MATERIAL
TECHNO-ECONOMICS

ELECTRONS, MOLECULES & QUBITS

A contribution to COP31 · Antalya, Türkiye · 9–20 November 2026

A net-zero world, closer:

COP31's 35 by 35

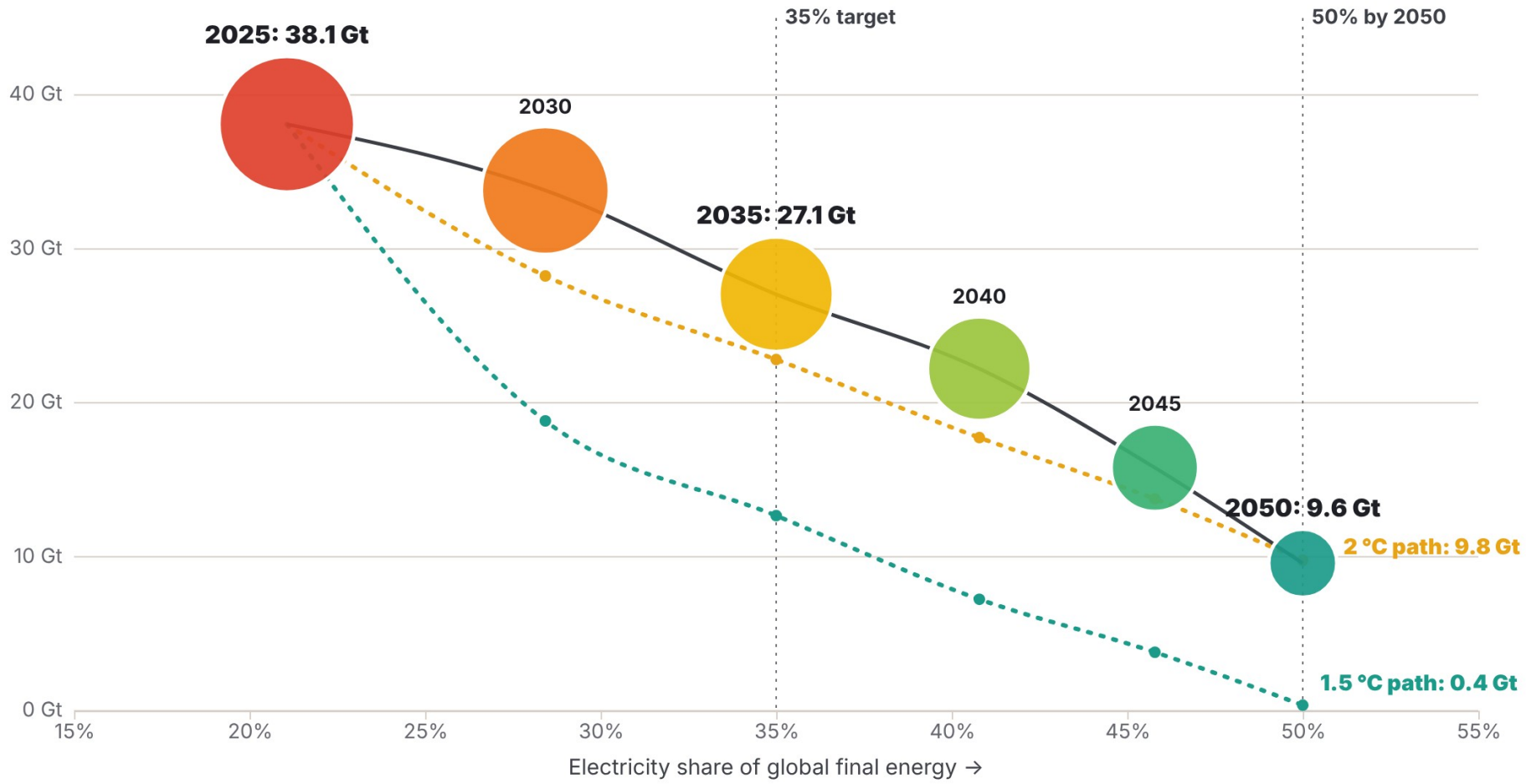
If electricity supplies 35% of final energy by 2035 and 50% by 2050, global CO2 falls from 38 Gt to 10 Gt: a 2 °C world, and back on track to net zero. Sector by sector, for 16 economies and the EU.

Material Techno-Economics, Zurich · November 2026

More electricity, less CO2

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As electricity's share of the world's final energy rises from 21% to 35% in 2035 and 50% in 2050, global CO2 falls from 38.1 Gt to 27.1 Gt and 9.6 Gt. Each bubble is one year. Dotted lines show where emissions need to be for 1.5 °C and 2 °C.



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Key numbers

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Scenario: 35 by 35 and 50 by 2050. Global CO2, electricity's share of final energy and electricity use, by year.

2025

38.1 Gt

Electricity 21% · 31,859 TWh

2035

27.1 Gt

Electricity 35% · 51,700 TWh

2050

9.6 Gt

Electricity 50% · 81,256 TWh

1.5 °C path, 2035

12.7 Gt

Gap 14.4 Gt

Year	Electricity share	Electricity use	Growth a year	Solar, wind, SMRs added	Global CO2
2025	21%	31,859 TWh	–	–	38.1 Gt
2030	28%	42,045 TWh	5.7%	5.1 TW	33.8 Gt
2035	**35%**	**51,700 TWh**	**4.2%**	**11.2 TW**	**27.1 Gt**
2040	41%	61,499 TWh	3.5%	16.7 TW	22.2 Gt
2045	46%	71,617 TWh	3.1%	21.5 TW	15.8 Gt
2050	50%	81,256 TWh	2.6%	24.8 TW	9.6 Gt

How fast electricity use has to grow

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Reaching 35% by 2035 needs electricity use to grow 5.0% a year, faster than the IEA's own 35% scenario (4.1%), which starts from 23% instead of 21%. Today's policies give about 3.1%. After 2035, 3.1% a year is enough for 50% by 2050.

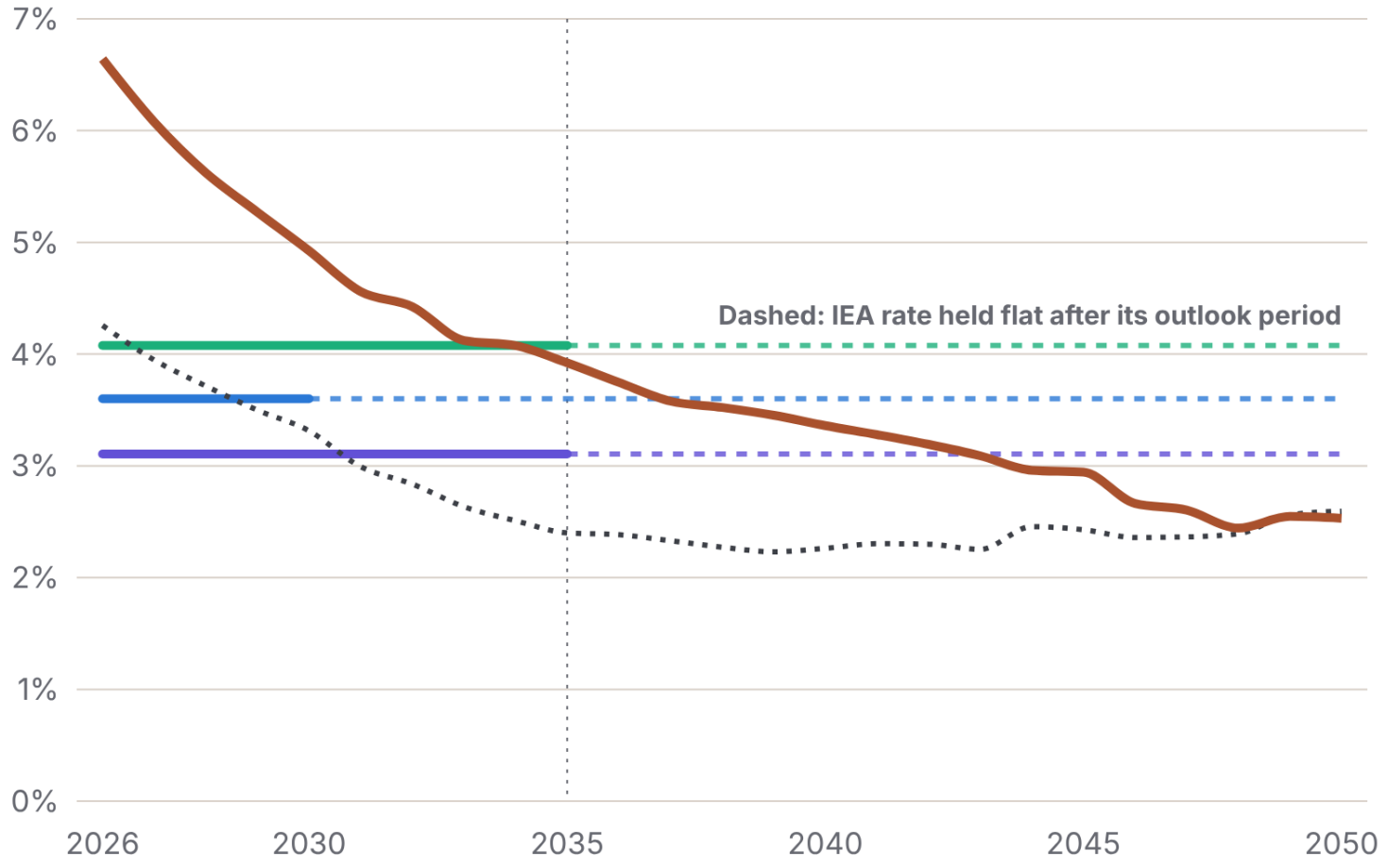
35 by 35 path
5.0% a year to 2035, 3.1% after

IEA High Electrification
35% by 2035: 4.1% a year

IEA forecast to 2030
Electricity 2026: 3.6% a year

IEA, today's policies
WEO 2025: 3.1% a year

Cheaper power only
3.2% a year to 2035



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Five big emitters

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China, the United States, India, the EU and Japan emit 62% of global CO2. Scenario: 35 by 35 and 50 by 2050.

