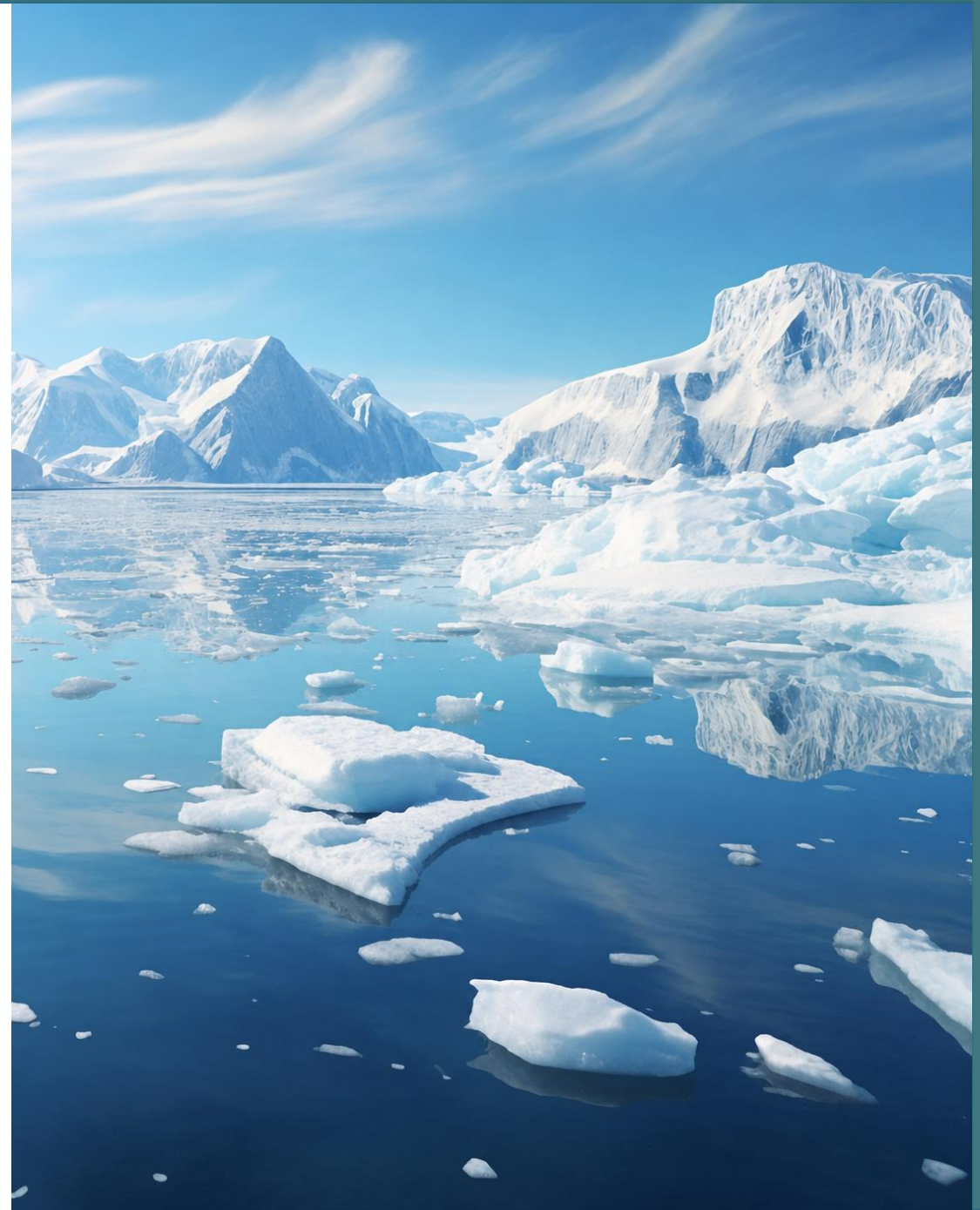




Have we lost the climate change war?

- Are our efforts making a difference?
- What are the implications for our investment strategies?
- Should we pivot to investing in climate adaptation?

29th April 2026



23 April 2026

Dear CREO Family Office Principals

Let me explain in more detail what I think will be a valuable discussion to have when we dine together at Sachi restaurant. Selfishly, I would love to hear how your thinking as family office investors in climate technology companies has evolved in the last few years as the world around us has changed in terms of:

- **Geopolitics:** Iran War, closing of the Strait of Hormuz and its implications for energy security, Chinese relations with the West and our dependencies on China and changes if Taiwan is taken back, Russian/Ukraine and implications for European national security.
- **Politics:** the US politicisation of climate policy where Republicans promote fossil fuels and Democrats promote low carbon energy. The reversals of clean energy policy support with the changing of the guard.
- **Artificial Intelligence:** its impact on energy demand and energy efficiency improvement opportunities

How are national governments, companies, consumers and investors' objectives changing with respect to where decarbonisations sits relative to national security, energy security and economic development?

In light of the range of scenarios that could emerge as answers to that question, how are you thinking about the impact you want to have over the next 10 years or more? And how are you changing where you want to invest to have that impact?

I am hoping that is the discussion you want to have with this amazing group we have assembled for dinner. If not, fire an email to me and I can revisit the best use of our time that evening.

I very much look forward to seeing you all on the eve of the 28th of April.

With kind regards,

Stan

The Sixth Energy Transition – The “Electrotech” Revolution (ET6)

Epoch	Primary Energy Source	Enabling Tech	Efficiency Leap	Era	Key Transformation
1. Fire Age	Biomass	Controlled fire	Heat on demand	~1M BC–3000 BC	Heat, cooking, metallurgy
2. Agrarian-Solar	Wind, water, passive solar, muscle (human/animal)	Water wheels, windmills, sails	Nature based kinetic energy	3000 BC–1700 AD	Agriculture, cities
3. Coal Age	Coal	Steam engine, iron, railways	Power on demand	1700–1900	Industrial revolution
4. Oil & Gas Age	Petroleum, gas	IC engine, turbines, petrochemicals	Transportable power in liquids	1900–2000 (recharged w shale)	Global transport, mobility
5. Nuclear & Digital	Uranium	Reactor, grid, semiconductors	Millions x more energy per mass	1950–Present	Electrification, computing
6. Renewable Age (Electrification Age)	Solar, wind, storage, advanced geothermal, biomass	EVs, photovoltaics, wind turbines, batteries, heat pumps, hydrogen	Lower cost, more efficient than fossil fuels	2000–Present	3x Power demand; Energy security; Electrify everything; Decarbonization,
7. Fusion Age	Fusion, space-based solar, artificial photosynthesis	Stellarators, AI-driven design	Nearly limitless zero-carbon baseload power	2050+	Post-scarcity energy; climate restoration

The Facts on what has changed over the last 18 months

Jan 2025: Donald Trump took office. He again dismissed climate change as a “hoax,” withdrew the US from the Paris agreement and promoted fossil fuel production as a strategic priority (“drill baby drill”).

Nov 2025: Of the 200 countries represented at COP 30 in Belem Brazil, 80 countries agreed to create a faster phase down of fossil fuels. The idea was blocked by Saudi Arabia and other oil-producing nations.

Jul 2025: In the Big Beautiful US Bill, EV incentives were scrapped, DoE funding was cut, but roughly two thirds (\$280B) of existing clean energy incentives were retained on a strictly partisan Republican vote.

Feb 2026: GOP members of the U.S. House Education and Workforce Committee are probing whether CalPERS’ ESG strategy is consistent with fiduciary obligations.

Feb 2026: The war in Iran has underscored the importance of countries not being dependent on fossil fuels, with some indications of accelerated investment in renewables.

Apr 2026: Ministers from nearly 60 countries gather in the Colombian city of Santa Marta for the first global conference on phasing out fossil fuels. The United States was not invited.

Today: US institutional investors are concerned about investigations by the US Administration for “woke climate investing.” This has to affect at least US institutional investing activity.

