THE BLACK SWAN MATRIX



The Black Swan Matrix is an *endgame* cascade of *unpredictable* climate shocks, subjugating fossil-fuel politics and runaway environmental feedback loops that defy linear forecasting. It is the *umbrella emergency that* envelops and eclipses all other human problems, demanding immediate, concerted action through Direct Atmospheric Carbon Removal on a scale of mobilization that has not been seen since WWII.

THE BLACK SWAN MATRIX

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"By the time we saw that Climate Change was really, really bad, our ability to fix it was extremely limited. If you reduce emissions, things are still going to get worse. If we don't remove the massive amount of carbon already in the atmosphere immediately, we will forfeit our children's future. Full stop."

- Bill Gates, Founder of Microsoft

"It's endgame for civilization. We just won't survive this. What we are saying is, we have to refreeze the Arctic region, and we have to refreeze it quickly."

- Sir David King, Chief Climate Advisor to the British Government

"This is the start of a new era in American energy production and job creation. We're going to have clean coal, really clean coal, and we will drill, baby, drill."

- Donald Trump, President of the USA

"The climate has always been changing. We should not be relying on all these foreign sources of energy. We should be unleashing energy dominance here in this country. We do it better for our environment than so many other countries do for theirs.

- Lee Zeldin, Administrator of the EPA

"Corporations are designed for making money, and the best way to do that is to keep citizens passively consuming and government under their ownership. But people need things other than profits - like justice, life and liberty – and that includes a survivable environment. Corporations scream like toddlers to just leave them alone, that they know what they are doing and everything will be fine. If you are tempted to believe that, look at global warming. The fossil majors pitched a fit, got their way, and now there is only a 12% chance our civilization will survive this century! Billions of deaths, decades of torment and a land saturated in PFAS and fracking fluid for all but the most fortressed wealthy. Any rational person can see corporations' argument for ungoverned self-rule

- Climate Deadline Alliance

ends there.... forever."

"The measure of iniquity is not yet filled; and unless we can return a little more to first principles, and act a little more upon patriotic ground, I do not know when it will—or what may be the issue." *

- George Washington 1779

"The tree of liberty must be refreshed from time to time with the blood of tyrants and patriots."

- Thomas Jefferson

"Every other human problem or endeavor is already in the shadow of Climate Change, and since January, we have a shadow over Washington as well - a *double shadow*, as it were. We must create some daylight in the next few years, or we will lose our ability to even exist on this planet."

- Climate Deadline Alliance

"Unrecoverable Tipping Point (UTP)s are so dangerous because if you pass them, the climate is out of humanities control. If an ice sheet disintegrates and starts to slide into the ocean, in turn releasing huge stores of methane, there's nothing we can do about that. Several times in Earth's history, rapid global warming occurred, apparently spurred on by these types of amplifying feedback. In each case more than half of plant and animal species became extinct."

- James Hansen, Former Director, NASA Goddard Institute

^{*} For George Washington, virtue wasn't optional; it was oxygen for a republic. When Washington spoke of the "measure of iniquity" nearing its brim, he was warning that a nation can only absorb so much greed, injustice, or neglect before it tips into chaos. Interestingly, it is also the same principle behind climate Unrecoverable Tipping Point (UTP).



CLIMATE DEADLINE ALLIANCE

Earth Systems Science Advising

Mail Address: 428 Childers Street, Pensacola, FL 32534 Private Voicemail: (800) 884-0824 – Facsimile: (888) 471-1642

Email: climaterepair@protonmail.com URL: www.climatedeadline2035.com

PRIOR CDA PROJECTS

1976 – Initial Op-Ed on concrete and atmospheric carbon pollution

1992 - The Power of Being (Book)

1992-Present – Lectures in more than 100 cities across the United States

2016 – Gore's Climate team (2016)

2017 – Alliance with the research group of Negative Emissions Technologies (2017)

2017 - Climate Deadline 2035 (Book)

2018 - Arizona Gubernatorial Candidate (Independent – Climate Recovery)

2019 - Federal Climate Lawsuit (CV-19-00293-TUC)

2020 - Omnicide Complaint (International Criminal Court)

2021 - Advised the White House on carbon removal elements in H.R. 3684

2021 - Federal Climate Lawsuit (CV-22-00077-TUC)

2023 - Carbon Negative Shot (Book)

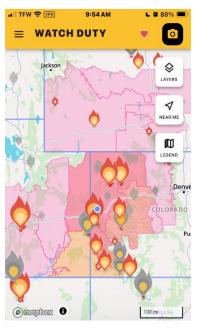
2024 - Funding Carbon Negative Shot - Our

Last Shot at Climate Change (Book)

2024 - Meetings with over 100 members of the U.S. House and Senate on DACR

2025 - Climate Deadline Alliance Office----

-----Blue Dot on Map Above



IMPORTANT NOTE: The Climate Deadline Association is truly independent. Since 1976, we have received no outside funding and have no connection with any agent, agency or organization, including those mentioned in this report.

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Executive Summary: Governors and Legislators' Strategic Planning Report for Climate Change Resolution

The climate crisis is no longer linear, predictable, or containable. It is a Black Swan Matrix emergency driven by accelerating feedback loops and converging resource limits that threaten societal stability. Our best science warns that we have less than 10 years to remove nearly 900 gigatons of legacy atmospheric carbon and halt the feedback cascades already pushing us toward 450 ppm CO₂. This is a threshold beyond which paleogeologic records show human survival has no precedent. Emissions reductions, sustainability, and mitigation, while essential, do not remove existing carbon. That carbon must be manually extracted through a massively upscaled interstate mobilization to Direct Atmospheric Carbon Removal (DACR). DACR is not speculative. It is real, measurable, and already operational at sites like Climeworks in Austria and Department of Energy Negative Emissions Technology hubs.

The question is no longer whether to act but whether we can act fast enough. Even the traditionally conservative World Economic Forum projects that by 2050, climate disruption may cause 14.5 million deaths annually and \$12.5 trillion in economic losses.

- More than 35,000 species are currently threatened with extinction, according to the International Union for Conservation of Nature (IUCN).
- Since 1970, global vertebrate populations have declined by **68% and 543 land vertebrate species have vanished**, as reported in *PNAS*.
- Thousands of paleoclimate records and advanced modeling confirm that once critical thresholds are crossed, Earth's systems reorganize, locking into a "new normal."

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The U.S. federal government has largely **deferred to free-market dynamics**, avoiding industrial regulation despite decades of warnings about fossil resource depletion and ecological collapse. This **laissez-faire approach** has left vital environmental support systems fragmented and underprepared. Now the federal government has declared an "Energy Emergency," allowing its fossil-fuel friends to increase profits to an omnicidal level.

Taking steps to resolve diffuse threats like climate change may seem politically challenging, yet public opinion is rapidly evolving. In June 2024, the largest global climate survey ever, conducted by UNDP, revealed overwhelming consensus: **89% of people want stronger climate action from their governments**, 81% support international cooperation, 61% believe large corporations are not doing enough to clean up their mess, and 72% favor a swift transition to renewable energy. Even in the climate-skeptical and heavily politicized U.S., Pew Research found 54% of adults consider climate change a "major threat," and 83% agree that human activity is the primary cause. Amid growing polarization, this issue is presenting an opportunity for forward-thinking state leadership to take decisive and resonant action.

This handbook presents a **non-technical**, actionable roadmap for multistate DACR deployment. It is built for Governors, legislators, and public advocates prepared to lead where federal policy has stalled. This document delivers:

- A Comprehensive Description of the Climate Emergency.
- A research-based explanation of the interactive environmental feedback loops and amplifying.
- A State-Based Direct Atmospheric Carbon Removal Strategy.
- Realistic Funding Models for Building a Workable Interstate DACR System with Recovered Carbon Profitability.

y I.

A Culture for Climate Catastrophe (2025 Snapshot)

Federal environmental policy is now aggressively putting states at risk. Decades of industrial-scale coal and oil production, not consumer habits, remain the primary drivers of global carbon emissions. Yet fossil fuel corporations have long deflected accountability, encouraging the public to obsess over personal carbon footprints while escaping scrutiny. In 2025, federal regulations further fortified these corporations, reversing climate safeguards, sidelining science, and intensifying extraction. Decades of coal and oil production account for the majority of global carbon emissions. Yet fossil fuel and other high-intensity greenhouse gas (GHG) emitting corporations have spent decades deflecting blame, encouraging citizens to fixate on personal carbon footprints while avoiding scrutiny for industrial-scale extraction. Now, a protective wave of federal regulations and orders has fortressed these corporations even further, reversing decades of climate safeguards, sidelining environmental science, and re-empowering fossil interests.

Environmental Rollbacks and Federal Deregulation (2025)

Executive Actions and Orders (2025)

- Coal Designated a Strategic Resource (*April*): Expanded mining leases, accelerated export infrastructure, and prioritized coal use in AI data centers. Resulted in stock surges for coal-linked firms.
- GHG Standards Repealed (*June*): EPA proposed eliminating CO₂ limits for new coal plants, stating it does not significantly endanger public health.
- Mercury and Air Toxics Rule Rolled Back (*June*): Reversion to 2012 standards raised health risks, especially for children and cardiovascular patients.

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- NEPA Regulations Gutted (*Feb*): Environmental impact reviews for federal projects eliminated, threatening Indigenous land and public health.
- California Clean Air Act Waiver Revoked (*Feb*): Triggered multistate legal battles over states' rights to set stronger pollution standards.
- EPA Guidelines Nullified (*Feb*): Power plant and vehicle emissions rules rescinded.

Key Environmental Rollbacks (2025):

<u>Action</u>	<u>Impact</u>
Revoked EPA GHG Standards	Removed emissions limits for
	plants and vehicles
Repealed Mercury/Air Toxics	Increased health risks for
Rule	vulnerable populations
Frozen Clean Energy Funding	Stalled solar, EVs, and grid
	modernization
Reopened Arctic and Public	Reversed longstanding
Lands for Drilling	conservation protections
Declared Coal "Strategic"	Directed federal support to aging
	fossil infrastructure
Eliminated Clean Energy Tax	Reduced renewable
Credits	competitiveness
Expanded Fossil Fuel Subsidies	Raised support above \$20B
	annually
Terminated Environmental	Erased protections for frontline
Justice and DEI Offices	communities
Slashed International Climate	Destabilized vulnerable global
Aid	regions

Direct Federal Anti-Climate Action (2025)

• Rescinding Climate Health Protections (April) – Ordered the EPA to revisit the 2009 "endangerment finding," threatening its mandate to regulate climate pollution as a public health hazard.

- Suspension of Fulbright and Peace Corps Programs (April) Slashed funding for global education and development, undermining long-standing bipartisan diplomacy.
- **EPA Grant Freezes** (*Spring*) Programs like "Solar for All" and climate pollution reduction grants were suspended, stalling efforts to cut emissions.
- Carbon Capture Undermined (Spring) DOE-backed pipeline projects (e.g., Summit Carbon Solutions) were mired in land disputes and lost federal momentum.
- Executive Order: Coal as Strategic Resource (April) Declared coal a federal priority. Expanded mining access, accelerated leasing, and directed agencies to boost coal exports and usage in AI data centers. Shares of coal-linked firms surged, prompting criticism as donor payback.
- Repeal of GHG Emissions Standards (June) EPA proposed eliminating greenhouse gas limits for new coal plants, claiming CO₂ "does not significantly endanger public health."
- Rollback of Mercury and Air Toxics Standards (MATS) (June) Reverted to 2012 rules. Medical experts warned of heightened risks to children's neurodevelopment and adult cardiovascular health.
- **Projected Regulatory Savings** (*June*) EPA estimated \$19 billion in reduced compliance costs over two decades. Public health advocates warned that human and environmental tolls would vastly outweigh any savings.
- **Federal Renewable Energy Silence** No new incentives for solar, wind, or EVs were introduced, while deregulation made fossil fuels artificially more competitive.
- Opening Federal Lands to Mining (April) Interior and Agriculture were directed to expedite coal leasing on federal lands, including areas near national parks.
- Clean Energy Program Cuts (Jan–Mar) Dozens of initiatives under the Inflation Reduction Act and Infrastructure Investment and Jobs Act were halted. Solar/EV rebates were frozen. DOE grants for green hydrogen and carbon-neutral cement were canceled overnight.
- **EPA Emissions Deregulation** (*Feb*) Via executive order, nullified power plant and vehicle emission limits. Revoked

- California's Clean Air Act waiver, spurring multistate legal pushback.
- Fossil Leasing in Protected Areas (May) Opened new tracts in the Arctic Refuge, coastal marine zones, and Utah's Grand Staircase via closed bids and minimal environmental review.
- **NEPA Regulations Gutted** (*Feb*) Stripped requirements for environmental impact assessments on major federal projects. Legal analysts warned of threats to public health and Indigenous land rights.
- Carbon Capture Downgraded (Spring) Federal guarantees for carbon pipeline projects were quietly withdrawn. DOE memos labeled them "low-priority" despite prior bipartisan support.
- USAID Climate Grant Cuts (Ongoing) Slashed funding for clean energy, drought mitigation, and coastal protection across vulnerable regions, prompting diplomatic warnings of instability and migration.
- Closure of National Climate Assessment Program (March) Disbanded the scientific body responsible for informing U.S. climate policy, restricting access to vetted environmental data.
- Expanded Fossil Fuel Leasing in Protected Areas (May) Additional federal tracts were opened to drilling, reversing longstanding conservation protections.
- **EPA Guidelines Nullified** (*Feb*) Emissions rules for the power and transport sectors were rescinded. States launched lawsuits in defense of clean air standards.
- Closure of EPA Office of Research and Development (July) Dismantled the agency's scientific core, limiting public access to air, water, and health data, seen by critics as an intentional move to shield polluters. August Additions to the Timeline
- Strategic Nuclear Submarine Deployment (Aug 1) In response to threats from Russian official Dmitry Medvedev, Trump ordered two U.S. nuclear submarines to reposition near Russia. Critics warned that this escalated tensions and blurred lines between diplomacy and military posturing.
- **EPA Structural Overhaul** (*Late July–Aug*) Following the July closure of the EPA's Office of Research and Development, internal memos suggest a broader restructuring plan is underway. Early reports indicate consolidation of regional offices and

- reallocation of enforcement staff to "economic development zones," raising concerns about regulatory capture.
- Revocation of Climate Emergency Designation (July) President Trump formally rescinded the federal climate emergency declaration issued in 2022, nullifying executive powers used to fast-track clean energy deployment and disaster response coordination.
- Suspension of International Climate Cooperation (Ongoing) U.S. participation in the Climate Club and Mission Innovation was quietly paused. State Department officials confirmed that climate diplomacy is being "re-evaluated under new strategic priorities."
- **Dismissal of National Climate Assessment Authors** (*July*) All contributors to the U.S. National Climate Assessment were removed from their posts. This effectively halted the next report cycle and severed the scientific backbone of federal climate policy.
- Executive Order: Regulatory Relief for Strategic Industries (July) President Trump signed four proclamations granting two-year exemptions from Biden-administration EPA rules for coal plants, chemical manufacturers, and taconite processors. Framed as national security measures, critics warned it would spike emissions in sectors tied to semiconductors and defense.
- EPA Staff Suspensions Over "Declaration of Dissent" (July) Approximately 140 EPA employees were placed on administrative leave after signing a letter criticizing the administration's climate rollbacks. Senators demanded reinstatement, citing First Amendment protections.
- Repeal of the Endangerment Finding Announced (*July*) EPA Administrator Lee Zeldin unveiled plans to revoke the 2009 ruling that greenhouse gases endanger public health. This would dismantle the legal foundation for all U.S. climate regulations from tailpipe standards to methane rules.
- Closure of Climate Diplomacy Programs (Ongoing) U.S. participation in Mission Innovation and the Climate Club was quietly suspended. State Department officials confirmed a strategic pivot away from international climate cooperation.
- **FEMA Flood Mitigation Program Canceled** (*July*) The Building Resilient Infrastructure and Communities (BRIC)

program was terminated, costing the Chesapeake Bay watershed nearly \$1 billion in climate resilience funding.

