Welchen Preis hat CO_2? Schadenskosten versus Vermeidungskosten

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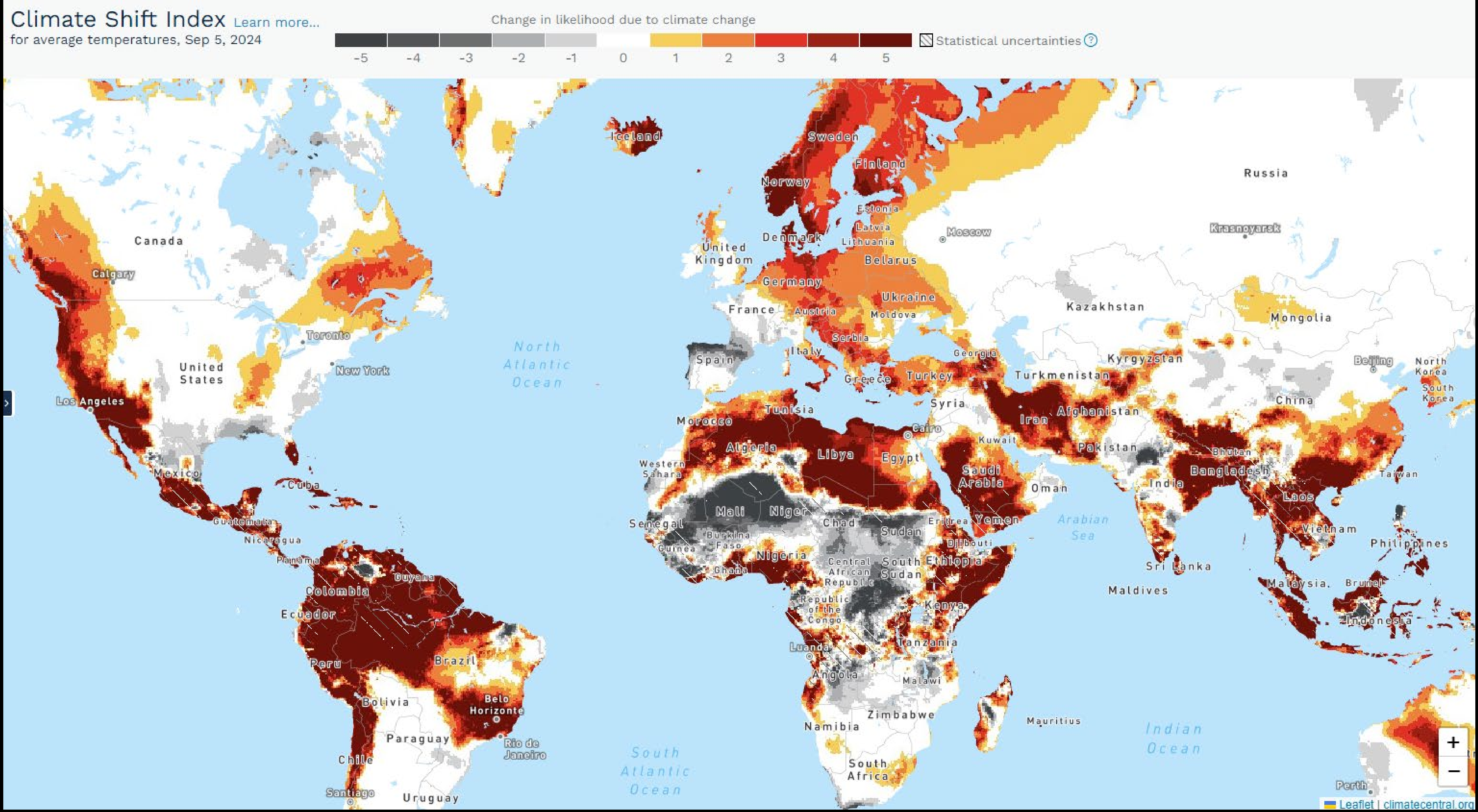
1 Climate risk ≻ known knowns