Builders Vision Climate Capital Reset Project - March 2026

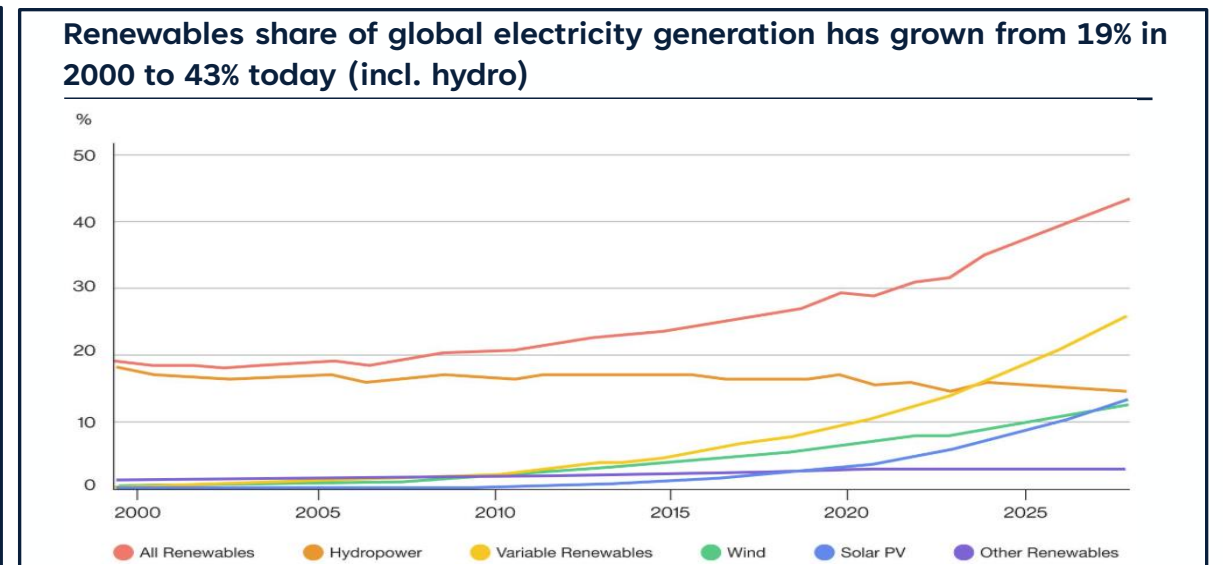
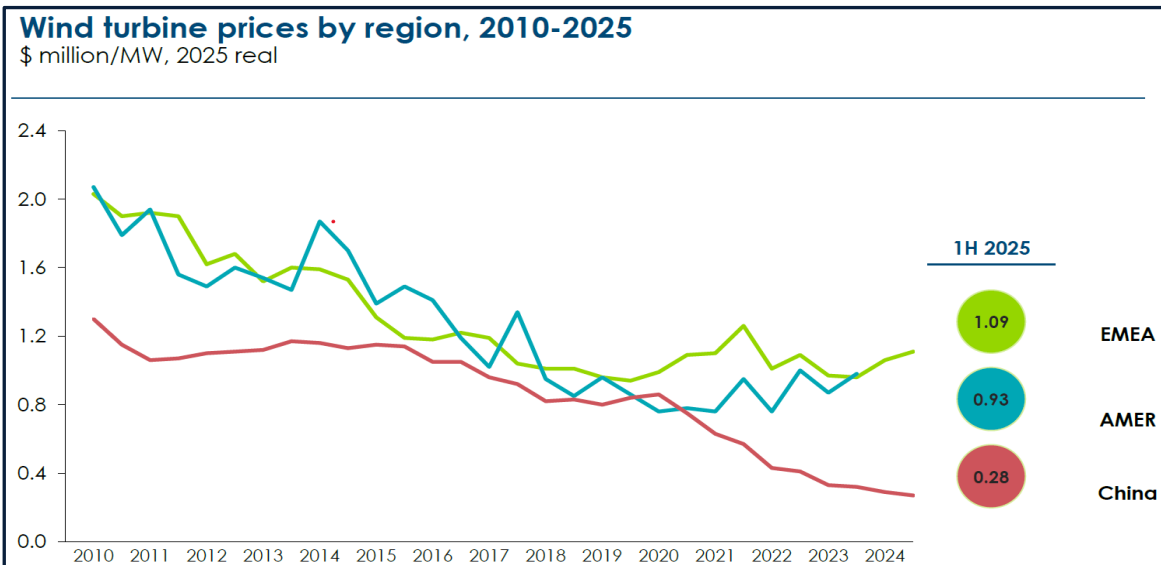
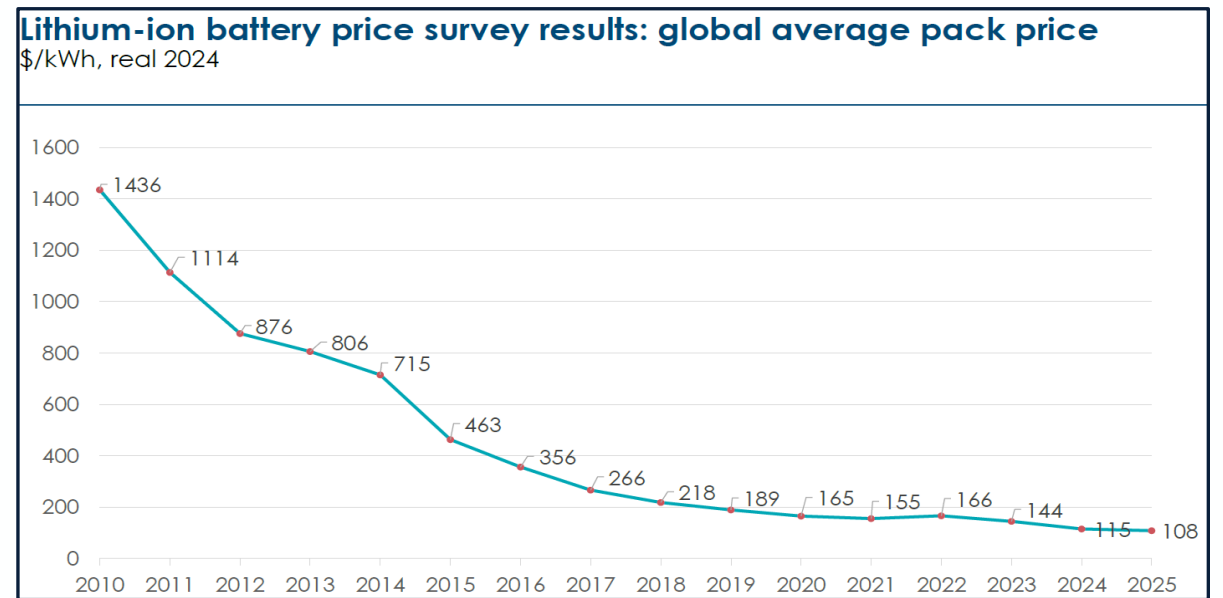
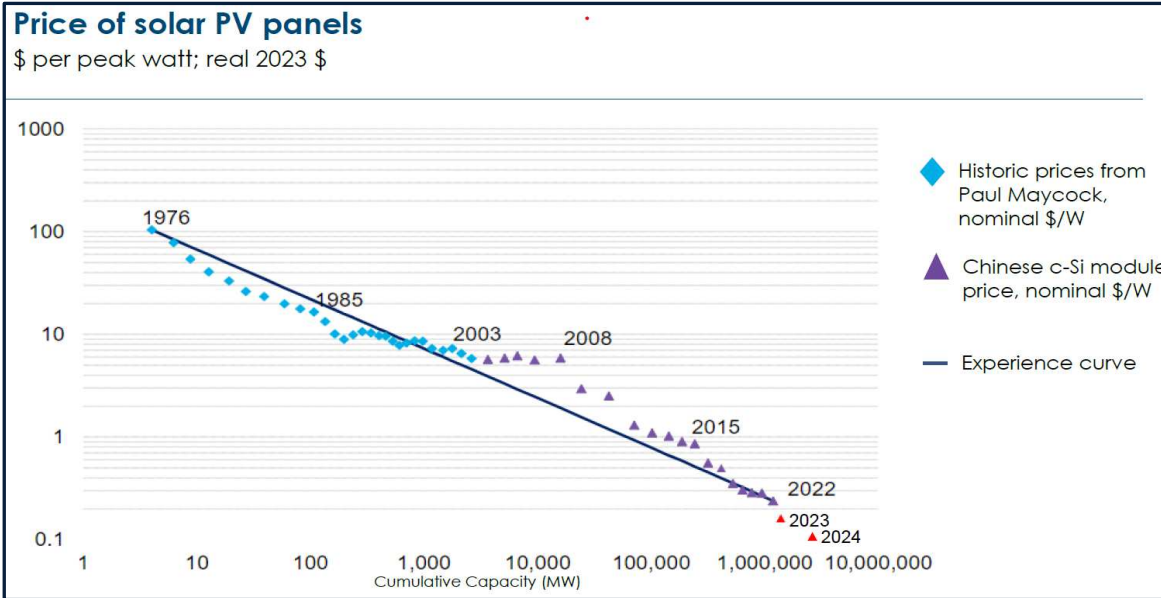
Advisors hired by Builders Vision conducted more than 150 confidential interviews with leading climate capital allocators, family office CIOs, venture and private equity investors, infrastructure fund managers, corporate executives, academics, former government officials, and other experts on the topic of changing climate investment priorities. This is what we took away from this report:

