Climate Risks, Uncertainties & Opportunities

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Risk ≡ draw from distribution

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

Risk ≡ draw from distribution

Uncertainty ≡ unknown distribution

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

Risk ≡ draw from distribution

Uncertainty ≡ unknown distribution

Climate uncertainties ≻ risks

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

But:

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

But:

“Uncertainty” → “wait and see”

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

But:

“Uncertainty” → “wait and see”

“Risk” → “manage”, “mitigate”

Wagner, “The Risky Language of Climate Uncertainty” (*OpenMind*, 2022)

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Climate risk = Financial risk

Wagner, “Climate risk is financial risk” (*Science*, 2022)

Climate risk = Financial risk

Climate risk = Policy risk

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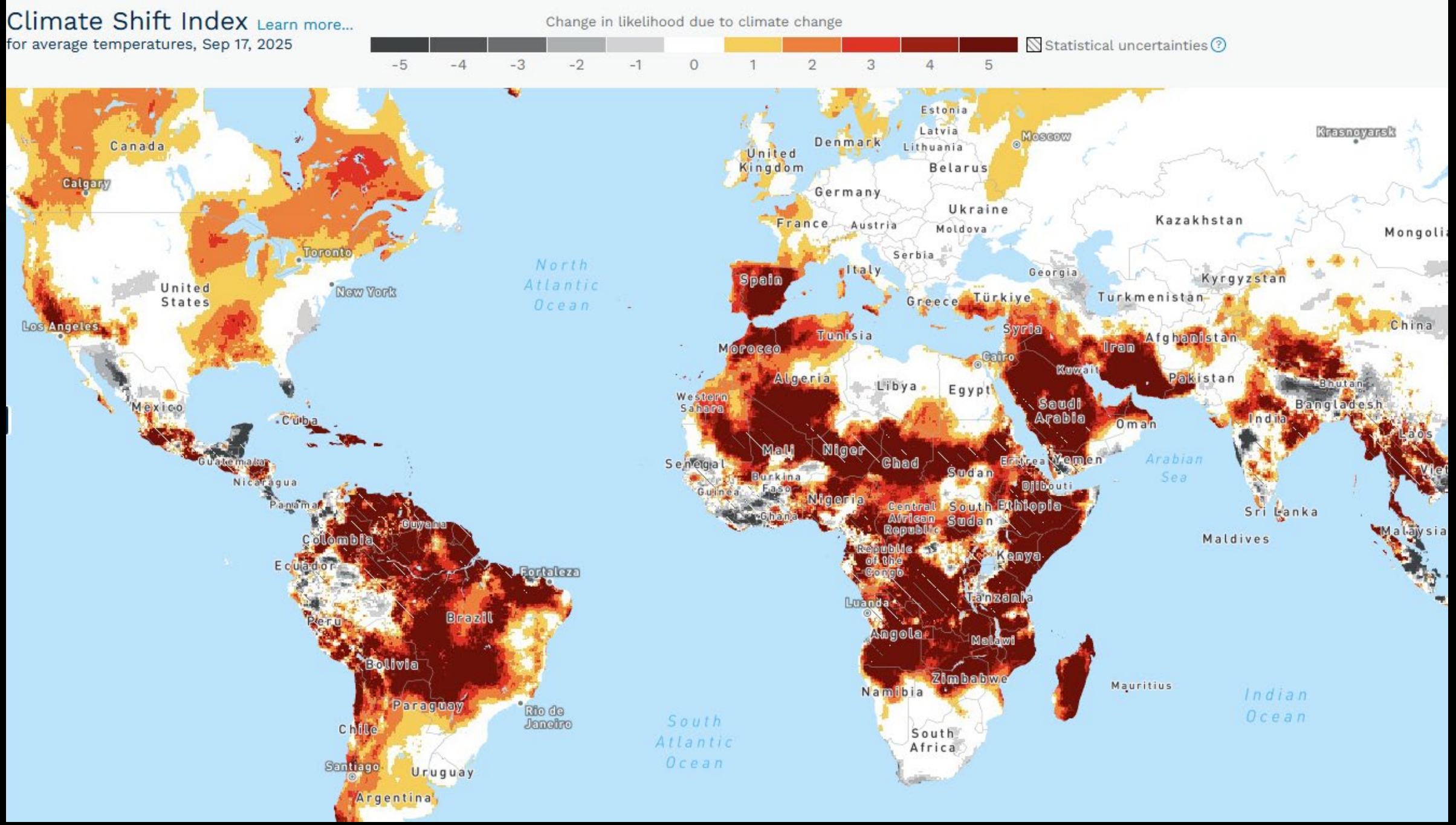
Climate risk = Reputational risk

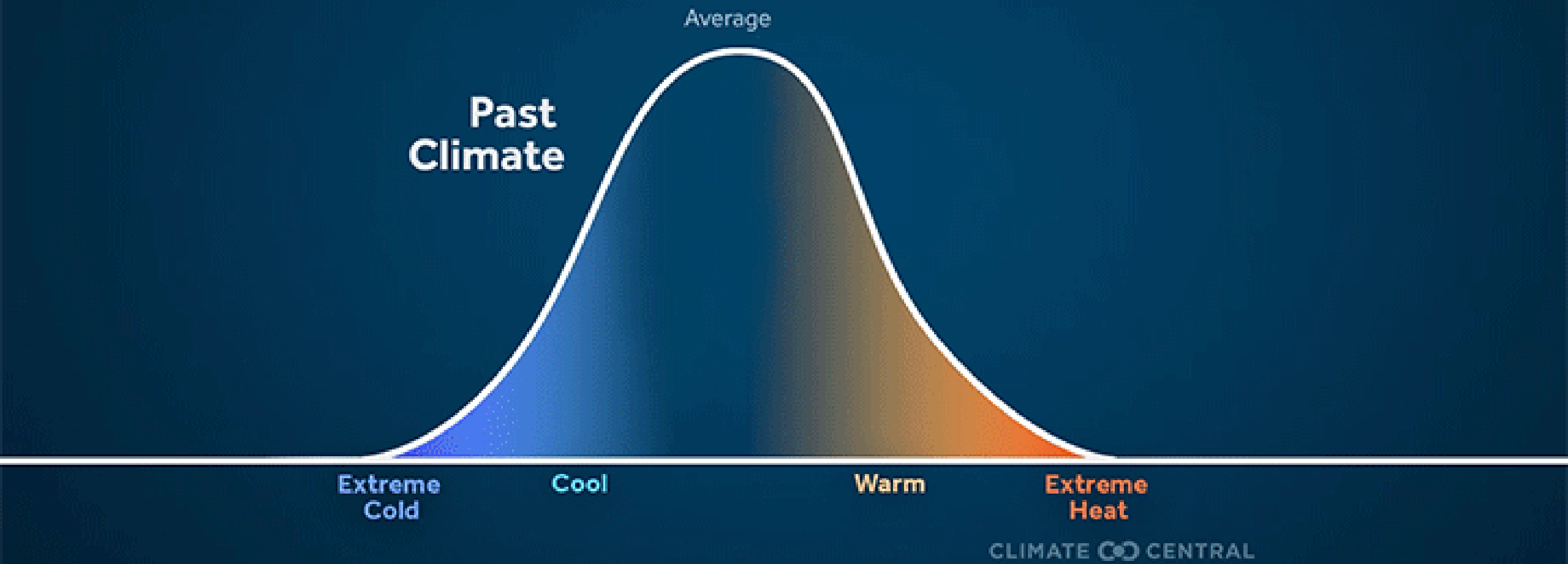
Climate risk = Legal risk

Wagner, "Climate risk is financial risk" (*Science*, 2022)