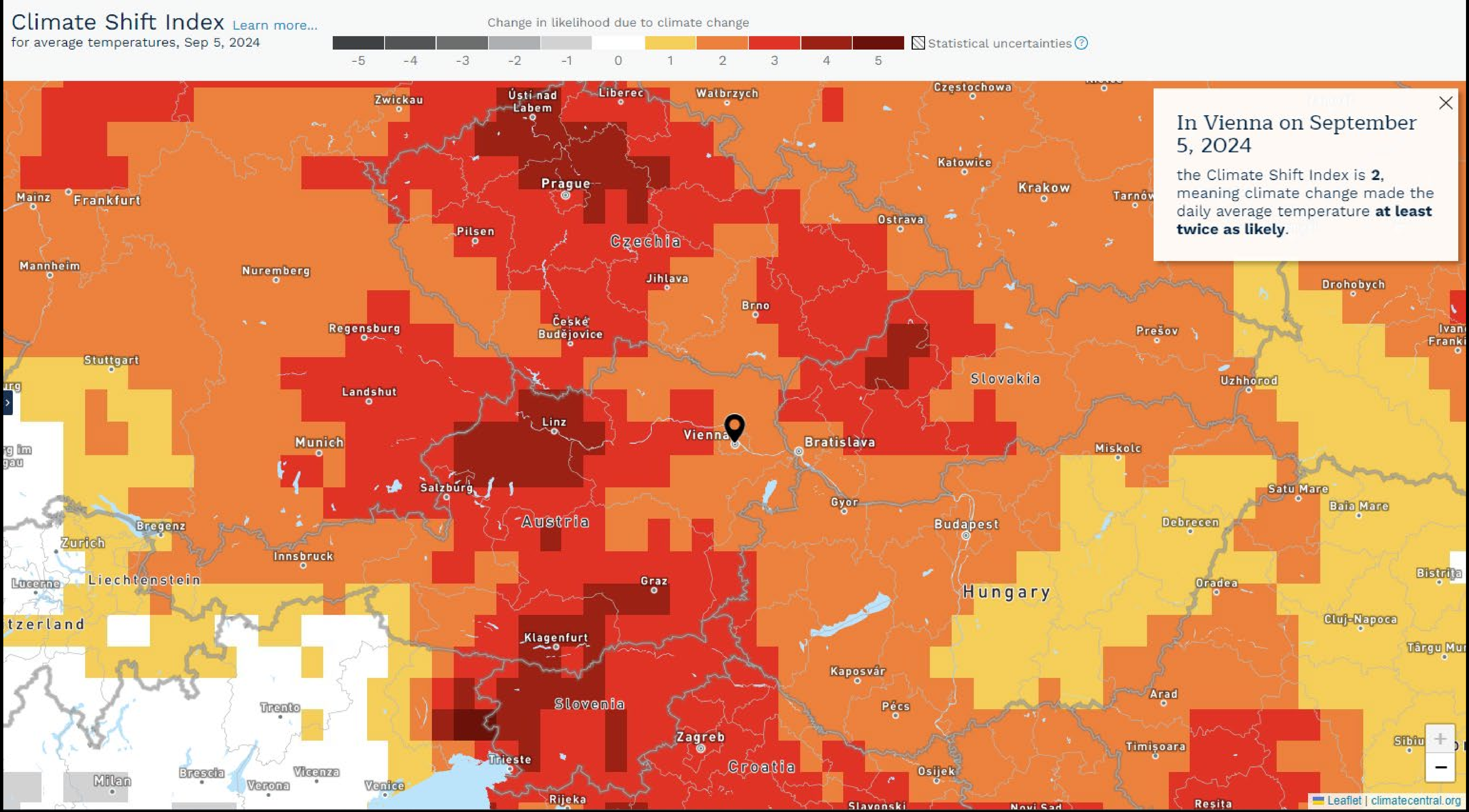
2 Climate policy = opportunity

3 Pricing carbon “+”

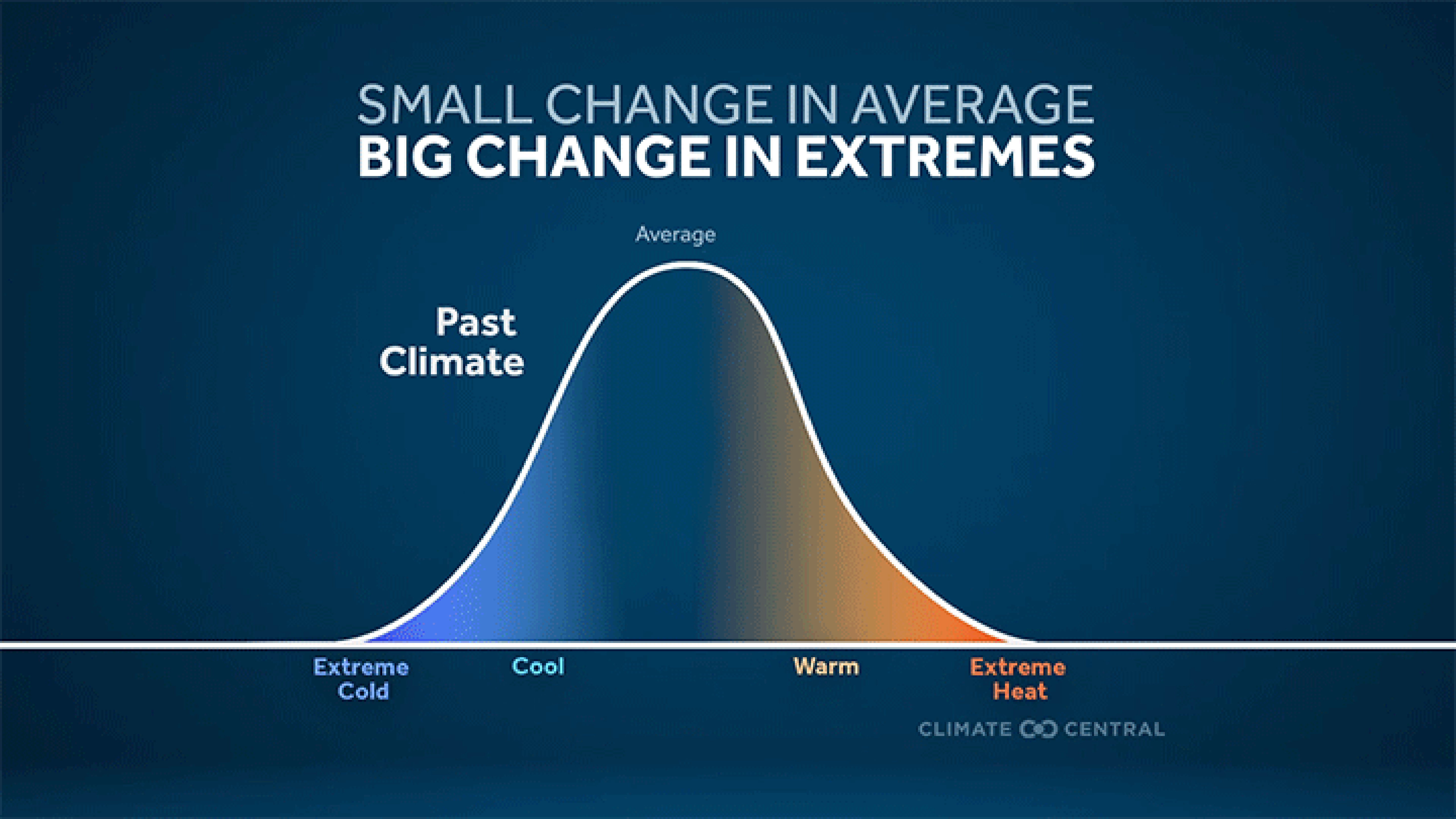
1 Climate risk ≻ known knowns

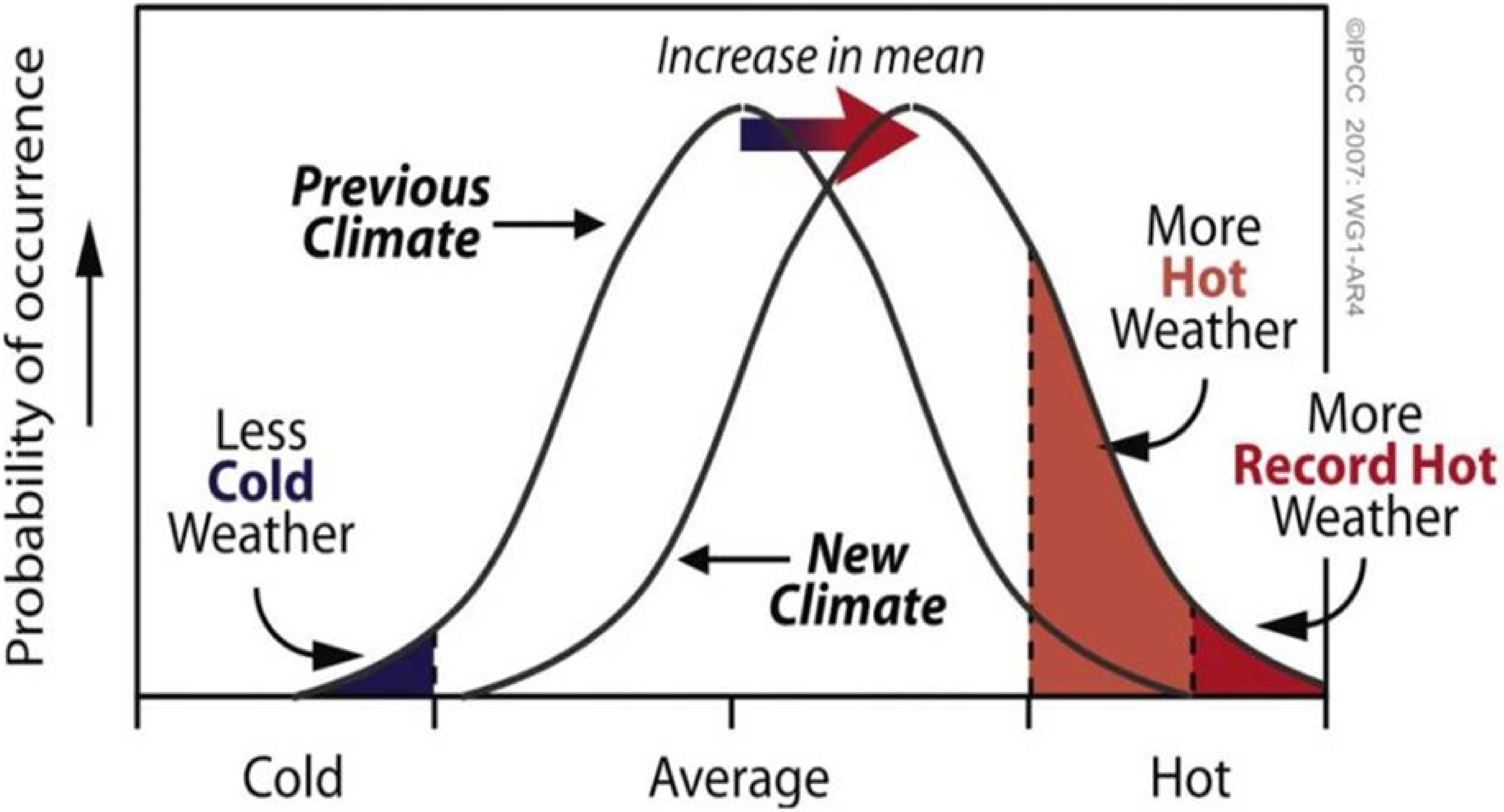


Source: climatecentral.org/climate-shift-index



Source: climatecentral.org/climate-shift-index


SMALL CHANGE IN AVERAGE
BIG CHANGE IN EXTREMES
Average
Past
Climate
Extreme
Cold
Cool
Warm
Extreme
Heat
CLIMATE CENTRAL



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

~$200 / t$CO_2$

~€200 / tCO_2

>€200 / tCO_2

~$200(!?) Social Cost of CO_2

Based on 2% discount rate, subject to external review

Table ES.1: Estimates of the Social Cost of Greenhouse Gases (SC-GHG), 2020-2080 (2020 dollars)

	SC-GHG and Near-term Ramsey Discount Rate								
	SC-CO_2 *(2020 dollars per metric ton of CO_2)*			SC-CH_4 *(2020 dollars per metric ton of CH_4)*			SC-N_2O *(2020 dollars per metric ton of N_2O)*		
Emission Year	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%
2020	120	190	340	1,300	1,600	2,300	35,000	54,000	87,000
2030	140	230	380	1,900	2,400	3,200	45,000	66,000	100,000
2040	170	270	430	2,700	3,300	4,200	55,000	79,000	120,000
2050	200	310	480	3,500	4,200	5,300	66,000	93,000	140,000
2060	230	350	530	4,300	5,100	6,300	76,000	110,000	150,000
2070	260	380	570	5,000	5,900	7,200	85,000	120,000	170,000
2080	280	410	600	5,800	6,800	8,200	95,000	130,000	180,000

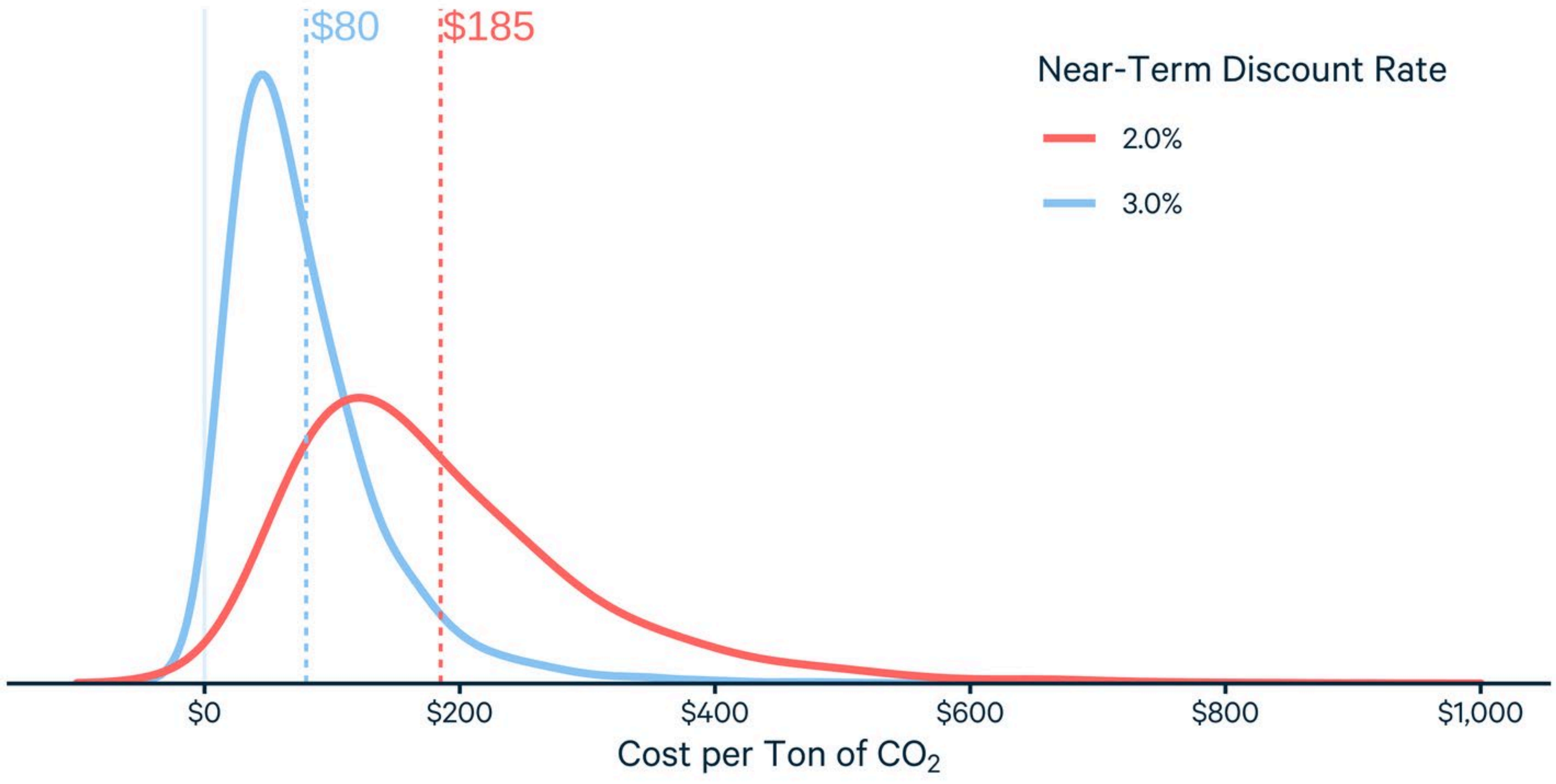
Values of SC-CO_2, SC-CH_4, and SC-N_2O are rounded to two significant figures. The annual unrounded estimates are available in Appendix A.4 and at: www.epa.gov/environmental-economics/scghg.