- 1. Survey respondents characterize the current investment environment as "unprecedented upheaval," "churn," and "disequilibrium."**
- 2. A climate capital "reset" is underway, bringing repricing and consolidation. Many companies may see down rounds in the coming months/years and many sectors will consolidate.**
- 3. The "blood on the streets" opportunity for secondaries refers to a classic market dislocation where extreme capital scarcity and illiquidity have forced previously stable institutional investors to become distressed sellers.**
- 4. We see a significant repositioning away from "net zero/decarbonization" toward "adaptation/resilience/infratech."**
- 5. The broader mainstream climate capital in the U.S. has hit a plateau, with many generalist investors "putting pens down" due to political uncertainty.**



The Climate Capital Reset Project is a collaborative research effort led by Will Coleman (Onramp Capital), Bill Tarr (Motiv Partners), & Dan Firger (Great Circle Capital Advisors) with the support of Builders Vision.

In Renewables, we are winning the war...with China's help



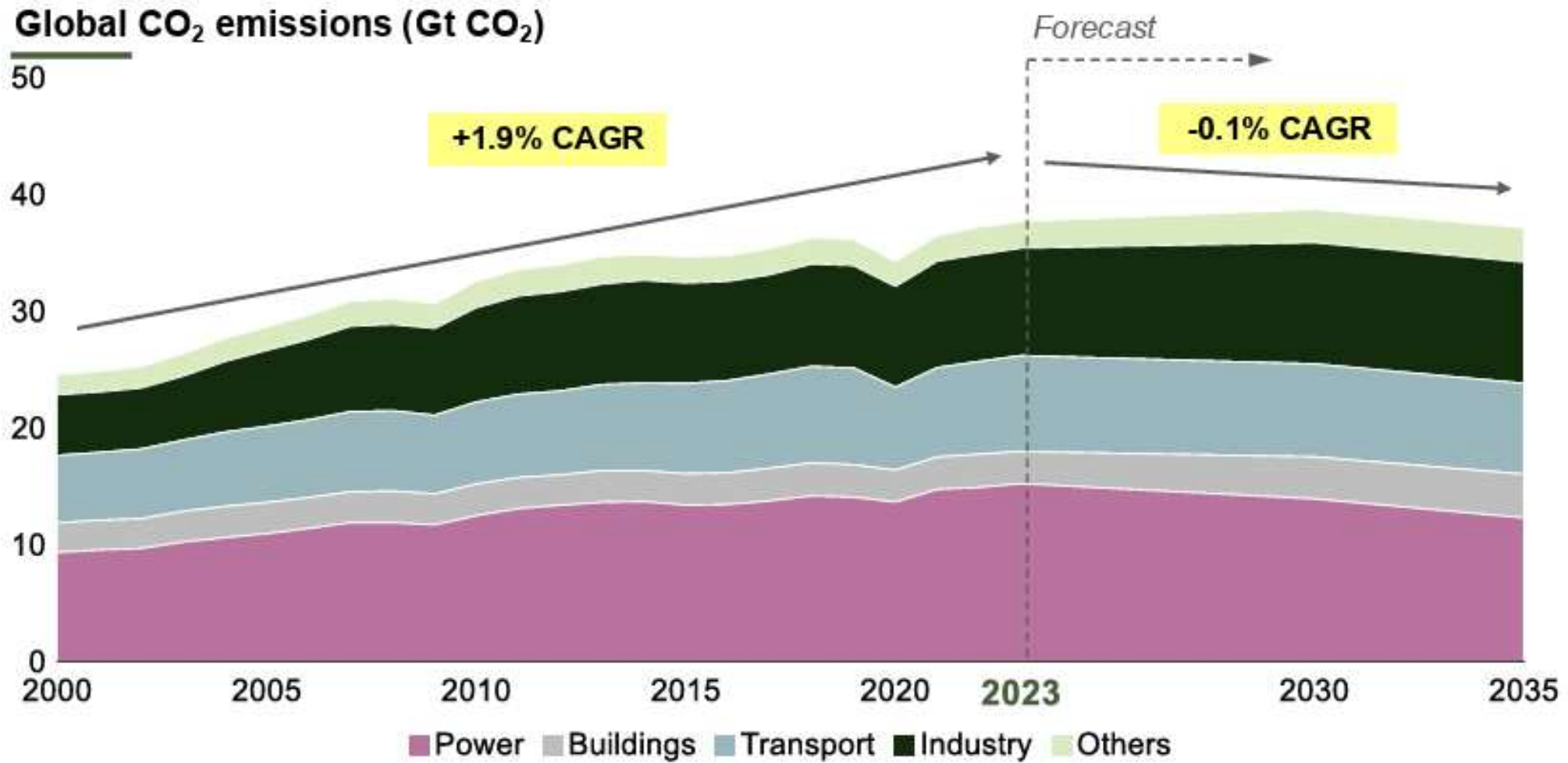
How big is the greenhouse gas problem in gigatonnes of CO₂e?

Annual Global Greenhouse Gases amount to 58Gt gross of natural sinks and 35Gt net

Greenhouse gas	Share of gross emissions	Human generated Emissions (GtCO ₂ e/year)	Natural Sinks (land and ocean) (GtCO ₂ e/year)	Net annual greenhouse emissions
CO ₂ - Carbon Dioxide	76%	44	-23	21
CH ₄ - Methane	16%	9		9
N ₂ O – Nitrous Oxide	5%	3		3
F-gases	3%	2		2
Total	100%	58	-23	35

Sources: Emissions taken from UNEP Emissions Gap Report (2025); Natural sinks taken from ESSD Global Carbon Budget (2024)

