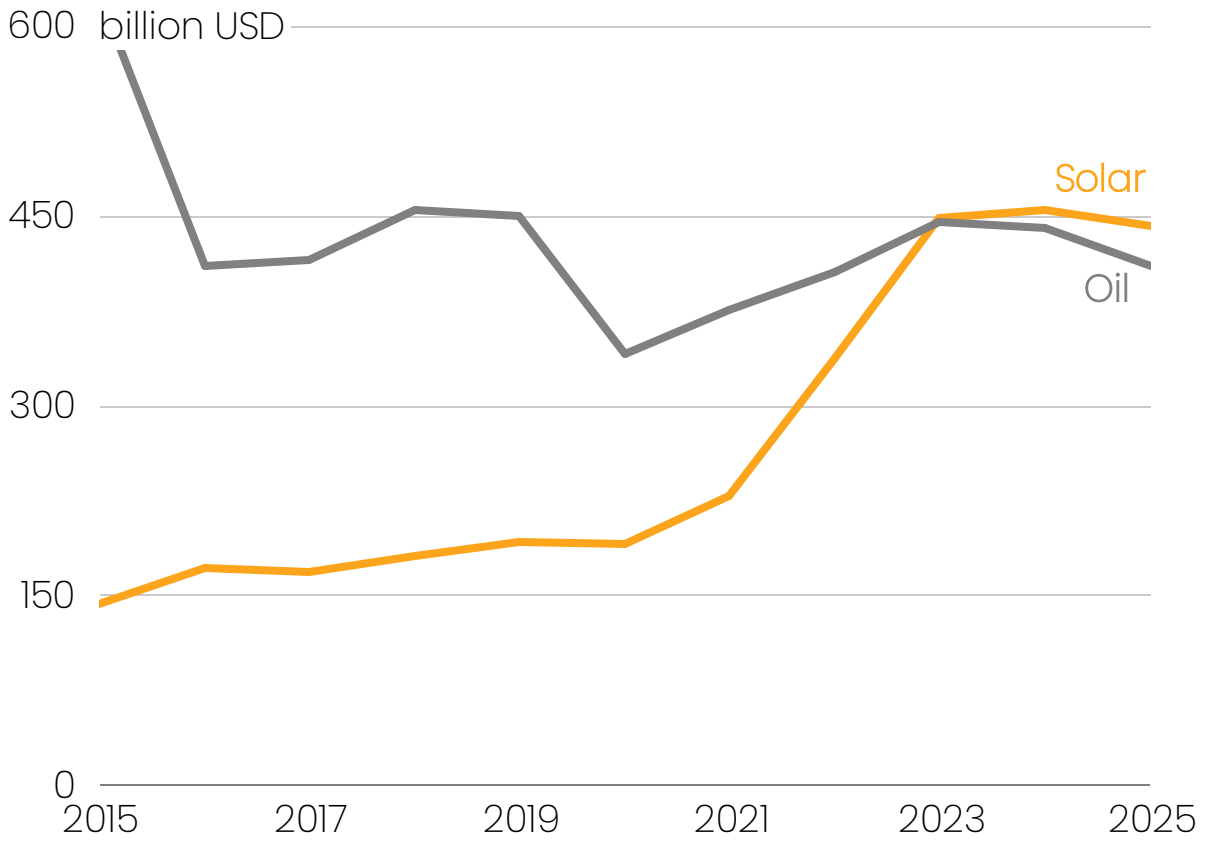
Electrotech investment is twice as big as fossils

And we spend more on solar capex than on oil

Energy investment by category



Solar and oil investment

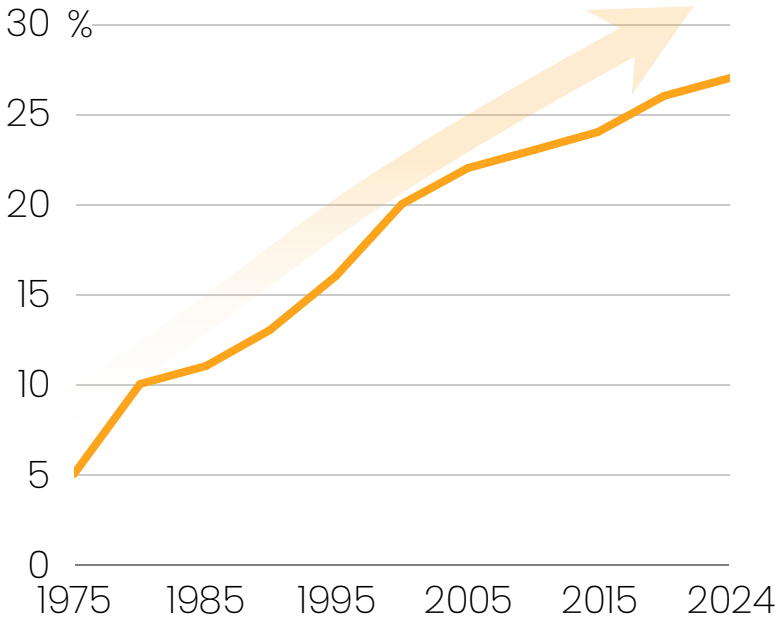


Sources: IEA WEI, Ember analysis – Note: Oil investment on the right hand side is upstream investment

Electrotech keeps getting better

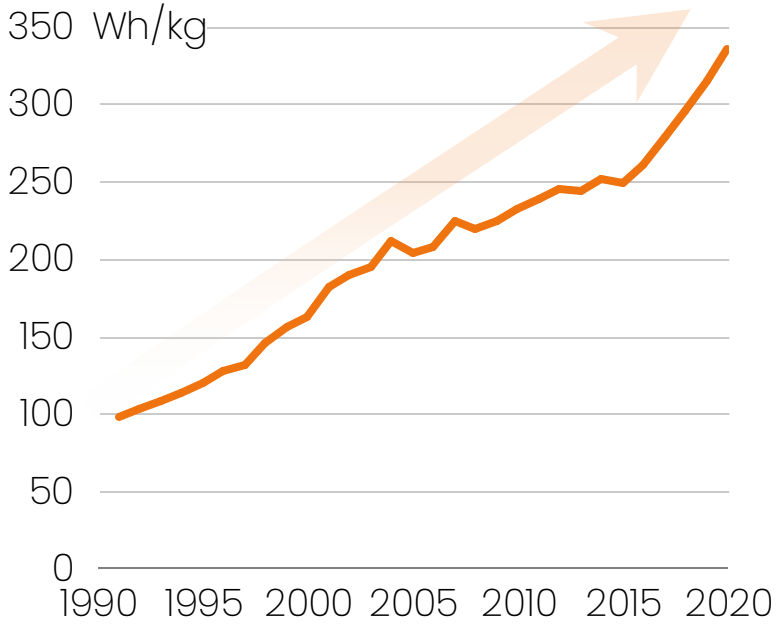
Decade after decade of innovation raises the ceiling of the possible

Solar cell efficiency



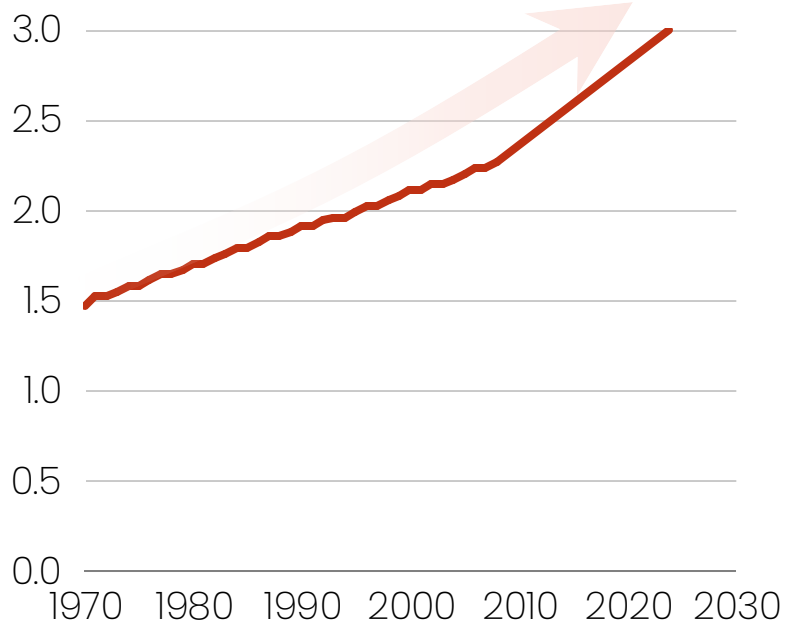
More efficient solar cells mean more space and material efficiency and lower cost

Top-tier battery cell density



Denser batteries mean longer EV ranges; new EV applications opening up and more material efficiency

Heat pump coefficient of performance, US sales average



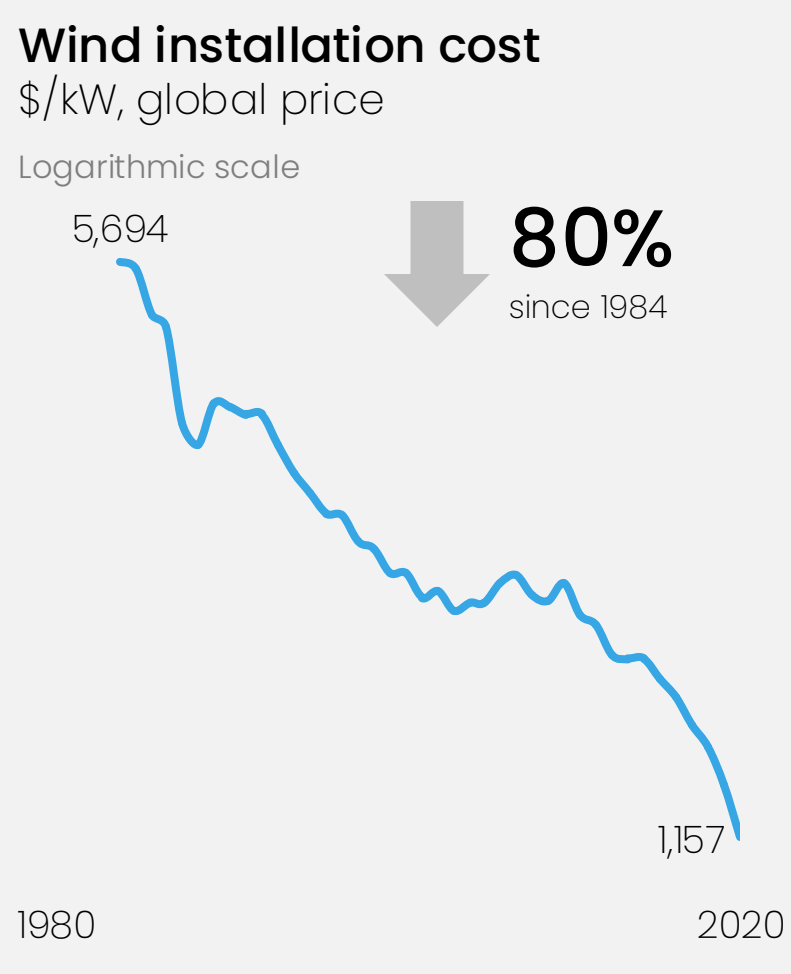
Higher COP means a more efficient and powerful heating system

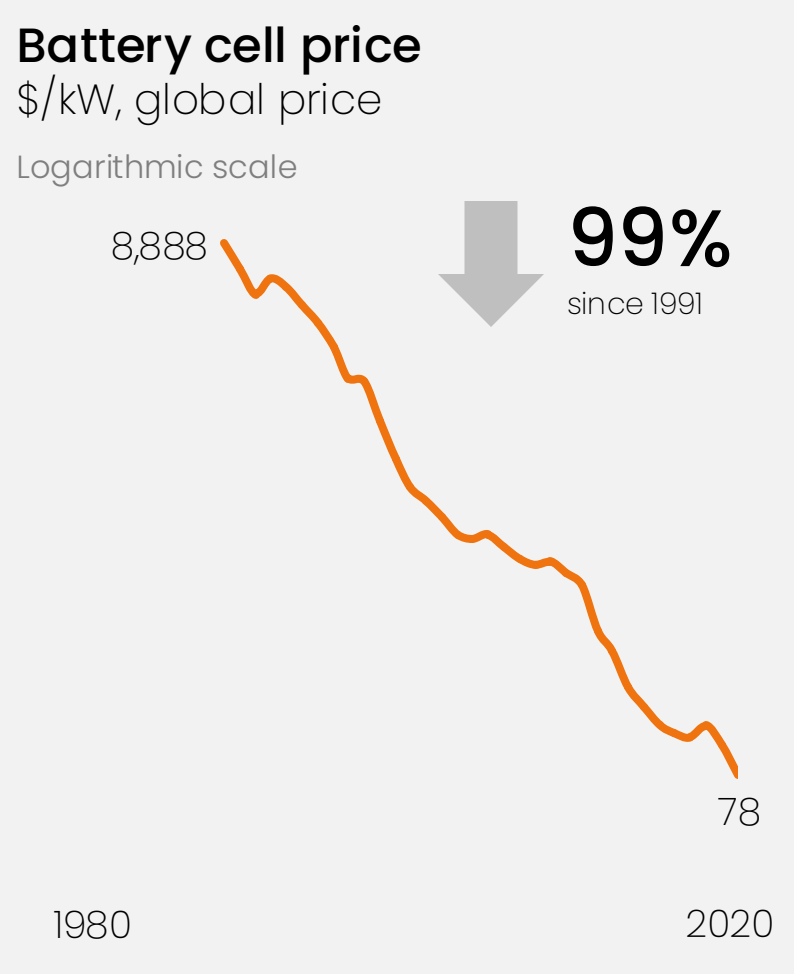
Sources: RMI X-Change Batteries, US DOE, US NREL; Ember analysis

Costs have been falling for decades on learning curves

Decades of steady cost innovation improved electrotech economics



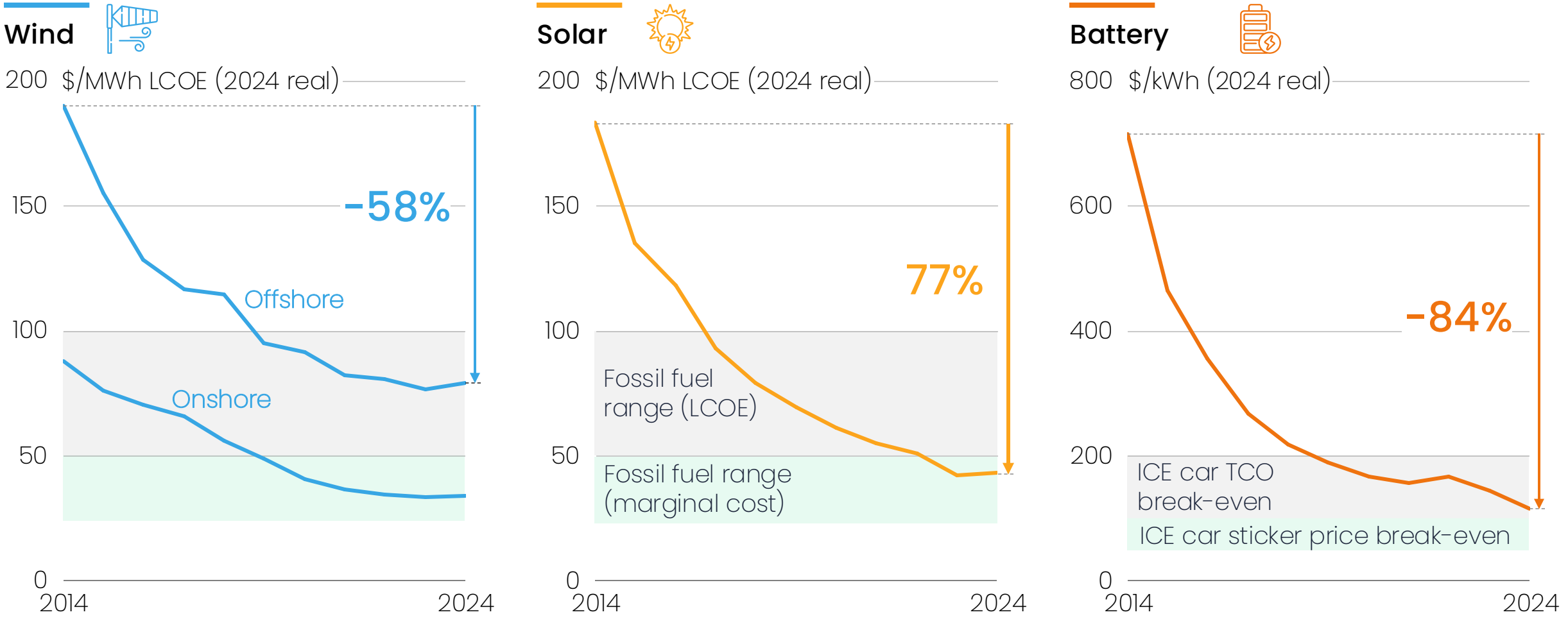




Sources: OWID; IRENA; BNEF/Avicenne

Cheap enough to challenge incumbents

After decades of cost innovation electrotech is now cheaper than fossils

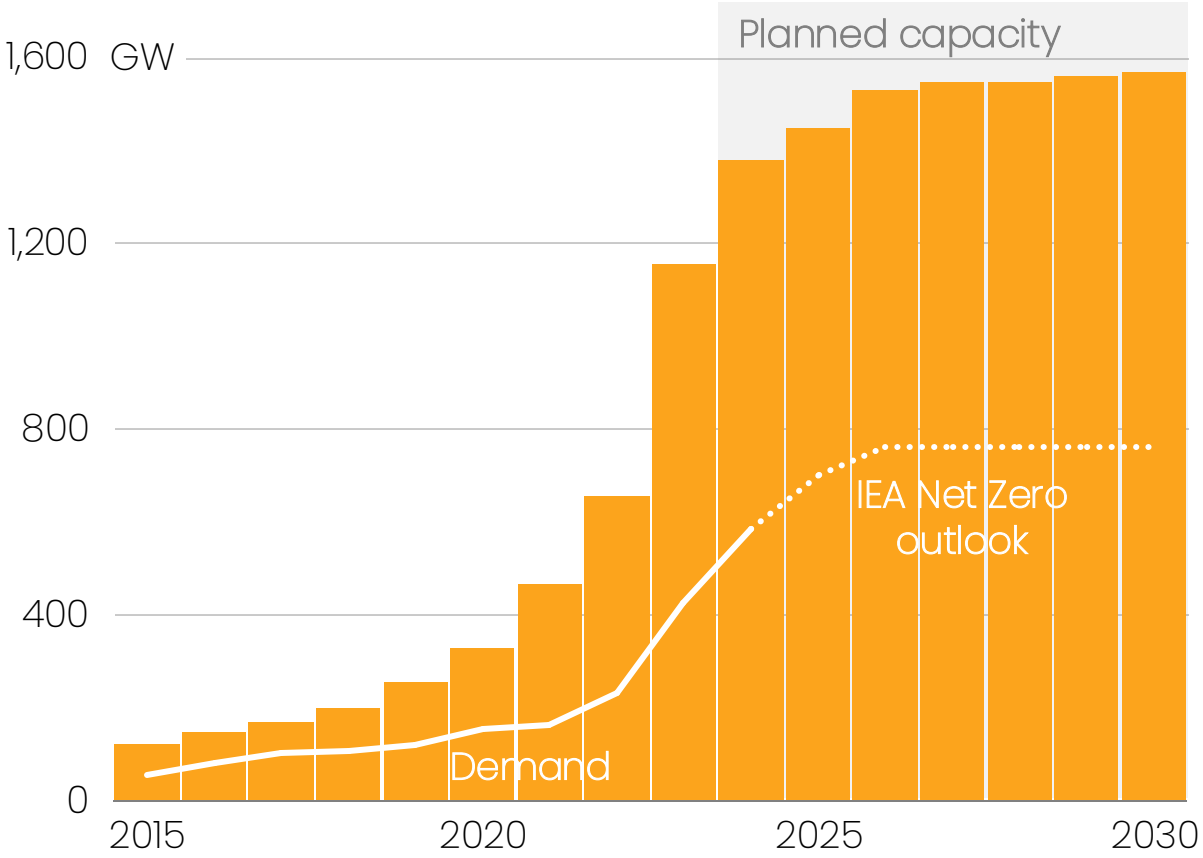


Sources: IRENA, BNEF (Batteries), Ember

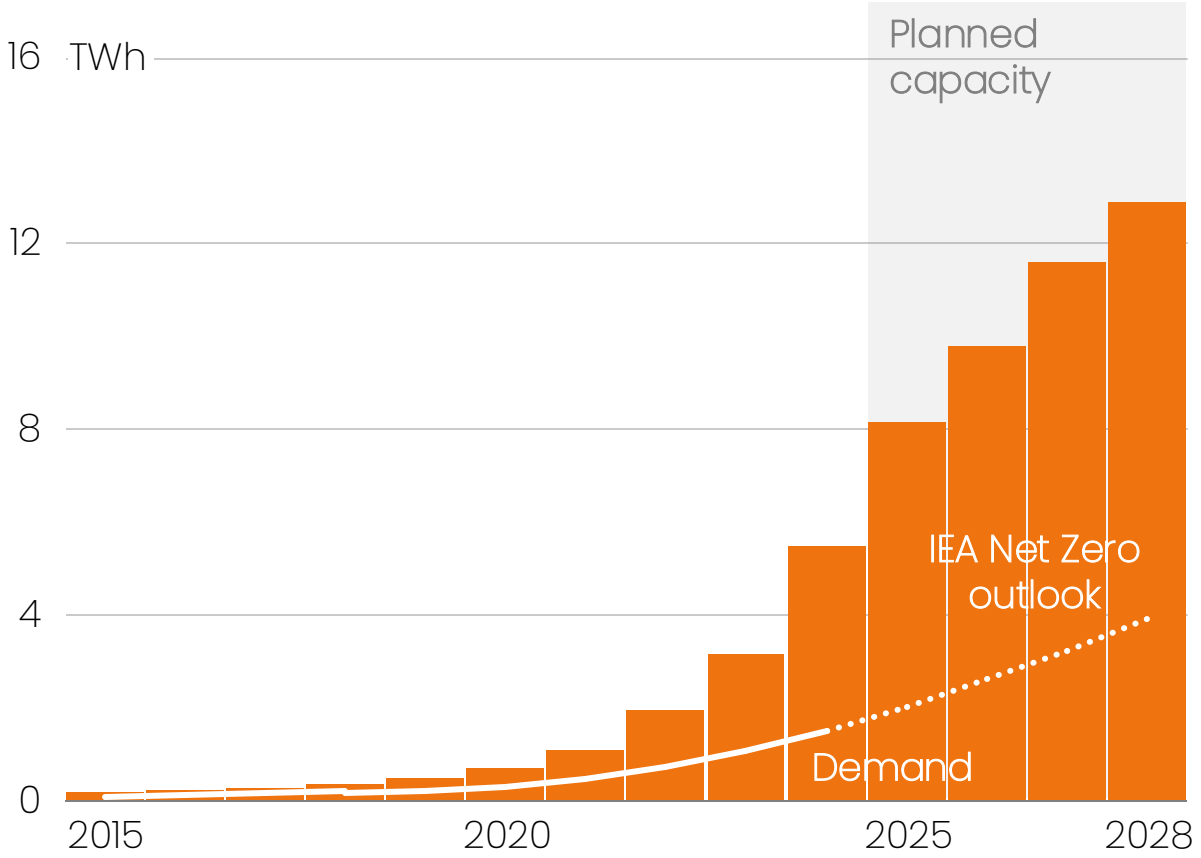
The manufacturing capacity is in place

Outpacing projected demand of even net zero scenarios

Solar PV manufacturing capacity



Battery manufacturing capacity

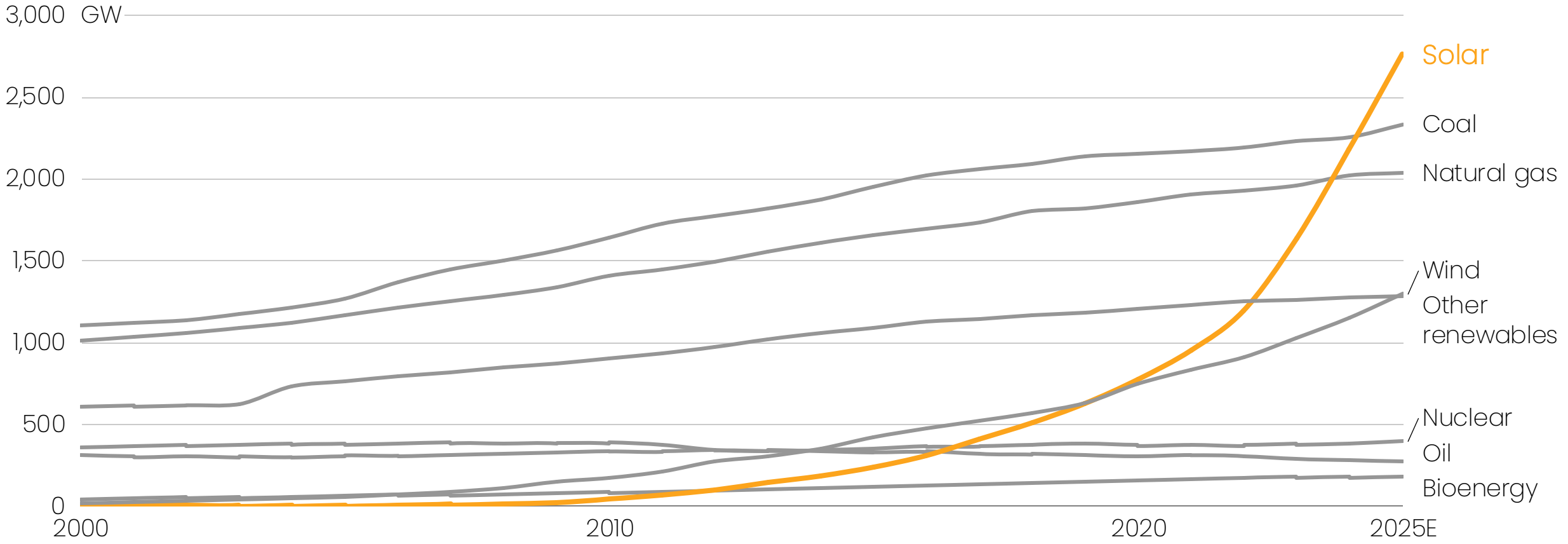


Sources: IEA; Ember analysis. The IEA net zero outlook is chosen as an illustration that capacity is above even this level.

Sunrise

Solar has gone from smallest to largest source of capacity in 15 years

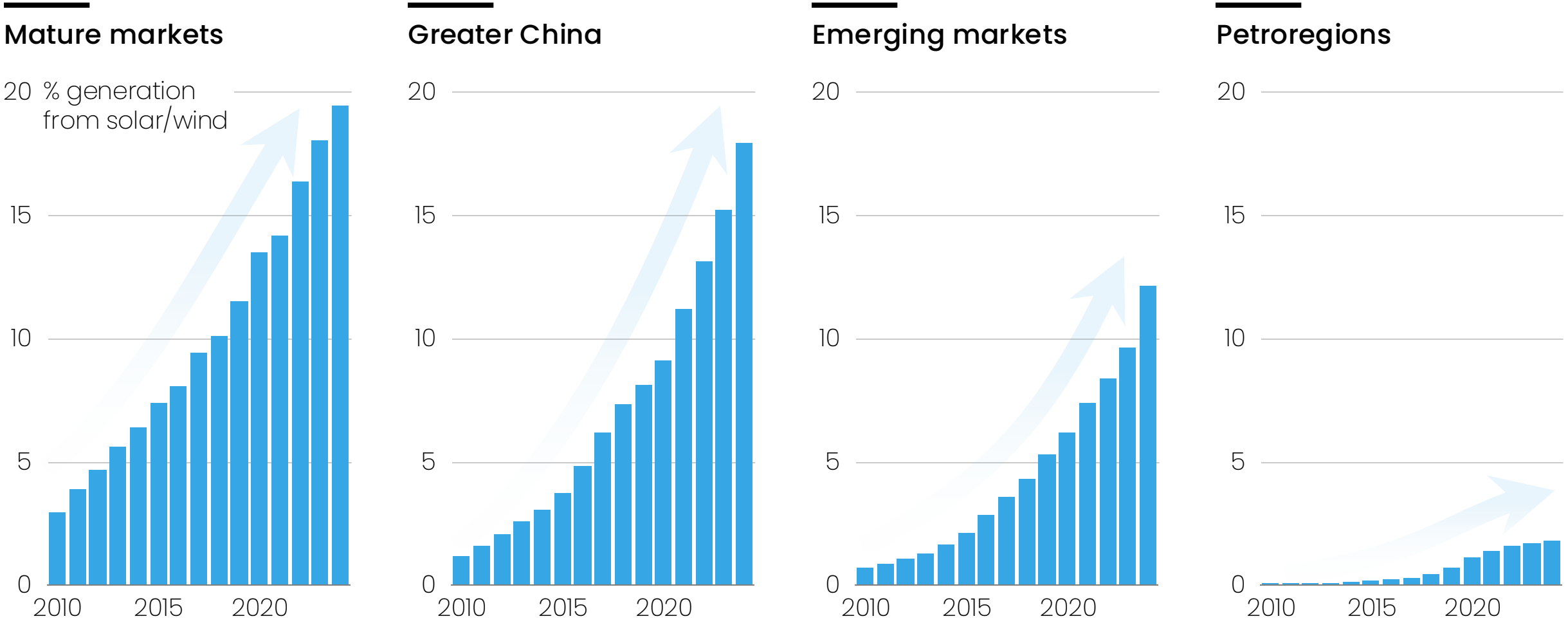
Global installed electricity capacity



Sources: BNEF

Solar and wind deployment is a global story

From mature economies to emerging markets

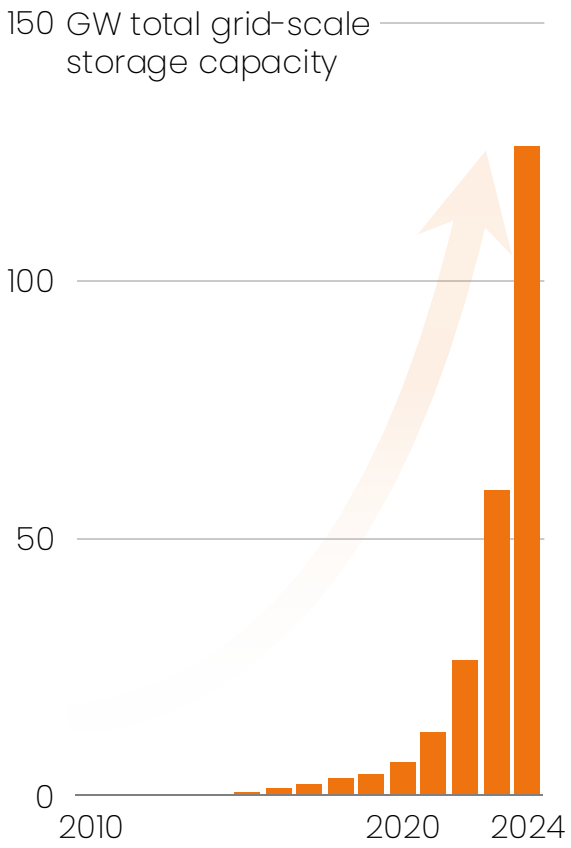


Sources: Ember. Note: Emerging markets include Latin America, Africa, South Asia and Southeast Asia; Petroregions include the Middle East and Eurasia.

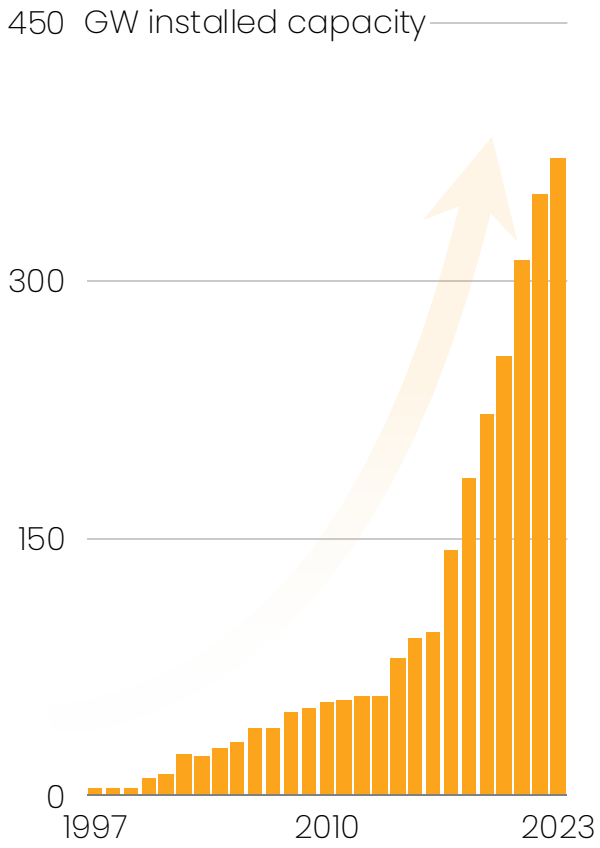
The rise of new connections

Flextech and gridtech smartly connect supply and demand

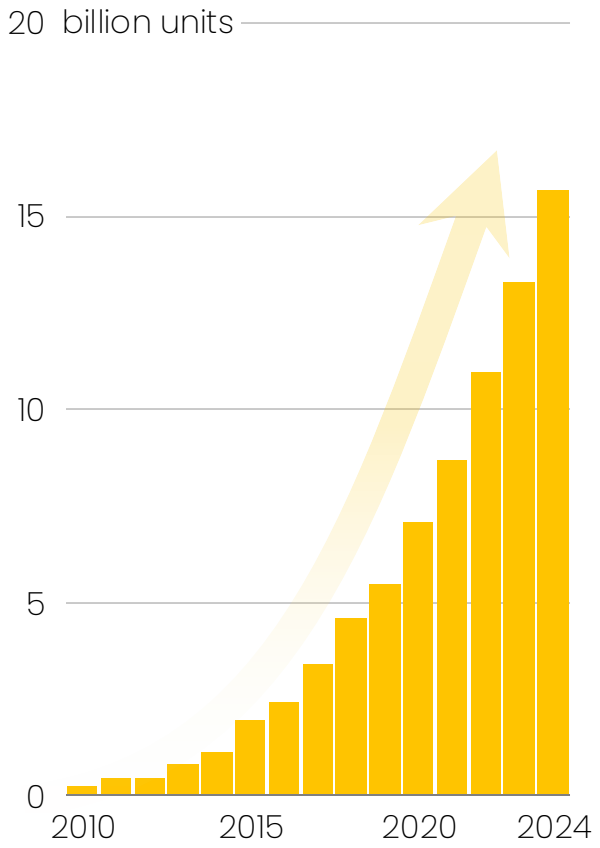
Battery storage capacity



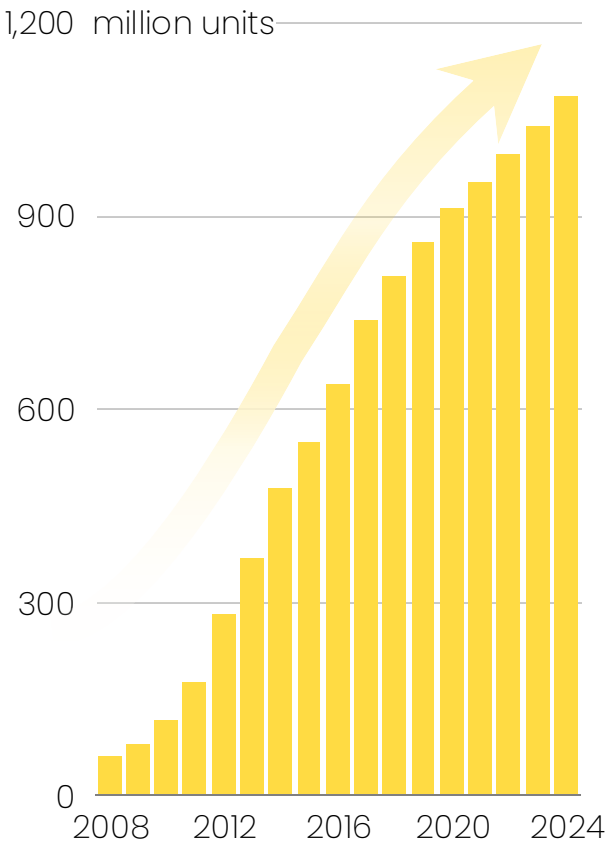
High voltage DC transmission



Internet connected devices



Smart meters installed

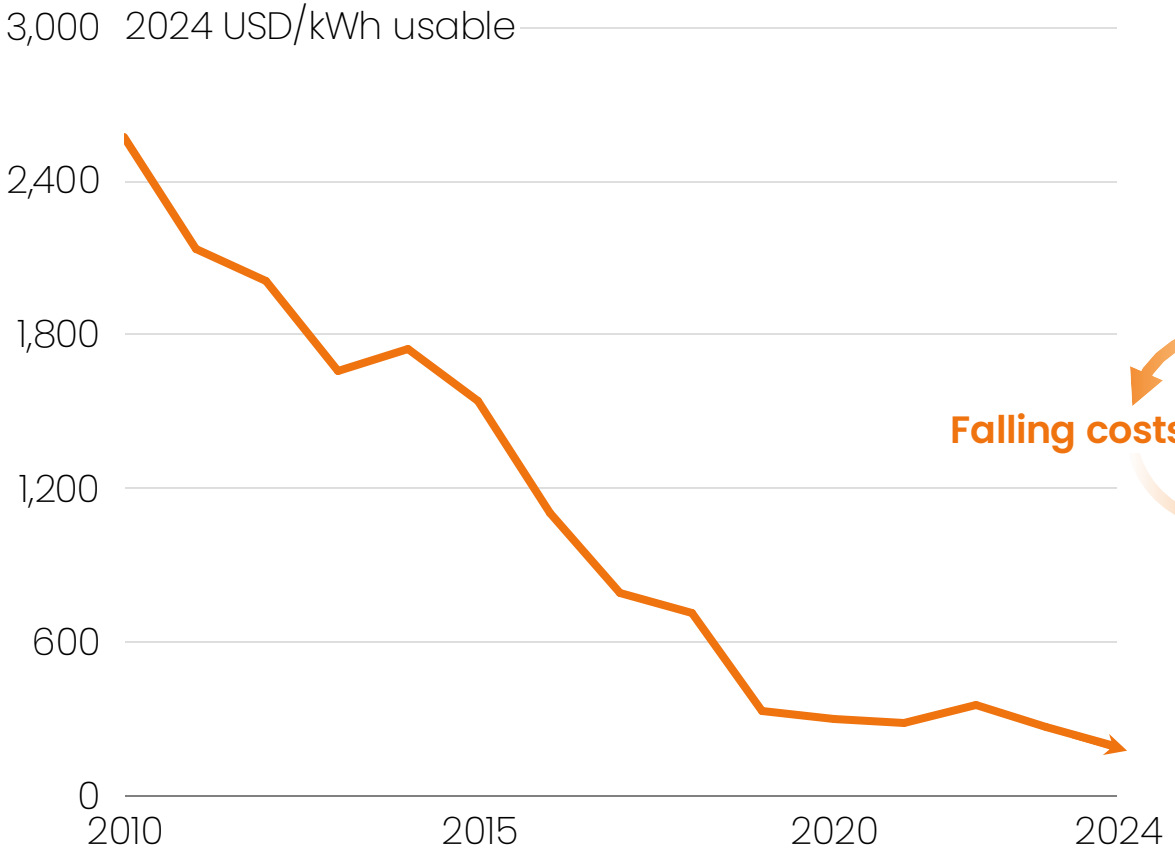


Sources: Energy Institute, IEA; Thunder Said; Ember analysis

The cheaper it gets, the faster it goes

The virtuous cycle between cost and volume is self-sustaining

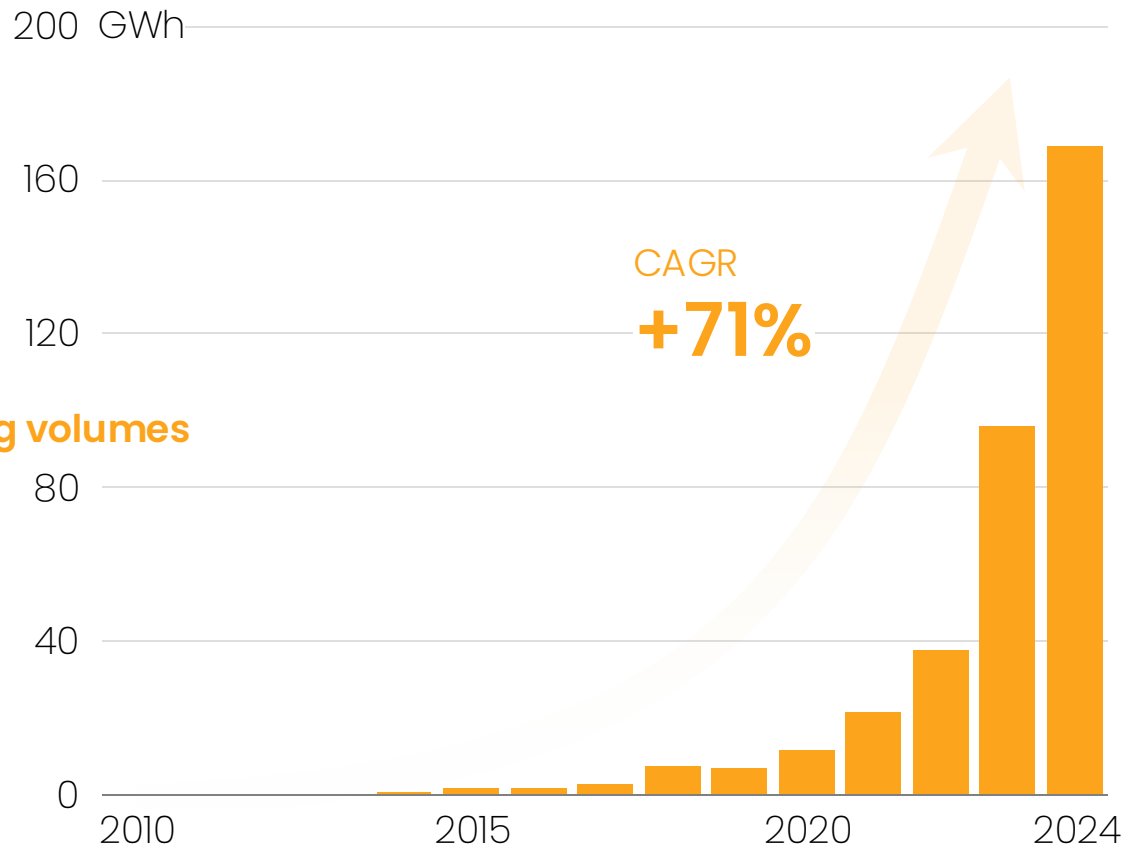
Utility-scale energy storage cost, global



Falling costs

Rising volumes

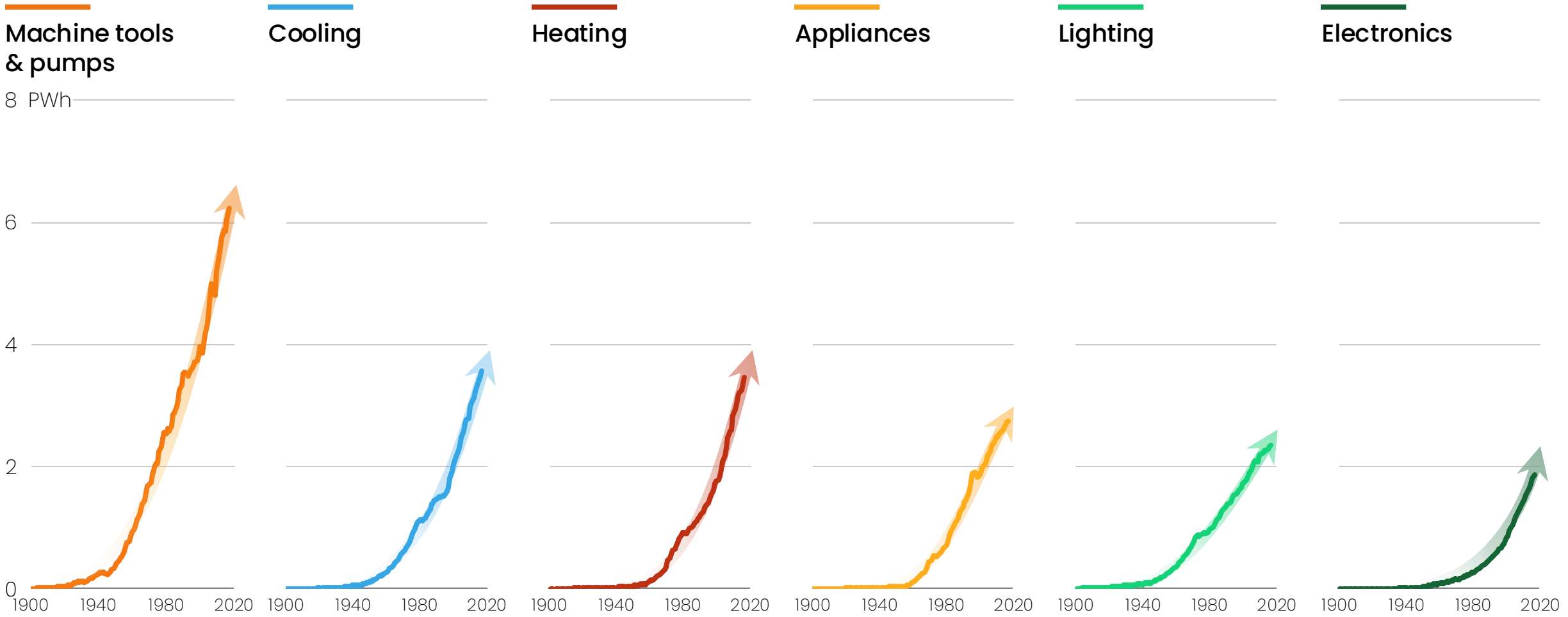
Utility-scale energy storage sales, global



Sources: IRENA, Ember

The long march of electrification

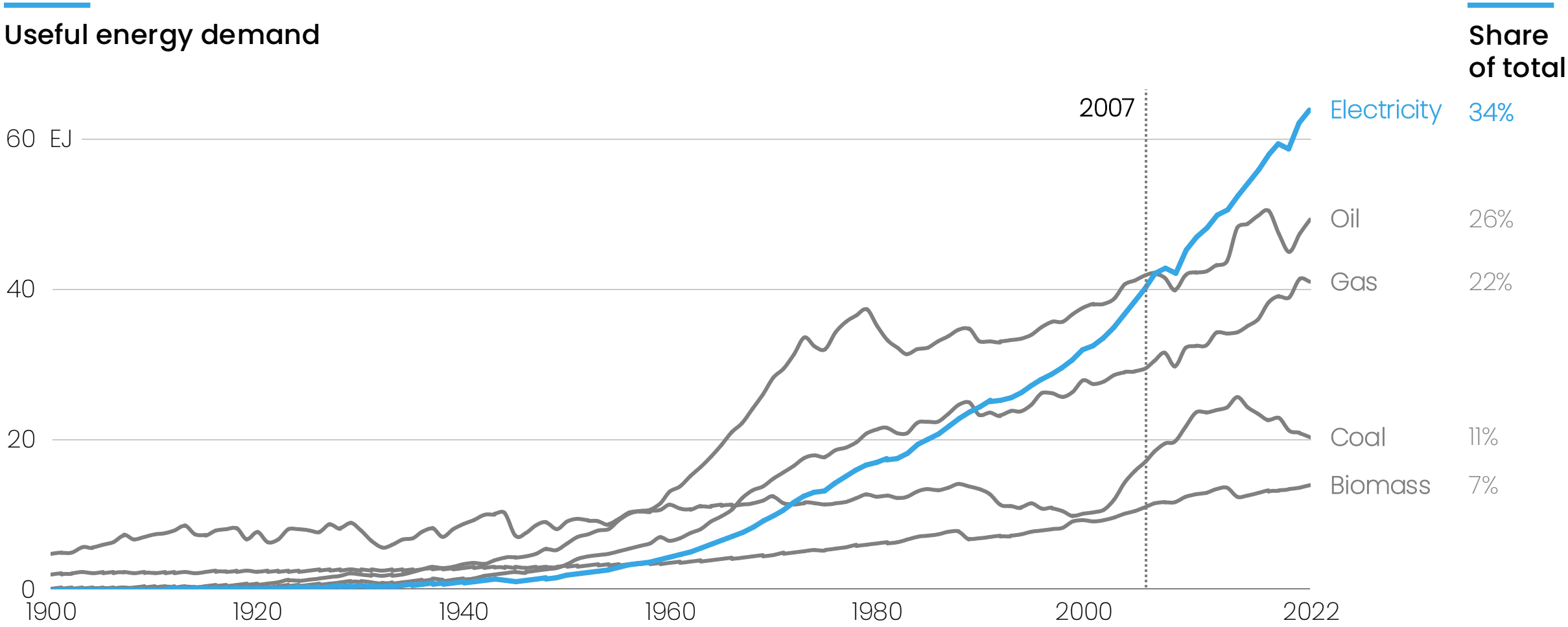
We've been electrifying the global economy for over a century



Sources: Pinto et al, 2023; Ember analysis. Electricity consumption by end-uses.