~$200 U.S. EPA SC-$CO_2$, subject to external peer review

Source: EPA External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances (September 2022)

~$185 Social Cost of CO_2

Based on 2% constant discount rate, with most of the increase due to discounting

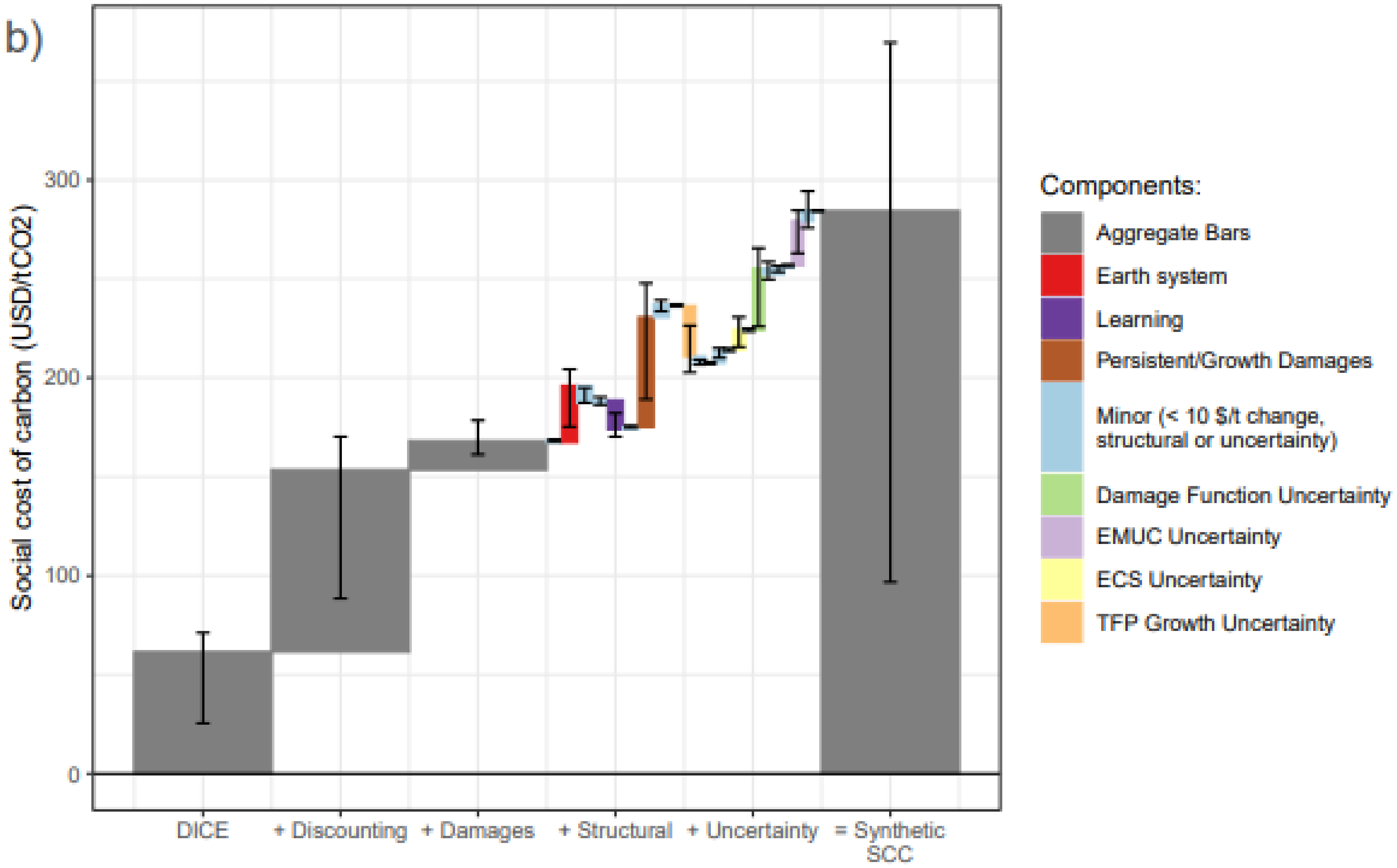


~$50 to ~$80 from updated damages,
~$80 to ~$185 from discounting

Source: Rennert *et al* "Comprehensive Evidence Implies a Higher Social Cost of CO_2" (*Nature*, September 2022).

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

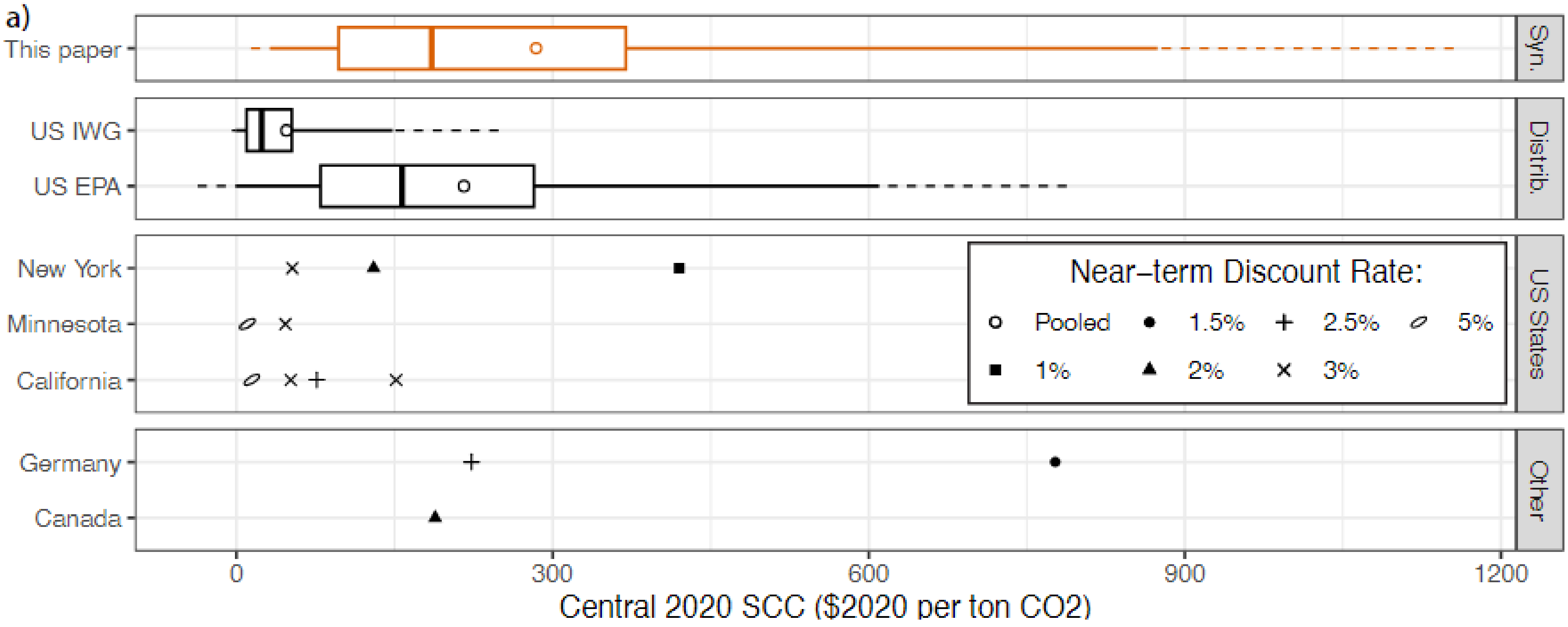
For 1 tonne of CO_2 emitted in 2020, in $2020, with 5%–95% range of $32–$874(!)