Undermining of Climate Science and Accountability (2025)

- Closed NOAA climate research labs and disbanded the U.S. Climate Assessment Program (*March*).
- Eliminated EPA's Office of Research and Development (*July*), restricting access to vital air, water, and health data.
- Took offline the U.S. Global Change Research Program portal.
- Cut 600+ National Weather Service staff, including flood forecasters.
- Replaced evidence-based policy with donor-driven ideological messaging.

Expanded Fossil Fuel Prioritization (2025)

- Opened new fossil leases in protected lands, including the Arctic Refuge, coastal marine zones, and near national parks (*April-May*).
- Directed Interior & Agriculture to fast-track coal leases.
- Fossil subsidies surged above \$20B annually; tax credits for renewables were eliminated.
- No new incentives were introduced for solar, wind, or EVs.
- Projected \$19B in regulatory "savings" drew warnings of devastating health and environmental costs.

Program Suspensions (2025)

- Halted dozens of clean energy initiatives under the IRA and IIJA.
- Froze solar and EV rebates.
- Canceled DOE grants for green hydrogen and carbon-neutral cement.

Carbon Capture Undermined (2025)

• DOE reclassified DAC and pipeline efforts as "low priority."

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- Withdrew federal guarantees for projects like Summit Carbon Solutions.
- Stalled pipeline progress due to land disputes and loss of federal support.

Emergency Preparedness Gutting (2025)

- Eliminated one-third of FEMA's workforce.
- Canceled BRIC (Building Resilient Infrastructure and Communities) program mid-cycle.
- Attempted to abolish FEMA entirely, shifting disaster recovery burdens to states.

Summary for Policymakers

These collective actions accelerated extraction, dismantled oversight, and reversed decades of progress. Governors and legislators must now contend with the fallout of policy engineered to amplify climate risk. These collective actions accelerated extraction, dismantled pollution safeguards, and reversed decades of climate progress. Governors and legislators now face a stark reality: the federal government has shifted from a climate partner to a systemic liability.

"Recovered-CO₂ is not just a climate solution—it's a tradable commodity. Every ton removed becomes a financial instrument that can be sold, retired, or reinvested."

¥ II.

Climate Change Is an Unparalleled Emergency

Key Issues

- Accelerating feedback loops and UTPs)
- Emerging second-tier feedback (e.g., microbial carbon release, cloud dynamics)
- Cascading interactions and tipping chains
- Underestimated warming projections (30–70% higher than expected)
- Compressed adaptation timelines
- Introduction and calibration of the North American Climate Pain Scale

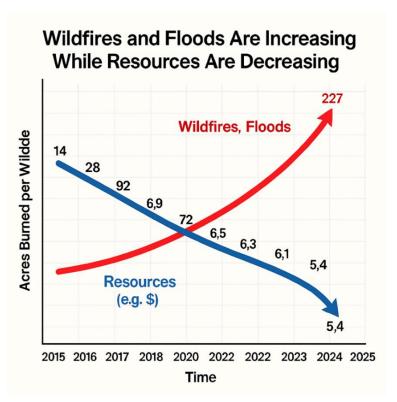
The "Axis of Climate Unraveling" (Climate + Corporatocracy + Feedbacks)

Climate change is a **nonlinear**, **multi-system crisis** of accelerating feedback loops, fossil politics, and converging resource collapse, sometimes referred to as a *Black Swan Matrix*. Scientific consensus warns we have less than a **decade** to remove over **900 gigatons of legacy carbon** before crossing **450 ppm**, a threshold above which **no human society has survived**, according to paleoclimate records.

1. Southern Ocean Circulation Reversal (SMOC)

- For the first time in recorded history, the **Southern Meridional Overturning Circulation (SMOC)** has reversed.
- Deep CO₂-rich waters are rising, releasing centuries of stored carbon and heat into the atmosphere.
- This could **double atmospheric CO₂ concentrations**, destabilize global weather systems, and trigger cascading feedback loops.

Indisputable Reasons for Immediate Action



2. Flash Flood Catastrophes

- Flooding is occurring all over the U.S. In July 2025, floods in Texas killed **over 80 people**, including 28 children, as the **Guadalupe River rose 26 feet in 45 minutes**, overwhelming infrastructure and emergency response.
- Experts link this to climate-driven "rain bombs" and hydrological instability.

3. Wildfire Emergencies

• While the **raw count of wildfires** *does* appear relatively consistent year to year, fluctuating between 50,000 and 65,000, that statistic is deceptive. **The intensity, acreage burned, cost**

per fire, and cascading human impacts are <u>escalating</u>, something Governors need to be concerned about.

- o Acres burned per fire: In 2025, the average fire size is **227 acres**, a significant increase from **47 acres** in 2023.
- Cost per incident: 2025 saw \$65B in damages from just two California fires, the highest-ever global wildfire cost.
- Recovery strain: Disasters are compounding: floods follow fires, insurers pull out, and federal relief slows down.
- o **Infrastructure hit**: Power grids, housing, and water systems are repeatedly damaged before full repair.

4. Legal Recognition of Climate Harm

- The Inter-American Court of Human Rights ruled that climate change is a human rights violation, requiring states to act under international law. This ruling applies to the U.S., reinforcing legal grounds for emergency declarations.
- The International Court of Justice (ICJ) in The Hague issued its first-ever advisory opinion on climate change, declaring it an "urgent and existential threat" and affirming that states have legal obligations under international law to protect the climate system, the ICJ stated that countries must cooperate to reduce emissions, uphold the Paris Agreement's 1.5°C goal, and protect both current and future generations from environmental harm. Failure to act on climate change, especially by major emitters, can now be interpreted as a violation of international law, not just a policy failure. The court emphasized that a clean, healthy, and sustainable environment is a human right, and that past emissions and resulting damage must be acknowledged and repaired in a nod to the concept of climate reparations.

5. Record-Breaking Marine Heatwaves

• The Mediterranean Sea hit 31°C (88°F) in July 2025, 6.2°C above historical averages.

• These heatwaves are reshaping ecosystems, killing marine life, and disrupting global ocean currents.

6. AMOC Collapse Risk

- The Atlantic Meridional Overturning Circulation (AMOC), which regulates global climate, is weakening and may collapse as early as 20259.
- Collapse would trigger a **European mini ice age**, Amazon dieback, and sea level rise along the U.S. East Coast.

7. Infrastructure Overload & Emergency Failures

- Kerr County, TX, lacked flood warning systems due to budget constraints.
- Emergency alerts failed to reach campers and residents in time, exposing systemic gaps in disaster readiness.

8. Extreme Weather Normalization

- "100-year floods" are now **annual events** in many regions.
- The frequency and intensity of storms, droughts, and heatwaves are **outpacing infrastructure and emergency planning**.
- This is not a future threat. It is a present collapse. The climate system is unraveling in real time, and our duty is to respond with the urgency it demands.

9. Permafrost Thaw: The Methane Bomb

- 2025 saw record-breaking permafrost temperatures across Siberia, Alaska, and Canada.
- Significant **methane plumes**, a gas 80x more potent than CO₂, are rising from thawing ground.
- "Zombie viruses" and antibiotic-resistant bacteria have emerged from ancient, thawed layers.
- Infrastructure is collapsing; villages in Alaska and cities like Norilsk, Russia, are sinking or cracking.

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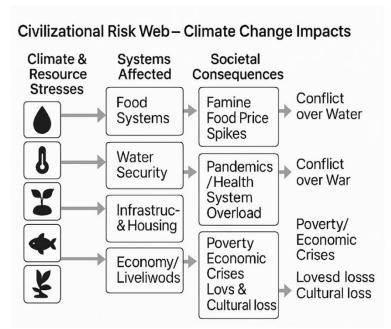
- Scientists warn of **irreversible carbon release**, even if global temperatures stabilize.
- The Arctic is warming nearly 4x faster than the rest of the planet.

10. Coral Bleaching: Ecosystem Collapse

- The Fourth Global Coral Bleaching Event is the worst ever recorded, impacting 84% of the world's reefs.
- Lizard Island (Great Barrier Reef) saw 92% coral mortality, with some areas exceeding 99%.
- Coral reefs support 25% of marine species and provide \$2.7 trillion/year in global services.
- Florida's reef has lost **90% of healthy coral cover** since the 1970s.
- Bleaching now affects reefs in **83 countries and territories**, including the U.S., Australia, and Caribbean nations.
- This marks one of the highest coral mortality rates ever documented globally.

11. Human Health: Legal and Medical Emergency

• The Inter-American Court of Human Rights ruled that climate change is a human rights violation, requiring urgent state action.



- The World Health Organization (WHO) declared climate change a health crisis already killing us, citing over 100,000 heat-related deaths in Europe alone.
- The Global Action Plan on Climate Change and Health (2025–2028) was adopted to build climate-resilient health systems.
- Climate change is driving food insecurity, infectious disease spread, and mental health crises.

12. Pandemics: Climate-Driven Spillover Risk

- The UN warns of a **new pandemic by 2030**, driven by climate-fueled zoonotic spillover.
- **H5N1 bird flu** is spreading to mammals, including cattle and cats, with **67 human cases in the U.S.**
- **Ancient pathogens** are emerging from thawing permafrost, including viable viruses and antibiotic-resistant bacteria.
- Vector-borne diseases like **dengue**, **chikungunya**, **and oropouche fever** are expanding due to warming and precipitation shifts.

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• Climate change accelerates spillover, with fatalities projected to be 12x higher by 2050 than in 2020.

We are **past the point of debating causes**. We are now racing against **Earth's reactions**, and current models **still underestimate** the velocity and volatility of climate change. Matters may be worse than even the data presented here today. The question is not whether we need to act, but whether we CAN act fast enough. **No prior version of human society has survived carbon levels above 450 ppm.** Our trajectory points toward mass extinction, partial or total.

- Even the traditionally conservative World Economic Forum projects that by 2050, climate disruption will cause 14.5 million deaths and \$12.5 trillion in economic losses globally.
- Currently, more than 35,000 species are considered to be threatened with extinction, according to the International Union for Conservation of Nature (IUCN).
- Since 1970, the populations of vertebrate species have declined by an average of 68%
- During the 20th century alone, as many as 543 land vertebrates became extinct, according to a research article in the journal PNAS.
- Thousands of paleo-climate records and sophisticated modeling make that clear. Once a certain threshold is breached, Earth's systems shift toward a "new normal."
- Even the conservative World Economic Forum projects that by 2050, climate disruption could cause 14.5 million deaths and \$12.5 trillion in economic losses annually.

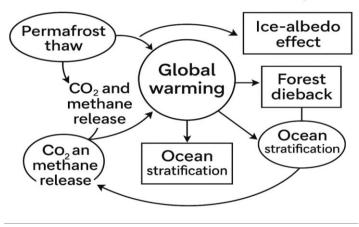
y III.

The Most Dangerous Aspects of Climate Change Are Environmental Feedback Loops, Unrecoverable Tipping Points (UTPs), and Resource Depletion

UTPs and Environmental Feedback Loops (EFLs)

Environmental feedback loops (EFLs) are nonlinear chain reactions of escalating complexity, such as permafrost thaw releasing methane that in turn traps more heat. They destabilize climate systems faster than our models can predict and interact with one another like physical systems in the body. As several systems are negatively affected and begin to interact, an exponential increase in failures arises. Some of us have been pressing for more research on this danger for many years, but until recently, the IPCC has largely failed to account for this effect.

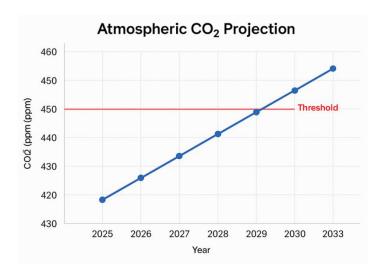
Climate Feedback Loops



Feedback Type Impact on Climate

Permafrost	Releases CO2 and
Thaw	methane as frozen soils
	melt
Ice-Albedo	Melting ice exposes
Effect	heat-absorbing surfaces
Ocean	Blocks vertical mixing;
Stratification	weakens CO ₂ absorption
Forest Dieback	Carbon sink turns
2 01 000 2 100 001	emitter under
	heat/drought
Methane	Seafloor destabilization
Hydrates	risks abrupt release
Soil Microbial	Converts carbon-rich
Activity	soils to GHG sources
Jet Stream	Triggers extreme
Disruption	weather and intensifies
I	feedback loops
Water Vapor	Increases climate
Amplification	sensitivity and warming
Arctic Wildfires	Releases vast stored
	carbon during peak fire
	seasons
Cloud Feedback	Alters heat retention and
Shifts	reflectivity patterns
	remotivity patterns

Some of these feedback loops can form UTPs. For example: Greenland Ice Sheet melt → weakens AMOC current → destabilizes West Antarctic Ice Sheet → triggers multi-meter sea-level rise.