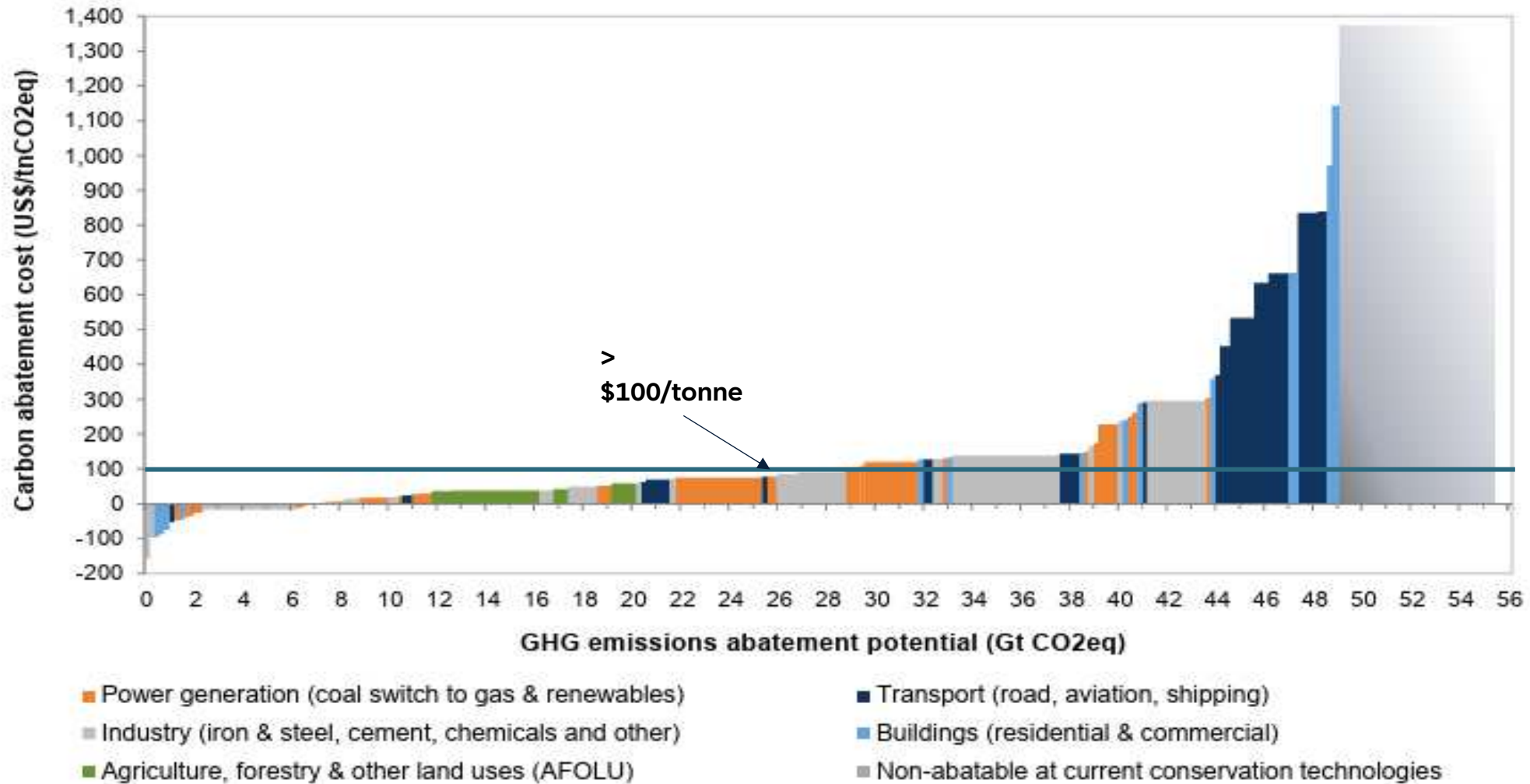
20+ years into an ambitious battle to tackle climate change, emissions growth has not yet slowed



Source: IEA Global Energy Review 2025

Over half of GHG emissions will cost > \$100/t to abate. Who will pay?

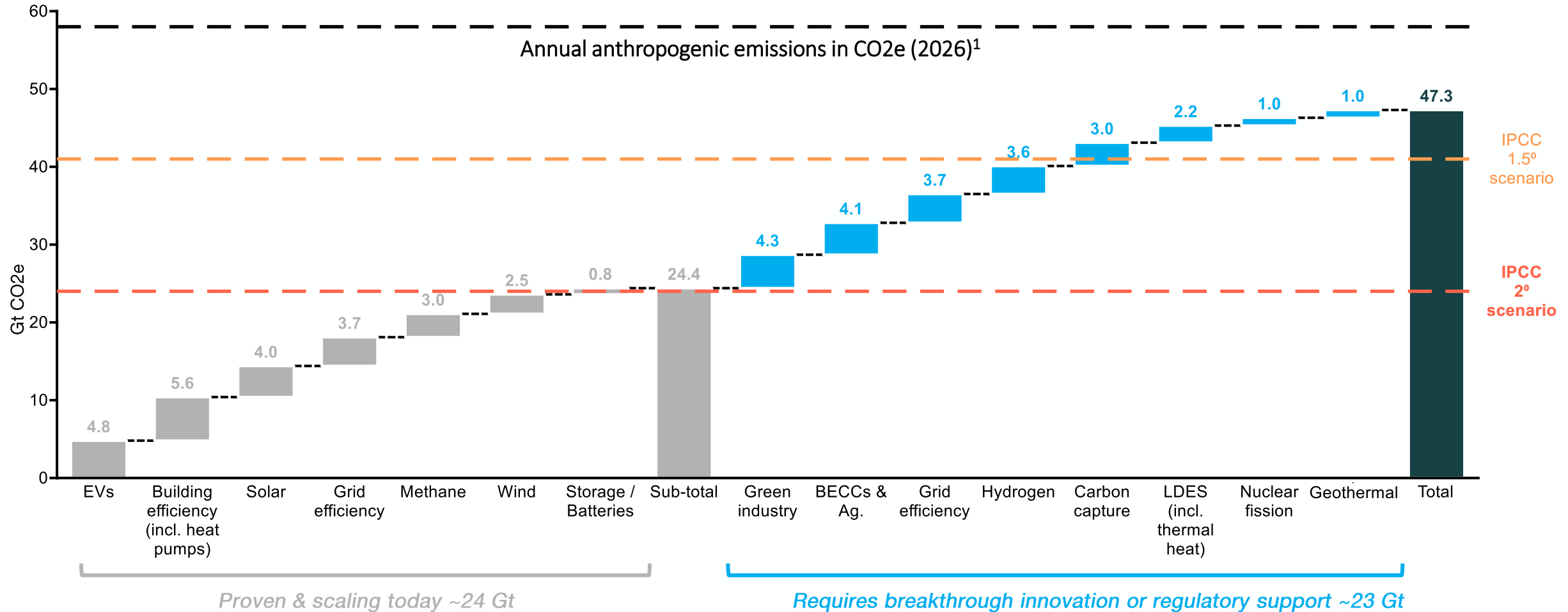
2023 carbon abatement cost curve for anthropogenic GHG emissions, based on current technologies and current costs, assuming economies of scale for technologies in the pilot phase



Source: Goldman Sachs 2025 Carbonomics Report

Of the 58Gt of human-generated CO₂e emissions/yr, 40% should be eliminated with current economically viable technology by 2050