Electricity is the king of energy

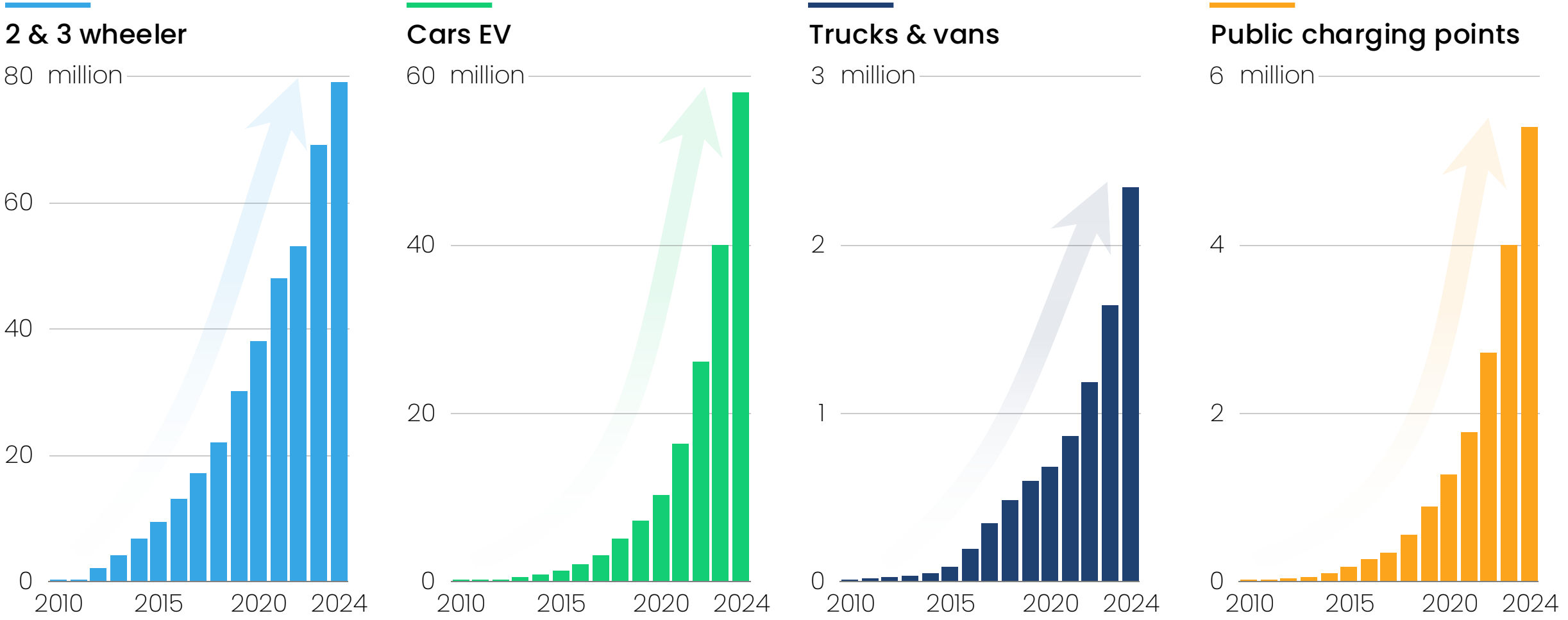
Electricity overtook oil as largest supplier of useful energy in 2007



Sources: IIASA, IEA, Ember analysis. All figures exclude feedstock use. Useful energy demand refers to the amount of energy used to perform a specific task, after accounting for energy losses in the process

The EV revolution is taking off

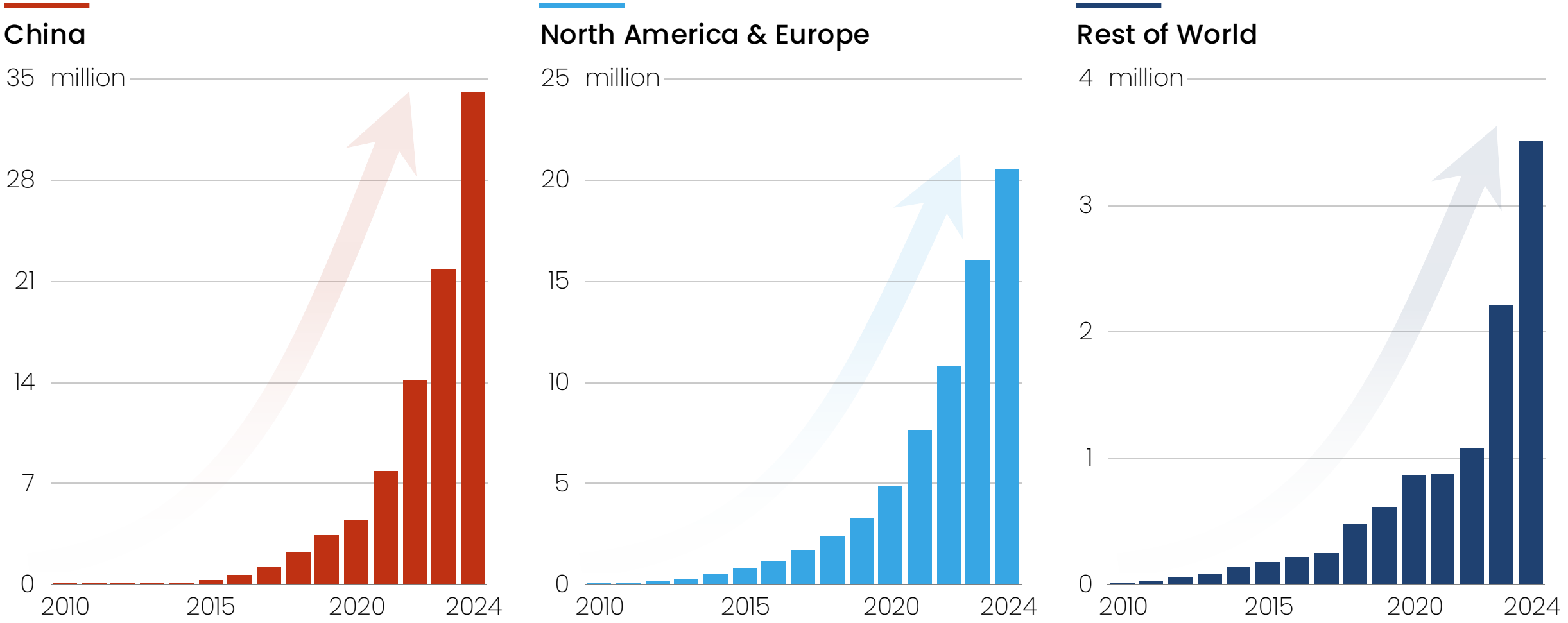
Electric mobility is growing exponentially across vehicle sizes



Sources: IEA. Note these figures are for the size of the fleet

EV deployment is growing exponentially

Double digit growth across the world

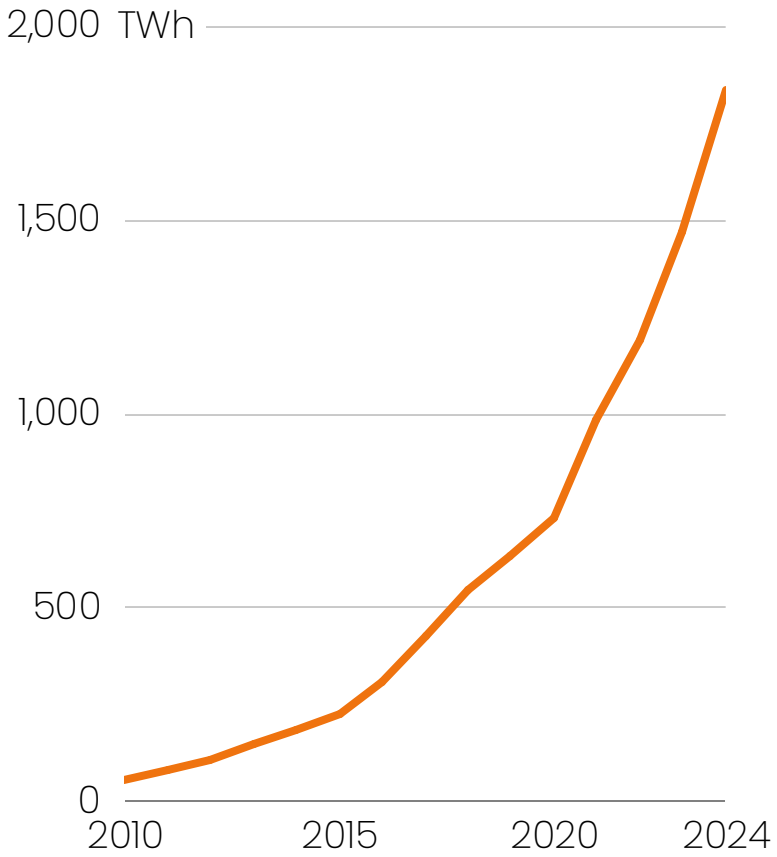


Sources: IEA, Ember analysis – Note: showing total fleet numbers for cars

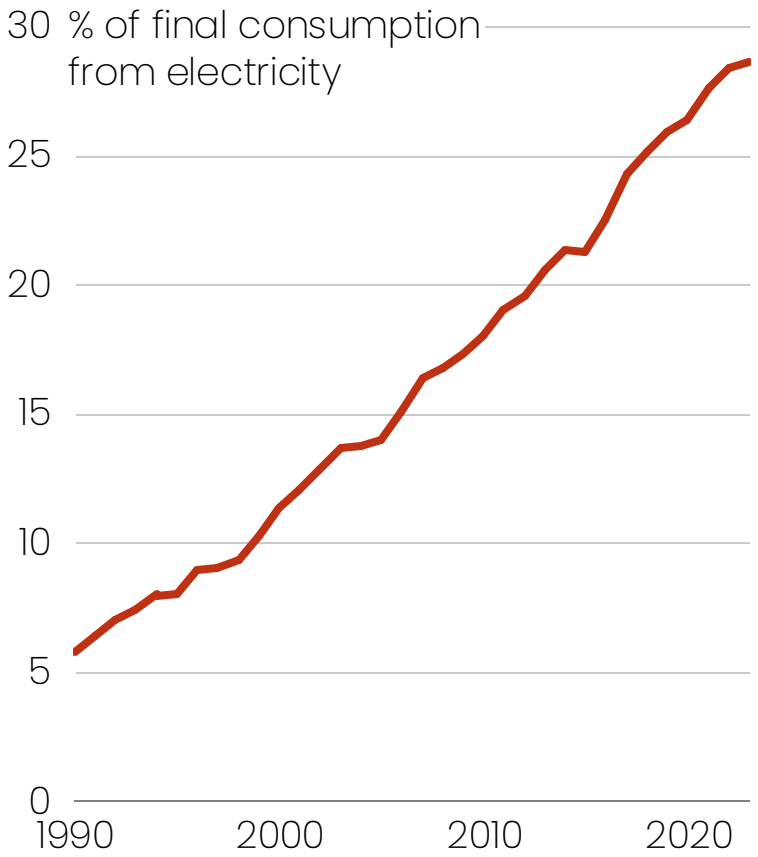
China is moving at lightning speed

Across renewables and electrification

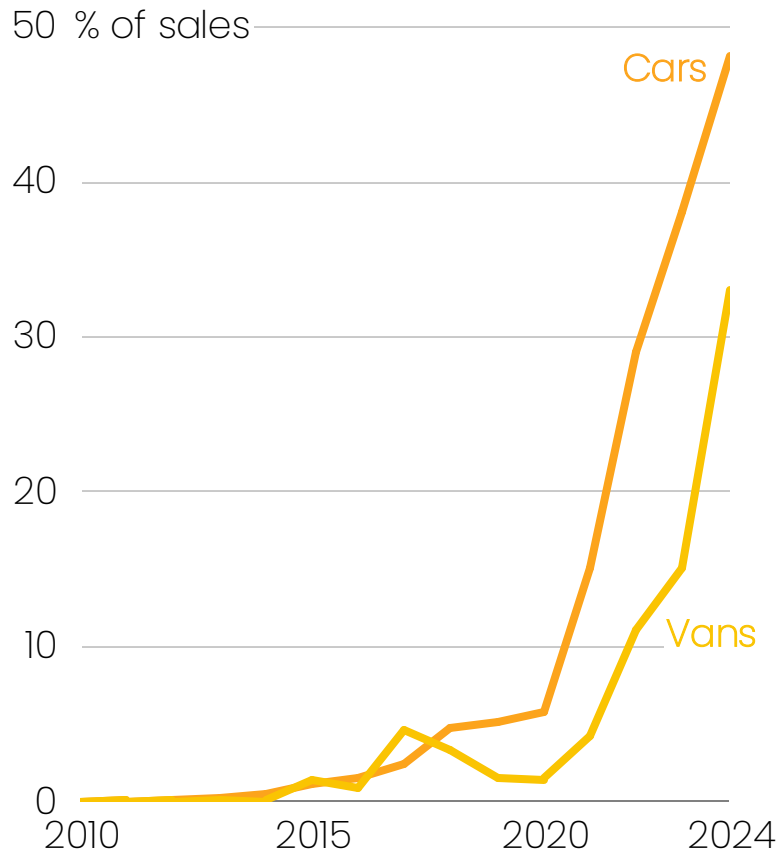
Solar and wind generation



Electrification



Electric vehicles

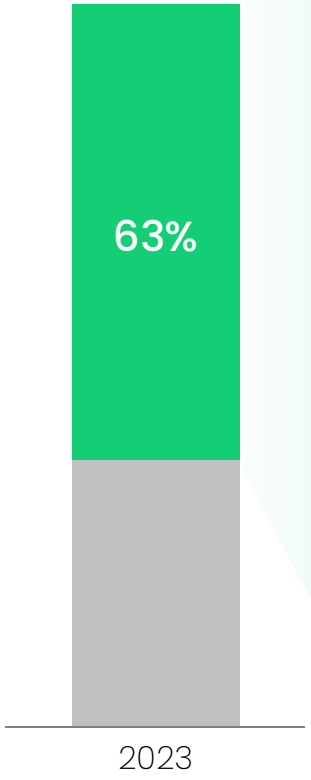


Sources: Ember, IEA

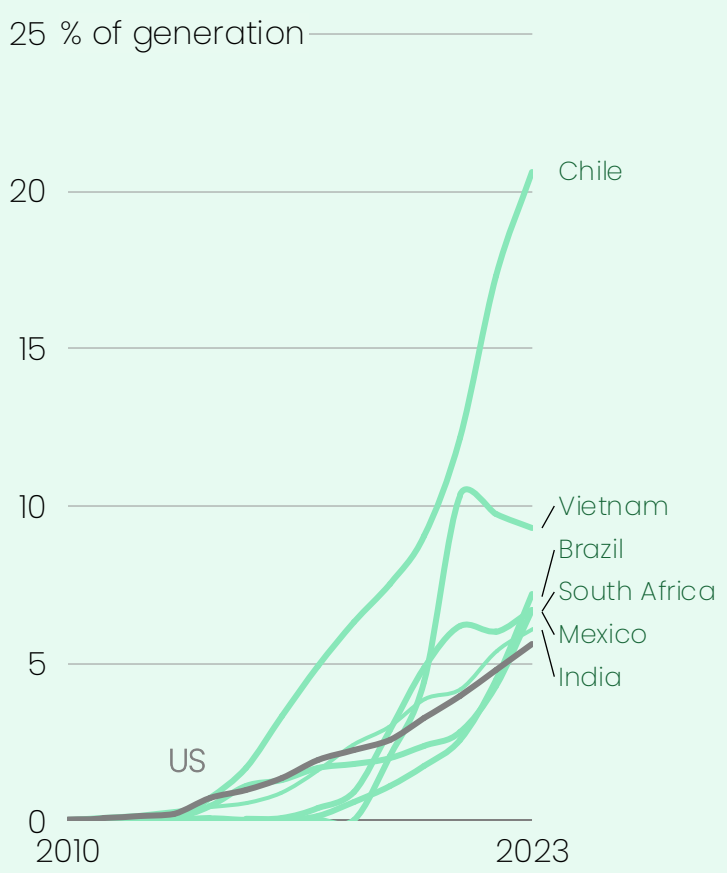
Emerging markets are leapfrogging

Two thirds are ahead of the US in solar deployment and a quarter in electrification

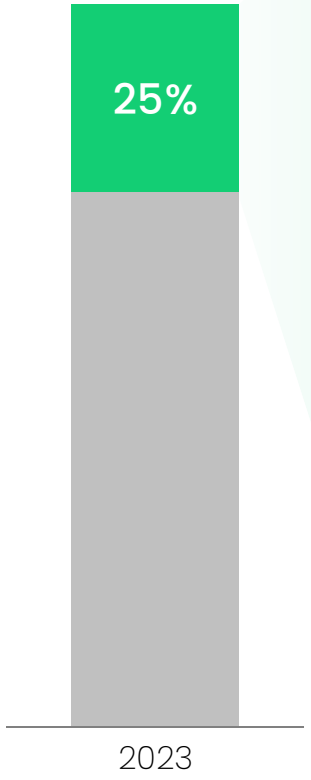
Share of EM ahead of US in solar uptake



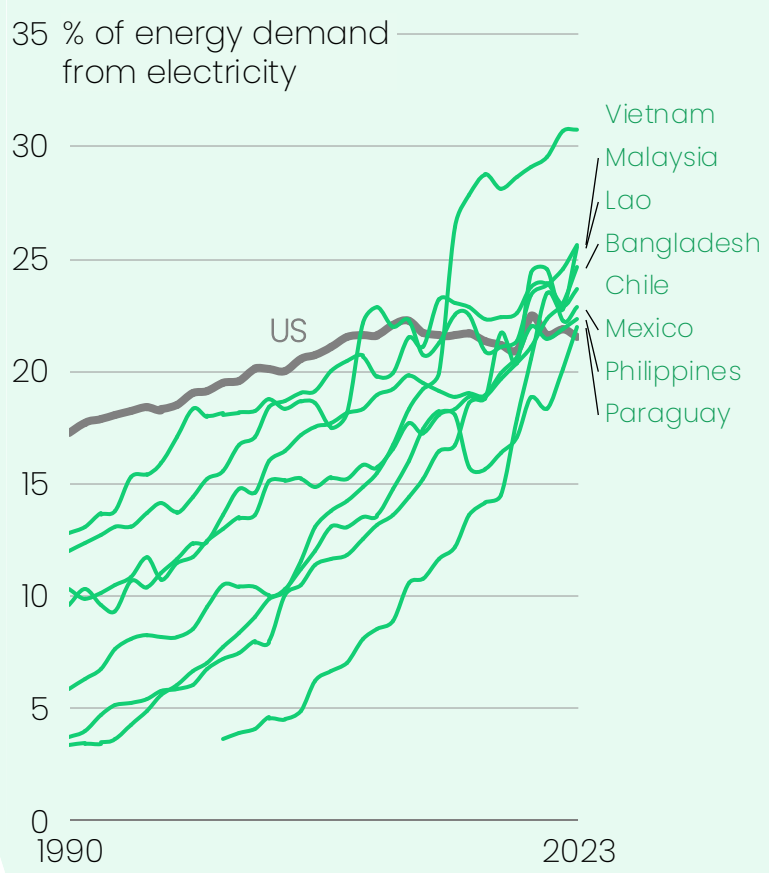
Example countries



Share of EM ahead of US electrification



Example countries



Sources: IEA; Ember analysis – Emerging markets (EM) defined as Latin America, Africa, South Asia and Southeast Asia and do not include the petroregions. Share of emerging markets is a share of electricity demand (l) and energy demand (r).

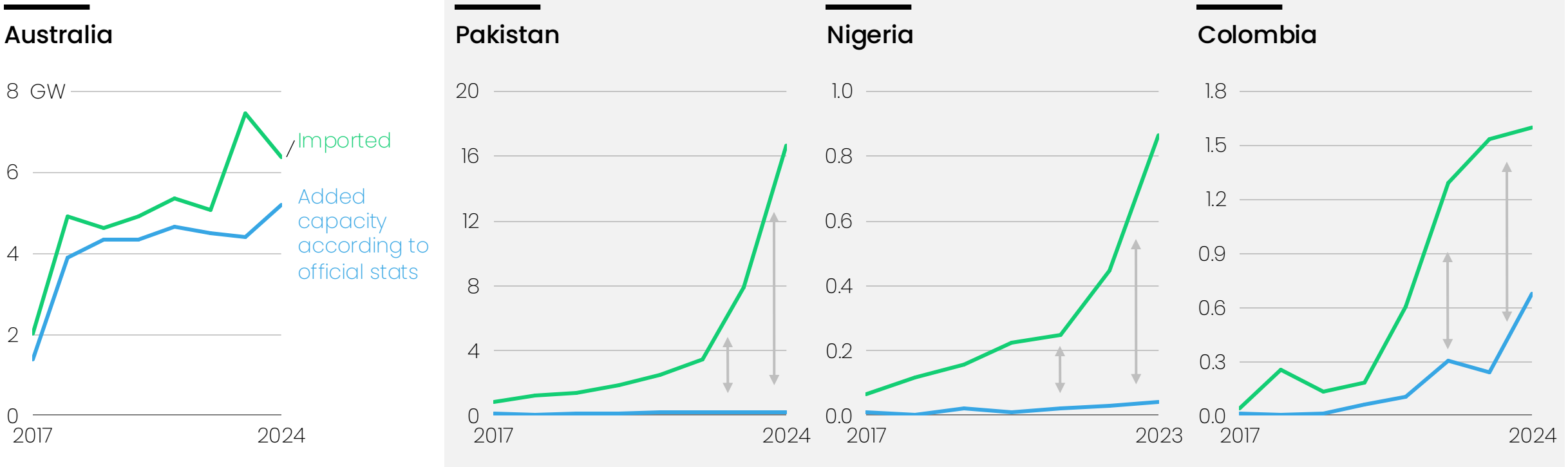
Change is happening faster than it can be recorded

Central grid statistics cannot keep up with what is happening on the ground

Solar capacity imported/installed

Imports generally convert to reported installed capacity within a year or so.

Across emerging markets, there is a growing gap between official statistics and import figures, which implies imported solar panels are not centrally connected and counted but installed decentrally.

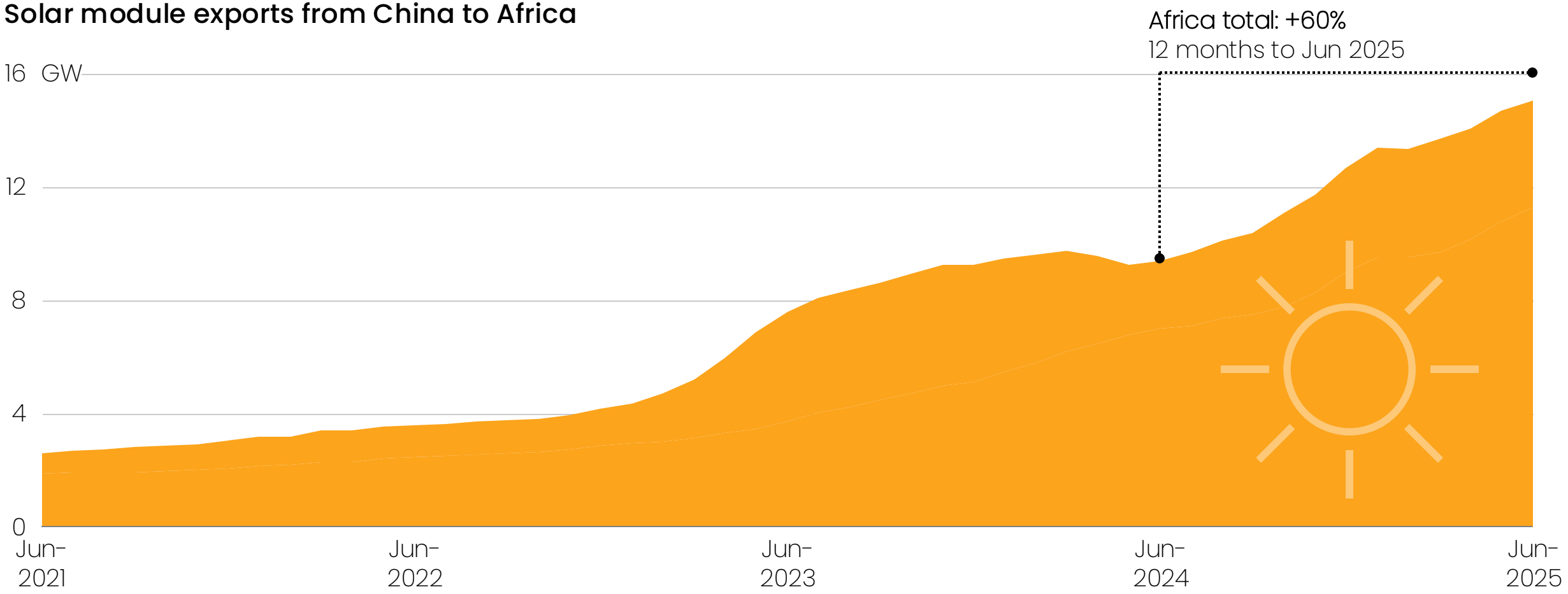


Sources: Ember data; Ember analysis • Notes: Imported statistics are in DC, while reported capacity is in AC. They should match within the expected inverter clipping ratio.

Africa is turning to the sun

Solar imports are up by 60% in the last 12 months

Solar module exports from China to Africa

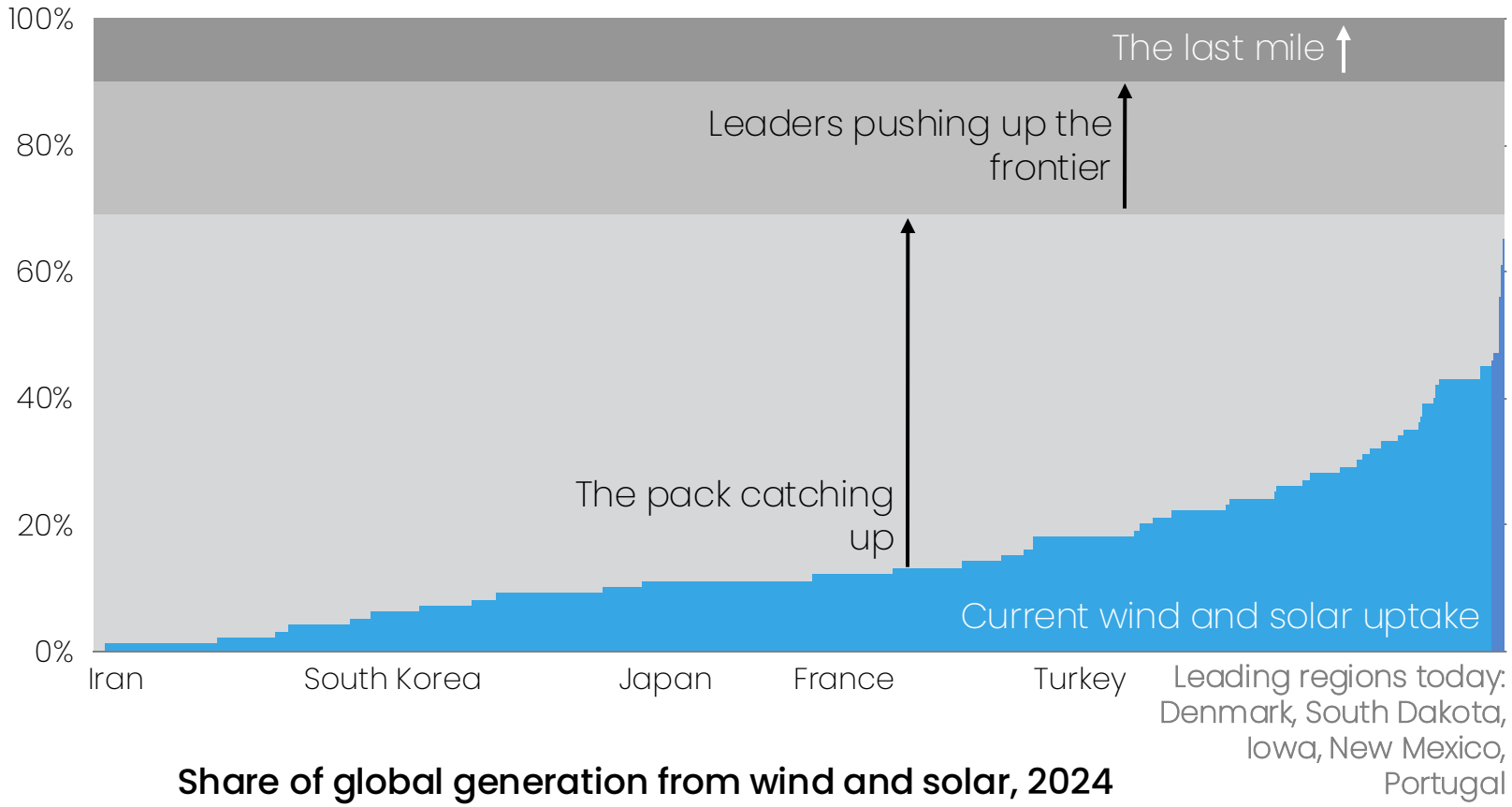


Sources: Ember China Solar Export Explorer

The renewables ceiling is high and rising

Some 70-80% penetration from solar and wind is within our reach today

Wind and solar share of generation



Share of global generation from wind and solar, 2024

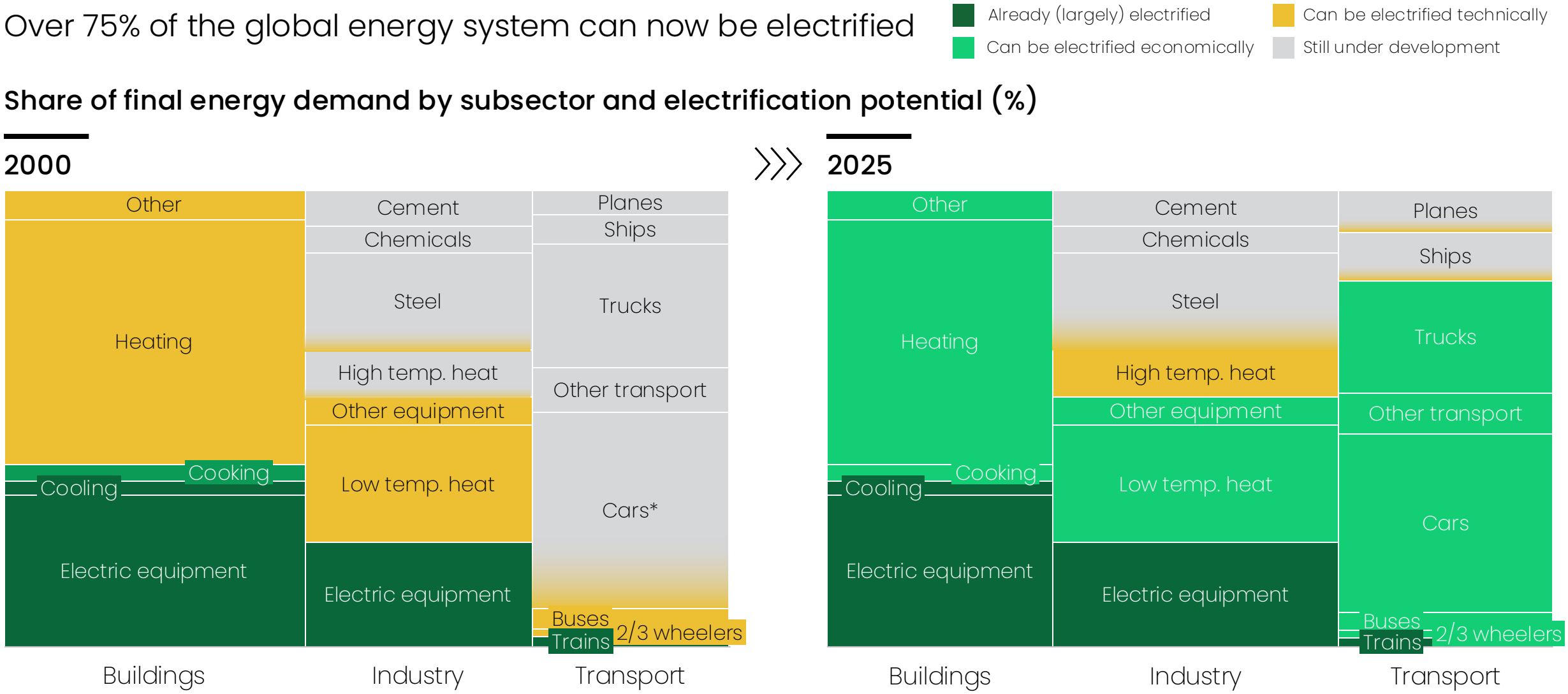
6 solutions to manage variability

- Demand side flexibility
- Flexible generation
- Smarter grids
- Bigger grids
- Energy storage
- Overbuild solar & wind

Sources: Ember analysis; ETC – Power Systems transformation

The electrification ceiling is high and rising

Over 75% of the global energy system can now be electrified

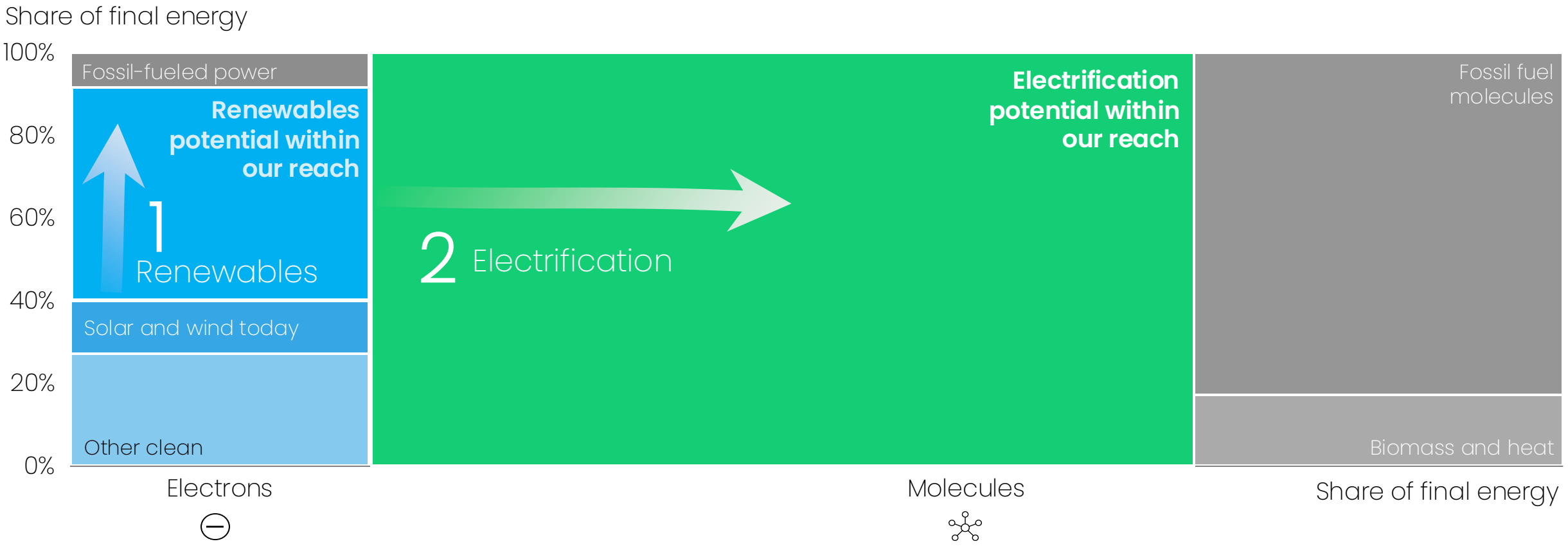


Sources: IIASA; IEA; BNEF; Ember analysis • Note: excluding feedstock *Technologies available for subset of total end-use with a clear path to expansion

The majority of the energy system is within reach

Renewables and electrification can triple

Global final energy demand in 2023



Sources: IEA, Ember – Note: Renewables potential includes solar and wind as well as other sources

Chapter 3
Peak fossil demand

01

Peak fossil demand for electricity

The rapid growth of solar and wind enables them to take a rising share of the growth in electricity demand, with 64% of the growth since 2018. In half of the world we have already seen peak fossil fuels for electricity, and initial indications for the first half of 2025 are that China has also peaked.

02

Peak fossil demand for final energy

Peaks are cascading from one area to the next. Fossil demand has been flat for industrial energy since 2014, for buildings since 2018, and for road transport since 2019

Meanwhile two thirds of the world has already seen peak fossil demand for final energy.

03

Peak China means peak global fossil demand

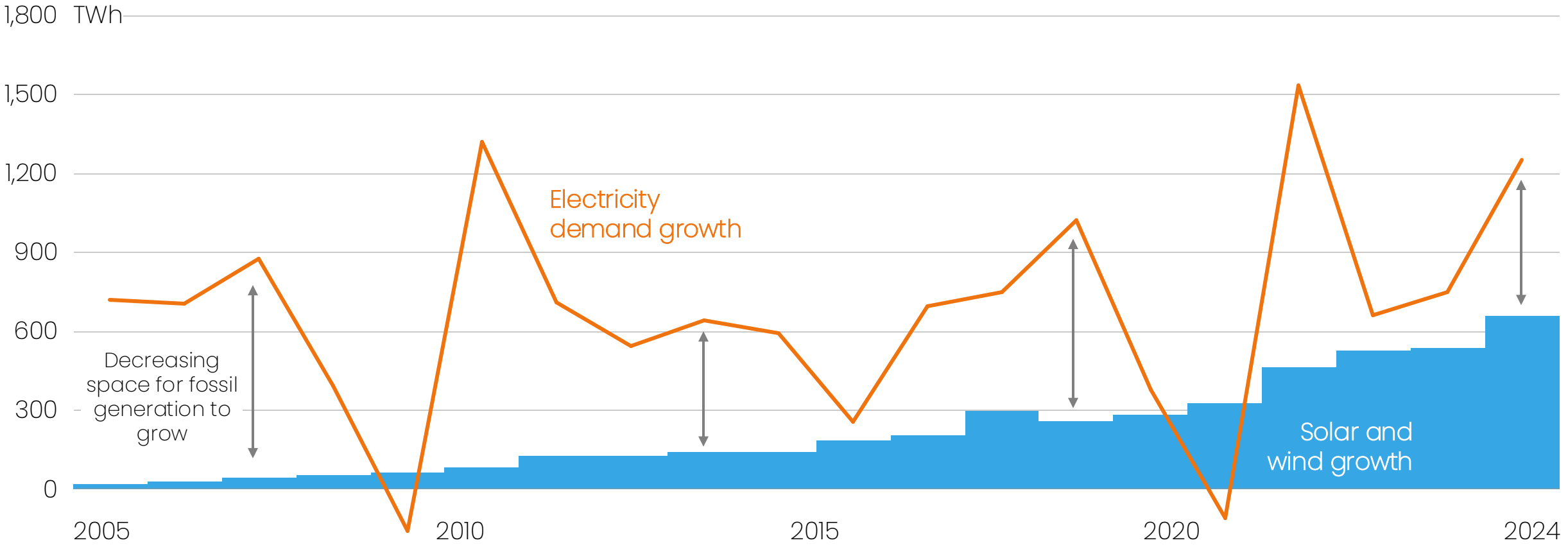
Fossil demand for final energy reached a peak in China in industry in 2012, in buildings in 2017, in transport in 2021, and in electricity in H1 2025. As a result total emissions are down by 1% year on year. Meanwhile, China is the pivot nation, as it accounted for 95% of the net growth in fossil fuel demand since 2018. As a result, a Chinese peak implies a global peak.

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No space for fossils to grow in electricity

Solar and wind are about to take all the growth

Annual change in electricity generation



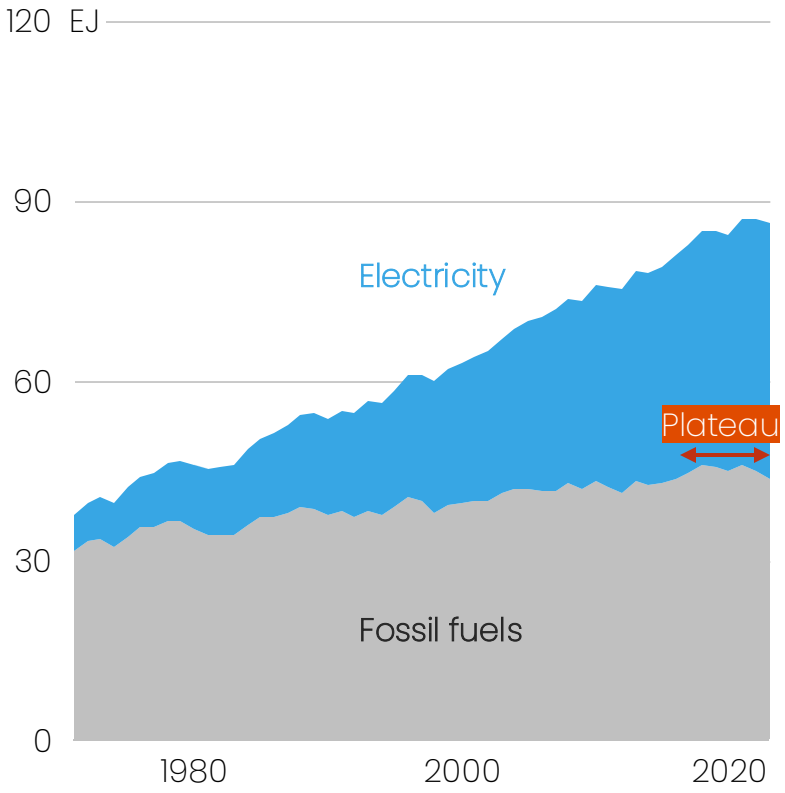
Source: Ember

Electricity is taking all the growth in final demand

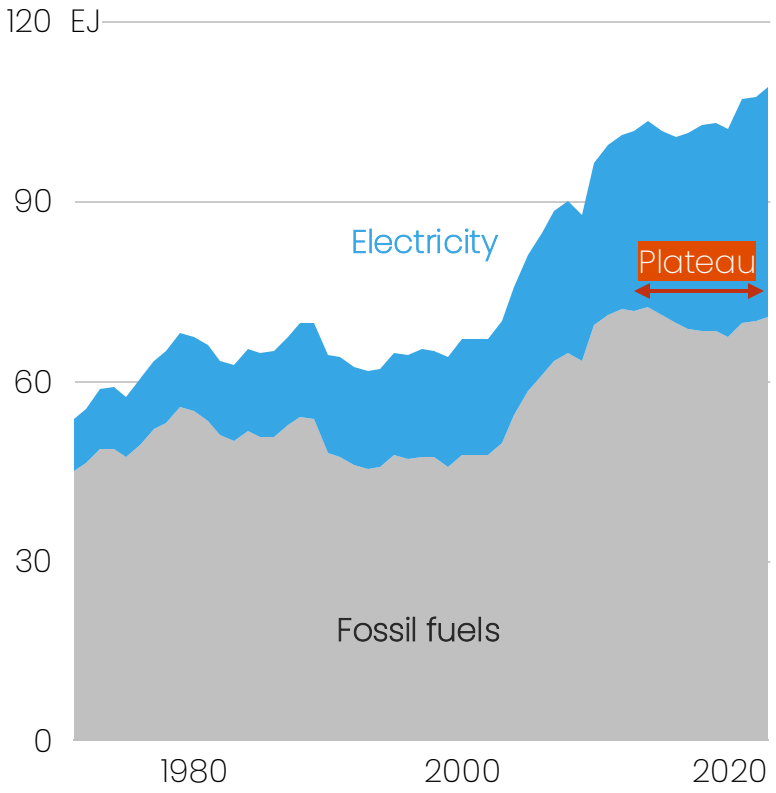
Peak fossils in industry was 2014 and in buildings was 2018

Final energy demand by sector

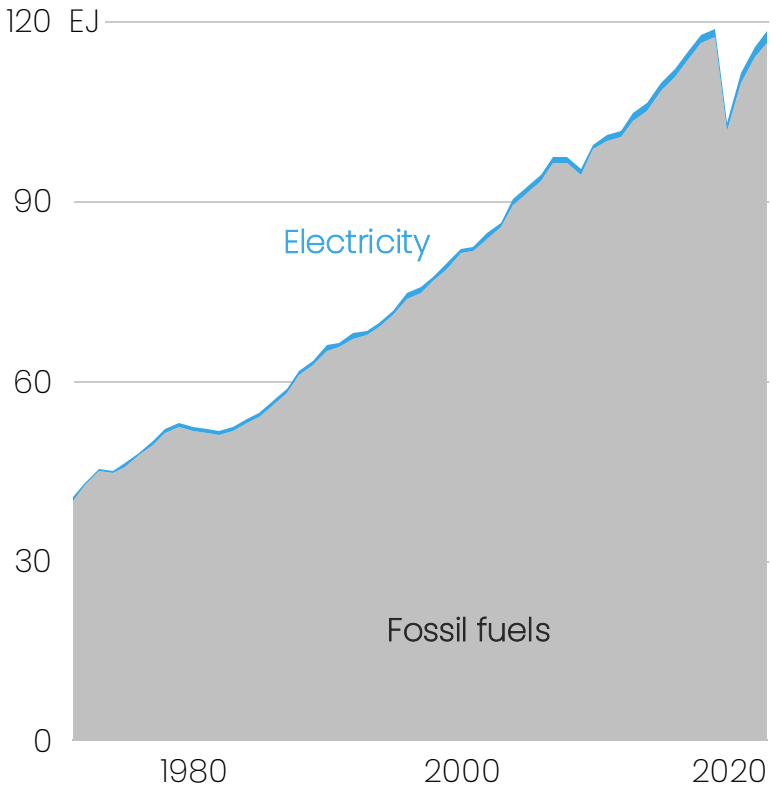
Buildings



Industry



Transport

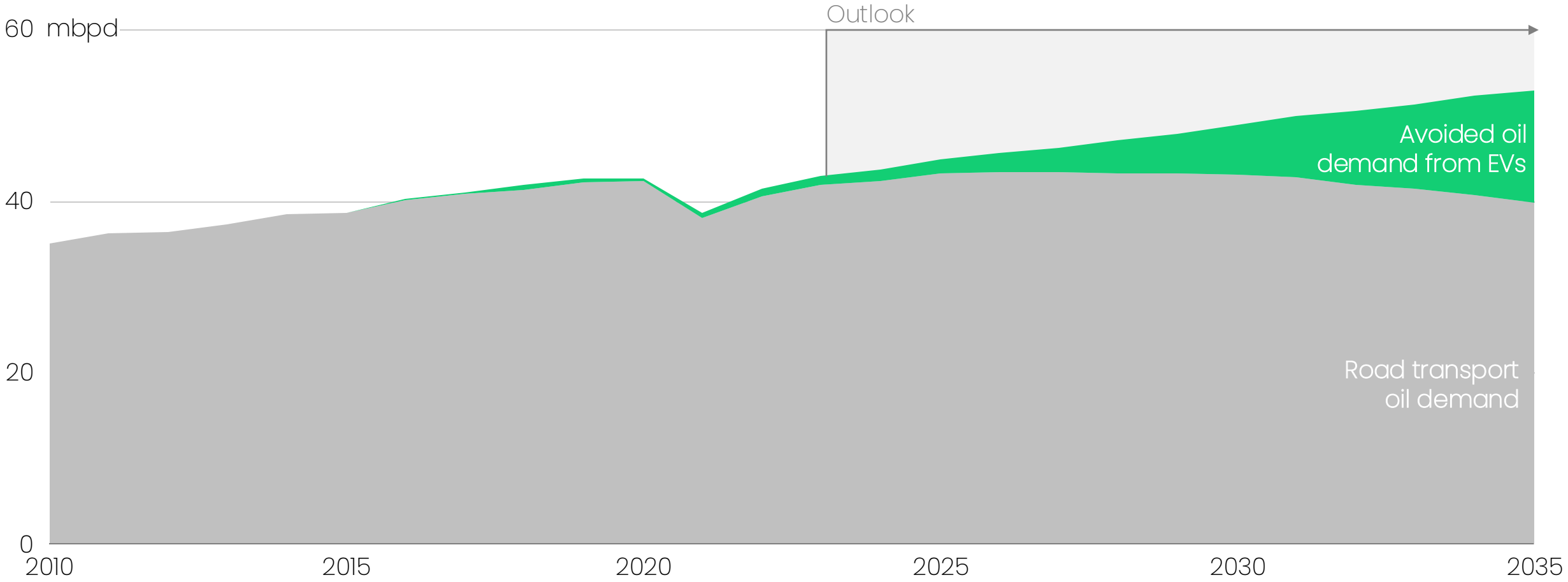


Sources: IEA WEB; Ember analysis. Note non-energy demand (42 EJ with growth of 1-2% pa) sits outside of industry in IEA WEB.