Temperature as the Trigger

- Feedback loops like **permafrost thaw**, **wildfire amplification**, and **ice-albedo loss** are **temperature-sensitive**. Once a threshold is crossed, these systems accelerate warming regardless of the original CO₂ source.
- For example, warming causes permafrost to release methane, which traps more heat—a classic **positive feedback loop**.

CO₂ as the Driver

- CO₂ concentrations are the primary driver of global temperature rise. Studies show that every 10 ppm increase in CO₂ leads to ~0.1°C warming.
- While feedback loops respond to temperature, the temperature itself is a function of CO₂ ppm, making both metrics deeply intertwined.

Feedback Loop Dynamics

- According to paleoclimate data, CO₂ and temperature rise together, but feedback loops kick in asymmetrically, meaning small temperature increases can trigger disproportionately large feedback effects.
- This is why some models underestimate future warming: they don't fully account for **nonlinear feedback amplification**.

Therefore, the increase in climate-induced feedback loops is linked with global temperature rise and those temperatures are themselves tightly linked to atmospheric CO₂ concentrations (ppm)—a nested relationship.

Global Resource Depletion and Societal Risk

In parallel with the rise of Feedback loops, as noted above, our planet's life-support systems are collapsing under rising demand and climate stress. By 2040, multiple systems will hit synchronized failure points, especially as the population peaks.

Resource	Milestones	Trajectory
Freshwater	2025: 3.5B stressed 2030:	Rising scarcity →
	40% deficit 2050: 5B affected	peak stress
Arable Soil	2020s: erosion surge 2050:	Steady decline →
	90% degradation risk	critical by 2050
Pollinators	2040s: mass extinction risk	Sharp decline \rightarrow
	2050: collapse	food chain collapse
Fisheries	2030: regional collapse	Accelerating decline
	2048: global stock crash	\rightarrow collapse
Phosphorus	2030: peak 2040s: supply	Volatile fertilizer
	instability	inputs
Energy	2030s: peak oil 2040s: grid	Fossil phase-out or
Security	instability 2050: net-zero	crisis
-	deadline	

Amplifying feedback and resource depletion are projected to converge between 2040–2050, resulting in compounding system failures with escalating climate consequences

How Climate Change is Already Affecting Citizens of Your State Now

These environmental stressors fuel **governance instability** and threaten food, water, migration, public health, and economic resilience. Examples like the **Russian Heat Wave** and pre-war **Drought in Syria** show how climate shocks can **ignite civil unrest** and occupy a large portion of State finances and resources, managing:

- Increased health risks from extreme heat more days of dangerous heat stress, especially for outdoor workers, children, and the elderly.
- **Higher grocery bills and food insecurity** crop failures and livestock stress from droughts, floods, or heat waves can drive up prices and limit access.
- **Rising home insurance costs** wildfires, floods, and hurricanes are making homes harder or impossible to insure in many areas.
- More frequent power outages extreme weather can knock out electricity, risking lives and disrupting work, especially in rural and underserved communities.
- Changing local landscapes from disappearing snowpack in the Rockies to dying trees in New England, familiar places of natural outstanding beauty are losing their seasonal rhythms.
- Worsening air quality wildfires and higher ozone levels can render breathing difficult even for those who are healthy, particularly in the Western and Southern states.
- **Property loss and displacement** flooding, coastal erosion, and stronger storms are forcing people to move, with nowhere truly "safe."

- **Mental health impacts** eco-anxiety, disaster trauma, and displacement stress are growing, especially among young people and frontline communities.
- Water shortages or contamination from shrinking reservoirs in the Southwest to storm runoff in the Northeast, safe water is increasingly fragile.
- Local wildlife decline bird songs disappearing, fewer pollinators, altered migration patterns—subtle but emotionally powerful shifts in our connection to place.
- Higher vehicle maintenance costs extreme heat wears down batteries, tires, and brakes faster; dust storms and flooding cause more frequent repairs, and roads buckle more often under heat stress.
- More expensive goods and services disrupted supply chains (fires, floods, closed ports) lead to shipping delays, rising prices on basics like clothes, appliances, and even home repairs.
- Worsening allergies and asthma longer pollen seasons and higher mold levels mean more days of discomfort, medication use, and ER visits, especially for kids and the elderly.
- **Increased risks for chronic health conditions** heart disease, respiratory illness, and kidney disorders can all be aggravated by extreme heat, poor air quality, and water contamination.
- Future job insecurity for young people climate-exposed industries (agriculture, tourism, outdoor trades) are becoming riskier, while green job transitions are uneven across regions.
- Child development and education disruptions disaster trauma, school closures from fires or floods, and unhealthy indoor air can impact learning and emotional stability.
- **Strained local medical systems** heat waves and climate-fueled disasters increase hospital admissions while reducing the resilience of rural clinics and underfunded health services.

- Pests and diseases moving into new regions ticks, mosquitoes, and water-borne illnesses thrive in warmer, wetter conditions, expanding their range and risk.
- **Rising utility and cooling bills** an increasing households must invest in air conditioning or filtration systems to stay safe, stretching tight budgets even thinner.
- Infrastructure damage that affects daily life melting asphalt, cracked foundations, contaminated water pipes, and overwhelmed storm drains all mean costly fixes or new dangers.
- Increase in emergency room visits, especially for mental health conditions. A nationwide study covering 3.5 million ED visits from 2010–2019 found that days in the 95th percentile of local temperatures were associated with: 8% higher risk of ED visits for *any* mental health condition
- 11% higher risk for childhood-onset behavioral disorders, 6—8% higher risk for mood, anxiety, substance use, and self-harm-related emergencies. Heat stress affects the brain by disrupting sleep, increasing irritability, and impairing emotional regulation, all of which can exacerbate existing conditions or trigger acute episodes. Vulnerable populations, including those with limited access to cooling, are especially at risk.
- Violent behavior also rises with heat. Multiple studies have shown that aggression, domestic violence, and even homicide rates tend to increase during heatwaves. The physiological stress of heat can lower impulse control and heighten emotional volatility.

To translate climate change into human experience, we developed the North American Climate Pain Scale (NACPS) diagnostic scale tracks progression from discomfort to uninhabitability, yielding a Climate Pain Index (CPI)

North American Climate Pain Scale				
Level	Human Experience	Year Bracket	Projected Events	Systemic Impact
1	Uptick in Hardships	2025-203	Mild regional disruptions	Resilient governanace
2	Significant Separation Between Rich and Poor		Heatwaves, ^O crop insura- nce strain	Rising adjustments, policy shifts
3	Increased Mortality in Vuinerable Pop	2040-204	Grid instability 5 migration uptick	Market instability rising public dissent
4	Widespread Disruption	2045-2056	Multi-state evacuations, wildfire regime expansion	Emergency governance
5	Crisis Mode	2050-2060	Emergency governance override	Fragmenta- tion national systems
6	Structural Breakdown	2070-2080	Fragmency governance onorride	Militarized zones
7	Societal Retraction	2080-2090 ເ	Suicidal sp: tailed cifies inlivale corrido	Decentralized survival rs systems
9	Collapse Threshold	2090-2019	Incremental die-off events	New governance paradigms or vacuum

CLIMATE PAIN INDEX (CPI) Level	<u>Condition</u>	5–6	Infrastructure strain; emergency zones; economic disruption
1–2	Mild seasonal shifts; background inconvenience	7–8	Chronic displacement; regional uninhabitability
3–4	Frequent disasters; manageable but costly	9–10	Systemic collapse; mass mortality; climate refugee surges

We are currently at CPI Level 3. By 2040, most regions will approach Level 6–7 unless legacy carbon removal begins immediately

Climate Change Costs to U.S. States: Historic and Projected

Even excluding the human element of Climate Pain, the cost to repair the Climate Change problem is projected to be less than the cost of keeping the problem.

Climate change has already cost \$5 trillion since the 1980s and is predicted to cost \$15 trillion by 2050.

Recent research in the Journal Nature Climate Change found that the richest 10% of individuals worldwide are responsible for 2/3 of global warming over most of the past 35 years, and the wealthiest 1%

contributed 26 times more to once-a-century heat waves and 17 times more to droughts in the Amazon.

Historic Economic Toll (1980–2024)

According to NOAA and E2 reports:

- **403 billion-dollar disasters** have struck the U.S. since 1980, totaling **\$2.915 trillion** in damages
- \$603 billion in damages occurred just in the last five years (2019–2023), a near doubling of the long-term annual average
- 2023 alone saw 28 separate billion-dollar events, costing \$92.9 billion, the highest number ever recorded in a single year
- Western states (CA, CO, AZ, NM) face rising costs from wildfires, droughts, and heatwaves, while Southern and Eastern states bear hurricane and flood-related losses

From 2017 to 2021, the U.S. endured its four most expensive wildfires, two of its three costliest hurricanes, and its most expensive winter storm—all within five years. CBO warns that UTPs, like ice sheet collapse or ocean current shifts, could trigger catastrophic costs beyond current projections.

Projected Costs by 2100 (CBO and NCA4 Estimates)

<u>Sector</u>	Projected Impact	<u>Source</u>
GDP	Up to 21% loss in worst-case	Congressional
	warming scenarios	Budget Office
Real Estate	Up to \$930 billion in property	CBO
	loss from sea-level rise	
Annual	Hundreds of billions across	National Climate
Sectoral	health, infrastructure,	Assessment (NCA4)
Losses	agriculture, and energy	
Federal	Expected to rise sharply due	CBO & GAO
Disaster	to compounding events	projections
Spending		

Disproportionate Burden

- Low-income and frontline communities face higher risks from flooding, heat, and pollution exposure.
- **Insurance markets** in states like California and Florida are destabilizing due to wildfires and hurricanes.
- **Infrastructure costs** for adaptation (e.g., seawalls, fireproofing, grid upgrades) are mounting, often without federal support.

"We're not just facing warming, we're facing faster, more volatile warming that our best models still underestimate."

- Synthesis PIK 2025 & IPCC-AR6

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Even at This Late Hour, We Can Fix the Climate Emergency, but Only if We Rapidly and Extensively Deploy Direct Atmospheric Carbon Removal (DACR)



Climeworks "Mammoth" DACR Plant in Iceland (2025)

Solving the CO2 Problem in Time:

We must first distinguish between anthropogenic CO_2 (from human activity) and the total atmospheric CO_2 .

Total CO₂ in Earth's Atmosphere (2024 estimate)

- The atmosphere currently holds about 3,341 gigatons of CO₂.
- Of that, roughly **900 gigatons** are attributed to **human emissions** since the Industrial Revolution, meaning ~27% of the total load is anthropogenic.

Why This Matters

- That 3,341 GtCO₂ corresponds to ~427 ppm (parts per million).
- Pre-industrial levels were around **280 ppm**, or ~2,200 GtCO₂,so we've added over **1,100 GtCO₂**, though not all remains airborne (some is absorbed by oceans and biosphere).
- The 900 GtCO₂ figure reflects what's still suspended in the atmosphere from human sources. The rest has been partially buffered by Earth's carbon sinks.

Implication

To restore pre-industrial levels, we would need to remove ~1,100–1,200 GtCO₂, depending on how much buffering continues.

Reframed Numbers with the 350 ppm Target

Here is how the math pivots based on the goal:

Metric	<u>Value</u>	<u>Notes</u>
Current CO ₂	427 ppm	Equivalent to $\overline{\sim}3,341$ Gt CO ₂
Level		
Emergency	350 ppm	Equivalent to ~2,700 Gt CO ₂
Target		
Required	~641 Gt	Just to reach 350 ppm; excludes
Drawdown	CO_2	future emissions

This means we are removing hundreds of gigatons from the existing stockpile. That reorients everything from a mitigation model to a full-scale mobilization.

Budgeting and State-Level Implications

Yes, this fundamentally changes how states might approach their carbon budgets and DACR investment strategies:

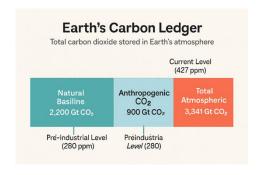
• **Baseline Shift**: Instead of budgeting for "net zero by 2050," states should allocate for **gross atmospheric drawdown**, which

means new line items for direct removal infrastructure, not just emissions reductions.

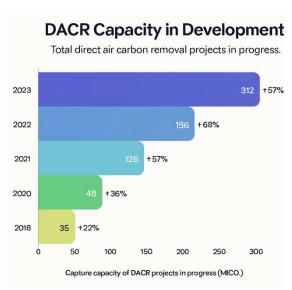
- **Cost Scaling**: If DACR costs ~\$200/ton CO₂ (conservatively), we're looking at:
 - \$128 trillion globally for full drawdown to 350 ppm obviously not one state's burden, but it highlights the scale.
 - States could break this into per-capita drawdown obligations or sectoral responsibility (e.g., energy vs agriculture).
- **Time Horizons**: Accelerated timelines (e.g., 20 years vs 50) will demand steeper upfront investments but could yield faster benefits in public health, biodiversity, and climate resilience.
- Integration Opportunity: States may fold DACR into infrastructure spending (e.g., using CO₂ in concrete or fuels), turning costs into dual-purpose investments.

Remember, Humanity is Adding More CO₂ Emissions All the Time!

Measurement	Value	Notes
GtCO ₂ /year	40 GtCO ₂	That's about 10.9 GtC, since 1 ton of $C = 3.67$ tons of CO_2
GtC/year	10–11 GtC	More accurate for tracking carbon atoms
Sources	Fossil fuels, land use	Fossil fuels = 90%



We are emitting around 10–11 GtC annually, which stacks fast when visualized over decades. Our emergency drawdown of 641 GtCO₂ (~175 GtC) is in addition to these yearly emissions, meaning any delay compounds the problem.



Direct **Atmospheric** Carbon Removal (DACR) is fundamentally different from traditional "Carbon Capture," which reduces emissions industrial at sources before they enter atmosphere. DACR. sometimes referred to as Direct Air Capture (DAC), legacy carbon removes dioxide already circulating in the atmosphere. This process reclaims dispersed CO₂ and either stores it permanently in geological

or oceanic sinks or repurposes it for infrastructure, fuels, and materials. Unlike emissions reductions or mitigation strategies, DACR directly reduces the concentration of atmospheric CO₂, addressing the root cause of climate change rather than merely attempting to slow its progression. If governments had taken action in the 1980s, it would still have been possible to leave legacy carbon for nature to remove slowly over hundreds to thousands of years. Now, artificial means must be used to solve our artificial problem.