Gt CO₂e abated per annum by 2050

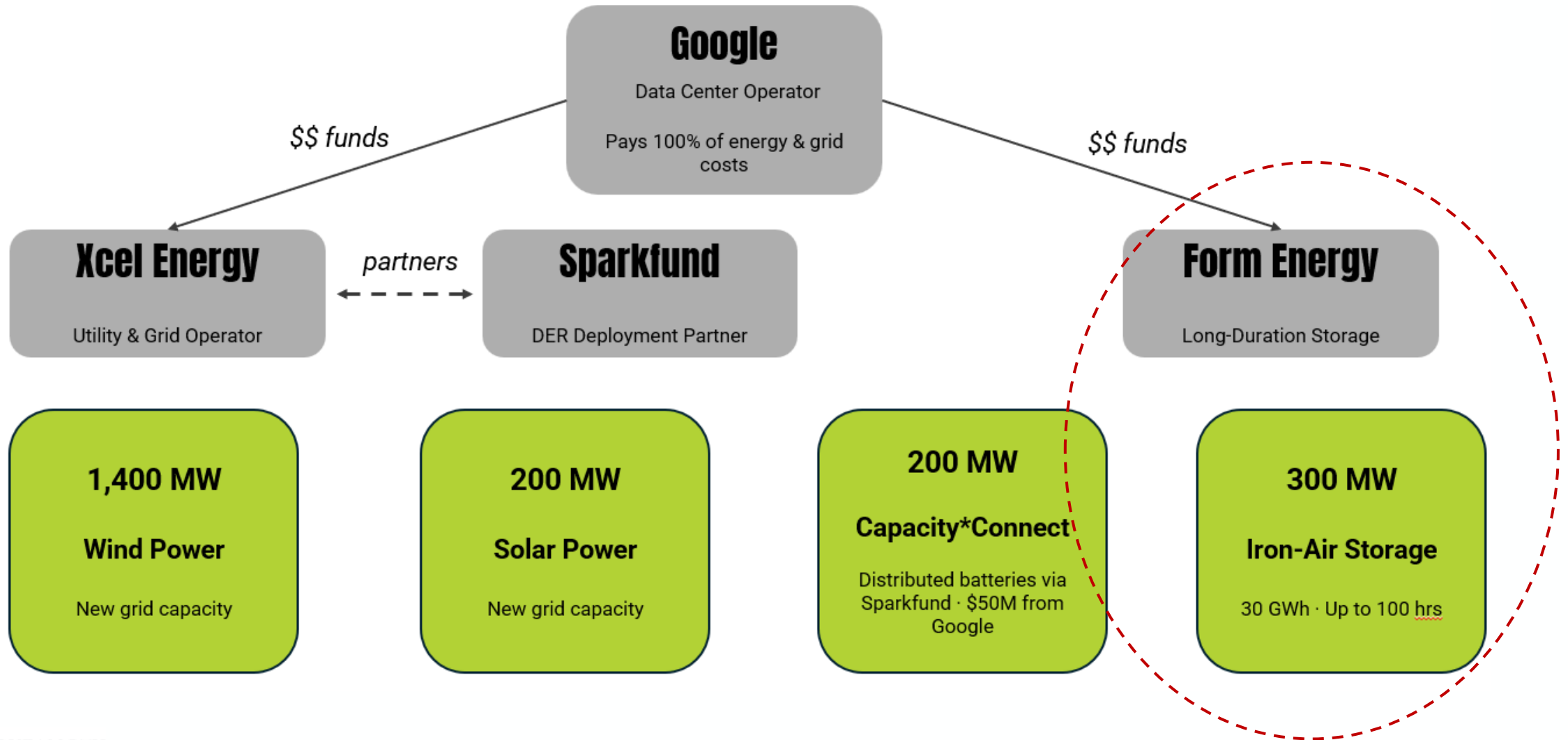


Source: TNI GHG Abatement Matrix — 2050 abatement estimates under a policy-supported scenario; represents a feasible upside scenario rather than a base case. See the Appendix for detailed assumptions.

Notes: 1) UNEP Emissions Gap Report (2025). 2) See Appendix for full explanations of calculations and sources.

Will the AI-boom restart the energy transition? Hyperscalers are supporting energy storage, geothermal and even nuclear to power DCs

Pine Island, Minnesota – 800MW Data Center “100% Renewable Power” Model

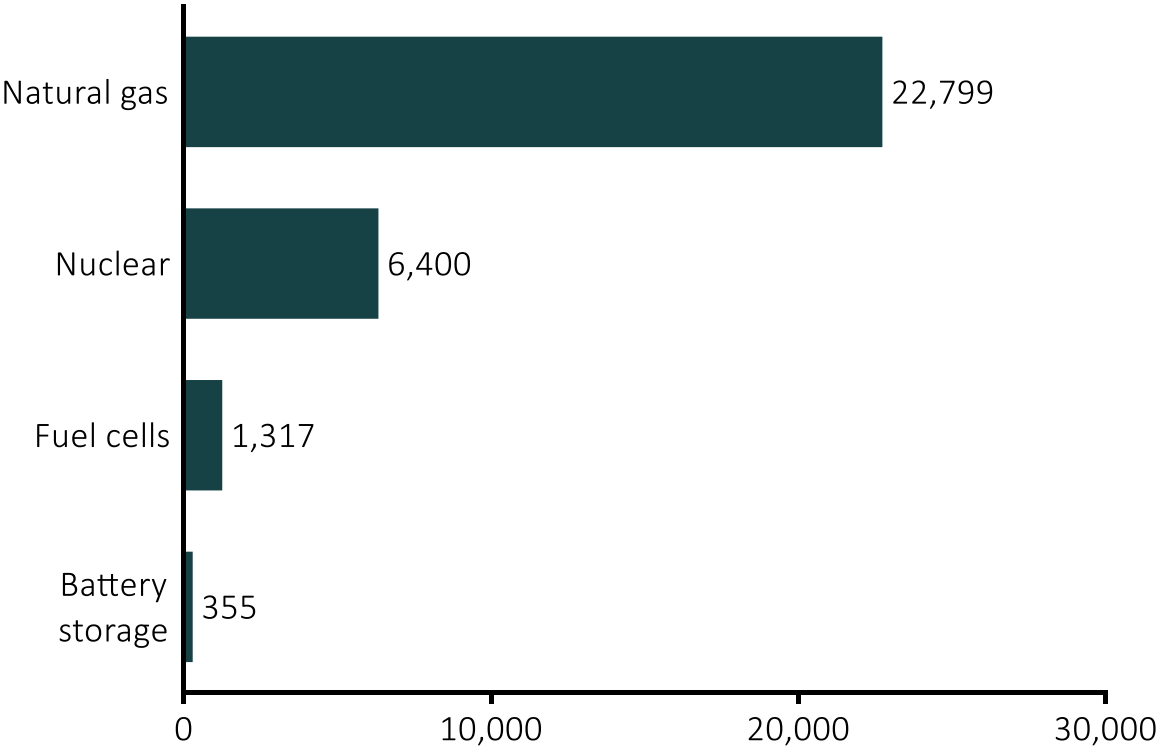


But Natural Gas is expected to be the dominant source of on-site power

Evolution of U.S. Data Center Power: Total Planned On-Site Capacity

MW of capacity

(Publicly disclosed Jan 2020 - Jan 2026)



- **Accelerating shift toward self-generation:** ~30% of planned U.S. data center capacity now features behind-the-meter power in order to bypass 5–10 year grid interconnection queues, up from ~0% a year ago.
- **Natural gas emerges as the primary fuel:** Natural gas accounts for ~75% of planned capacity, creating a structural infrastructure "lock-in" for the next 20–30 years.
- **Other investment implications may include enlarged carbon offset purchases** and markets as most of the hyperscalers have net-zero commitments and natural gas emissions will tally up to large offset requirements. However, Microsoft just stopped their carbon offset programme

Source: Cleanview: Data Centers in the United States, 2026.

Climate change policies are taking a back seat to more urgent priorities – especially in the current geopolitical environment

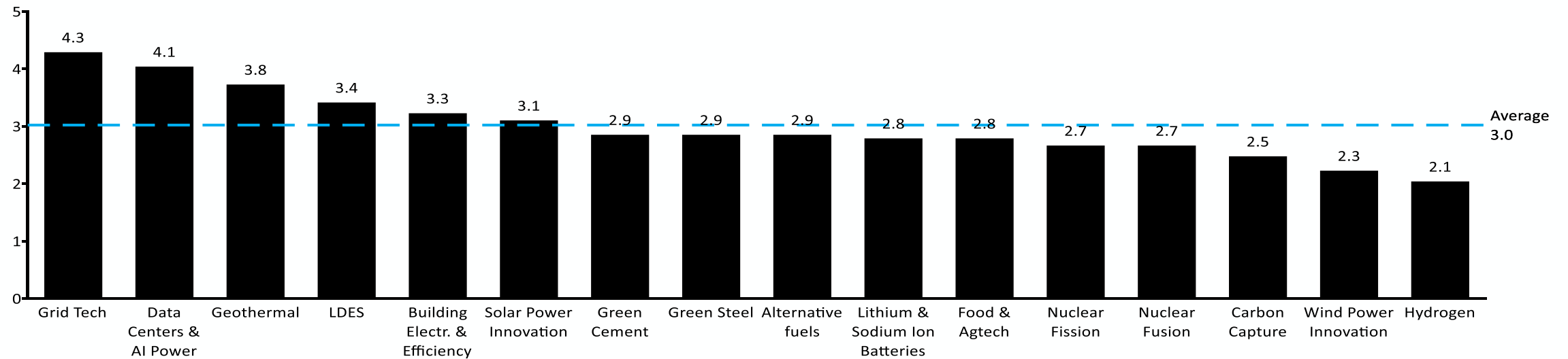
EU/UK 2020	EU/UK 2026	US Biden (21-24)	US Trump (25-28)
<ol style="list-style-type: none"> Climate Change (Green Deal) Digital Transformation Economic Prosperity Global cooperation (multilateralism) Migration, public services Rule of Law 	<ol style="list-style-type: none"> Security & Defence Competitiveness/ Industrial policy Green Transition Digital and AI Leadership Strategic Autonomy Migration EU as Geopolitical Actor 	<ol style="list-style-type: none"> Pandemic Response Economic Prosperity Climate Change Racial equity Healthcare Global Alliances Immigration 	<ol style="list-style-type: none"> Lead world in AI Economic Prosperity National Security Federal Spending Healthcare Immigration Drill baby drill Public Safety