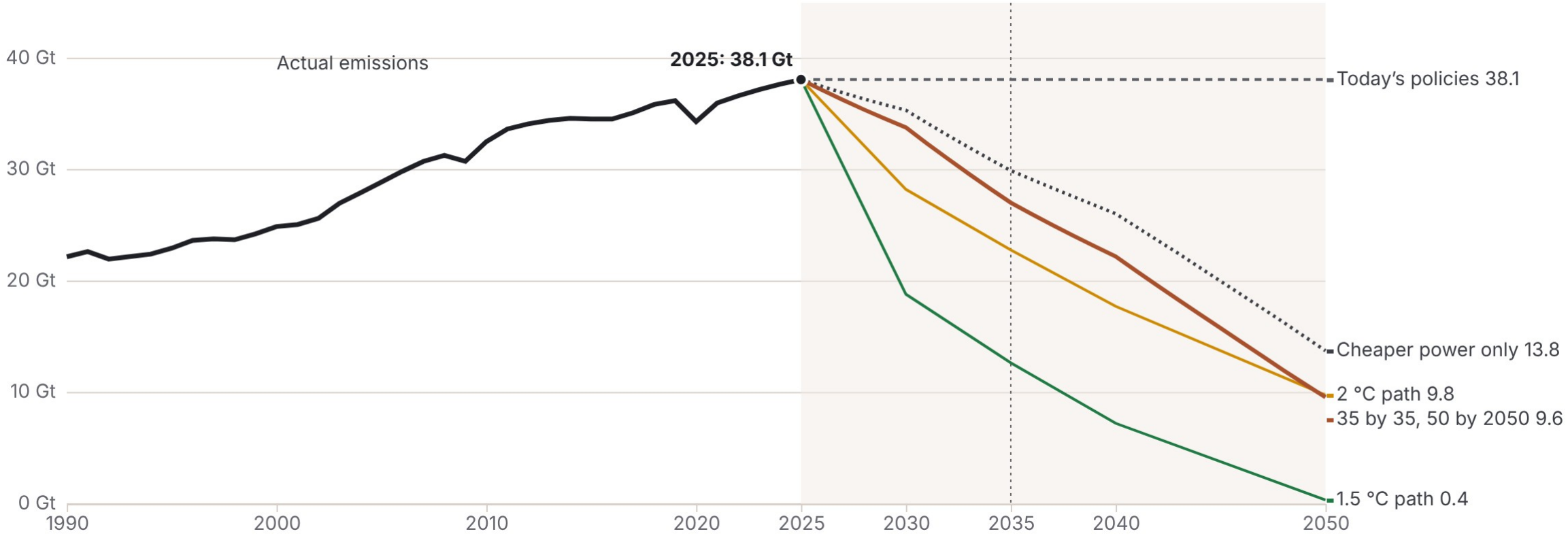
Region	CO2 2025	CO2 2035	CO2 2050	Electricity 2025 → 2035 → 2050	Power price 2035	Rungs green 2035
China	12.1 Gt	8.4 Gt (−31%)	2.2 Gt (−82%)	29% → 46% → 63%	$90/MWh	4 of 15
United States	4.8 Gt	3.3 Gt (−31%)	1.2 Gt (−76%)	22% → 37% → 54%	$78/MWh	3 of 15
India	3.2 Gt	2.4 Gt (−25%)	0.8 Gt (−73%)	19% → 34% → 49%	$97/MWh	3 of 15
European Union	2.4 Gt	1.5 Gt (−37%)	0.5 Gt (−78%)	23% → 40% → 56%	$169/MWh	3 of 15
Japan	0.9 Gt	0.6 Gt (−32%)	0.2 Gt (−83%)	29% → 43% → 55%	$142/MWh	3 of 15

The next five slides show, for each region, the power price at which each sector becomes cheaper on electricity, and how its emissions fall.

How far is the world from 1.5 °C?

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If electricity reaches 35% of final energy by 2035 and 50% by 2050, global CO2 falls from 38.1 Gt in 2025 to 27.1 Gt in 2035 and 9.6 Gt in 2050. With cheaper power alone, 2035 emissions are 29.9 Gt. A 1.5 °C path needs about 12.7 Gt by 2035. At today's emissions, the remaining 1.5 °C carbon budget runs out in about four years.

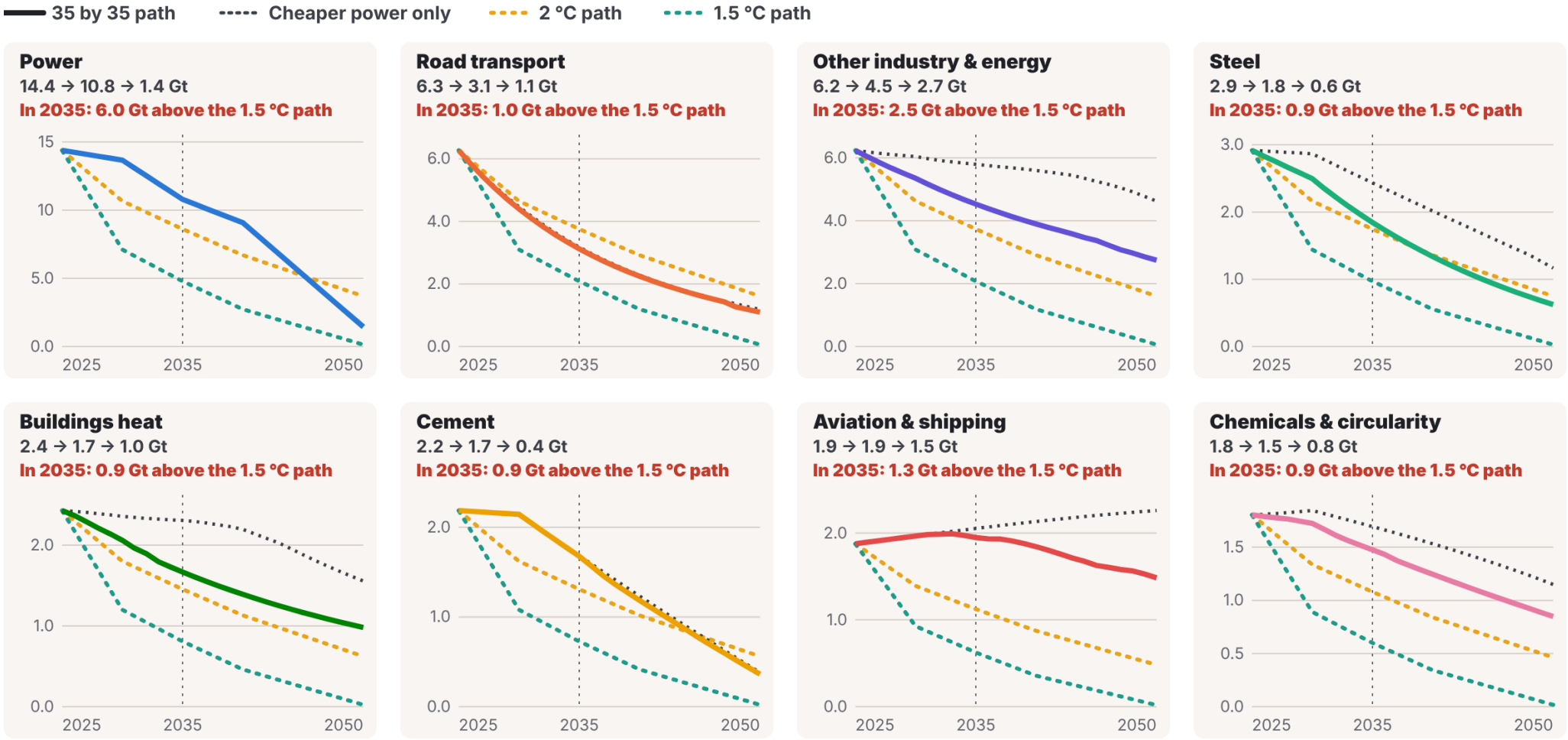


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How far each sector is from 1.5 °C

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The same chart, one panel per sector. No sector is on a 1.5 °C path in 2035. Power is furthest away (6.0 Gt over), followed by other industry & energy (2.5 Gt) and aviation & shipping (1.3 Gt). Together the sectors are 14.4 Gt over in 2035. Road transport is on or below the 2 °C path.

