How to Foster a Direct Air Capture Cost 'Miracle': What DAC Can Learn from Solar

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Introduction

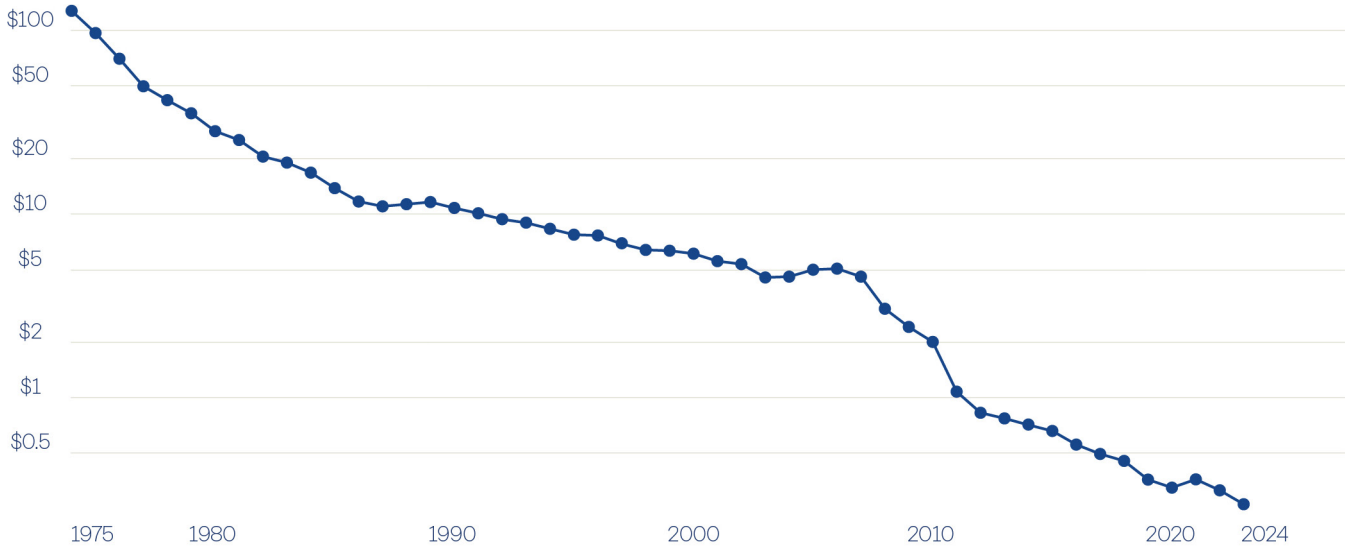
Over the past 50 years, the cost of solar photovoltaic (PV) panels fell from more than $125 per watt to less than $0.15 per watt (Dardour et al. 2025). In the past 20 years alone, costs decreased by over 90% (Figure 1). Solar power is now cheaper than fossil power in most markets, even without subsidies (Dardour et al. 2025).

In fact, solar has become the largest source of new electricity capacity added worldwide—and has passed 10% of total installed electricity capacity globally—powering economic growth without adding to climate change (Figure 2, Ember 2026).

This policy digest asks what it would take to repeat that achievement for direct air capture (DAC) technology—from not only a technical perspective, but also a political, economic, and social perspective. Could DAC costs fall by 90% within two decades, as solar PV did? And could a sustained, multi-decade campaign drive DAC to the scale needed not only for it to contribute meaningful towards achieving a net-zero economy, but also for enabling a net-negative economy by 2050 that draws down the legacy CO_2 already committed to the climate system?