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

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

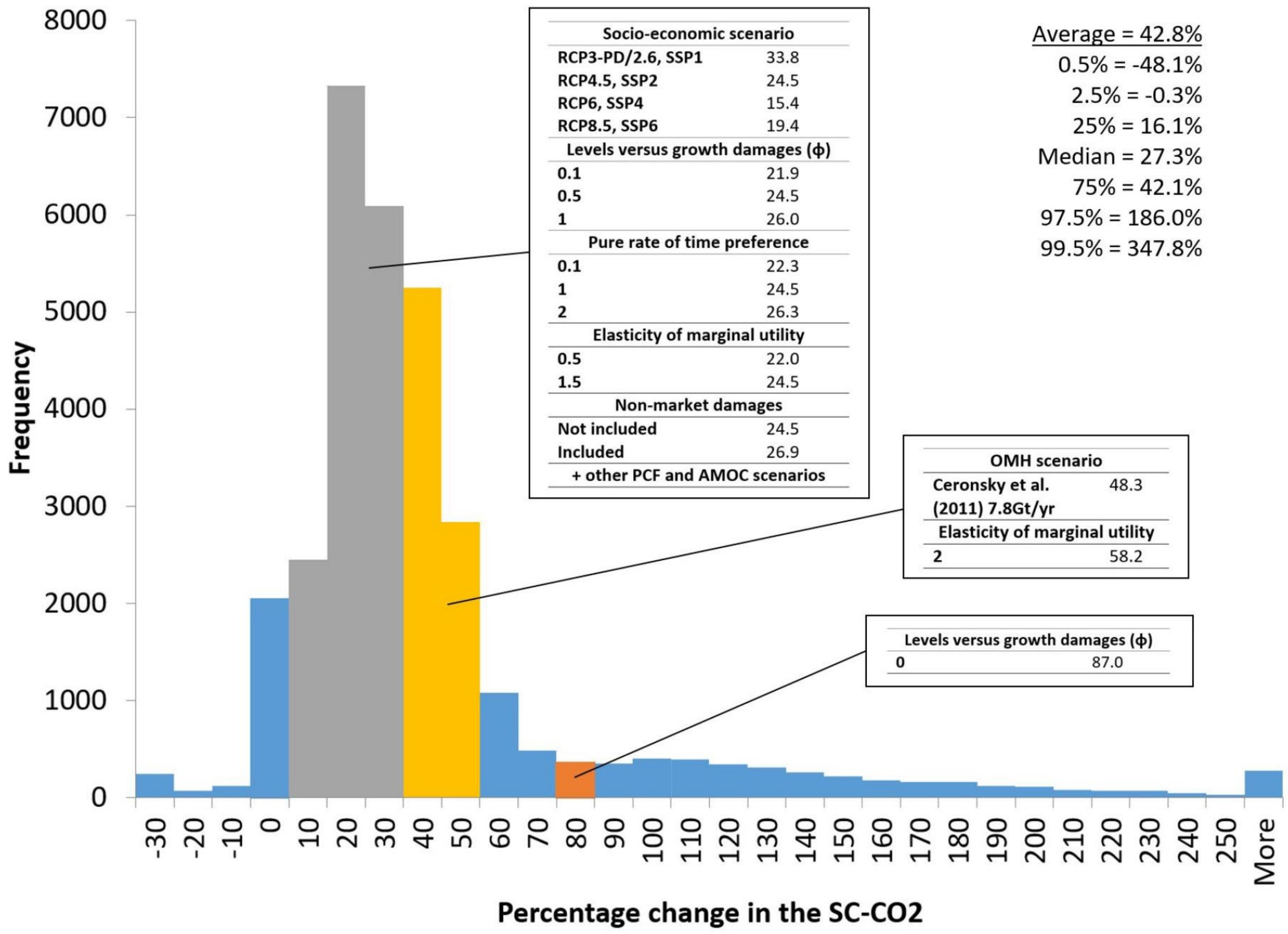
For 1 tonne of CO_2 emitted in 2020, in $2020, with 5%–95% range of $32–$874(!)



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

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

=

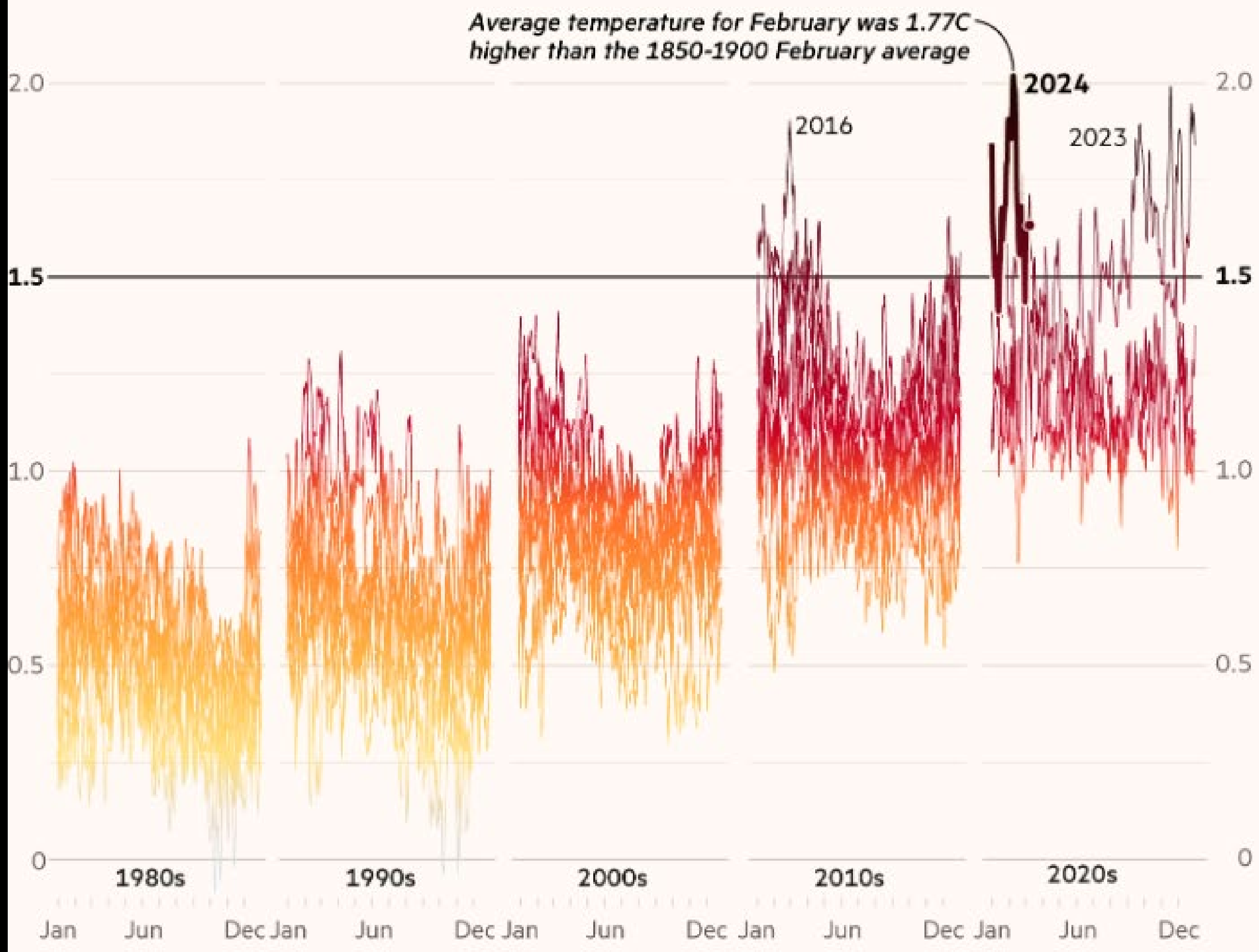
~50%(!!) of *global* GDP

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

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

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)

Leaders | A $25trn hit

Global warming is coming for your home

Who will pay for the damage?

The potential costs stem from policies designed to reduce the emissions of houses as well as from climate-related damage. They are enormous. By one estimate, climate change and the fight against it could wipe out 9% of the value of the world's housing by 2050—which amounts to $25trn, not much less than America's annual GDP. It is a huge bill hanging over people's lives and the global financial system. And it looks destined to trigger an almighty fight over who should pay up.