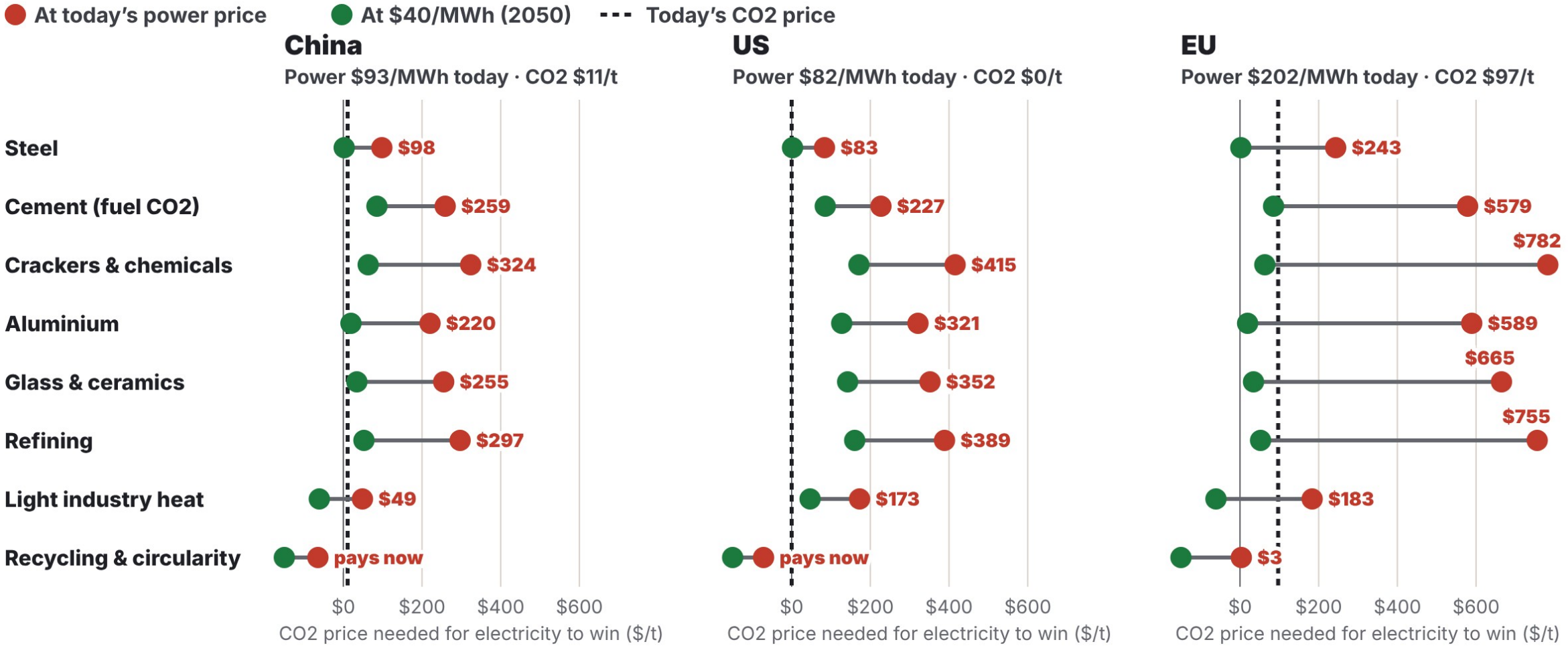


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Cost to decarbonise industry: China, US and EU

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At today's power prices, heavy industry needs a CO2 price of $243–782/t in the EU, $98–324/t in China and $83–415/t in the US to switch to electricity. The EU pays $97/t, China about $11/t and the US nothing at federal level. At $40/MWh no sector needs more than about $171/t. Cheap clean power is the industrial policy.

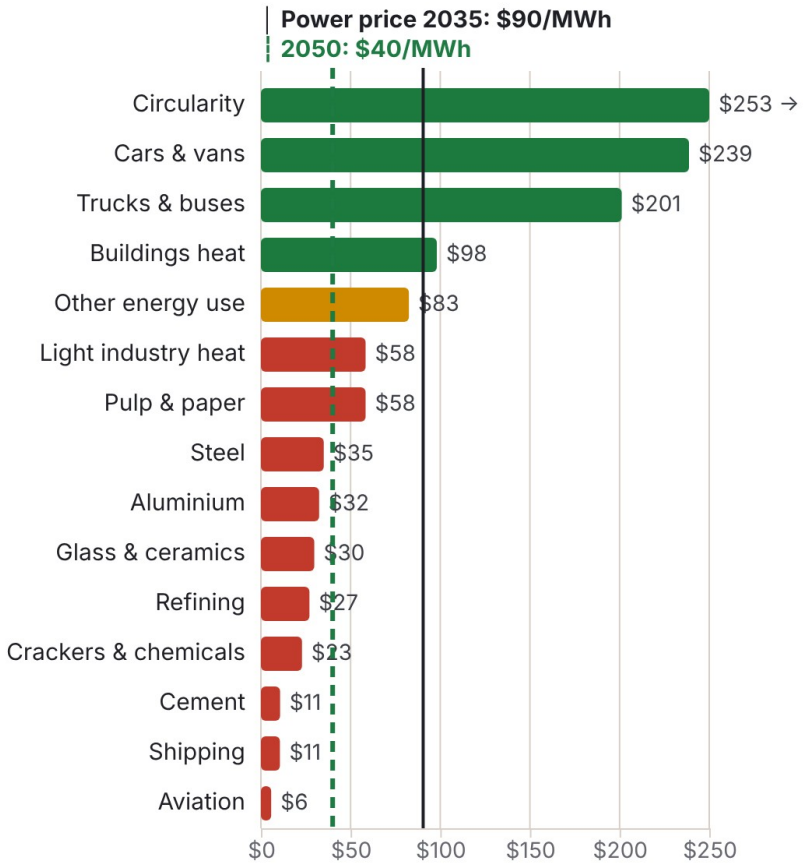


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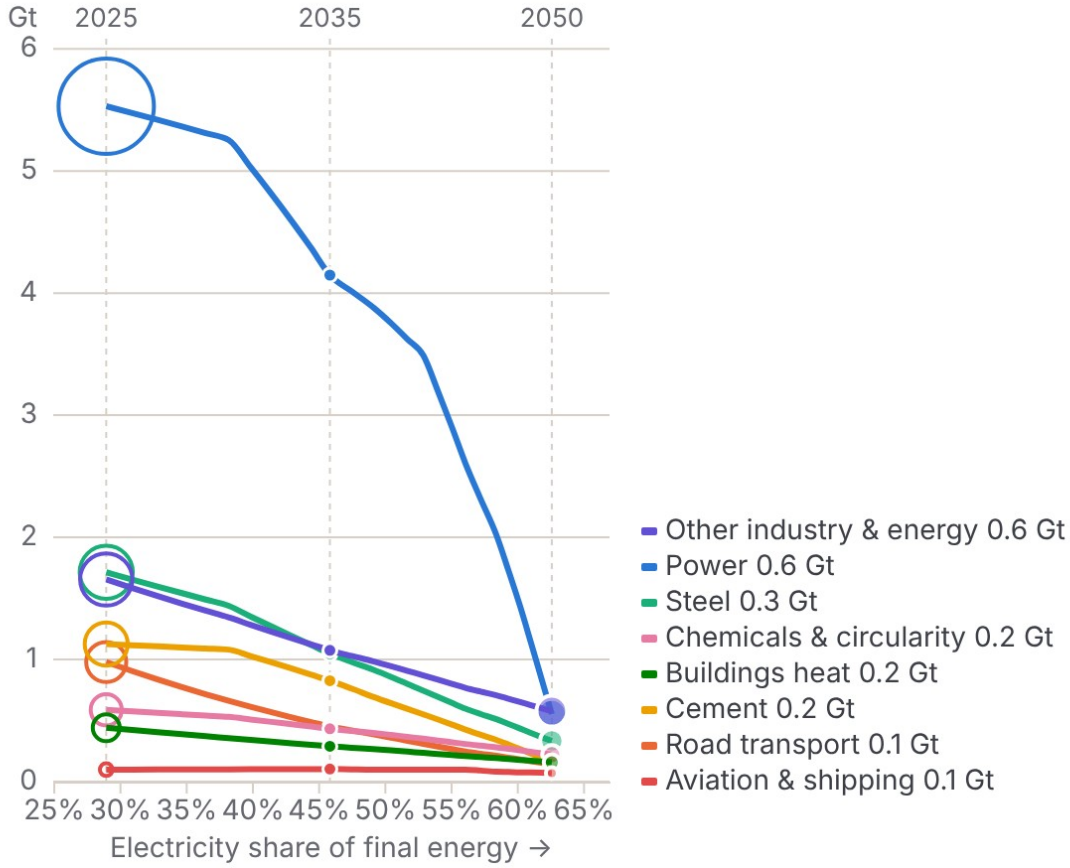
China in 2035

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Power costs $90/MWh in 2035. 4 of 15 sectors are cheaper on electricity: cars & vans, trucks & buses, circularity, buildings heat. CO2: 12,130 Mt (2025), 8,372 Mt (2035), 2,211 Mt (2050). Electricity share: 29%, 46%, 63%. China aims for carbon neutrality before 2060. A straight line to zero in 2060 means about 3,466 Mt in 2050; this path gives 2,211 Mt, ahead of that line.



Power price at which each sector beats fossil fuels ($/MWh). Green: cheaper now. Amber: within 30%. Red: not yet.