Carbon vs. CO2: A Quick Breakdown

• Carbon (C): A versatile element found in everything from diamonds to DNA. It is essential to life and cycles naturally through ecosystems.

• Carbon Dioxide (CO₂): A specific compound made of one carbon atom and two oxygen atoms. It's the **gas** that traps heat in Earth's atmosphere and drives climate change when concentrations rise unnaturally.

Why the Distinction Matters

- Stating "carbon" when we mean "CO₂" can blur the specifics. Climate strategies differ depending on whether you're managing solid carbon materials, carbon-based fuels, or greenhouse gases like CO₂.
- In DACR, we are dealing explicitly with CO₂ molecules, not just generic "carbon."

DACR Can Reverse Climate Change and Is Already Operational... At Small Scale

DACR as a technology is now mature enough to be deployed as **essential public infrastructure**, on par with roads, power lines, and water systems. The Global Carbon Capture and Storage Institute (CCS) is now tracking **41 projects in operation and 351 in development globally**.

However, at the current rate of carbon removal, it will take <u>26 billion</u> <u>years</u> to reach a safe level (agreed to be 350 ppm). As has been true in other global crises (e.g., WWII), waiting for grant funding and private development to take hold will be too little, too late. The Climate Deadline Alliance has calculated that we need 26 U.S. states to mobilize.

ClimeWorks: A Premier Direct Atmospheric Carbon Removal Company

Climeworks is a Swiss climate tech company founded in 2009 as a spinoff from ETH Zurich, specializing in **Direct Air Capture and Carbon Storage (DACCS)**. Led by co-founders Jan Wurzbacher and Christoph Gebald, Climeworks designs and operates cutting-edge facilities that remove CO₂ directly from ambient air using modular collectors powered by renewable energy. With flagship plants like *Orca* and *Mammoth* in Iceland, the company has become a global leader in engineered carbon removal, serving clients ranging from Microsoft to Stripe. Climeworks is known for its commitment to transparency, scientific rigor, and scalable climate solutions. (Please note Climate Deadline Alliance has no affiliation with Climeworks and receives no funding from them.)

The most modern Climeworks "Mammoth" Plant in Hellisheiði, Iceland, uses solid sorbent-based DACR to extract CO₂ from ambient air. The process begins with large axial fans that draw air into modular collector units, each containing a highly porous solid sorbent material, typically amine-functionalized compounds that chemically bind with CO₂ through adsorption.

Once the sorbent is saturated, the collector doors close and low-grade geothermal heat (100°C) is applied to trigger thermal desorption, releasing a concentrated stream of CO₂ mixed with steam. This mixture is piped into a process hall, where it undergoes condensation and purification via heat exchangers and pumps. The purified CO₂ is then stored in a low-pressure balloon before being compressed to 20 bar.

The final purification and injection step uses an **absorption tower**, where pressurized CO₂ is dissolved into water. This aqueous solution is injected underground through wells operated by **Carbfix**, where the CO₂ reacts with **basalt rock** in a process called **mineral carbonation**. Over 12–24 months, the CO₂ transforms into **stable carbonate minerals**, effectively locking it away for thousands of years.

This modular system is designed for scalability, with Mammoth targeting 36,000 tons of CO₂ capture annually. The plant's V-shaped collector layout also reduces piping complexity and energy losses, improving overall efficiency. Compared to its predecessor, Orca, Mammoth achieves 90% CO₂ recovery rates, thanks to fewer purification steps and optimized thermal integration.

Thanks to pioneers like Climeworks, a State Office of Carbon Upcycling (OCU) deployment strategy no longer needs to begin with pilot-scale plants (36,000 tons CO₂/year) and can move directly to full-scale production. Current technology will continue to develop and

improve, enabling higher levels of extraction per dollar spent. This trajectory mirrors historical clean-tech expansions, leveraging cost reductions through research, development, and economies of scale.

This plan reframes DACR as a **material solution**, not a market abstraction. Carbon credits have failed to deliver meaningful removal at scale. Instead, recovered CO₂ (R-CO₂) becomes a building block, embedded in roads, schools, homes, and disaster recovery projects. DACR transforms carbon from a liability into a resource.

Solving the CO₂ Problem in Time

Before we can solve it, we must define it, because not all atmospheric CO₂ is created equal.

Two Types of CO₂ in the Atmosphere

- Anthropogenic CO₂: Introduced by human activity: fossil fuel combustion, deforestation, and land-use change.
- Natural Baseline CO₂: The stock that existed before industrial disruption.

Total CO₂ in Earth's Atmosphere (2024 Estimate)

- Atmosphere currently holds 3,341 GtCO₂, aligned with 427 ppm.
- Of that, ~900 GtCO₂ is anthropogenic—legacy carbon suspended from human emissions.
- Pre-industrial levels were 2,200 GtCO₂, equivalent to 280 ppm.
- Buffering from oceans and biosphere accounts for the missing margin but can't keep pace.

Reframing the Emergency

<u>Metric</u>	<u>Value</u>	<u>Notes</u>
Current CO ₂ Level	427 ppm	~3,341 GtCO ₂
Emergency Target	350 ppm	~2,700 GtCO ₂

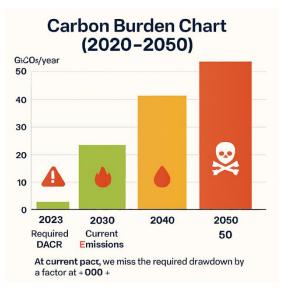
Required Drawdown		~641 GtCO ₂	Excludes future emissions	
Equivalent Atoms	in	Carbon	~175 GtC	$1 \text{ ton C} = 3.67 \text{ tons CO}_2$

That's **641 gigatons** we must actively remove from the atmosphere, not just offset, not defer.

Budgeting and State-Level Implications

This new benchmark flips every climate strategy from "net-zero by 2050" to **net-negative**, **now**.

- Baseline Shift: States must fund gross atmospheric drawdown, not just annual emissions cuts.
- DACR Cost Modeling:
 - If DACR averages \$200/ton CO₂, global full drawdown = \$128 trillion.
 - States can break down costs by:
 - Per-capita obligation
 - Sectoral drawdown (energy, agriculture, etc.)
- Compressed Timelines:
 - 20-year
 mobilization =
 steeper upfront
 spend, faster
 resilience returns.
 - Health, heat mitigation, biodiversity, and equity are all cobenefits.
- Infrastructure Integration: DACR can be folded into:
 - Concrete production
 - o Fuel systems



Disaster recovery and rebuilding

Remember: Humanity Is Still Adding More CO₂

Measurement	<u>Value</u>	<u>Notes</u>
GtCO2/year	40 GtCO ₂	= 10.9 GtC
GtC/year	10–11 GtC	More precise for atomic-scale modeling
Emission	Fossil fuels	+ Land use
Sources	(90%)	

The 641 GtCO₂ emergency drawdown sits on top of our annual additions. Delay equals debt—atmospheric, economic, and ecological.

Climeworks U.S. Expansion Highlights

Climeworks is already making a bold push into the U.S. with several high-impact Direct Air Capture (DAC) initiatives. Here is a breakdown of their key moves:

• Project Cypress, Louisiana:

- Located in Calcasieu Parish, this is Climeworks' flagship U.S. DAC facility.
- Will demonstrate Generation 3 DAC technology with two stages:
 - Stage 1: 300,000 tons/year capacity
 - Stage 2: 1 million tons/year capacity
- o Partnering with CapturePoint Solutions for CO₂ transport and Class VI geologic storage
- o Part of the DOE's **Regional DAC Hubs** program

• Other Proposed Hubs:

o California and the Northern Great Plains are also in the pipeline for DAC hubs

- These aim for megaton-scale capacity by 2030, leveraging local infrastructure and renewable energy
- U.S. Headquarters:
 - Climeworks has established its American HQ in Austin, Texas, with hiring focused across TX, NY, CA, and D.C.

Strategic Partnerships

- Collaborating with **Battelle** and **Heirloom Carbon Technologies** on Project Cypress
- Long-term carbon removal agreements with major U.S. companies like **Microsoft** and **BCG**5

Economic and Policy Impact

- Expected to create **thousands of direct jobs** by 2030 across construction, operations, and supply chains
- Benefiting from Bipartisan Infrastructure Law and DOE funding, over \$600 million allocated to Climeworks projects

The Climate Deadline Alliance stands ready to assist Governors and legislators with advisory support, planning frameworks, and public engagement strategies. DACR is a **resilience engine**, a job creator, and a foundation for long-term economic stability. States that act now will lead the next era of infrastructure, climate recovery, and public trust. Fortunately, the Trump Administration is likely to approve of, or at least not vigorously resist DACR.

"We phased out ozone-depleting gases and fixed the ozone hole. With CO₂, we refused to act early. Now we must remove carbon, mechanically, massively, together."

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Establishing a "State Office of Carbon Upcycling (OCU)"

Your state's Office of Carbon Upcycling (OCU) can redefine for citizens Direct Atmospheric Carbon Removal as a major advance in public infrastructure, not a niche climate tech.

We are taking **essentially free carbon** out of the air and using it to make and repair things. Through strategic funding, community integration, and tailored state rollouts, DACR becomes a **job-creating**, **resilience-enhancing**, **carbon-removing backbone** of your 21st-century economy.

During the summer and fall of 2025, the climate deadline alliance is approaching states that have optimal resources and will be for the development of Direct Atmospheric Carbon Removal (DACR)

MIDWESTERN	WESTERN	EASTERN
(7)	(7)	(10)
Colorado	New	Michigan
Kansas	Mexico	Georgia
Missouri	Arizona	Virginia
Illinois	Nevada	Maryland
Wisconsin	California	Delaware
Minnesota	Oregon	New Jersey
Iowa	Washington	Connecticut
	S	Massachusetts
		Maine
		New York

Where we are now, forty years too late, climate recovery now exceeds the reach of any of these states alone (or even the fossil-fuel industry, which largely spawned the problem).* Only a coordinated **Interstate Climate**

Infrastructure Program (think Interstate Highway System for carbon recovery) can deliver the **volume**, **speed**, **and resilience** required. This is **national reconstruction**. Like the states that fought for our independence in the 1700s, DACR states will create a clear, equitable pathway to climate recovery.

As Churchill said, this battle to survive climate disruption will be won by superior will, "wrestling victory upon the narrowest of margins" and at a grave cost, but it will be won.

*Note: In the late 1800s and early 1900s, electric automobiles were the original frontrunners with battery technology rapidly improving. The tide turned to internal combustion when infrastructure, affordability, and industrial momentum aligned behind gasoline. In other words, industry had a choice and industry *chose* to change the course of history to one dominated by carbon emissions.

Atmospheric Stabilization Strategy: Cost Breakdown for States

Interstate Goal:

- Target: Reduce atmospheric CO₂ from 450 ppm to 350 ppm
- Equivalent Removal: 213 GtC = 781 GtCO₂
- State Target (26 states): 33.91 GtCO₂ per state over 10 years

Our collective goal does not need to be the removal of all 900 gigatons of anthropogenic carbon in the atmosphere, but rather staying in a safe range and not exceeding 450 parts per million dissolved atmospheric carbon

Based on the latest NOAA data, atmospheric carbon dioxide levels reached 430 ppm in June 2025, and the annual increase is currently averaging about 2.0-2.6 ppm per year (with 2024 marking a record jump of 3.75 ppm, but let's not think about that).

Year	CO ₂ (ppm)	2	030	437.69	
2025	427.69	2	031	439.69	
2026	429.69	2	033	443.69	
2027	431.69	2	034	445.69	
2028	433.69				
2029	435.69				

Projected DACR Deployment Progress (2025–2035)

Year	Cost/Ton	Deployment	Focus
		Progress	
2025	\$500	5%	Pilots, foundational builds
2026	\$450	10%	Regional hub scale-up
2027	\$405	20%	Multi-sector integration
2028	\$365	30%	Rural–urban infrastructure alignment
2029	\$330	45%	Major federal & bond funding
2030	\$295	60%	Full-state coverage expansion
2031	\$265	75%	Municipal budget integration
2032	\$240	85%	Procurement goes carbon- based
2033	\$215	95%	Scaling peaks
2034	\$195	98%	Final deployment bursts
2035	\$175	100%	DACR network complete

Crossing the 450 ppm threshold will occur around 2032, assuming no major mitigation efforts. If the annual increase remains closer to 3.75 ppm, we will hit 450 ppm even earlier, by mid-2031. By the mid-2030s, we will have surpassed the point where any known technology can rescue your state's citizens. After that, you will just be cleaning up disasters until you run out of resources, and then you will just be watching your citizens die uncomfortably.

"The ozone hole was fixed because we phased out emissions. With greenhouse gases, we refused. Now we must remove them, mechanically, massively, and together."

¥ VI.

Managing the Cost of Survival for Your State's Citizens

Step One: Re-Setting Our Target From 450ppm to 350ppm

Although we have 900 GtC of excess atmospheric carbon (and are adding on average 37 gigatons to this larder each year), we do not **necessarily** need to remove it all to avoid catastrophic feedback loops and tipping levels and reach a **safe zone**. Safe would be good enough for now, and along the way, informed by the realization of our close brush with oblivion, we can negotiate traditional and alternative energy and the mistakes in governance that got us to the precipice of human survival.

Therefore, we re-focused our targeting on a safe level of atmospheric pollution, so our spreadsheet starts to look like this:

- 1 ppm of CO₂ = 7.81 gigatons of CO₂ (GtCO₂) in the atmosphere based on the total mass of Earth's atmosphere and the molecular weight of CO₂
- Target reduction: From 450 ppm \rightarrow 350 ppm = 100 ppm decrease
- Required removal: $100 \text{ ppm} \times 7.81 \text{ GtCO}_2/\text{ppm} = 781 \text{ GtCO}_2$
- Converted to carbon (C): CO₂ contains 27.3% carbon by mass \rightarrow 781 GtCO₂ × 0.273 = 213 GtC
- So, instead of removing 900+ GtC (which includes all historical emissions), we only **need** to remove 213 GtC to reduce the CO2 saturation level in the atmosphere to a safe zone of 350 ppm (assuming emissions halt or are offset in parallel).
- This is still a monumental task, but it's **less than one-quarter** of the full historical load and falls within the realm of the possible.