1 Climate risk $\succ$ known knowns

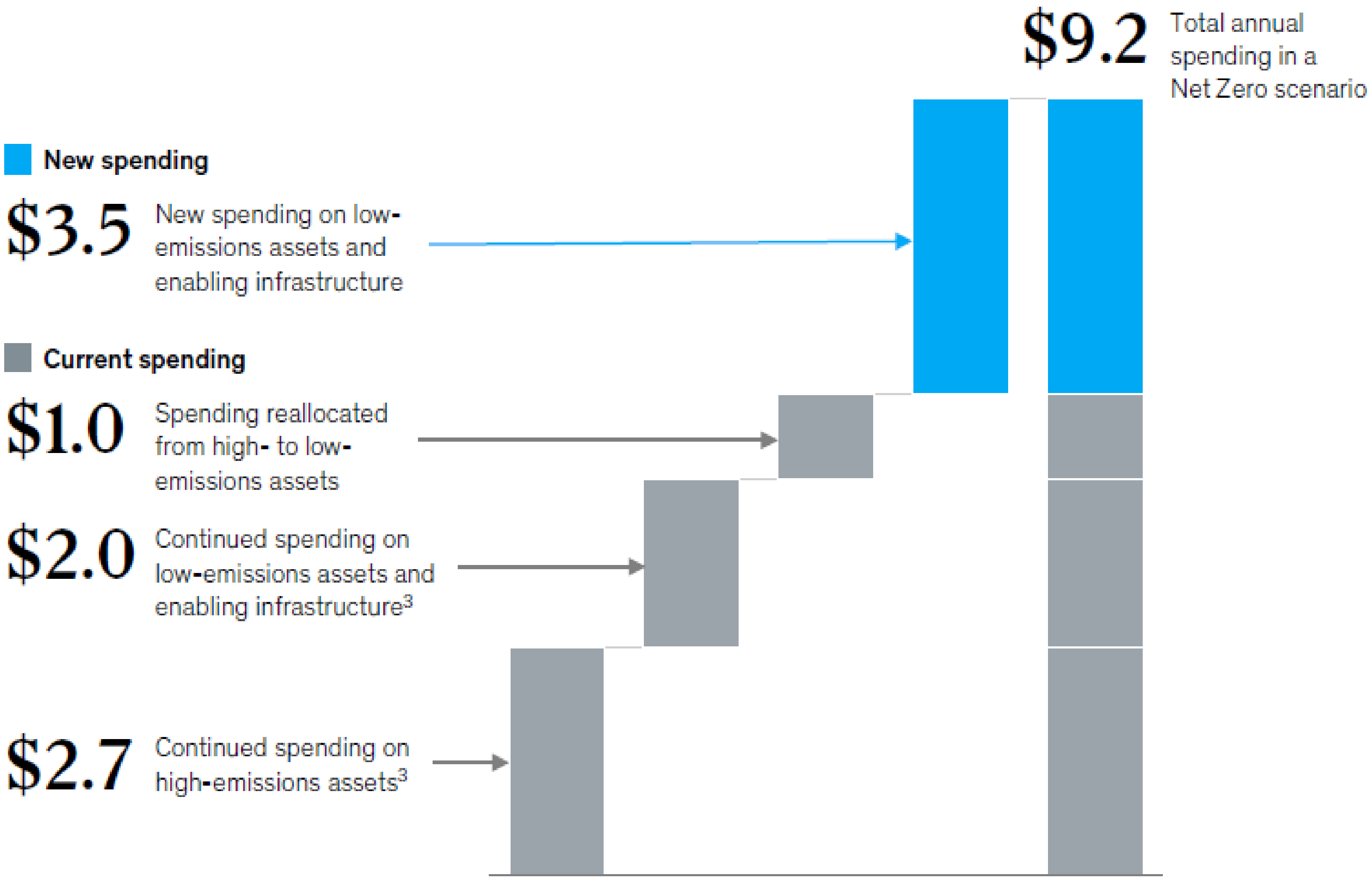
Climate policy = insurance

1 Climate risk ≻ known knowns

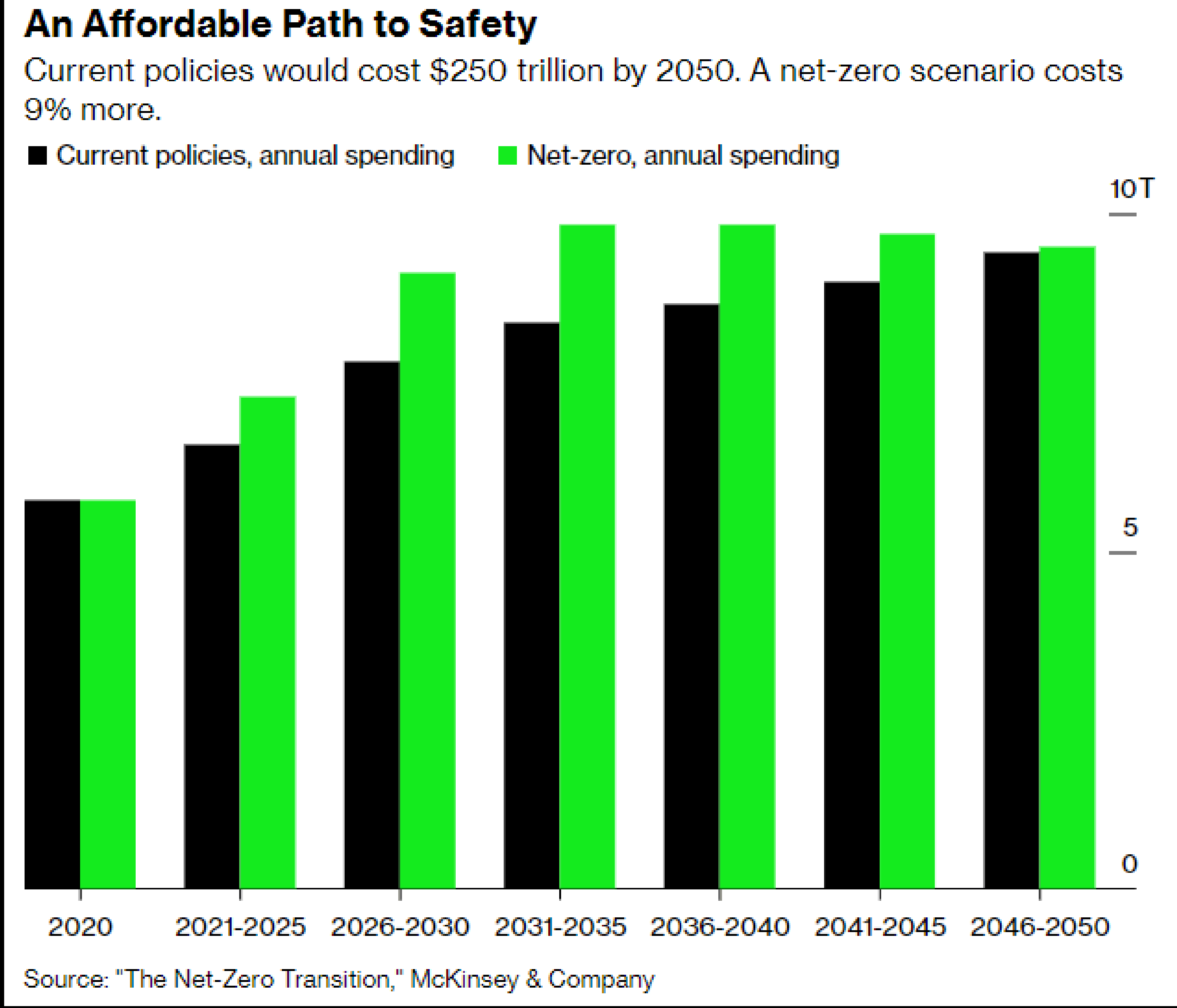
2 Climate policy = opportunity

Spending on physical assets for energy and land-use systems in the NGFS Net Zero 2050 scenario would rise to about $9.2 trillion annually, or about $3.5 trillion more than today.

Annual spending on physical assets for energy and land-use systems[1] in a Net Zero 2050 scenario,[2] average 2021–50, $ trillion



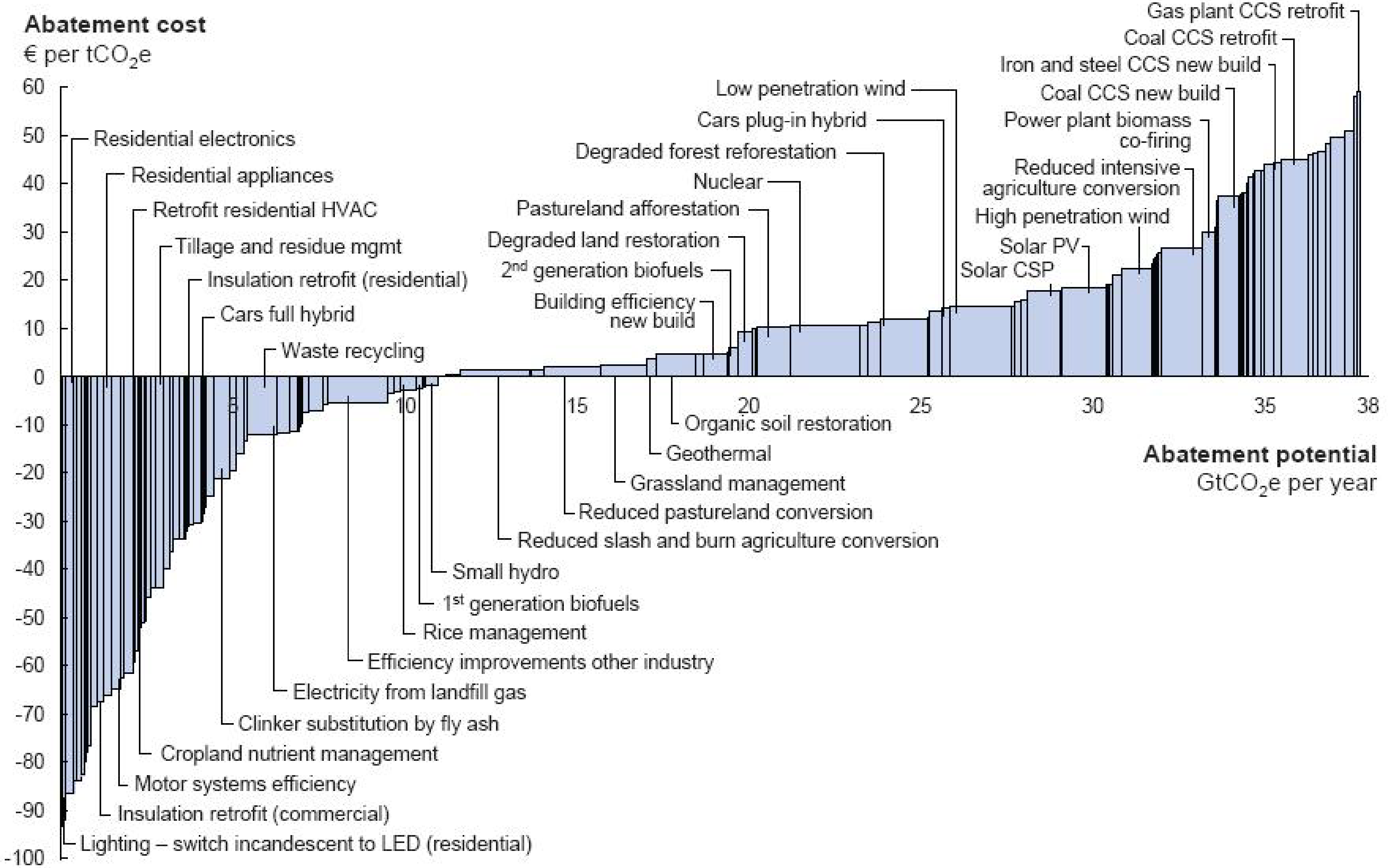
McKinsey's 2022 *The Net-Zero Transition* report



Wagner, "The Cost to Reach Net Zero By 2050 Is Actually a Bargain," *Bloomberg Green* Risky Climate (28 January 2022)

Large abatement opportunities available at low or no cost

McKinsey Global v2.0 effort in 2009 identified 38 $GtCO_2e$ abatement potential in 2030