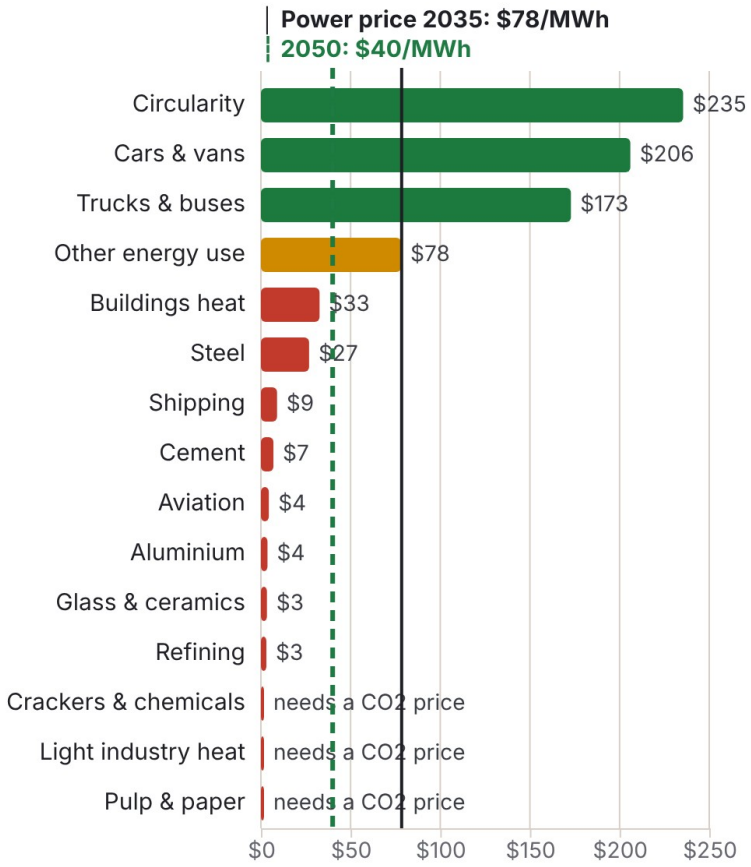


Emissions by sector as electricity's share rises. Open circle: 2025. Filled: 2050.

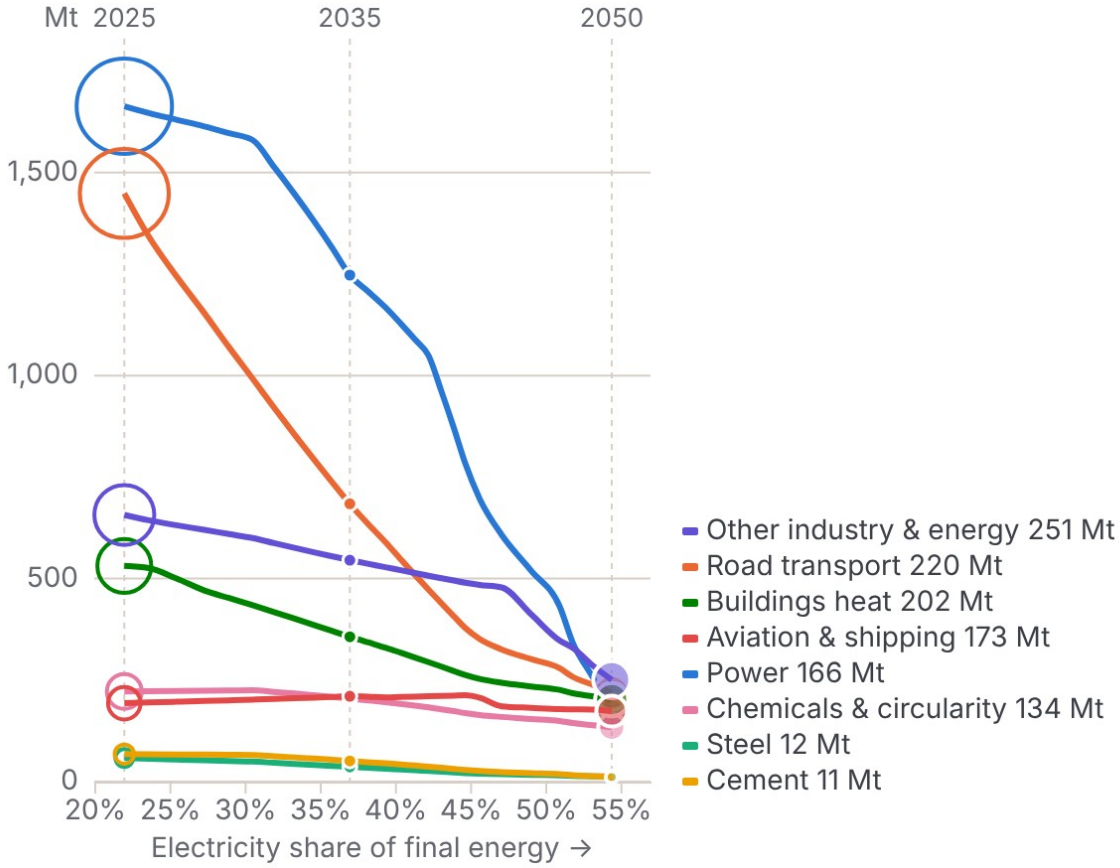
United States in 2035

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Power costs $78/MWh in 2035. 3 of 15 sectors are cheaper on electricity: cars & vans, trucks & buses, circularity. CO2: 4,841 Mt (2025), 3,335 Mt (2035), 1,169 Mt (2050). Electricity share: 22%, 37%, 54%.



Power price at which each sector beats fossil fuels ($/MWh). Green: cheaper now. Amber: within 30%. Red: not yet.

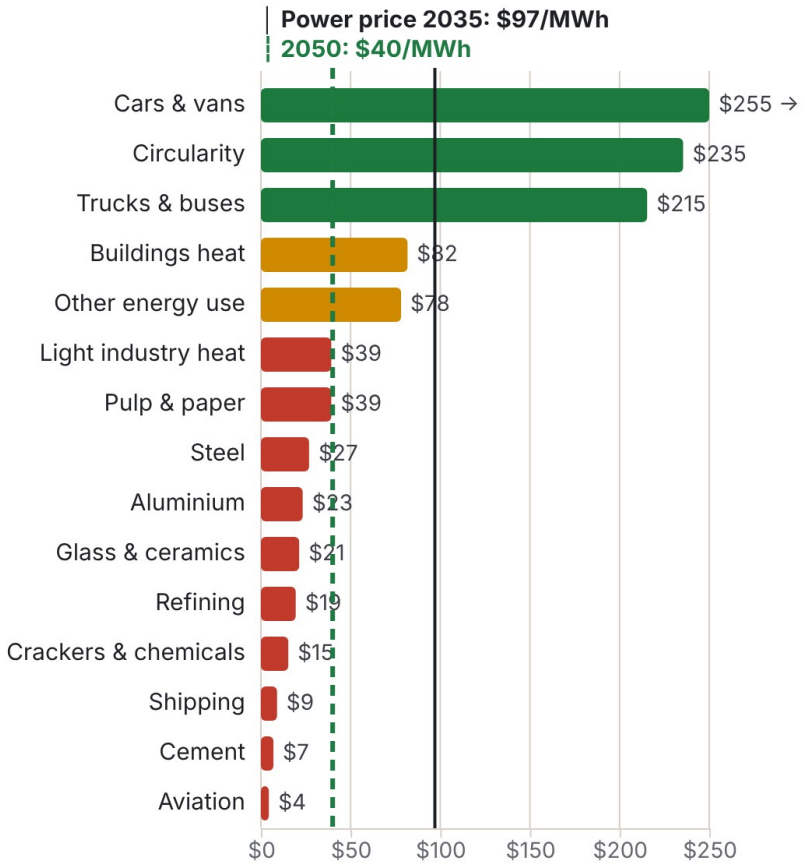


Emissions by sector as electricity's share rises. Open circle: 2025. Filled: 2050.

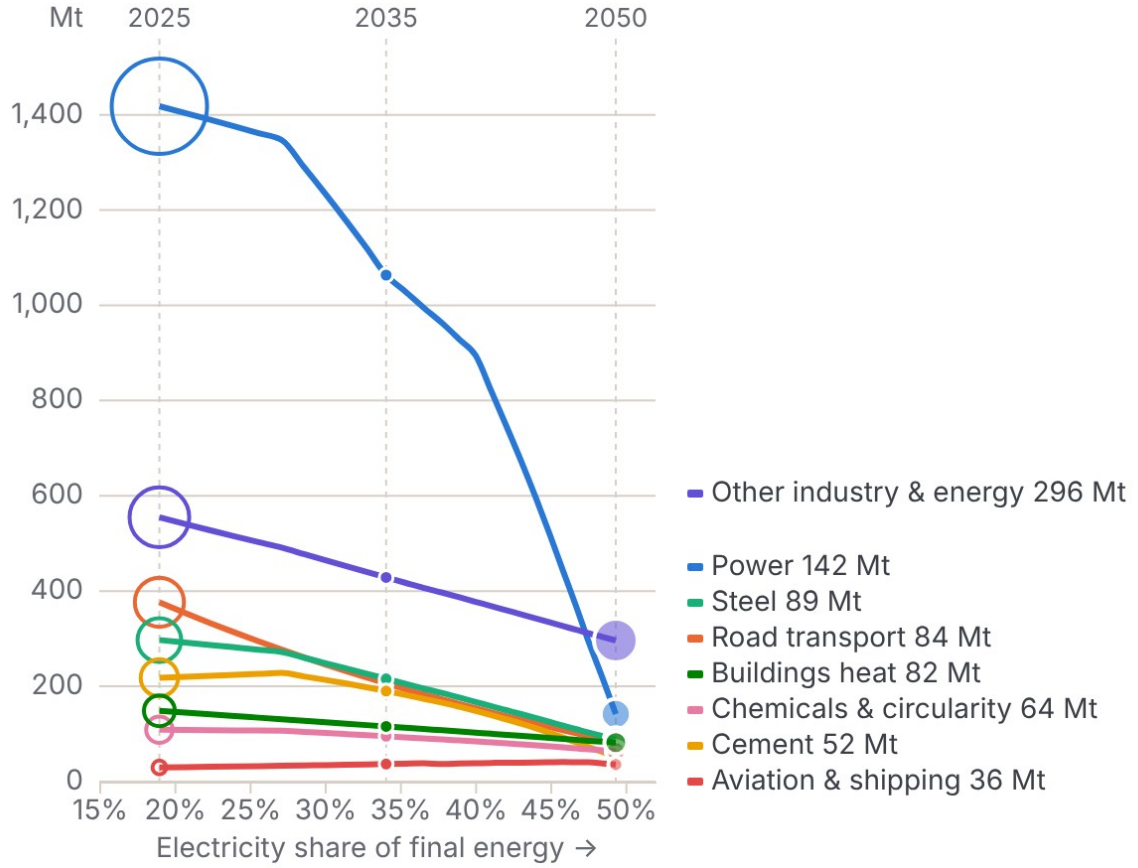
India in 2035

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Power costs $97/MWh in 2035. 3 of 15 sectors are cheaper on electricity: cars & vans, trucks & buses, circularity. CO2: 3,152 Mt (2025), 2,352 Mt (2035), 844 Mt (2050). Electricity share: 19%, 34%, 49%.