EVs are driving a plateau in road transport

And road transport is 75% of transport energy demand

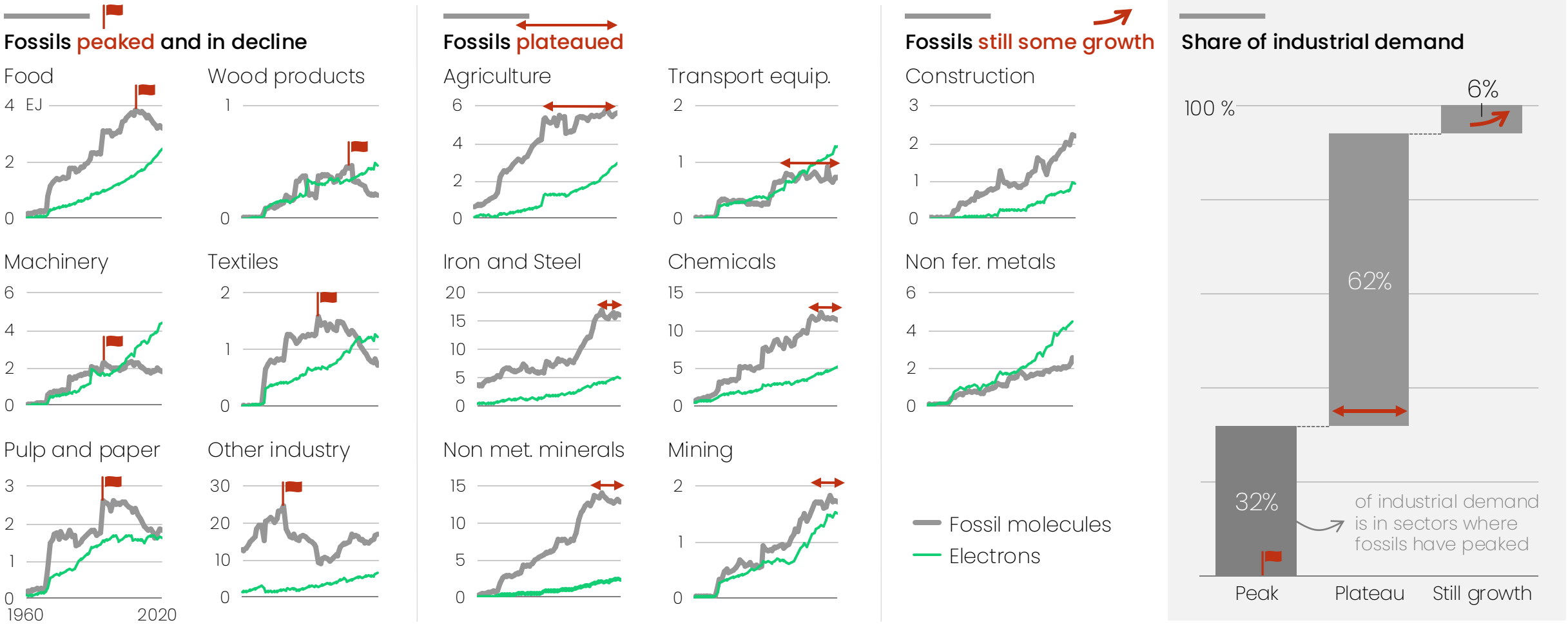
Oil demand in road transport in the IEA STEPS scenario and savings from EVs, 2010-2035



Sources: IEA WEO 2024 STEPS scenario – Note: STEPS is the IEA's most conservative scenario

Industrial peaks everywhere

Only 6% of energy demand comes from sectors which still have structural fossil growth



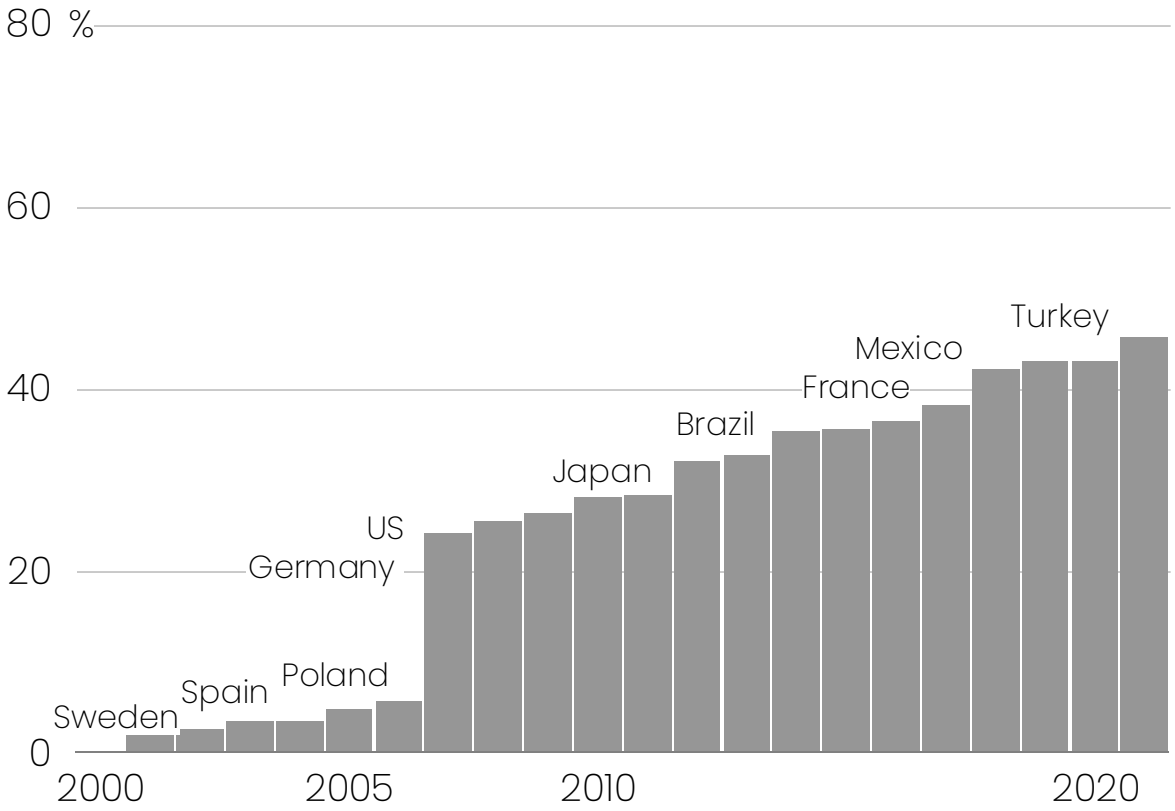
Sources: IEA WEB; Ember analysis. Note: Feedstock demand of 42 EJ is not included in the industrial sector in IEA WEB

Most of the world is past peak fossil fuels

Two-thirds of the world is past peak fossils in final energy and nearly half in power generation

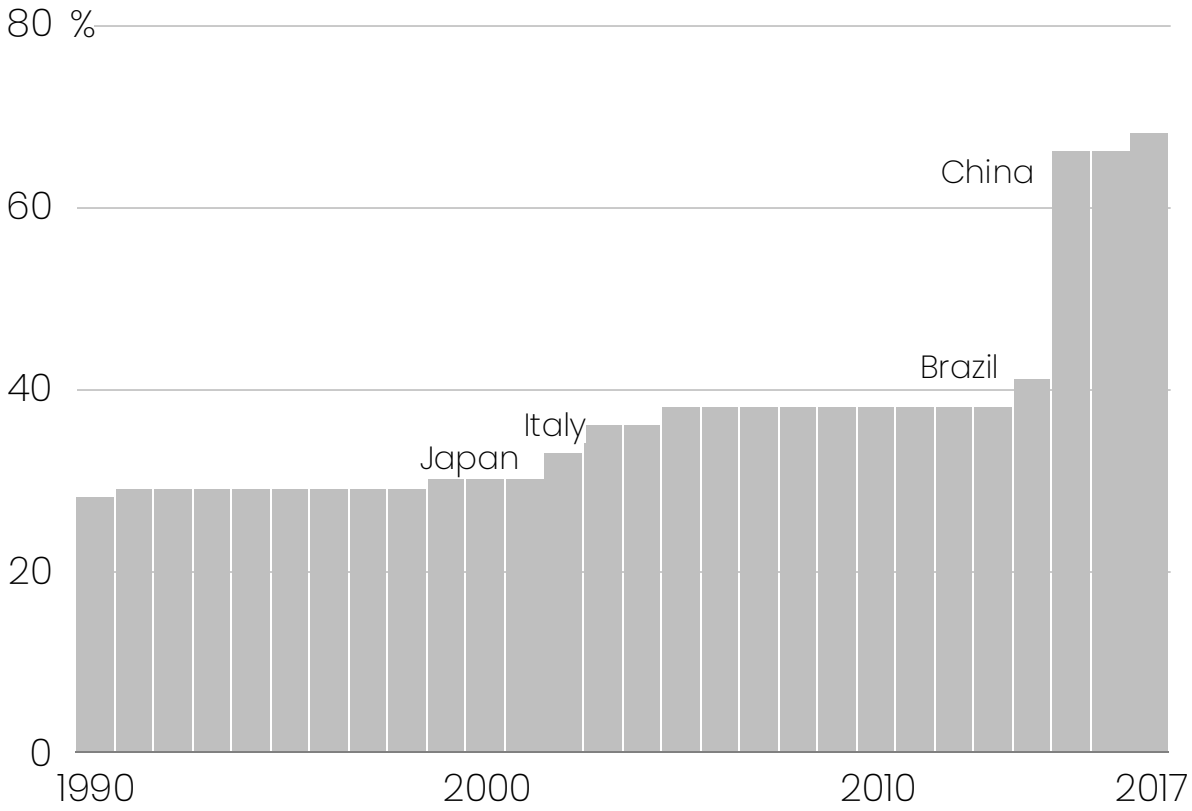
Share of the world past peak fossil demand for electricity

Driven by clean power and efficiency



Share of the world past peak final fossil energy demand

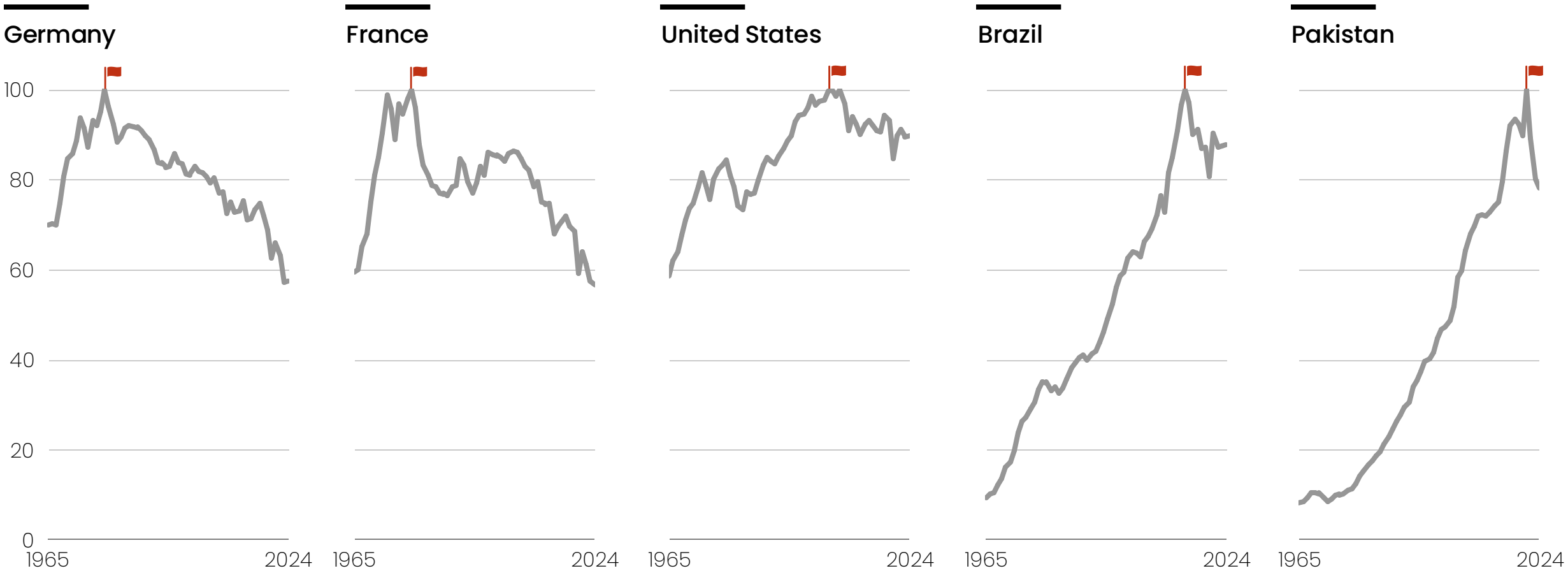
Driven by efficiency and electrification



Sources: Ember. Share of world measured in 2023 energy. Final energy excludes non-energy.

After the peak comes the fall

Countries don't have long plateaus although the world does

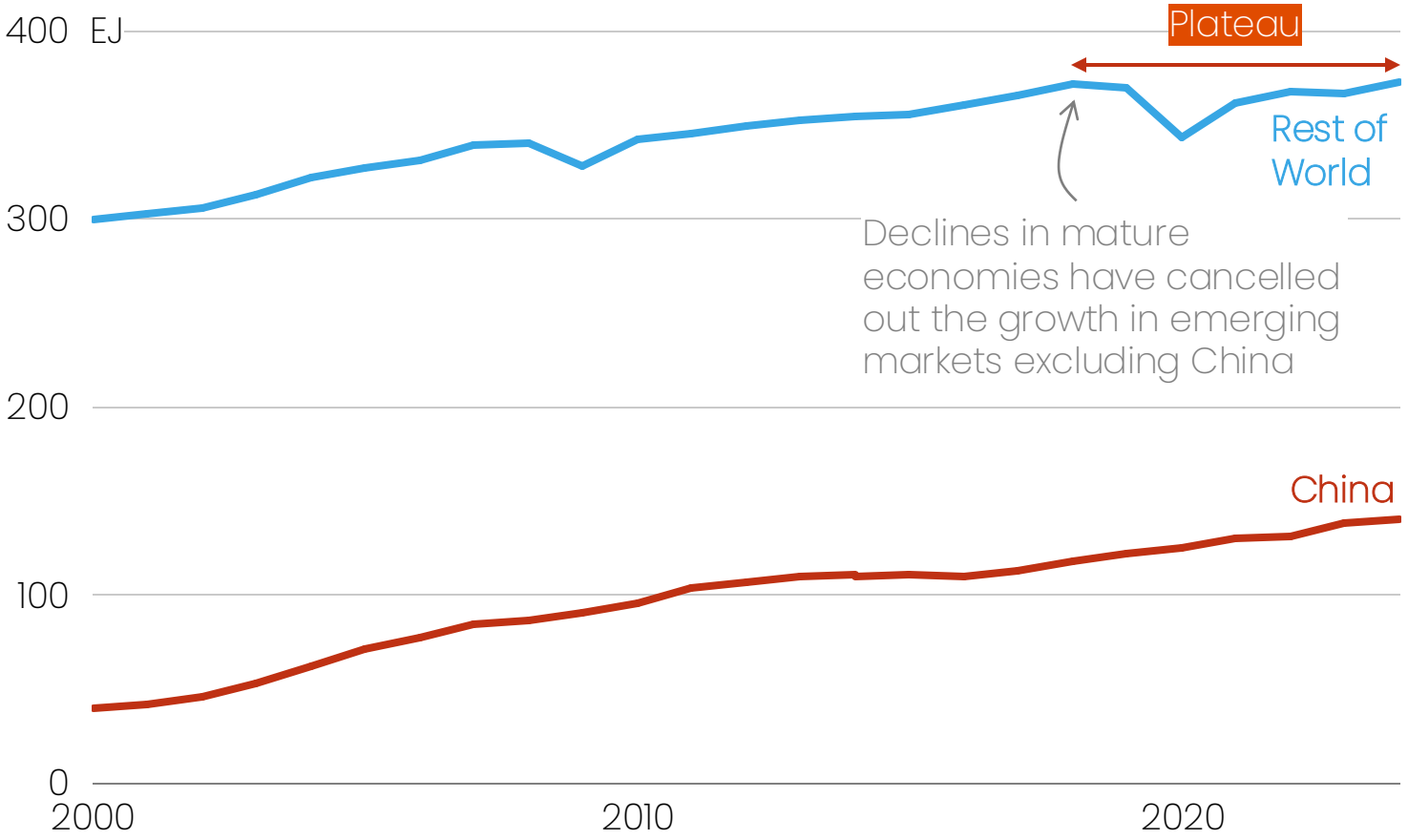


Sources: Energy Institute; Ember analysis

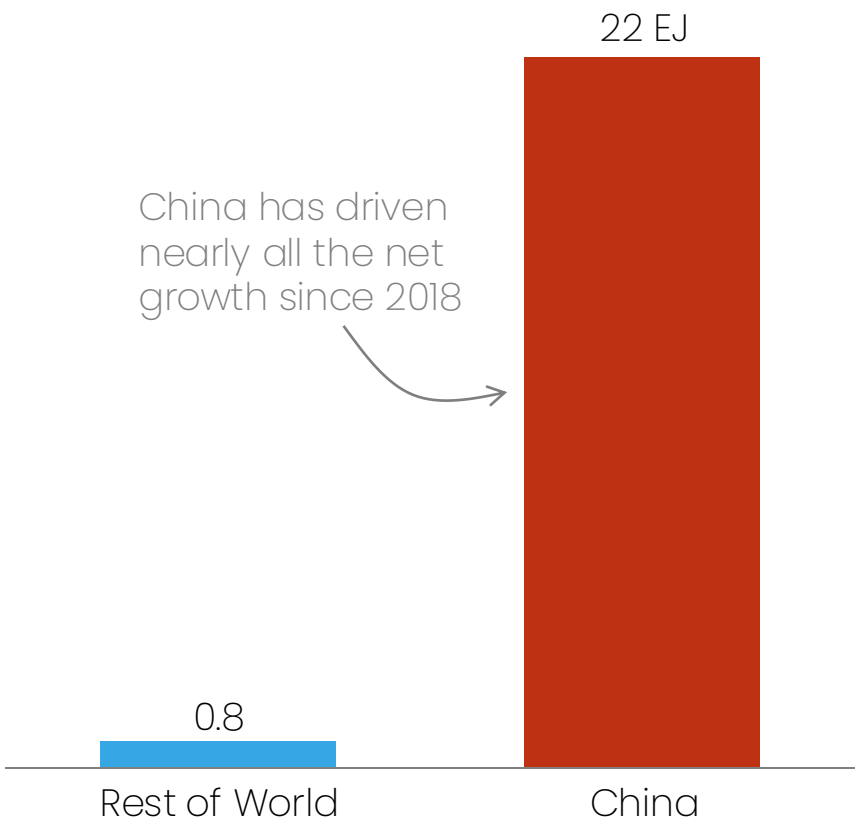
China is the pivot nation

Fossil fuel demand has already reached a plateau outside China

Primary fossil fuel demand



Change in fossil fuel demand 2018-2024

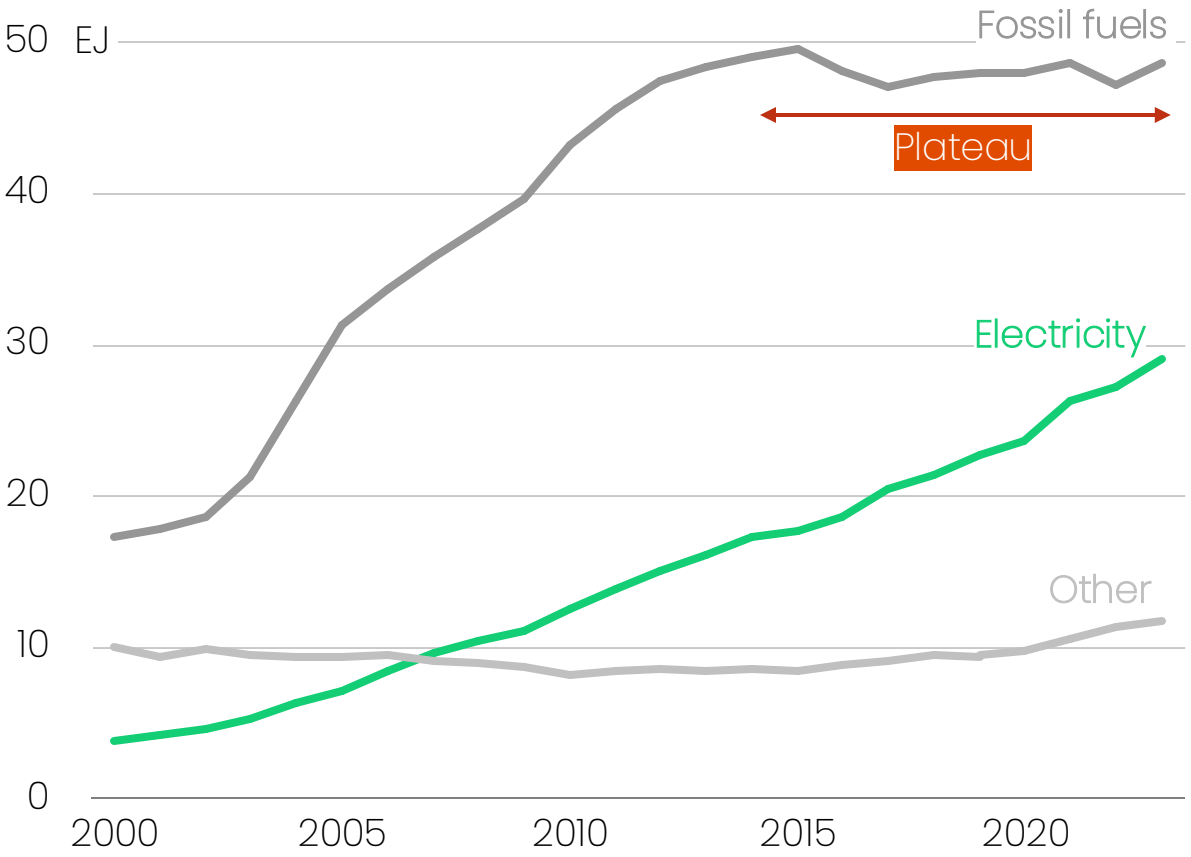


Sources: Energy Institute, Ember analysis

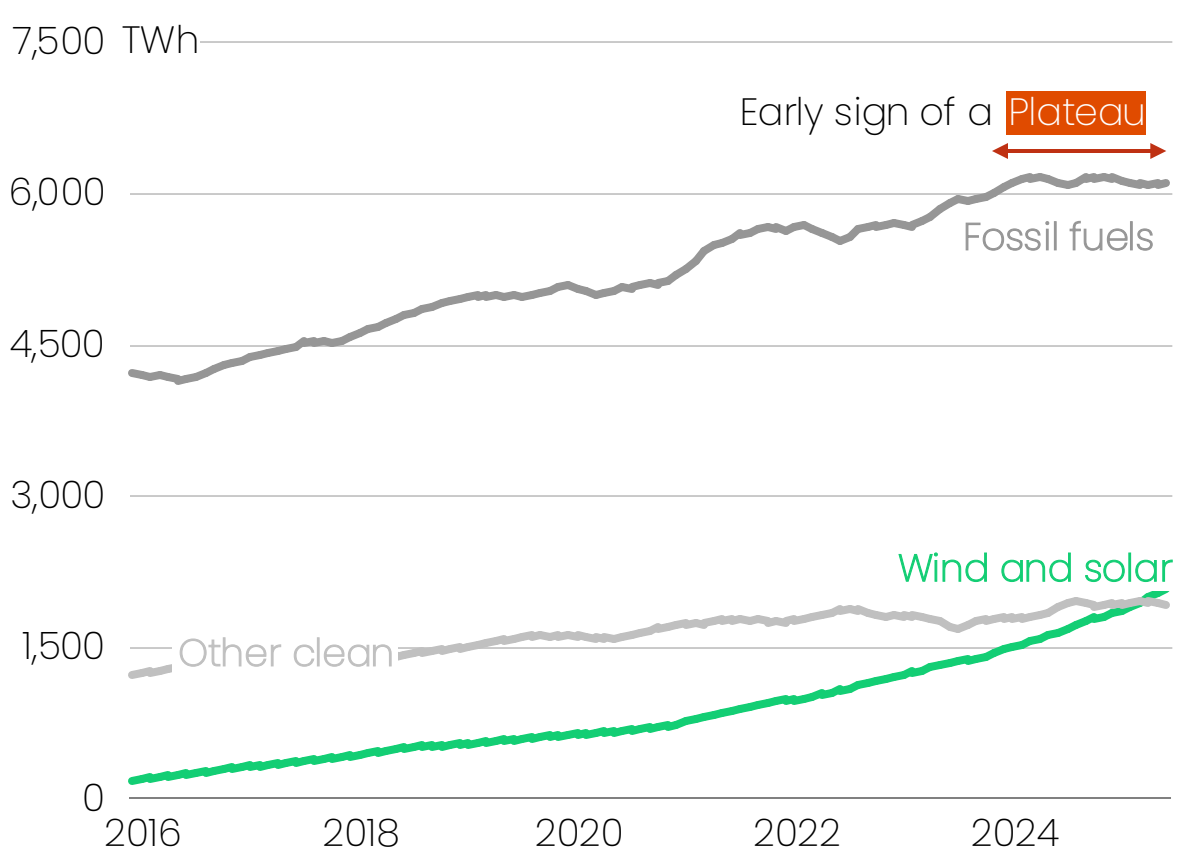
Fossil fuel demand is peaking in China

Final fossil demand stopped growing in 2014 and fossil electricity in H1-2025

Final energy consumption



Electricity generation, 12-month rolling sum



Sources: IEA WEB; Monthly electricity data, Ember. Note: final energy excludes non-energy.

Chapter 4
Three fundamental drivers of change

Physics
Electrotech is more efficient than alternatives



Economics
Electrotech as a technology has learning curves and growth curves



Geopolitics
Electrotech is a key tool of energy security



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Chapter 4.1
The physics of change

01

Fossil fuels are very inefficient

The fossil fuel system wastes two thirds of its primary energy. $4.6 trillion a year goes up in smoke, and this sets up a very attractive environment for more efficient solutions.

02

Electrotech is three times more efficient

Electrotech is three times more efficient than fossil tech in sectors that make up two thirds of fossil fuel demand: electricity; road transport; and low temperature heat. Fossil fuels have to be burnt, requiring 17,000 million tonnes (mt) a year to be shipped around the world. Electrotech needs annual deployment of under 300 mt to build out the infrastructure required to harness the sun and wind.

03

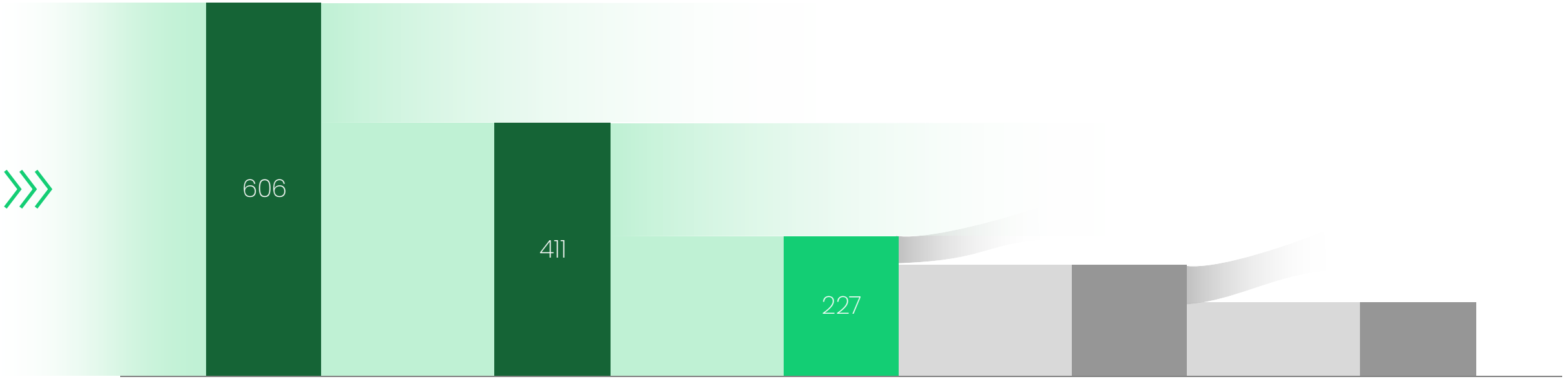
Electrotech beats the rest of cleantech

Electrotech is far more efficient than other cleantech solutions like CCS, biomass or hydrogen.

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Energy is all about efficiency

At its core, the energy system is about converting energy into useful forms as efficiently as possible



	Primary energy Energy going into the global energy system	Final energy Energy delivered to consumers	Useful energy Energy turned into functional forms	Energy services Useful energy turned into activities	Prosperity Activities turned into value
Examples	e.g., crude oil, coal	e.g., gasoline, electricity	e.g., hot water, vehicular motion	e.g., goods transported, ton steel produced	e.g., wealth, satisfaction, happiness

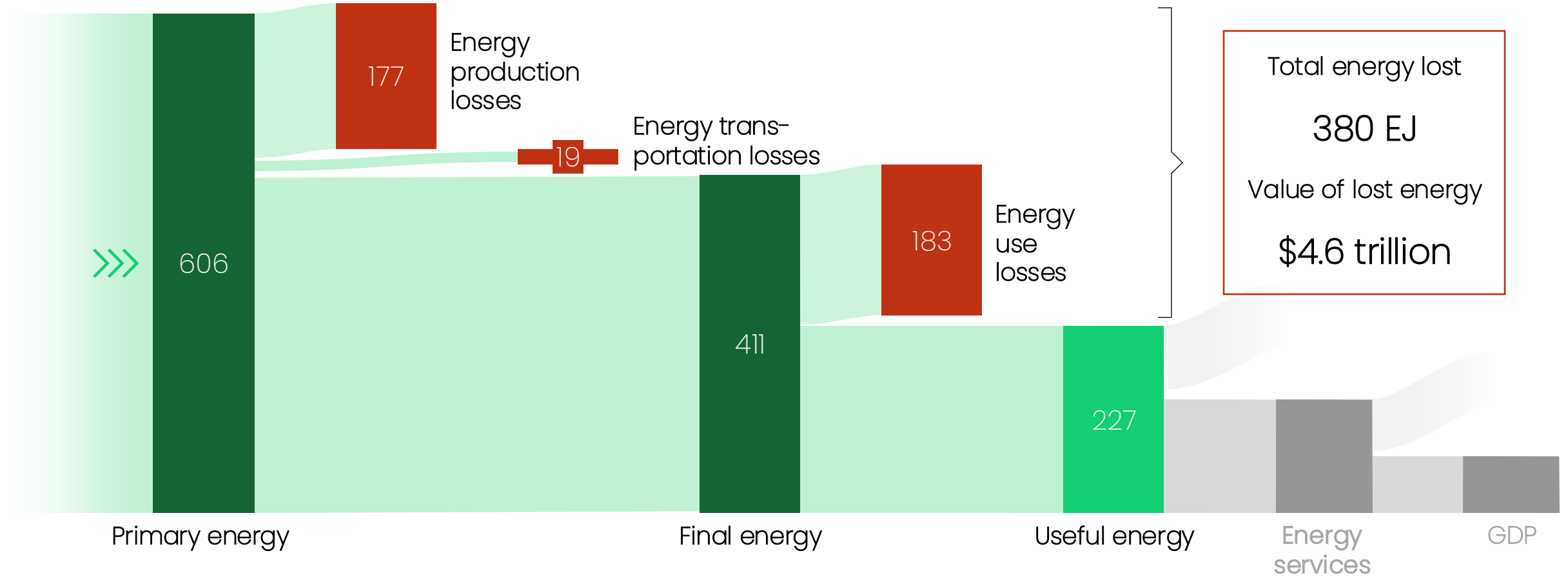
WHAT EVERYONE TALKS ABOUT → **WHY WE ACTUALLY CARE ABOUT ENERGY** →

Sources: RMI

The current fossil energy system is incredibly inefficient

We lose some two thirds of the energy we put into the system

Global energy flows and waste, EJ per year, 2019



Sources: RMI

Electrotech is 3x more efficient

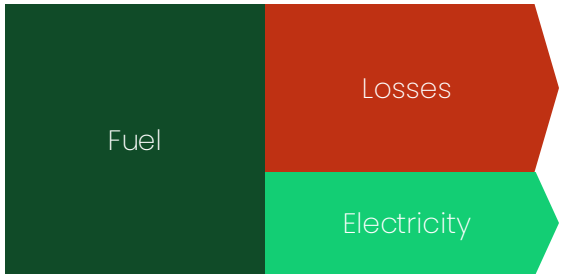
It offers a leap in energy efficiency across the economy

Supply

Electricity generation

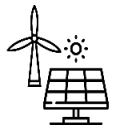
Fossil thermal





30-40% efficiency

Wind & solar



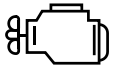


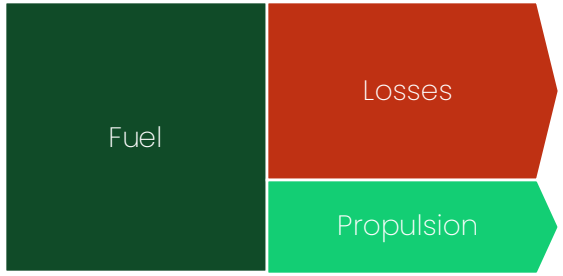
100% efficiency

Demand

Transport

Internal combustion engine





25-40% efficiency

Electric vehicles



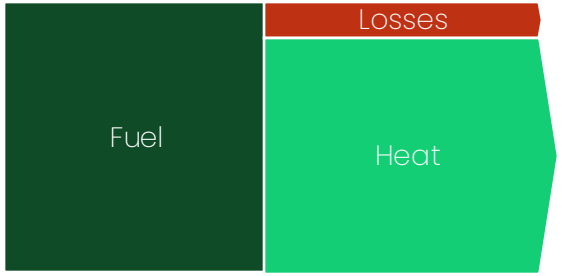


80-90% efficiency

Heating

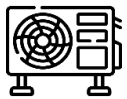
Gas boiler

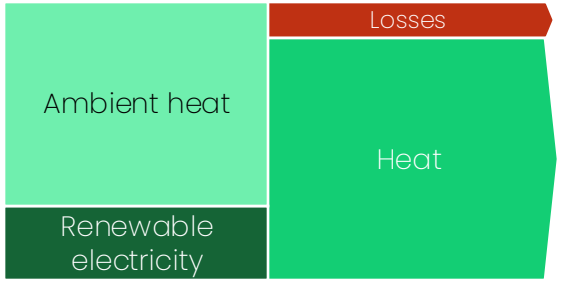




85% efficiency

Heat pumps





300-400% efficiency

2-3x
as efficient

2-4x
as efficient

3-4x
as efficient

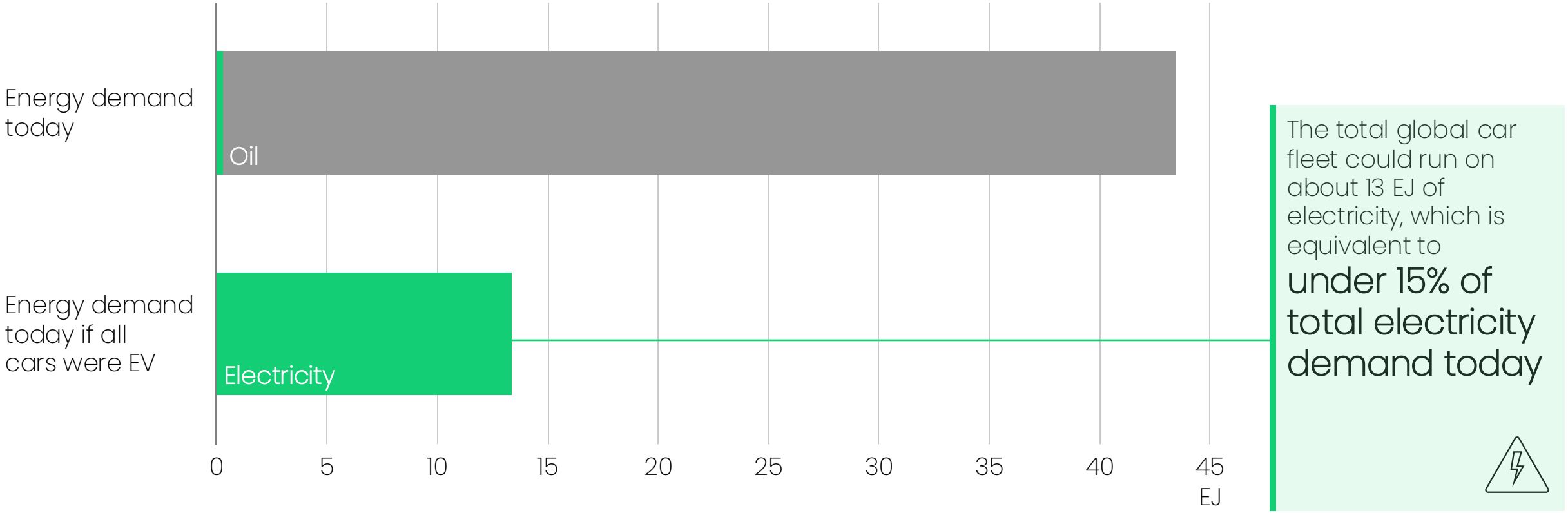
Sources: IEA, IIASA, Visual adapted from Prof. Tomas Kåberger and RMI • Note: heating refers only to low temperature heating

Electrotech enables us to get much more for much less

Electrotech can provide the same useful services for three times less final energy

Example: passenger cars

Final energy demand



The total global car fleet could run on about 13 EJ of electricity, which is equivalent to

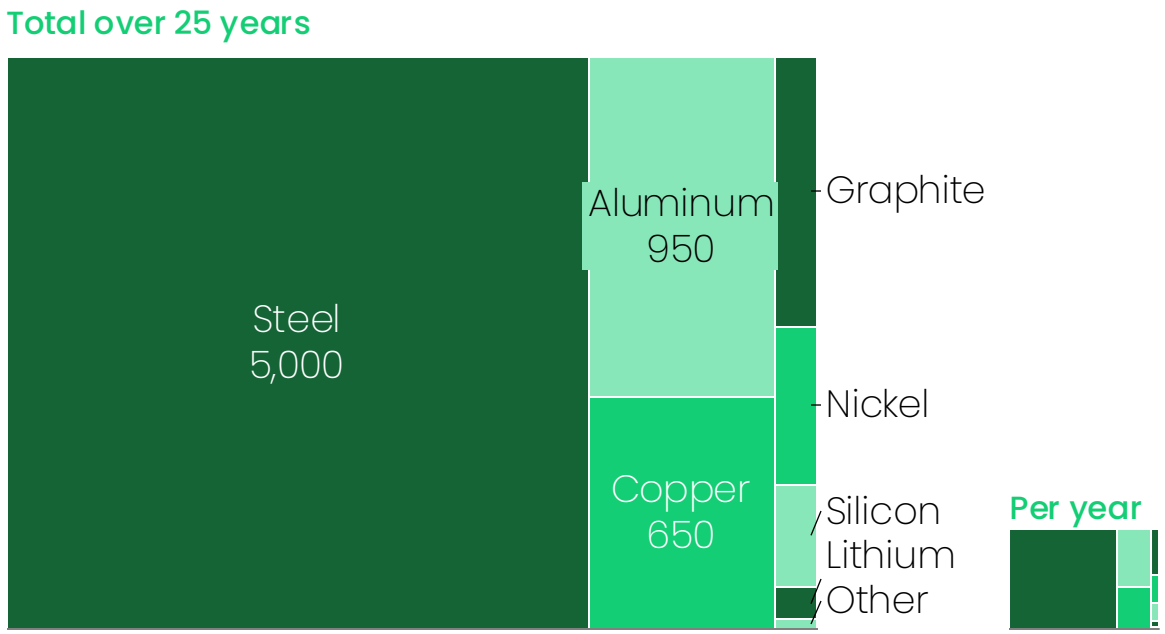
under 15% of total electricity demand today

Sources: BNEF; Ember analysis

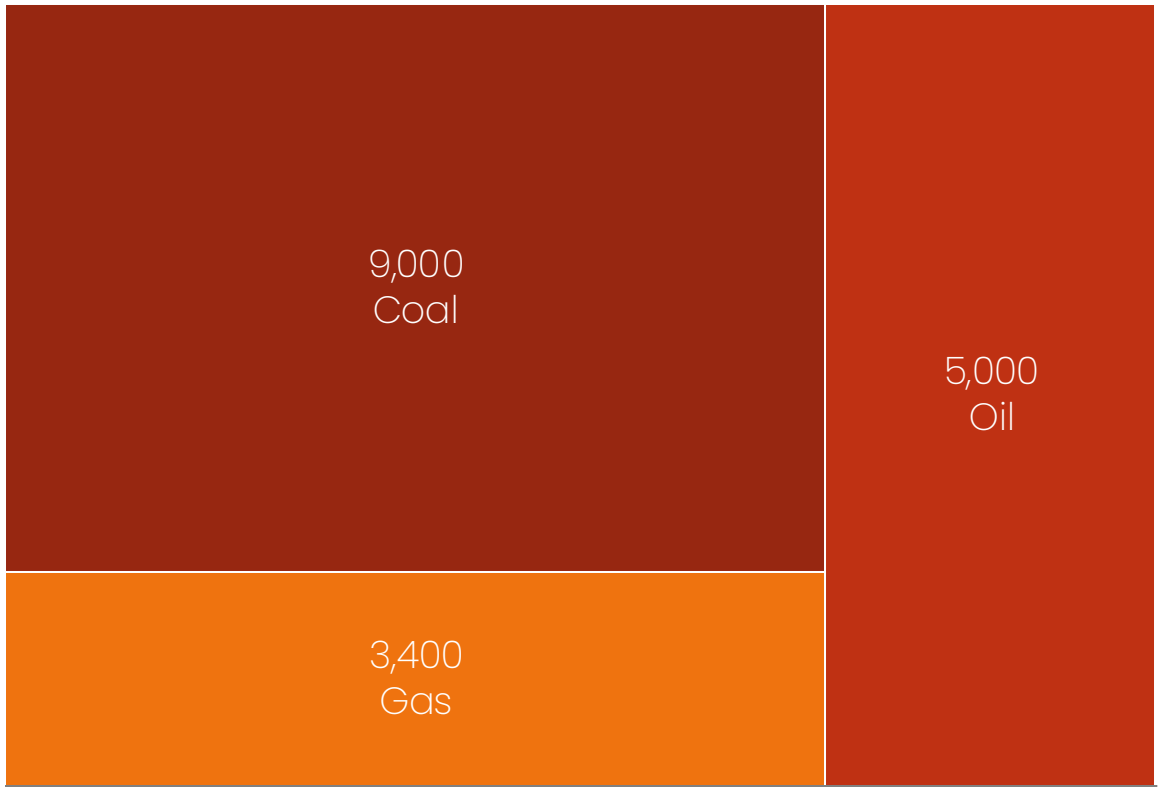
The unbearable heaviness of the fossil fuel system

The fossil fuel system requires over 50x more materials than electrotech

Total material demand for the energy transition for 25 years (*2024-2050*), Million metric tons



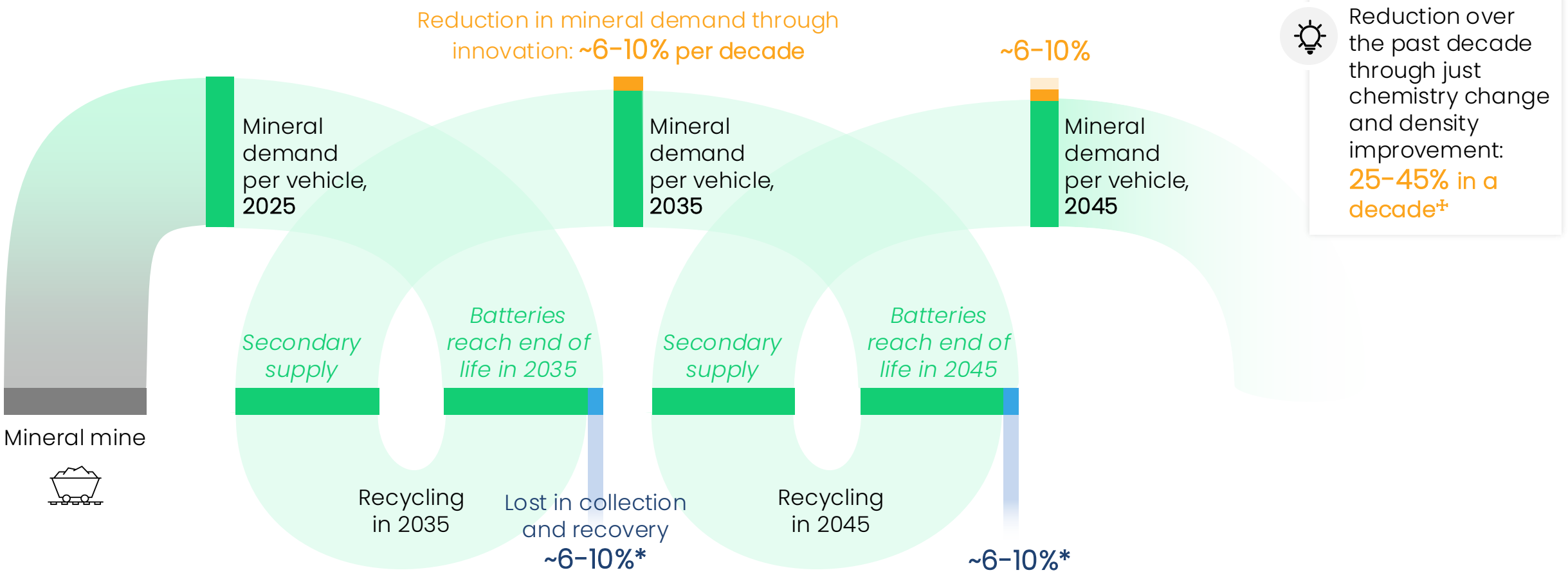
Fossil fuel extraction *per year today*, Million metric tons



Sources: ETC; EI; Ember analysis

Borrowing, not burning

If you recycle batteries and improve performance, you don't need to extract new minerals

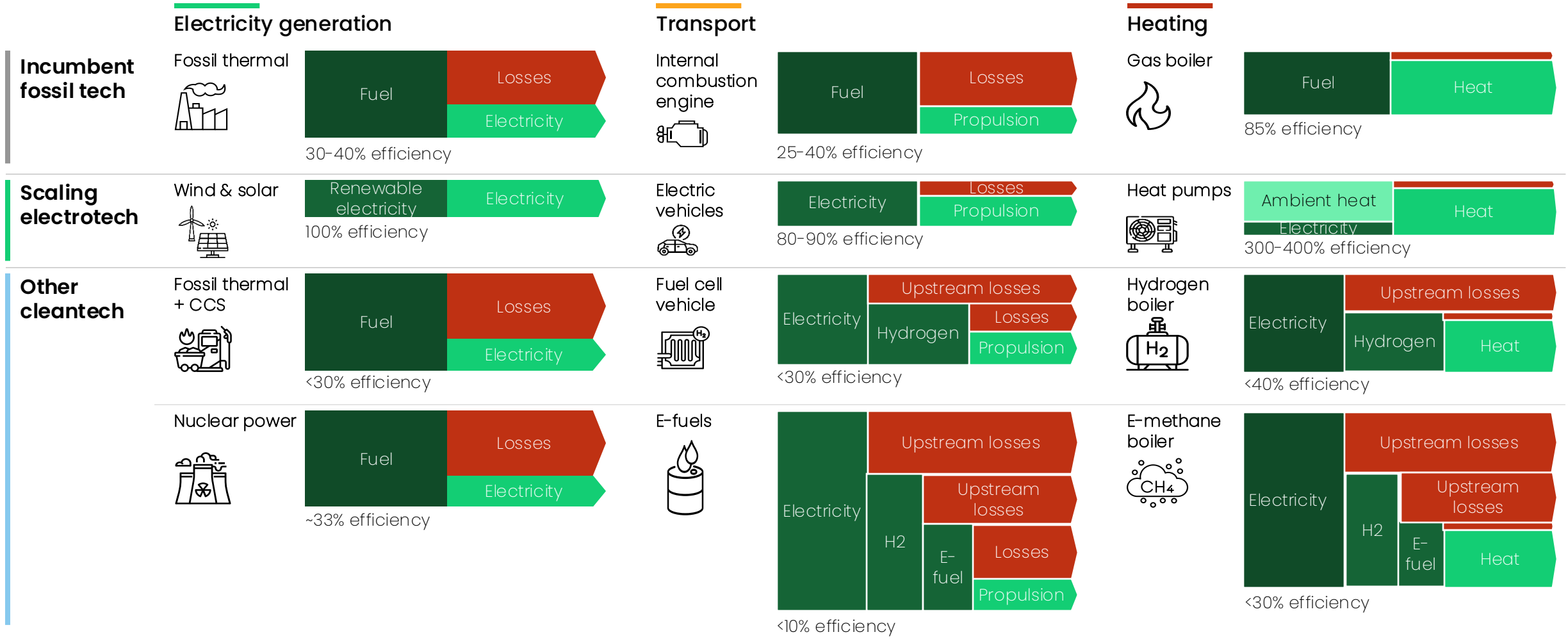


Reduction over the past decade through just chemistry change and density improvement: 25-45% in a decade‡

Sources: RMI • Notes: Useful battery lifetime of a decade is indicative; lifetimes are likely longer. * Accelerated case ‡ About 25% for lithium, about 50% or more for nickel and cobalt

Efficiency differentiates electrotech from other cleantech

Molecule-based cleantech does not enjoy the tailwinds of being more efficient



Sources: IEA, IIASA, Visual adapted from Prof. Tomas Kåberger and RMI • Note: heating refers to low temperature heating

Chapter 4.2
The economics of change

01

Technologies have learning curves

Electrotech is small and modular with lots of opportunity to innovate. The more electrotech you deploy, the cheaper it gets because of learning curves of around 20% for every doubling of deployment. In contrast, fossil fuels need to fight a constant battle against depletion.