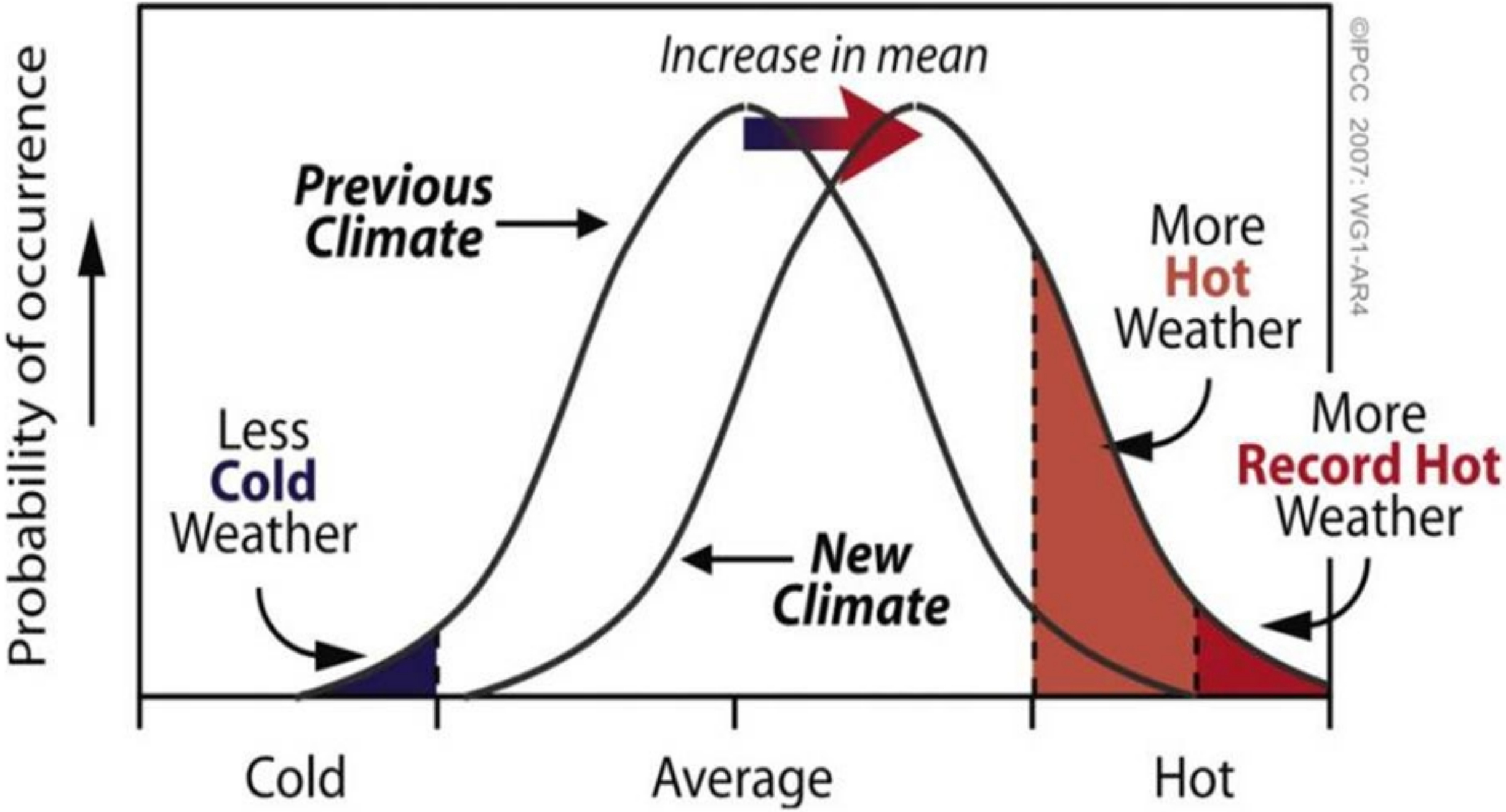


Source: climatecentral.org/climate-shift-index

SMALL CHANGE IN AVERAGE
BIG CHANGE IN EXTREMES



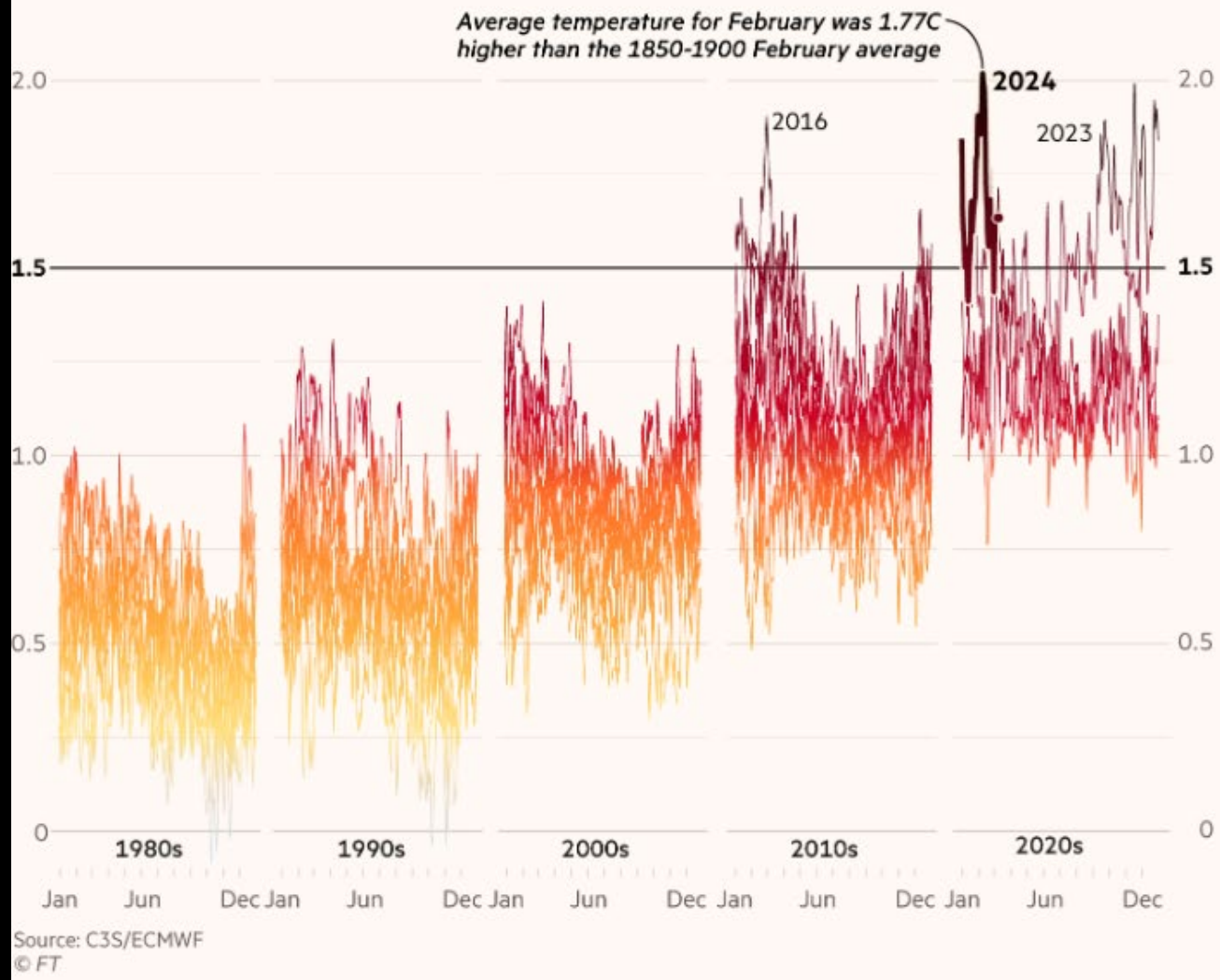
CLIMATE CENTRAL


Probability of occurrence
Increase in mean
Previous Climate
New Climate
Less Cold Weather
More Hot Weather
More Record Hot Weather
Cold
Average
Hot
©IPCC 2007: WG1-AR4

Climate graphic of the week

Global temperatures continue run of record highs in February

Difference between global 2-metre temperatures from 1980 to 2024 and pre-industrial average (C)



Source: C3S/ECMWF
© FT

Warmer, wetter, hotter, drier — February caps unending stretch of record temperatures

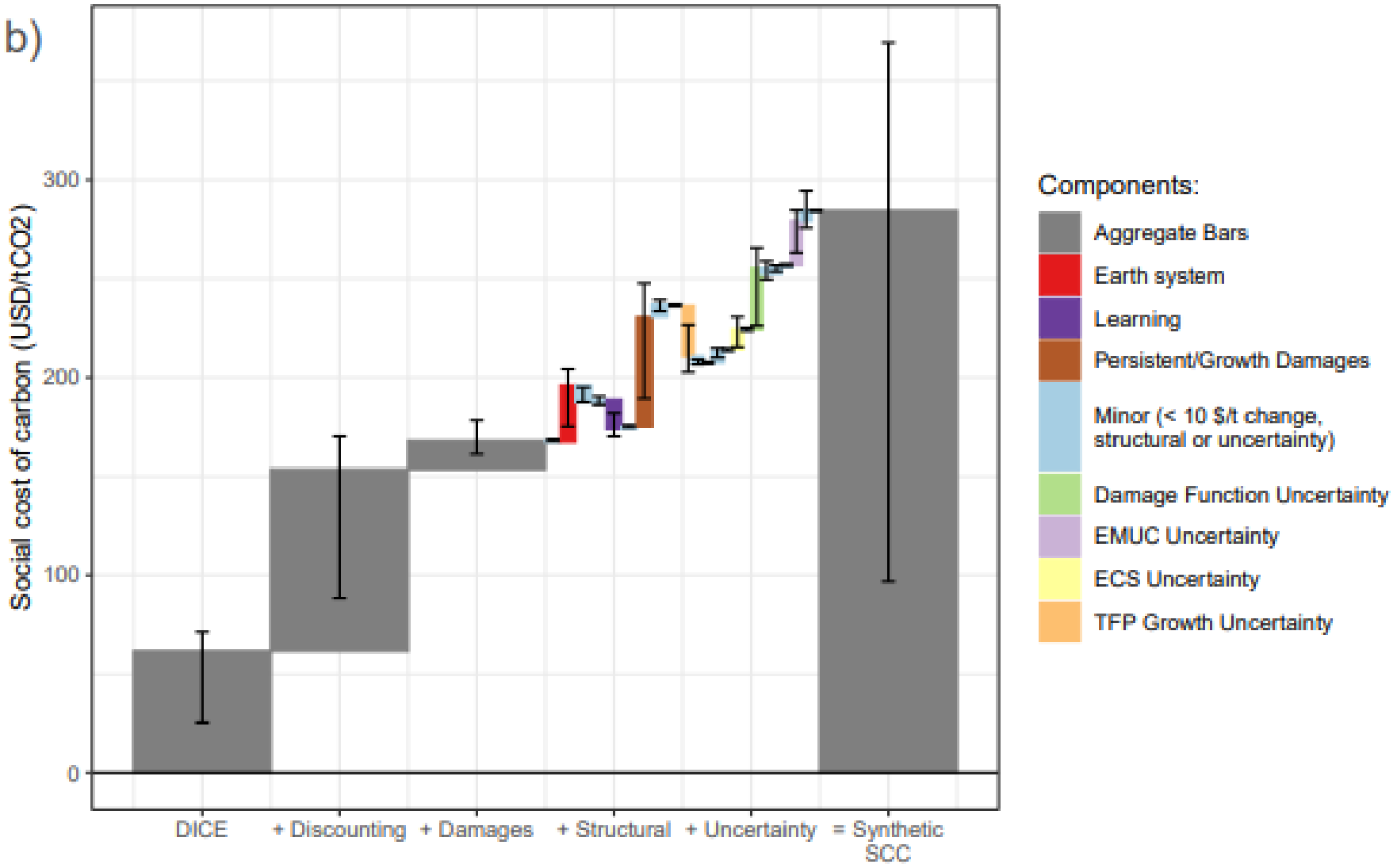
Global average temperature rise in February reaches 1.77C above pre-industrial levels

Source: *Financial Times* (10 March 2023)

$> \$200 / tCO_2$

“Synthetic” Social Cost of Carbon with median = $185 and mean = $284

For 1 tonne of CO_2 emitted in 2020, in $2020, with 5%–95% range of $32–$874(!)