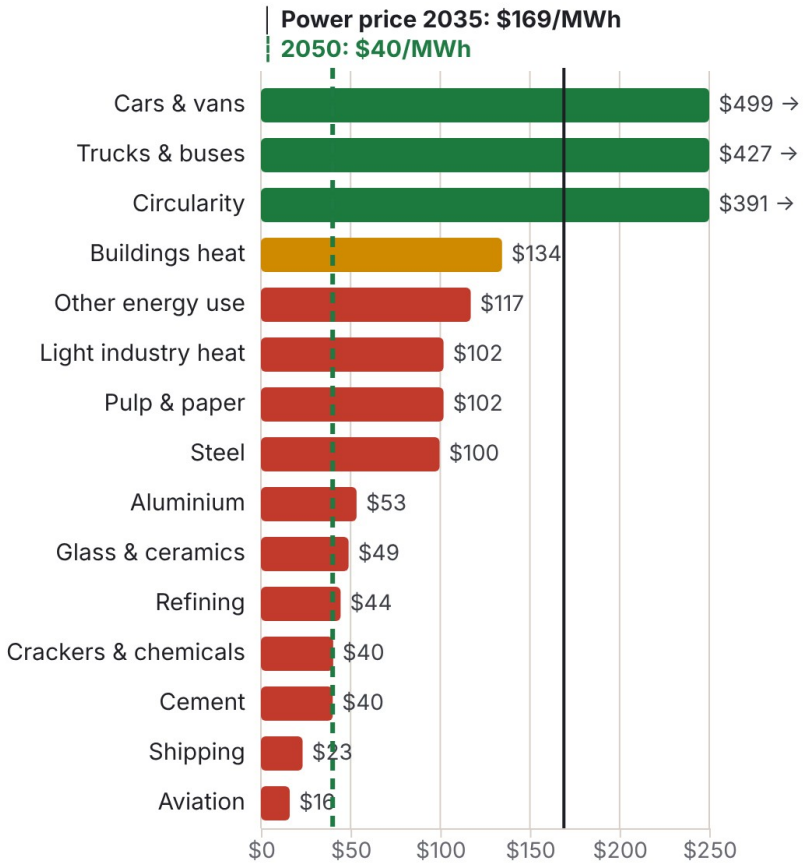
Power price at which each sector beats fossil fuels ($/MWh). Green: cheaper now. Amber: within 30%. Red: not yet.



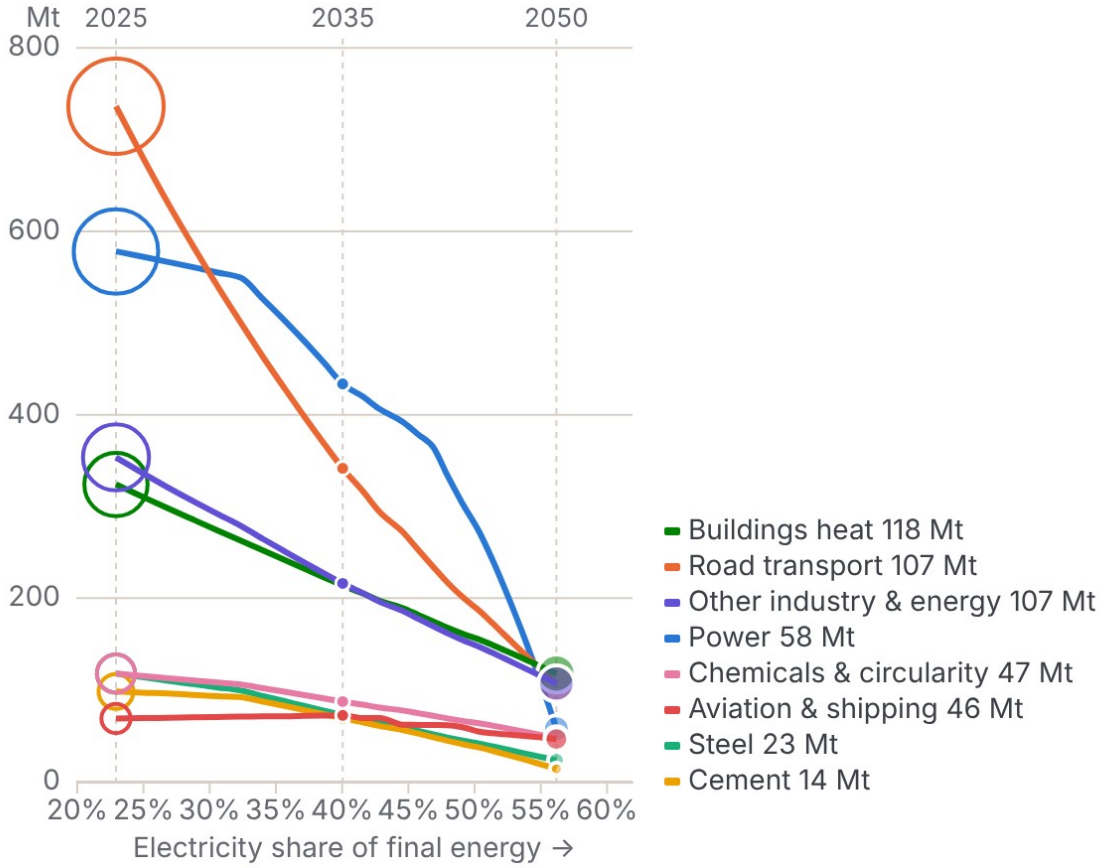
Emissions by sector as electricity's share rises. Open circle: 2025. Filled: 2050.

European Union in 2035

Power costs $169/MWh in 2035. 3 of 15 sectors are cheaper on electricity: cars & vans, trucks & buses, circularity. CO2: 2,395 Mt (2025), 1,506 Mt (2035), 520 Mt (2050). Electricity share: 23%, 40%, 56%. The EU keeps today's ETS and aims for climate neutrality by 2050.



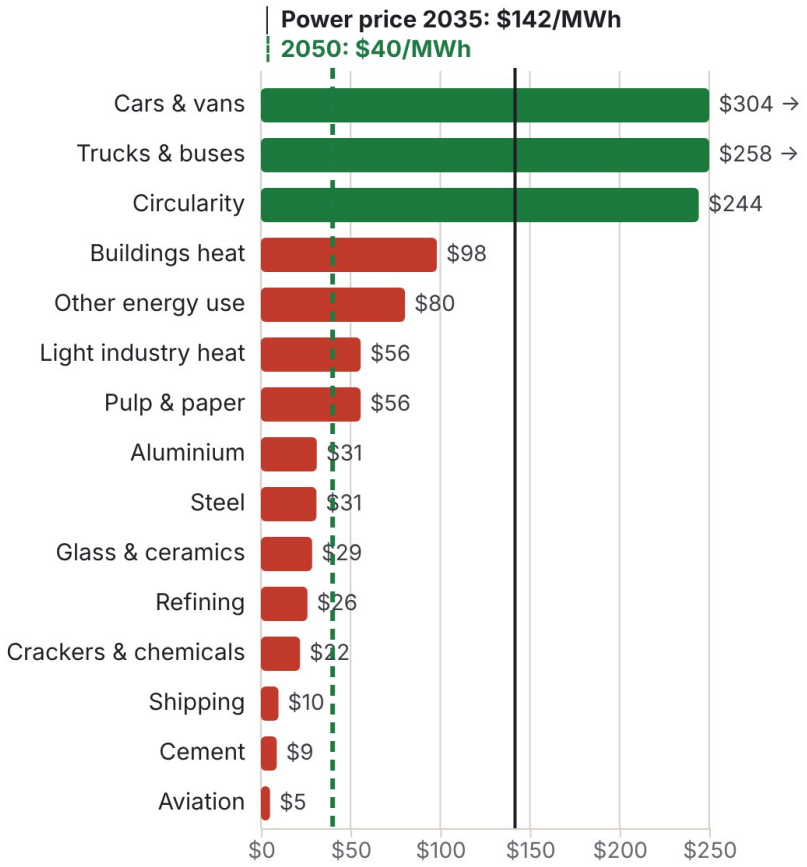
Power price at which each sector beats fossil fuels ($/MWh). Green: cheaper now. Amber: within 30%. Red: not yet.