02

Technologies grow exponentially

Electrotech grows rapidly on standard S-curves that we have seen in many other technologies over decades. For 30 years, solar capacity has been doubling every three years on average, and since 2020 battery storage has been nearly doubling every year.

03

Electrotech makes you rich

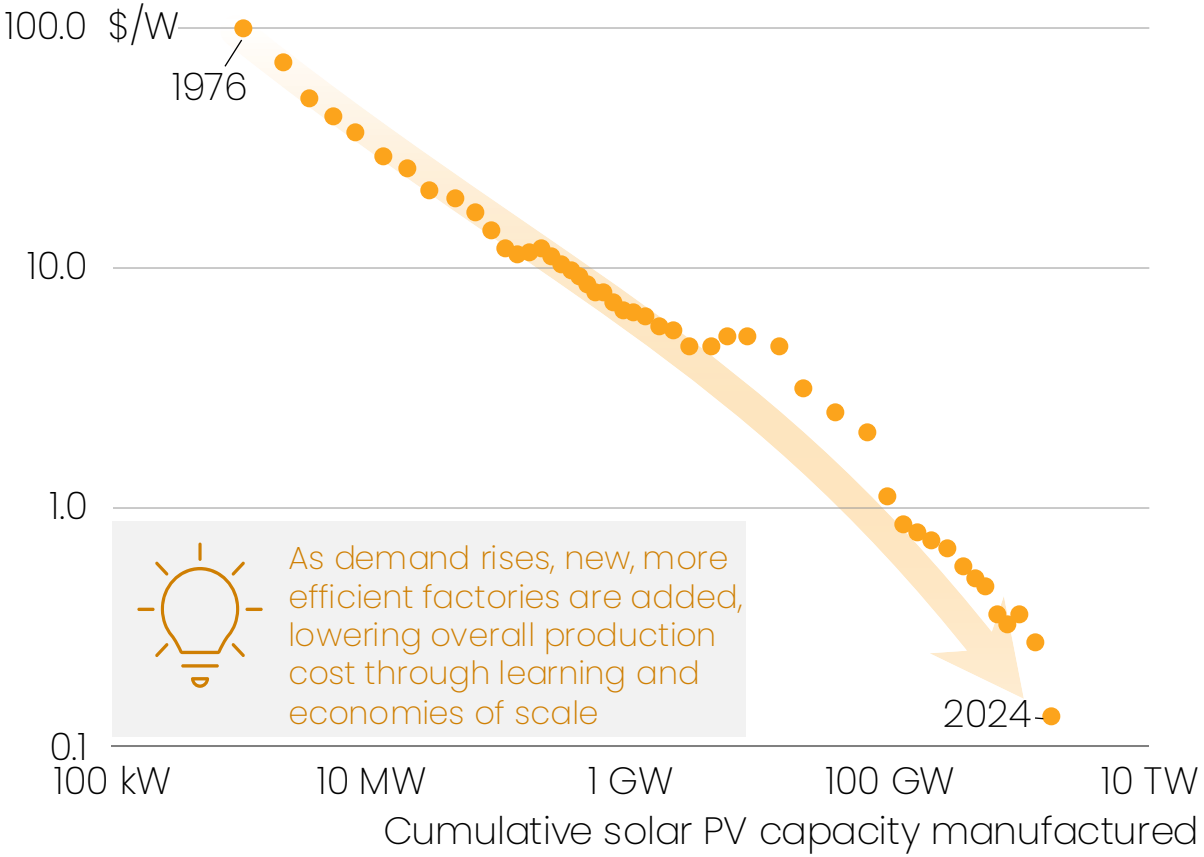
Electrotech drives GDP growth, powers the industries of the future and supplies all the expected growth in energy jobs.

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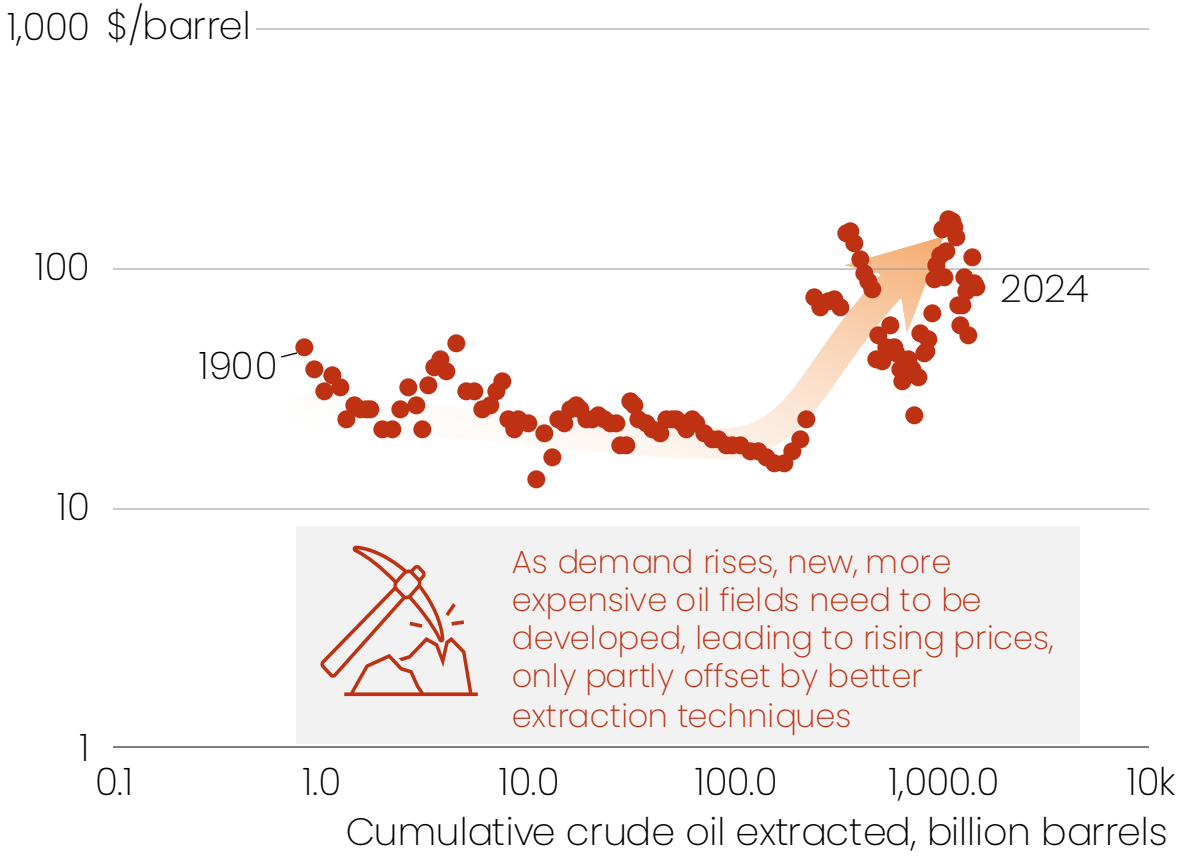
Learning beats digging

Electrotech gets cheaper with scale, whereas fossil fuels get more expensive

Solar panel price cost versus amount manufactured



Oil price versus amount extracted

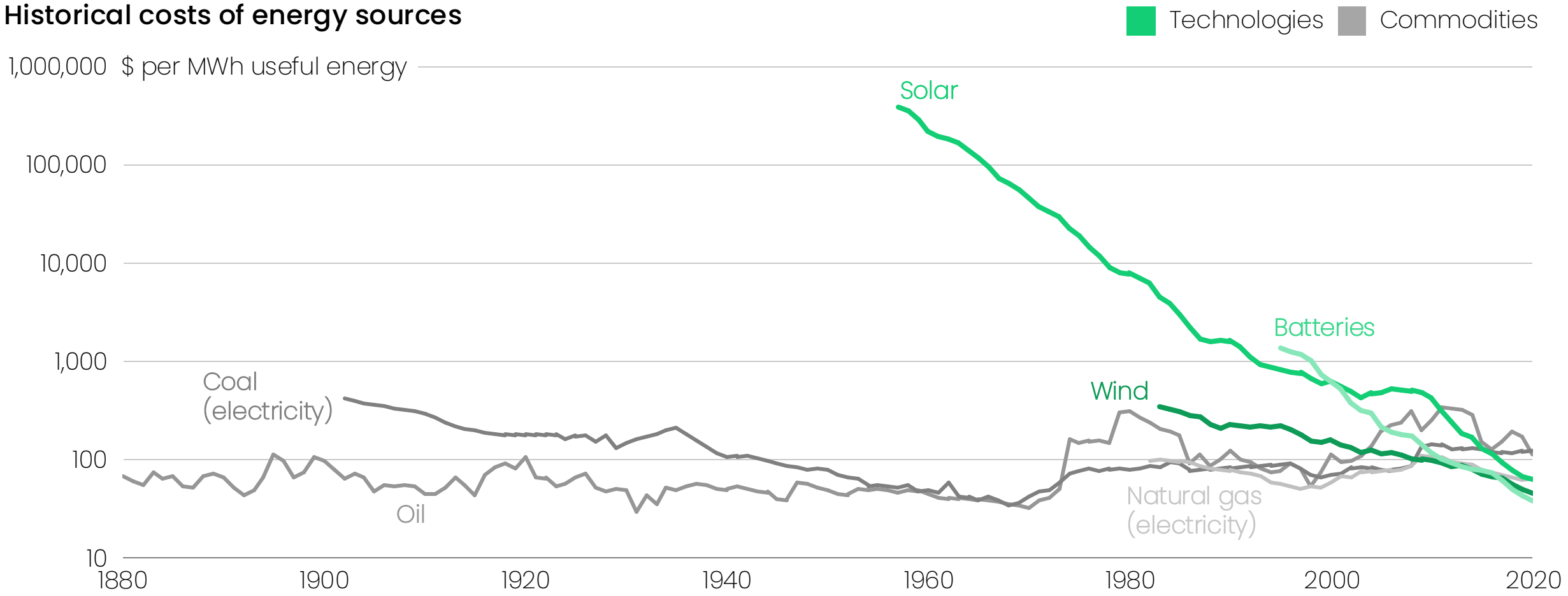


Sources: Rystad; BNEF; Ember analysis

Technologies beat commodities on cost

Electrotech is the triumph of brain over brawn

Historical costs of energy sources

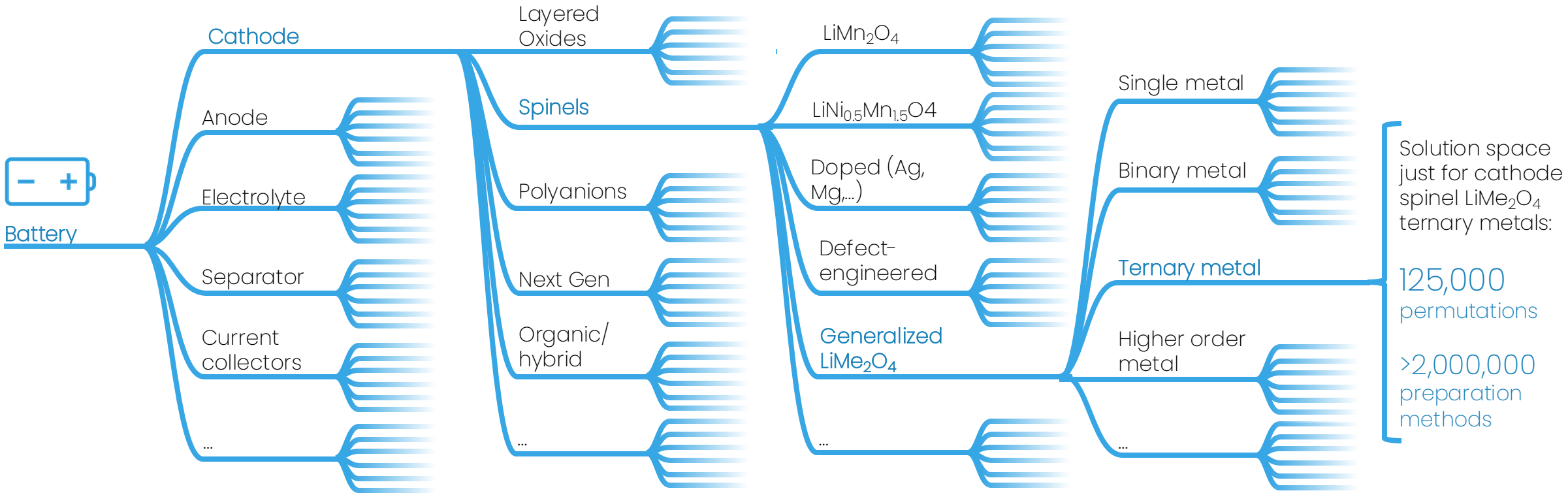


Sources: Way et al. 2022. Fossil fuel extraction has learning curves but empirically this has been matched by depletion.

There is a huge solution space to explore

The electrochemical solution space underlying electrotech is enormous

Example: battery cell solution space

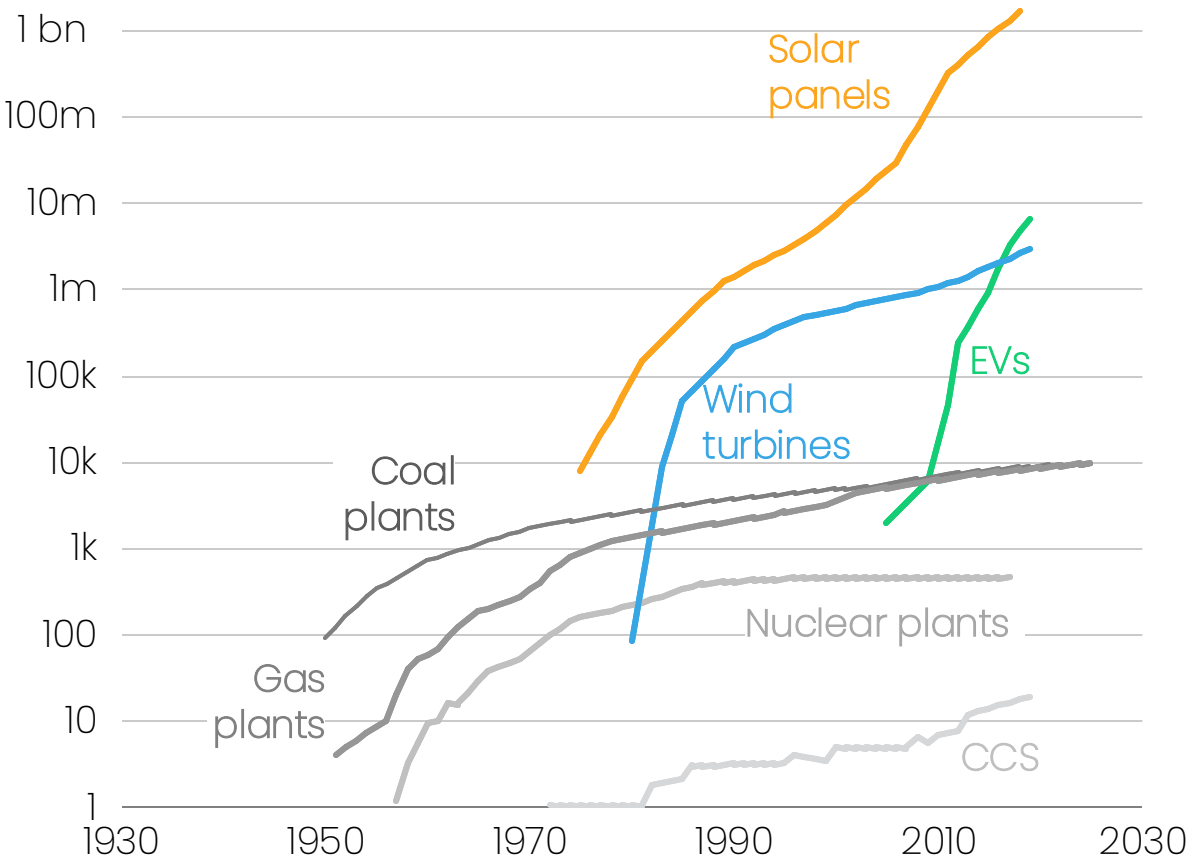


Sources: Volta Foundation; Yesuraj et al. (2024), Marincas et al. (2020), Liang et al. (2020), Choi et al. (2024), Nisar et al. (2021), Huang et al. (2021) – Note: Me = transition metal

Learning by doing

Electrotech is small, modular and cheap, allowing for a lot of experimentation and learning

Cumulative units produced



Typical deployment effort

Solar panels
1-6 months
$ 100/unit

EVs
1-6 months
$ 30,000/unit

Wind turbines
6-24 months
$ 3,000,000/unit

Gas plants
3-4 years
$ 800,000,000/unit

Coal plants
4-6 years
$ 3,000,000,000/unit

Nuclear plants
6-10 years
$ 7,000,000,000/unit

CCS projects
5-10 years
$ 1,000,000,000/unit

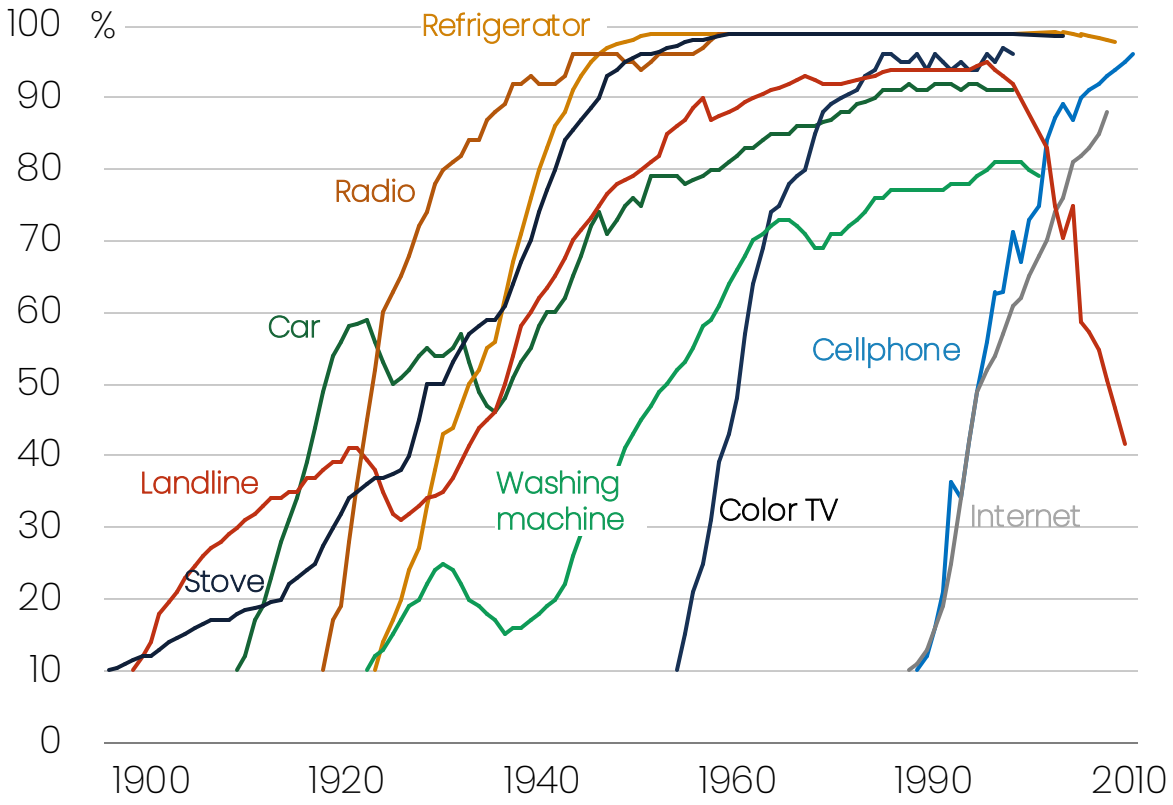
Sources: Global Energy Monitor, Greg Nemet, Ember

S-curve as usual, not business as usual

Successful technologies grow along S-curves

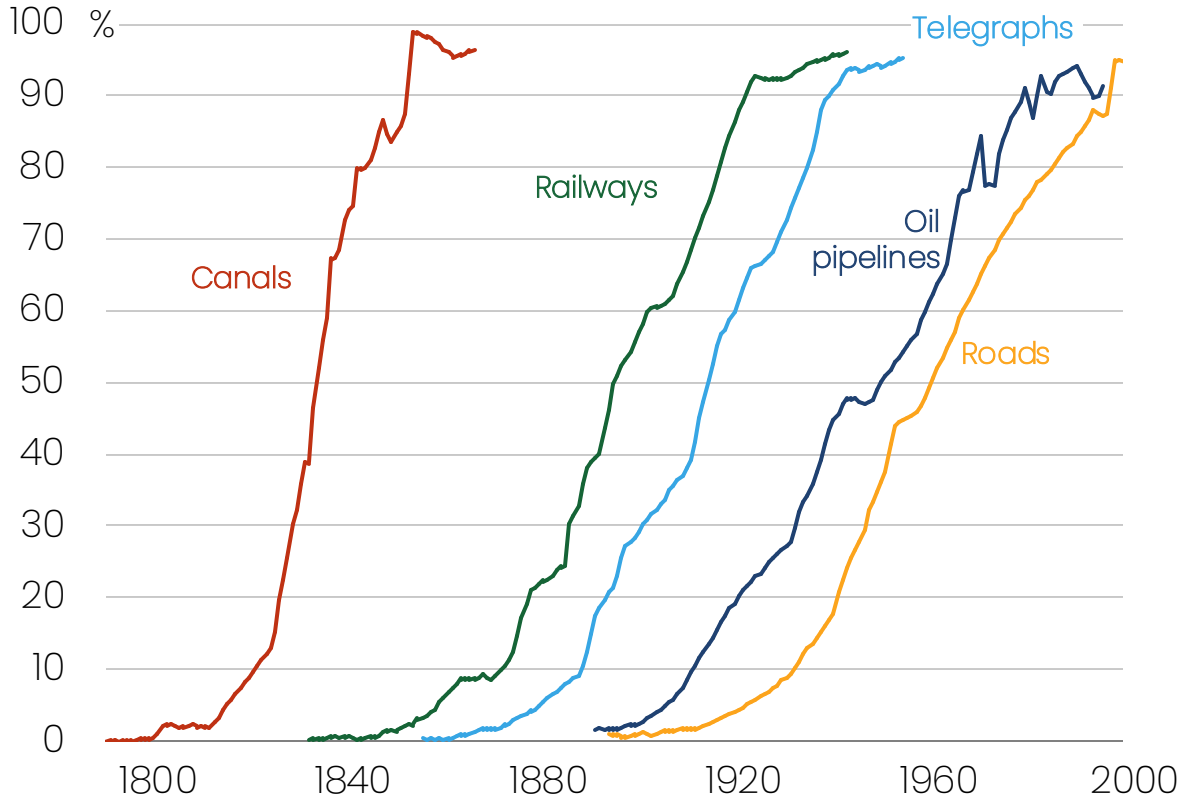
Individual products

Technological adoption by household in the United States



Infrastructure systems

Share of maximum size in the United States

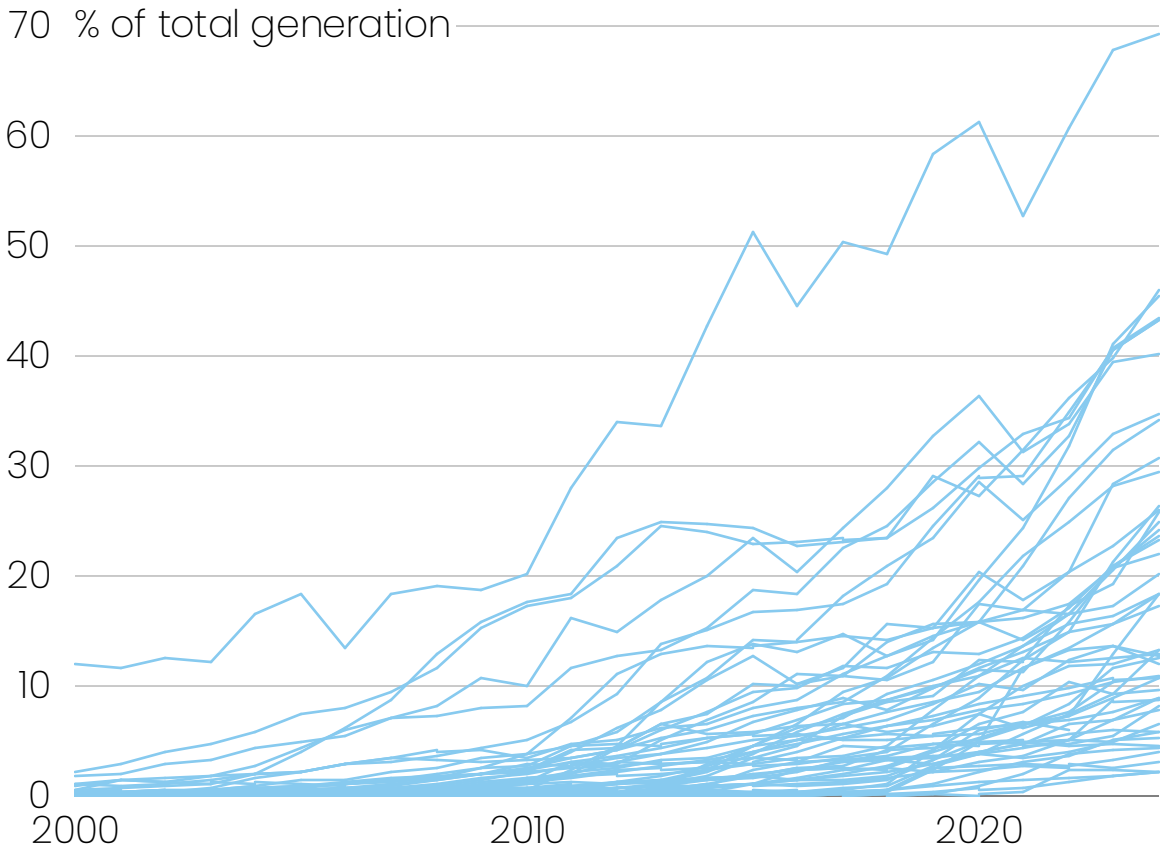


Sources: Comin & Hobijn via OWID, Grubler, RMI.

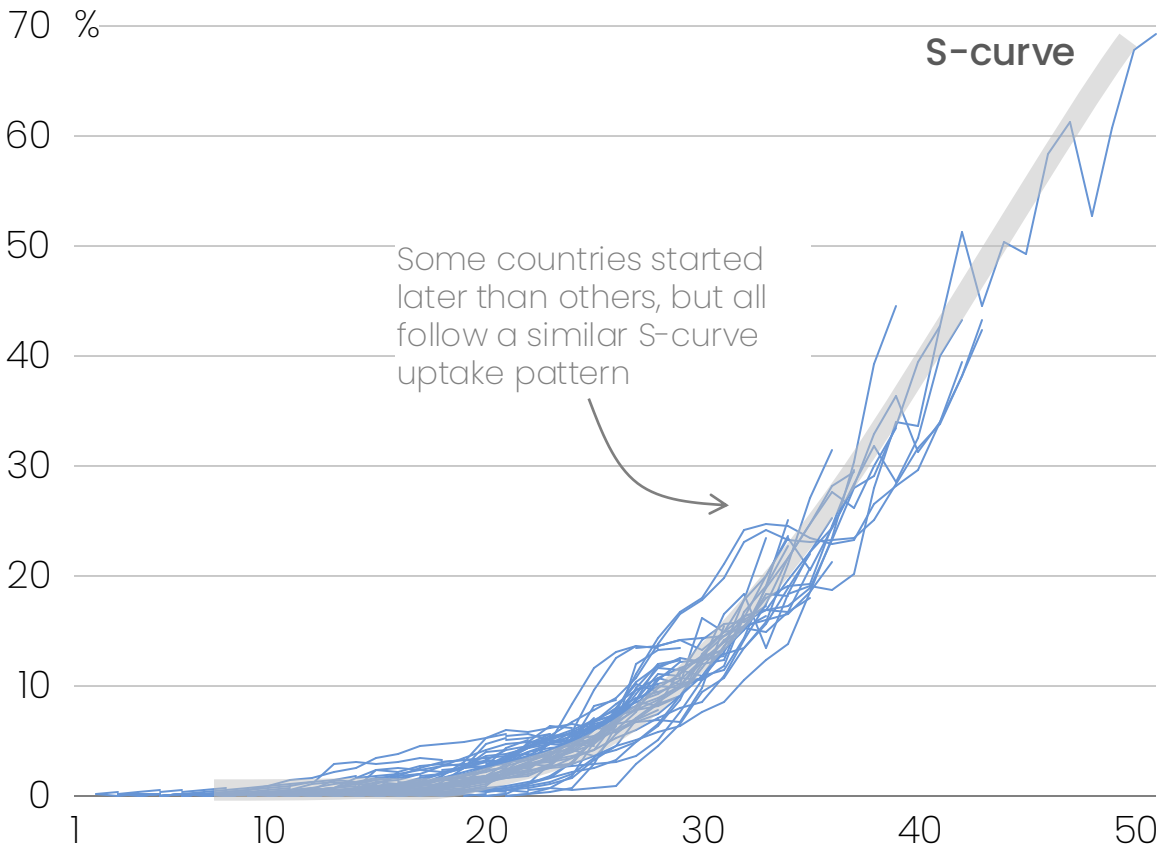
S-curves are the signal in the noise

Electrotech is growing on S-curves; timing varies but the shape is surprisingly uniform

Solar and wind uptake by country – actual



Solar and wind uptake by country – time-shifted

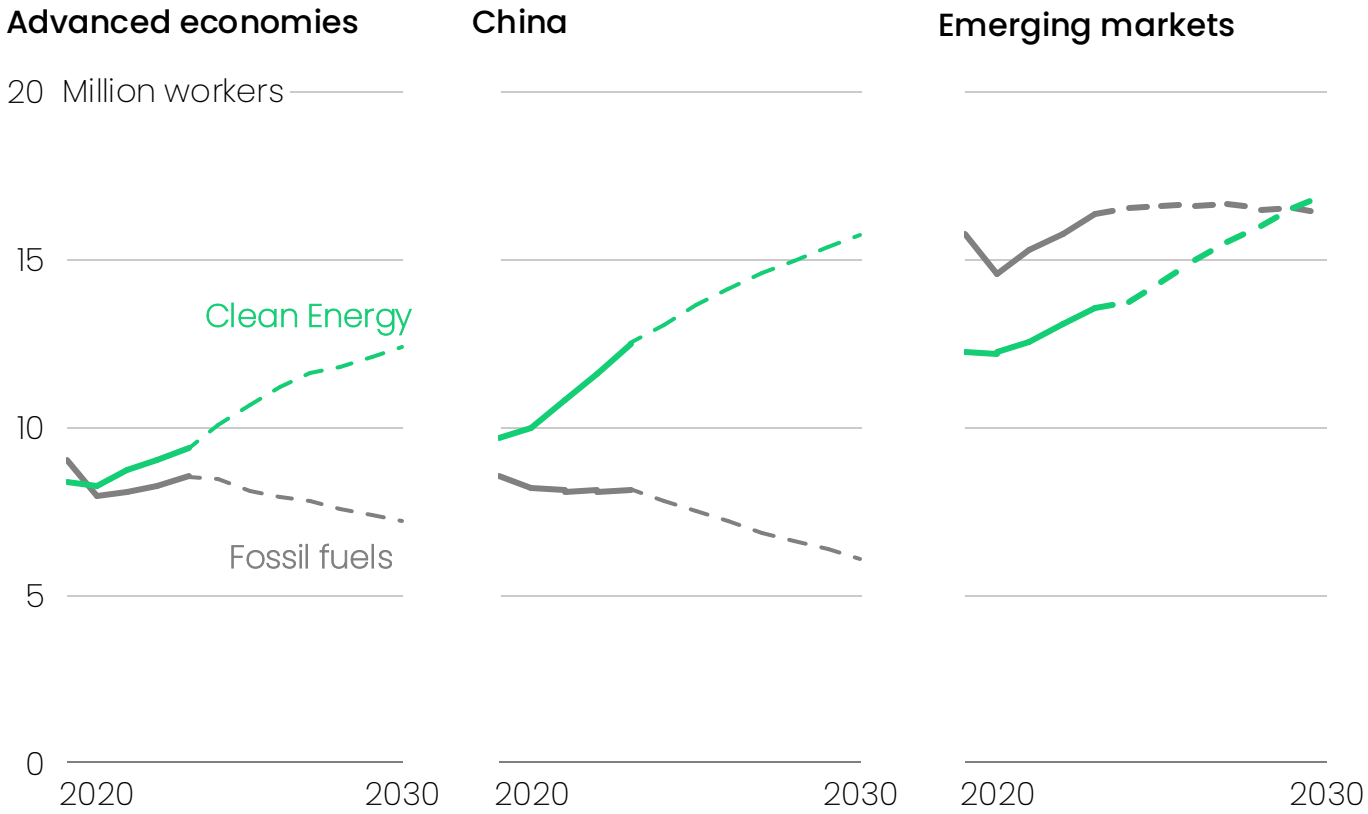


Sources: Ember data & analysis. Note: Based on the 75 largest economies by electricity demand, filtered by countries with >2% of generation from solar and wind (N=52). Country solar & wind shares were time-shifted to a global logistic S-curve.

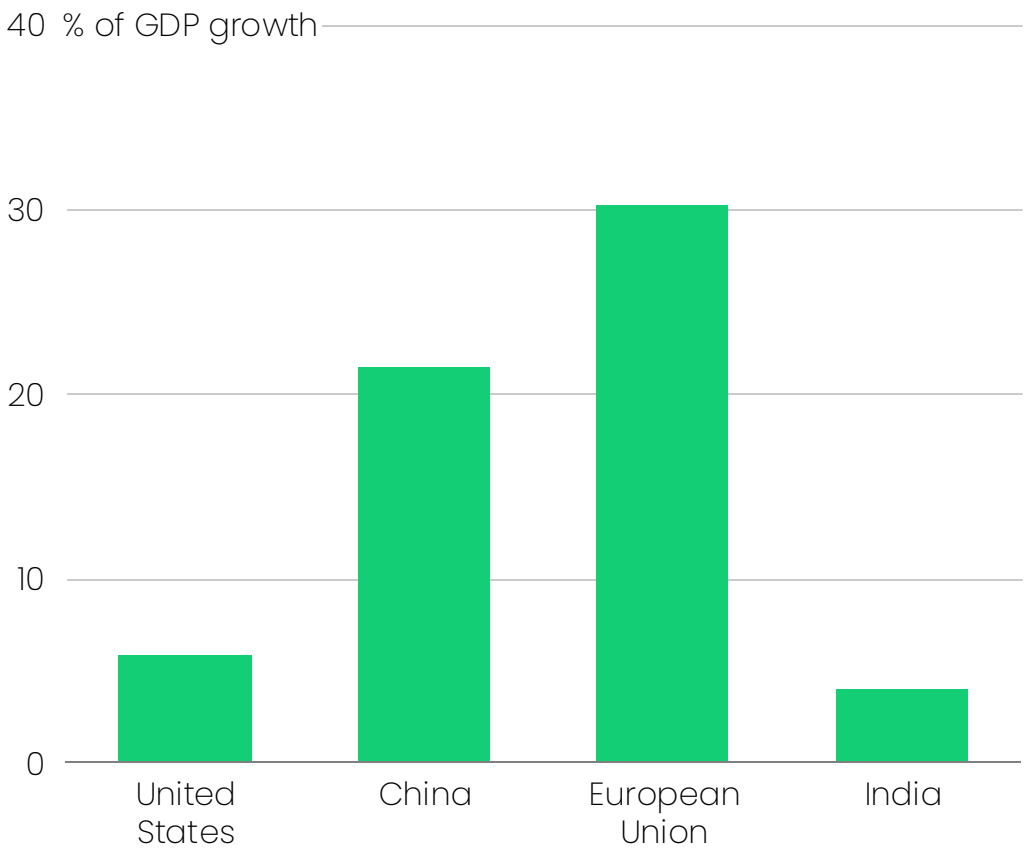
To the victor go the spoils

Winning at electrotech means gaining cheap energy, jobs, growth, and future industries

Change in energy employment, 2019-2030



Contribution of cleantech to GDP growth, 2023



Sources: IEA World Energy Employment 2024 for STEPS scenario (I), IEA ETP

Chapter 4.3
The geopolitics of change

01

Fossil fuels create dependency and risk

Fossil fuels are burnt every day and have to be bought again the next day, creating system risks for the buyers. Three quarters of the world live in fossil fuel importers, and regions like Europe are dependent on imported fossils for two thirds of their energy supply. In a world of rising tension, that is far too much risk to bear.

02

Electrotech enables energy security

Electrotech is the foundation of energy security because every country has access to the sun and wind, and can electrify end demand. Renewables added to the electrification of transport and low temperature heat can reduce fossil imports by 70%. Once electrotech is bought, it lasts for decades, providing insulation from the vagaries of global pricing.

03

China is leading the race to the top

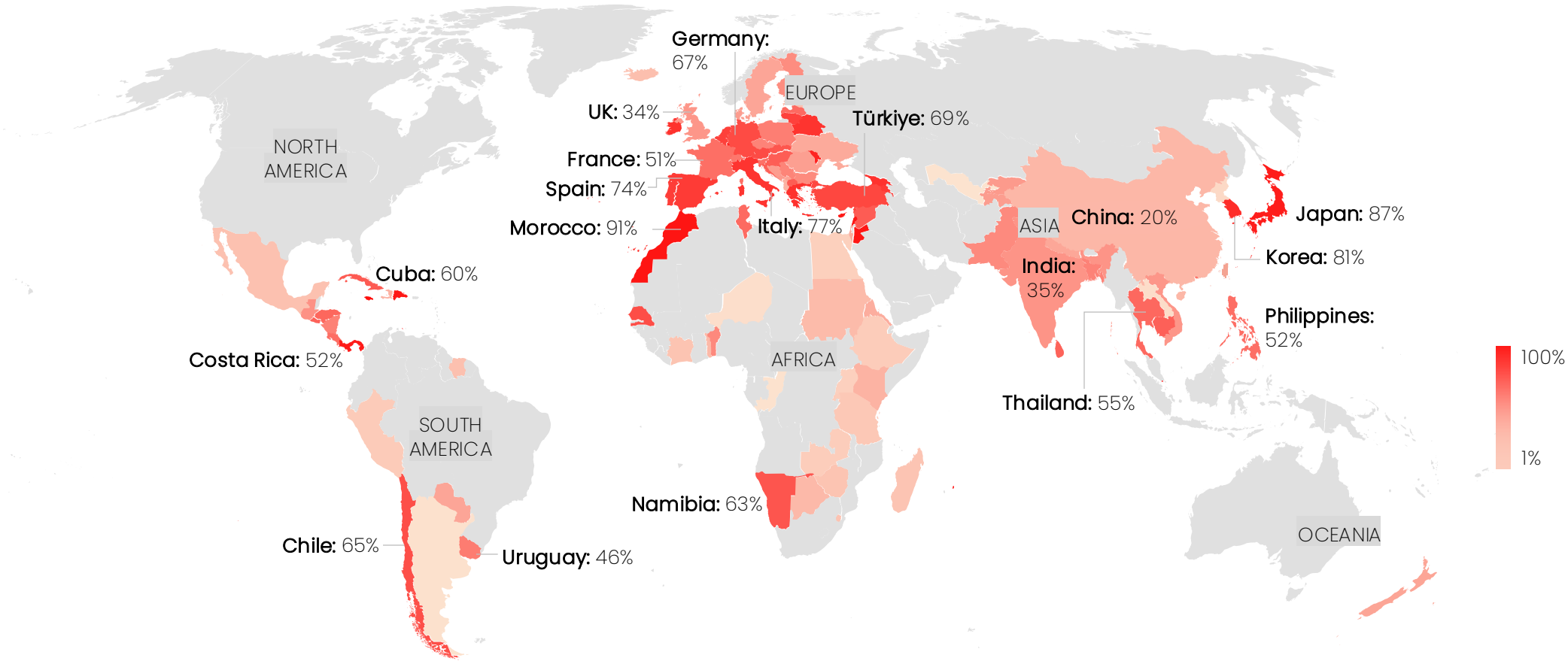
China is leading the electrotech revolution and deploying its technology at scale and speed into the emerging markets. Other countries seeking independence and influence will need to compete in this race to the top for the superior technologies of the future.

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Fossil import dependency is widespread

Over 50 countries import more than half their primary energy as fossil fuels

Fossil net imports as a share of primary energy demand 2022, %

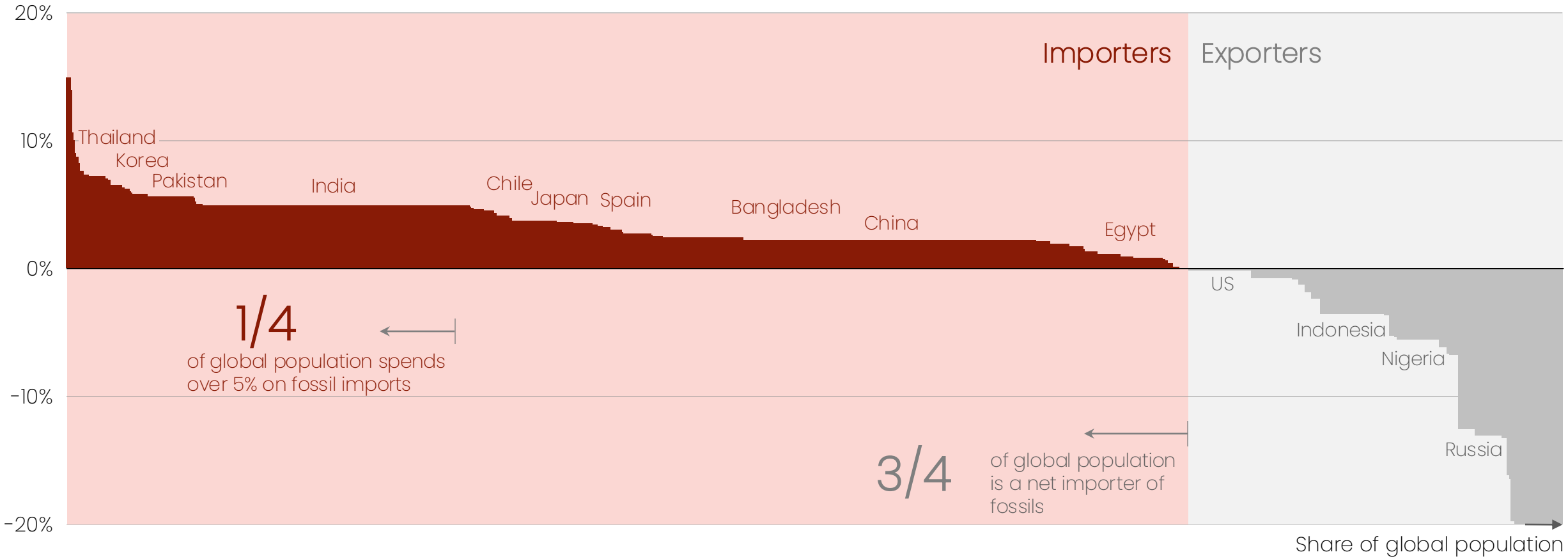


Sources: IEA WEB, Ember analysis. Map boundaries are from Microsoft Bing and do not imply any judgment on legal status or sovereignty.

Fossil fuel imports are very expensive

A quarter of the world spends over 5% of GDP on annual fossil fuel imports

Fossil fuel net imports (-) and exports (+) value as share of GDP, 2022

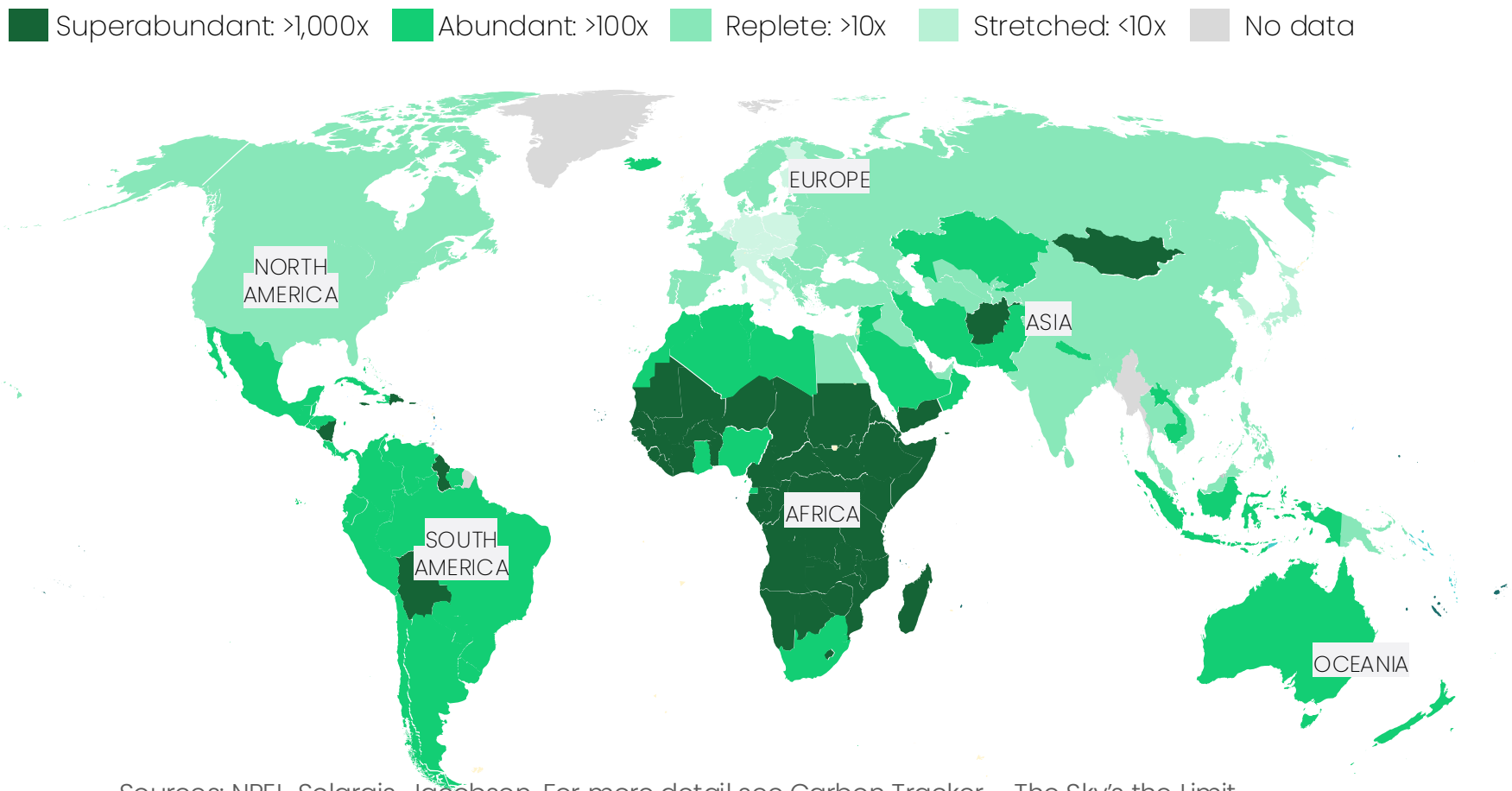


Note: GDP balance based on energy trade balances in EJ from 2022, multiplied by typical commodity prices from IEA.
Sources: IEA WEB, Ember analysis. • Note 1: the y-axis is capped at -20% for readability.