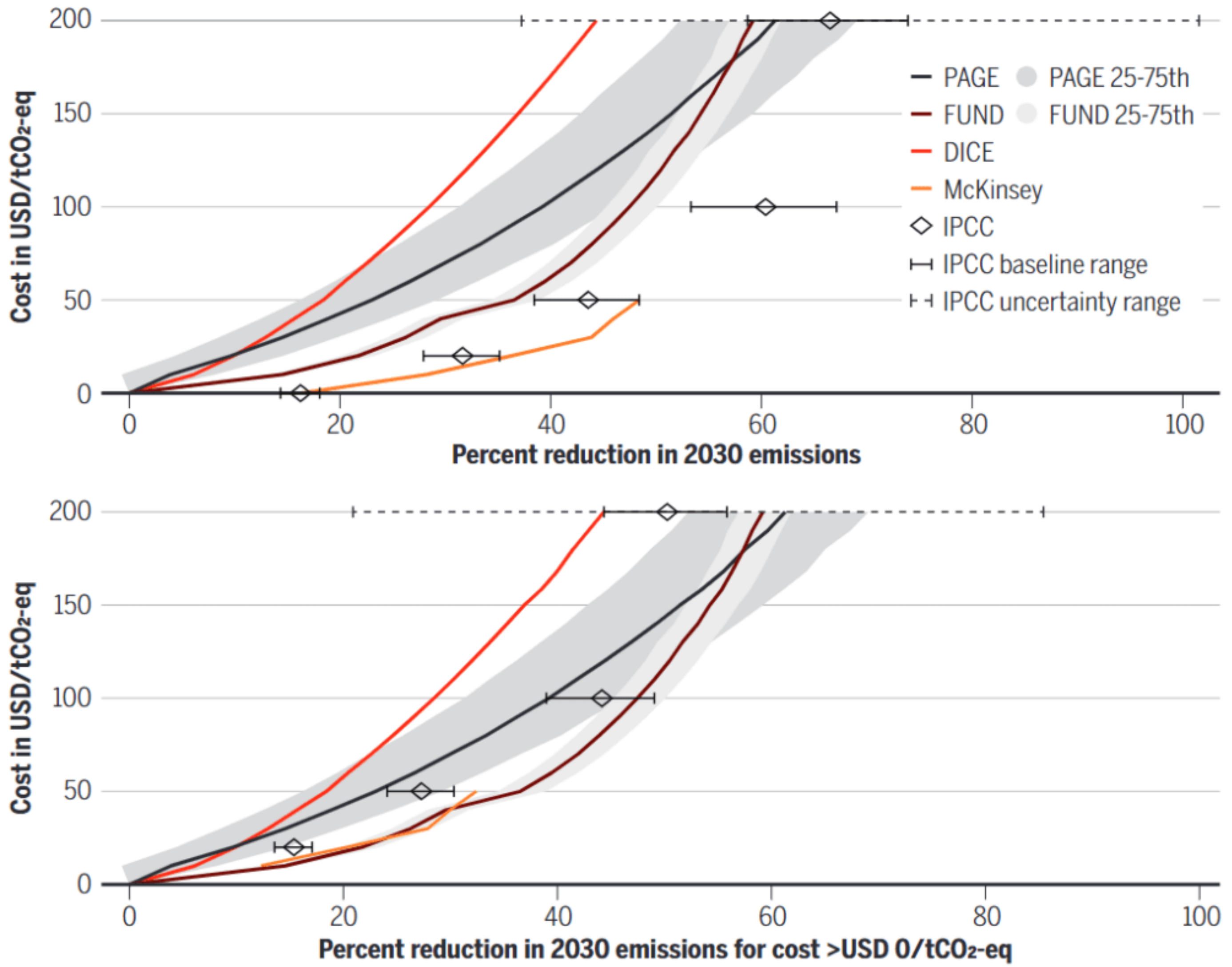
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: Global GHG Abatement Cost Curve v2.0

How costly, or costless, is climate emissions mitigation? p. 1001

Comparison of global mitigation potentials at different costs

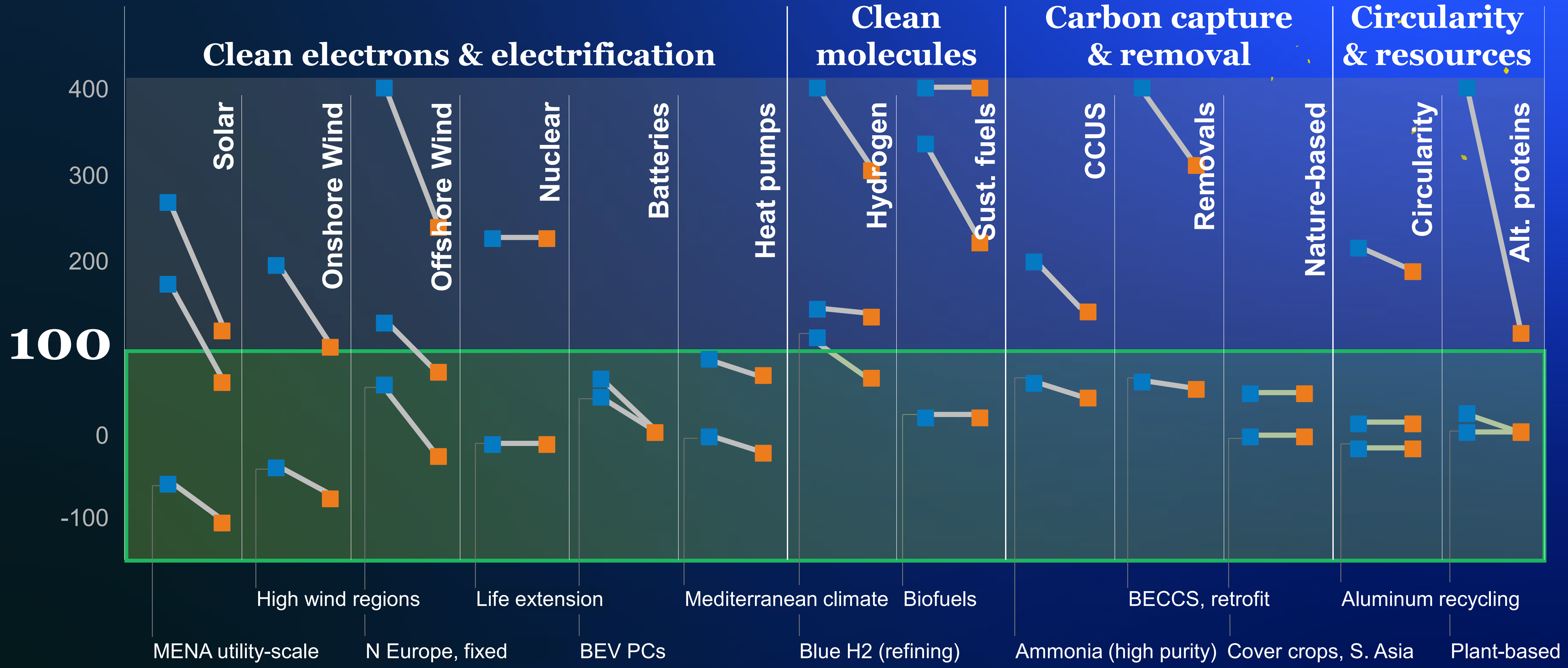
The IPCC results use different baseline emissions to calculate the range of mitigation potentials. The top panel reports the full set of results, and the bottom panel reports only the mitigation potentials with costs >$0 per tonne of CO_2 equivalent (tCO_2-eq). USD reported in 2020 dollars. See supplementary materials.



Source: Kotchen, Rising & Wagner. "The costs of "costless" climate mitigation." *Science* (30 November 2023).

100$/t$CO_2$ carbon tax would make most techs competitive

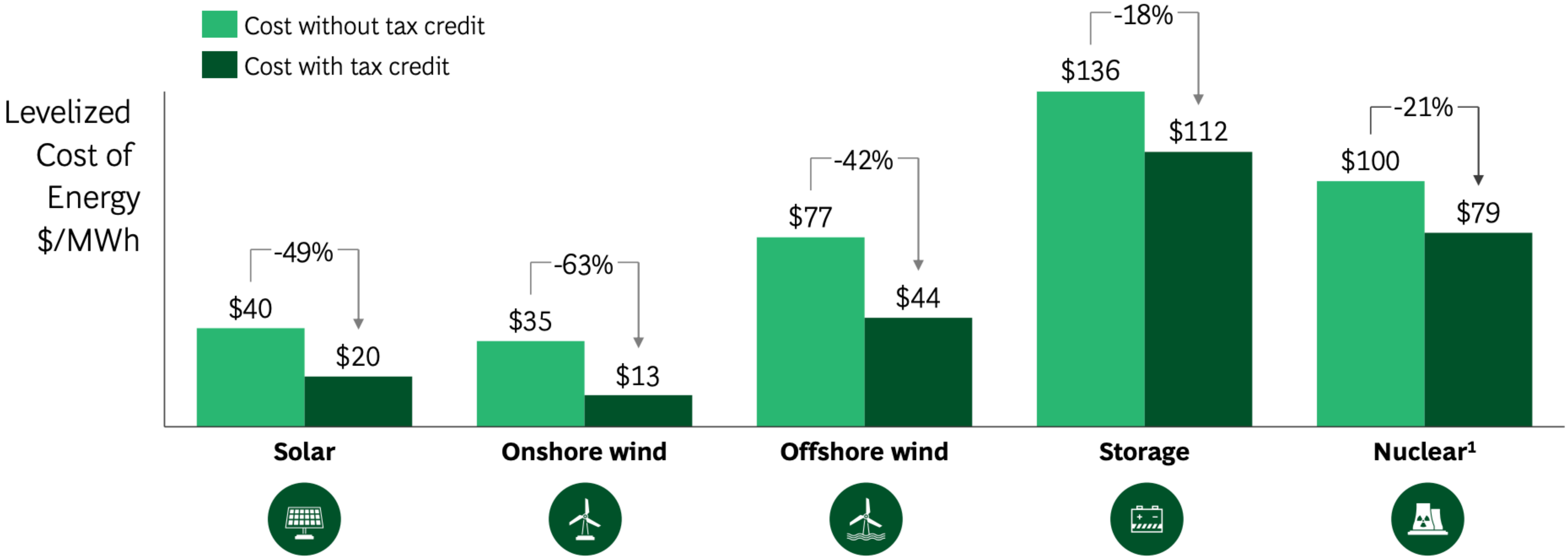
Estimated abatement costs, USD/tCO_2e



Source: McKinsey Global MACC with regional/product estimations

McKinsey & Company

Impact of IIJA + IRA on Climate Solutions



Post-IRA incentive applied	Solar	Onshore wind	Offshore wind	Storage	Nuclear[1]
	60% Investment Tax Credit	**$35/MWh[2]** Production Tax Credit	**60%** Investment Tax Credit	**50%** Investment Tax Credit	**$31/MWh[2]** Production Tax Credit