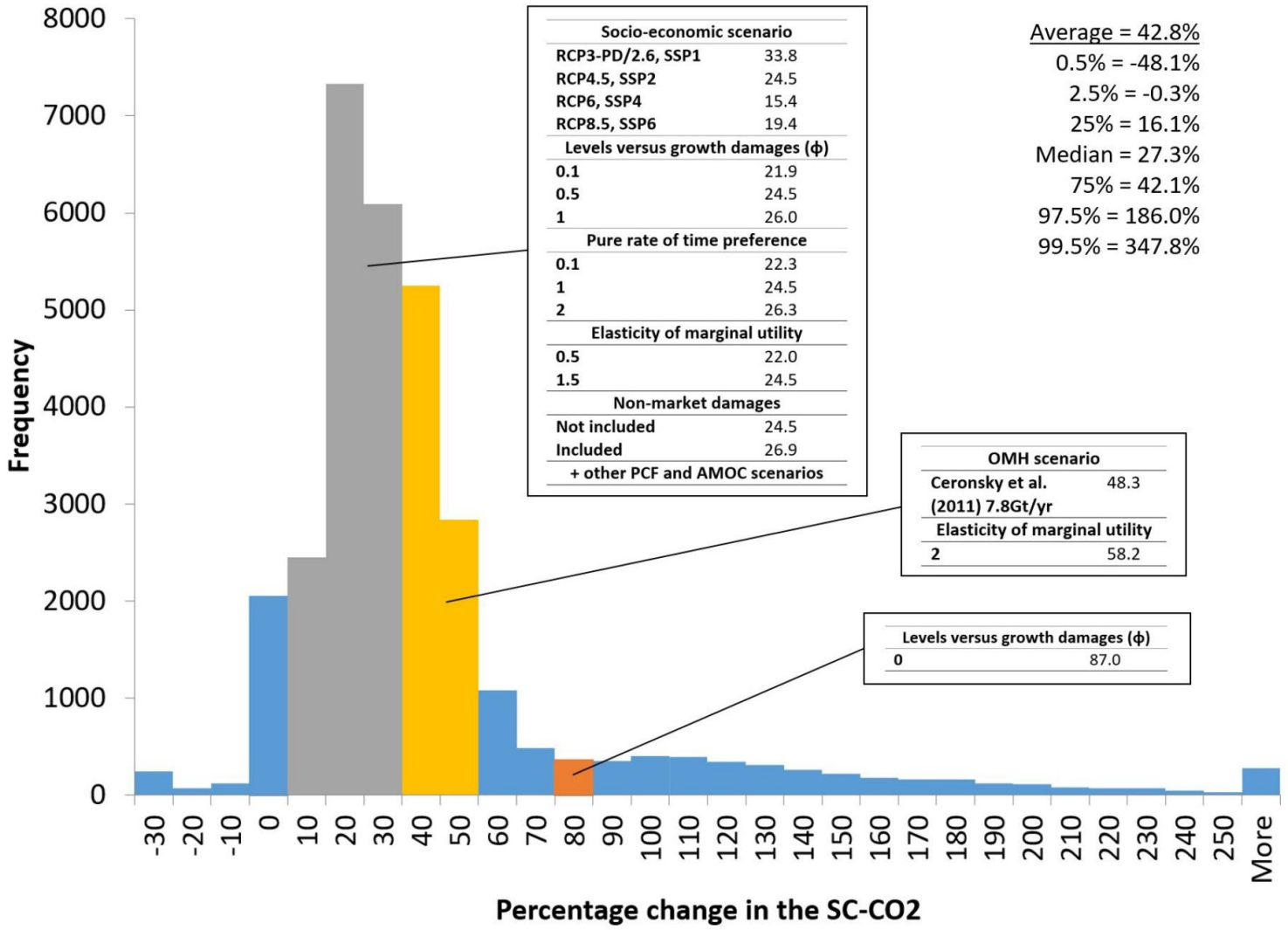
Source: Moore, Drupp, Rising, Dietz, Rudik & Wagner (*PNAS* 2024), gwagner.com/synthesis-scc

>~$200 / tCO_2 :

- Climate damage quantification
  - including tipping points
- Tail risks
- Discounting
- Risk calibration, equity, etc.

Economic impacts of tipping points in the climate system

Tipping points increase SCC by between ~27-43%, with large, right-skewed distribution



Source: Dietz, Rising, Stoerk & Wagner (*PNAS* 2021), gwagner.com/tipping-economics