Step Two: State-by-State Responsibility Matrix

We will distribute the national drawdown target (781 GtCO₂ to reach 350 ppm) evenly across the **26 DACR coalition states**, each aiming for:

• Removal Goal: 33.91 GtCO₂ per state over 10 years

• Annual Target: 3.39 GtCO₂/year per state

Step Three: Goal — Remove 213 GtC Per State

Phase	Amount (USD)	Notes
Baseline	\$10.18	At \$300/ton CO ₂ , scaled DACR
Deployment Cost	trillion	pricing
Strategic	-\$5.18	Cost reducers stack applied over
Reductions (Avg)	trillion	decade (more on this later)
R-CO ₂ ROI Offset	-\$2.5 trillion	Material value through substitution + reuse (more on this later)
Federal & Bond Financing	-\$1.5 trillion	Green bonds, 45Q credits, DOE grants
Final Net Exposure (est.)	\$1.0–1.5 trillion	State share after all offsets

 Annualized over 10 Years: \$100-150 billion/year (Key Insight: This figure is not direct spending; it includes bondable infrastructure, leveraged federal funding, and ROI-generating assets.)

This represents approximately three times the annual budget of many U.S. states, which we estimate at around \$38 billion, with larger states such as California and Texas being exceptions. **Therefore, let's look at this situation** not as a budget hit, but as a **multi-sector investment platform**, combining:

- Carbon-stored infrastructure (roads, concrete, polymers)
- Resilience upgrades tied to removal facilities
- Innovation hubs for carbon reprocessing and reuse

- Shared federal risk pools and emergency relief integration This makes DACR eligible for:
 - Green bonds and climate funds
 - Federal co-financing and grants
 - Regional DACR-as-a-Service leases
 - Public-private partnerships (PPP) leveraging R-CO₂ as a commodity

Step Four: DACR Cost Decline (2025–2035)

At first blush, the cost of deploying DACR on a worthwhile scale is intimidating, but over the past 5 years, the cost of DACR per ton has already dropped significantly, thanks to:

- Process optimization (e.g., modular DAC units, better sorbents)
- Energy efficiency gains (e.g., Climeworks Gen 3 tech cuts energy use by 50%)
- **Economies of scale** from pilot deployments and manufacturing ramp-up

Assuming continued steady innovation and deployment, DACR costs are projected to drop by 10–12% annually, mirroring trends seen in solar, batteries, and related climate technology. The curve should look something like this:

Year	Cost	Cumulative	2029	\$330	34%
	per	Cost Drop	2030	\$295	41%
	Ton		2031	\$265	47%
2025	\$500		2032	\$240	52%
2026	\$450	10%	2033	\$215	57%
2027	\$405	19%	2034	\$195	61%
2028	\$365	27%	2035	\$175	65%

Divide that across 26 states, and the total cost drops from \$575 trillion to \$115 trillion.

This chart shows the **downward trend** in cost per ton, about a 65% reduction over a decade, driven by scaling, innovation, and strategic deployment. It's your "Smart Spend Curve": the longer we plan wisely, the lower the price tag.

Funding Funnel and Economic Strategy

DACR is a **commodity economy**. Every ton of R-CO₂ becomes an instrument of infrastructure finance.

Step Five: Cost Model (Per State, Per Year)

Baseline Cost @ \$300/ton CO₂:

- Gross Cost: \$10.18 trillion over 10 years
- \$1.02 trillion/year

This is clearly unsustainable alone, so we layer in strategic offsets.

Step Six: DACR Cost Reducers Strategic Reductions

- Cost-Reducer Stack Savings: 50%
 New Cost: \$5.09 trillion over 10 years
- \$509 billion/year

Strategy	Key Benefit	Estimated Savings/State
Modular		\$2.5T
Manufacturing	Rapid prefab install and scaling	
Waste Heat Integration	Lower operating energy costs	\$1.75T
CO ₂ Co-Location with Utilization Sites	Cuts transport, boosts local monetization	\$1.25T

Dynamic Load Matching w/ Renewables	Uses surplus power, lowers grid strain	\$1.5T
Carbon Removal-as-a- Service (CRaaS)	Avoids capex, defers costs	\$4.0T
Multi-Market Monetization	Stacks credit value 2–3×	\$3.0T
State Procurement Mandates	Locks demand via material substitution	\$1.75T
Circular Carbon Supply Chains	Shortens logistics, boosts reuse	\$1.25T
AI-Optimized Siting and Ops	Reduces permitting, downtime, land waste	\$1.5T
Tribal and Community-Led Deployment	Accelerates permitting, unlocks funding	\$1.5T

Step Seven: Financial Engineering

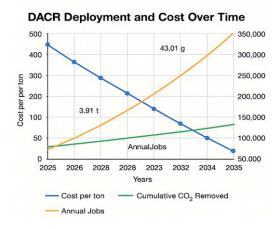
R-CO₂ ROI

- Carbon-stored materials, goods, and infrastructure
- Projected value: \$2.5 trillion/10 years

Financing Tools

 To deploy DACR without new tax burdens, states can layer existing tools, bonding, procurement, federal grants, and service models into a powerful funding stack.

- Green Bonds & Climate Funds: \$1.5 trillion
- Federal Grants/Credits (IRA, DOE): \$1 trillion
- DACR-as-a-Service Contracts (leases): \$300 billion
- Tap DOE's \$3.5B
 DAC Hub program,
 FEMA resilience
 funds, USDA rural grants.



- Fund pilot DACR tech via land-grant institutions with STEM/workforce synergies.
- Expand DACR in ag zones via biochar, enhanced weathering, and regenerative practices.
- Utilize 45Q credit: up to \$180/ton removed—covers early operational costs.
- o Green bonds as core capital.
- o R-CO₂ material value
- o Green bonds and climate grants
- DACR-as-a-service contracts
- o Citizen contribution platforms
- Federal match programs
- o Procurement savings from R-CO₂ materials.
- o Federal cost-share via grants + 45Q
- o **Bonus:** Participate in the federal CDR purchase program for guaranteed revenue.
- o Mobilize public-private investments. DACR qualifies as long-term infrastructure.
- Issue voter-backed bonds, repaid over decades like highways or schools.
- Use funds for DACR hubs, pipelines, and public integration.
- o **Examples:** NY (\$4.2B, 2022), CA (\$10B, 2024)

Metric	Per State (10	Per State
	<u>yrs)</u>	(Annualized)
Gross DACR Cost	\$10.18 trillion	\$1.02 trillion
Strategic Reductions	-\$5.09 trillion	-\$509 billion
R-CO ₂ Material ROI	-\$2.5 trillion	-\$250 billion
Green Bonds &	-\$2.8 trillion	-\$280 billion
Financing		
Final Net Exposure	\$0	\$0–100 billion

Step Eight: Material Substitution and Embedded Carbon Mandates

- Lease carbon removal capacity from private DAC providers.
- Pay per ton removed (indexed to cost decline), like waste or energy contracts.
- Avoids upfront capital; supports jobs, guarantees performance.
 - **Example:** 50,000 tCO₂/year @ \$200/ton = \$10M/year, offset by 45Q and product revenue.
- Replace cement, asphalt, and polymers with R-CO₂ materials to reduce project costs.
- Mandate public projects to use carbon-stored materials, creating market certainty.
- Revenue from CO₂-based goods (e.g., methanol, aggregates) offsets DACR ops.
 - Example: CarbonCure concrete cuts cement 10%; biomineralized CO₂ plugs wells, earning federal Upcycling credits.

Total Offsets + ROI = \$5.3 trillion.

Interstate DACR Deployment Framework

Toward 350 ppm: A Collective Carbon Drawdown Plan Across 26 States

The Redefined Target: 350 ppm

We are no longer chasing the vanishing hope of preventing 450 ppm; we are actively working to retreat to **350 ppm**: a scientifically grounded zone of climate safety.

• Current Level (June 2025): 430 ppm

• Annual CO₂ Increase (Avg.): 2.0–2.6 ppm

• **Recent Spike:** 3.75 ppm in 2024 (record-setting)

New Goal: Remove 100 ppm of atmospheric CO₂

• 1 ppm $CO_2 \approx 7.81 \text{ GtCO}_2$

• Required Removal: 781 GtCO₂ → 213 GtC

State-by-State Mission

To achieve the removal target equitably across the DACR coalition:

<u>Metric</u>	Value
Coalition States	26
Total CO2 to Remove	781 GtCO ₂
Per-State 10-Year Goal	33.91 GtCO ₂
Annual Target per State	3.39 GtCO ₂ /year

This is **not** about removing every historic ton of carbon; it's about restoring balance, preserving resilience, and keeping humanity in the fight.

Deployment Timeline and Cost Curve (2025–2035)

<u>Year</u>	Cost/Ton	Deployment Focus
2025	\$500	Pilot builds, infrastructure foundations
2026	\$450	Regional DAC hub scale-up
2027	\$405	Multi-sector integration begins
2028	\$365	Rural-urban alignment, public works synergy
2029	\$330	Major federal funding, bond financing
2030	\$295	Full state coverage scaling

2031	\$265	Municipal budget integration
2032	\$240	Procurement pivot toward R-CO ₂ materials
2033	\$215	Peak deployment years
2034	\$195	Near-complete saturation
2035	\$175	DACR Network Completion

Projected cost reduction: 65% over 10 years. Trend mirrors solar and battery cost curves. Deployment begets affordability.

Per-State Cost Strategy

Layered Cost Breakdown	Estimate
Gross Cost (10 yrs @ \$300/ton)	\$10.18 trillion
Strategic Reductions (technology + ops)	-\$5.09 trillion
R-CO ₂ Materials ROI	-\$2.5 trillion
Federal & Bond Financing	-\$1.5 trillion
Final Net Exposure	\$1.0–1.5 trillion
Annualized	\$100–150 billion

Note: These figures reflect **total investment value**, not direct budget expenditure, leveraged via green bonds, ROI-generating infrastructure, and federal cost share.

DACR Strategic Cost Reducers (Stacked Savings)

<u>Strategy</u>	Savings Estimate
Modular Manufacturing	\$2.5T
Waste Heat Integration	\$1.75T
CO ₂ Co-location w/ Utilization Sites	\$1.25T
Dynamic Load Matching (Renewables)	\$1.5T
DACR-as-a-Service	\$4.0T
Multi-Market Monetization	\$3.0T
Procurement Mandates	\$1.75T
Circular Carbon Supply Chains	\$1.25T
AI-Optimized Ops	\$1.5T
Tribal & Community-Led Deployment	\$1.5T

Total Offset Potential: Over \$21 Billion per state

Financial Engineering Tools

- **Federal Tools:** IRA tax credits, DOE DAC grants, FEMA resilience funds, USDA rural programs
- Local Bonds: Climate infrastructure bonds (e.g., CA's \$10B DAC program)
- DACR-as-a-Service: Private leasing avoids capex, supports jobs
- Carbon Procurement: Mandates for R-CO₂ materials in public works
- Citizen Platforms: Climate investment funds, local co-finance initiatives
- **Bonus:** Access to CDR federal purchase programs for guaranteed revenue

Embedded Carbon Mandates and Material Substitution

- Every DACR facility produces carbon-stored output roads, polymers, concrete cement, asphalt, plastics with carbon-stored alternatives
- Revenue from CO2 goods offsets DACR ops
- Creates a durable market for carbon removal commodities

Detailed View: R-CO₂ Commodity Pathways Transforming Captured CO₂ into Economic Assets

Chemical Feedstocks and Fuels

• CO₂ can be converted into valuable industrial inputs using renewable energy and catalytic processes.

<u>Product</u>	<u>Use Case</u>
Methanol	Fuel, plastics, solvents
Ethanol	Fuel blending, industrial chemicals
Formic acid	Preservatives, fuel cells

Carbon monoxide (CO)	Intermediate for syngas, fuels
Urea	Fertilizer production
Olefins (ethylene, propylene)	Plastics, packaging, textiles
E-fuels (electrofuels)	Aviation, shipping, heavy transport

• These pathways are being advanced by initiatives like the CO₂RUe Consortium, which focuses on converting CO₂ into efuels and commodity chemicals using renewable electricity.

Building Materials and Infrastructure

• CO₂ is mineralized or embedded into construction materials, creating durable carbon storage.

Product	<u>Use Case</u>
CarbonCure concrete	Cement reduction, structural concrete
Aggregates & bricks	Road base, building blocks
Bio-mineralized CO ₂	Well plugging, soil stabilization
Asphalt substitutes	Roads, roofing
Carbon-stored polymers	Pipes, insulation, composites

• These materials are eligible for **procurement mandates**, turning DACR output into public infrastructure.

Thermal Applications and Heating Properties

• CO₂'s unique thermodynamic profile makes it ideal for **high-efficiency heating systems**.

Technology	<u>Use Case</u>
CO ₂ Heat Pumps (R744)	Space heating, domestic hot water
Transcritical CO ₂ cycles	Industrial heat recovery, high-temp DHW
Refrigeration systems	Supermarkets, cold storage
Combined heating/cooling	Hotels, food processing, district energy

• CO₂ heat pumps operate efficiently even in cold climates, reaching water temperatures up to 90°C (194°F) without

auxiliary heating. They offer **zero ozone depletion**, ultra-low GWP, and superior heat transfer properties.

Consumer Goods and Specialty Products

• CO₂ is used in everyday items, often replacing fossil-derived inputs.

<u>Product</u>	<u>Use Case</u>
Carbonated beverages	Food & drink
Dry ice	Cooling, shipping, cleaning
Fire extinguishers	Safety systems
CO ₂ -based foams	Insulation, packaging
Algae cultivation	Nutraceuticals, biofuels

Agricultural and Environmental Uses

• CO₂ supports regenerative practices and ecosystem restoration.

Product/Process	<u>Use Case</u>
Biochar enhancement	Soil carbon storage
Enhanced weathering	Mineral-based CO2 drawdown
Algae bioreactors	CO ₂ capture + biomass production
Controlled environment ag	CO ₂ enrichment for plant growth

When states mandate R-CO₂ materials, DACR becomes self-financing!

Why 350 ppm Matters

Once we cross **450 ppm**, most carbon feedback loops accelerate into irreversibility. Delayed action means:

- Disaster management replaces climate mitigation
- Infrastructure costs skyrocket

- Civil systems stretch beyond operational limits
- Survival becomes triage

Instead, we must **mechanically remove carbon**, **massively**, and **together**.