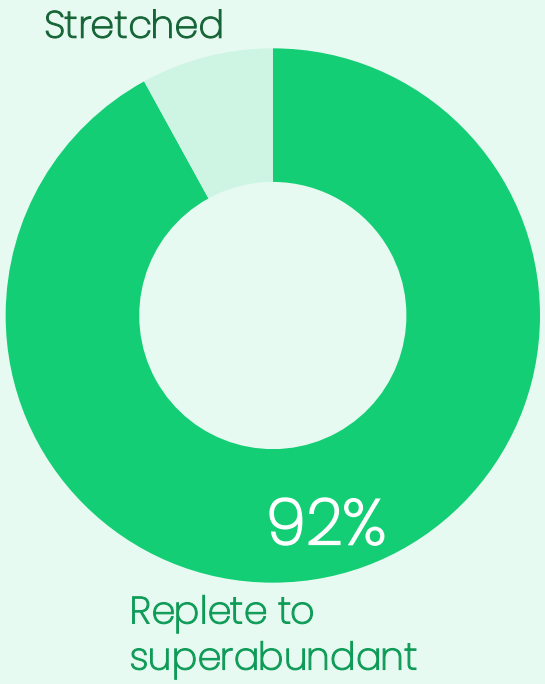
Renewables are available to all

They are 100x bigger than fossil fuels and every country has enough to be self-sufficient

Renewable potential as a multiple of energy demand in 2022



Share of population endowed with replete or better renewable resource



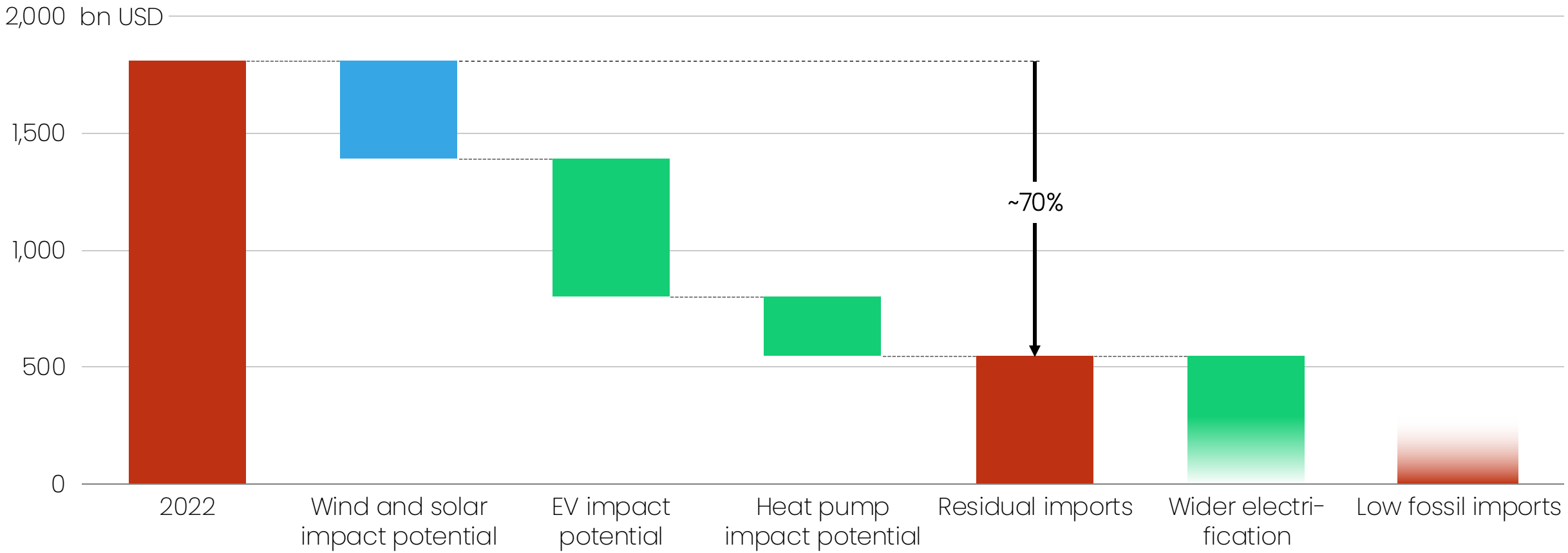
Sources: NREL, Solargis, Jacobson. For more detail see Carbon Tracker – The Sky's the Limit
Map boundaries are from Microsoft Bing and do not imply any judgment on legal status or sovereignty.

EMBER 82

Renewables, EVs and heat pumps set you free

Just a few technologies can reduce global energy imports by 70%

Global net spending on fossil fuels by importers

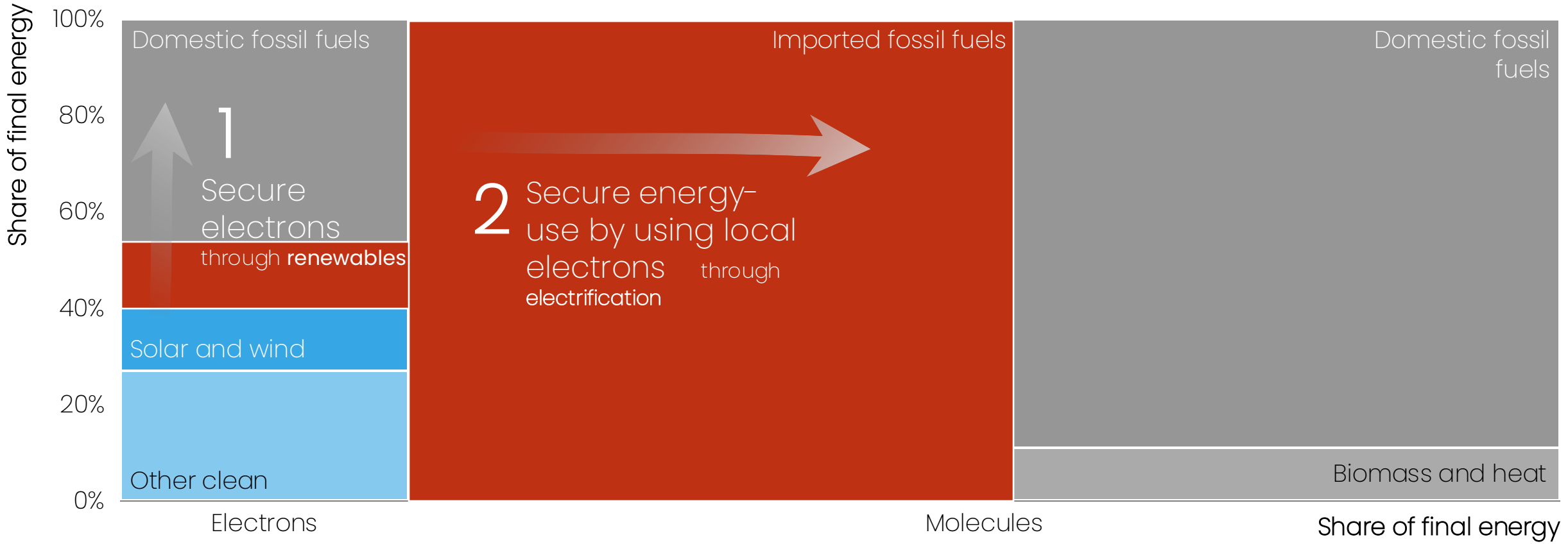


Sources: IEA WEB, World Bank, Ember - Energy Security in an insecure world. The chart illustrates the reduction in fossil fuel imports possible by deploying solar, wind, electric vehicles and heat pumps

Electrotech brings energy security

More domestic renewables and electrification can drastically curb energy dependence

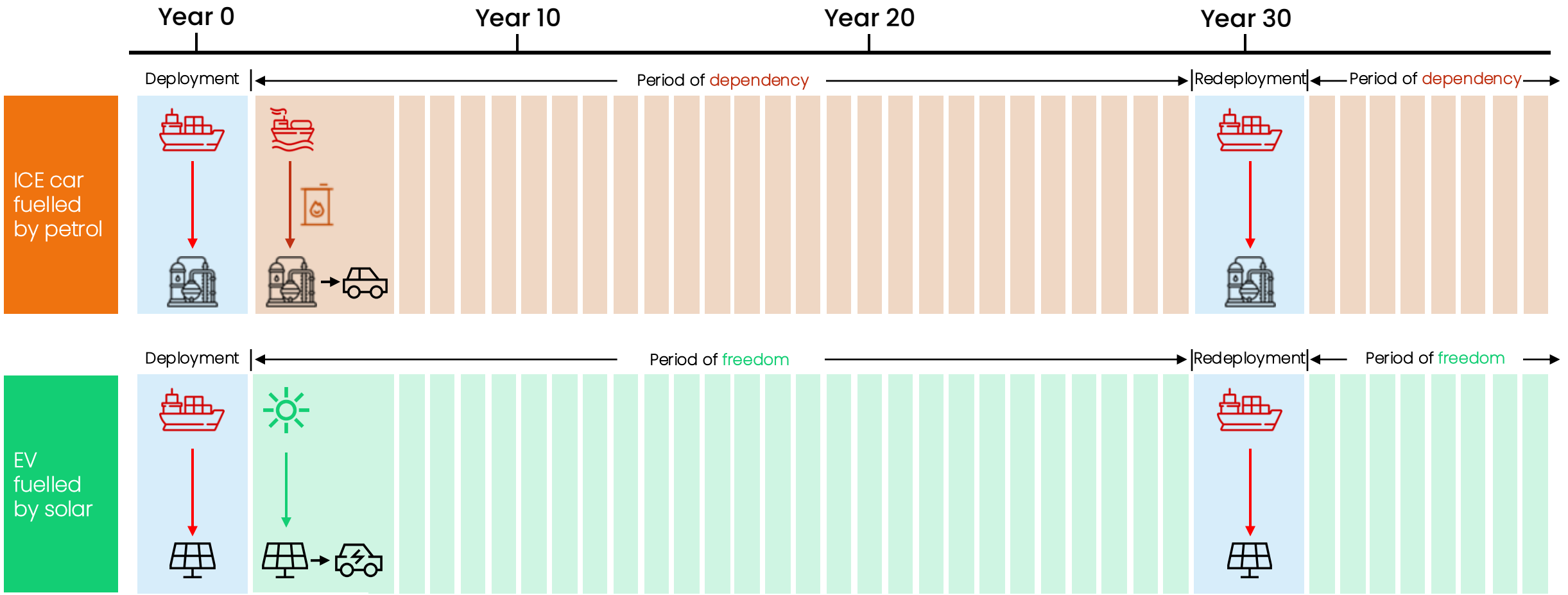
Global energy demand in 2023



Sources: IEA WEO 2024, IEA WEB, Ember • Notes: In gross terms and in final EJ. Other clean electrons are mainly hydro and nuclear.

You can’t turn off the sun

A solar panel provides 30 years of energy freedom

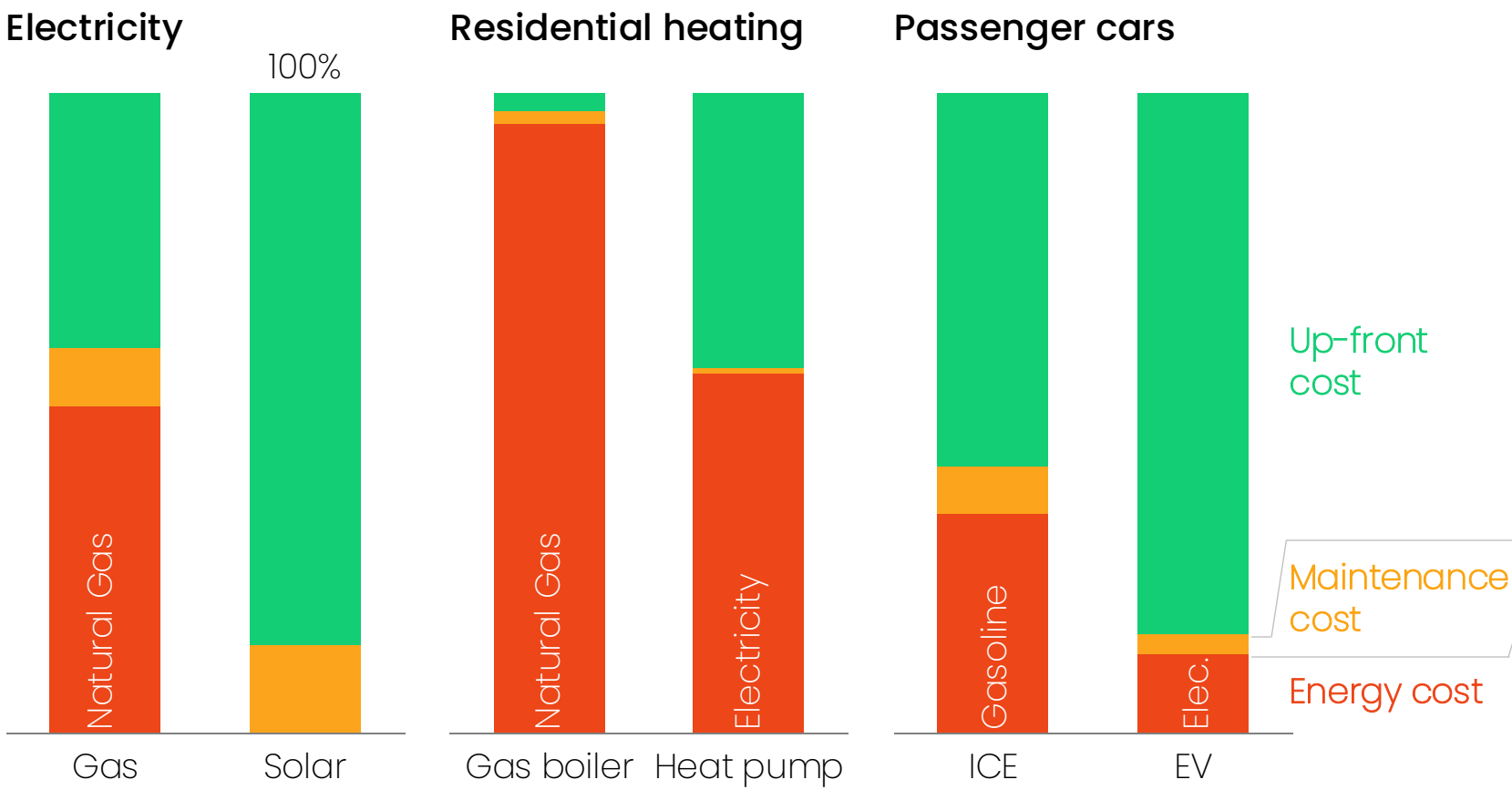


Sources: Ember

Electrotech saves you from fossil volatility

Once installed, electrotech costs remain stable — even if global supply chains falter or fuel costs rise

Total cost of ownership breakdown, %, US examples



Inflation risk after deployment

Low/ None — Cost already sunk
Cost don't change with inflation as technology is already deployed.

Mid — Labor & manufacturing inflation
Inflation in labor and replacement parts can raise maintenance cost.

High — Energy inflation
Note: This applies less to electricity, as purchased electricity can originate from renewables like solar power, which primarily involve fixed costs and therefore carry minimal inflation risk.

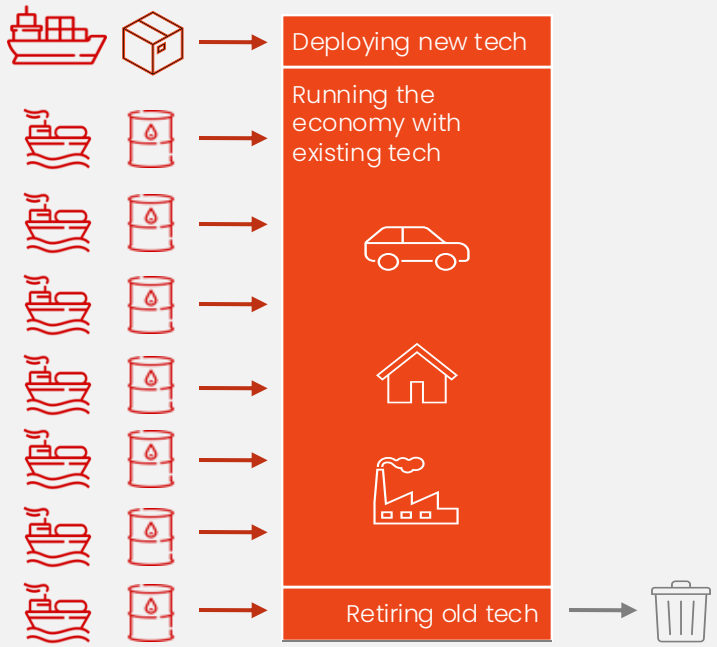
Sources: Lazard 2024; NREL; IEA EV TCO tool; RMI analysis

Electrotech offers a path to permanent energy security

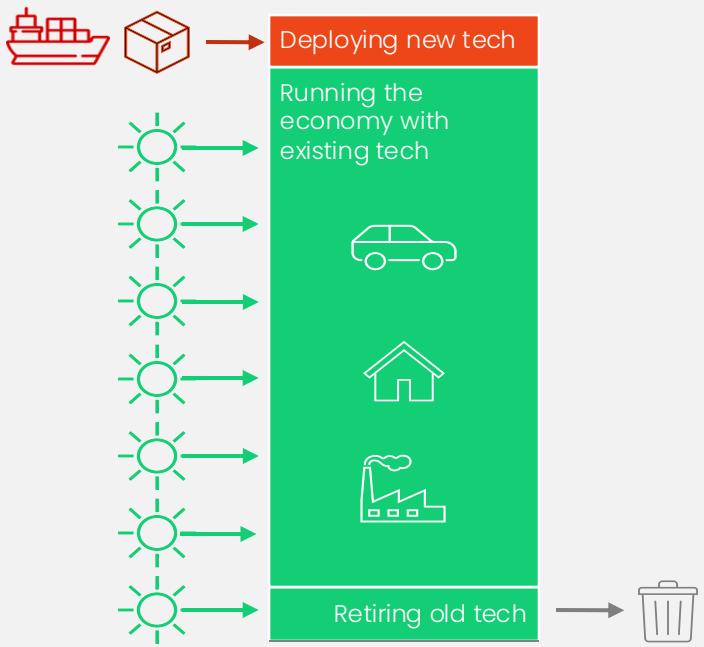
When fossil flows stop, the economy stops. When electrotech flows stop, only growth is at risk

From fossil import dependency... → ...to electrotech import dependency... → ...to full circular energy independence.

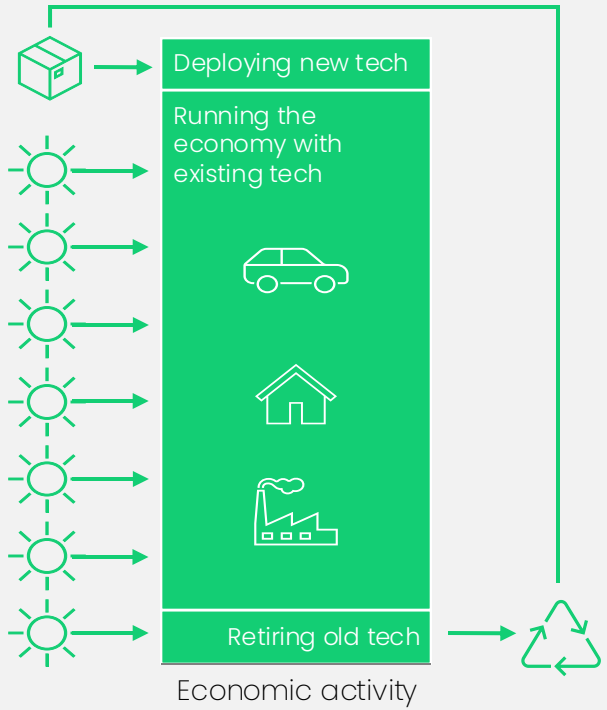
In an economy running on fossil imports, **when imports stop, all activity stops**



In an economy running on imported electrotech, **when imports stop, only growth is inhibited.**



In an economy running on local circular electrotech, **trade shocks have little impact**



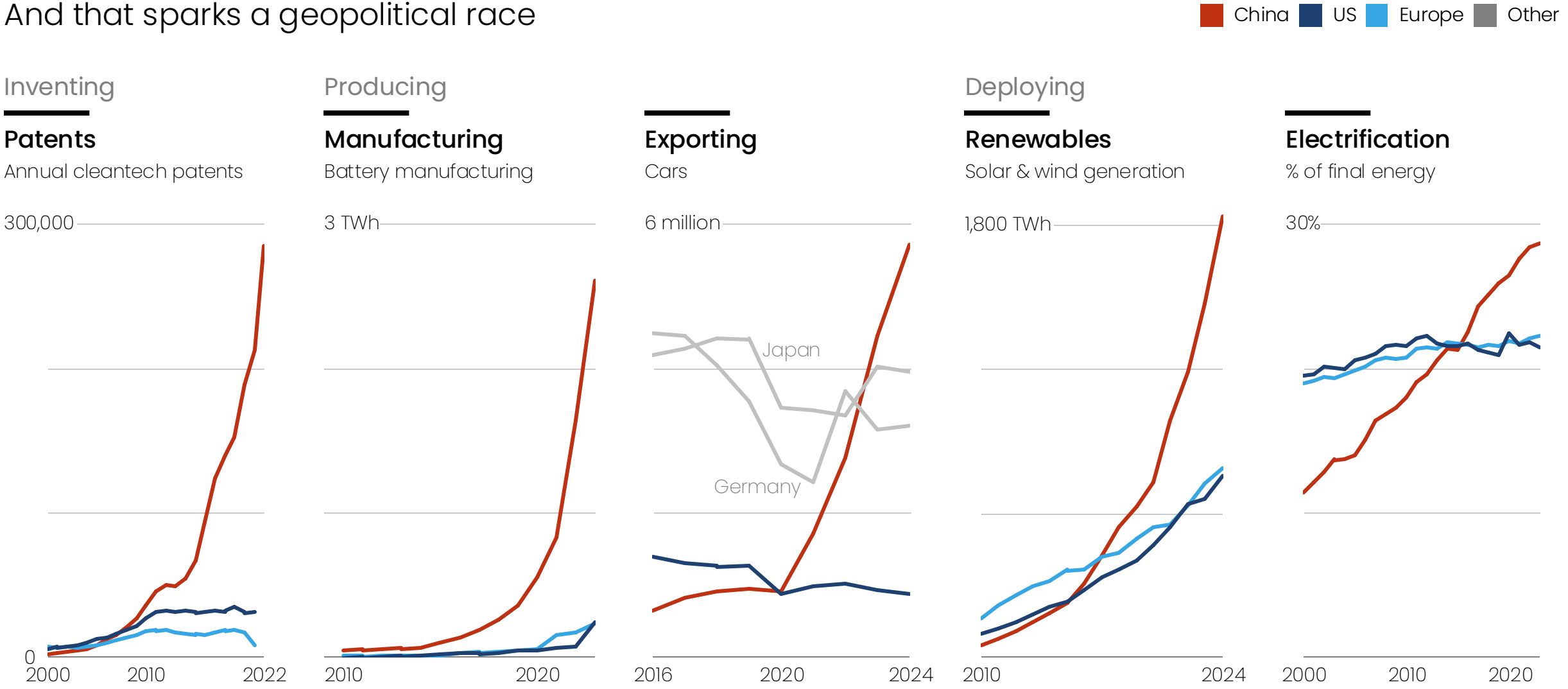
At immediate risks without imports

Not at immediate risk

Sources: Ember• Note: bar sizes are illustrative

China is the first major electrostate

And that sparks a geopolitical race



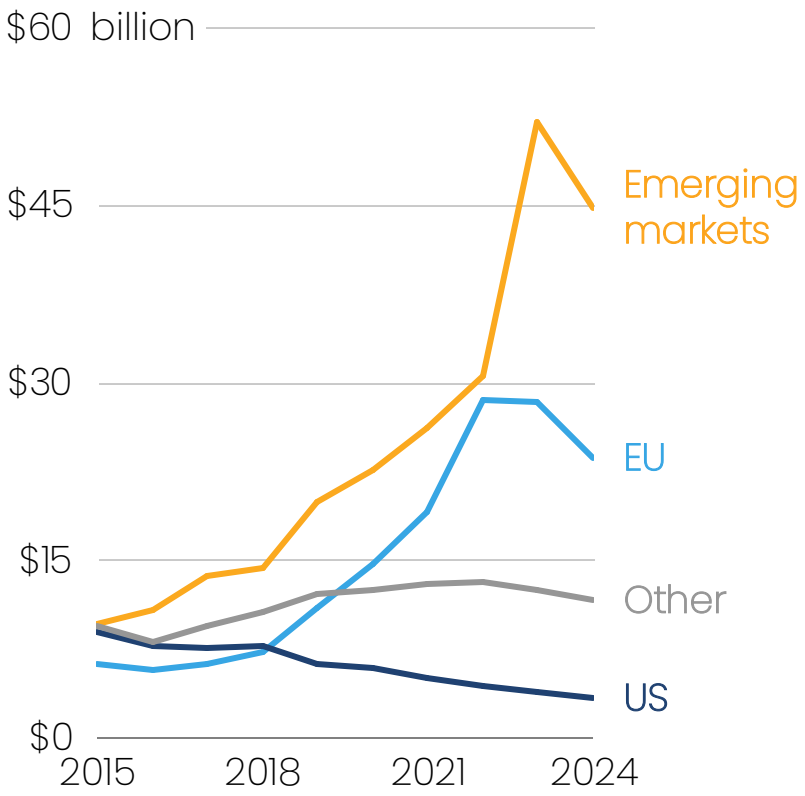
Sources: Ember, IEA WEB, IRENA, BNEF, NYT.

China is exporting the electrotech revolution to the world

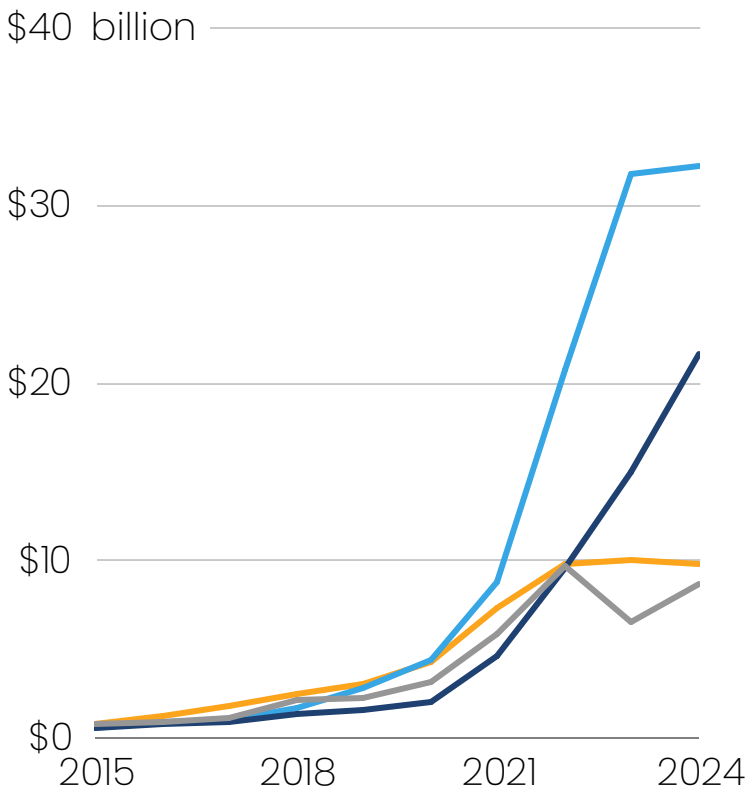
Gaining allies along the way — especially in the emerging markets

Chinese exports

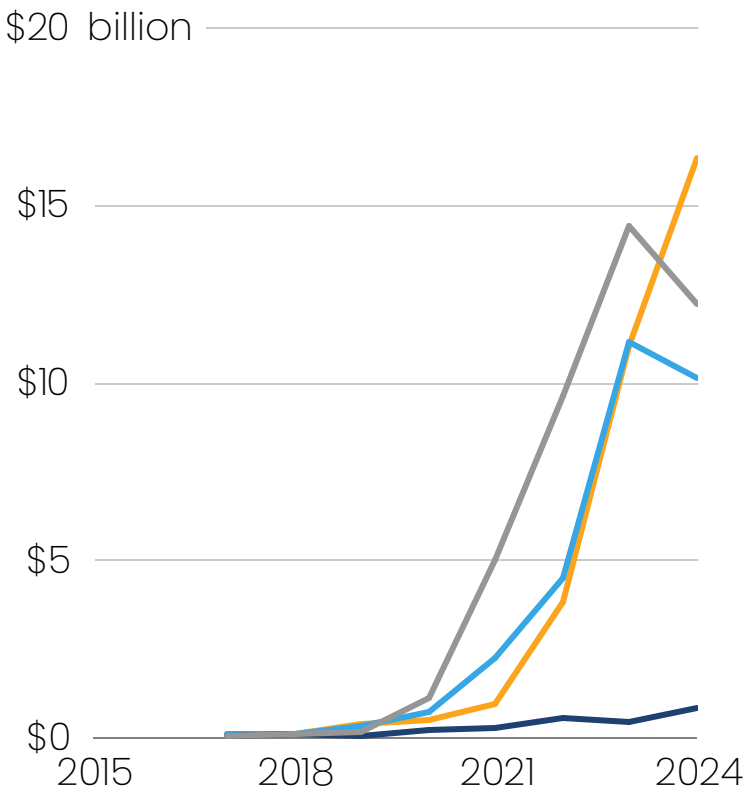
Solar PV



Batteries



Electric vehicles

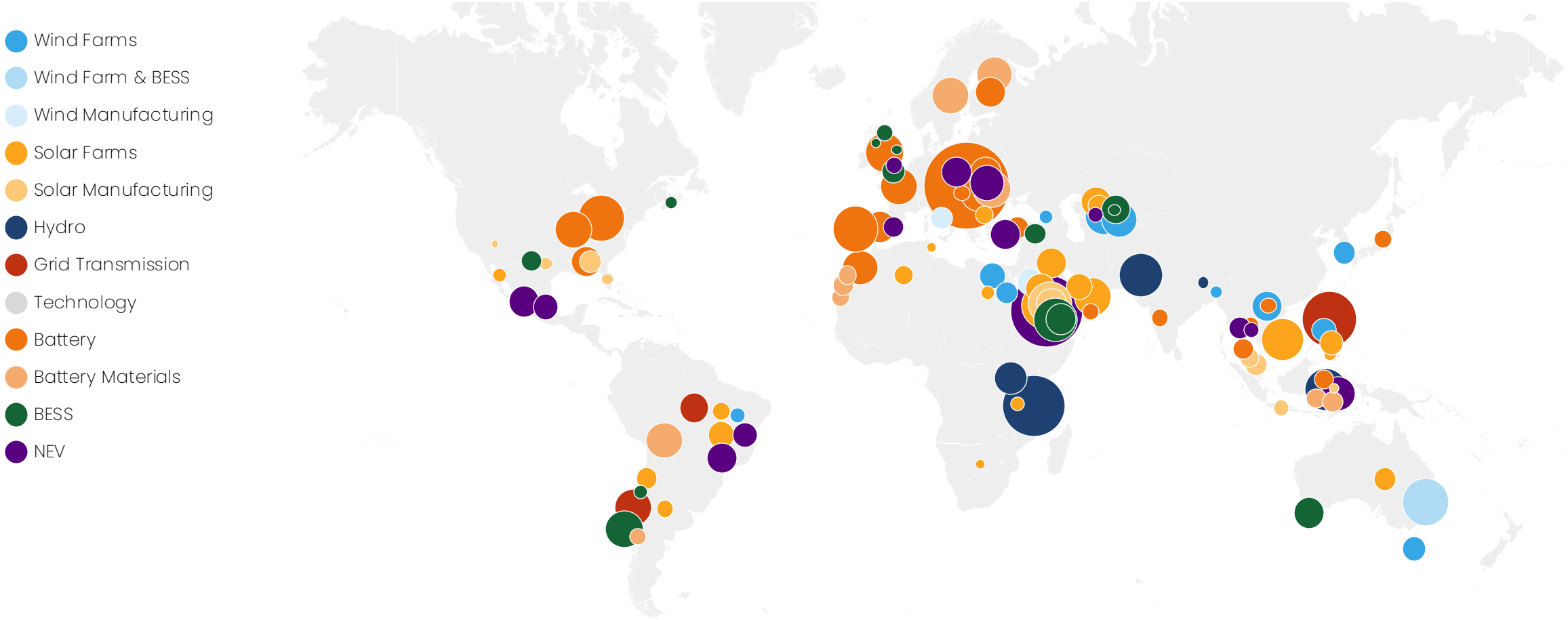


Sources: Comtrade; Dialogue Earth; Nat Bullard

China is exporting the capacity to build electrotech

Over $100bn of outbound FDI on electrotech since 2023

Chinese electrotech investment since 2023



Sources: Climate Energy Finance: Power Shift, Ember annotation

Chapter 5.1

Profound impact on the energy system

01

Electricity 2.0 speeds up change

Electrotech solutions are converging into a river of change which will drive more rapid electrification and a continuation of the growth of renewables up S curves.

02

The emerging market leapfrog continues

The emerging markets will continue their energy leapfrog, led by the growth nations of Asia. Many emerging markets are deploying renewables more rapidly than developed markets did before them and are electrifying end demand more quickly.

03

Fossil fuel demand will be in decline by 2030

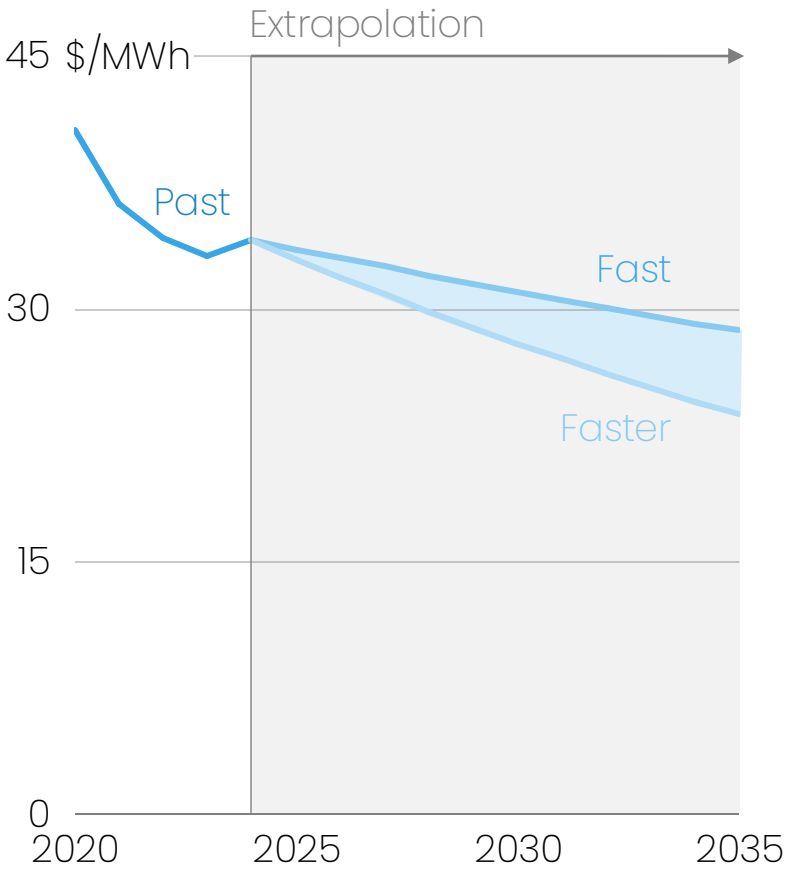
Fossil fuel demand is on a bumpy plateau at present, but the continued rapid growth of electrotech will increasingly push fossil fuels into decline by the end of the decade. This is substitution not addition. And that creates vulnerability for areas such as refining or LNG.

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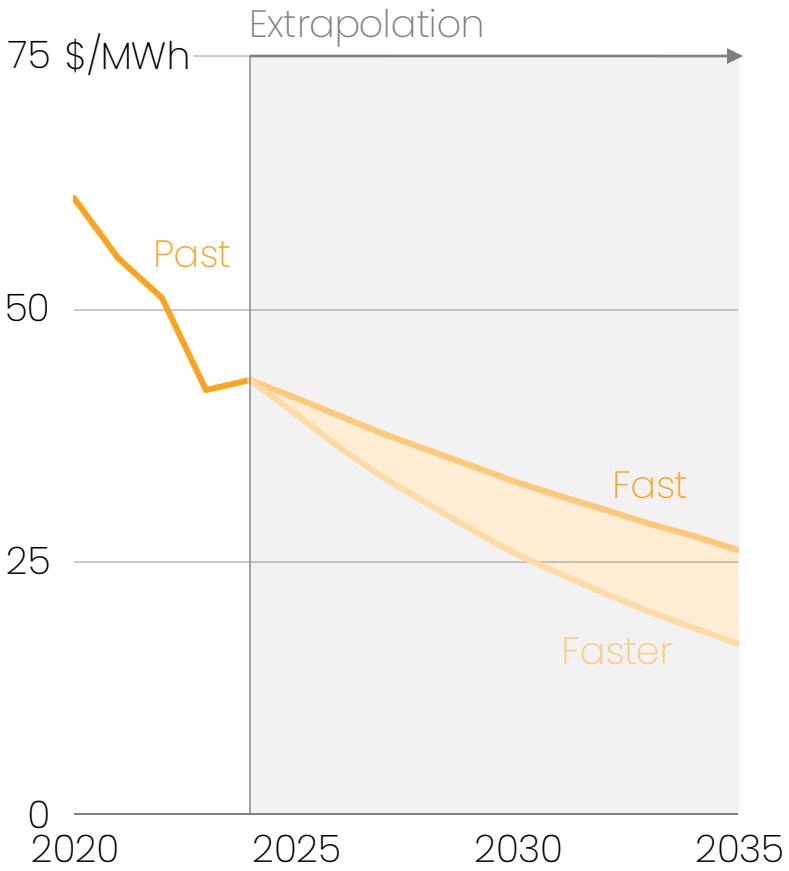
Electrotech will get cheaper driven by learning curves

From competitive to irresistible

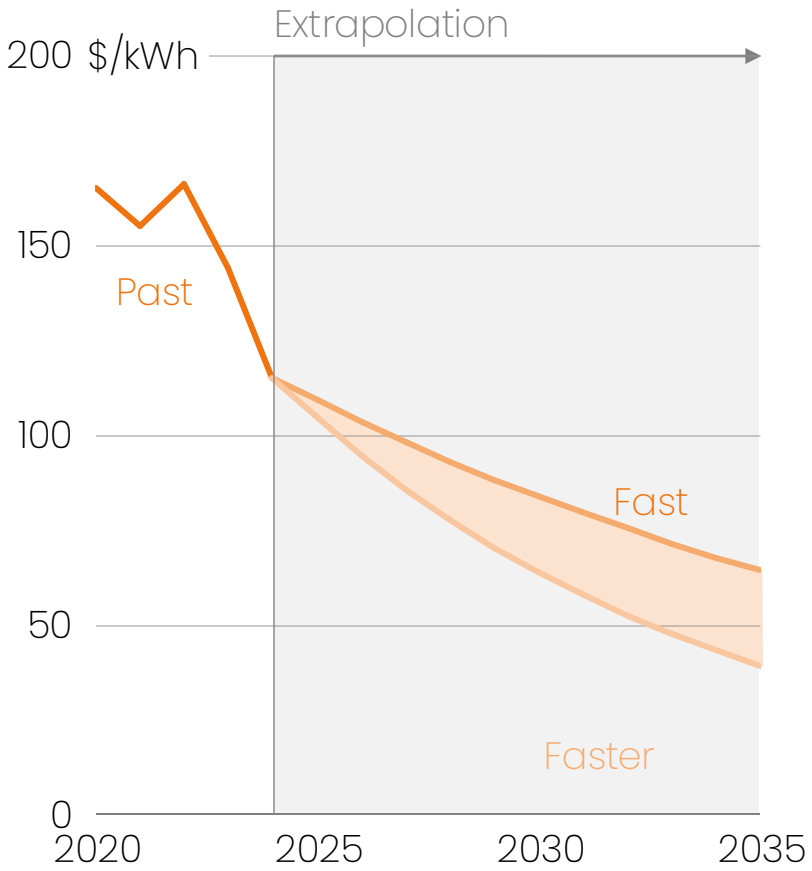
Wind costs



Solar costs



Battery costs



Sources: IRENA, BNEF, Ember Futures extrapolation based on learning rates; a method set out in detail by Oxford INET among others. Costs are derived by extrapolating historic growth rates and learning rates for each of the key technologies for the next decade. Solar assumes growth (g) of 15%-18% and learning rates (LR) of 20-30%. Wind 8-13%(g) growth 12-17% (LR). Batteries 19-22% g & 19-29% LR.

Electricity 2.0 is here

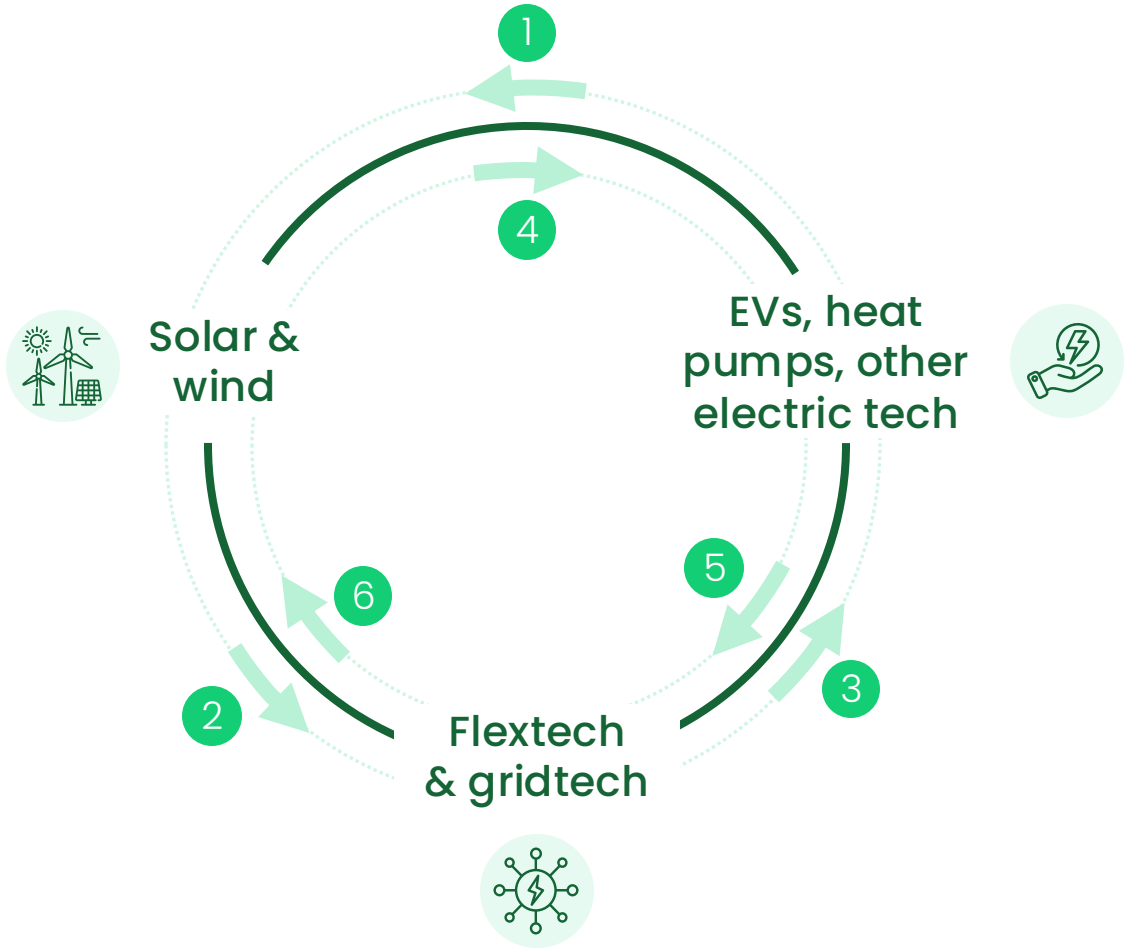
Electrification will speed up driven by cheaper, more efficient, local and digital electricity

Electricity 1.0	Driven by inefficient burning	Reliant on imported fuels	Volatile costs set by commodities	Centralised generation	Analogue, static demand	Non-fungible
Electricity 2.0	Directly from the sun, without combustion	Local	Falling costs set by technologies	Decentralised generation	Digital, adaptive demand	Fungibility from batteries

Sources: Ember

Electrotech unleashes a virtuous spiral

Advances in one area make the other areas more attractive



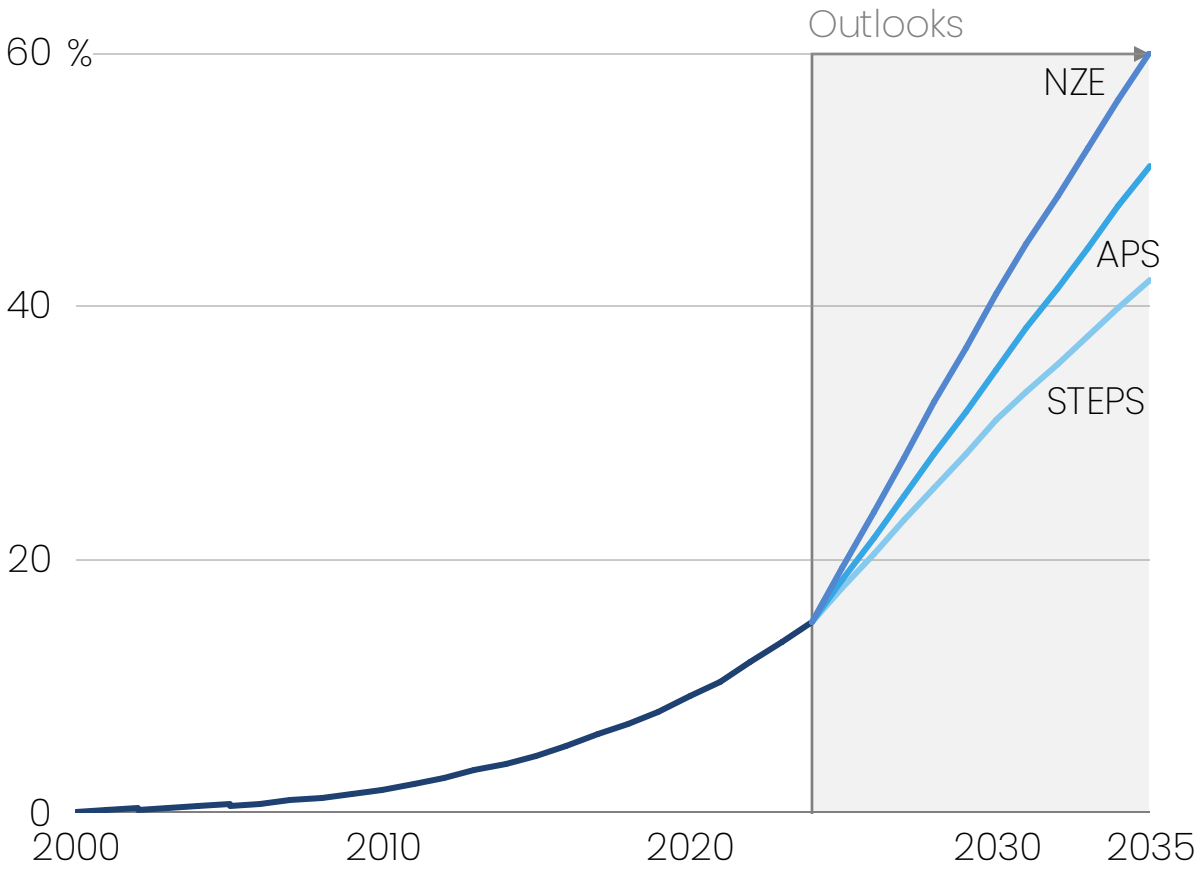
1. Electrified demand scales renewables, driving costs lower
2. Variable renewables need smoothing and create arbitrage opportunities for flextech
3. Using electricity when it's cheapest incentives demand
4. Cheaper, local renewables make electrifying more attractive
5. More demand to pool & optimise
6. Flex & gridtech enable higher penetration