~ $200 / tCO_2

=

~8-10% of

global GDP

~ $1,000 / tCO_2

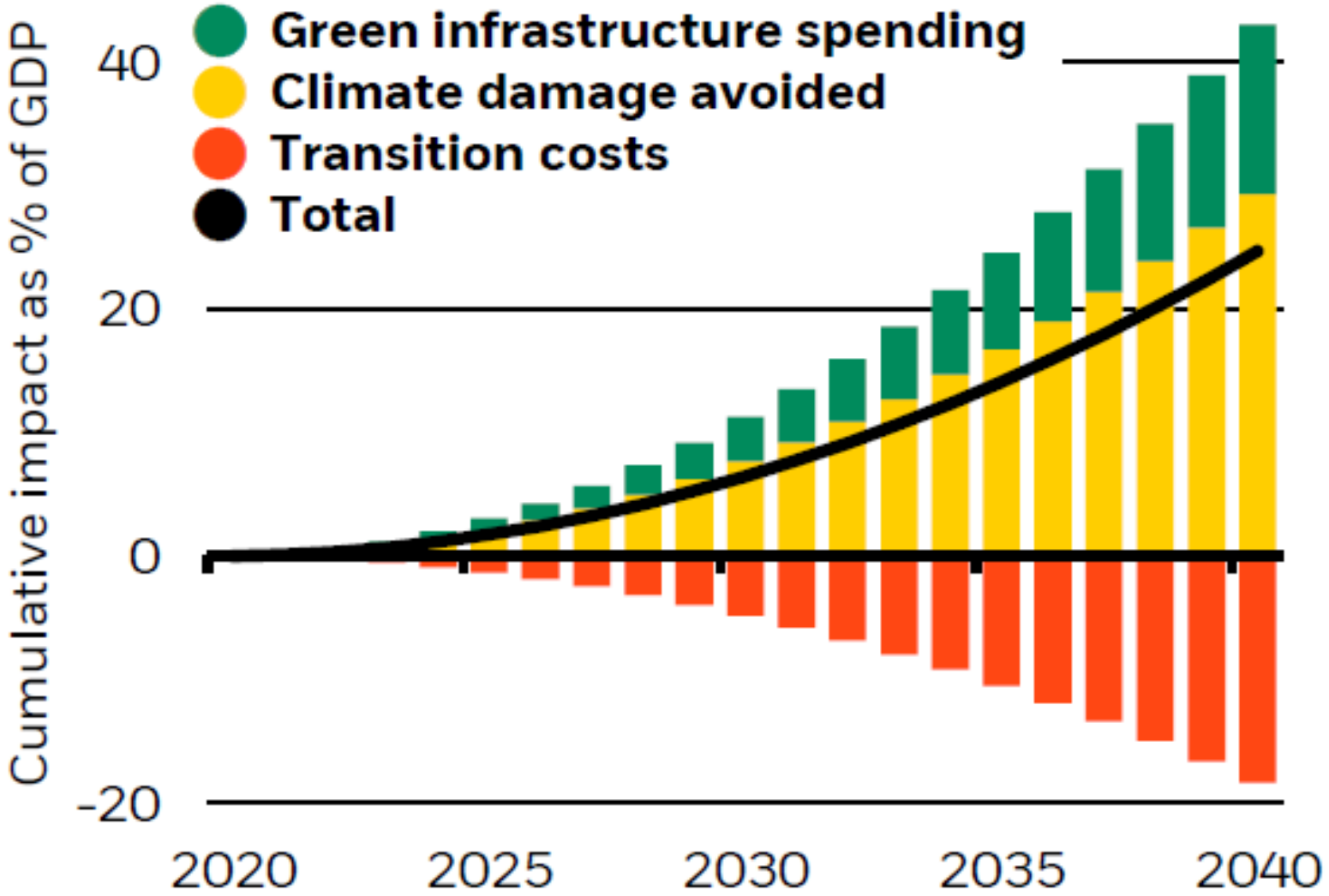
=

~50%(!!) of *global* GDP

Source: Bilal & Känzig (NBER, 13 May 2024), nber.org/papers/w32450

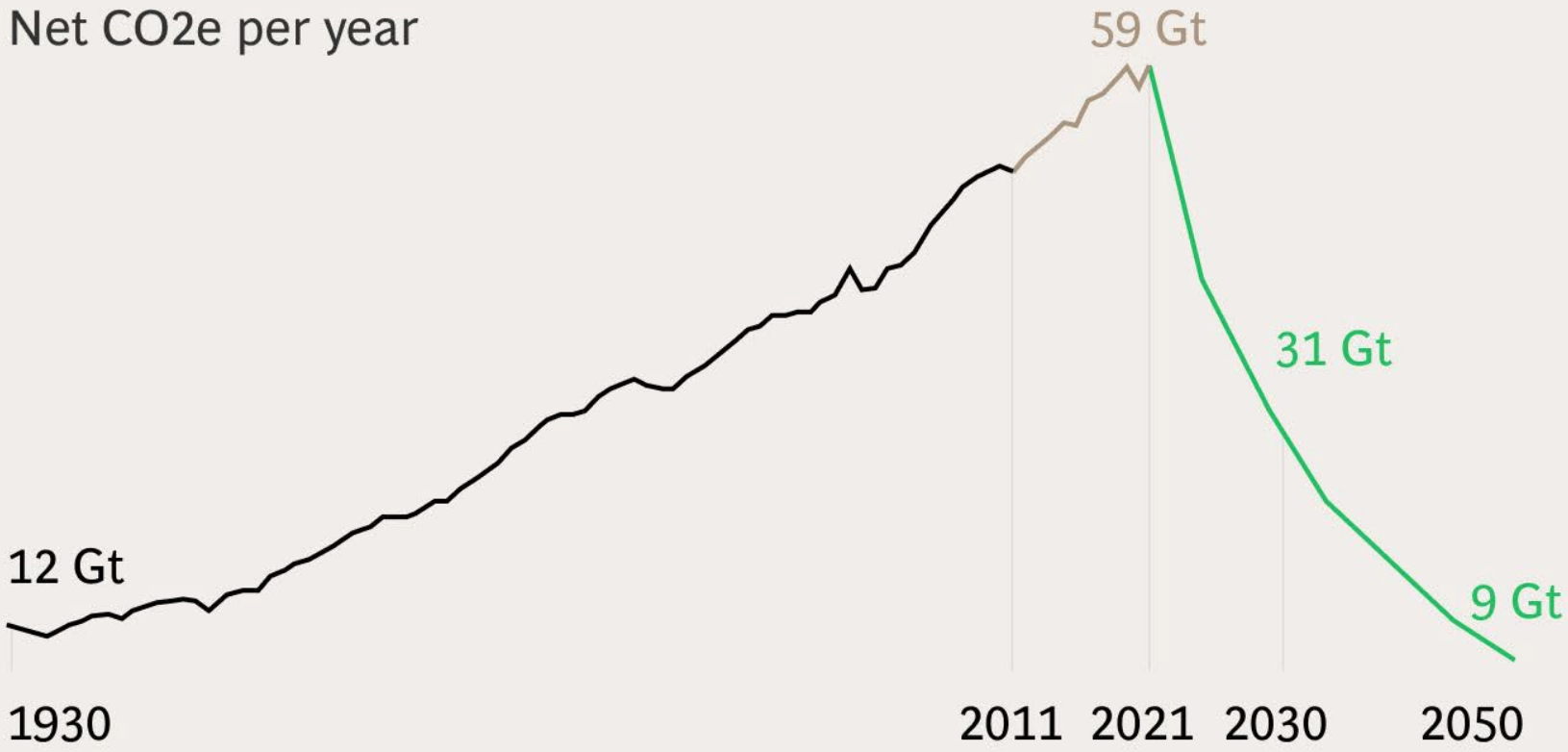
Transition results in net economic gain

Estimated cumulative GDP impact of transition, 2020-40



BlackRock

Major course correction needed to achieve the 1.5°C ambition



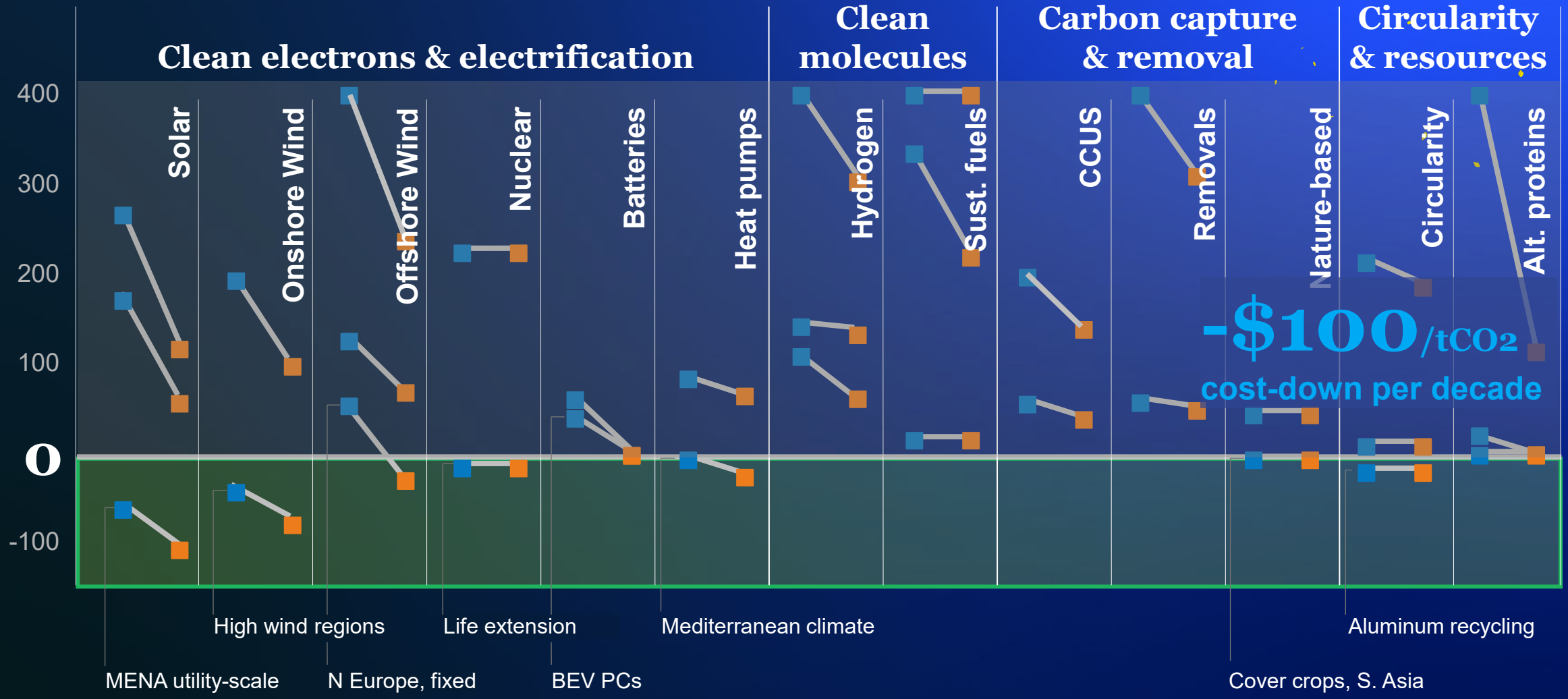
-7%
annual reduction in emissions needed by 2030 to meet the 1.5°C pathway

+1.5%
recent annual increase in emissions from 2011-2021

Sources: IPCC, PIK, BCG analysis

10 % of techs in the money today – steep cost-down to 2030

Estimated abatement costs, USD/tCO_2e

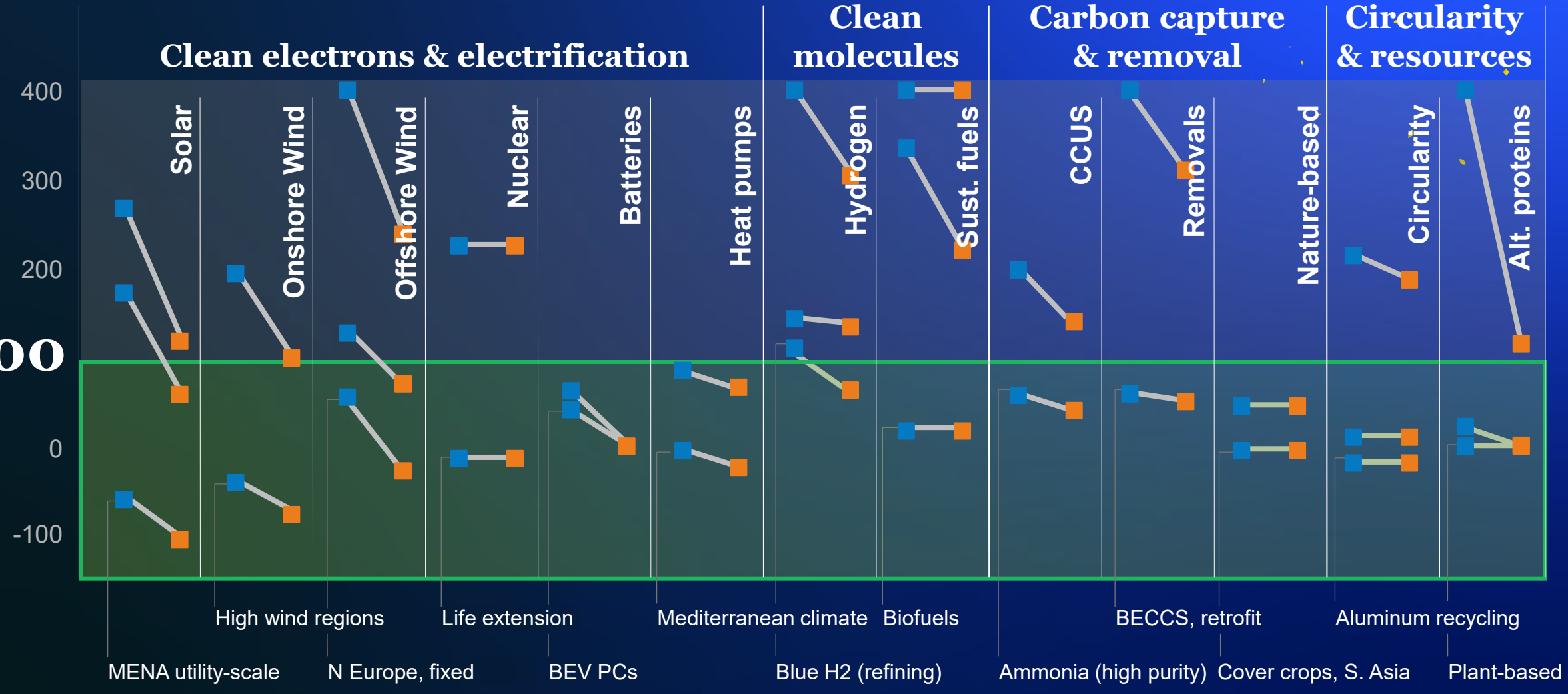


Source: McKinsey Global MACC with regional/product estimations

McKinsey & Company

100$/tCO$_2$ carbon tax would make most techs competitive

Estimated abatement costs, USD/tCO$_2$e

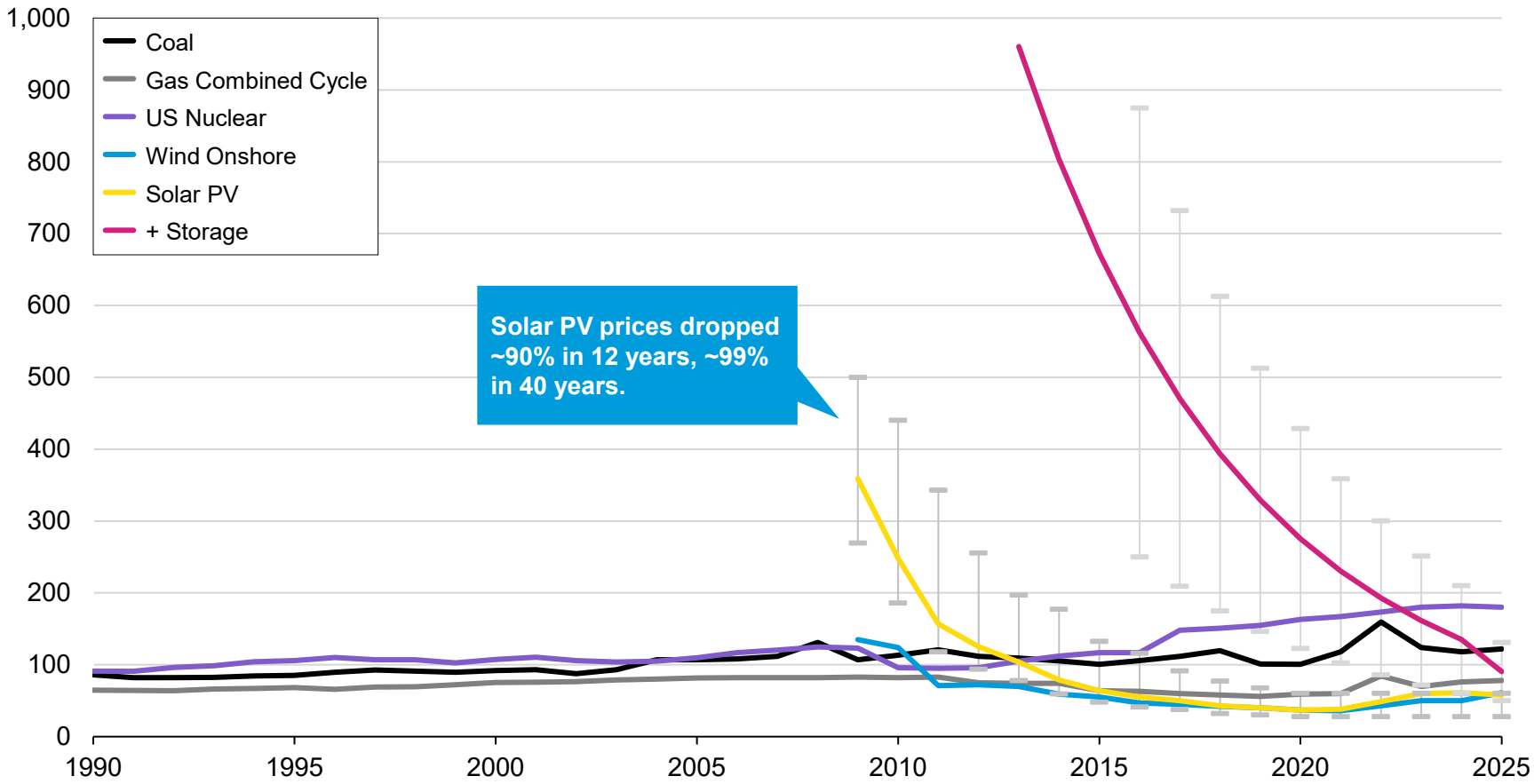


Source: McKinsey Global MACC with regional/product estimations

Wagner, “The Climate Policy Pendulum” (16 January 2025)

Utility-scale solar and wind now cheaper than fossil fuels, battery storage costs not far behind and falling fast

Levelized cost of electricity (LCOE) & storage (LCOS) ($USD/MWh)



Observations

- **Solar photovoltaic (PV) prices dropped by ~80% in the past decade,** wind by ~70%, and lithium-ion battery costs by ~90%.
  - PV price drop primarily driven by **improvements in module efficiency** and **economies of scale.**
  - **Onshore wind** remained the cheapest for the longest, **now beaten by PV**.
  - Lithium-ion **battery costs fell 20% in 2023** alone.
- **Gas combined cycle** power plants **cheaper than coal**, more expensive than both solar and wind.
  - Rapid scale-up of utility-scale batteries "killer app" to replace gas on grid.
  - **Battery prices expected to continue falling** due to cell manufacturing overcapacity, economies of scale, and switch to lower-cost lithium-iron-phosphate (LFP) batteries.