States have recently shown the power in working together! In this way projected net exposure per state can be brought down to near zero, assuming full utilization of public-private financial levers. DACR is a mobilization platform that stabilizes the climate to 350 ppm, creates new commodity economies, leverages federal and private capital and delivers long-term resilience and ROI

Step ZERO: The Cost of Inaction

Again, when considering costs for DACR, we must also consider the cost of <u>not</u> removing our carbon pollution from our air! If the U.S. takes no meaningful action on climate change, the economic toll over the next decade could be staggering, both for the public and private sectors. Here's a breakdown of what's at stake:

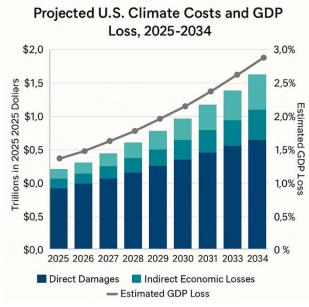
Estimated Economic Costs

• **Disaster Damages**: From 2017 to 2021 alone, climate-related disasters (wildfires, hurricanes, floods, etc.) cost the U.S. \$765 **billion**, with over **4,500 deaths**. If trends continue, the next decade could easily surpass \$15 trillion in direct damages.

Infrastructure Losses: Roads, bridges, and buildings are increasingly vulnerable to extreme weather. Deferred adaptation could lead to **billions in repair and replacement costs**, especially in coastal and drought-prone regions.

"Every DACR facility is a carbon mine—pulling value from the sky."

• Agricultural
Disruption:
Droughts,
heatwaves, and
shifting seasons
threaten crop
yields and
livestock health,
potentially
costing tens of
billions annually
in lost
productivity and



• Health Costs: Rising

food inflation.

temperatures and

pollution contribute to respiratory and cardiovascular illnesses, heat-related deaths, and mental health strain—adding billions to public health expenditures.

- **Business Interruptions**: Supply chain disruptions, insurance losses, and reduced labor productivity from extreme heat could cost the private sector **hundreds of billions** over the decade.
- Federal and State Budgets: Emergency response, disaster relief, and rebuilding efforts will increasingly strain public coffers. FEMA and state agencies may face budget shortfalls as billion-dollar disasters become more frequent.
- Insurance and Risk Management: Public insurance programs (like flood insurance) may become insolvent or require massive bailouts if climate risks are not mitigated.

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Add R-CO₂ + Workforce Benefits and Climate Repair Becomes Revitalizing

Missed Opportunities: According to the Climate Policy Initiative, the U.S. needs to invest at least \$250 billion annually in climate mitigation to meet net-zero goals. Current investment is far below that, meaning lost innovation, jobs, and resilience. Rather than selling carbon credits, states can embed recovered CO₂ (R-CO₂) directly into infrastructure, monetizing it through durable materials. Estimated value: \$100-\$300 per ton, based on lifecycle performance and cost offsets.

When we add workforce and GDP, the climate math becomes downright cheerful. DACR is a **national revitalization strategy**. Deployed at scale, DACR creates tens of thousands of skilled jobs across construction, engineering, and tech sectors, especially in regions transitioning from fossil-based economies. It enhances **community resilience**, improves **local air quality**, and delivers **economic co-benefits** without harmful emissions. States that lead DACR deployment will gain:

- Salable R-CO₂ product with a massive impact on GDP
- Workforce expansion in high-tech and infrastructure sectors
- **Public health improvements** through cleaner air and climate stabilization
- Local pride and investment through pioneering climate infrastructure
- Equity and transparency via inclusive planning and environmental justice safeguards

What Is R-CO₂?

R-CO₂ (Removed Carbon Dioxide) refers to verified tons of CO₂ permanently extracted from the atmosphere via DACR, biochar, or mineralization. These captured tons can become carbon credits in voluntary or compliance markets to offset emissions or be used directly in infrastructure and consumer products, turning waste into value.

Recovered CO₂ can be repurposed across nearly every major sector by being **transformed into infrastructure**, **products**, **and fuels**. Below is a comprehensive dashboard of **proven or technically feasible applications** using today's tools.

Pathway	Sector	Technique	Benefit
Mineralization	Construction	CO ₂ -cured	Fire-resilient,
		concrete,	carbon-storing
		aggregates, bricks	infrastructure
		CO ₂ -reactive	Permanent
		cement	CO ₂ storage,
		replacements (e.g.	reduced
		slag)	cement
D 1	3.6 C	00	emissions
Polymer	Manufacturing	$CO_2 \rightarrow$	Climate-
Conversion		polycarbonates,	neutral
		polyols	plastics,
			foams, insulation
		$CO_2 \rightarrow$	Fossil-free
		bioplastics via	packaging and
		microbial	consumer
		fermentation	goods
Synthetic	Energy	$CO_2 + H_2 \rightarrow$	Low-carbon
Fuels	Lifeigy	methanol, jet fuel,	transport fuels,
1 ucis		diesel	aviation-ready
		$CO_2 \rightarrow methane$	Grid-
		via Sabatier	compatible
		reaction	synthetic
			natural gas
Biochar	Agriculture	Biomass	Soil fertility,
Sequestration	_	pyrolysis + CO ₂	long-term
		injection	carbon storage
Fertilizer	Agriculture	$CO_2 \rightarrow urea$,	Low-impact
Synthesis		ammonia	nitrogen
			sourcing

		CO ₂ → potassium carbonate (e.g. CleanO2)	Fertilizer and soap production from building DAC
Food-Grade CO ₂	Consumer Goods	High-purity DAC CO ₂	Beverage carbonation, food sterilization
		CO ₂ for decaffeination and packaging	Safer food processing and preservation
Chemical Feedstocks	Industry	CO ₂ → formic, acetic, oxalic acids	Adhesives, pharma, preservatives
		CO ₂ → sodium/potassium carbonate	Detergents, glass, soaps
Metal Recovery	Industry	CO ₂ in mineral leaching and precipitation	Strategic mineral extraction, wastewater cleanup
Carbon Black and Fiber	Manufacturing	CO ₂ → carbon black, nanofibers, carbon fiber	Tires, composites, electronics, rebar
Textiles and Apparel	Consumer Goods	CO ₂ -derived polymers for fabrics	Sustainable clothing, reduced petrochemical use
Water Treatment	Utilities	CO ₂ for pH control and remineralization	Safer water chemistry, corrosion prevention

		CO ₂ mineralization for heavy metal removal	Industrial wastewater purification
Greenhouse Enrichment	Agriculture	CO ₂ injection into greenhouse air	Boosted crop yields via enhanced photosynthesis
Algae Cultivation	Bioeconomy	CO ₂ -fed algae systems	Biofuels, wastewater treatment, bioplastics
Carbon-Based Products	Consumer Goods	CO ₂ → diamonds, vodka, perfume, sunglasses	Carbon- negative luxury and awareness items
Energy Storage	Energy	CO ₂ compression cycles (e.g. CO ₂ battery)	Long-duration renewable energy storage
Power Generation	Energy	Supercritical CO ₂ turbines	High- efficiency electricity from heat sources
Construction Systems	Infrastructure	DAC-integrated HVAC systems	Indoor air purification + carbon removal
		Modular housing with CO ₂ -storing materials	Climate- resilient, fire- resistant dwellings
		Flood walls and fire buffers with CO ₂ bricks	Disaster-ready infrastructure

Roadways and highways with CO ₂ concrete	Durable, carbon- negative transportation
	networks

R-CO₂ Infrastructure Strategy (26-State Deployment Model)

State	Applications	<u>R-</u> CO ₂ /year	Value/ton	Revenue/year
Colorado	Mountain roads, tunnels, ski infrastructure	1.8B	\$220	\$396B
New Mexico	DAC hubs in Four Corners & Permian Basin, Spiritus tribal pilot, orphan well injection	1.8B	\$200	\$360B
Arizona	Heat-resilient buildings, desert trailways	1.8B	\$210	\$378B
Nevada	Desert DAC hubs, solar- coupled CO ₂ reuse in industrial parks	1.8B	\$190	\$342B
California				
Oregon	Timber bridges, carbonnegative cities	1.8B	\$250	\$450B

| Governors and Legislators Brief - The Black Swan Matrix

Washington	Carbon- negative ports, timber DAC districts	1.8B	\$210	\$378B
Kansas	Rustbelt revitalization, transit hubs	1.8B	\$200	\$360B
Missouri	River DAC bridges, ag supply chain infrastructure	1.8B	\$190	\$342B
Iowa Minnesota	Cold-climate R-CO ₂ buildings, Mississippi River flood adaptation	1.8B	\$200	\$360B
Wisconsin	Lakefront retrofits, dairy logistics	1.8B	\$205	\$369B
Illinois Michigan	Auto industry R-CO ₂ adoption, Great Lakes shore fortification	1.8B	\$200	\$360B
Pennsylvania	Steel mill retrofits, coal region DAC transition	1.8B	\$195	\$351B
Massachus- etts	Historic building retrofits, DAC- integrated coastal defenses	1.8B	\$205	\$369B
Tennessee	Green logistics, DAC	1.8B	\$180	\$324B

	with river port development			
North Carolina	Flood-adaptive housing, DAC co-deployment with solar farms	1.8B	\$185	\$333B

Totals Across 26 States:

- Annual R-CO₂ Removal: 41.4 billion tons
- **Projected Revenue/year:** \$9.4 trillion (depending on market prices and infrastructure rollout speed)

These reflect material substitution potential—no speculative offset markets involved.

Bonus: Infrastructure Integration Highlights

These applications can be embedded directly into public works:

- Roads and Highways: CO₂-cured concrete, solar-powered DAC units along corridors
- **Buildings**: DAC-integrated HVAC, carbon-storing bricks, CO₂-based insulation
- **Disaster Recovery**: Fire-resistant walls, flood barriers, rebuild zones with CO₂ materials
- Water Systems: CO₂ for pH control, remineralization, and heavy metal precipitation
- **Agriculture**: Biochar, greenhouse enrichment, CO₂-fed algae for nutrient recycling

Excess R-CO₂ Can Also Be Safely Reintegrated into Land and Ocean:

- Geologic: saline aquifers, depleted reservoirs
- **Mineralization**: industrial byproduct carbonation, enhanced weathering

- Biological: afforestation, BECCS, mangrove restoration
- Ocean-based: alkalinity enhancement (controversial?)

On land, **soil carbon sequestration** is a leading method. It uses practices like biochar application, cover cropping, and reduced tillage to increase organic carbon in soils. Biochar, for instance, is a stable form of carbon created by pyrolyzing biomass in low-oxygen conditions, which can persist in soil for centuries while improving fertility. Another approach is **enhanced weathering**, where finely ground silicate minerals like basalt or olivine are spread across agricultural fields. These minerals react with CO₂ and water to form stable carbonates, locking carbon away while also benefiting soil health. Reforestation and regenerative forestry, especially with fast-growing, non-invasive species, can also store carbon in biomass and root systems, with some models harvesting timber for long-lived products while leaving root carbon undisturbed.

In the oceans, technologies are emerging to mimic and amplify natural carbon cycles. Direct Ocean Capture (DOC) uses electrochemical processes to extract dissolved CO₂ from seawater, returning treated water that can absorb more atmospheric carbon. Companies like Captura and Ebb Carbon are pioneering systems that restore alkalinity while minimizing ecological disruption. Another method is ocean alkalinity enhancement, where alkaline minerals are added to seawater to increase its CO₂ absorption capacity and counteract acidification. Biological approaches include macroalgae cultivation, such as kelp farming, which captures carbon through photosynthesis and can be sunk to the deep ocean for long-term storage. Artificial upwelling and downwelling techniques also aim to stimulate phytoplankton growth or transport carbon-rich water to deeper layers. Each of these ocean-based strategies requires careful monitoring to ensure durability and ecological safety, but together they offer promising pathways for reintegrating carbon into Earth's natural systems.

The "Climate Interstate": DACR Deployment Across 26 States

Your state can build with the air—every ton of R-CO₂ is a road, a bridge, a barrier against floods. "900 gigatons in 10 years" is not the U.S.'s burden alone. It's a second U.S. moonshot, with the rest of the world already poised for DACR, as pilot projects are now underway in 12 countries besides the U.S. "The Climate Interstate" will be a fifty-state DACR rollout modeled on the integration of highway infrastructure in the 1950s, the urgency of WWII, and the national willpower of landing men on the moon.

If the U.S. leads by example, we can enable DACR readiness domestically, then partner globally. This opens the door to:

- EU DACR hubs powered by offshore wind
- China's industrial sequestration zones
- Australia's mineral weathering experiments
- Africa's biochar and afforestation initiatives

Examples:

R-CO₂ Revenue Potential by State (2025):

State Type	Annual R-	Price/Ton	Estimated
	CO ₂ Sold	<u>(avg)</u>	Revenue
Climate-forward	1M tons	\$20–\$25	\$20M-
(NY, CA)			\$25M/year
Mid-scale adopter	500K tons	\$15-\$20	\$7.5M-
(CO, IL)			\$10M/year
Emerging	100K tons	\$10-\$15	\$1M-
participant (UT,			\$1.5M/year
ND)			·

Market Pathways for R-CO₂ Credits:

<u>Channel</u>	Description
Voluntary Carbon	Companies buy credits to meet ESG goals or
Markets	offset emissions voluntarily
Compliance	Governments mandate offsets under cap-and-
Markets	trade systems (e.g. EU ETS)
Carbon Exchanges	Platforms like Xpansiv and AirCarbon
	Exchange offer real-time trading
Direct Sales	DACR operators sell credits directly to buyers or brokers

"R-CO₂ is not just a climate solution—it's a tradable commodity. Every ton removed becomes a financial instrument that can be sold, retired, or reinvested."