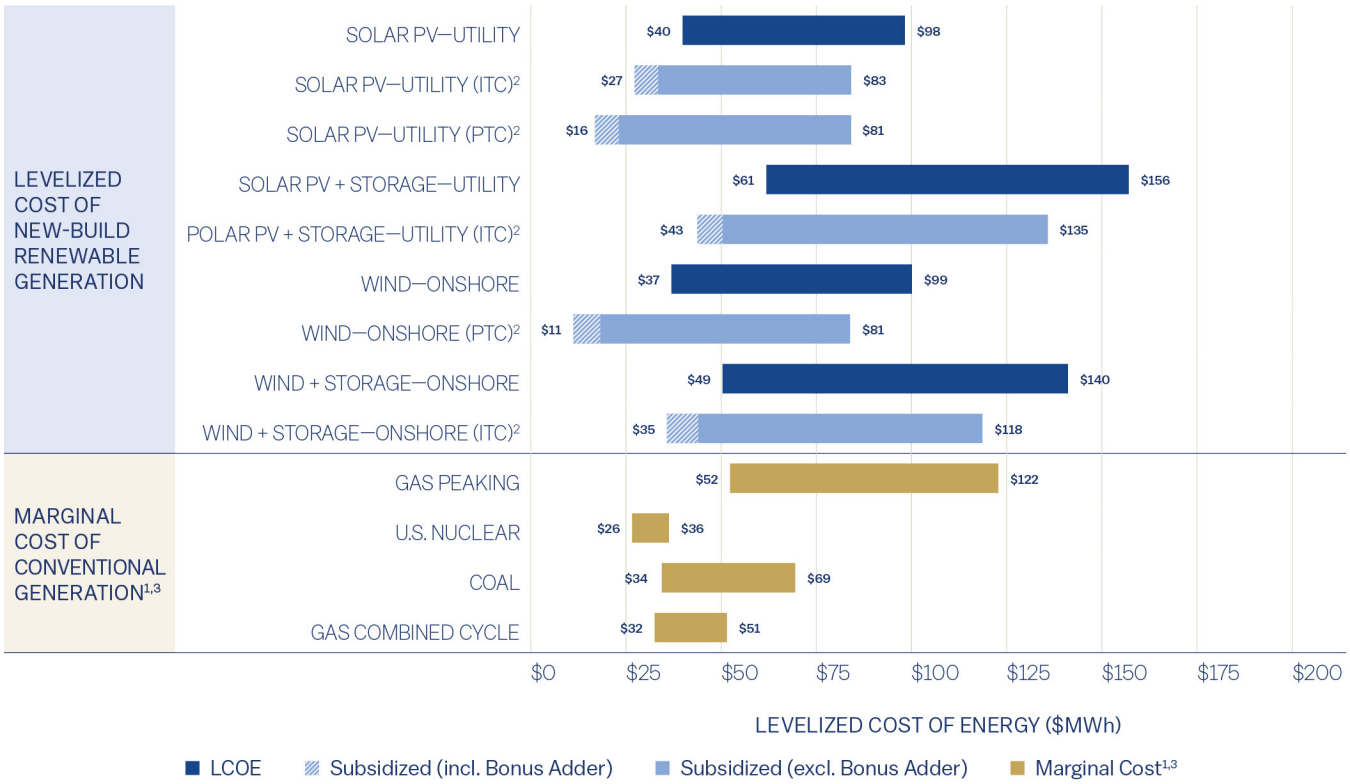
This analysis draws on secondary research and primary interviews with practitioners from the U.S. solar PV industry, and it closes with policy recommendations for the U.S. DAC sector grounded in five decades of solar commercialization.

Figure 1: Global Solar PV Module Prices, 1976–2024 (U.S. Dollar per Watt, Log Scale)



Source: Our World in Data 2024.

Figure 2: Levelized Cost of Energy (LCOE) by Technology in Dollars per Megawatt-hours ($/MWh)

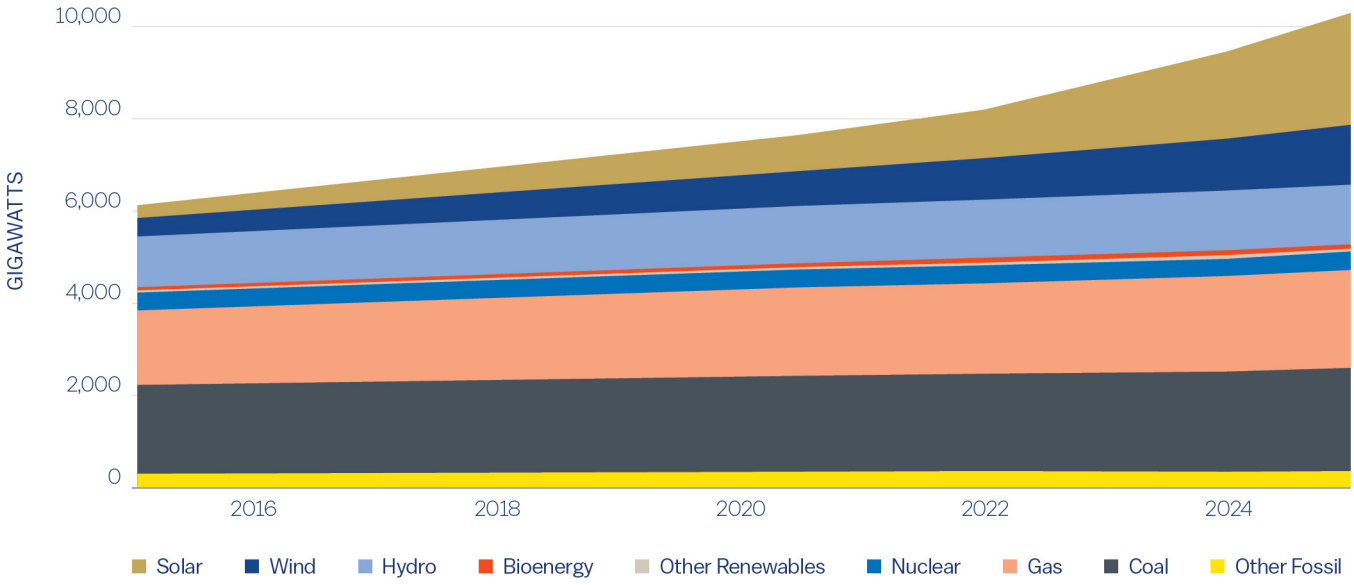


See footnotes at original source.