Sources: Lazard, LCOE+ (2025); Our World in Data, Our World in Data (2024); Energy Institute, Statistical Review of World Energy (2024); BNEF, Battery Price Survey (2024); Kavlak *et al.,* Evaluating the Causes of Cost Reduction in Photovoltaic Modules (2018).
Credit: Hyae Ryung Kim, Xiaodan Zhu, and Gernot Wagner. Share with attribution: Kim *et al.,* "Scaling Solar" (14 August 2025).

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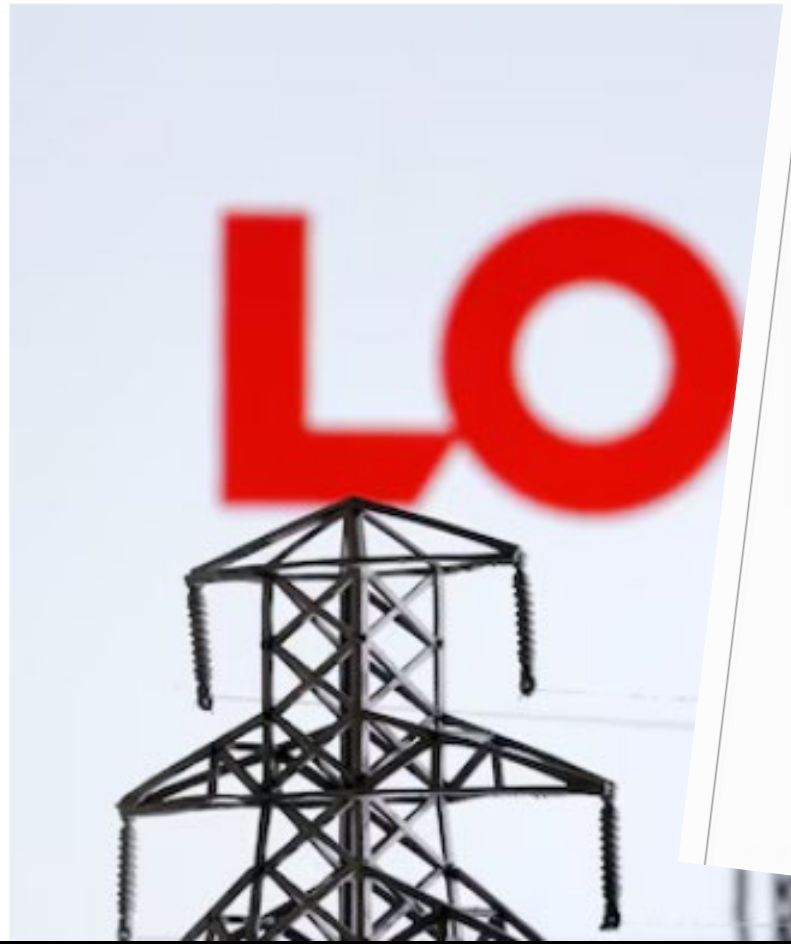
Technology

China's Longi says it will lay off about 5% of employees

By **Reuters**

March 18, 2024 10:34 PM EDT · Updated 4 months ago



Bloomberg

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Green

Longi Layoffs Speed Move in Solar Production Away From China

- Most of the job cuts will likely be in China, says Daiwa's Ip
- Chinese firms increasingly looking to move capacity offshore

Market Summary > LONGi Green Energy Technology Co Ltd

16.74 CNY

+15.66 (1,450.00%) ↑ all time

Sep 2, 3:00 PM GMT+8 • Disclaimer

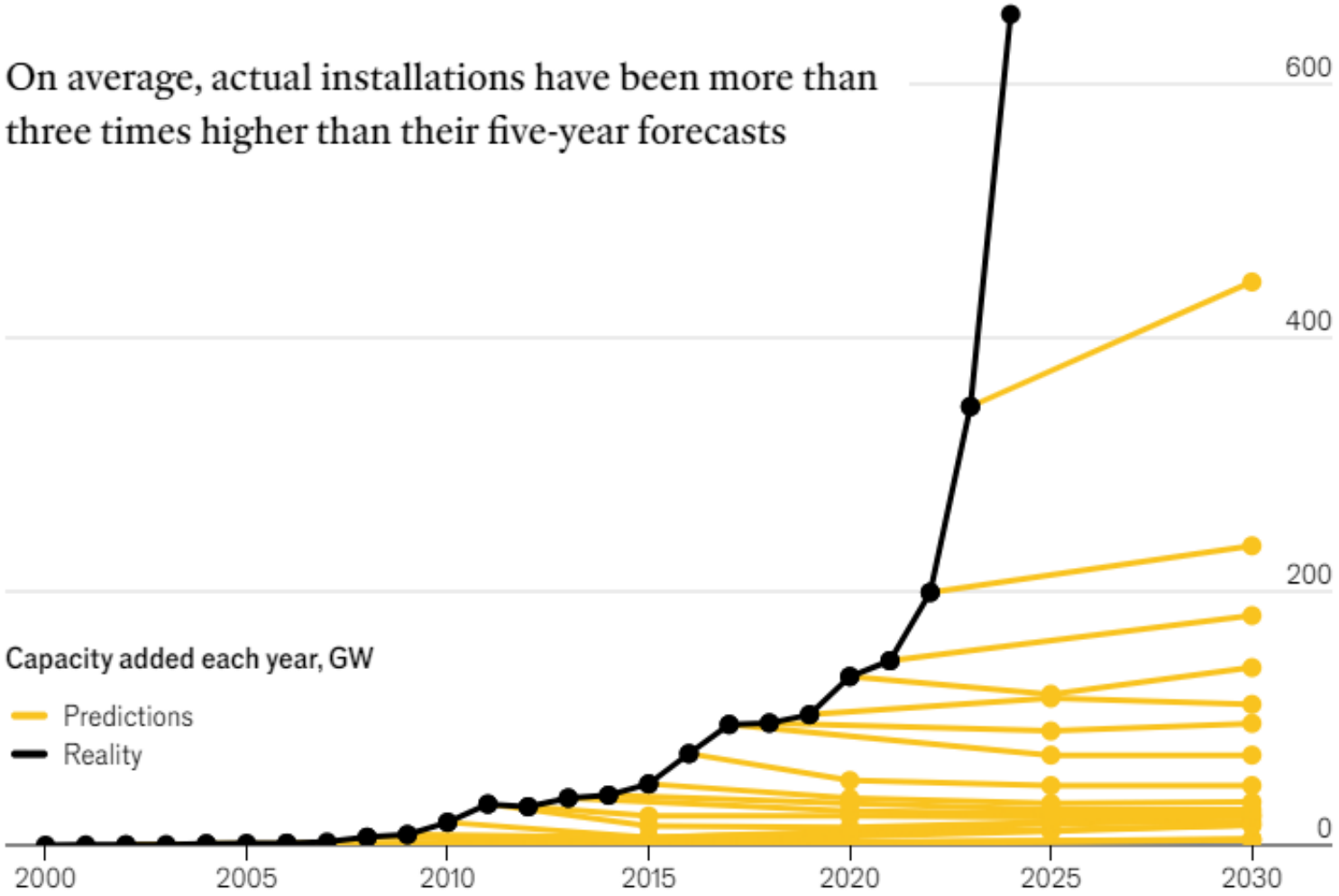
+ Follow

1D | 5D | 1M | 6M | YTD | 1Y | 5Y | Max

Open	17.08	Mkt cap	127.99B	52-wk high	21.17
High	17.47	P/E ratio	-	52-wk low	12.71
Low	16.62	Div yield	-	Qtrly Div Amt	-

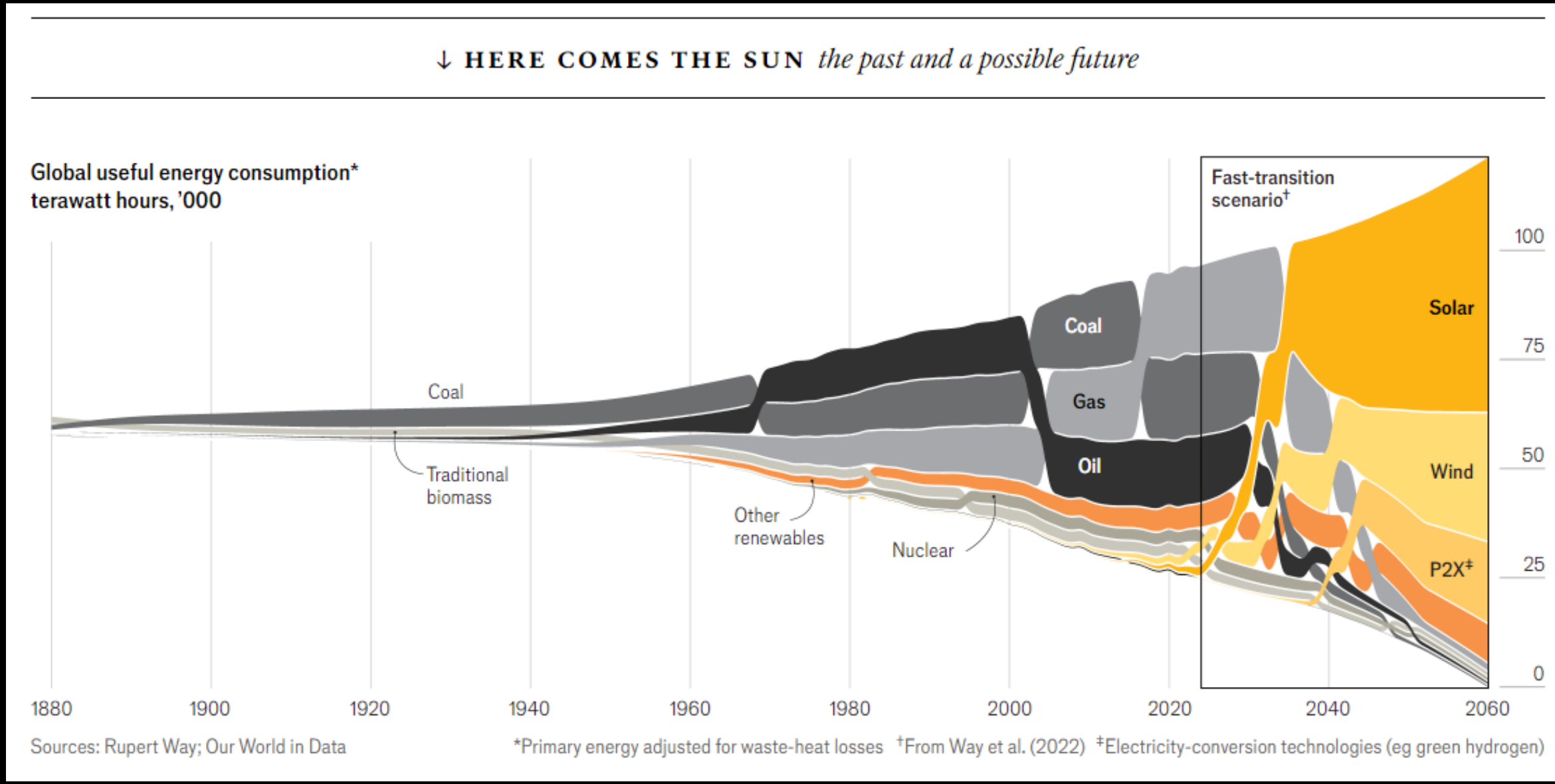
↓ **EASY PV** *how solar outgrew expectations*