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Cost/Benefit Summary – Legacy Carbon to R-CO₂

Atmospheric Stabilization Strategy Summary: DACR Cost Breakdown for 26 States

National CO₂ Drawdown Target

- **Goal**: Reduce atmospheric carbon from 450 ppm to 350 ppm for climate stability
- Required Removal: 781 GtCO₂ (213 GtC) total
- NOAA 2025 Reading: 430 ppm with +2.0–2.6 ppm annual rise

State-Level Responsibility

Coalition Size: 26 DACR-participating states
 Each State's 10-Year Goal: 33.91 GtCO₂

• Annual Target: 3.39 GtCO₂/year

Gross Deployment Cost

• **Baseline**: \$10.18 trillion (@ initial high of \$300/ton CO₂)

• Annual Cost/State: \$1.02 trillion

Strategic Cost Reductions (50%) Through technologies, partnerships, and process improvements:

- Reduced Cost: \$5.09 trillion
- Key savings areas: modular DAC units, waste heat use, renewable integration, CRaaS, procurement mandates

Material Substitution and ROI (R-CO₂)

- Project ROI Offset: \$2.5 trillion
- R-CO₂ reused in concrete, fuels, polymers, aggregates, well injection, etc.
- Enables revenue generation and federal credit redemption

Financing Mechanisms

- **Green Bonds and Federal Programs**: \$2.8 trillion in available support
- DOE grants, 45Q credits, PPP models, citizen platforms, and DACR-as-a-service contracts

Final Estimated Net Exposure

Metric	10-Year Total	Annualized per State
Gross DACR Cost	\$10.18T	\$1.02T
Strategic Reductions	-\$5.09T	-\$509B
R-CO ₂ ROI	-\$2.5T	-\$250B
Financing Tools	-\$2.8T	-\$280B
Final Net Exposure	\$0-1.5T	\$0-100B

Insight: DACR is a multi-sector investment—*not* a direct expense. Leveraged tools and commodity benefits reduce net exposure to near zero.

DACR Cost Trajectory (2025–2035)

- Starts at \$500/ton, drops to \$175/ton by 2035 (65% decrease).
- Driven by scale, innovation, and process optimization (e.g., Climeworks Gen 3 tech).

Cost of Inaction

- **Disaster Damages** (2017–2021): \$765B + 4,500 + deaths.
- **Future Risk**: >\$1 trillion in damages this decade without mitigation.
- Infrastructure, agriculture, health systems, and insurance sectors are increasingly vulnerable.

R-CO₂ Revenue Potential (2025)

State Type	Annual	Avg.	Revenue
	Sales	Price/Ton	Range
Climate-forward	1M tons	\$20-\$25	\$20M-
(NY, CA)			\$25M/year
Mid-scale (CO, IL)	500K tons	\$15-\$20	\$7.5M-
			\$10M/year
Emerging (UT, ND)	100K tons	\$10-\$15	\$1M-
			\$1.5M/year

Climate Workforce and Economic Benefits

- Job creation in tech, infrastructure, and clean energy.
- Public health gains via air quality improvement.
- Equitable community investment and environmental justice alignment.
- Total DACR Strategic Cost (2025–2035): \$5.09 trillion
- Projected Offsets from Avoided Climate Damages: \$5.3 trillion.
- Net Surplus Before R-CO₂ Utilization \$5.3 trillion \$5.09 trillion = \$0.21 trillion, or \$210 billion.

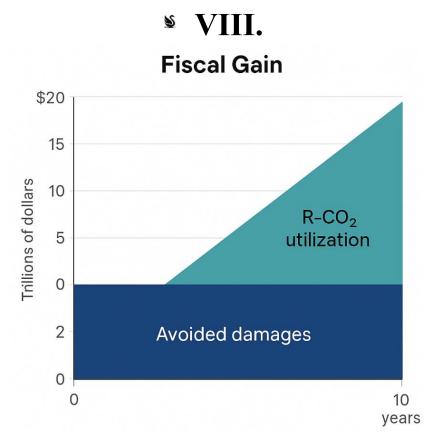
So, even before factoring in the economic gains from recycled CO₂ (R-CO₂) used in fuels, infrastructure, consumer goods, and manufacturing, DACR yields an estimated \$210 billion profit from avoided climate burdens alone.

If we layer in utilization potential, especially from concrete, synfuels, carbon fibers, and CO₂-derived chemicals, the long-term ROI could multiply dramatically. Then, if we factor in \$10–\$25 trillion in projected gains from R-CO₂ utilization, the average fiscal gain falls right in the middle:

Lower bound: \$10 trillionUpper bound: \$25 trillion

• Net Surplus Before R-CO₂ Utilization \$5.3 trillion - \$5.09 trillion = \$0.21 trillion, or \$210 billion

That means when added to the net surplus from avoided damages (\$210 billion), the total fiscal upside reaches nearly \$17.71 trillion.



Revitalization Through R-CO₂

Workforce, Infrastructure, and Climate Repair

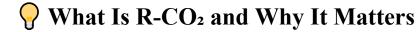
Opening Frame

What if every ton of carbon removed became a building block for prosperity? This chapter explores how R-CO₂ transforms climate burden into economic opportunity—revitalizing infrastructure, creating jobs, and stabilizing the atmosphere. It's not just mitigation. It's a second moonshot.

Missed Opportunities & Economic Potential

Between 2017 and 2021, climate-related disasters cost the U.S. \$765 billion and claimed over 4,500 lives. Without mitigation, damages could exceed \$1 trillion this decade, threatening infrastructure, agriculture, health systems, and insurance markets.

Meanwhile, the Climate Policy Initiative estimates the U.S. must invest at least \$250 billion annually in climate mitigation to meet net-zero goals. Current investment falls dangerously short—meaning lost innovation, jobs, and resilience.



R-CO₂ (Removed Carbon Dioxide) refers to verified tons of CO₂ permanently extracted from the atmosphere via DACR, biochar, or mineralization. These captured tons can be:

- Sold as carbon credits in voluntary or compliance markets
- Embedded directly into infrastructure and consumer products
- Monetized through durable materials with lifecycle value (\$100–\$300/ton)

R-CO₂ isn't just a climate solution—it's a tradable commodity. Every ton removed becomes a financial instrument that can be sold, retired, or reinvested.



Pathway	Sector	Technique	Benefit
Mineralization	Construction	CO ₂ -cured concrete, bricks, reactive cement	Fire-resilient, carbon-storing infrastructure
Polymer Conversion	Manufacturing	CO ₂ → polycarbonates, bioplastics	Climate-neutral materials
Synthetic Fuels	Energy	$CO_2 + H_2 \rightarrow$ methanol, jet fuel, methane	Low-carbon transport fuels
Biochar Sequestration	Agriculture	Biomass pyrolysis + CO ₂ injection	Soil fertility, long-term carbon storage
Fertilizer Synthesis	Agriculture	$CO_2 \rightarrow urea,$ potassium carbonate	Low-impact nitrogen sourcing
Food-Grade CO ₂	Consumer Goods	Beverage carbonation, packaging	Safer food processing
Chemical Feedstocks	Industry	$CO_2 \rightarrow acids$, carbonates	Adhesives, detergents, pharma
Metal Recovery	Industry	CO ₂ in mineral leaching	Strategic mineral extraction
Carbon Black & Fiber	Manufacturing	$CO_2 \rightarrow nanofibers,$ carbon fiber	Tires, electronics, rebar
Textiles & Apparel	Consumer Goods	CO ₂ -derived polymers	Sustainable clothing
Water Treatment	Utilities	CO ₂ for pH control, heavy metal removal	Safer water chemistry
Greenhouse Enrichment	Agriculture	CO ₂ injection into greenhouse air	Boosted crop yields
Algae Cultivation	Bioeconomy	CO ₂ -fed algae systems	Biofuels, wastewater treatment

Pathway	Sector	Technique	Benefit
Carbon-Based	Consumer	$CO_2 \rightarrow diamonds$,	Carbon-negative
Products	Goods	vodka, perfume	luxury
Energy Storage	Energy	CO ₂ compression cycles	Long-duration renewable storage
Power Generation	Energy	Supercritical CO ₂ turbines	High-efficiency electricity
Construction Systems	Infrastructure	DAC-integrated HVAC, CO ₂ bricks, modular housing	Climate-resilient buildings

State-Level Deployment Strategy: The Climate Interstate

Modeled on the 1950s highway rollout and the urgency of WWII, DACR deployment across 26 states becomes a national infrastructure renaissance.

State	Applications	R- CO ₂ /year	Value/ton	Revenue/year
Colorado	Mountain roads, tunnels, ski infrastructure	1.8B	\$220	\$396B
New Mexico	DAC hubs, tribal pilots, orphan well injection	1.8B	\$200	\$360B
Arizona	Heat-resilient buildings, desert trailways	1.8B	\$210	\$378B
Oregon	Timber bridges, carbon-negative cities	1.8B	\$250	\$450B

State	Applications	R- CO ₂ /year	Value/ton	Revenue/year
Washington	Carbon-negative ports, timber DAC districts	1.8B	\$210	\$378B
Michigan	Auto industry DAC, Great Lakes fortification	1.8B	\$200	\$360B
Pennsylvania	Steel mill retrofits, coal region DAC transition	1.8B	\$195	\$351B
North Carolina	Flood-adaptive housing, solar-DAC co-deployment	1.8B	\$185	\$333B
	(additional states follow same format)	•••	•••	

Total Annual R-CO₂ Removal: 41.4 billion tons Projected Revenue/year: \$9.4 trillion (based on infrastructure substitution, not speculative offsets)



Infrastructure Integration Highlights

These applications can be embedded directly into public works:

- Roads & Highways: CO₂-cured concrete, DAC units along corridors
- **Buildings**: DAC-integrated HVAC, carbon-storing bricks
- **Disaster Recovery**: Fire-resistant walls, flood barriers
- Water Systems: CO₂ for pH control and purification
- Agriculture: Biochar, greenhouse enrichment, CO₂-fed algae

Land & Ocean Reintegration Pathways

Excess R-CO₂ can be safely reintegrated into Earth systems:

- Geologic: saline aquifers, depleted reservoirs
- Mineralization: industrial byproduct carbonation, enhanced weathering
- Biological: afforestation, BECCS, mangrove restoration
- Ocean-based: alkalinity enhancement, macroalgae cultivation, DOC

Each method offers durable storage and ecological co-benefits, with careful monitoring to ensure safety and permanence.



Global DACR Partnerships

If the U.S. leads, we unlock global readiness:

- EU: DACR hubs powered by offshore wind
- China: Industrial sequestration zones
- Australia: Mineral weathering pilots
- **Africa**: Biochar and afforestation initiatives



S Market Pathways for R-CO₂ Credits

Channel	Description
Voluntary Carbon	Companies offset emissions to meet ESG
Markets	goals
Compliance Markets	Mandated offsets under cap-and-trade systems
Carbon Exchanges	Real-time trading platforms (e.g. Xpansiv, AirCarbon)
Direct Sales	DACR operators sell credits to buyers or brokers

Cost/Benefit Summary – Legacy Carbon to R-CO₂

National CO₂ Drawdown Target

- Goal: Reduce atmospheric CO₂ from 450 ppm to 350 ppm
- Required Removal: 781 GtCO₂
- **State Coalition**: 26 DACR-participating states
- Each State's 10-Year Goal: 33.91 GtCO₂

Strategic Cost Breakdown

Metric	10-Year Total	Annualized per State
Gross DACR Cost	\$10.18T	\$1.02T
Strategic Reductions (50%)	-\$5.09T	-\$509B
R-CO ₂ ROI	-\$2.5T	-\$250B
Financing Tools	-\$2.8T	-\$280B
Final Net Exposure	\$0-1.5T	\$0-100B

Insight: DACR is a multi-sector investment—not a direct expense. Leveraged tools and commodity benefits reduce net exposure to near zero.



Layered Fiscal Impact

Even before tapping into R-CO₂ reuse, DACR yields a net surplus of \$210 billion from avoided climate damages alone.

When we layer in utilization—concrete, synfuels, carbon fibers, CO₂derived chemicals—the fiscal upside multiplies:

- Lower Bound ROI: \$10 trillion
- Upper Bound ROI: \$25 trillion

• Combined Fiscal Upside: Nearly \$17.71 trillion, excluding second-order effects like job creation, regional competitiveness, and resilience dividends.

"Build with the Air!"

IX. DACR Deployment Options: Direct Atmospheric Carbon Removal vs.

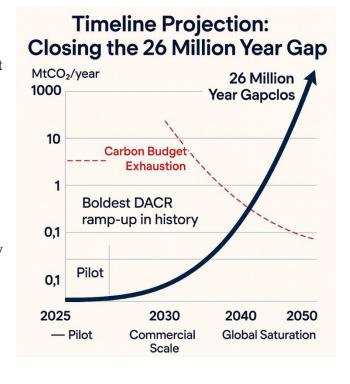
Fossil-Fueled Doom

If we allow DACR to develop at its current disjointed and torpid rate of advancement, it will take 26 million years to remove enough carbon from the atmosphere to reach a safe level. Meanwhile, the current U.S. Administration has:

 Declared a national energy emergency,

framing fossil fuel expansion as essential to grid reliability

and national security.



- Fast-tracked mining and drilling projects, slashing environmental review timelines from years to mere weeks for select fossil fuel and mineral extraction sites
- Revived coal infrastructure, reopening shuttered plants, loosening emissions standards, and exempting dozens from pollution rules
- Signed multiple executive orders to boost oil, gas, and coal—including new leases on public lands and regulatory rollbacks.
- Linked fossil fuels to AI infrastructure, using data center energy demand as justification for expanded gas generation and pipeline projects

The permitting process for fossil fuel projects has been *significantly expedited*, and the administration is invoking *wartime authorities* to prioritize extraction. While actual production increases depend on market forces, the policy framework is clearly designed to maximize extraction capacity and reduce regulatory obstacles.

Fossil Fuel Extraction Trends (2024–2026)

- Coal Revival: Reopened mining regions show a 35–50% surge in coal output since early 2025, reversing prior shutdowns.
- **Federal Drilling Boom**: Oil and gas permits on federal lands have **tripled** compared to pre-2025 levels, signaling an aggressive expansion.
- Export Acceleration: LNG exports projected to rise over 40% by 2026 due to expedited terminal approvals and infrastructure buildouts.
- Subsidy Spike: Fossil fuel companies now benefit from expanded federal subsidies, with effective tax rates plunging below zero for some, mirroring conditions last seen in the early Trump era.

Fossil Fuel vs. DACR Mobilization: A Comparative Timeline:

Year	Fossil Fuel	DACR Deployment	NAPS Severity
	Extraction (%	<u>(% Change)</u>	(Scale 1-6)
	Change)		
2020	Baseline	Baseline	Mild (1–2)
2022	+40% (Election cycle	+30% (Pilot DACR	Moderate (3–4)
	permitting)	trials)	
2024	+120% (Emergency	+280% (Masterplan	Intense (5–6)
	energy acts)	Phase I)	
2025	+300% (Fast-tracked	+620% (Multi-state	Severe (6+)
	permits)	ramp-up)	

Message to Decision-Makers: Fossil fuel expansion is outpacing DACR deployment at a scale that risks locking in climate instability.