Source: US priorities are published by the Whitehouse overlaid using AI with budget allocations and speeches content. European Commission Political Guidelines; there are no official ranked lists, but AI used to synthesise based on frequency of appearance in commission agendas and speeches, budget allocations and legislative output.

Climate tech with the worst stand-alone commercial prospects are the lowest investor priorities, naturally

Question 1: Rate each of these energy transition sectors in investment attractiveness from 1 to 5.

16 VC and Growth investors surveyed: Average score by technology



Sub-sector rating breakdown (count of responses) (N=16 VC and Growth Investment firms)

5*	10	8	8	3	3	2	3	3	2	-	2	1	2	-	-	1
4*	3	5	2	4	4	5	3	3	3	3	4	6	4	3	3	1
3*	2	1	1	6	5	4	1	1	6	8	2	1	1	5	2	1
2*	-	-	4	3	2	3	7	7	1	4	5	3	5	5	7	8
1*	1	2	1	-	2	2	2	2	4	1	3	5	4	3	4	5
Average	4.3	4.1	3.8	3.4	3.3	3.1	2.9	2.9	2.9	2.8	2.8	2.7	2.7	2.5	2.3	2.1

Climate Adaptation Investing - more naturally publicly funded investments - not much needs private capital

1. Weather Intelligence & Early Warning Systems
2. Wildfire Prevention & Management
3. Flood & Water Management
4. Climate Risk Assessment & Analytics
5. Resilient Infrastructure & Buildings
6. Heat Stress Management
7. Climate-Adaptive Agriculture
8. Satellite & Remote Sensing
9. Nature-Based Solutions Tech
10. AI & Open Climate Models

A lot of people are talking about climate change, not enough action

UN / Intergovernmental Architecture

- United Nations Framework Convention on Climate Change (UNFCCC)
- Conference of the Parties (COP)
- Intergovernmental Panel on Climate Change (IPCC)
- United Nations Environment Programme (UNEP)
- United Nations Development Programme (UNDP)
- International Energy Agency (IEA)
- International Renewable Energy Agency (IRENA)
- World Bank Group
- Green Climate Fund
- Global Environment Facility

Major Climate Conferences & Conveners

- Climate Week NYC — organized by Climate Group
- United Nations Climate Change Conference (COP)
- World Economic Forum Annual Meeting
- Bloomberg Green Summit
- VERGE by GreenBiz
- Global Climate Action Summit
- New York Climate Week
- Ecosperity Week
- ChangeNOW
- Blue Earth Summit
- Global Landscapes Forum
- TED Countdown

Think Tanks / Policy NGOs

- RMI (formerly Rocky Mountain Institute)
- Climate Crisis Advisory Group (CCAG)
- World Resources Institute
- Energy Transitions Commission
- Climate Policy Initiative
- Center for Climate and Energy Solutions
- Carbon Tracker Initiative
- Ember
- TransitionZero
- Third Way
- Breakthrough Energy
- Clean Air Task Force
- Resources for the Future

NGO Coalitions & Advocacy Networks

- Climate Action Network (CAN)
- 350.org
- Extinction Rebellion
- Fridays for Future
- Citizens' Climate Lobby
- Stop Climate Chaos
- Climate Group
- We Mean Business Coalition
- C40 Cities
- CDP
- The Climate Pledge
- Race to Zero

Finance & Investment Ecosystem

- Glasgow Financial Alliance for Net Zero (GFANZ)
- Institutional Investors Group on Climate Change (IIGCC)
- Climate Action 100+
- Principles for Responsible Investment (PRI)
- Task Force on Climate-related Financial Disclosures (TCFD)
- Transition Pathway Initiative
- Climate Bonds Initiative
- Sustainability Accounting Standards Board
- International Sustainability Standards Board

Philanthropic Foundations

- ClimateWorks Foundation
- Children's Investment Fund Foundation
- Bloomberg Philanthropies
- Bezos Earth Fund
- William and Flora Hewlett Foundation
- European Climate Foundation
- Quadrivium Foundation

Scientific / Academic Networks

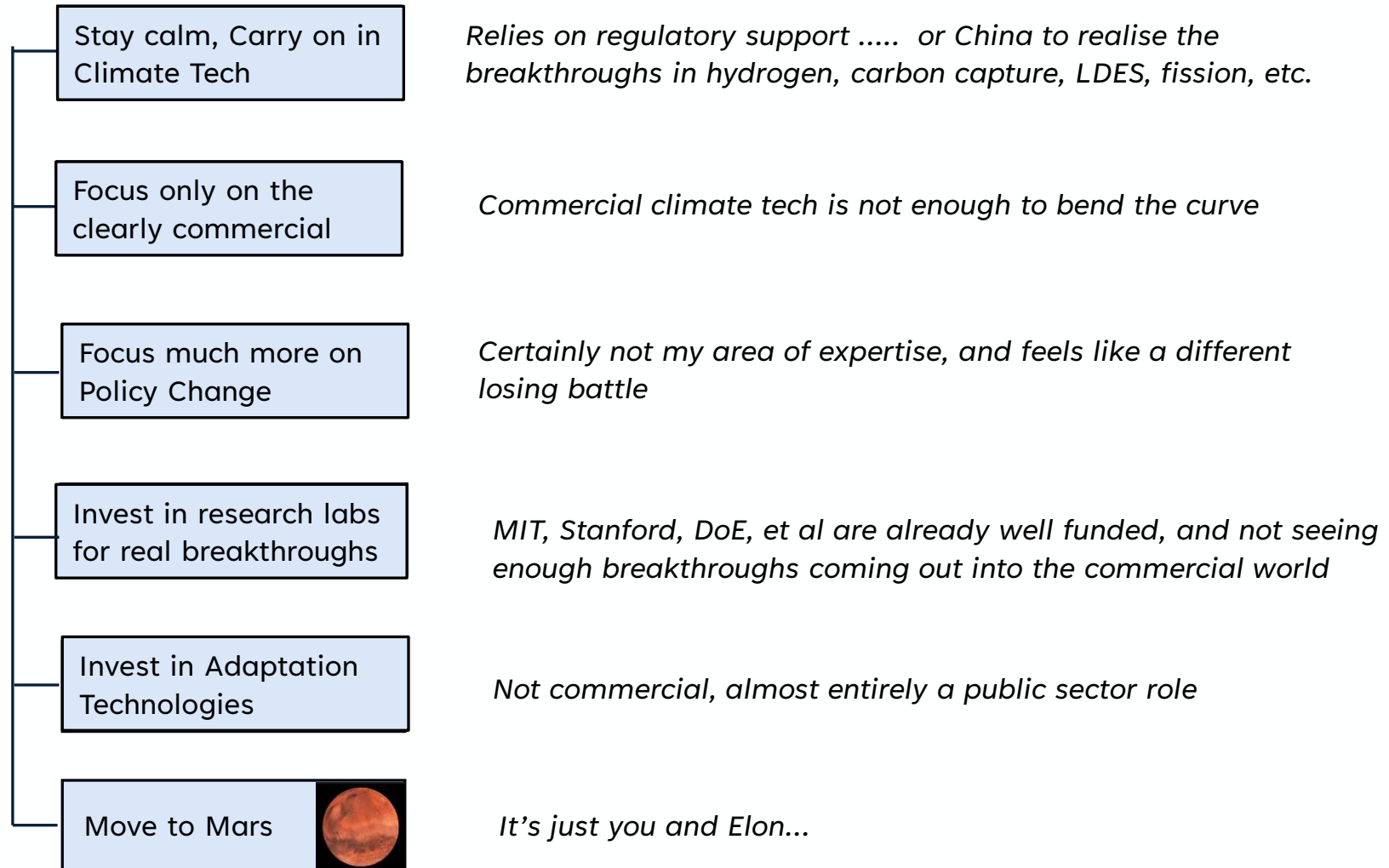
- Potsdam Institute for Climate Impact Research
- Stockholm Resilience Centre
- Tyndall Centre for Climate Change Research
- Climate Change Committee
- National Renewable Energy Laboratory