Sources: Ember

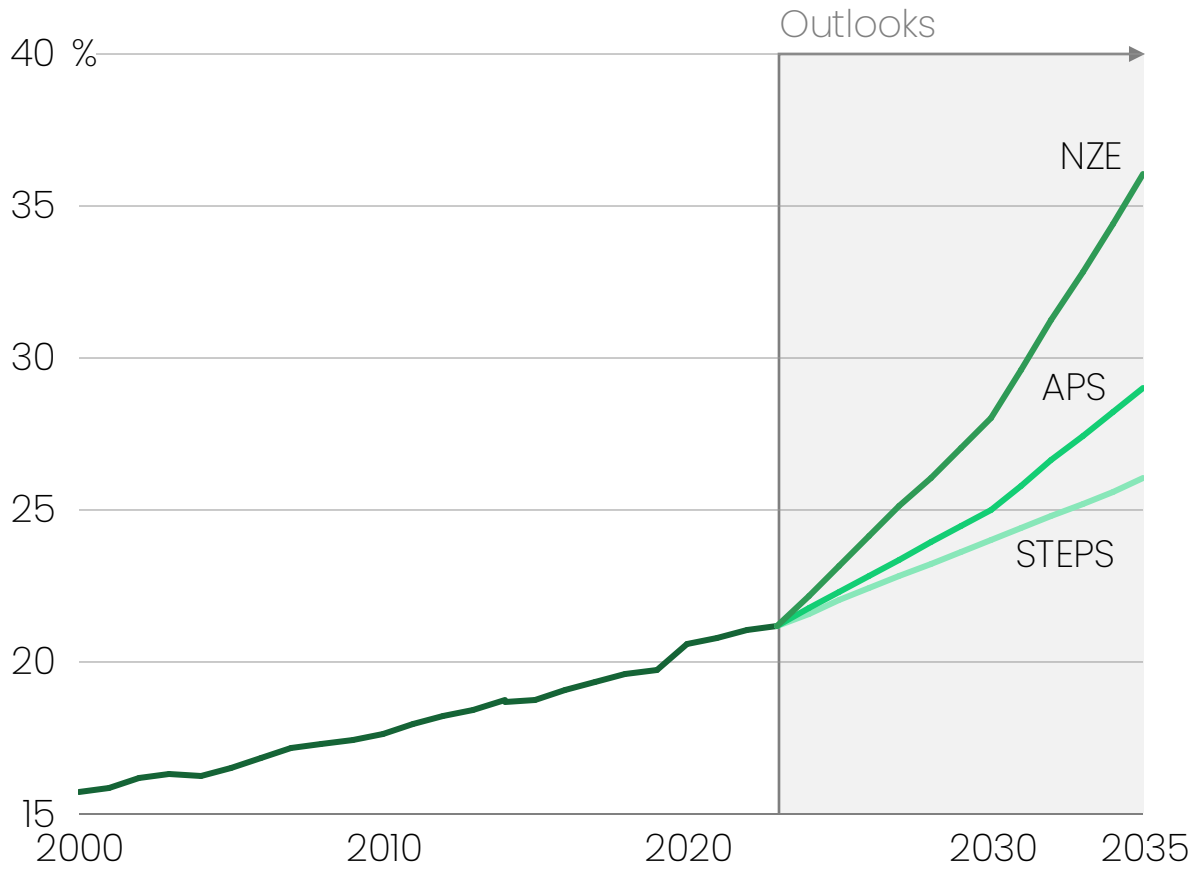
Renewables and electrification will keep growing

The momentum will continue

Solar & wind share of global generation



Electricity share of final energy



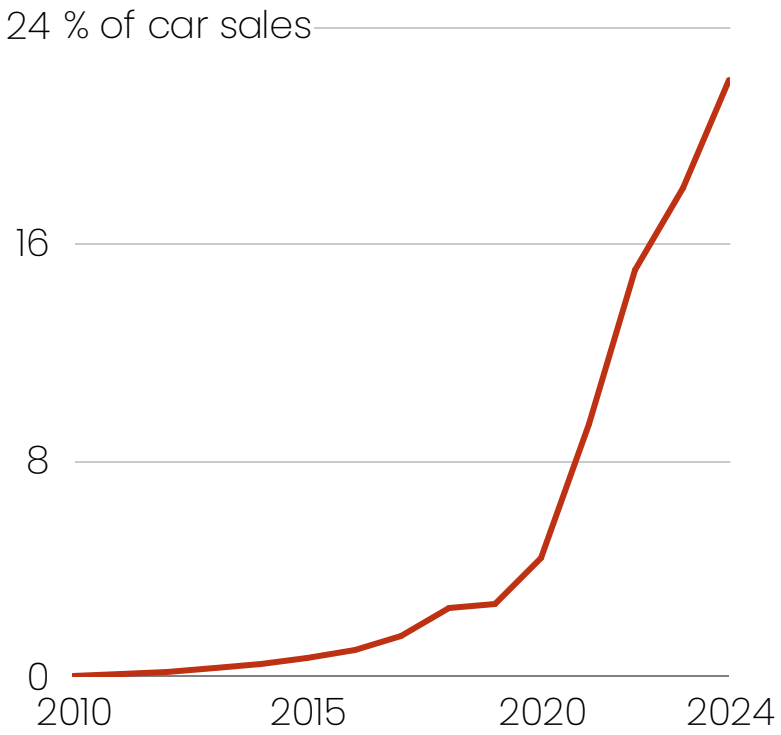
Sources: Ember, IEA WEO scenarios. Note NZE stands for (Net Zero), Announced Policies (APS), Stated Policies (STEPS)

Don’t expect the road to be smooth

Global curves are smooth; but locally it is a bumpy ride of lagging and leading

Smooth global curve

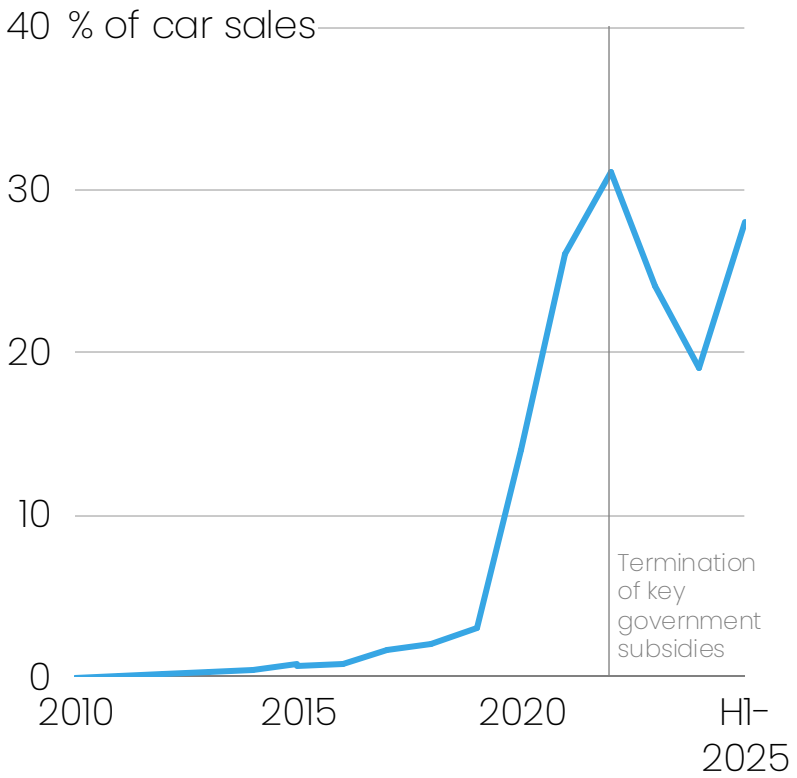
Global EV car sales



Bumpy local curves

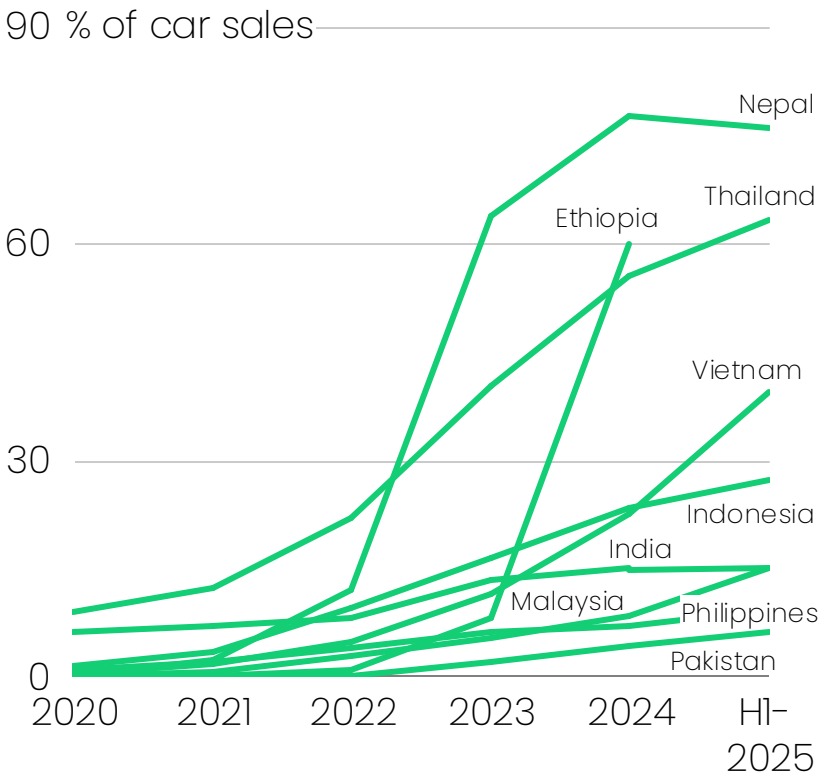
Larger-than-expected slowdown

Germany EV sales



Faster-than-expected acceleration

Emerging market EV sales

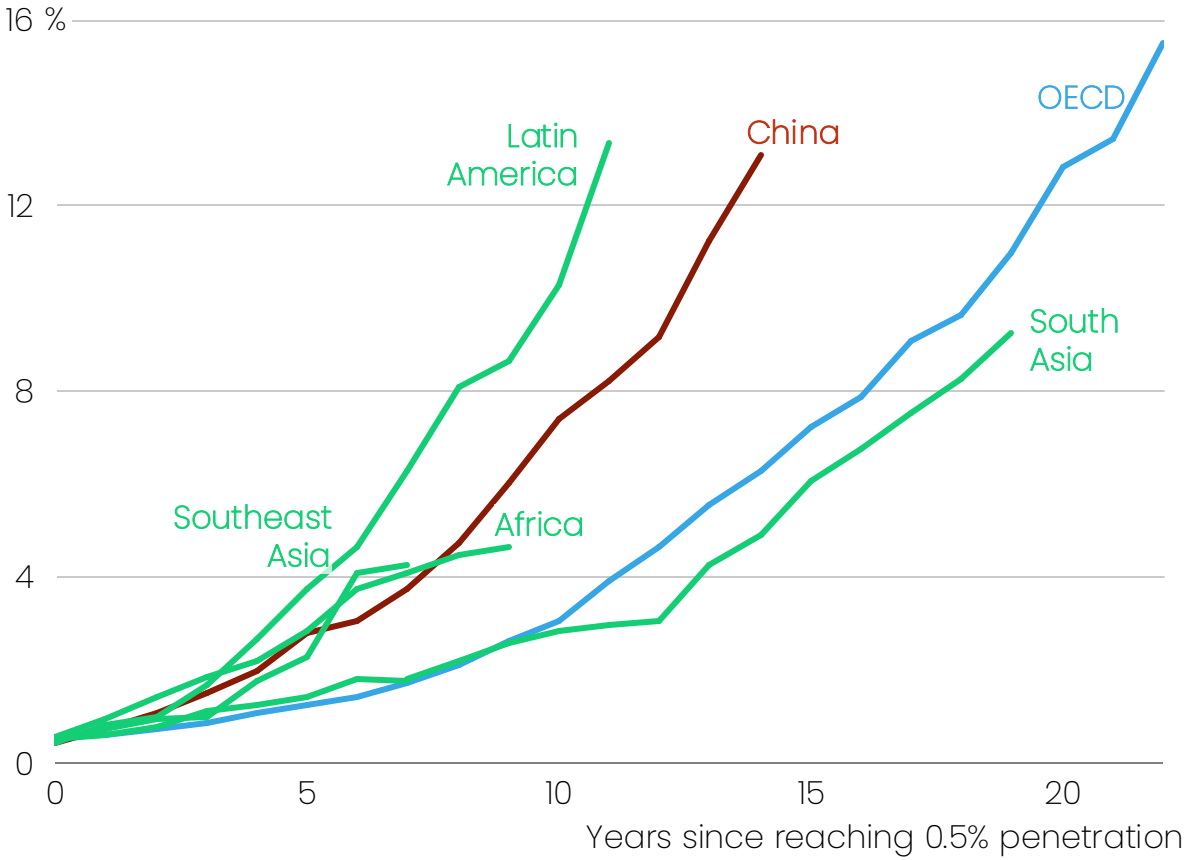


Sources: IEA; Segment Y via New York Times; Ember analysis

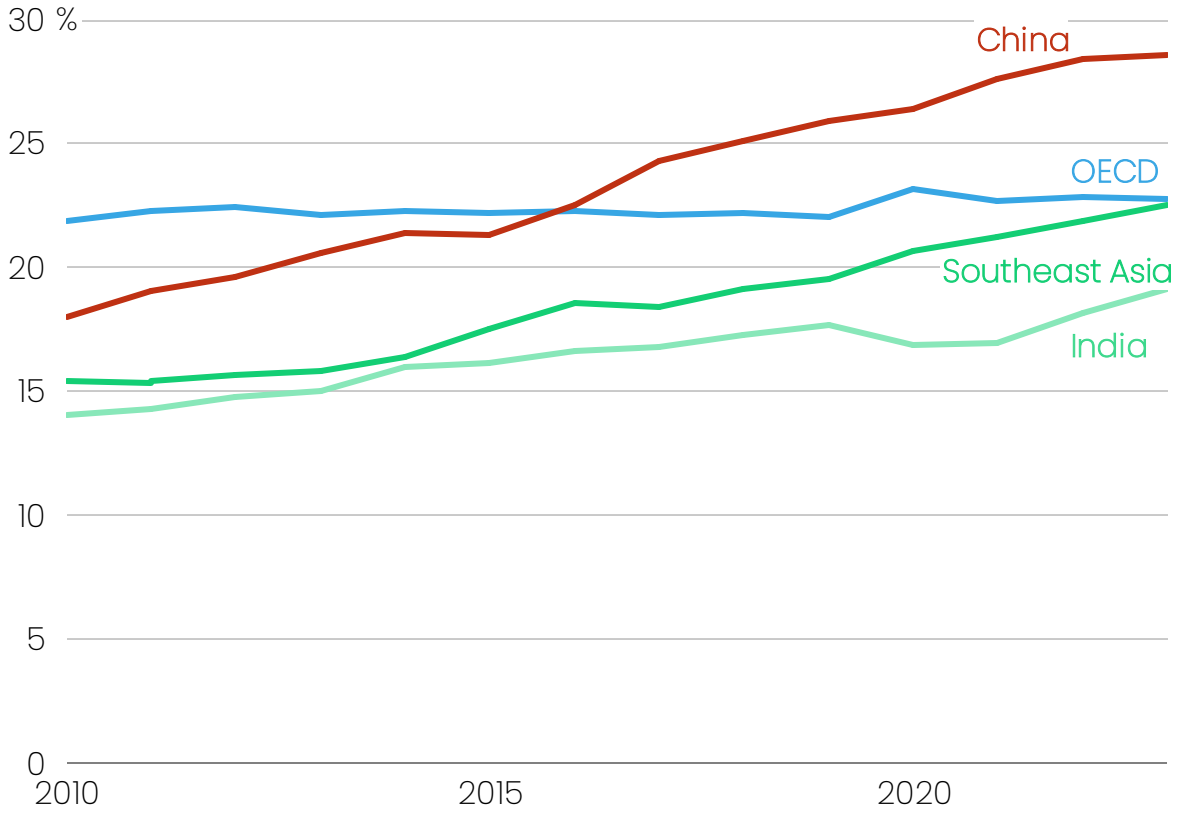
The emerging market leapfrog has strong momentum

Change is happening faster than in the West

Solar & wind share of electricity generation, time-shifted



China and Asia are leapfrogging the OECD in electrification

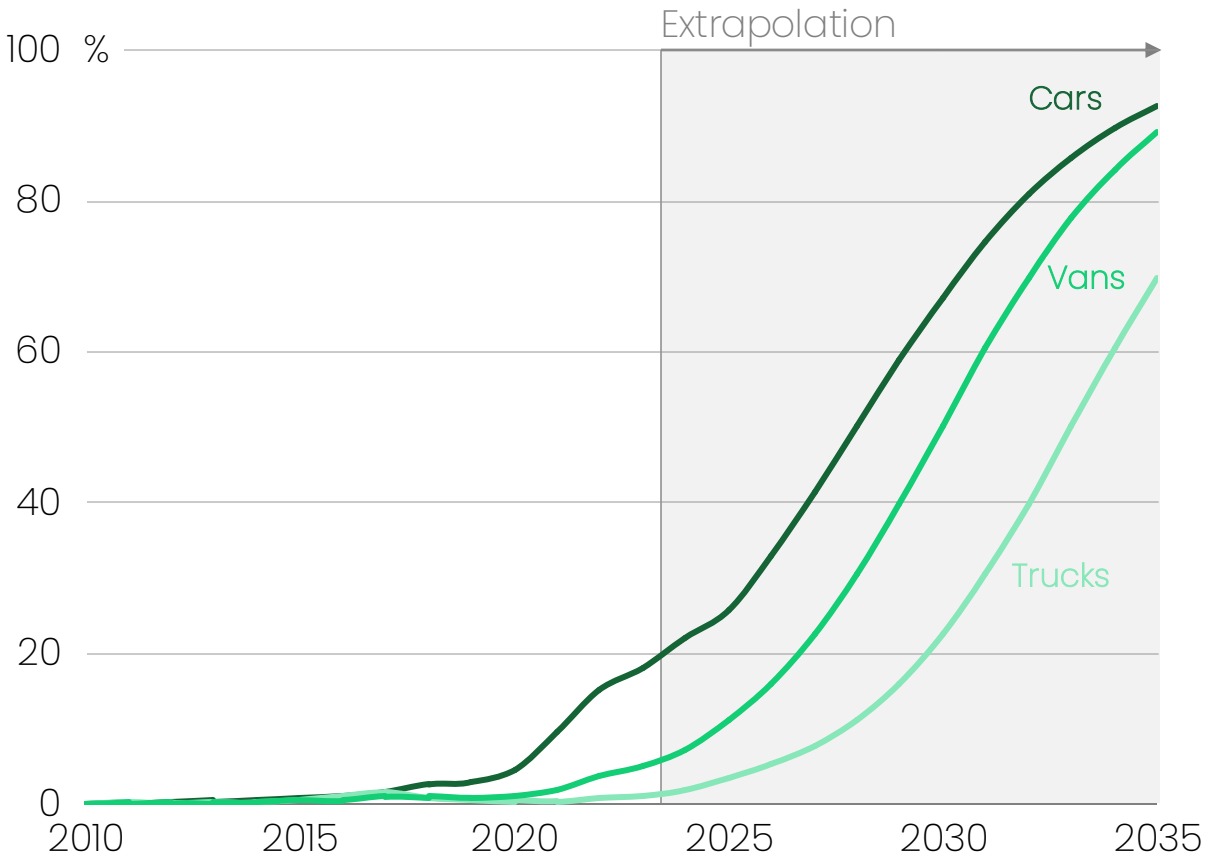


Sources: IEA, RMI, Ember

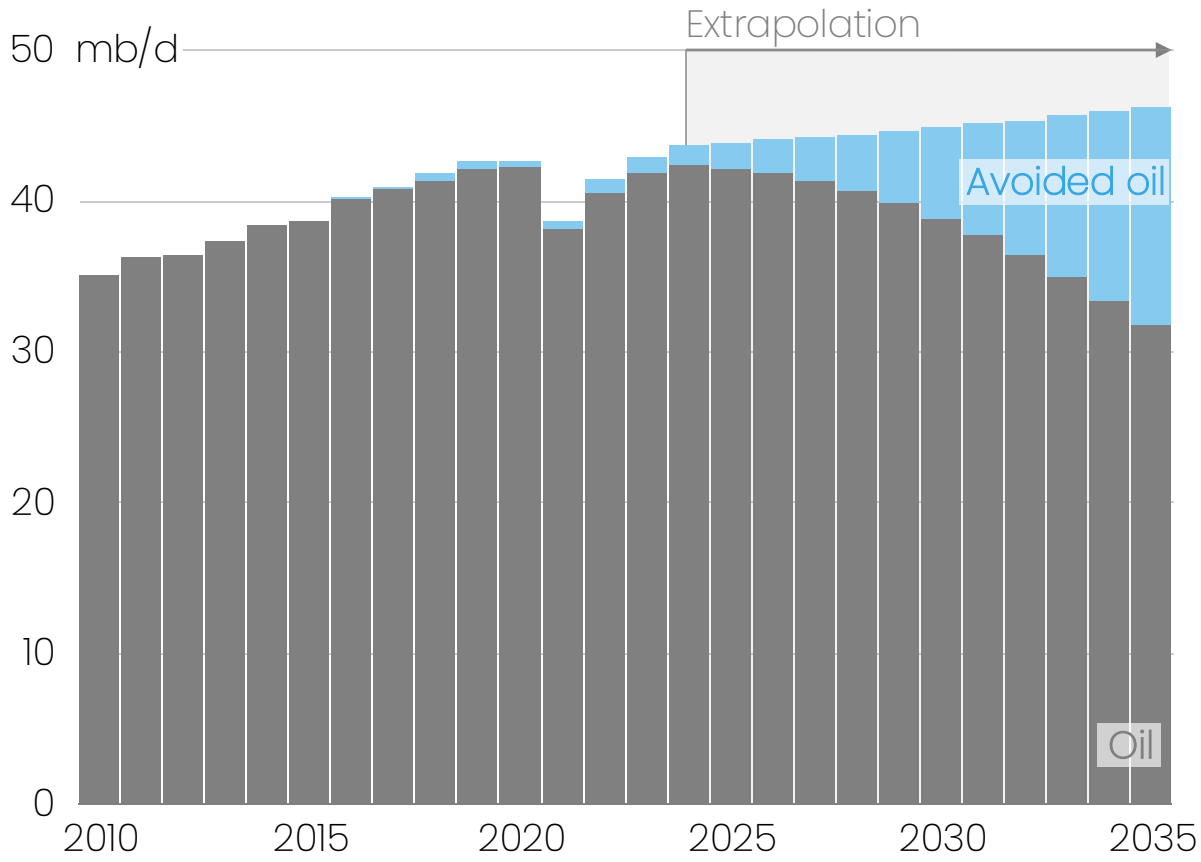
Road transport is the soft underbelly of the oil system

Sales translate into stocks within 15 years or less

Electric vehicle sales



Oil demand for road transport

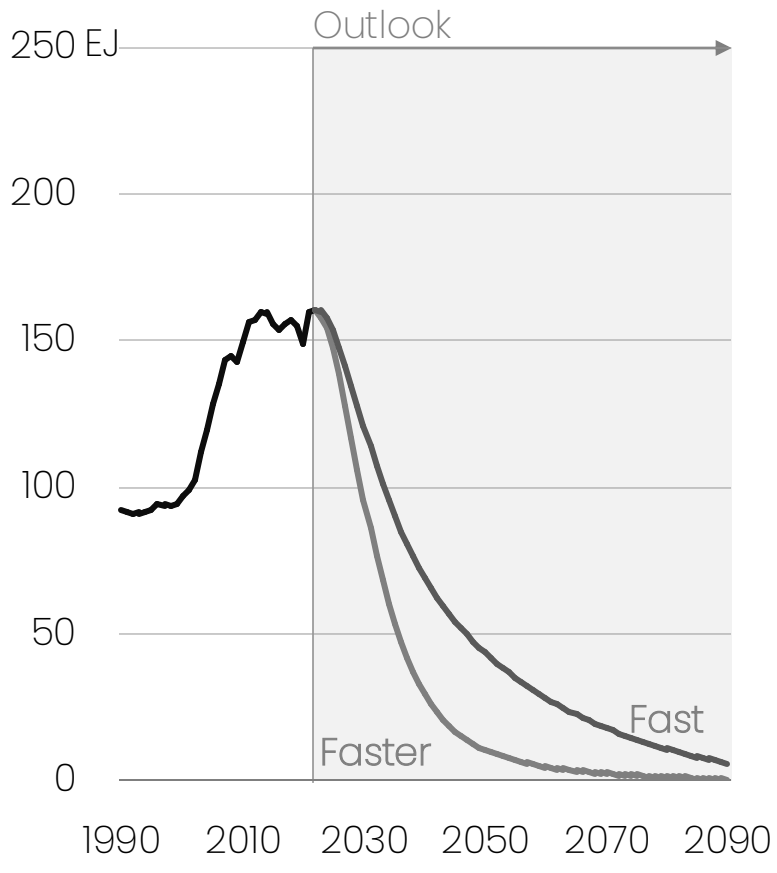


Sources: IEA (past), Ember Futures extrapolation. EV sales are modelled on logistic S-curves and converted to stocks using a standard scrappage formula.

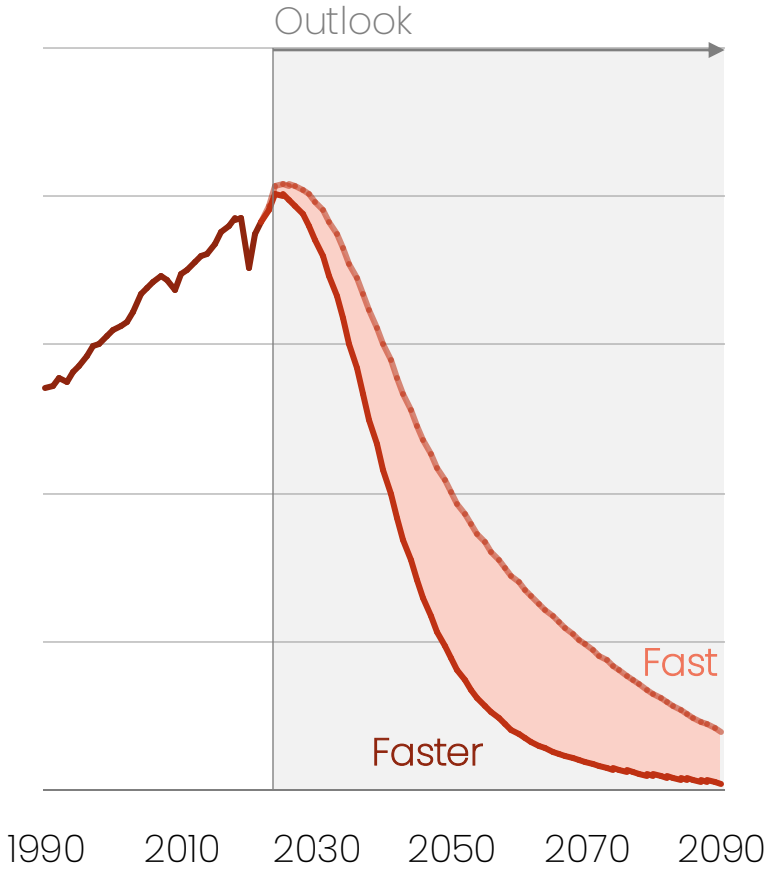
The growth of electrotech means the decline of fossil fuels

After taking all the growth by the end of this decade, electrotech will start to push fossils out

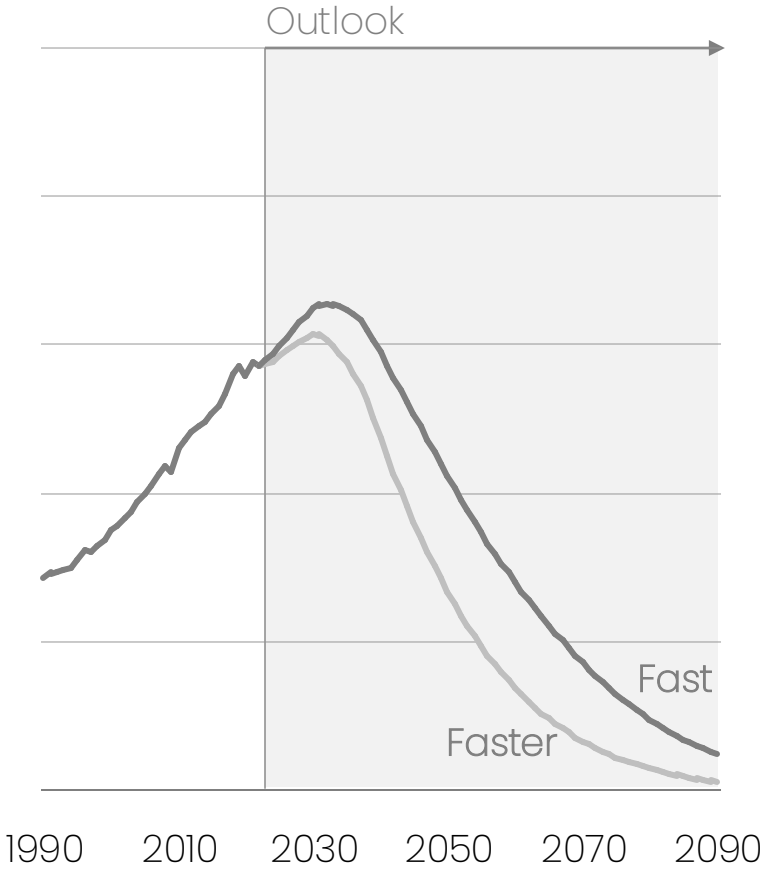
Global coal demand



Global oil demand



Global gas demand



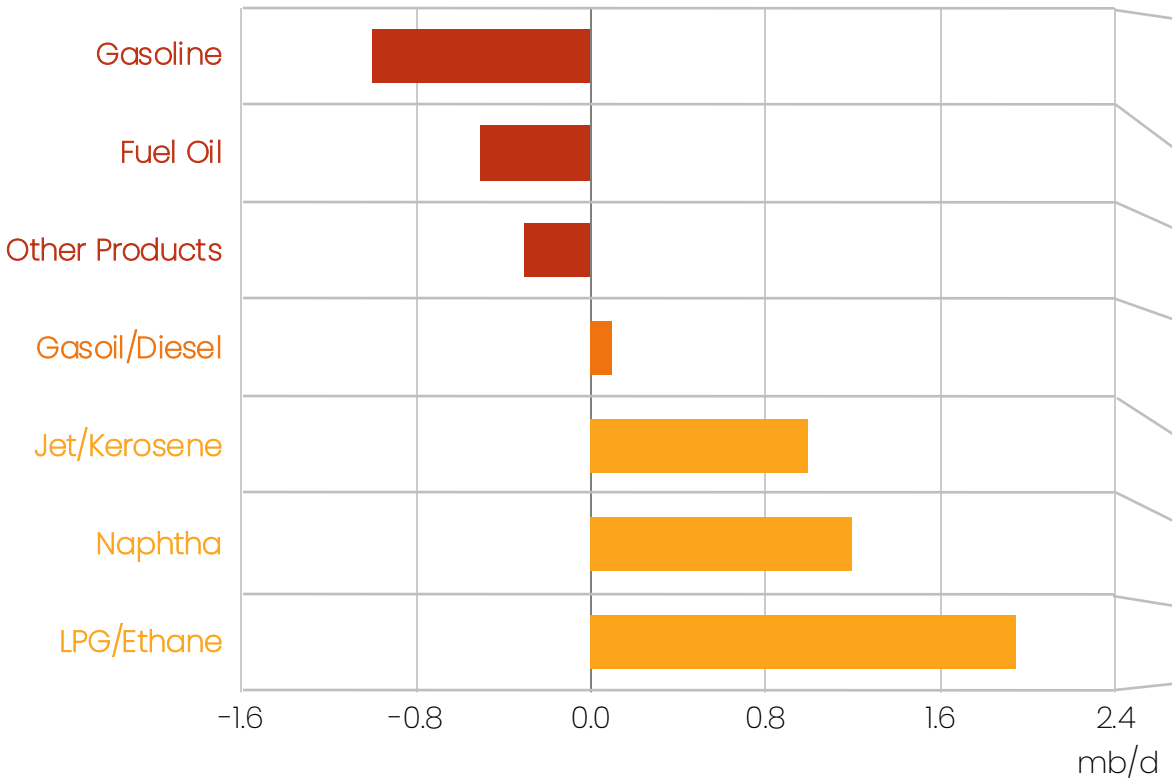
Source: Rystad Energy (Fast 1.8°C, Faster 1.6 °C), RMI

Skewed oil demand will disrupt refining

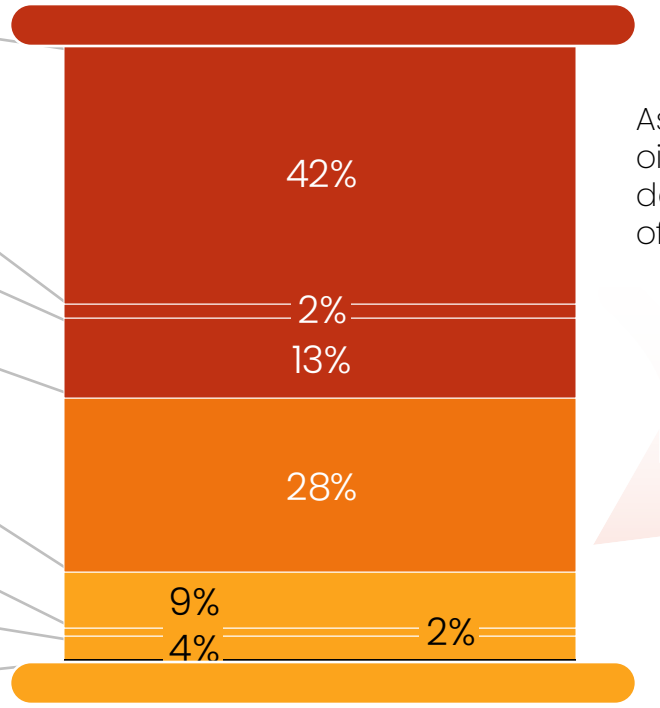
For the first time in history, the demand for a certain part of the barrel will start to structurally decline…

…which will put many refineries which are dependent on gasoline and other product revenues under pressure

Growth in world oil demand by product, 2024-2030



Typical yield of one barrel of oil in a refinery



As demand for gasoline, fuel oil and other products falls, it depresses prices for over half of typical refinery output

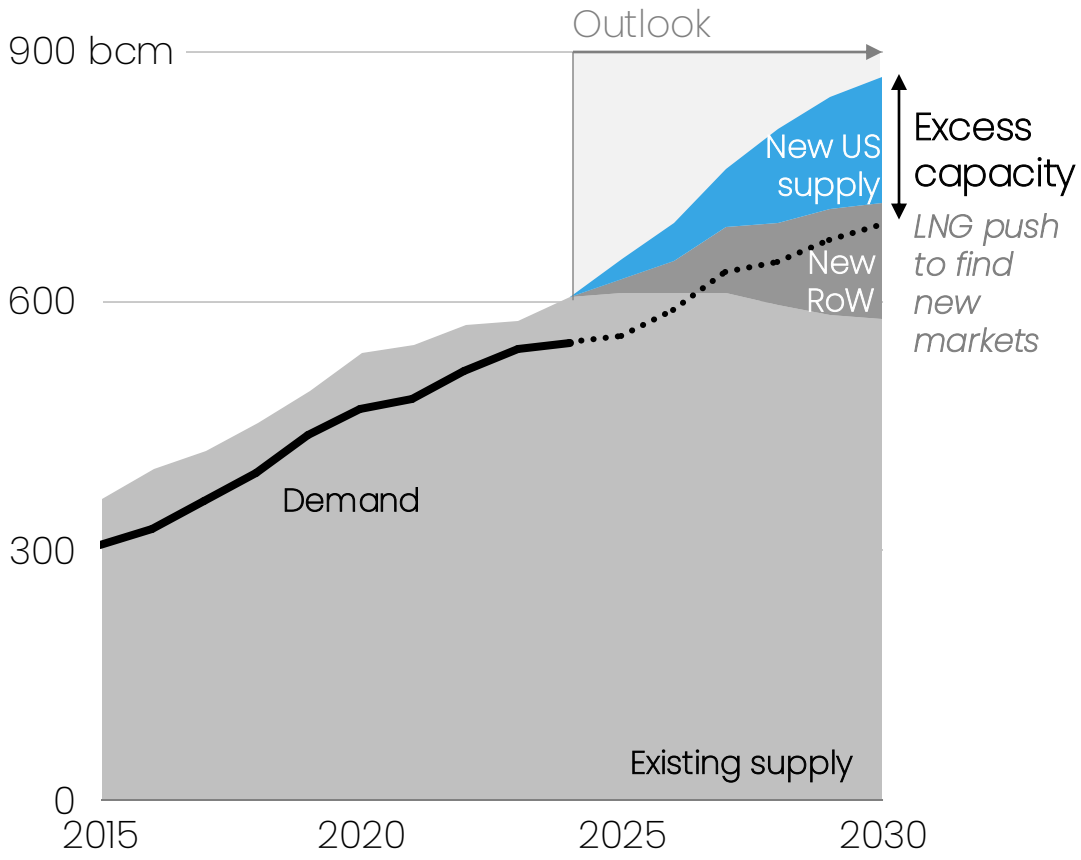
Only more complex refineries can shift (some) of the barrel to kerosene or other chemical products — many refineries cannot and will struggle

Sources: IEA; EIA; Ember analysis

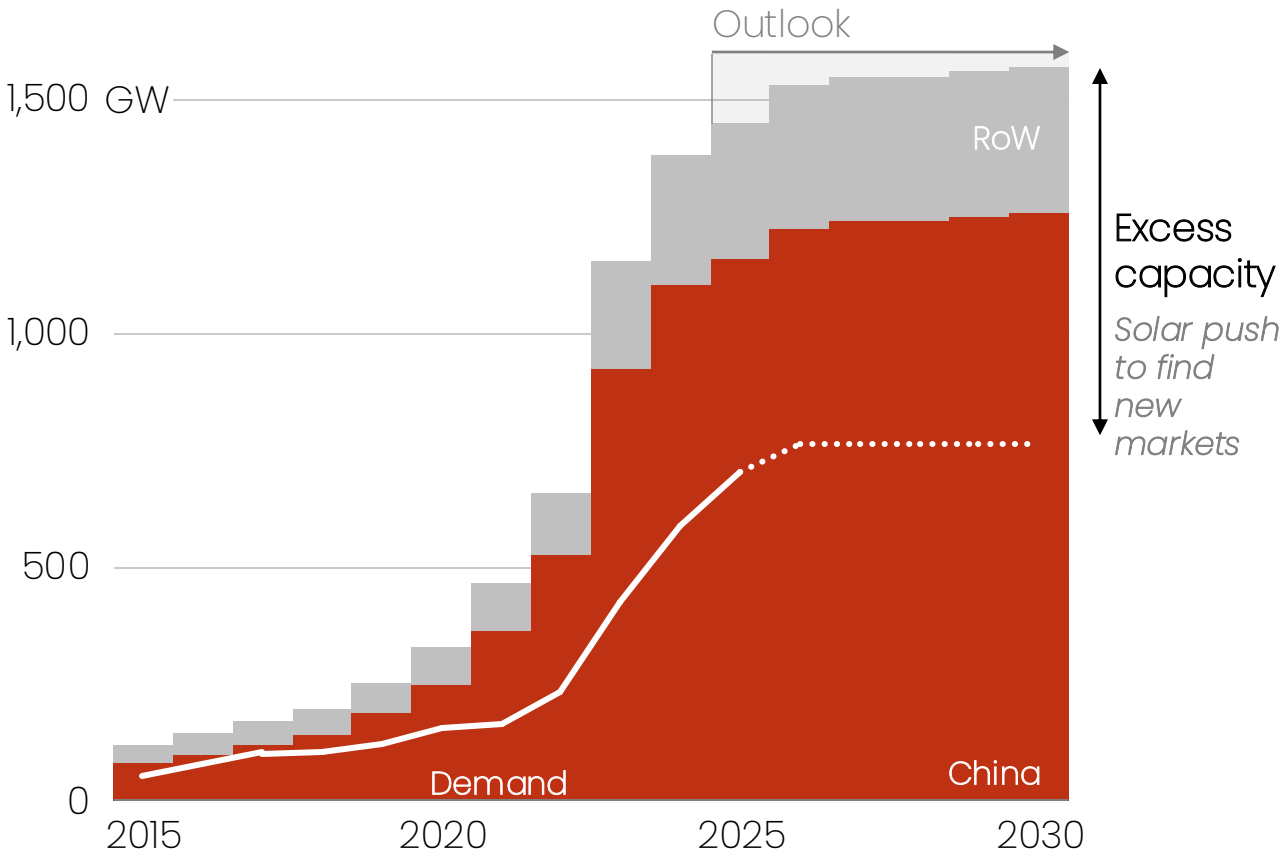
A battle between overcapacities

LNG versus solar is the great battle for the future of energy

LNG overcapacity – supply and demand



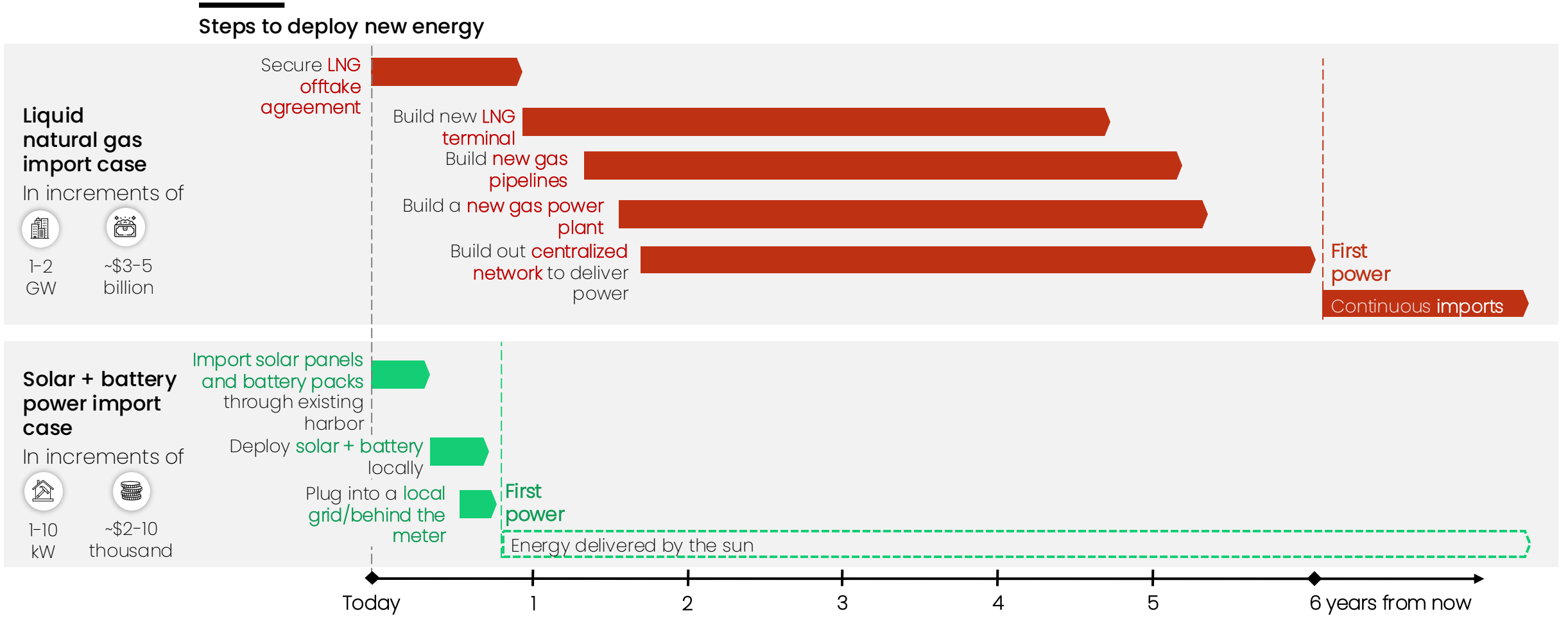
Solar PV module overcapacity — supply and demand



Sources: IEA; Ember analysis

Solar will win the battle for the energy future

Because solar offers a better deal: more efficient, faster, cheaper, and local



Sources: Rystad, Ember analysis • Note: timelines are averages and indicative

Chapter 5.2
Wider implications of changes in energy

01

Energy change means system change

IT and AI have brought the marginal cost of information down to the marginal cost of electricity. Electrotech is now doing the same for energy itself, pushing its marginal cost toward zero. Together, this unlocks a world of abundant energy and information. That means the end of oil intensive development.

02

Winners will be digital and solar-powered

A new class of industrial nations will rise—those with both abundant sunlight and the AI to harness it. The opportunity is greatest in the global sunbelt.

03

Losers will be those who cling to the old

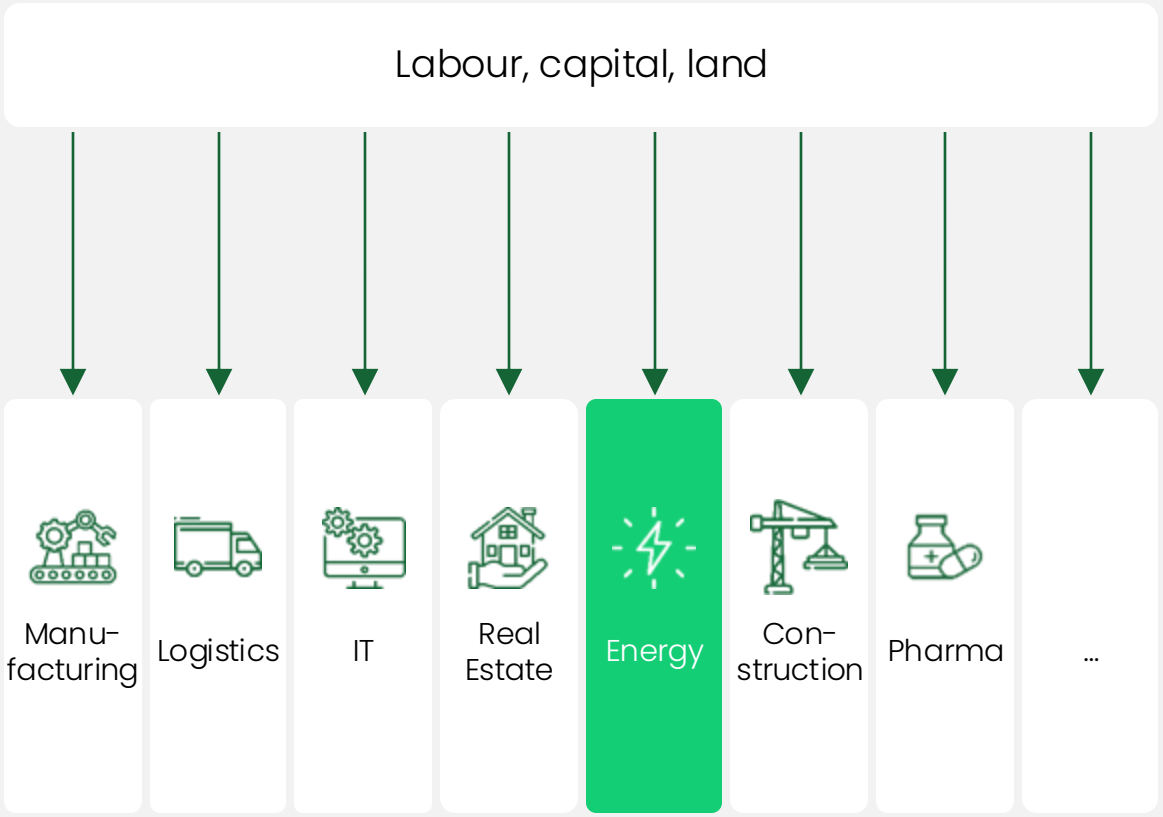
As fossil demand slips off the plateau, price swings will intensify—triggering crises for countries and companies that remain dependent on fossil revenues for too long. Fossil assets at the top of the cost curve will be stranded, and returns to new fossil projects will disappoint.