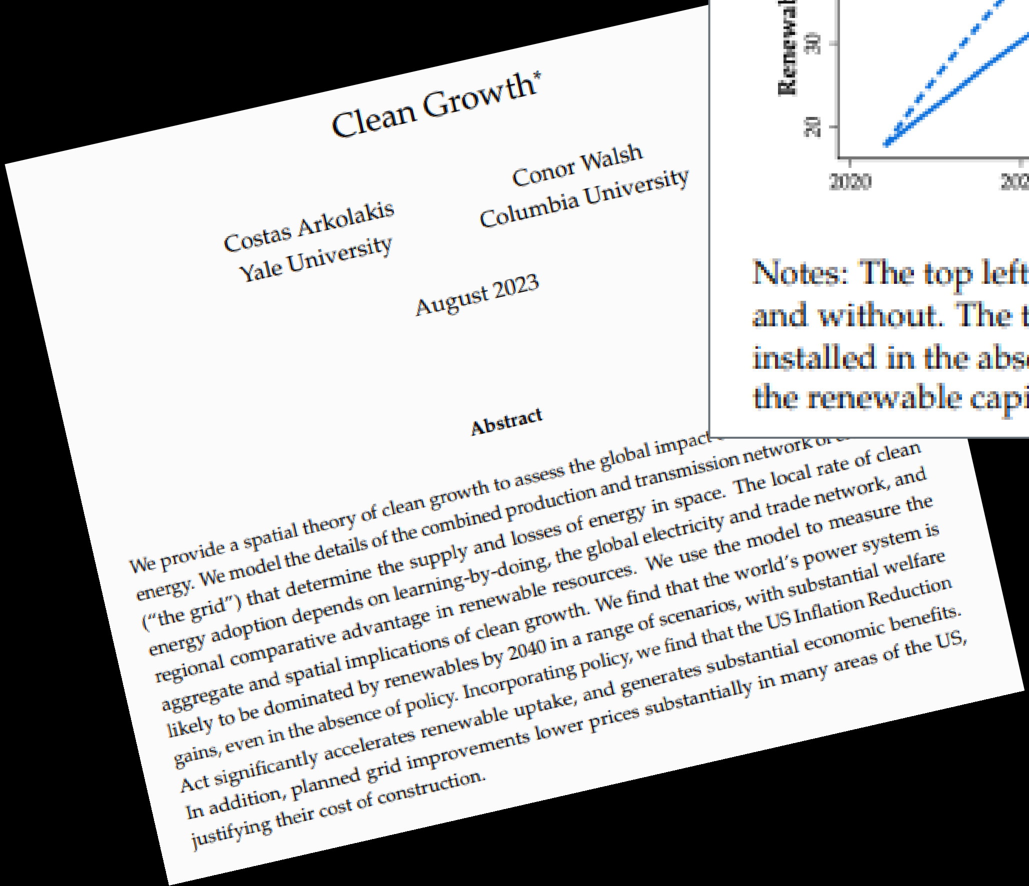
1. New small-modular reactor; 2.Assumes $15/MWh incentive, inflation adjusted and with bonuses; Note: all technologies assume base + prevailing wage bonus + domestic production bonus + energy community bonus, and wind and solar also include low-income bonus Source: Lazard, BCG analysis

Source: BCG

Negative climatic tipping points, meet the positive socio-economic ones the IRA is jumpstarting

- The challenge: Addressing ‘fossilflation’ while keeping ‘greenflation’ in check
- Direct effects are important
  - e.g. get $8k rebate for your heat pump, $2.5k to improve electric wiring, … $250b in DOE loans
  - adding up to $1.2 trillion in federal spending over first decade, spurring $2.9 trillion in total spending over first decade, >$10 trillion by 2050, per Goldman Sachs Research,

  But:
- It’s the external effects, norm changes, positive socio-economic tipping points that will make the real difference


Clean Growth*

Costas Arkolakis
Yale University

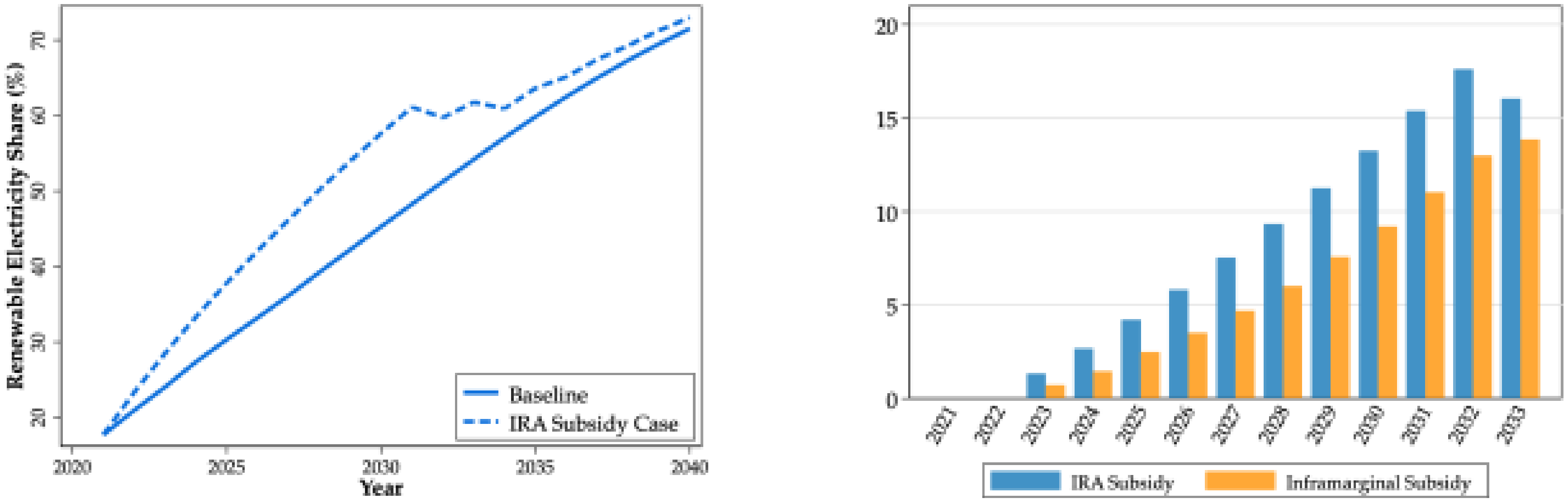
Conor Walsh
Columbia University

August 2023

Abstract

We provide a spatial theory of clean growth to assess the global impact energy. We model the details of the combined production and transmission network of ("the grid") that determine the supply and losses of energy in space. The local rate of clean energy adoption depends on learning-by-doing, the global electricity and trade network, and regional comparative advantage in renewable resources. We use the model to measure the aggregate and spatial implications of clean growth. We find that the world's power system is likely to be dominated by renewables by 2040 in a range of scenarios, with substantial welfare gains, even in the absence of policy. Incorporating policy, we find that the US Inflation Reduction Act significantly accelerates renewable uptake, and generates substantial economic benefits. In addition, planned grid improvements lower prices substantially in many areas of the US, justifying their cost of construction.

Figure 11: The Impact of the Inflation Reduction Act



Notes: The top left panel shows the model's projection for renewable power share under the IRA production tax credit, and without. The top right panel shows the total cost of the bill (in blue), and subsidies going to capital that would be installed in the absence of the subsidy. The bottom left shows GDP growth in both scenarios, and the bottom right shows the renewable capital price.