Climate Media & Information Platforms

- Heatmap News
- Canary Media
- Latitude Media
- Carbon Brief
- Trellis (formerly GreenBiz)
- Bloomberg Green

Climate Investment Strategy “Reset” Options

Climate Investment Strategy Reset Options



Is everyone pivoting from decarbonization to “resilience?”

Direct quote from the Managing Partner of a leading European Climate Focused late-stage VC

In the past year we have deliberately evolved the way we talk about energy decarbonisation, very consciously trying to reflect the present political and economic realities. We don't frame the energy transition as being led by policy, subsidies, and long-dated multi-lateral climate targets. We emphasise that successful climate-aligned technologies are pulled through by the classic business drivers: cost efficiency, competitiveness, security, resilience, and flexibility. Decarbonisation is positioned as a consequence of solving economic and strategic problems, not something anyone pays a premium for.

When we talk about energy transition, we lead with the facts about the teams and their businesses that can generate revenue and make money on their own merits, without green premiums, and happen to deliver lower-carbon outcomes because they are simply better, cheaper, or more resilient solutions. If they also are supported by regulatory tail winds and benefit from grants and subsidies that's great but tail winds can't be or become a dependency.

Is this where we have all landed with respect to our current strategy?

True North Institute's View?

Collaborative investing is the
key to breakthrough climate
technologies

There are too many startups, each with insufficient funding

Number of energy transition startup companies by critical sector and amount (\$M) invested to date









Critical Sector	# of venture backed start-ups	Av rounds / Company	Total capital invested (\$M)	Av capital invested / Company (\$M)	Average # investors per company
Nuclear Fusion	87	4.5	\$12,680	\$146	9
Nuclear Fission / SMRs	49	4.1	\$9,220	\$188	9
Hydrogen	280	3.3	\$7,320	\$26	4
Geothermal	80	3.7	\$3,960	\$50	6
Carbon Capture	105	4.4	\$3,100	\$30	6
Energy Storage (Thermal Batteries)	85	5.5	\$1,750	\$21	6
Energy Storage (LDES & Next Gen Battery Tech)	33	5.2	\$1,700	\$52	8
Battery Materials & Critical Minerals	42	3.8	\$1,160	\$28	6
Waste to Energy (BioFuels / Electrofuels)	76	3.5	\$830	\$11	3
Other Cleantech	890	3.3	\$13,480	\$15	3
Total VC-backed Energy Transition technology companies	1727	3.7	\$54,750	\$32	5

Source: Pitchbook (23.03.26)

Notes: (1) We have selected VC deals only across all VC stages of investment; (2) PitchBook uses various sub-sector categorizations; we have taken the "Emerging Space" categorization where possible; (3) Combined Electrofuels & Biofuels & Waste to Energy categorisation. Biofuels companies are those focused on "biofuel production" under PitchBook categorization. Infinium is listed as sole company under Electrofuels as per our VC filter in Pitchbook; (4) Nuclear fission companies are focused on "next-generation nuclear fission" based on PitchBook categorization. Also combined this categorisation with SMR Pitchbook categorisation; (5) Some PitchBook categorizations may include a broader definition, encompassing businesses associated with energy production rather than directly producing it. However, these typically make up only a small percentage of the total; (6) Battery Materials & Critical Minerals include "Lithium extraction technology" as per Pitchbook categorisation; (7) Hydrogen includes Hydrogen Energy and Geological Hydrogen, as per PitchBook categorisation; (8) Other Cleantech companies under "Emerging Energy" within Pitchbook includes the following categorizations: Smart Grid, Concentrated Solar Power, Batteryless IoT Sensors, Renewable Ocean Energy, EV Charging Infrastructure.

The energy transition has already produced multiple category-defining champions from syndication

Leading energy transition champions¹, sorted by valuation:

Company	Category	Sector	Listing status	Description	Year founded	Capital raised to pre-IPO / to-date ²	Most recent valuation ³	Notable investors
 TESLA	Champion	EVs	Public (2010)	Vertically integrated electric vehicle manufacturer with in-house battery, software and AI capabilities, including autonomous driving and robotics.	2003	\$1.4B	\$1.4T	Alphabet, Capricorn , DFJ, Jeffrey Skoll, JP Morgan, Larry Page, Mercedes, Sergey Brin, Valor Equity Partners
 Bloom energy	Champion	Fuel Cells	Public (2018)	Designs and manufactures solid oxide fuel cell systems for on-site power generation, with fuel flexibility across natural gas, biogas and hydrogen; also produces electrolyzers.	2001	\$1.6B	\$63B	Apex Venture Partners, CPP, E.ON, Exelon, Goldman Sachs, Kleiner Perkins, Morgan Stanley, NEA
 First Solar.	Champion	Solar Power	Public (2006)	Manufactures cadmium telluride (CdTe) thin-film solar modules for utility-scale projects; largest global thin-film producer and leading US-based solar OEM.	1999	N/a	\$18B	True North Partners
 NEXT POWER™	Champion	Solar Power	Public (2023)	Provides single-axis solar tracking systems and software that optimise panel orientation and increase energy yield in utility-scale and distributed solar projects.	2013	\$45M ⁴	\$15B	DBL Partners, Presidio Partners, Sigma Partners, TPG Rise
 energy	Emerging champion	Nuclear Fission / SMR	Filing for IPO	Develops the Xe-100 small modular reactor (80 MWe per unit, scalable to 320–960 MW) using a high-temperature gas-cooled design and proprietary TRISO-X fuel.	2009	\$3.0B ⁵	~\$7.5B ⁶	Amazon (The Climate Pledge), Ares, ARK, Emerson, Galvanize , Jane Street, Ken Griffin, NGP , OTPP, Point72
 REDWOOD MATERIALS	Emerging champion	Battery Recycling	Private	Builds a closed-loop battery supply chain by recycling batteries and producing critical materials domestically.	2017	\$2.3B	\$6B	Breakthrough Energy , Capricorn , Coatue, CPP, Fidelity, Ford, GS Asset Management, Microsoft, nVentures, OMERS, T. Rowe Price, Tesla
 Form energy	Emerging champion	LDSE	Private	Develops multi-day energy storage systems enabling high penetration of intermittent renewable energy.	2017	\$1.4B	\$3.4B	Breakthrough Energy , Capricorn , Coatue, CPP, EIP , Engine Ventures, GE Vernova, GIC, Gigascale , Macquarie, NGP , Prelude , Temasek ⁷ , TPG Rise
 FERVO ENERGY	Emerging champion	Geo-thermal	Filing for IPO	Develops next-generation geothermal projects using advanced drilling and reservoir engineering to deliver firm, carbon-free power.	2017	\$3.4B	\$7.6B ⁶	AllianceBernstein, B Capital, Breakthrough Energy , CalSTRS, Capricorn , Congruent , CPP, DCVC , Galvanize , Liberty Mutual, Macquarie, Prelude

Key: [AACN member](#)

Sources: Pitchbook (22.04.26); Bloomberg (22.04.26)

Notes: (1) Does not include Chinese champions (i.e., BYD, CATL) or publicly listed companies who have underperformed (i.e., Sunrun, QuantumScape) (2) Includes VC, growth equity, corporate M&A, project finance and debt, prior to IPO. (3) Taken as Enterprise Value for publicly listed companies. (4) NextPower was acquired by TPG Rise in an LBO before being taken public, this is not included as capital raised. (5) Includes \$1.3B in DOE grants. (6) IPO valuation 14 May 2026. (7) Temasek has since established two dedicated climate entities, Decarbonization Partners and GenZero, both of which are part of the AACN.