On average, actual installations have been more than three times higher than their five-year forecasts



Installations for 2024 are an estimate from BloombergNEF for direct current solar capacity

Sources: IEA; Energy Institute; BloombergNEF

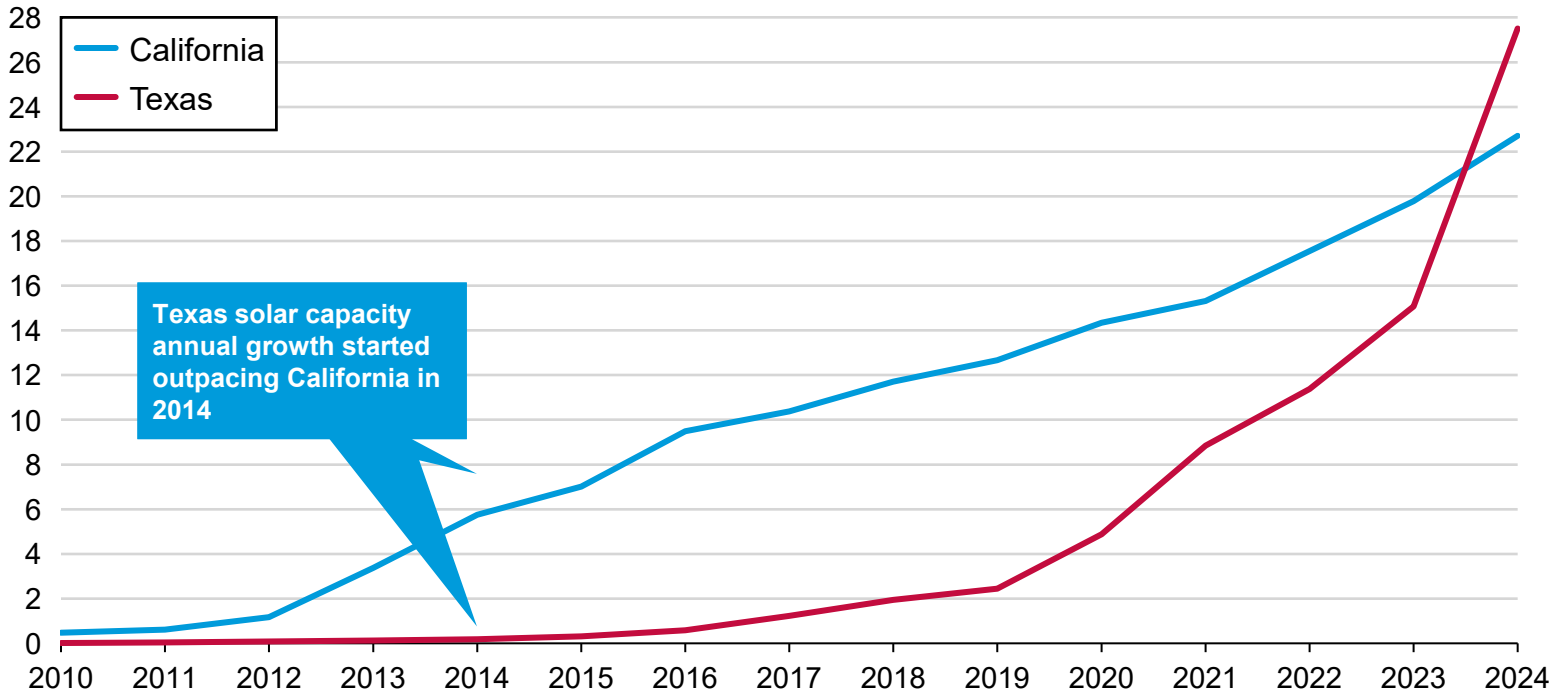


Source: *Economist* "Sun Machines" (20 June 2024)

Deregulated Texas energy market boon for solar, surpassing California in 2024

Total installed utility-scale solar capacity in Texas and California (GW)

CAGR '10-'15	CAGR '15-'20	CAGR '20-'24
CA: 71%	CA: 15%	CA: 12%
TX: 87%	TX: 73%	TX: 54%



Observations

- **Texas surpassed California** as leading solar PV state after **adding 1.6 GW in Q2 of 2024** (ACP).
- Texas installed nearly **9 GW of new solar by the end of 2024** – over one-fourth of the U.S. 2024 additions – for a **total capacity of 27.5 GW** (ACP).
- Texas is **expected to install 11.6 GW** new utility-scale solar in 2025 (EIA).
- **Texas' advantage:**
  - ⊕ Deregulated, electricity-only energy market
  - ⊕ Streamlined approval process
  - ⊕ Abundant land
  - ⊖ Minimal state-incentives
- **California's challenge**:
  - ⊕ Strong state incentives
  - ⊖ Strict regulations
  - ⊖ Interconnection delays

Source: ACP, Clean Power in 2024 (2025); EIA, Solar, Battery Storage to Lead New U.S. Generating Capacity Additions in 2025 (2025).
Credit: Hyae Ryung Kim, Taicheng Jin, Isabel Hoyos, and Gernot Wagner. Share with attribution: Kim *et al.*, "Scaling Solar" (14 August 2025).

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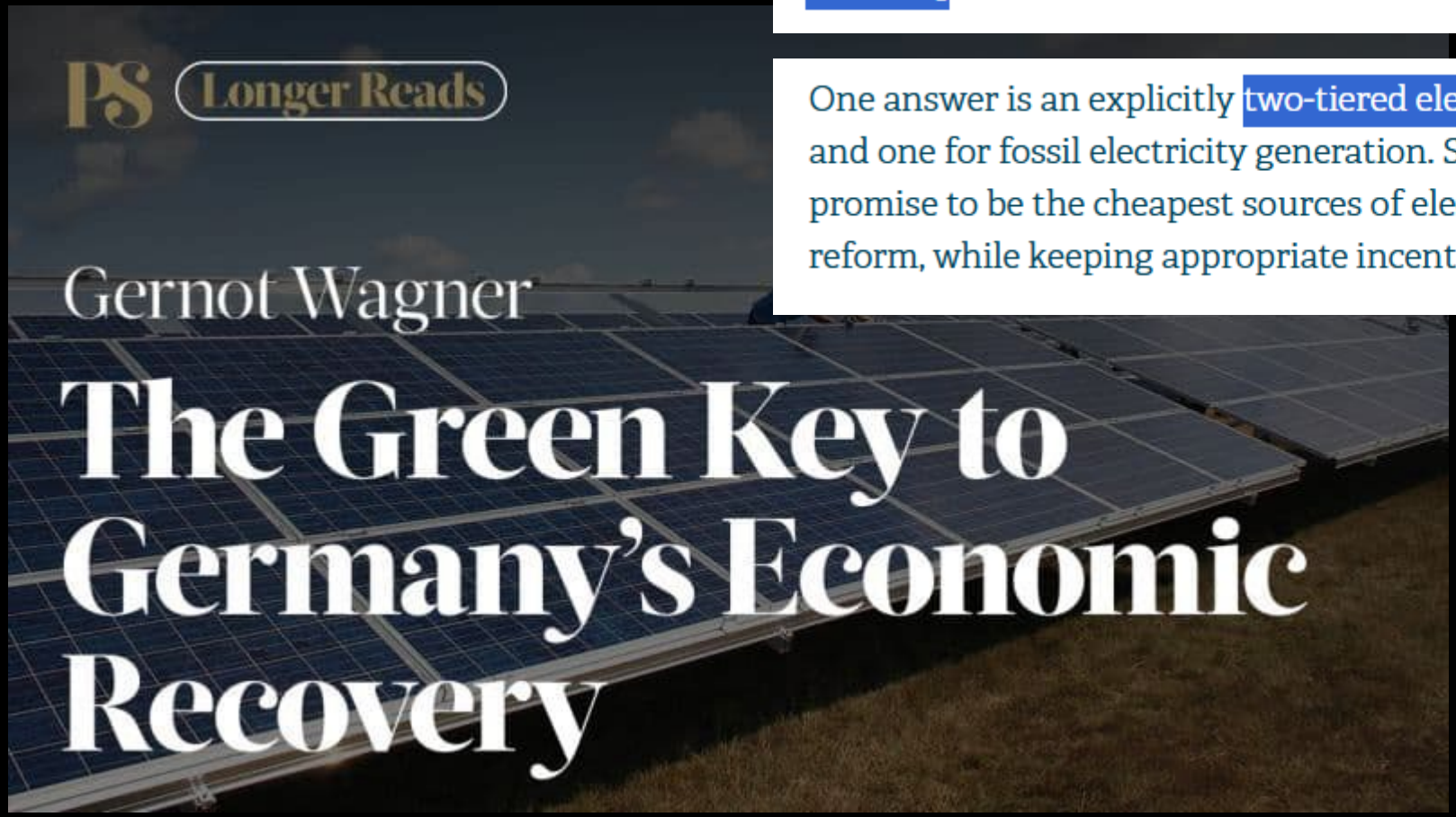
It is tempting to look to Texas, which has become the North Star of electricity-market liberalization. The state recently surpassed California in total solar-power deployment. On most days, a live view of its grid shows that wind, solar, and battery storage provide the majority of electricity – and at rock-bottom rates. After accounting for nuclear, which provides around 10% of baseload power, the state's power grid often has a smaller relative carbon footprint than those in California or Germany.