Relevant acronyms: ITC = investment tax credit, PTC = production tax credit.

Source: Lazard 2026.

Figure 3: Annual Global Power Capacity Additions by Source in Terrawatt-hours (TWh)



Source: Ember 2026.

Why a Direct Air Capture (DAC) Miracle Matters

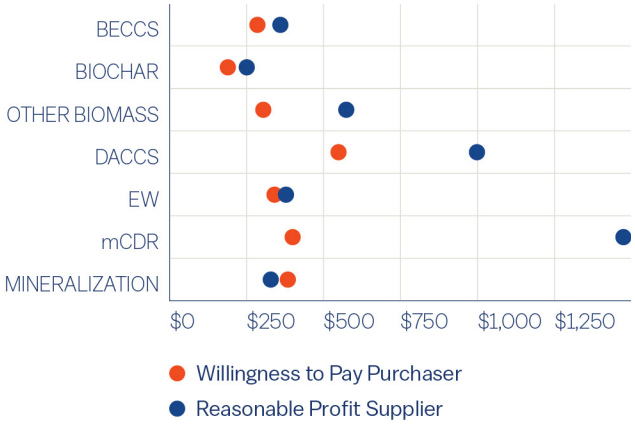
To achieve net-zero emissions globally and then to reverse any carbon budget overshoot associated with Paris Agreement targets, carbon removal is needed at the gigatonne per year scale within a few decades (Lamb et al. 2024). To deliver carbon removal at this scale, a DAC cost breakthrough is essential.

A portfolio of low-cost, large-scale removal is essential to meeting climate goals affordably. DAC is a key option in the carbon removal portfolio, with significant scale potential (Rodriguez et al. 2025). But DAC today costs roughly between $500 and $1,000 per ton of CO_2 removed (CDR.fyi 2026a)—costs will need to fall by several multiples for large-scale deployment to be affordable.

Carbon prices sit between $25 and $75 per ton in most large compliance markets in which DAC could theoretically compete (World Bank 2025). These prices are projected to exceed $100 per ton in systems such as the European Union Emissions Trading System (EU ETS) by 2030 (Catsaros 2025). But even these higher prices are unlikely to support DAC commercialization alone.

Niche markets for voluntary removal credits are high-priced today and have supported a number of early DAC demonstration projects (Figure 4). But voluntary carbon markets are dominated by a limited set of buyers (Figure 5). As a result, there are significant concerns that they will not scale to volumes anywhere close to compliance markets, and cannot carry DAC to scale for much longer.

Figure 4: Direct Air Capture Price Estimates, 2026

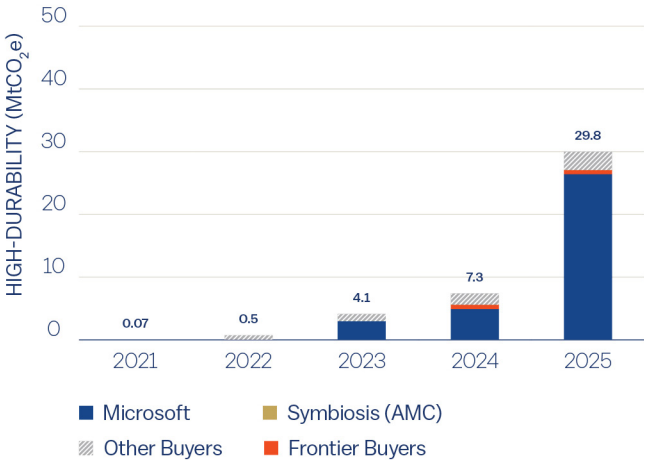


"What price (USD per tonne) would your organization be willing to pay if it were to make purchases for the following methods?" / "For your primary durable CDR method, what price (USD per tonne) would provide a reasonable profit if sales were made in that year, at prevailing market prices at the time, rather than contracted in advance for future delivery?"

Relevant acronyms: CDR = carbon dioxide removal, BECCS: bioenergy with carbon capture and storage, DACCS = direct air carbon capture and storage, EW = enhanced weathering, mCDR = marine carbon dioxide removal.

Source: CDR.fyi 2026a.

Figure 5: Forward Offtake Agreements for CDR Credit Purchases



Relevant acronyms: $MtCO_2e$ = megatons of carbon dioxide equivalent, AMC = advance market commitment.

Source: Carbon Direct 2026.