Members of All Aboard Co-Investment Network

We have assembled a coalition of top-tier investors committed to co-investing at the scale-up stage—effectively de-risking the investment as it brings speed, credibility, and alignment to every round

All Aboard Coalition Members (signed MoUs)



Have we lost the war on climate change? CONCLUSIONS

- **We are not “losing,” but not winning fast enough**
Renewable adoption is accelerating (now ~43% of electricity), yet global emissions continue to rise. Progress is real but insufficient.
- **Climate priorities are being overtaken by geopolitics and security**
Governments are increasingly prioritizing energy security, AI leadership, and national defence over decarbonization.
- **A major “climate capital reset” is underway**
Investment is shifting from net zero ambitions → resilience, adaptation, and infrastructure, with capital becoming more selective and commercially driven.
- **Policy support is less reliable; economics now lead**
Successful climate solutions must stand on cost, competitiveness, and resilience, not subsidies or ESG narratives.
- **Decarbonization is getting harder and more expensive**
Over half of emissions require > \$100/tonne to abate, and current technologies alone won't achieve net zero.
- **Breakthrough innovation is essential**
Roughly half of required emissions reductions depend on technologies that are not yet technically proven and economically competitive with fossil fuel substitutes; hydrogen and CCS, in particular.
- **Energy demand (especially AI) may slow progress on fossil fuels, but support it on geothermal, storage and nuclear.**
Data centre growth is driving increased reliance on natural gas, risking long-term carbon lock-in.
- **Investment implication: follow commercial viability**
Capital is flowing toward climate solutions that are profitable today, not just environmentally beneficial.
More syndication of private investors to invest behind the first commercial scaling stages will bring more technologies to viability (as the All Aboard Coalition is doing today).

Appendix: Technology carbon impact waterfall slide – sources and calculation assumptions

Proven & scaling today (24.4 Gt)

- 1) **EVs (4.8 Gt).** Passenger and light commercial vehicles emit c.5.1 Gt within the 10.1 Gt 2050 transport baseline. BNEF projects c.95% electrification of this segment by 2050, driven by cost-parity economics rather than incremental policy: $5.1 \times 95\% = 4.8$ Gt.
- 2) **Building efficiency including heat pumps (5.6 Gt).** IPCC AR6 quantifies 8.2 Gt of 2050 mitigation potential in buildings, equivalent to 61% of the 13.4 Gt BAU baseline. This brick takes only the 5.6 Gt efficiency lever, covering envelope improvements, appliances, lighting, smart controls and heat-pump electrification at COP > 1.
- 3) **Solar (4.0 Gt).** Wind and solar rise from 11.9% of global electricity in 2023 to 67% by 2050, creating 6.5 Gt of combined abatement. Solar is allocated 62% of this total based on the TNI Renewables Whitepaper solar:wind ratio: $6.5 \times 62\% = 4.0$ Gt.
- 4) **Grid efficiency – proven half (3.7 Gt).** Accelerating energy-intensity improvements from 1.8% to 2.8% per year reduces 2050 electricity demand by 21,300 TWh versus the historical-efficiency case. At 0.35 tCO₂/MWh displaced fossil intensity, this gives 7.4 Gt of total grid-efficiency abatement, with the proven half relying on smart meters, demand response, motor standards, HVAC controls and basic grid modernisation.
- 5) **Methane (3.0 Gt).** IEA Methane Tracker 2025 puts anthropogenic methane at c.580 Mt CH₄, including c.135 Mt from energy and 75 Mt from landfills. Applying AR6 GWP-100 factors gives c.1.5 Gt from oil and gas methane, 0.5 Gt from coal mine vent methane and 1.0 Gt from landfill methane.
- 6) **Wind (2.5 Gt).** Wind is allocated 38% of the combined 6.5 Gt wind and solar abatement brick, based on the TNI Renewables Whitepaper solar:wind ratio: $6.5 \times 38\% = 2.5$ Gt. This is split 50:50 between onshore wind and offshore wind.
- 7) **Storage / batteries (0.8 Gt).** The model assumes 3,200 GW of short-duration storage by 2050, comprising c.2,500 GW of 4-hour grid-scale LFP batteries and c.700 GW of pumped hydro. At 250 cycles per year, 4-hour discharge and 0.25 tCO₂/MWh displaced fossil intensity, this gives $3,200 \text{ TWh} \times 0.00025 = 0.8$ Gt.

Requires breakthrough innovation or regulatory support (23 Gt)

- 1) **Green industry (4.3 Gt).** Industrial decarbonisation excluding hydrogen and CCS contributes c.4.3 Gt across three sub-components: steel at 1.6 Gt from material efficiency, scrap-EAF mix shift and BF-BOF efficiency; cement at 1.2 Gt from clinker substitution; and other industries at 1.5 Gt across chemicals, refining, aluminium, pulp and paper, and other manufacturing.
- 2) **BECCS and agriculture (4.1 Gt).** BECCS contributes c.3.0 Gt, within the IPCC AR6 range but constrained by sustainable biomass supply, land use and water intensity. Agriculture contributes c.1.1 Gt through dietary shifts and soil practices, giving $3.0 + 1.1 = 4.1$ Gt.
- 3) **Grid efficiency – breakthrough half (3.7 Gt).** The remaining half of the 7.4 Gt grid-efficiency opportunity requires advanced grid digitalisation, large-scale demand response, AI-enabled grid optimisation, HVDC and superconductor interconnects, V2G integration and regulatory reform of capacity markets.
- 4) **Hydrogen (3.6 Gt).** Clean hydrogen abatement is built bottom-up from c.300 Mt of clean hydrogen demand by 2050. Key sources are grey-H₂ replacement in refining, ammonia and methanol, steel DRI, long-haul trucking FCEVs, shipping fuels, aviation e-fuels / SAF and peaking power replacing gas. Combined abatement is c.3.6 Gt, but remains policy-dependent given clean hydrogen at \$4–6/kg versus grey hydrogen at \$1–2/kg.
- 5) **Carbon capture (3.0 Gt).** Carbon capture contributes c.3.0 Gt across power, cement and steel: 1.5 Gt from power CCS, 1.0 Gt from cement CCS and 0.5 Gt from steel CCS-DRI deployment.
- 6) **LDES and thermal heat (2.2 Gt).** Long-duration storage and industrial process heat contribute c.2.2 Gt in total: 1.0 Gt from 4,000 GW of LDES capacity by 2050, 1.0 Gt from mid-temperature industrial thermal heat below 500°C, and 0.2 Gt from high-temperature cement kiln electrification.
- 7) **Nuclear (1.0 Gt).** Incremental nuclear generation of c.2,000–2,500 TWh by 2050 displaces fossil generation at c.0.5 tCO₂/MWh, giving c.1.0 Gt of abatement.
- 8) **Geothermal (1.0 Gt).** TNI projects 250 GW of geothermal capacity by 2050, compared with a 120 GW IEA/IRENA base case. Net new capacity of 234 GW at an 80% capacity factor produces c.1,640 TWh per year, displacing coal-heavy EM generation at c.0.55 tCO₂/MWh: $1,640 \times 0.00055 = 0.9$ Gt, rounded to 1.0 Gt.