One answer is an explicitly two-tiered electricity pricing system – one for renewables, and one for fossil electricity generation. Solar, wind, and, increasingly, batteries promise to be the cheapest sources of electricity. Making this a reality requires market reform, while keeping appropriate incentives for the necessary investments.

Wagner (16 May 2025), gwagner.com/german-recovery

Not *if*, *when*

EN English

Sustainability Now

The Green Growth Mindset

Sep 29, 2023 | GERNOT WAGNER

Heated academic debates b
traditional economic grov
television, but they offer l
demands that we achiev
activity and economic s

عقلية النمو الأخضر

Sep 29, 2023 | GERNOT WAGNER

نيويورك – كل شخص يحتاج إلى شيء مغاير وبالنسبة للعديد من الذين يركزّون على المناخ والاستدامة، فإن النمو الاقتصادي – الرأسمالية – يشكل هدفاً مناسباً، وهذا أمر مفهوم. إن التوسع الاقتصادي هو جوهر الضرورة الرأسمالية، لكن النمو المادي المستمر الى ما لا نهاية على كوكب محدود الموارد هو أمر مستحيل فعليًا، ومن هنا ظهر مصطلح "تراجع النمو"، و"وإعطاء الأولوية للرعاية الاجتماعية مقارنة بالنمو"، و "ما بعد النمو"، وغير ذلك من المفاهيم التي نشأت لدعم الانتقادات المعقّدة ظاهريا للنموذج الاقتصادي "القياسي".

30 | DONNERSTAG, 5. OKTOBER 2023 KOMMENTAR DER ANDEREN DER STANDARD

Die grüne Wachstumsmentalität

Muss zur Bekämpfung der Klimakrise die Wirtschaft schrumpfen? ich können wir auf Aktivitäten hinweisen, von denen wir lieber weniger en würden. Eine schnelle Dekarbonisierung gelingt so jedoch nicht.

Gernot Wagner

und ist damit praktisch gleichbedeutend mit wirtschaftlicher Produktivität, einer der Hauptkomponenten der üblichen makroökonomischen Wachstumsmodelle.

Dieser semantische Punkt ist zweischneidig. Es gibt Entwicklungsländer im globalen Süden und bestimmte Regionen in den fortgeschrittenen Volkswirtschaften, die weiterhin stark von der Förderung und dem Export fossiler Brennstoffe abhängig sind. Diese Sektoren und Volkswirtschaften werden zwangsläufig schrumpfen, wenn der Rest der Welt den Übergang zu saubereren Energiequellen vollzieht, und es ist gut möglich, dass sie am Ende ärmer und destabilisierter sein werden. Aber das ist nicht das, was die meisten Befürworter von „Degrowth" im Sinn haben.

Produktiver Weg

Ja, es gibt Unternehmen und Menschen, die massiv von der Ausbeutung der Ressourcen unseres Planeten, der Lobbyarbeit bei politischen Entscheidungsträgern und der Verschleierung der von ihnen verursachten Schäden profitiert haben. Das motiviert in vielerlei Hinsicht die vielen Überlegungen zur Wachstumskritik. Wir alle können auf bestimmte Aktivitäten hinweisen, von denen wir lieber weniger sehen würden. Aber die Frage ist, wie es am zielstrebigsten dazu kommen wird. Ich vermute stark, dass der produktive Weg nach vorn darin besteht, sich auf die Billionen Euro schweren Geschäftsmöglichkeiten zu konzentrieren, die eine schnelle Dekarbonisierung bietet, und auf die vielen positiven Geschichten der Transformation, die damit verbunden sind.

Letztlich geht es darum, eine Balance zu finden zwischen der Entfesselung des unternehmerischen „can do"-Geistes und seiner Kanalisierung in die richtigen Bahnen; zwischen dem Silicon-Valley-Mantra „move fast and break things" und dem ärztlichen Eid „first to do no harm". Letzteres geht natürlich Hand in Hand mit der Übernahme der Kosten für die eigene Umweltverschmutzung. Diese Umweltverschmutzung sollte der eigentliche Gegner sein und nicht das Wirtschaftswachstum, das sich aus dem Versuch von Regierungen und Unternehmen ergibt, sie einzudämmen.

Übersetzung: Andreas Hubig

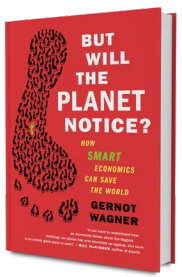
GERNOT WAGNER ist Klimaökonom an der Columbia Business School. Zuletzt erschienen: „Und wenn wir einfach die Sonne verdunkeln?" (oekom, 2023) und „Stadt Land Klima" (Brandstätter, 2021).

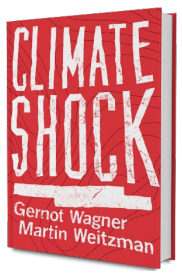
…z spielen ebenfalls eine …ge Rolle, weshalb der IRA …ein „High-Efficiency Electric … Rebate Program" vorsieht. …r isolierte Gebäude und effizi… Verkehrsmittel werden dazu …agen, die Kohlenstoffemissio… …zu reduzieren, lange bevor …gie und Strom vollständig de… …onisiert sind. Mit anderen Wor… Effizienz reduziert die heutige …lenstoffbelastung.

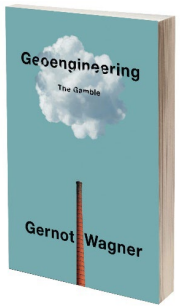
…ei Lager

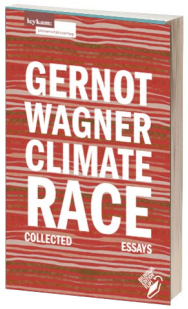
Die Gegenüberstellung von …achstum durch saubere Energie …nerseits und Effizienzmaßnah… …en andererseits scheint die Lager …grünes Wachstum" versus „De…growth" widerzuspiegeln. Das ist …aber eine Illusion. Effizienz bedeu…tet, mit weniger mehr zu erreichen,

Source: gwagner.com/green-growth-mindset









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One Big Beautiful Bill Act phases out incentives for solar & wind, biggest impacts on EV adoption and US manufacturing

Technology	IRA Incentives (2022-2025) vs OBBBA Policy Changes (2025 onward)	Industry Outlook[2] in the U.S. with OBBBA
Solar & Wind	 • 48E and 45Y credits available until 2033 • Phased out after 2027[1]; sourcing rules tightened (FEOC)	 • Continued growth trend through 2030, significant slow-down by 2035[3] • Overall higher electricity end-user prices
Green Hydrogen	 • 45V credit available until 2033 • Phased out by 2028	 • Deployment undermined by weak demand, loss of incentives, and sourcing restrictions
Electric Vehicles	 • 30D, 25E, and 45W credits for EVs; 30C for charging infrastructure • Phased out by 2026 (30D/25E/45W by Oct 2025, 30C by Jul 2026)	 • Consumer adoption hit by loss of credits and policy uncertainty
Manufacturing	 • 45X and 28C credits support clean tech supply chain • 45X phased out after 2027 (wind) and 2028 (solar/storage); 48C compromised by sourcing rules	 • Clean energy manufacturing hit by loss of credits and supply chain constraints • Subsidy loss threatens existing investments
Carbon Capture	 • 45Q credit available until 2033 • Preserved; EOR provisions enhanced	 • Growth in oil and gas CCS, challenged by foreign entity restrictions
Energy Storage	 • 48E credit available until 2033 • Preserved in full	 • Preserved credits support growth, challenged by foreign entity restrictions
Biofuels	 • 45Z credit available until 2027 • Extended to 2029; feedstock sourcing rules tightened; capped SAF	 • Slow adoption, challenged by foreign entity restrictions
Geothermal	 • 48E and 45Y credits available until 2033 • Preserved in full	 • Moderate growth from low baseline • R&D support for superhot geothermal
Nuclear	 • ITC/PTC for new, 45U for existing plants available until 2033 • Preserved in full; fuel sourcing rules apply after 2028	 • Challenges remain for large ~1GW reactors • More optimistic outlook for SMRs, XMRs
Oil, Gas	 • No support • Gains tax breaks, public land access, and regulatory rollbacks	 • Stable or rising share, as renewables face disadvantage

(1) Construction by 4 July 2026 = 4 years to completion, after = in service before 2028. (2) EV, Carbon Capture, Energy Storage, Biofuels, Hydrogen and Oil, Gas & Coal's Outlook use EIA's reference case and alternative transportation case. (3) Outlook expectations for solar and wind based on EIA's 2025 AEO, using "Reference" Case and "High Zero-Carbon Technology Cost" Case. Sources: Congress, One Big Beautiful Bill Act (2025); DOE, Inflation Reduction Act (2022); Norton Rose Fulbright, Effects of "One Big Beautiful Bill" On Projects (2025); CKI Analysis (2025). Credit: Mariana Castaño, Ariela Farchi, Nicolas Herrera Isaza, Isabel Hoyos, Hyae Ryung Kim, and Gernot Wagner. Share with attribution: Castaño *et al,* "Climate Impact of One Big Beautiful Bill Act" (15 July 2025).

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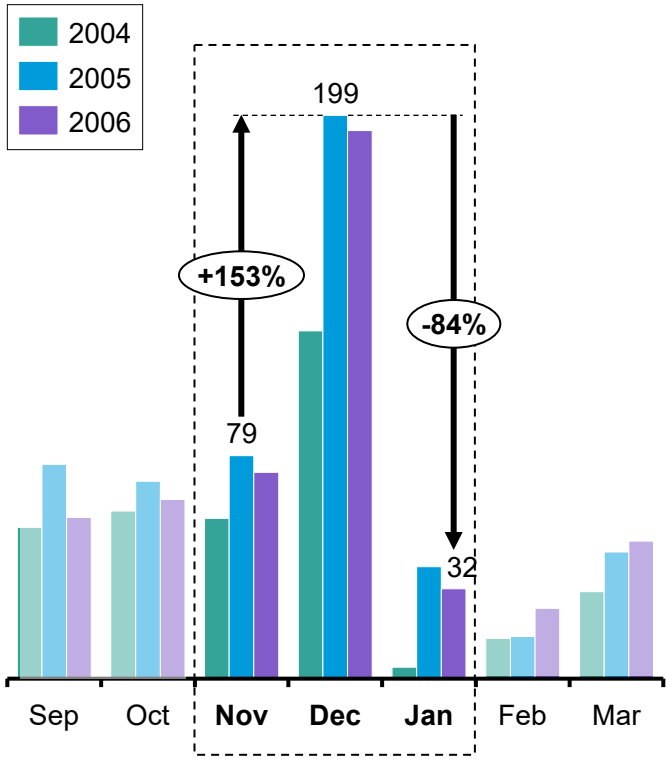
Spikes in 2025 Chinese solar deployment mirror effects of gradual feed-in tariff (FIT) phase-out in Germany from 2004 to 2006