Driving the cost of DAC down the cost curve would provide significant political benefits for climate policy. If DAC could compete in major carbon markets as an affordable, scalable offset for hard-to-abate sectors, it would help sustain political will for net-zero by limiting the rise of carbon prices as the economy nears full decarbonization.

And without affordable DAC, cleaning up legacy emissions at the multi-gigatonne scale needed to reverse carbon budget overshoot becomes far harder. The history of agreements such as the Montreal Protocol shows that policymakers struggle to mandate pollution controls until technically- and economically-viable control technology exists (Parsons 2003). DAC offers one of the best opportunities for affordable and scalable carbon removal that could enable such political agreements on carbon removal in the future.

A DAC Miracle Hangs in the Balance

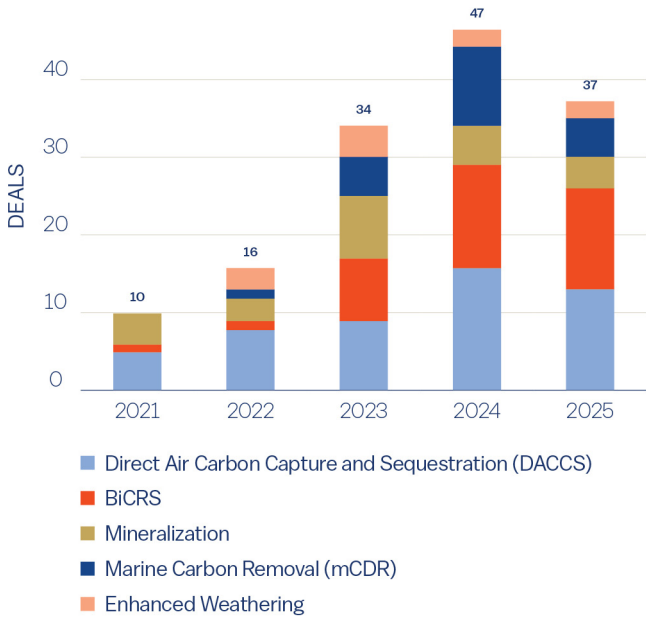
Support for DAC is at an inflection point today. Over the past decade, public and private funding carried DAC from academic concept to nascent industry. But the tailwinds are reversing. The number of venture capital deals for carbon dioxide removal (CDR) fell from 2024 to 2025 (CDR.fyi 2026b), as investors wrote fewer—although larger—checks to existing startup companies (Edwards et al. 2026). Additionally, Microsoft's announced pause in future CDR credit purchases threatens voluntary corporate demand (Meyer 2026).

Federal support has also stalled. The 45Q tax credit[1]—the federal incentive that now pays up to $180 per ton for DAC—was preserved in the 2025 One Big Beautiful Bill Act (OBBBA) (Carbon Capture Coalition 2025), but roughly $3.6 billion in Bipartisan Infrastructure Law funding for DAC Hubs (U.S. Department of Energy (DOE) 2024) and federal CDR purchasing (U.S. DOE 2023) is now at risk of being either frozen or rescinded (Edwards et al. 2026).

The consequences of that retrenchment are uncertain. But the history of solar PV offers a close analog and a set of lessons for navigating exactly this kind of moment.

1 Section 45Q of the U.S. Internal Revenue Code provides a per-ton tax credit for captured CO_2 that is securely stored or used. The 2022 Inflation Reduction Act set the credit at up to $180 per metric ton for CO_2 captured via DAC and stored in secure geologic formations.

Figure 6: Venture Investment in Carbon Dioxide Removal, 2021–2025



Relevant acronyms: BiCRS = biomass carbon removal and storage, DACCS = direct air carbon capture and storage.

Source: CDR.fyi 2026b.

The Solar PV Miracle

Solar PV's cost decline is well documented. Analyses such as Greg Nemet's *How Solar Energy Became Cheap* attribute it to a stack of factors: scientific discovery, engineering breakthroughs, and manufacturing and financing innovation (Nemet 2025). But none of it would have mattered without early policy support that created demand while solar remained more expensive than the alternatives.

Part 1: A Solar Spark, 1970s

The 1970s saw a wave of both public and private investment in solar PV innovation. The U.S. DOE moved beyond funding basic research on solar PV technology, and launched a "Block Buy" program to drive early demand for solar PV panels. This program was justified primarily on national and energy security grounds in the wake of the energy crises of the 1970s and projections of falling U.S. oil production (Nemet 2025). Oil major Exxon also launched a wholly-owned subsidiary—Solar Power Corporation—designed to commercialize solar PV technology.

As a result of this innovation, solar PV prices dropped from roughly $150 per watt ($/W) to less than $15/W by the early 1980s. Despite this massive progress, solar PV costs would need to come down by another order of magnitude before the technology would begin to be commercially viable at meaningful scale.