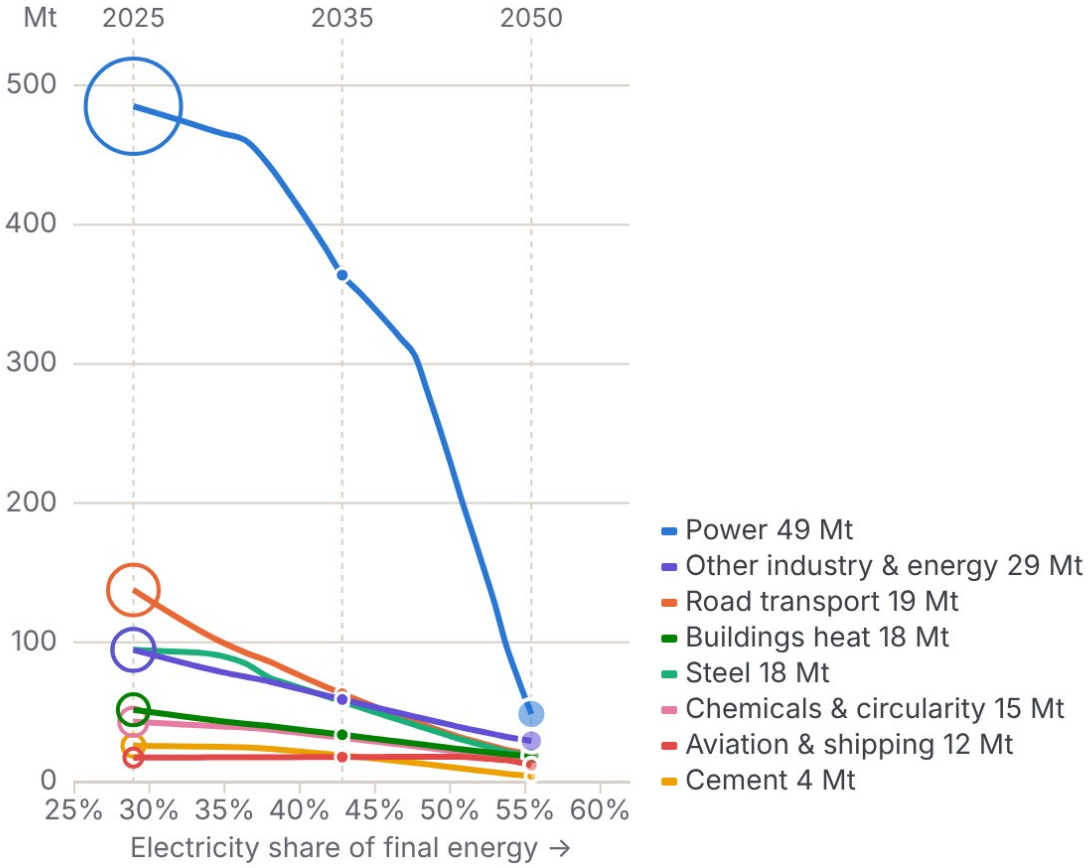
Emissions by sector as electricity's share rises. Open circle: 2025. Filled: 2050.

Japan in 2035

Power costs $142/MWh in 2035. 3 of 15 sectors are cheaper on electricity: cars & vans, trucks & buses, circularity. CO2: 949 Mt (2025), 645 Mt (2035), 165 Mt (2050). Electricity share: 29%, 43%, 55%.



Power price at which each sector beats fossil fuels ($/MWh). Green: cheaper now. Amber: within 30%. Red: not yet.

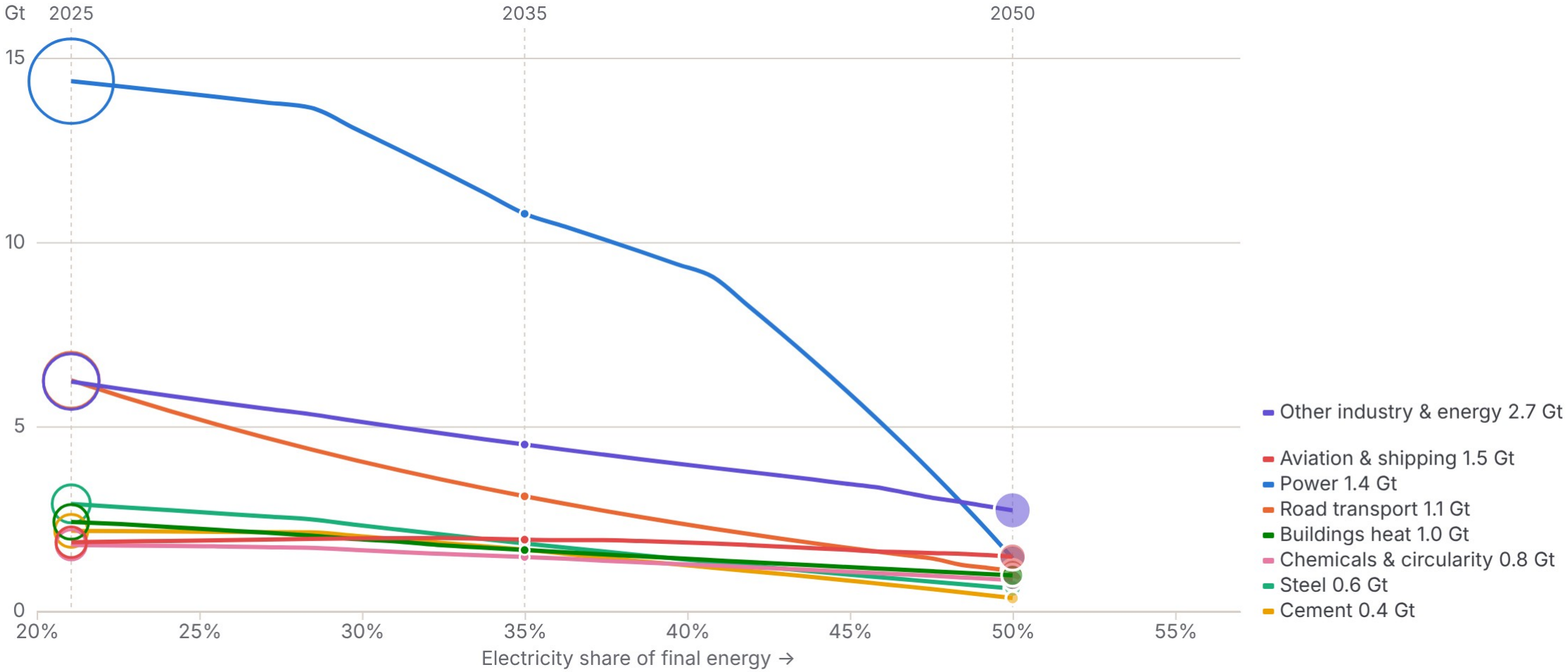


Emissions by sector as electricity's share rises. Open circle: 2025. Filled: 2050.

Global emissions by sector as electricity’s share grows

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Each line is one sector. Open circles show 2025 emissions and filled circles show 2050. Power and road transport account for 64% of the 28.5 Gt cut by 2050.



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When each sector becomes cheaper on electricity (2035)

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In 2035, electricity is cheaper than fossil fuels in 59 of 255 region and sector pairs. Road transport and recycling are already cheaper in most regions. Steel, cement and chemicals only get there as power nears $40/MWh, or earlier where CO2 has a price. Each cell shows the first year electricity is cheaper.