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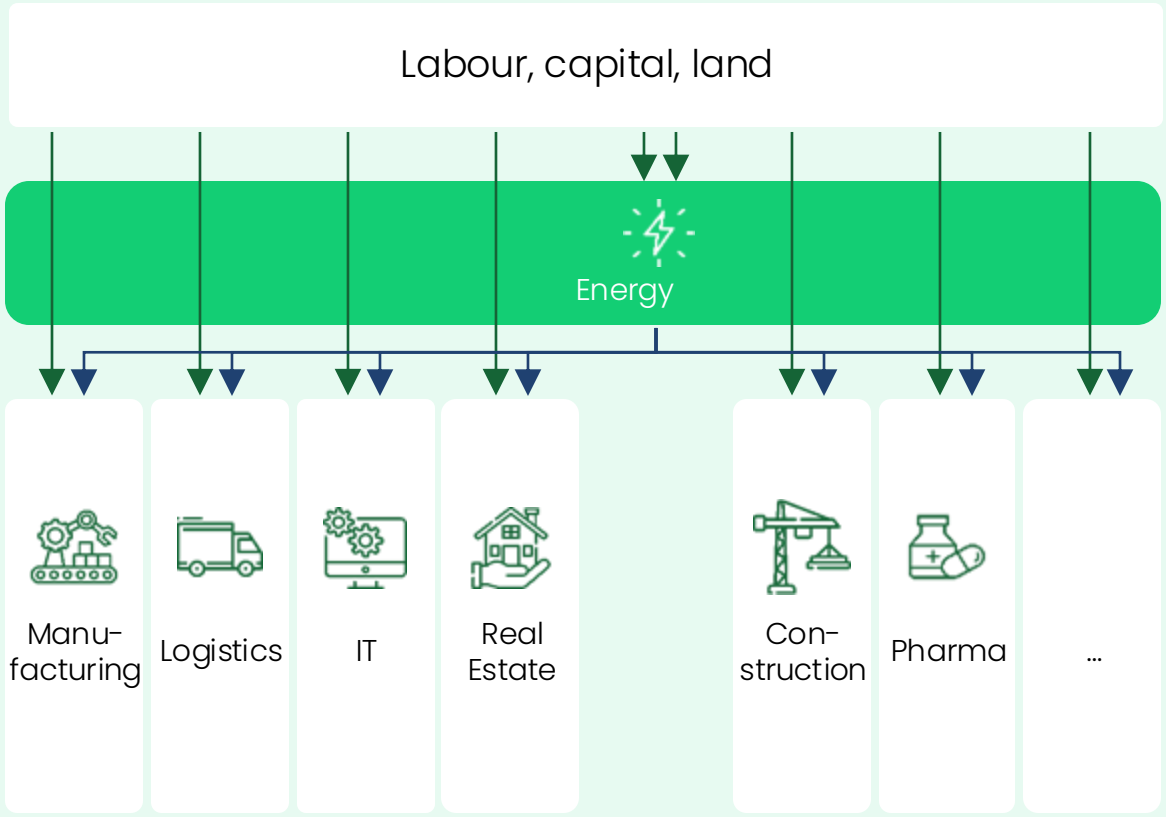
Everything is driven by energy

So energy transition means economic transition

The conventional, wrong view of the energy sector



The more accurate, systemic view of the energy sector



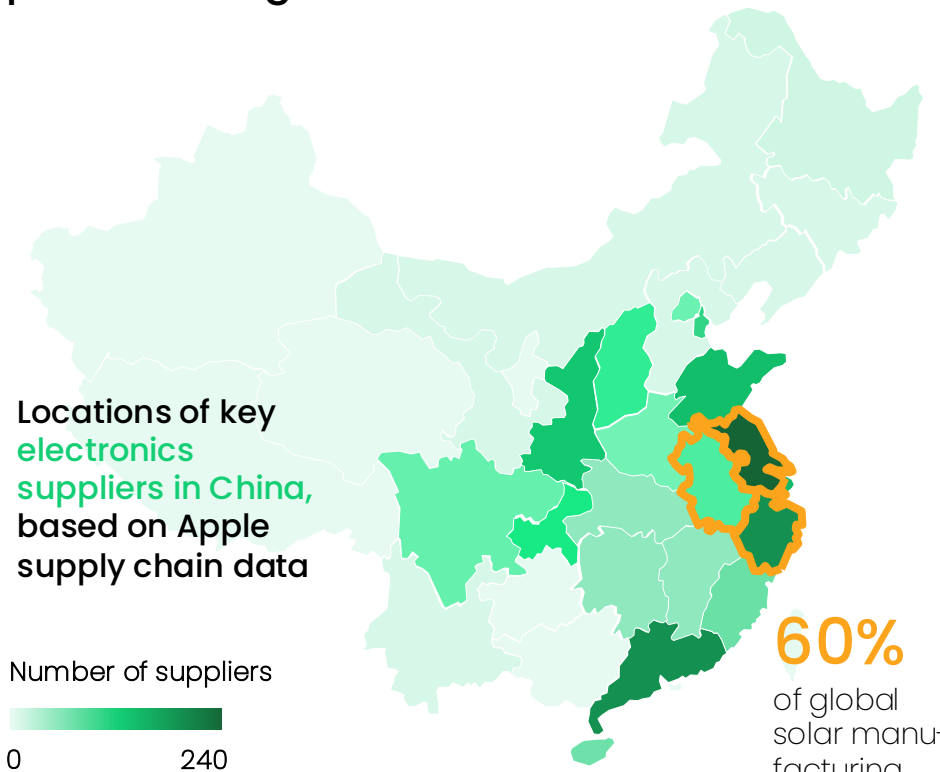
Sources: Ember

Tech is coming for the energy sector

The same people and places that made digital tech, mainly in China, are now making electrotech

ILLUSTRATIVE AND NON-EXHAUSTIVE

Electrotech is manufactured in the same places as digital tech



60% of global solar manu-facturing capacity

Many electrotech leaders started in digital tech



CATL

Robin Zeng Yuqun

Founder & Chairman

Spent a decade at ATL developing Li-polymer batteries for iPhones and other smartphones



BYD

Wang Chuanfu

Founder, Chairman & CEO

As GM at BAK Battery Co., scaled Li-ion cells for Nokia & Motorola phones



SUNTECH

Shi Zhengrong

Founder & Chairman (until 2013)

Led thin-film PV R&D at UNSW, pioneering semiconductor-style solar cell fabrication before commercial scale-up.



NIO

William Li (Li Bin)

Co-founder & CEO

Built Bitauto app as an online auto-services platform, before starting Nio



LONGi

Li Zhenguo

Founder & President

Early role at Huashan Semiconductor Materials, processing wafers for PC & mobile chips, building semiconductor expertise.



XPENG

He Xiaopeng

Co-founder & Chairman

Co-founded UCWeb, developing China's leading mobile-browser, then applied that mobile-tech know-how to EVs.



NEBULA

Huang Shilin

Former Vice Chairman & Deputy GM, CATL

Spun off ATL's CE-battery arm into EV focus, leveraging his battery-tech background in consumer electronics.



Li Auto

Li Xiang

Founder, Chairman & CEO

Created Autohome as a data-driven car-sales & AI platform, blending digital-marketing and automotive retail.

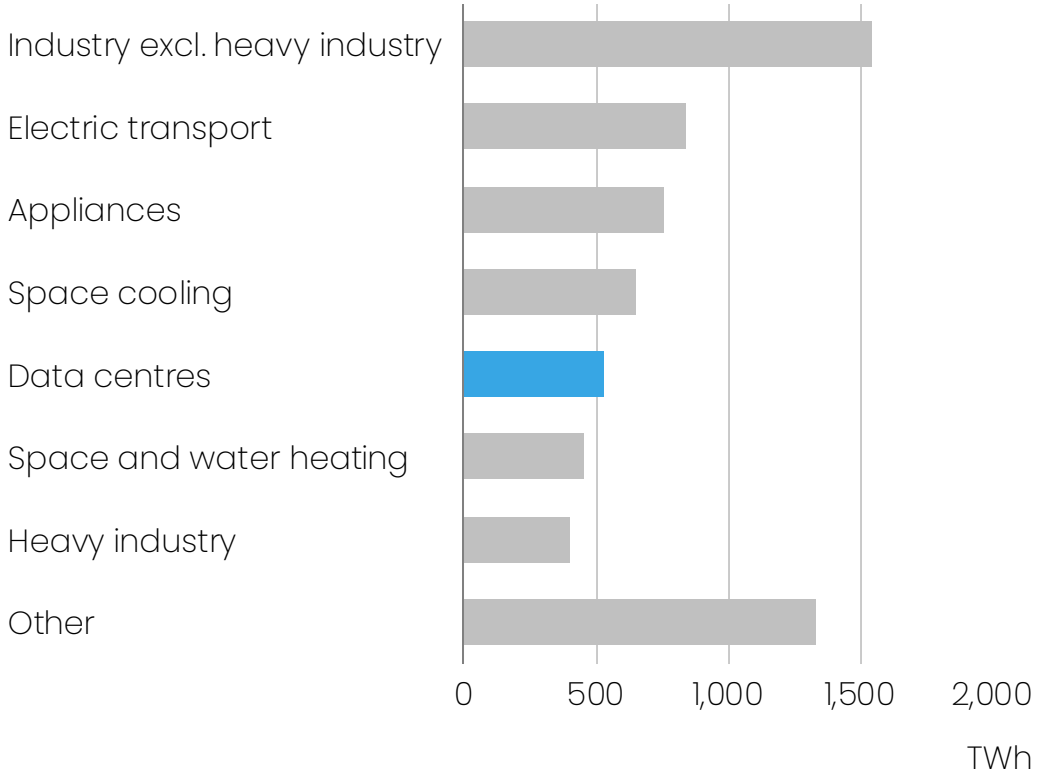
Sources: RMI; Bloomberg; FT; Apple; Ember analysis; Company websites; Press search

AI accelerates change

AI may raise electricity demand, but it is of tremendous benefit to scaling electrotech

AI energy demand growth in context

Increase in electricity demand by sector, 2024-2030



Impact of scaling AI on electrotech, examples

- Predictive maintenance
- Autonomous operations
- Smart charging
- Adaptive heating
- Grid optimisation
- Battery longevity
- Materials discovery
- Power-electronics tuning
- Automated permitting

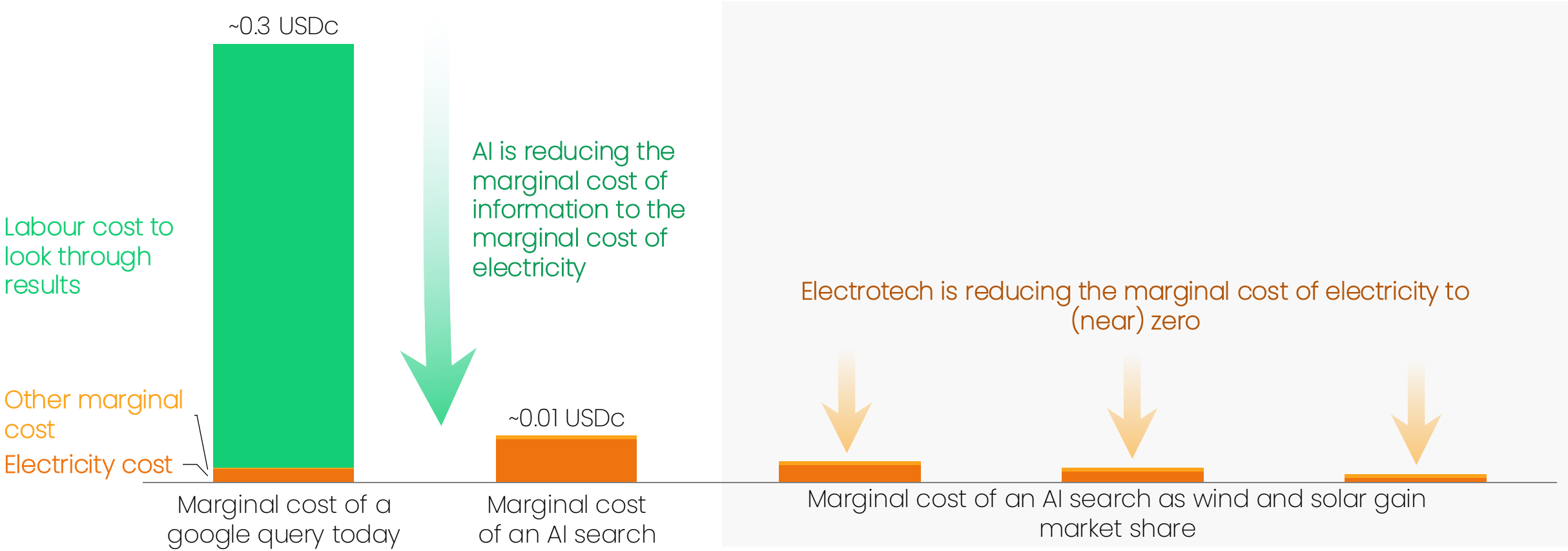
Sources: IEA Energy and AI; Ember analysis

The zero marginal cost economy is coming

Between AI and electrotech, the marginal cost of energy and information will fall dramatically

ILLUSTRATIVE

Cost of information

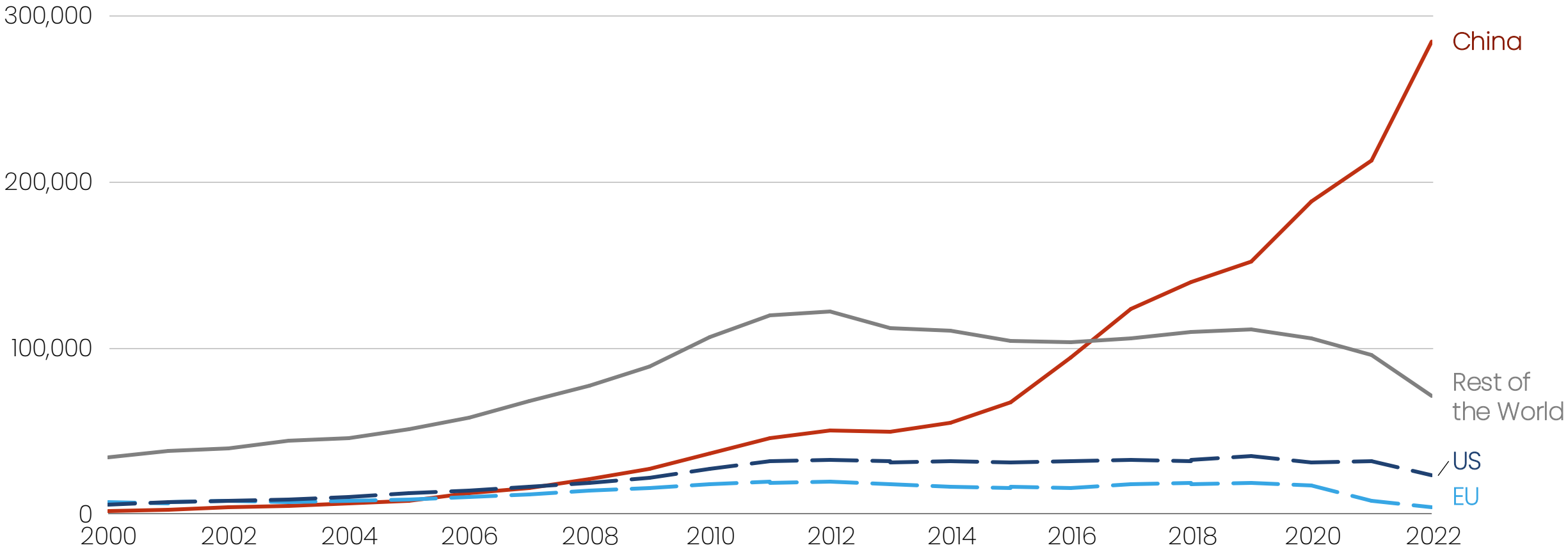


Sources: Google; Ember analysis • Note: this page focuses on marginal cost, not levelized cost; i.e., without capex write-offs

The energy technology frontier has moved East

Patents are a leading indicator of where the leading companies of the future will be

Annual applications for patents in clean energy technologies

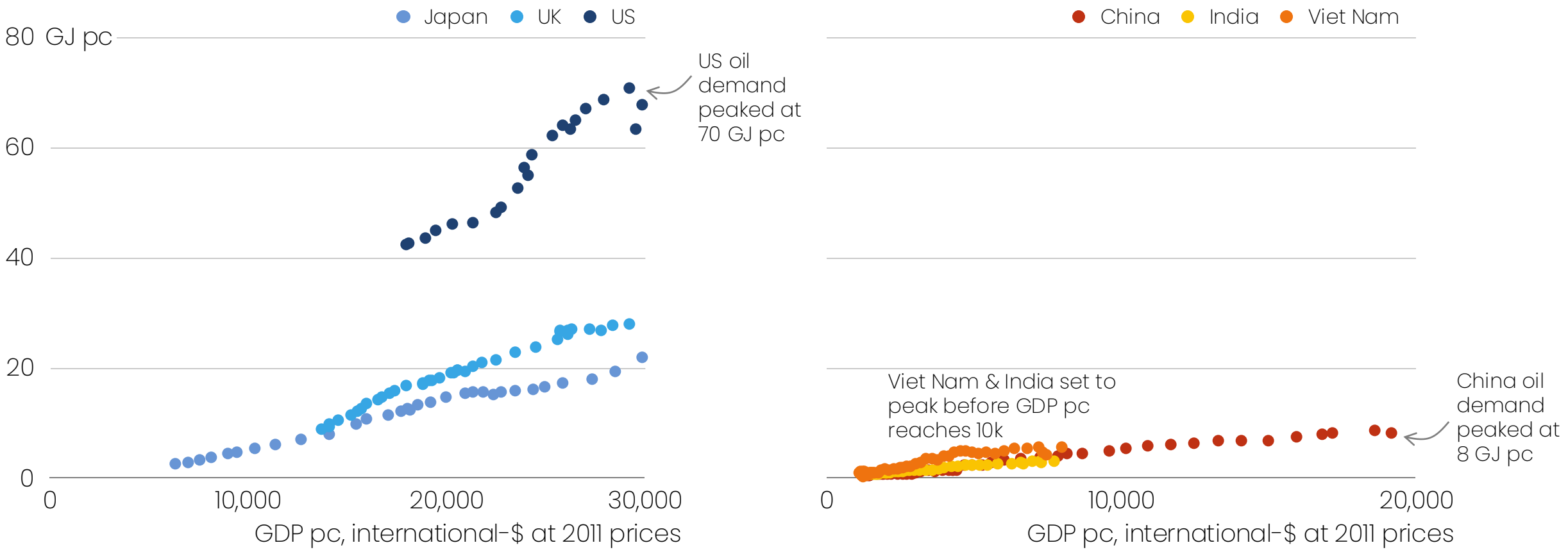


Sources: IRENA, Ember analysis

The end of oil-intensive development

China's per capita road oil demand peaked at a tenth of US levels – other emerging markets are set to follow

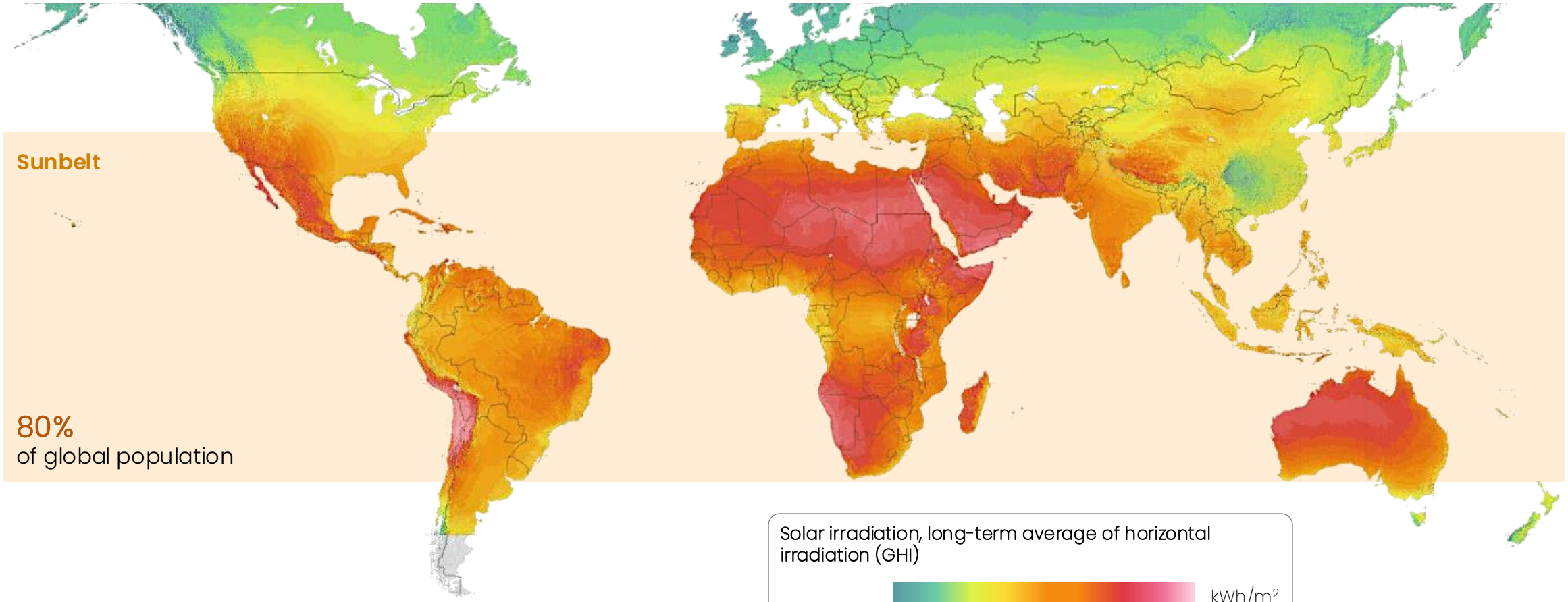
Per capita road oil demand and GDP



Sources: Maddison (via OWID), IEA WEB; Ember analysis. Note: LHS x-axis ends at 30k pc.

Electrotech liberates the power of the Sunbelt

The emerging markets will have the lowest electricity cost

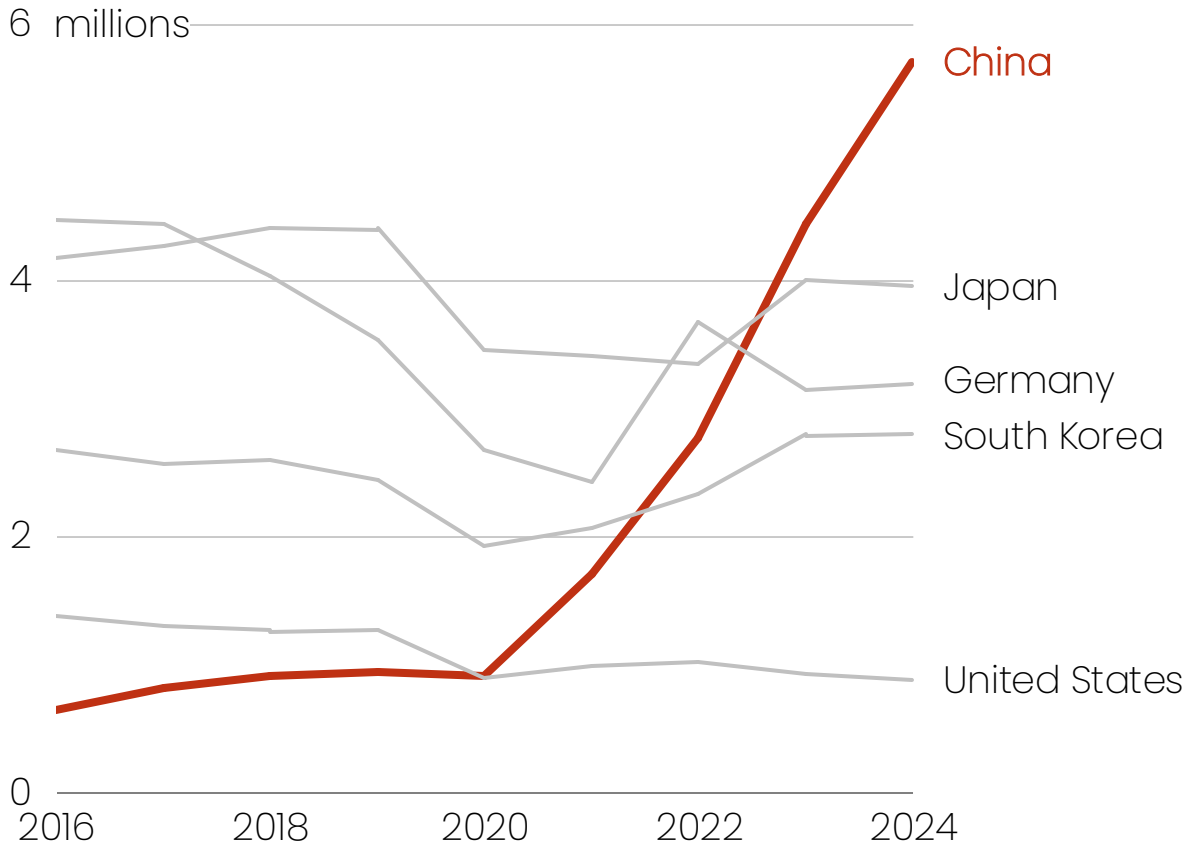


Sources: Global Solar Atlas, Ember. Map boundaries do not imply any judgment on legal status or sovereignty.
ETC for long-term forecasts of electricity costs by region

The automotive sector is a warning sign for other industries

In four years, China went from small to dominant

Car exports: China is taking over, enabled by EVs



Role of automotive in selected economies

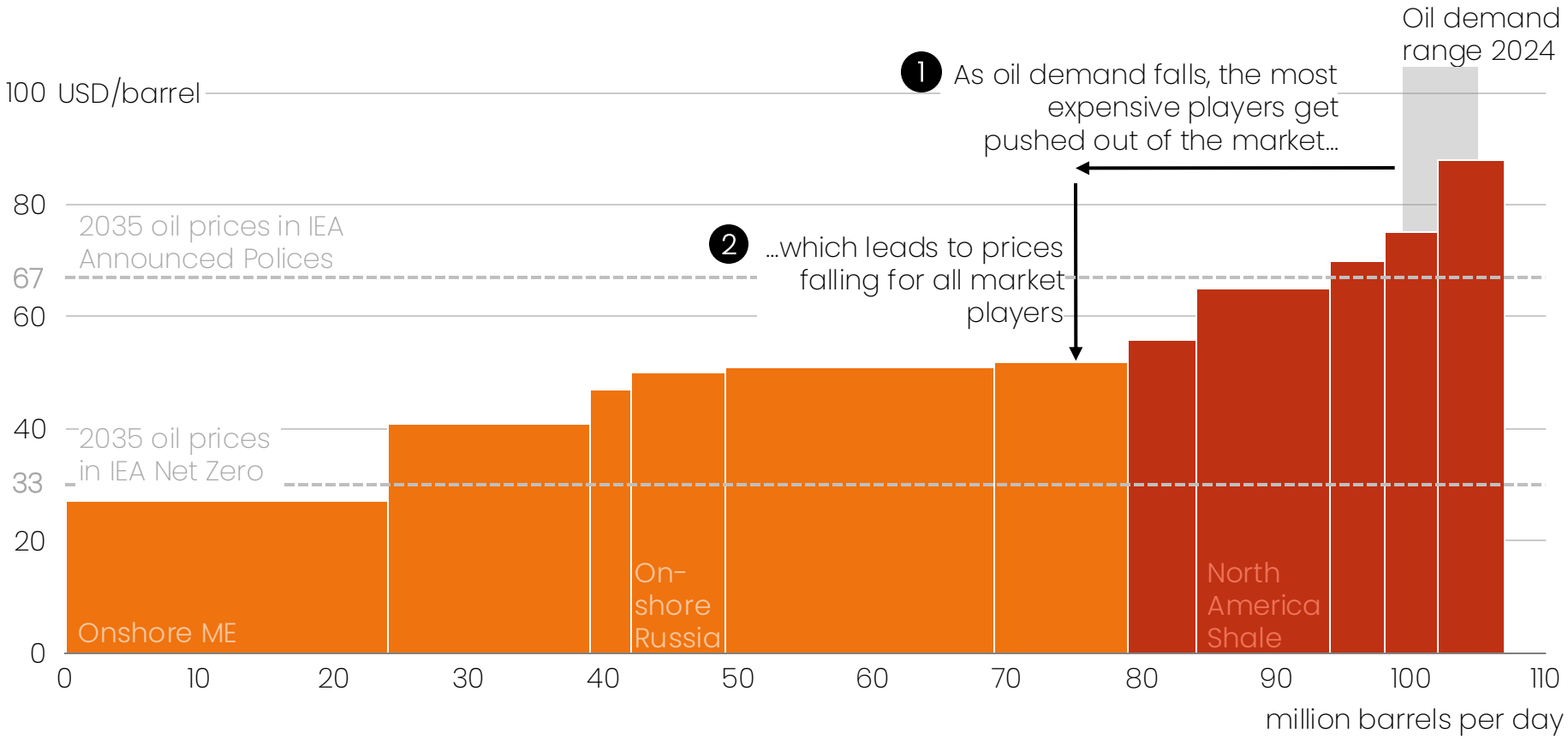


Sources: Alix Partners, NYT, OICA, Wikipedia • Note: 2024 values are estimated.

The first few million barrels decline will hurt

Companies and countries dependent on the price of oil will face hardship as prices fall

Global oil supply cost curve



Notes

1. Top quartile is dominated by independents and majors, and fewer national oil companies. Even a few percent decline in oil demand can evaporate most of the production of some players.

2. Many petrostates need oil prices well over $50/bbl to have government finances break even:

Fiscal breakeven oil price

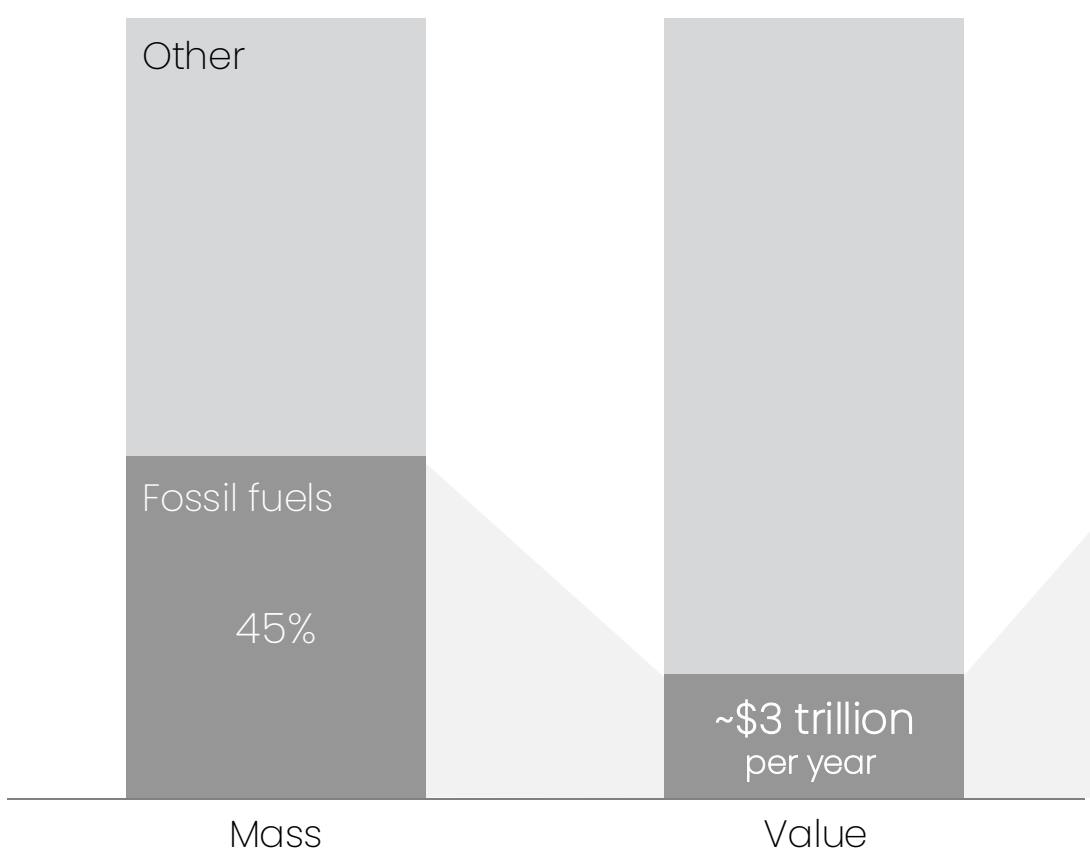
- Saudi Arabia: $98/barrel
- Iraq: $84/barrel
- Kuwait: $88/barrel
- UAE: $51/barrel

Sources: Rystad; IEA; Ember Analysis

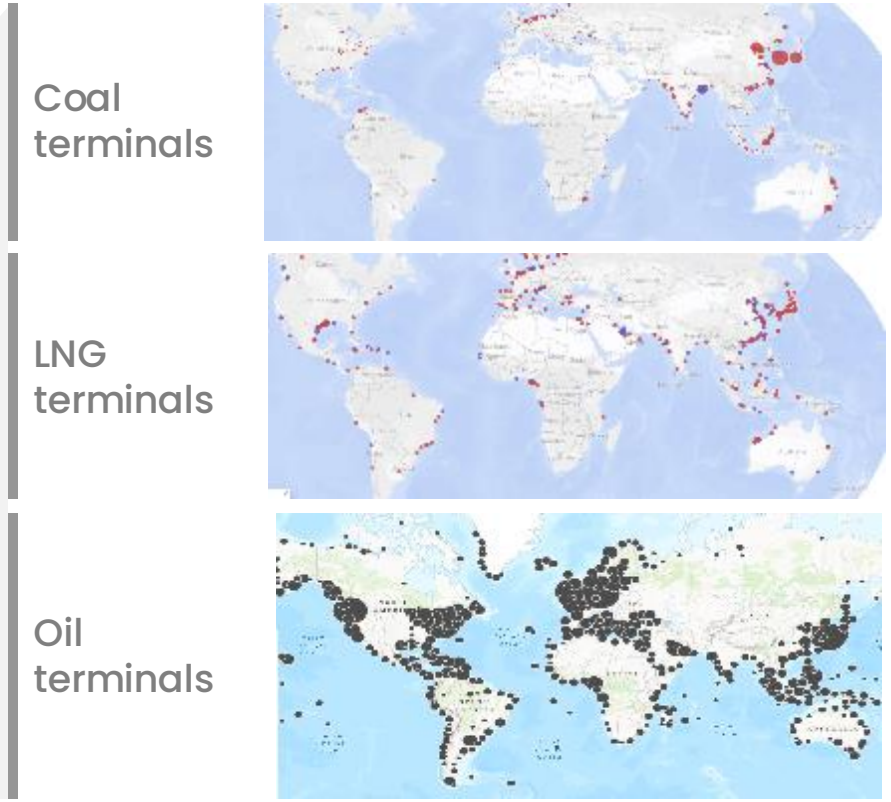
Fossil demand decline will have much wider implications

For example, ports all over the world are set to lose major customers

Share of global shipping from fossil fuels



Fossil ports around the world



Sources: Global Energy Monitor; IEA; Ember analysis

Chapter 6
Seize the opportunity

01

The time is now

This is the decade that everything changes. Leaders will build the capacity, electrotech prices will become irresistible, electrotech will continue to grow up S-curves, and fossil demand will start to decline. It is time to rethink standard energy models because by 2030 the new reality will be priced into markets.

02

Change is hard

Inertia and the lobbying power of incumbents combine to make change difficult. It is hard to deploy new technologies and identify future leaders. Even policymakers who want to drive change can pick the wrong solutions.

03

Intelligent policy action is vital

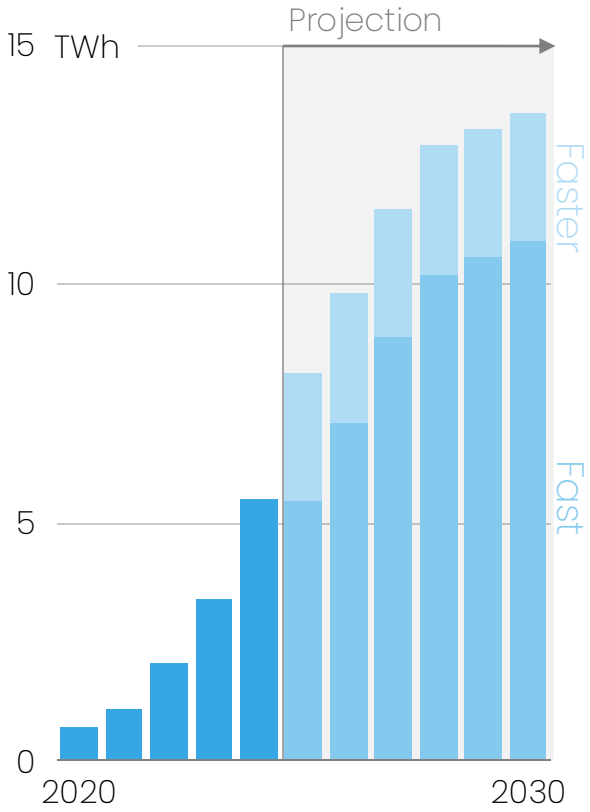
Policymakers who wish for their countries to reap the benefits of the electrotech era need to rethink their strategy. That means getting the price of electricity down and electrifying end demand. It also means experimenting with policy, and moving on from failed solutions.

>> Return to Table of Contents

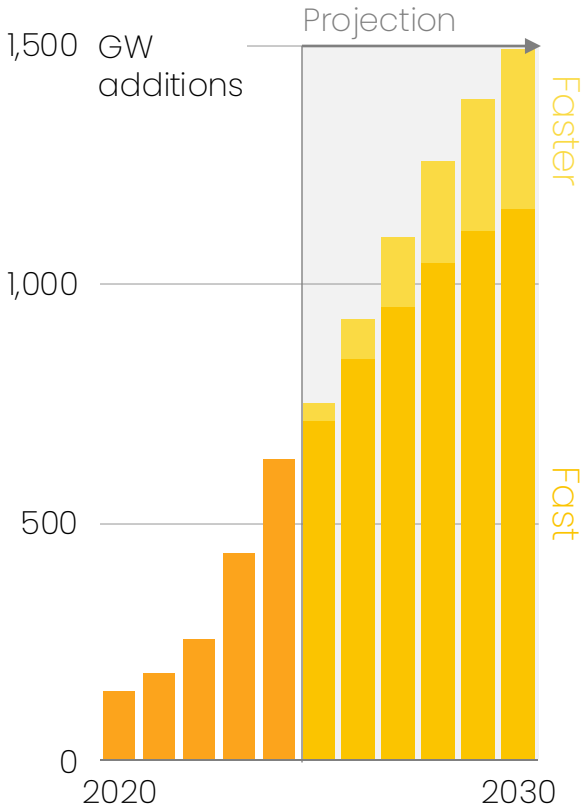
This is the decisive decade

A century in the making, electrotech will define this decade

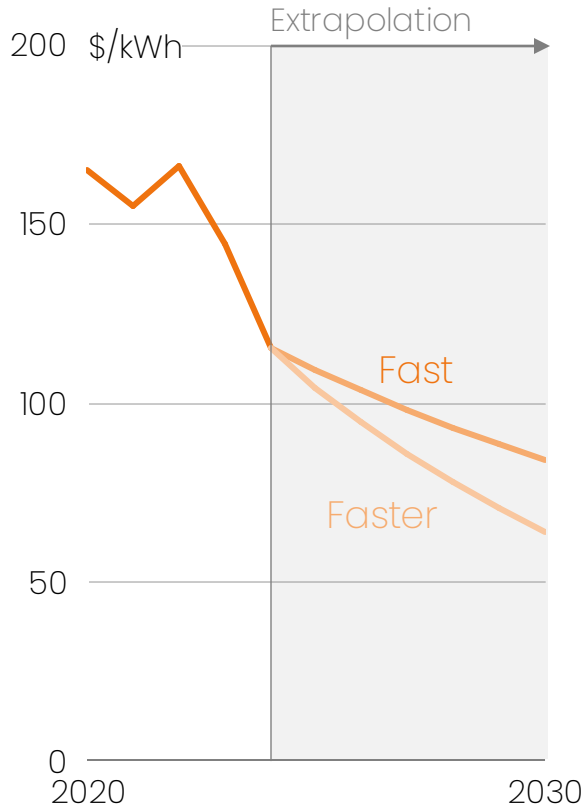
Manufacturing capacity is built: Batteries



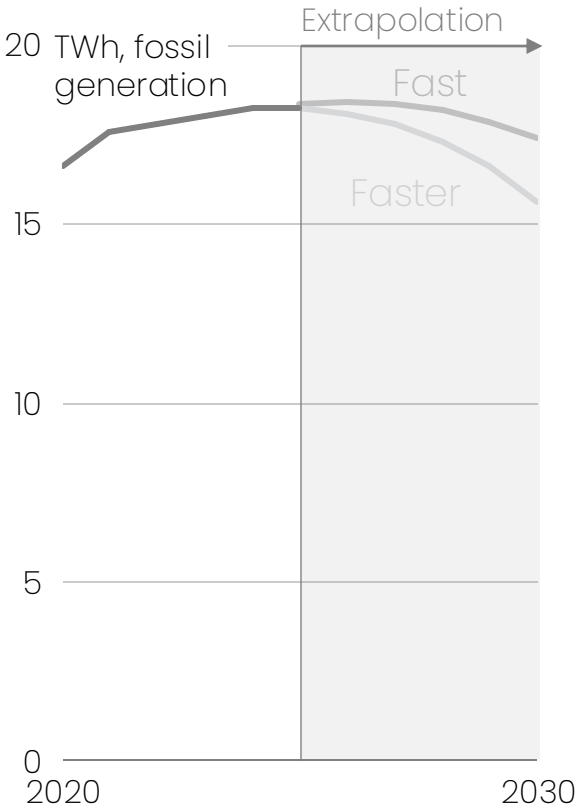
S-curves hit their steepest parts: Solar



Electrotech get too cheap to resist: Batteries



Fossil fuel demand enters terminal decline

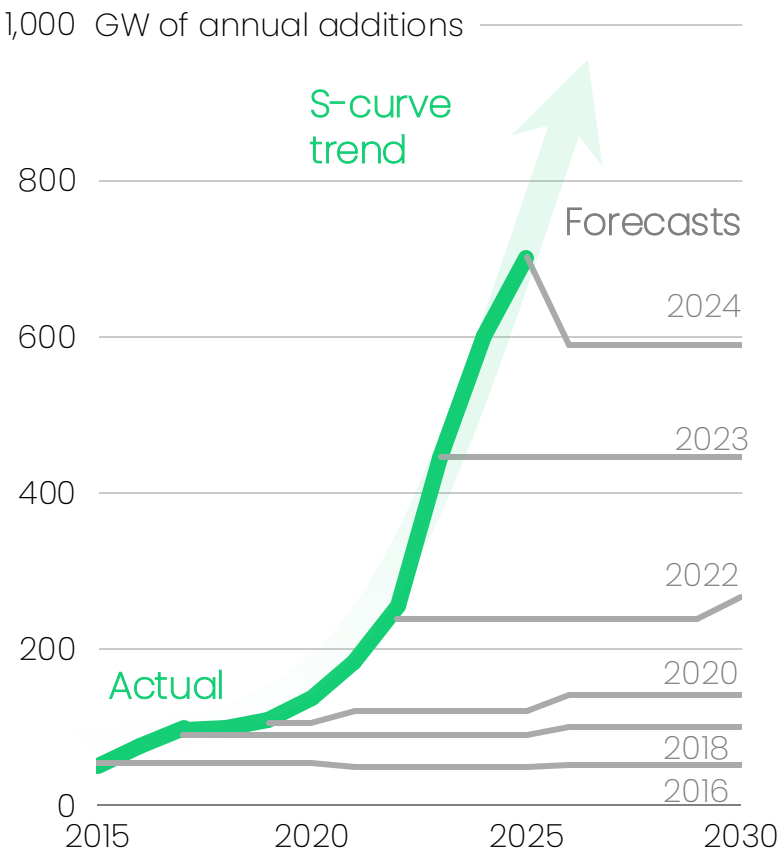


Sources: BNEF, RMI, Ember Futures extrapolation for fossil fuel demand, assuming 3% growth in electricity demand and 15-20% growth in solar and wind supply

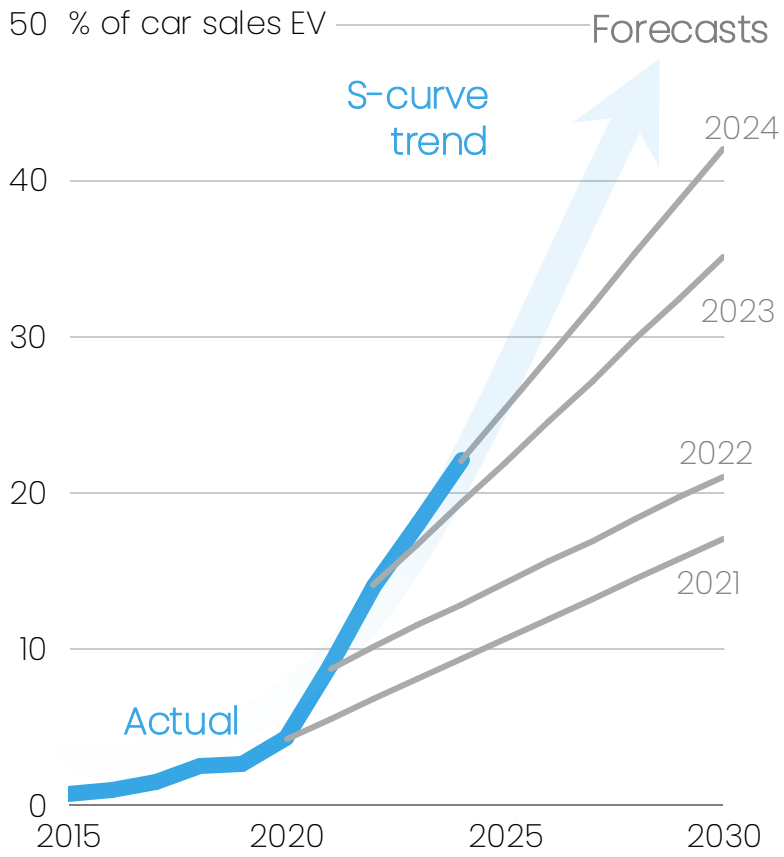
Beware of the limits of old energy models

Complex models are missing the reality of exponential change

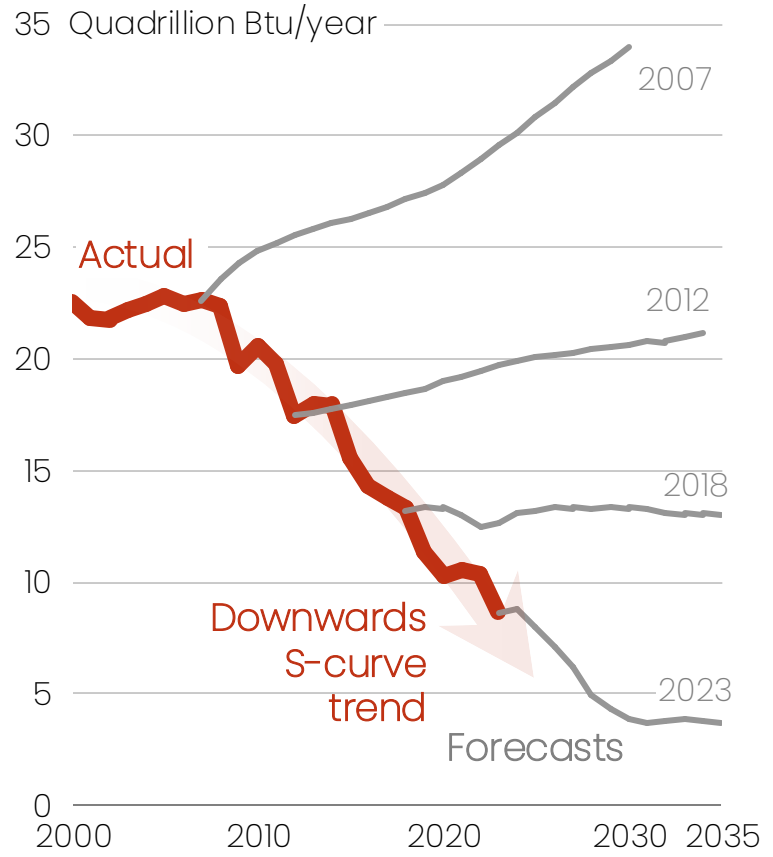
New solar additions



EV share of sales



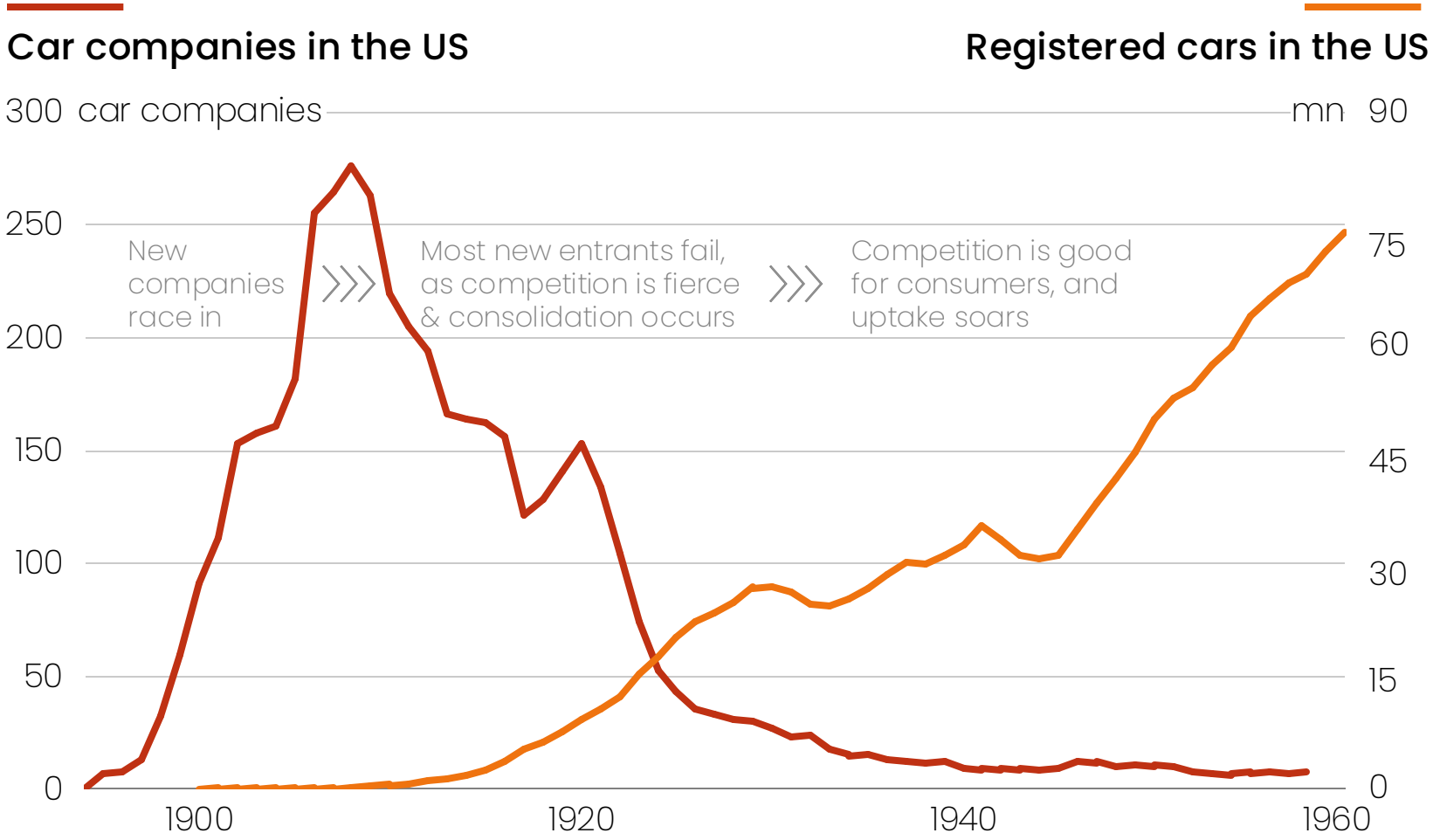
US coal demand



Sources: BNEF (solar actuals), IEA STEPS for WEO forecasts (solar & EVs), EIA via RethinkX (coal demand)

Nobody said it was easy

Investing in technology revolutions is always risky



Normal playbook

01 Brutal competition drives overcapacity and shakeouts

02 Most new entrants fail in the early stages

03 Companies and investors chase growth before profits

04 Market volatility is highest during the early phase

05 The winners win big

06 Failure at the firm level is a necessary part of advance-ment at an economy level

Source: US Department of Transport, Mazzucato & Semmer (1999)

Focus on the fundamentals

Three key questions to gauge new energy technology in times of peak confusion

Physics

Does it make the energy system **more efficient?**

Economics

Is it **small and modular**, so it can be manufactured at scale and **benefit from learning curves**?