Part 2: Thin Ice, 1980s–1990s

Initial U.S. government and private sector support for solar PV waned substantially in the early 1980s, throwing the field into decades of slower progress. The cause of the decline in solar PV innovation progress was not technical—solar manufacturing required no input technology or breakthrough innovation that was missing in the 1980s, but was present in the 2000s. There was also no exogenous macroeconomic or geopolitical reason for this slowdown—the global economy did not collapse, and no war degraded the capacity to innovate.

The slowdown instead reflected policy and market choices (Nemet 2025). In the early 1980s, the Reagan administration unwound the U.S. DOE's "Block Buy" program (Potter 2023), and Exxon shut down its Solar Power Corporation (Hsu 2019). Shortly thereafter, Saudi Arabia flooded global markets with low-cost oil, depressing energy prices and dulling the affordability and energy-security case for solar (Yergin 1991). As a result, the solar PV field nearly died in the late 1980s. Solar panels were far cheaper than a decade earlier, but were still well above the cost of fossil power. Niche markets, such as solar-powered calculators in Japan, were nearly all that kept the industry, and its cost curve, alive.

Part 3: Revival, 2000s

Policy revived the industry in the 2000s. On the demand side, climate-focused governments—Germany (in 2004), California (in 2006), Spain (in 2007) and others—mandated or subsidized solar purchases. On the supply side, and later during the global financial

crisis, China subsidized manufacturing at scale. Together these created a reinforcing cycle of falling costs, rising deployment, and new policy that carried solar to where it stands today (Nemet 2006; van der Zwaan 2003).

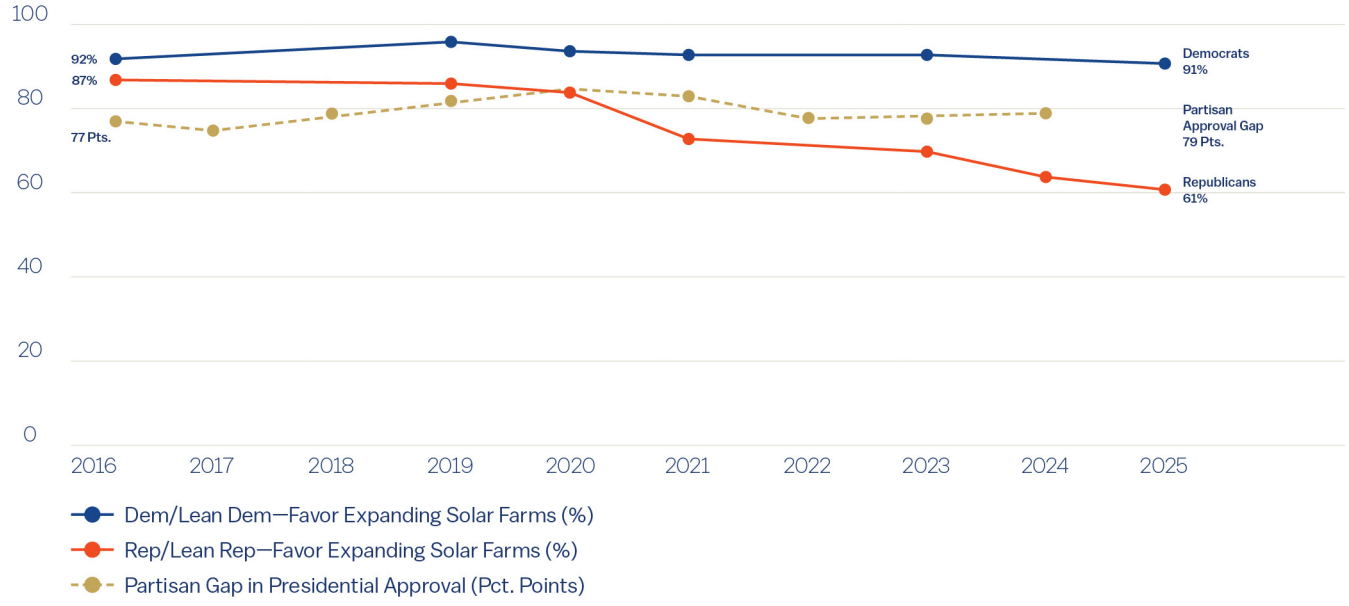
Key Lessons of the Solar PV Miracle

It is notable that policy was not only needed as a catalyst for the industry in the early days, but instead as a durable companion of technology and market advances over decades. Even now, unsubsidized solar paired with battery storage has not fully displaced the cheapest firm power on a system-wide basis, showing the importance of durable policy frameworks.

Solar PV's experience also shows that while technology learning has proven durable, political support has not. The U.S. federal solar tax credit lurched from deadline to deadline over two decades, often leaving the industry unsure whether the credit would survive the year (King et al. 2024). Additionally, the bipartisan backing solar enjoyed in the 2000s eroded as the broader U.S. electorate polarized (Figure 7).