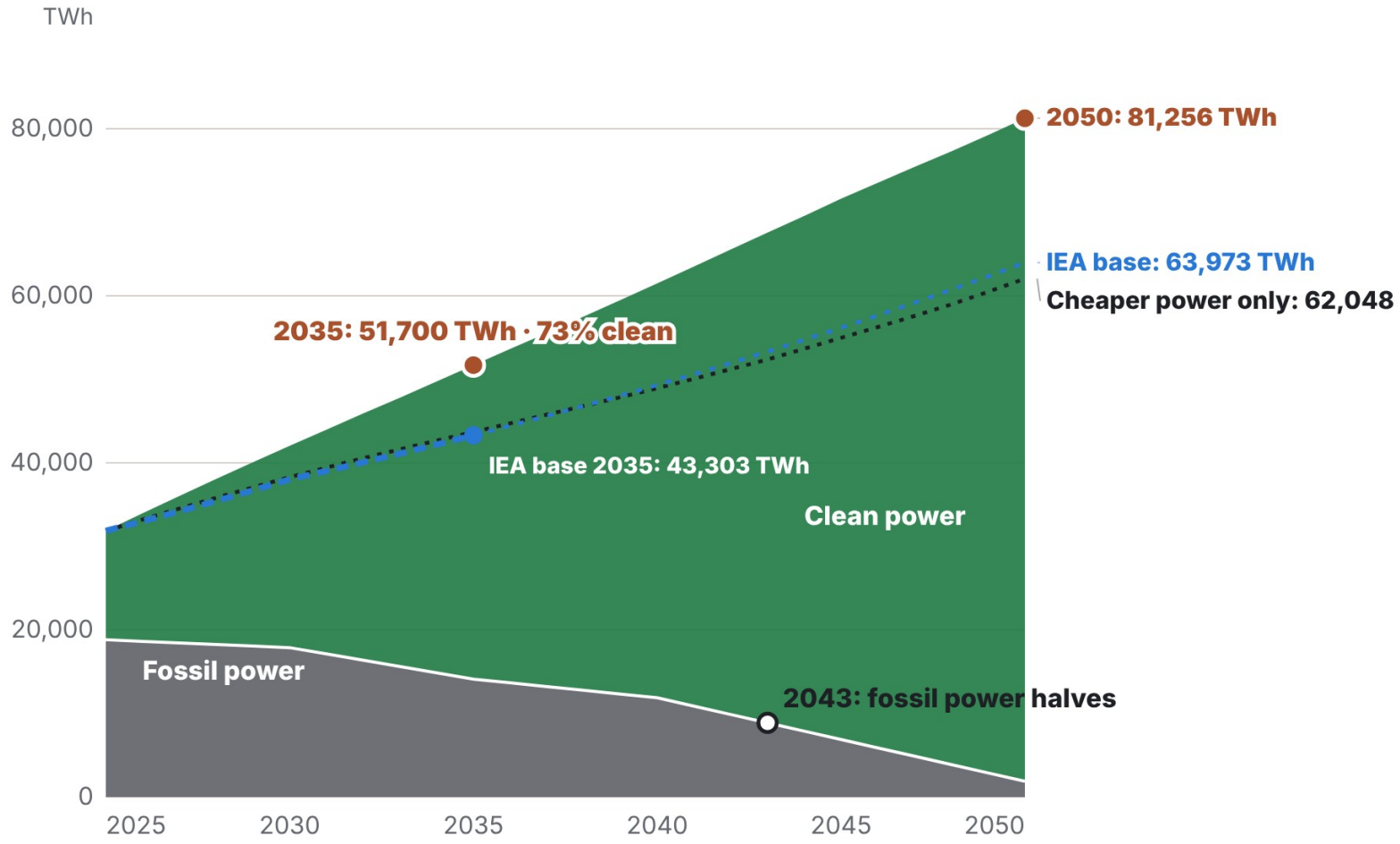
	Cars & vans	Trucks & buses	Circularity	Light industry heat	Pulp & paper	Buildings heat	Glass & ceramics	Aluminium	Crackers & chemicals	Cement	Steel	Refining	Other energy use	Shipping	Aviation
China	now	now	now	'44	'44	now	–	–	–	–	'49	–	'39	–	–
United States	now	now	now	–	–	'44	–	–	–	–	–	–	'36	–	–
European Union	now	now	now	'44	'44	'40	'49	'49	'50	'50	'44	'50	'43	–	–
India	now	now	now	'48	'48	'30	–	–	–	–	–	–	'42	–	–
Russia	now	'26	now	–	–	'44	–	–	–	–	–	–	now	–	–
Japan	now	now	now	'47	'47	'41	–	–	–	–	'50	–	'45	–	–
Iran	'50	–	now	–	–	'36	–	–	–	'50	now	–	now	'39	'45
Indonesia	'29	'32	now	'50	'50	'37	–	–	–	–	–	–	'31	–	–
Saudi Arabia	'31	'33	now	–	–	'43	–	–	–	–	–	–	now	–	–
South Korea	now	now	now	'44	'44	now	'50	'50	–	–	'50	–	'43	–	–
Canada	now	now	now	'50	'50	'45	–	–	–	–	'35	–	now	–	–
Mexico	now	now	now	–	–	'45	–	–	–	–	–	–	'43	–	–
Brazil	now	now	now	'43	'43	now	–	'50	–	–	–	–	'42	–	–
Türkiye	now	now	now	'48	'48	'40	–	–	–	–	–	–	'43	–	–
Australia	now	now	now	'49	'49	'42	–	–	–	–	–	–	'44	–	–
South Africa	now	now	now	'44	'44	'29	–	–	–	–	'50	–	'40	–	–
Rest of world	now	now	now	'49	'49	'41	–	–	–	–	'50	–	'42	–	–

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Clean power needed worldwide

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On the 35 by 35 path, electricity use reaches 51,700 TWh in 2035, 19% more than the IEA base case, and 81,256 TWh in 2050. Building the clean power and grids costs about $42.5 trillion to 2050.



World, 2025–2050

	Extra TWh +49,397 % of world	Investment $42.5 tn % of world
China	22%	25%
US	13%	13%
India	10%	10%
EU	7%	6%
Japan	2%	2%
Other 11	18%	18%
Rest of world	29%	26%

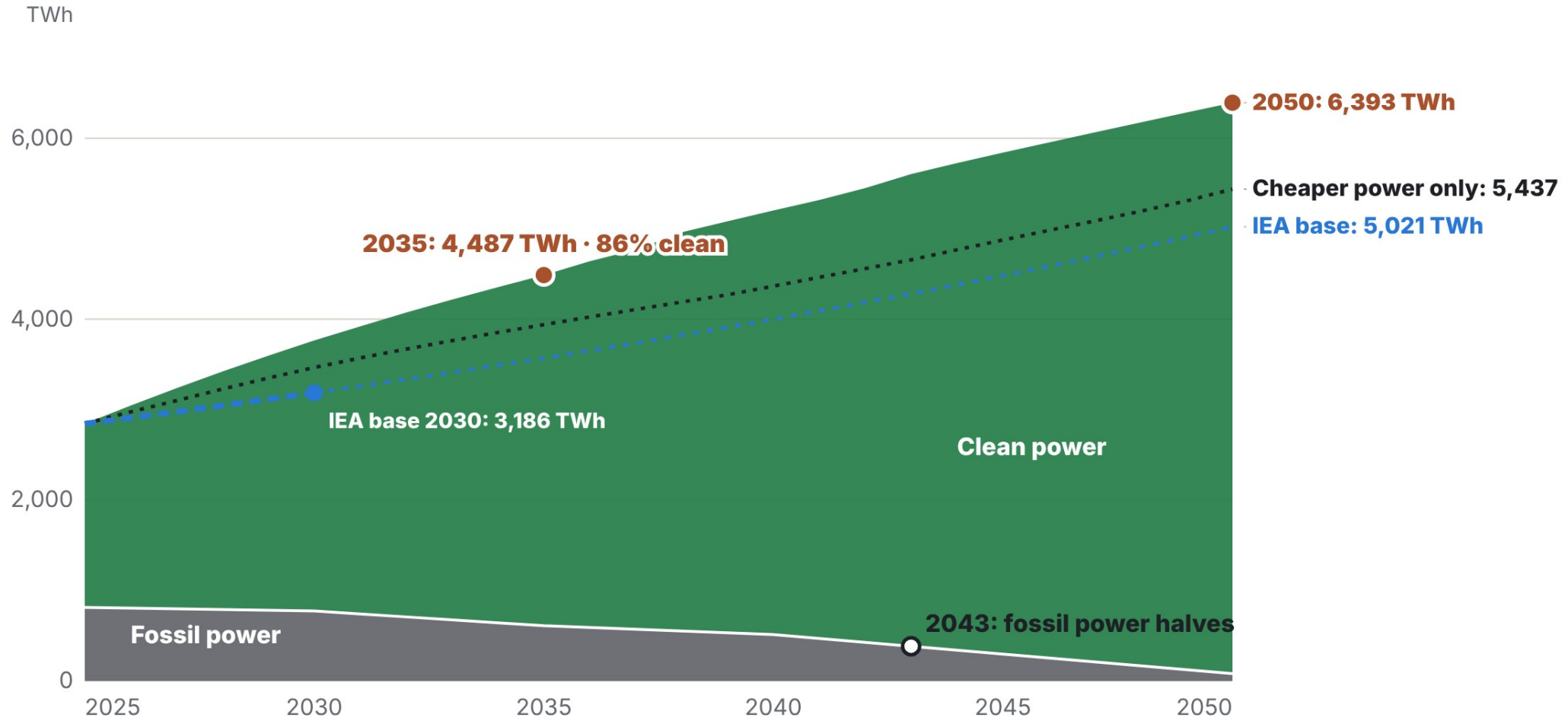
Other 11: Russia, Iran, Indonesia, Saudi Arabia, Korea, Canada, Mexico, Brazil, Türkiye, Australia, South Africa. Investment: new solar, wind, SMRs and batteries, plus grids. Includes AI demand (IEA base case). Extra TWh: electricity use in 2050 minus 2025.

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Clean power needed in the EU

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On the 35 by 35 path, EU electricity use grows from 2,844 TWh in 2025 to 4,487 TWh in 2035 and 6,393 TWh in 2050. The IEA expects 3,186 TWh in 2030 (2.3% a year), so the ladder path is 18% higher by 2030. Fossil power halves by 2043. The EU aims for climate neutrality by 2050.