Geopolitics

Does it **enhance the independence and security** of its user?

Pick technologies that have the wind in their back

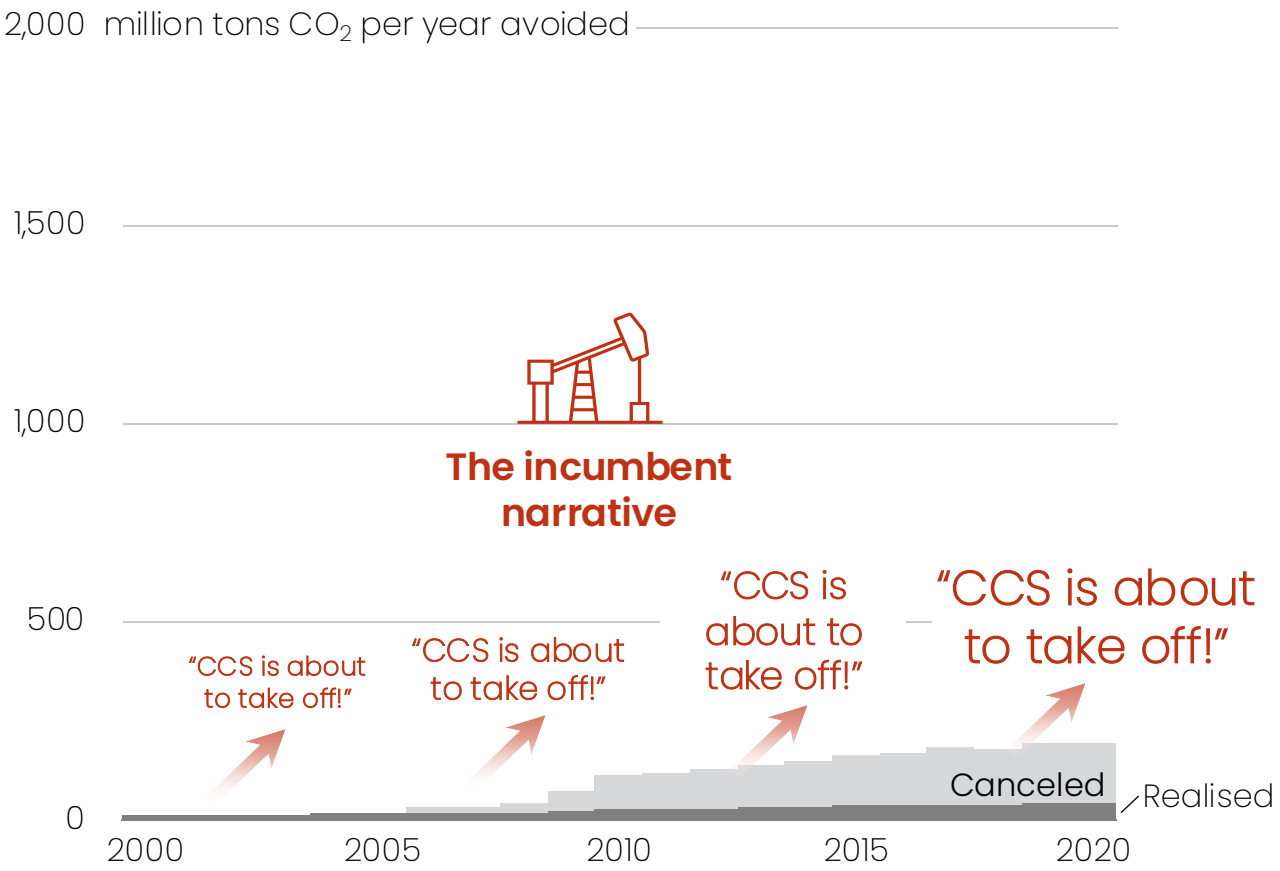
Many popular solutions will struggle in the face of reality

	Physics Does it make the energy system more efficient?	**Economics** Is it small and modular, so it can be manufactured at scale and benefit from learning curves?	**Geopolitics** Does it enhance the independence and security of its user?
CCS	✗ **No**	✗ **No**	✗ **No**
Biofuels	✗ **No**	✗ **No**	✗ **No** **unless you are Brazil**
Green hydrogen	✗ **No**	✗ **Not really** **except for the electrolyser**	✓ **Yes** **unless imported**
Electrotech	✓ **Yes**	✓ **Yes**	✓ **Yes**

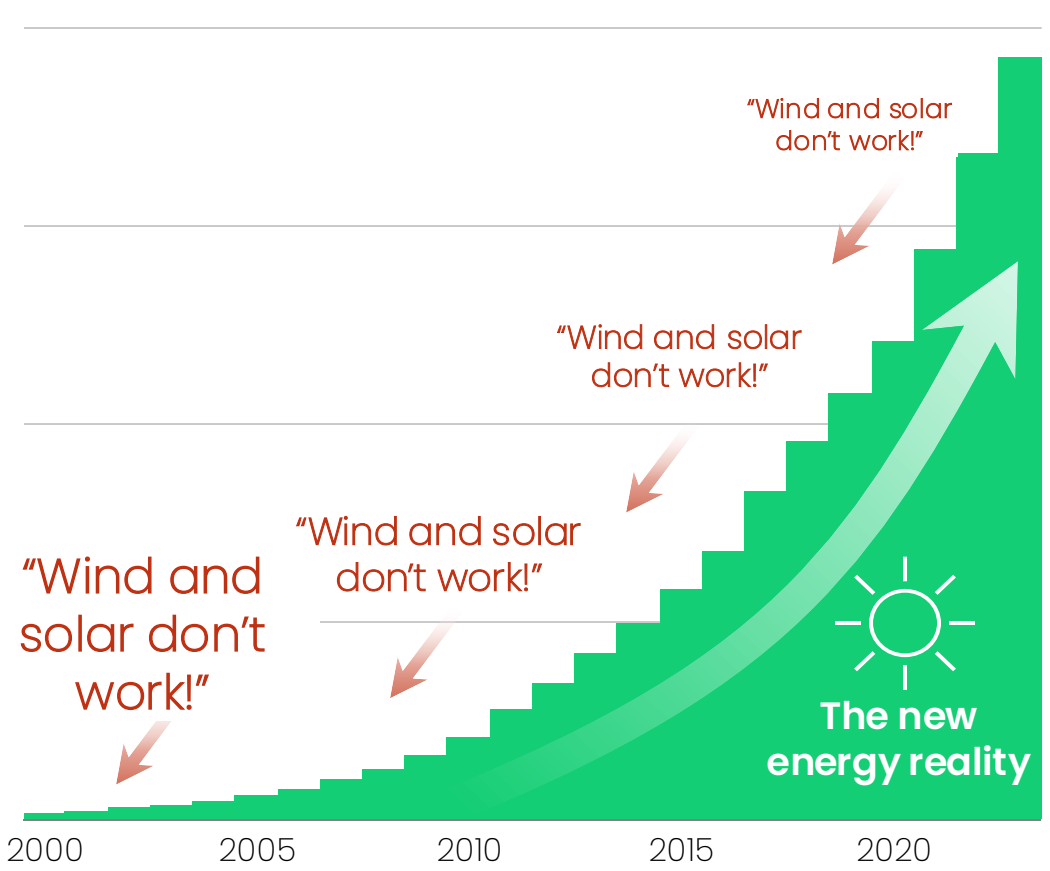
Avoid the distractions

Some cleantech only gets louder; electrotech actually delivers

Global installed CCS capacity



Wind and solar avoided emissions

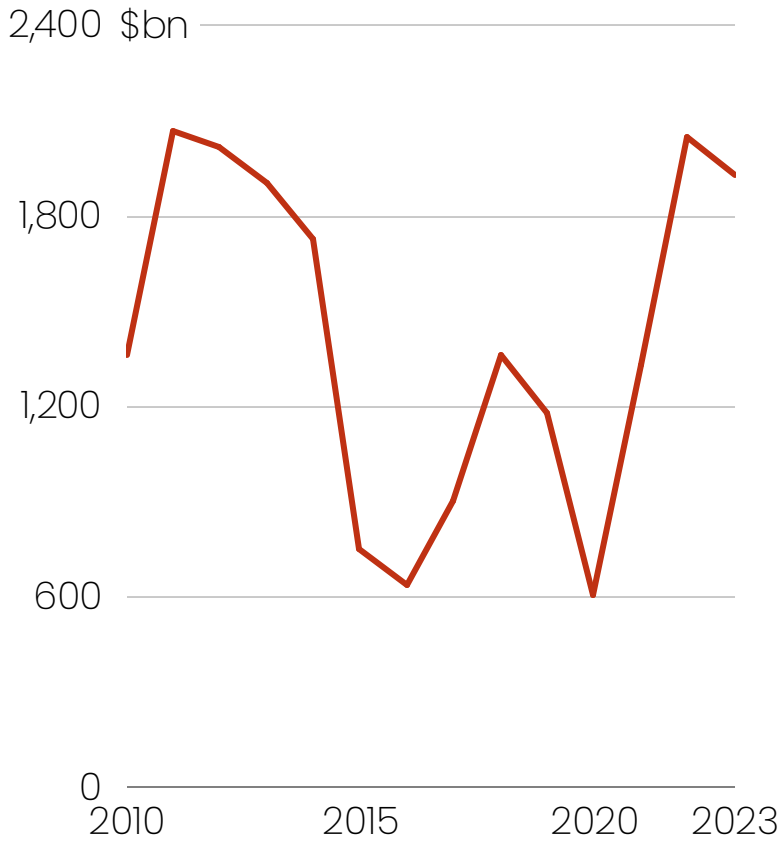


Sources: IEA, BNEF • Note: avoided emissions estimated based on average global grid emission intensity.

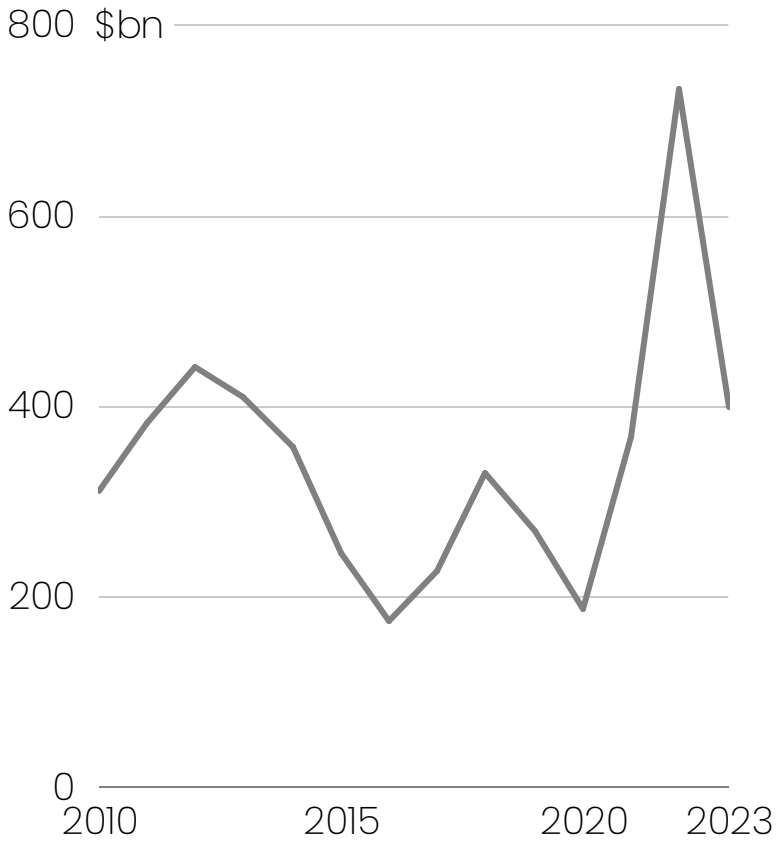
Incumbents resist change because the status quo is so profitable

Governments need to decide what is in their country's best long-term interest

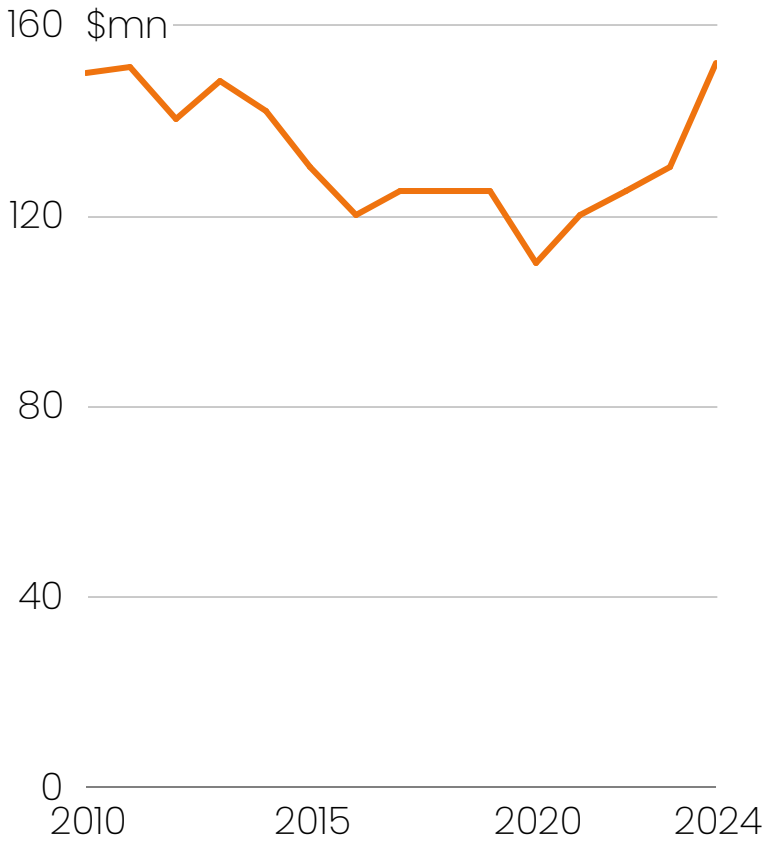
Oil rents



Fossil fuel subsidies



Oil and gas lobbying in the US

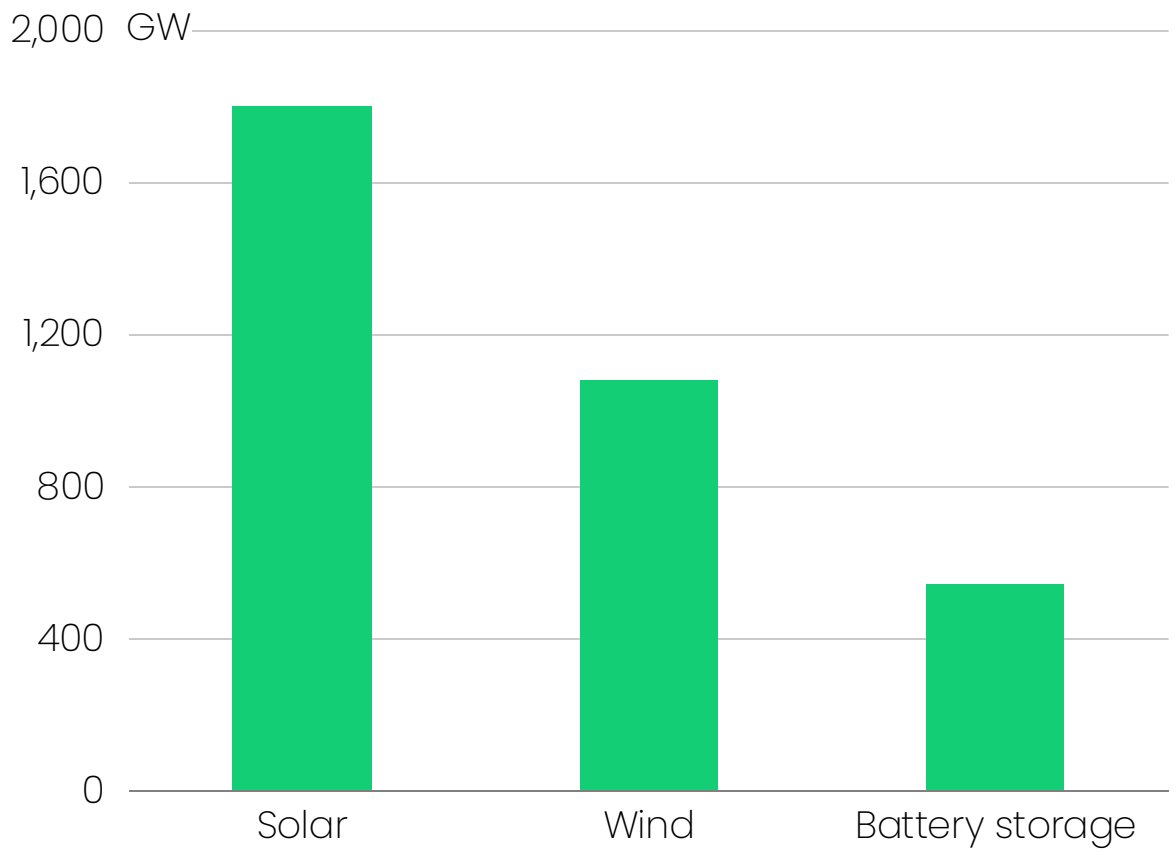


Sources: World Bank, IEA, Open Secrets

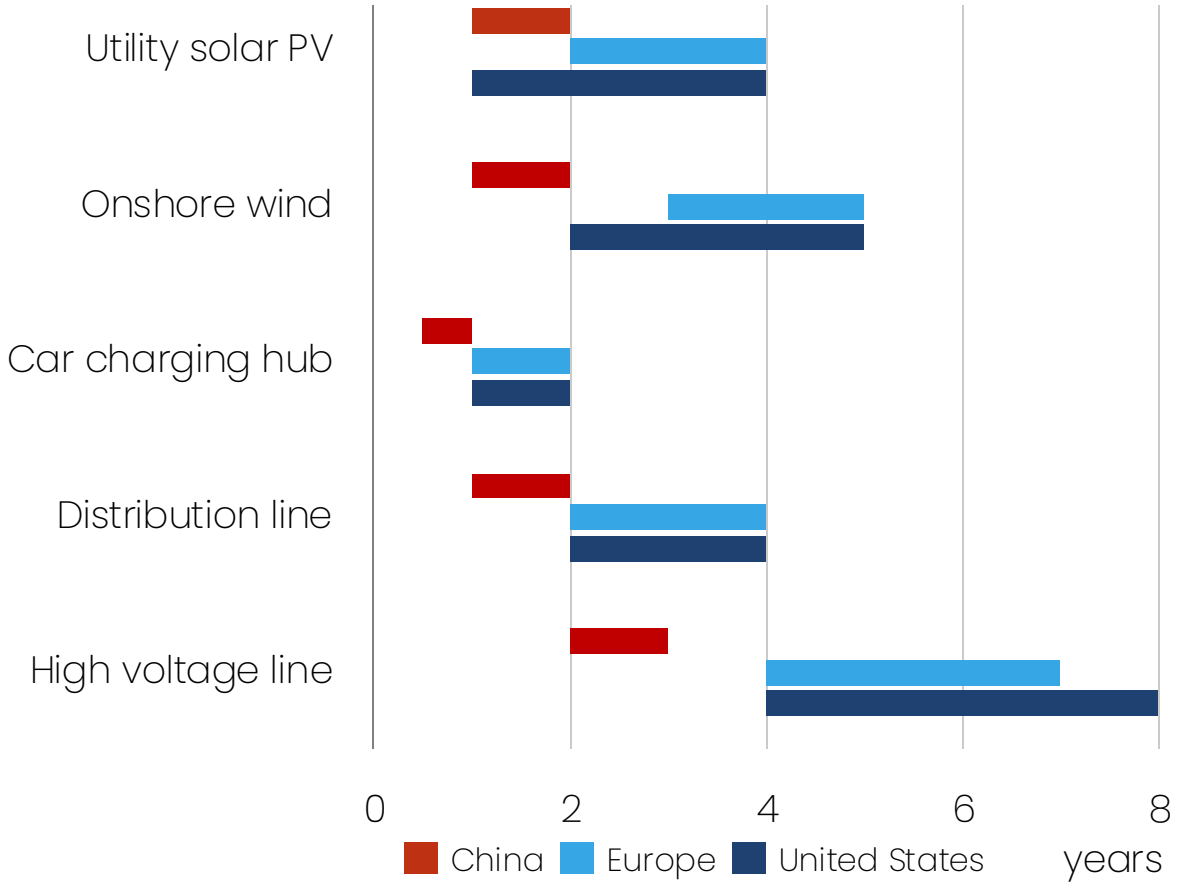
Back the builders not the blockers

Unlock the queues of electrotech that want to come online

Clean energy stuck in the connect queue



Typical deployment time



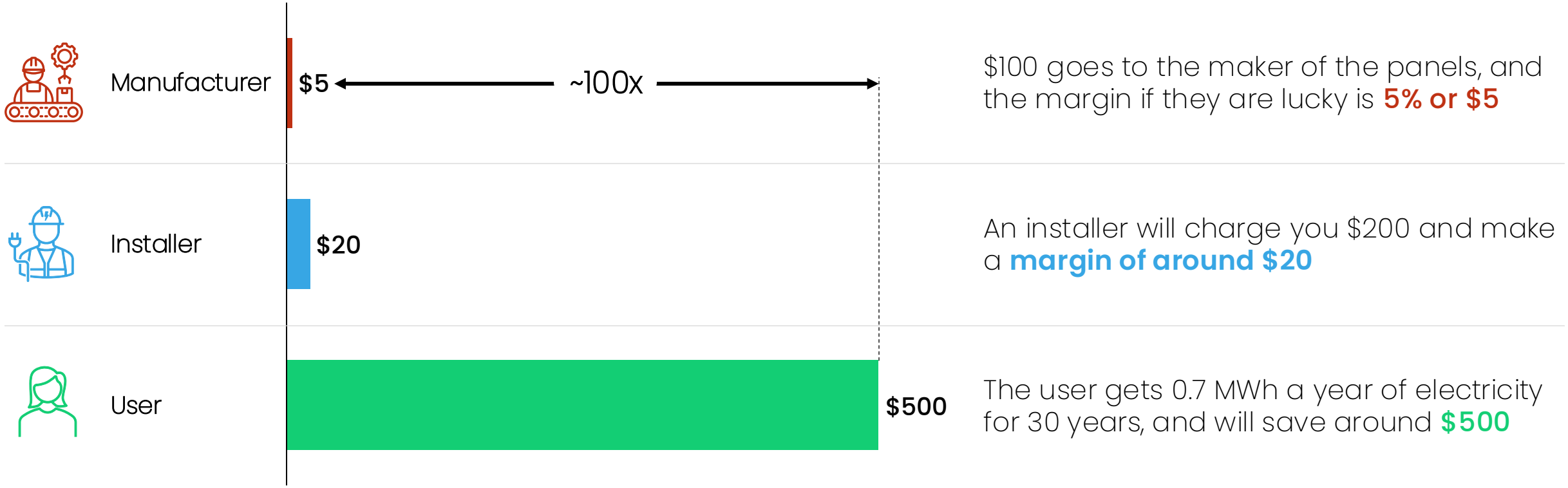
Sources: IEA. Note: solar & wind queue is global; battery storage is in select markets only.

It’s not all about manufacturing

The user benefits are 100x greater than the manufacturer profits

The economics of putting up a couple of solar panels with 1kWp of capacity, UK example

Profits



$100 goes to the maker of the panels, and the margin if they are lucky is **5% or $5**

An installer will charge you $200 and make a **margin of around $20**

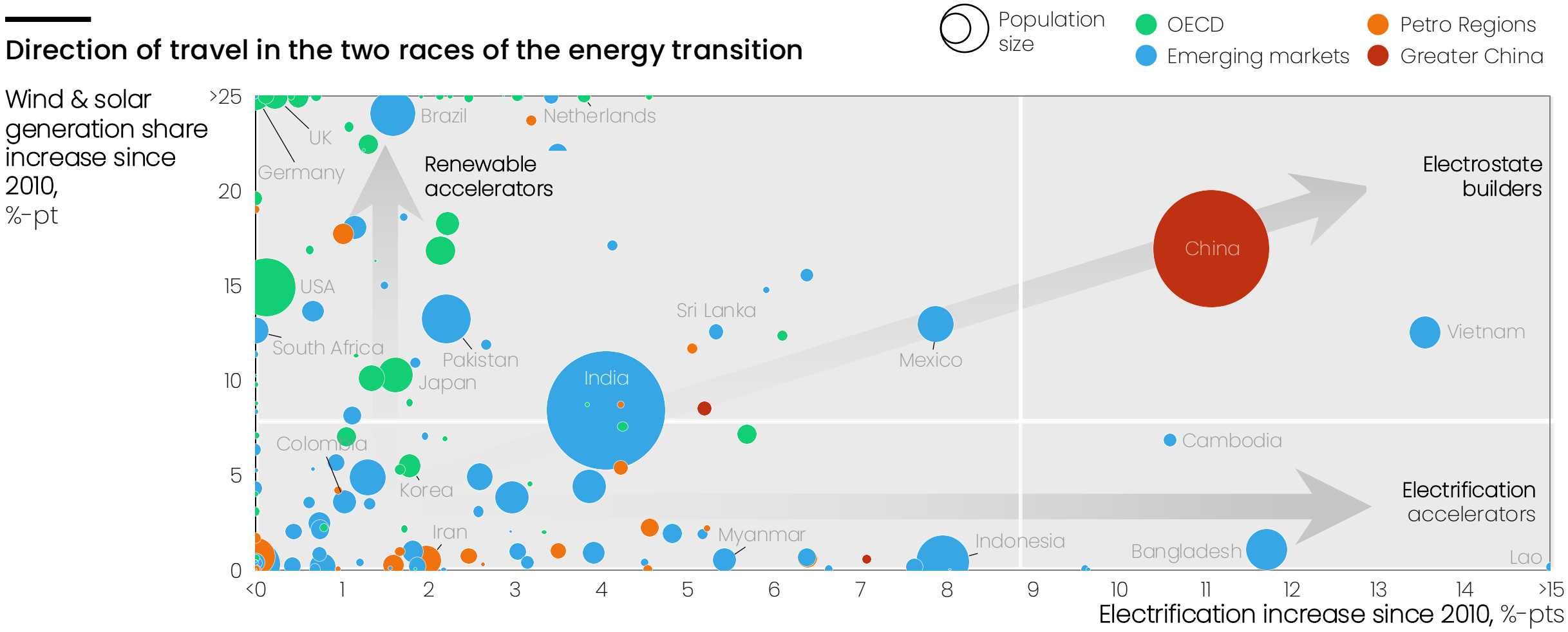
The user gets 0.7 MWh a year of electricity for 30 years, and will save around **$500**

Sources: Alibaba for solar panel costs, Greenmatch for installation costs, NPV calculation for the net savings made by a retail consumer based on data from the Renewable Energy Hub and at a 7% cost of capital.

The electrification imperative

Many countries are building renewables; few an electrostate

Direction of travel in the two races of the energy transition

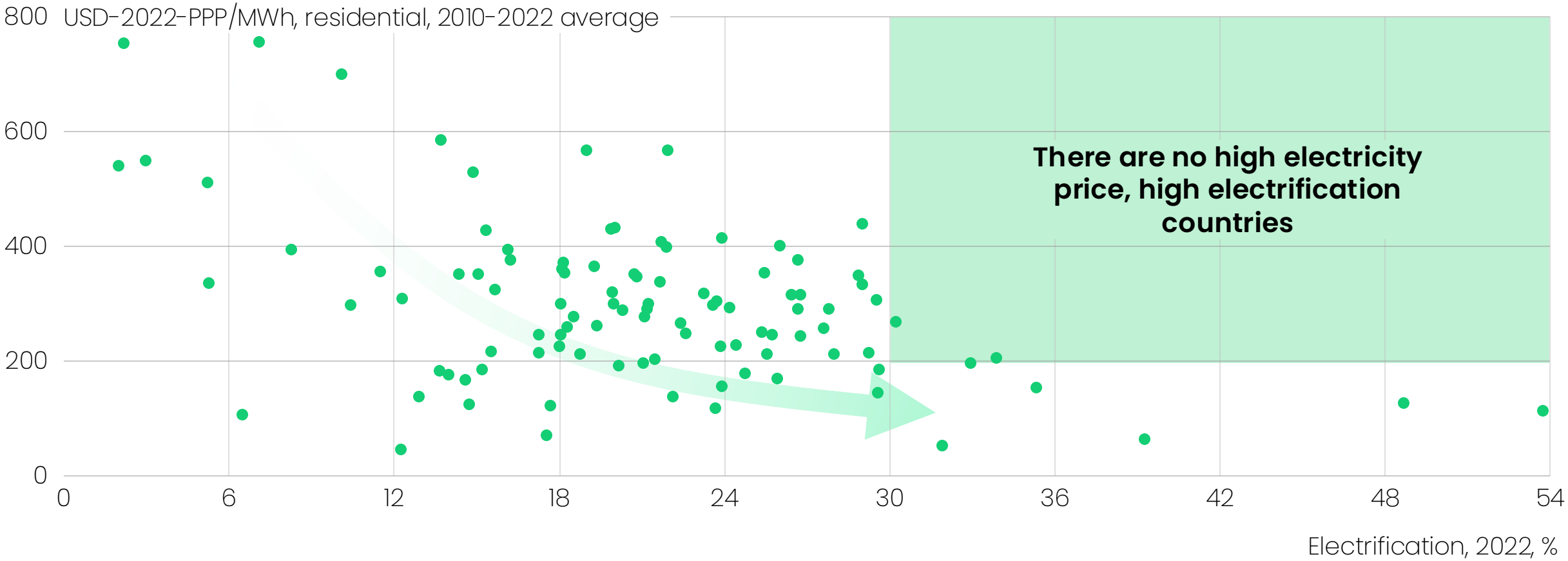


Sources: IEA WEB; Ember; Ember analysis • Note: Shown values cut off at 0-25% for wind & solar and 0-15% for electrification rates

Econ 101

Lower prices incentivise uptake

Electricity price

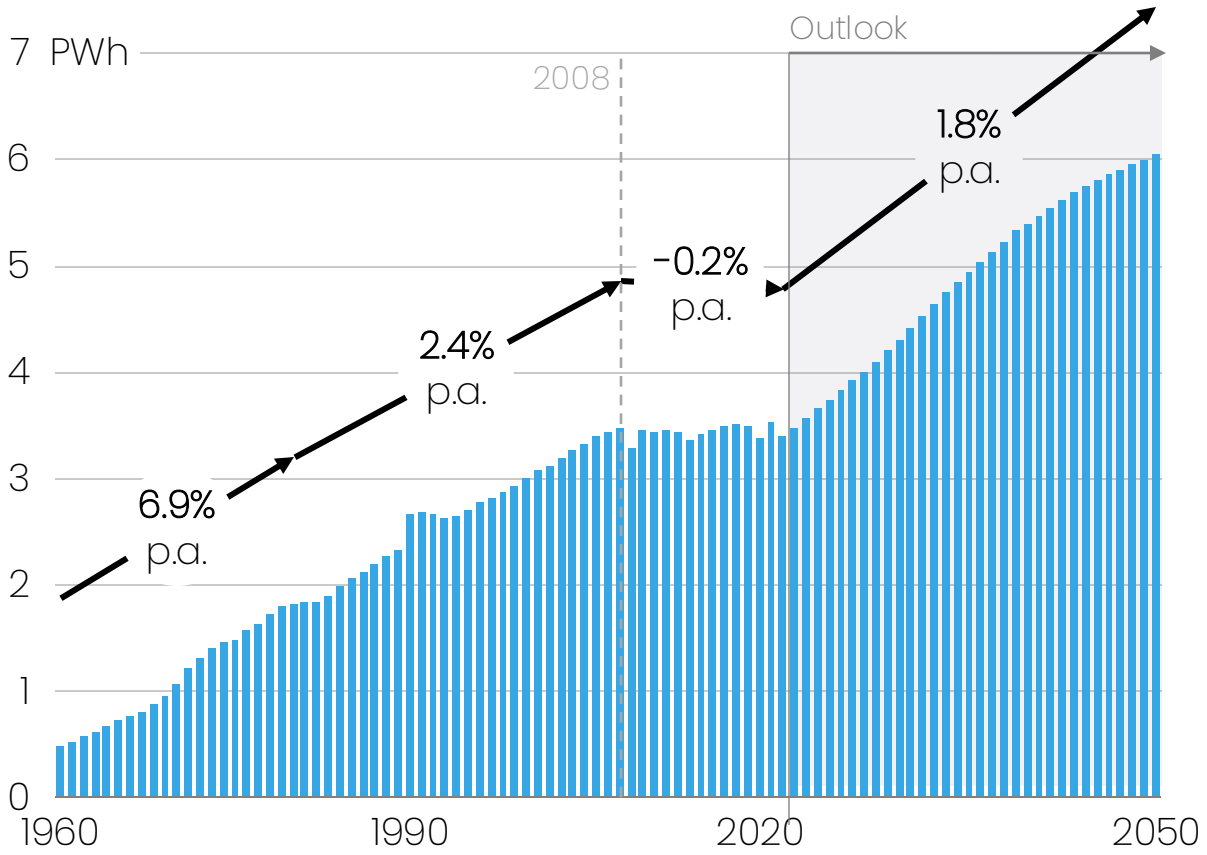


Sources: IEA; Ember analysis

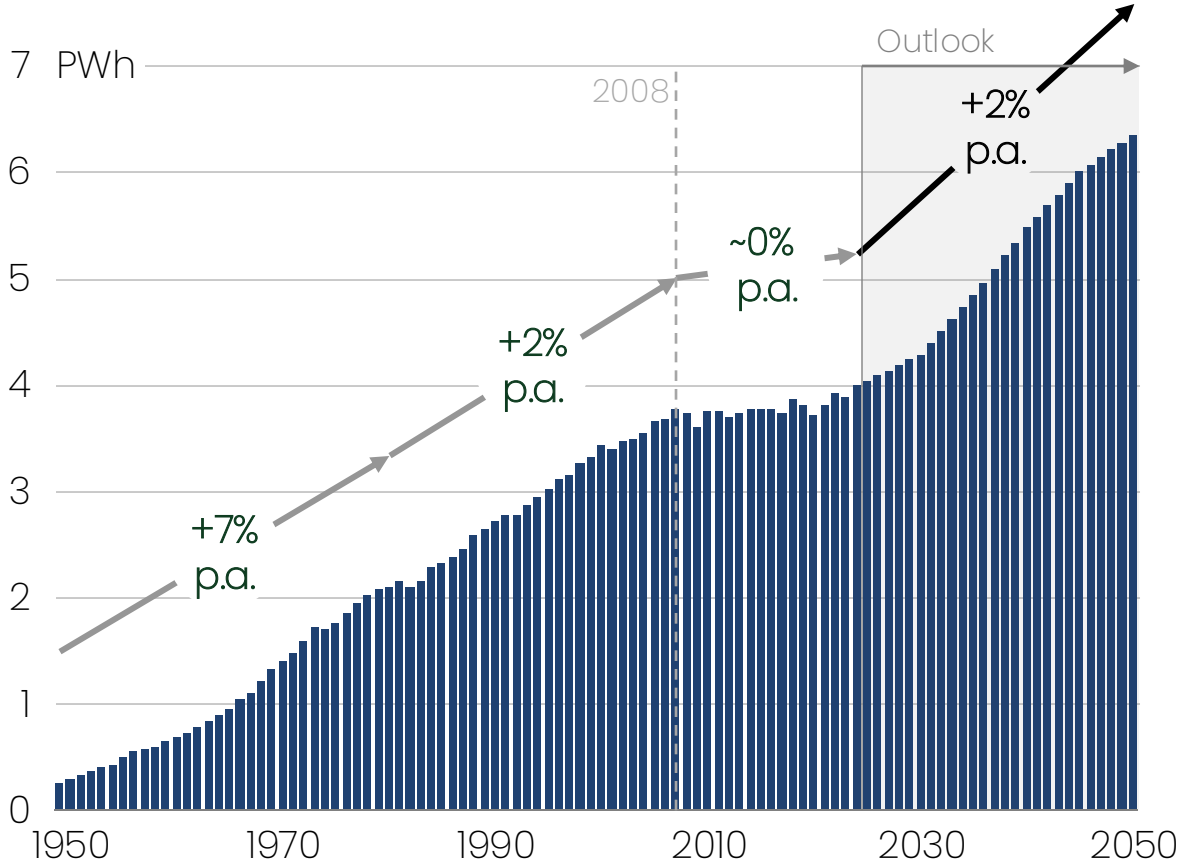
The West can get back on track with electrification

Europe and the US were able to grow electricity demand rapidly for decades before 2008

Europe electricity demand



US electricity demand

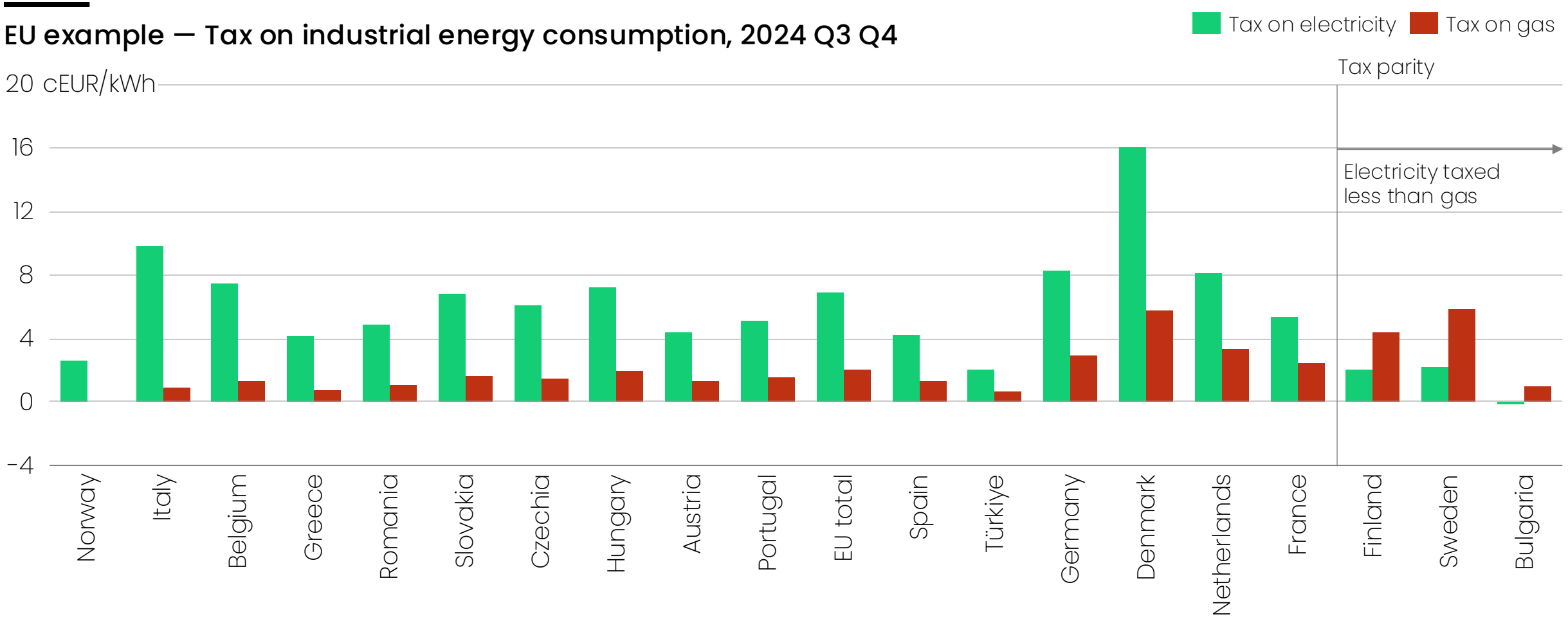


Sources: IEA WEB; IEA APS; Ember analysis

Tax what you want to phase out

High taxes on electricity will only slow down electrification

EU example — Tax on industrial energy consumption, 2024 Q3 Q4



Sources: Eurostat; Ember analysis — based on mid-sized industrial consumer

Experiment with policy and regulation

Just as we experiment with new tech, we should test new policies and regulations

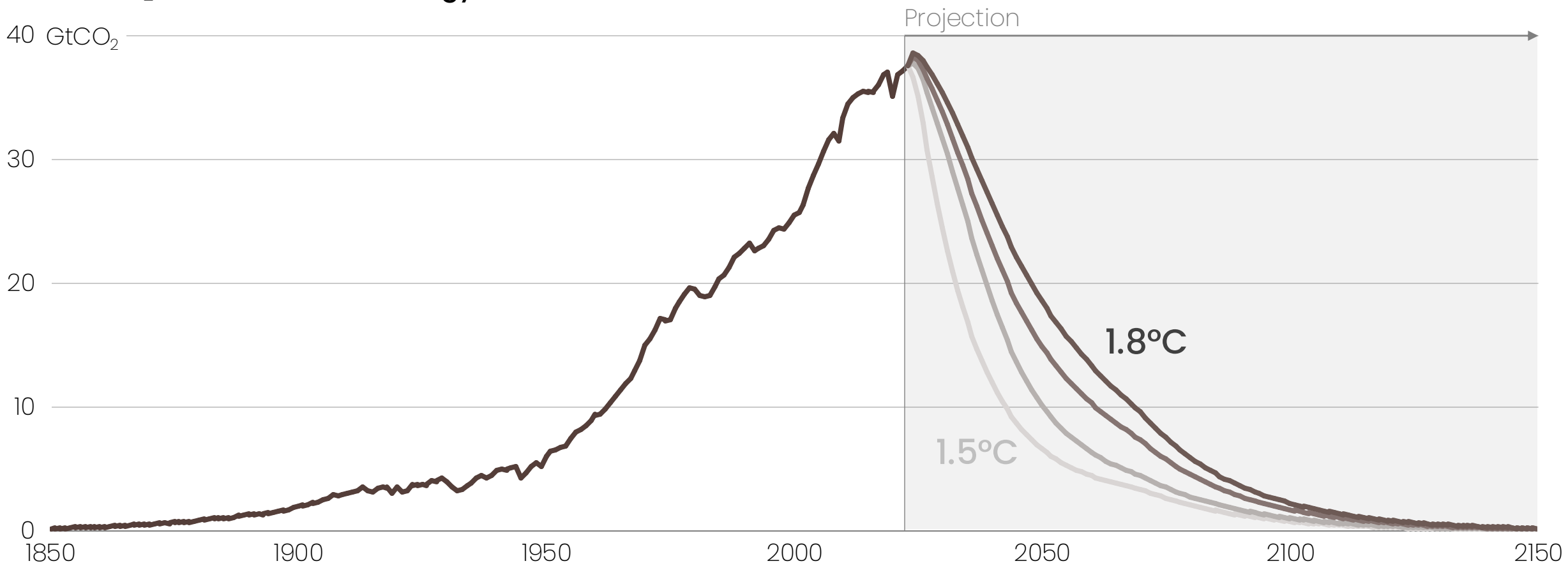
New electrotech	Different tech specs versus fossil incumbent	Example policies and regulations to experiment with to better match new tech		
Utility-scale wind & solar	Variable with weather; available everywhere; zero marginal cost	Regional pricing	Nodal/local battery tenders	Power price-setting reform
Rooftop solar & microgrids	Consumers become prosumers; power flows two ways	Connection fast tracking	Locational tariffs	Microgrid resilience payments
EVs and heat pumps	Loads get more local, mobile, and can be flexed sub-hourly; availability varies by user behavior and season	TOU and availability pricing	Storage buffer incentives	Interoperability / API sandbox
Industry electrification	Very large, shiftable electricity demand for some sites; hard baseload for other sites	Zonal demand tenders	Flexible industrial contracts	CfD for offtake prices
Grid upgrades & advanced sensing	New sensors and controls give fast, local visibility and automated options	Dynamic line rating	Performance-based payments	Private power lines

Sources: Systemiq analysis for the ETC; Ember

Falling emissions are a consequence of the Electrotech Revolution

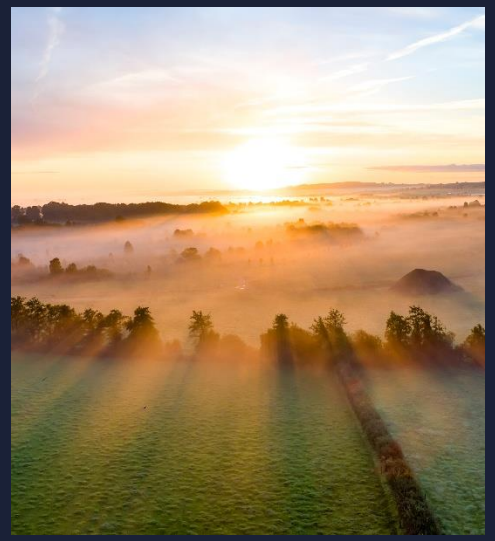
The faster electrotech grows, the faster emissions will fall

Global CO_2 emissions from energy



Sources: Global Carbon Project, OWID (1850-2023), Rystad Energy to 2023-2070; RMI illustrative onwards.

The time is now



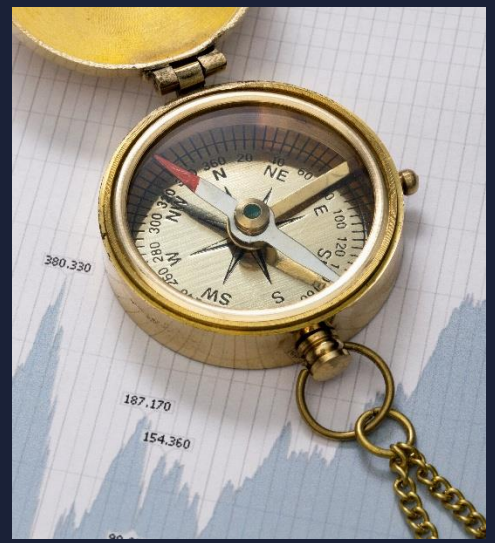
01

For the first time in history, we can harness the exceptional power of the sun through electrotech



02

After a century of evolution, electrotech is now coming together in a decade of revolution; surging globally, replacing fossil fuels, and powering emerging economies



03

Change is driven by the fundamental forces of of physics, economics and geopolitics, not just climate action



04

This revolution will come faster and go further than most think, stranding more than just energy assets, and reshaping global leadership



05

This is the decisive decade. Surf the electrotech wave or be dragged under

About Ember

Ember is an independent 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.

About Ember Futures

This report is the first annual pitch deck from Ember Futures, a new research initiative established to help leaders navigate the rapid rise of electrotech and the decline of fossil fuels, and what this transition means for energy, financial markets, and geopolitics.

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