Source: conor-walsh.com/s/CleanGrowth.pdf

1. Climate risk ≻ known knowns
2. Climate policy = opportunity
3. Pricing carbon "+"

Carbon Barometer

Policy Contributions

The Carbon Barometer framework allows users to clearly understand the relative contribution of various policies to a country-level Carbon Price

Individual Policy Contribution to Carbon Barometer Price

Country	Carbon Barometer Price $USD/MTCO_2$	Fossil Fuel Subsidies $USD/MTCO_2$	Carbon Tax $USD/MTCO_2$	Emissions Trading Systems $USD/MTCO_2$	Carbon Barometer Price $USD/MTCO_2$	Fossil Fuel Subsidies $USD/MTCO_2$	Carbon Tax $USD/MTCO_2$	Emissions Trading Systems $USD/MTCO_2$
	2021				2022			
Global	$18.97	-$11.07	$1.03	$3.09	$4.08	-$27.67	$1.12	$6.00
France	$120.64	-$34.85	$26.69	$19.91	$63.71	-$110.32	$25.55	$34.61
United States	$18.47	-$1.99	$0.00	$1.21	$17.85	-$2.91	$0.00	$2.03
China	$13.93	-$2.38	$0.00	$0.35	$18.87	-$2.37	$0.00	$4.55

Green H_2, electrolysis, and CCUS could reduce steelmaking CO_2 emissions by over 85% if implemented at scale

	1	2	3
	100% Green Hydrogen (H2) DRI-EAF	**Iron Ore Electrolysis**	**Carbon Capture, Utilization, and Storage (CCUS)**
Description	• **Green hydrogen** replaces **natural gas** as an iron ore reductant in DRI shaft; the rest of the process remains the same • Generates **water as a byproduct** instead of CO_2	• **Two different processes** are possible: **Molten oxide electrolysis:** High current runs through mixture of iron ore and liquid electrolyte to split ore into pure molten iron **Electrowinning-EAF:** Iron from iron ore is dissolved in acid. Iron-rich solution is then electrified to form pure solid iron	• **CCUS equipment** can be added to **existing steel-producing infrastructure** to **capture** emitted CO_2 • Captured CO_2 is then **sequestered underground** or **reused**
Real-time sector initiatives	HYBRIT 100% fossil fuel-free DRI-EAF production with green H_2 used for DRI	Electra Electrowinning to produce high-purity iron plates ready for EAF input (no DRI or MOE step)	ArcelorMittal Carbalyst® captures carbon from a blast furnace and reuses it as bio-ethanol. However, technology not proven at scale
Applicability to conventional routes	**Applicable to existing DRI-EAF route**, with minor retrofitting	**Full overhaul** of BF-BOF equipment required; **replacement** of DRI shaft in DRI-EAF	**Retrofitting** of capture technology is possible on **conventional BF-BOF and DRI-EAF**
Decarbonization potential (vs. BF-BOF)	**~90%**	**~97%**	**~90%** — Hypothetical best-case scenario
Estimated production cost (excl. CapEx)	**<$800 per tonne of steel**	**~$215 per tonne of iron + cost of 'stranded' iron ore**	**~$380 – 400 per tonne**

Sources: Columbia Center on Global Energy Policy (2021); IEA, Iron and Steel Technology Roadmap (2020); McKinsey (2020); Mining Technology (2023); Tata Steel; Primetals Technologies; Edie, ArcelorMittal accused of net-zero greenwashing (2023). Credit: Mimi Khawsam-ang, Max de Boer, Grace Frascati, and Gernot Wagner (13 March 2024); share/adapt with attribution.
Contact: gwagner@columbia.edu

Since H2GS announced, over ~40mt green steel projects have been promised by 2030

DRI announcements in Europe today, *mt liquid steel*

2025
- H2 green steel 2.5mt
- ArcelorMittal 2.3mt

2026
- HYBRIT ▶▶▶ FOSSIL-FREE STEEL 1.3-2.7mt
- thyssenkrupp 2.5mt
- SALZGITTER AG Stahl und Technologie 1.9mt
- BLASTR Green Steel 2.5mt
- LIBERTY 3.0mt
- GravitHy 2.0mt

2027
- ArcelorMittal 2.3mt
- voestalpine ONE STEP AHEAD. 1.9mt
- SHS - STAHL-HOLDING-SAAR 2.0mt

2028
- TATA STEEL 4.5mt

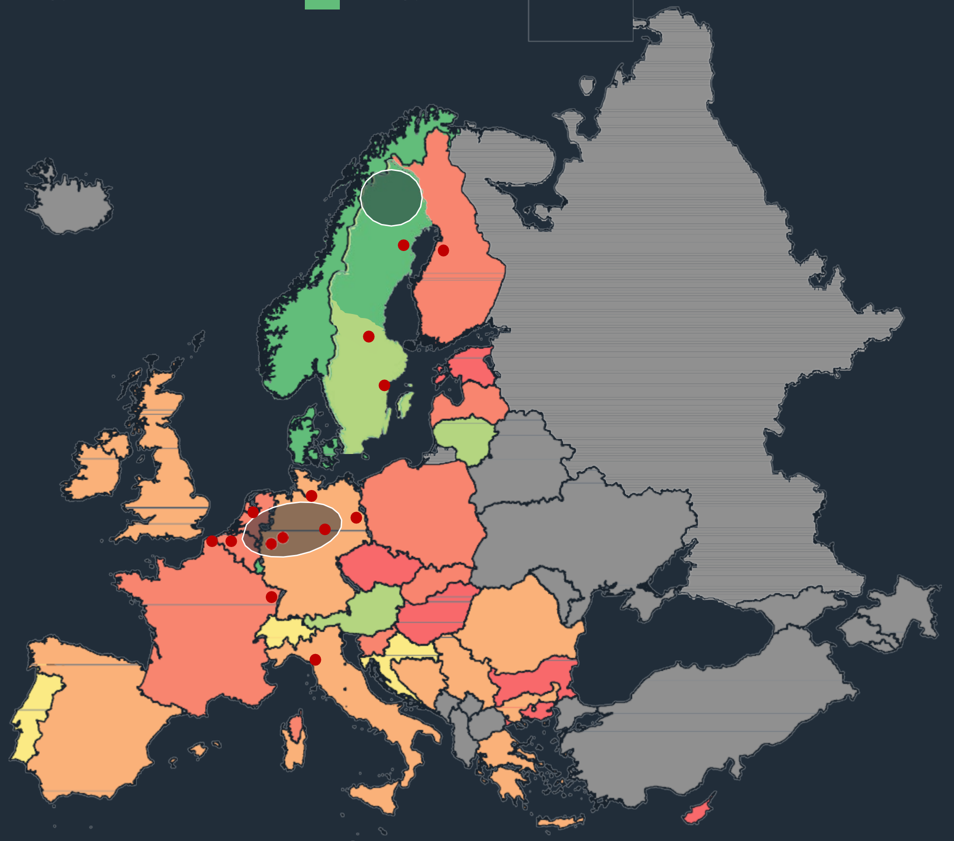
2029
- LKAB SSAB 5.0mt
- ArcelorMittal 7.0mt

2030
- H2 green steel 2.5mt
- SALZGITTER AG Stahl und Technologie 1.9mt

Northern Sweden has unique advantages from low-cost renewable electricity and iron ore deposits

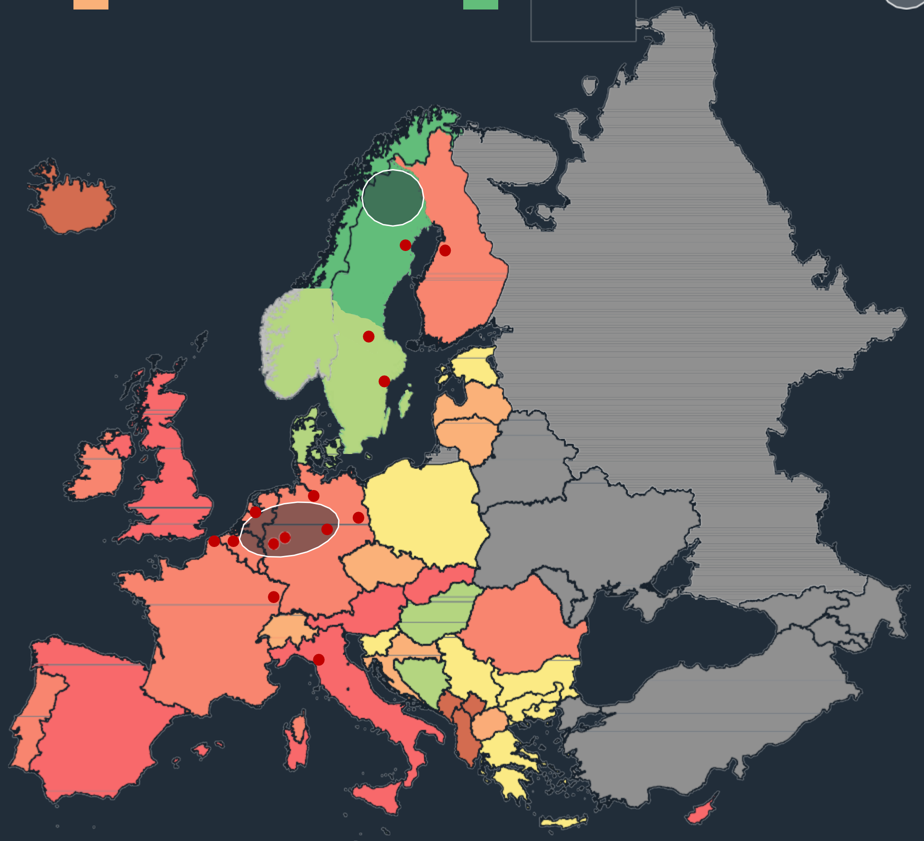
Renewable share in electricity production in Europe
2019

- <15%
- 15-30%
- 30-45%
- 45-60%
- 60-75%
- >75%



Industrial electricity prices in Europe
2019

- >7cEUR/kWh
- 6-7cEUR/kWh
- 5-6cEUR/kWh
- 4-5cEUR/kWh
- 3-4cEUR/kWh
- <3cEUR/kWh
- Major European steel plants
- Current or former major iron ore deposit region



Source: International Energy Agency (IEA); Eurostat; ProMine

H2greensteel

Potential projects in North America

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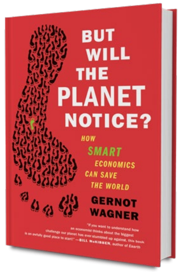
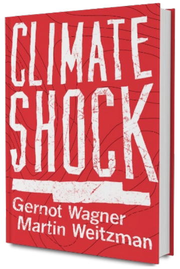
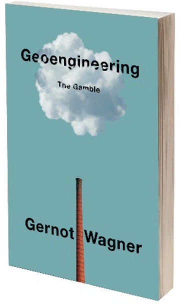
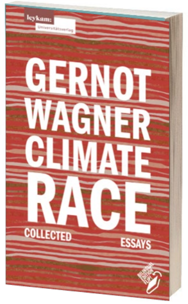
Mercedes Teams Up With Green Steelmaker to Slash Emissions

Carmaker locks in supply for factories in Europe and North America









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