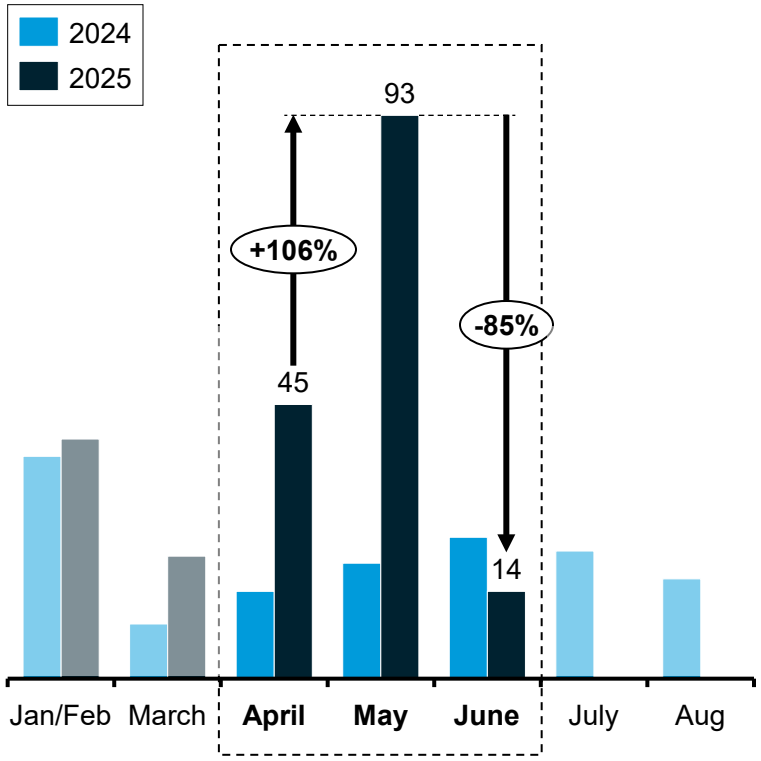
German FIT phase-out led to capacity spikes in December, before rate decreases

Germany's monthly solar capacity additions, *MW*



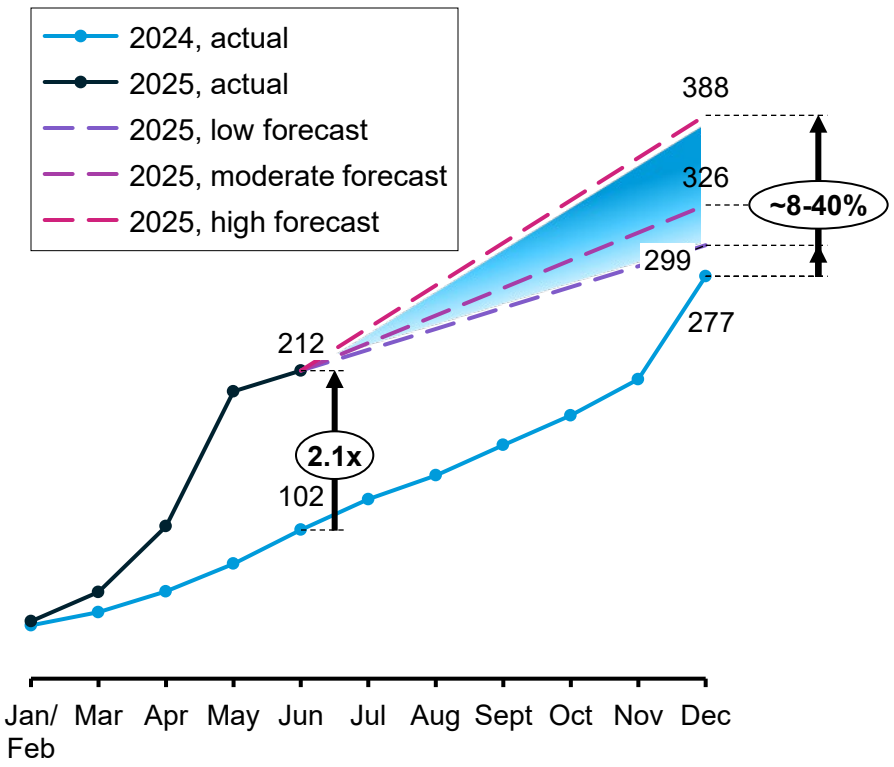
Recent Chinese FIT phase-out saw spike in May before decrease, then large drop in June

China's monthly solar capacity additions, *MW*



Chinese deployment proceeds apace, ~2x same period last year, on track to surpass 2024 deployment ~8-40%

China's cumulative solar capacity additions, *MW*



Sources: CKI Analysis, IRENA, (2025); Open Power System Data, (2020); PV Tech (2025)
Credit: Brenda Rain, Nicolas Herrera Isaza, Isabel Hoyos, Hyae Ryung Kim, and Gernot Wagner. Share with attribution: Kim *et al.*, "Scaling Solar" (14 August 2025).

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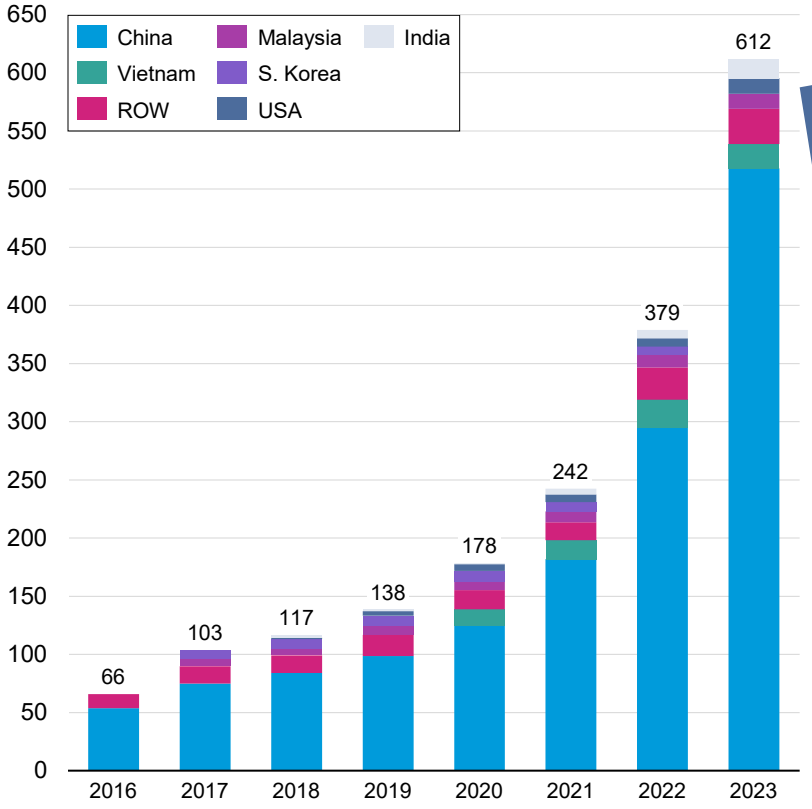
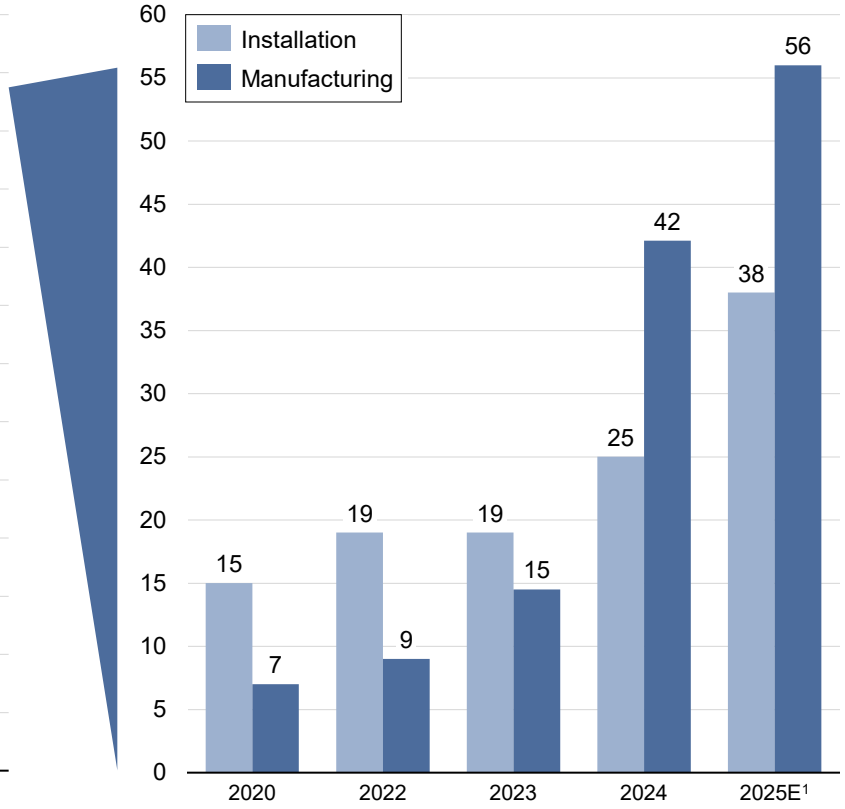
Bolstered by the IRA, the United States' solar PV manufacturing capacity grew ~50% annually since 2020

Global solar PV panel production (GW)



US PV manufacturing & installation capacity (GW)



Observations

- **China still dominates the global market:**
  - As of 2025, China's manufacturing capacity exceeds 1,200 GW/year which accounts **for 80-90% of the global supply** across key stages (polysilicon, wafers, cells, modules).
  - China has aggressively increased **solar module production** along with producing in countries in APAC region such as Vietnam, Malaysia, and S. Korea.
  - China benefits from **economies of scale, vertically integrated supply chains and low productions costs.**
- **US manufacturing capacity is growing rapidly:**
  - US module manufacturing capacity grew from ~7 GW in 2020 to over 56 GW as of May 2025.
  - The **IRA was a game changer** unlocking billions in public and private investment.
- **China's market faces headwinds** as overcapacity and price crashes in 2024/2025 are pressuring Chinese manufacturers.
- While the **US cannot match China's scale**, the country strategically built high-quality, incentivized and politically supported capacity from 2022 to 2025, starting to **position itself as a strategic alternative supplier in the West to mitigate geopolitical and supply chain risks.**

(1) US solar PV manufacturing & installation capacity as of May 2025 (SEIA, 2025)
Source: SEIA, Solar Industry Research Data (2025); IEA PVPS, Trends in Photovoltaic Applications 2024 (2024); IRENA, Stats Tool (2025).
Credit: Yosafat Partogi, Heonjae Lee, Isabel Hoyos, Hyae Ryung Kim, and Gernot Wagner. Share with attribution: Kim *et al.*, "Scaling Solar" (14 August 2025).