The lesson is that manufacturing, finance, and installation gains—which represent the bulk of cost reductions once foundational engineering has been derisked—are all contingent on bankable demand. Given low-cost incumbent sources of fossil energy, bankable demand for solar PV was contingent on strong and durable policy frameworks. When policy wavers, the chain needed to keep up the pace of innovation weakens.

Figure 7: Partisan Divergence in Clean-Energy Support Over Time

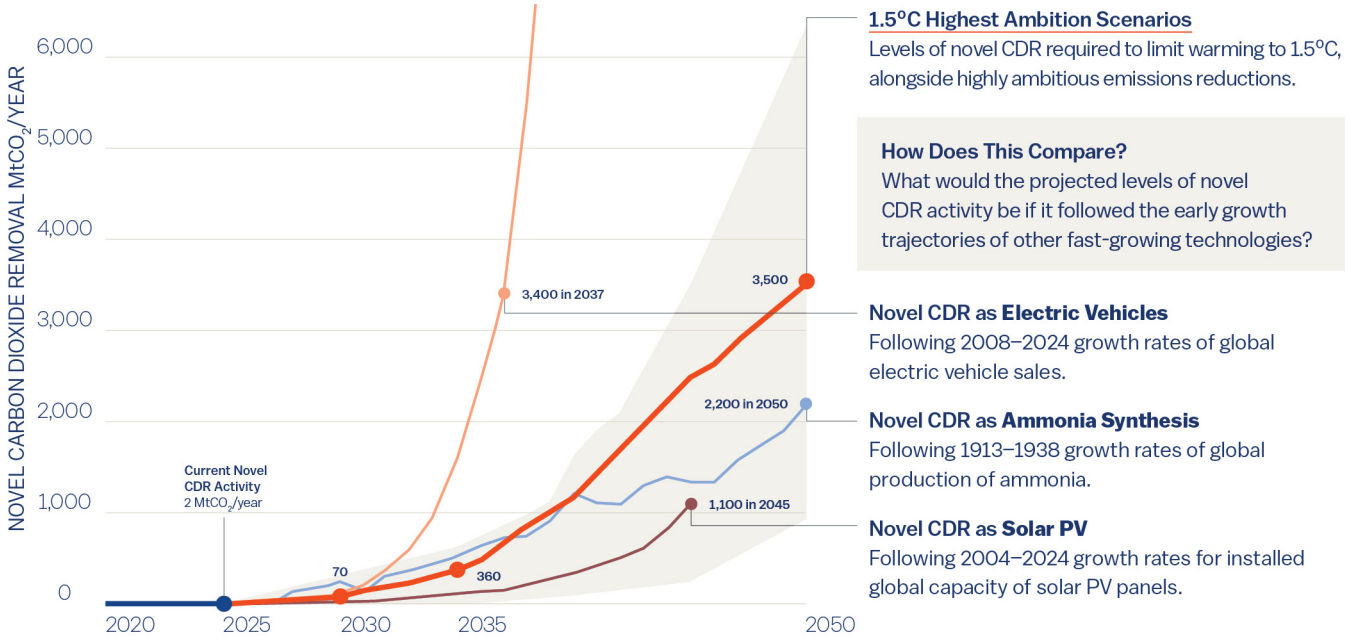


% who favor expanding solar panel farms, by party—with the annual partisan gap in presidential job approval.

No party breakout was published for 2022, or for Democrats in 2024. Both measures are in percentage points, so they share one axis, but they are different quantities and the chart implies no causal link.

Sources: Pew Research Center (solar), Gallup (approval gap, through 2024). Figure source: Author analysis.

Figure 8: Solar PV Compared to Other Technologies that Share Similarities to DAC



Source: Edwards et al. 2026.

Solar PV as an Analog to DAC

In many—though not all—respects, solar PV is an apt analog for DAC. Technically, it is plausible that DAC follows a similar cost trajectory to solar PV. The National Academies' 2018 assessment found that even early-generation DAC could approach $100 per ton through compounding improvements to existing technology, with no new invention required (National Academies of Sciences, Engineering, and Medicine 2019; van der Spek et al. 2025).

The "State of CDR" report also finds that solar PV is not a unique analog for technology scaling that is relevant to DAC (Edwards et al. 2026). Other technologies, including those like ammonia synthesis that look technically more similar to DAC than solar PV, have also scaled as fast as DAC would need to scale to contribute meaningfully to Paris Agreement-aligned decarbonization trajectories.