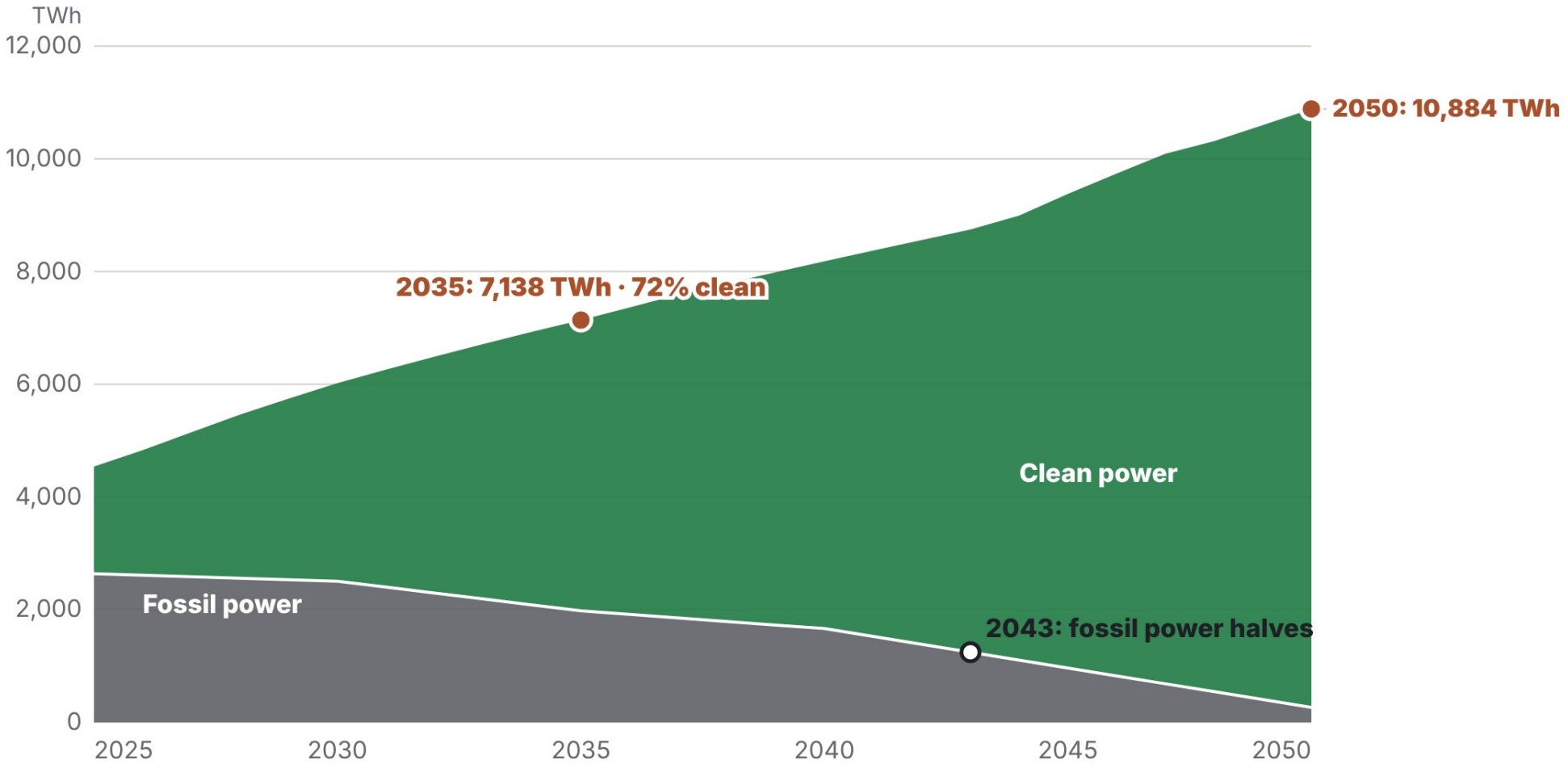


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Clean power needed in the US

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On the 35 by 35 path, US electricity use grows from 4,537 TWh in 2025 to 7,138 TWh in 2035 and 10,884 TWh in 2050, including data centres. Fossil power halves by 2043. Building the clean power and grids costs about $5,582 billion to 2050.

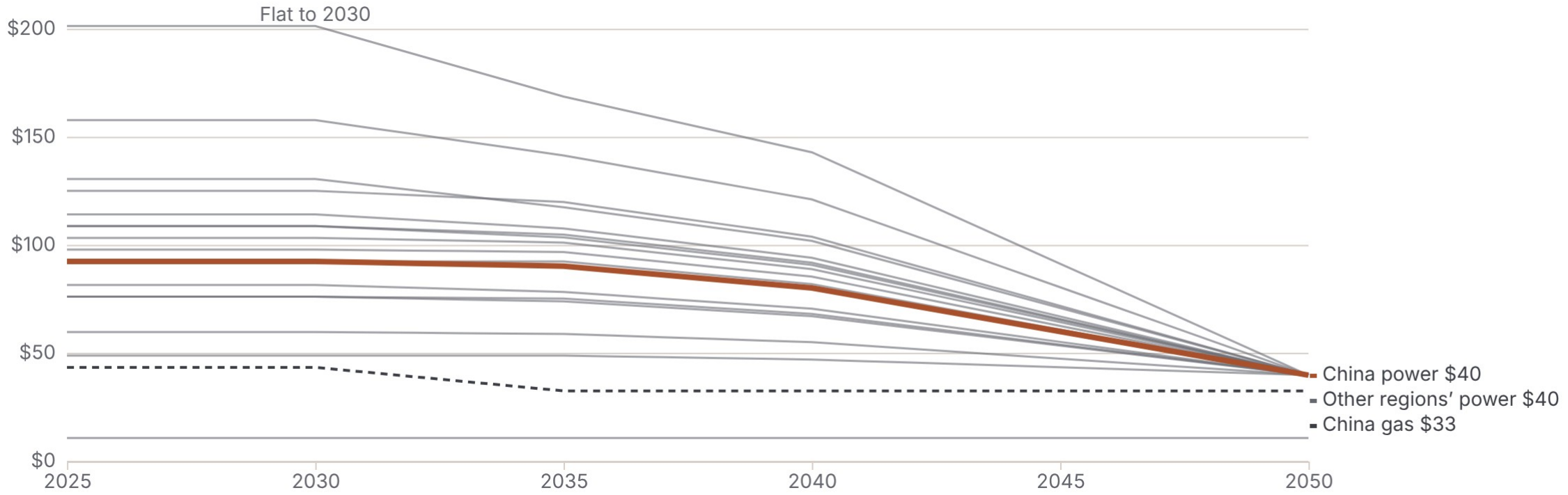


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Power, gas and CO2 prices used

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Power prices stay at 2025 levels until 2030. They then fall as gas returns to pre-crisis prices, and reach $40/MWh by 2050 in every region once SMRs at $30/MWh are added to renewables and batteries from 2040. Regions that already pay less keep their lower price. Highlighted: China.



Assumptions and sources

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Assumption	Value used	Source
Starting power prices	2025 average industrial price per region (EU $202, US $82, China $93, India $98/MWh…); all prices in US$ at $1.09 per €	MTE estimates from Eurostat, EIA, IEA and national tariffs
Power price path	Flat to 2030; falls to 2035 as gas eases; $40/MWh in all regions by 2050 (SMRs $30 + networks $10)	Rafael Cayuela scenario
Gas	2025 prices to 2030, back to 2019–21 levels by 2035	Rafael Cayuela scenario
SMRs	$30/MWh from 2040	Scenario assumption; optimistic versus today's cost estimates
Clean power	Renewables and batteries cover new demand; fossil output 75% of 2025 in 2035, 10% in 2050	In line with the COP28 pledge to triple renewables
AI and data centres	1.0× the IEA base case: 485 TWh in 2025, 950 TWh in 2030, 1,200 TWh in 2035, then growing at the 2030–2035 rate. Split about 45% US, 25% China, 12% EU, 3% Japan, rest by demand. Counts toward the electricity share.	IEA Energy and AI (2025) and update (Apr 2026)
CCS	Competitive, cost passed through; 100% of potential from 2030 (cement 90%, chemicals 60%, steel 60%)	Scenario assumption
Bio and waste routes	100% of each sector's potential by 2050	MTE estimates
Demand growth	Sector output grows with GDP and industry, faster in India and Southeast Asia, slower in China, Europe and Japan; electricity demand more than doubles by 2050	McKinsey Global Energy Perspective 2025; IEA World Energy Outlook 2025
EU carbon price	EU ETS $97/t held flat (EUA €89/t, 30 Oct 2026); ETS2 $60/t from 2028; CBAM as legislated	EU legislation in force
Other carbon prices	Today's schemes only (China, Korea, Canada, Japan GX, South Africa)	World Bank Carbon Pricing Dashboard
Emissions 2024–25	16 economies + EU block = 81% of global CO2; 2025 = 38.1 Gt (2024 +1.1%), all regions scaled to that total	Global Carbon Budget 2025; Our World in Data
Power sector and grid mix	2024 power-sector CO2, demand and fossil share by region	Ember / Energy Institute via Our World in Data
Sector split	Direct CO2 by sector per region, scaled to national totals	MTE estimates from IEA, worldsteel, GCCA and national inventories
1.5 °C and 2 °C paths	CO2 −48/−65/−80/−99% (1.5 °C) and −22/−37/−51/−73% (2 °C) vs 2019 in 2030/35/40/50	IPCC AR6 Synthesis Report
35 by 35	Electricity share of final energy from just over 20% to 35% by 2035; COP31 Presidency Action Agenda target (9 June 2026). 50% by 2050 is our extension	UNFCCC, COP31 Presidency

How the model works

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How the model works. We split 2025 CO2 for 16 economies, the EU, the rest of the world and international shipping and aviation into 15 sectors plus power. Each sector grows with GDP and industrial output. A sector switches to electricity once power is cheap enough to beat fossil fuels, at the pace its equipment is replaced: about 12 years for cars and 30 for cement kilns. In the 35% scenario, sectors switch in order, cheapest first, until the world reaches the target each year. Bio-based and waste routes and CCS grow alongside. Renewables, batteries and, from 2040, SMRs supply the new demand. The results are estimates, meant to show the size of the cuts and which sectors move first.

Sources: UNFCCC (COP31 Presidency target, 9 June 2026); Global Carbon Budget 2025; Our World in Data CO2 and energy data (Ember, Energy Institute); IPCC AR6 Synthesis Report; McKinsey Global Energy Perspective 2025; IEA World Energy Outlook 2025; World Bank Carbon Pricing Dashboard; MTE ETS Scissors model.