Even more so than solar PV, whether DAC actually descends that curve depends on sustained policy and investment. There is no inherent market for atmospheric removal services or market, and no carbon market currently has prices high enough and at significantly large scale to fund early commercialization on its own. Furthermore, DAC represents one of the highest cost voluntary CDR credit options, making overall voluntary carbon removal demand generally likely a significant overestimate of overall voluntary DAC demand specifically (Mistry et al. 2024).

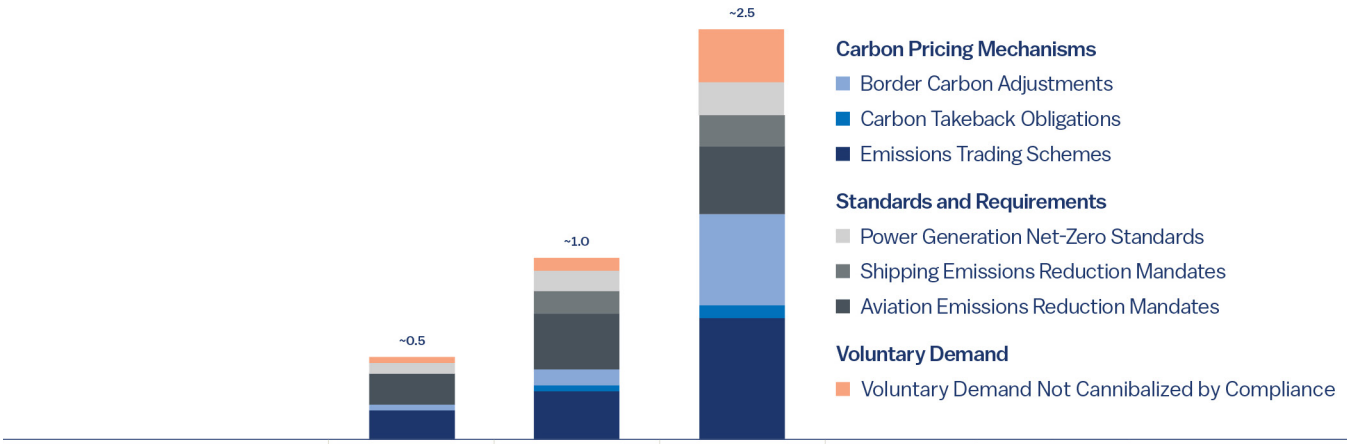
Solar PV is a weaker analog in one crucial respect—the "temporary" nature of its support. DAC will require a bankable (i.e., a steady and meaningfully high priced) demand driver—a carbon market/regulation, procurement, tax incentive, or some combination—to deliver climate-relevant removal even after it completes a cost breakthrough (Hickey 2003). That makes steady political support even more important for DAC than it has been for solar.

Reaching roughly $100 per ton will likely take at least 20 years even in optimistic scenarios, a span that will see repeated political swings in the U.S. and other key markets. Policies that retain appeal regardless of who holds power are therefore essential; stop-and-go

support would delay deployment, cause slow learning, and undermine the public-market financing the industry needs, much like a lack of steady policy has likely delayed solar PV's scale up.

DAC also depends more heavily on carbon accounting than solar did. Renewable energy credits mattered for solar, but for DAC, rigorous carbon accounting is the core product for credit purchasers that dominate early markets. That accounting is simpler than for many removal pathways, yet still demands careful judgment, particularly in accounting for the energy DAC consumes (Hausfather et al. 2022).

Figure 9: 2050 Projected Voluntary Versus Policy-Driven CDR Demand (Gt CO_2)



	LOW SCENARIO	MEDIUM SCENARIO	HIGH SCENARIO	RELEVANCE OF SCENARIO CONDITIONS TO DRIVERS		
Strength of Policy Pressure to Address Emissions	Weak	Moderate	Aggressive	✓	✓	Some effect from increased compliance demand cannibalizing voluntary demand
Prioritization of Durable CDR vs. Non-Durable, by Governments	Low	Medium	High	✓	✗ "Like-for-like" approach requires durable only	
Average CDR Portfolio Price (Including Low Durability CDR)	Moderate	Moderate	High	✓	✗	✓
Average Durable CDR Price per ton CO_2	~$200–$300	~$150–$250	~$100–$200	✓	✓	✓
Degree of Demand Reductions due to Behavior Change	Significant	Moderate	Minimal	✓	✓	✗

Relevant acronym: Gt CO_2 = gigatonnes of CO_2.

Source: Mistry et al. 2024.

Six Lessons for DAC

Solar PV's history makes it clear that for DAC to succeed, it needs steady and robust policy support that creates sufficient bankable demand to drive deployment-led cost reductions over the coming decades. Solar PV's history also offers six specific lessons for ***how*** the U.S. DAC sector can achieve such steady and robust demand-side policy support, drawn from interviews with solar policy practitioners.

1. **Anchor messages beyond climate.** Early solar advocates were often climate-motivated, but the field won policy victories only after adopting other frames. Consumer affordability, business savings, and energy security all resonated where climate did not. Leading with non-climate frames is harder for DAC, but not impossible. Support for DAC can be framed around the jobs it will create for communities that host projects (Jones et al. 2023) and the regional economic benefit that DAC-related investment can bring (Pett-Ridge et al. 2023). DAC is also already an affordability strategy in some carbon markets, notably low-carbon aviation (Deich 2026). And it can pair with data center growth to enable hyperscalers to maintain voluntary climate commitments (McKey et al. 2025). DAC can also embrace utilization—for e-fuels and enhanced oil recovery[2]—to support innovation on energy and national-security grounds (Deich 2025), even where those uses do not optimize for removal.
2. **Don't let perfect be the enemy of the good.** Solar's history shows that a sub-optimal policy enacted sooner beats a better one enacted later. In the mid-2000s, solar advocates succeeded at modifying an existing federal investment tax credit, rather than attempting to build a new production tax credit that some clean energy advocates preferred. Because the investment credit proved financeable, moving fast let the field build projects, cut costs, and widened its coalition of political supporters. For DAC, this argues for continuing to expand 45Q, even if tax credits are not the ideal long-run framework, and for riding broader carbon-management and climate legislation, rather than focusing on standalone bills—which also broadens the political base.
3. **Make early adopters advocates.** Solar advocates invested heavily in local coalitions where policy conditions were favorable. Groups such as Vote Solar mobilized early adopters and supply-chain beneficiaries into political activity (Vote Solar n.d.). DAC can do the same with communities, workers, investors, corporate offtakers, and academics. The playbook will differ given DAC's business-to-business nature, but building the broadest, most vocal early base possible will maximize traction.
4. **Keep the coalition unified.** Early solar faced pushback from entrenched incumbents and survived by delivering clear, consistent messages from a wide range of voices—which required hard compromises on strategy. For DAC, that means prioritizing compromise among early stakeholders and focusing on as few core priorities as possible; competing priorities dilute every effort.
5. **Build a political contribution strategy.** After *Citizens United*, sustained political contributions are increasingly decisive in policy outcomes. Solar learned that bipartisan, bicameral giving across multiple cycles is critical and cannot be assembled quickly, though it can be lost much faster. For DAC, building that capacity should start now; on the order of tens of millions of dollars per cycle at the federal level is becoming table stakes for industries to advance their core policy priorities.
6. **Diversify geographically.** Solar benefited from policy in Germany, Japan, China, and Australia, and from U.S. state action alongside federal credits—grassroots and grass-tops coalitions in states like California proved decisive for early rooftop and net-metering mandates. DAC is already advancing in places like Canada, Europe, and Kenya, with increasing interest in places like Japan and Australia. The industry should build that patchwork into a more cohesive global ecosystem that can withstand swings in any single jurisdiction. In the U.S., California's large carbon markets and states with major data center buildouts offer particular openings, where regulators can pair high demand with deep corporate balance sheets to finance early DAC.

2 On utilization pathways for captured CO_2, see Singh et al. 2024 and Tiwari et al. 2025.

Conclusion

DAC can learn a great deal from solar PV, but translating those lessons into effective policy will be challenging. The field is young and cannot pursue every lesson at once. It will have to concentrate its bets on a few geographies and strategies. It will also need luck, as solar's policy wins were never inevitable and depended on macro conditions aligning with motivated policymakers and enthusiastic early advocacy bases at the right moment.

The success of DAC, similarly, is far from inevitable. Advocates need to be clear up front what it will likely cost to start seeing cost reductions, with near-term milestones that give the public a clear view into what the learning curve for DAC is in practice, not just theory—and what to do if DAC costs are falling slower than hoped. Over time, the DAC community will also need to manage increasingly larger coalitions necessary for political support, requiring their political strategies to evolve in parallel.

The encouraging corollary is that only a few dedicated actors are needed to shift DAC's early trajectory today. Because DAC still sits below the most contested political fights of the day, it draws little attention—but the policymakers who do engage can make a real difference without needing to assemble large coalitions or risking significant political cost. By the same logic, advocates do not need vast budgets to win. They do need sustained advocacy and strategic communication focused squarely on supporting the early projects that move DAC down the cost curve—even if that means unusual alliances and messages tailored to stakeholders whose motivations differ from their own.

If the DAC sector can marshal that support, there is no technical reason a DAC cost "miracle" cannot arrive in the coming decades—provided policymakers in the U.S. and other key markets prove persistent, consistent, and forward-looking.

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Noah Deich is a senior fellow at the Kleinman Center. He served in the Biden administration's deputy assistant secretary for carbon management at the Department of Energy and supported a range of carbon capture and carbon removal initiatives. Previously, Noah co-founded Carbon180, a NGO focused on advancing carbon removal solutions.

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