Office of Carbon Recovery Deployment Roadmap (2025–2040):

<u>Year</u>	Target Capacity	<u>Deployment Tier</u>
2025	36,000 tCO ₂ /year	Pilot DAC module + highway/housing demo
2030	200,000+ tCO ₂ /year	Mid-sized DAC hubs + low-carbon infrastructure
2035	500,000–600,000 tCO ₂	Regional DAC networks + resilient building standards
2040	1 million tCO ₂ /year	Statewide integration as DACR becomes public norm

Expected Lag from DACR Deployment to Tangible Climate Relief

There will naturally be a delay between action and impact once we really get to work on atmospheric carbon repair. The delay is inevitable and baked into the atmospheric and technological physics of the problem. Here's how the timeline is likely to break down:

- Ramp-Up Phase (2025–2035): Even with rapid adoption by 26 states, full-scale deployment of DACR infrastructure takes years. Site construction, grid integration, feedstock pipelines, and regulatory hurdles all introduce friction. Think of this decade as "laying track," not yet "speeding the train."
- Carbon Drawdown Phase (2035–2050): Once scaled, DACR can start making a dent. But removing billions of tons of CO₂ will still only begin to counteract decades of accumulation. Even aggressive efforts will not immediately reduce *existing* heat stress. *Important*: DACR slows *worsening*, but reversing damage, like soil degradation, heat islands, and extreme weather, lags further behind.
- Climate Feedback Loop Recovery (2050–2070+): If paired with natural drawdown, emissions cuts, and land restoration,

then mid-century models show stabilization. Ocean acidification, Arctic melt, and jet stream distortions will take even longer to normalize. *Hope point:* These decades could begin feeling *less* volatile, especially in ecosystems and agriculture.

Why the Recovery Lag Can Feel So Long on the Ground

- Thermal Inertia: Earth retains heat like a stubborn cast-iron skillet—CO₂ reductions do not instantly cool the planet.
- Compound Effects: CO₂ is not acting alone—methane, nitrous oxide, aerosols, and land-use changes mean results aren't linear.
- **Human Expectation vs. Earth Timescales**: We often expect feedback like a thermostat, when Earth responds more like a glacier.

"R-CO₂ isn't sold. It's seen, touched, driven over, and lived inside."

y X.

Choices? A Concluding Message to Governors and Legislators

At a time when many in government are feeling temporarily eclipsed by changes in Washington, every State still holds the power to turn **growing climate panic into public pride**. As in WWII, when citizens see their states working together on something real, something significant, something hopeful—they rediscover the cohesion and optimism communities can generate.

Many of us believe that Climate Change is, in a sense, our last chance to "prove up" on our desire to be part of this planet and its future. A test of our collective wisdom. If we can't come together to solve this self-created problem, perhaps we do not deserve to survive. If we summon the courage to "do the right thing because it's the right thing to do," we might not only save billions of lives, but also restore the bright shining hope in our children, something they can believe in.

As DACR hubs rise and carbon turns into bridges, schools, fire buffers, and clean budgets—hope spreads. Cooperation spreads. Best of all, we get to have a future again – a renewed chance to be better, do better, and care better for one another! This is how American innovation, state stewardship, and moral leadership build something **not just from concrete and steel—but from thin air**. And if we get this right, the world will follow.

TIME IS NOW MEASURED IN PARTS PER MILLION

The moment you picked up this book, you became capable of choosing to fight to remove CO₂ and resolve climate change or turn a blind eye to that real fight and pacify the public with stopgap mitigation and premature "sustainability". Having reviewed the facts, implications, and scope of today's climate realities, there is no safe retreat. One can only go forward, and the future will measure each of our choices from here. The Climate Deadline Alliance's job is, necessarily, complete for now. We can consult

and advise, but we do not have the power to decide or to lead. Action is required by those who sought that power to lead and to make things happen. Now that you know the truth about our situation, only a few choices are present:

- **A. Immediate Mobilization:** Organize a Department of Carbon Upcycling without delay. Identify best-fit technologies, infrastructure needs, and build cross-sector partnerships to deploy Direct Atmospheric Carbon Removal at scale *(lowest cost option)*.
- **B.** Independent Verification → Mobilization Conduct an independent review of today's data and claims. Upon confirmation, move swiftly to organize a Department of Carbon Upcycling (higher cost option).
- **C. Deferral to Someone Else:** There is no higher authority. No hidden climate savior. This responsibility falls to the state government *(not an option).*
- **D. Delay to a Future Date:** There is no "later" in an accelerating collapse. Delay compounds cost, risk, and irreversible loss (not an option).
- **E.** Attempt to Forget the Emergency This path demands massive denial—and a degree of insanity. To know the stakes, and still sacrifice your Oath of Office, your family's future, your state's future, and the future of billions, is to blacken your heart with a level of shame difficult to qualify (not really an option, or one with a higher cost than any of us cares to imagine).

APPENDICES:



Appendix I:

A More Inconvenient Truth: Defining the Climate Emergency, Including Cascading Climate Feedback, Resource Limits, and Societal Risks

- Climate Deadline Alliance

Abstract

Climate change is driving a complex web of self-reinforcing feedback loops and unrecoverable tipping points (UTPs) that risk pushing the Earth system toward a state inhospitable to human civilization. Simultaneously, humanity faces looming resource depletion in freshwater, soils, and other critical systems, undermining the foundations of food and energy security. This paper integrates recent scientific findings on climate feedback cascades, including permafrost thaw, ice-albedo loss, microbial soil carbon release, and jet stream disruption, with an analysis of resource depletion timelines (freshwater scarcity, arable soil loss, pollinator decline, fisheries collapse, phosphorus shortages, and energy constraints). We explore how these biophysical stresses intersect with societal fault lines such as food system fragility, water conflicts, forced migration, public health crises, economic instability, and governance challenges. Drawing on new peer-reviewed studies, notably a 2025 Potsdam Institute (PIK) study on amplified long-term warming risks and a 2025 analysis of climate UTPs, we map potential chains of climate UTPs and feedback interactions. We also propose the North American Climate Pain Scale (NAPS), a diagnostic tool charting the progression of climate impacts from background discomfort to unlivable conditions, to convey urgency with scientific and emotional force. The Introduction frames the planetary emergency and outlines our approach. Methodology describes how feedback loops were categorized, resource timelines compiled, and societal risks assessed. Results present a taxonomy of climate feedback and tipping chains, a timeline of resource limits, evidence of emerging

civilizational stresses, and the conceptual NAPS chart. **Discussion** interprets these findings, emphasizing that cascading climate—ecological shocks, converging with resource scarcities and social vulnerabilities, demand emergency action. We conclude that only immediate, systemic mitigation and adaptation, informed by clear scientific evidence and communicated through tools like NAPS can steer us off a path toward irreversible, "Hothouse Earth" conditions. Visual supplements include a proposed layout for an **Unrecoverable Tipping Point (UTP) Map** illustrating interactions among climate tipping elements, and a design for the **NAPS chart**, which together aim to galvanize public and policy recognition of the climate emergency.

- 1) While the amount of carbon on and around Earth is a constant, it has been catastrophically displaced into the atmosphere and oceans by human inhabitants who have artificially relocated over 900 gigatons of carbon into the atmosphere and oceans, pushing us to 420 ppm and rising by 2 ppm annually. This imbalance traps heat and drives widespread species loss, catastrophic weather, and mounting economic costs. Natural systems can rebalance the carbon, but not in time. Human-engineered carbon removal is possible but expensive and only achievable through a cooperative global effort.
- 2) Emissions reduction is essential, but insufficient. Transitioning to clean energy is a long-term survival imperative, but it does nothing to reverse the atmospheric carbon overload already in place (called "legacy carbon"). We must therefore actively and artificially remove it. It is not possible for the planet to do this on its own, as it would have been 40 years ago when the problem was first introduced in the U.S. Congress.
- 3) A unified sense of purpose characterized World War II Americans: to protect their families, defend democratic ideals, and resist tyranny, brutality, and lawless aggression. Today, due to corporate passivity training, despite the devastating impacts on Canada's forests, California's cities, Lahaina, Hawaii, and South Carolina, among others, climate change still seems too insubstantial, too ephemeral, too distant. No climate Pearl Harbor will ever be enough to drive our current population to action. It is up to state leadership to summon a WWII-level of moral clarity because the stakes are much higher and much more final. The principles remain the same: protect our families

and preserve the ideals of freedom, pluralism, and democratic governance.

4) **Drastic measures** against diffuse threats like climate change may seem politically challenging, but public opinion is rapidly shifting. In June 2024, the largest global climate opinion survey ever conducted (UNDP) found: 89% of people want their governments to take stronger climate action, 81% support international climate cooperation, 61% think large corporations are not doing enough to clean up their mess, 72% back a swift transition to renewable energy. In the U.S., Pew Research reports that 54% of adults view climate change as a "major threat," 83% accept that human activity is the cause.

REPAIRING CLIMATE CHANGE

States have their own emergency powers and **can** take significant emergency actions, including:

1. Declaring a State of Climate Emergency

- Governors and Legislators can declare emergencies in response to disasters, public health crises, or security threats.
- This allows states to **mobilize resources**, **bypass** regulations, and access emergency funding.

2. Invoking Emergency Procurement & Production Laws

- Some states have laws allowing them to prioritize contracts for critical supplies, similar to DPA Title I.
- States can mandate production shifts for essential goods during crises.

3. Using the National Guard for Emergency Response

 Governors and Legislators can deploy the National Guard to assist with disaster relief, infrastructure protection, and crisis management.

4. Passing Emergency Legislation

 State legislatures can fast-track laws to address urgent issues, such as funding for disaster response or economic recovery.

5. Interstate Compacts for Resource Sharing

 States can form agreements to share emergency resources, like medical supplies or energy infrastructure.

While states **cannot** invoke the **Defense Production Act**, they **do** have powerful tools to respond to emergencies and direct resources where needed. States have used emergency powers in various ways throughout history to address crises. Here are some notable examples:

- **Texas Winter Storm (2021)**: Texas declared an emergency during the severe winter storm, enabling the state to bypass certain regulations and coordinate relief efforts more effectively.
- New York COVID-19 Response: During the COVID-19 pandemic, New York used emergency powers to enforce lockdowns, mandate vaccinations, and allocate resources to hospitals.
- Florida Hurricane Relief: Florida Governors and Legislators have declared emergencies ahead of hurricanes, allowing preemptive evacuations, emergency funding, and rapid response coordination.
- **Michigan Water Crisis**: Michigan declared an emergency during the Flint water crisis, enabling state intervention and federal assistance.

"DACR as a public works project, not a tax hike."

These examples demonstrate that states can act quickly in emergencies, even without federal intervention. In the case of Direct Atmospheric Carbon Removal, the process can also be economically beneficial, revitalize infrastructure, create jobs, and rebuild American esprit de corps, which has been significantly damaged in recent years.

STATE-LEVEL STRATEGIES TO TAX AND RETAIN HIGH-EMITTERS

These companies are responsible for a significant share of global emissions. In fact, just 57 companies were linked to 80% of global CO₂

emissions between 2016 and 2022. What's even more staggering is that offsetting the continuing emissions from the reserves held by the top 200 fossil fuel companies would require planting forests larger than the entire landmass of North America, an impossible task without displacing communities and ecosystems.

Top Carbon-Emitting Fossil Fuel Companies (Cumulative Emissions as of 2023)

- 1. Saudi Aramco (Saudi Arabia)
- 2. ExxonMobil (U.S.)
- 3. Gazprom (Russia)
- 4. National Iranian Oil Company (Iran)
- 5. BP (UK)
- 6. Shell (UK/Netherlands)
- 7. Coal India (India)
- 8. Pemex (Mexico)

1. Carbon Intensity Fees

- Tax companies based on **emissions per unit of output**, not just total emissions.
- This rewards efficiency and penalizes polluters without driving them out.
- For example, California's Low Carbon Fuel Standard uses this logic for fuel producers.

2. Infrastructure-for-Compliance Deals

- States offer exclusive access to DACR infrastructure, clean energy zones, or R-CO₂ materials in exchange for staying local and reducing emissions.
- Think: "You stay, you clean up, you get priority access to carbon-negative concrete for your next refinery upgrade."

3. Extended Producer Responsibility (EPR) Laws

• Already gaining traction in states like Maryland and Oregon.

- Companies pay fees based on the lifecycle emissions of their products.
- These laws can be tailored to fossil majors—charging for extraction, transport, and combustion impacts.

4. Carbon-Embedded Procurement Mandates

- Require public projects to use R-CO₂ materials and offer contracts only to companies that contribute to local DACR.
- This creates a **captive market** for high emitters who want to sell to the state.

5. "Stay-and-Offset" Tax Credits

- Offer tax breaks only if companies **offset emissions locally**—via DACR, biochar, or mineralization within the state.
- No outsourcing offsets to other countries or states.

6. Green Bank Leverage

- States with green banks (like NY and CA) can **tie financing access** to emissions reductions and local investment.
- "You want low-interest loans for your next facility? Show us your DACR receipts."

7. Additional Strategies

- **Site-specific permits**: Tie emissions allowances to physical locations. If they move, they lose the permit.
- Land-use covenants: Require DACR or emissions mitigation as a condition of land ownership or lease.
- **Public-private MOUs**: Lock in multi-year commitments with clawback clauses if companies relocate or fail to meet targets.

"R-CO₂ isn't sold. It's seen, touched, driven over, and lived inside."

DEFINING A CLIMATE EMERGENCY

Climate stability is maintained by a delicate balance of interacting Earth system components. Human activities have increasingly disrupted this balance, pushing the planet toward critical thresholds. Climate feedback loops, processes that can amplify or dampen warming, are now of paramount concern. Positive (self-reinforcing) feedback, such permafrost thaw releasing methane, sea-ice loss reducing Earth's reflectivity, and soil carbon decomposition by microbes, all accelerate climate change once triggered. This feedback risk initiates UTPs, abrupt, potentially irreversible transitions in climate subsystems, which could propagate through the Earth system in cascading interactions. For example, warming-driven Greenland Ice Sheet melt can freshen the North Atlantic, slowing the Atlantic Meridional Overturning Circulation (AMOC); a weakened AMOC accumulates heat in the Southern Ocean, which may destabilize the West Antarctic Ice Sheet. Scientists warn that many such linkages are destabilizing. Recent literature finds that 13 of 19 identified interactions among major climate tipping elements tend to amplify overall system change. This implies that crossing one Unrecoverable Tipping Point (UTP) could make others more likely, creating a "UTP" that pushes the climate into a dramatically different state.

At the same time, human civilization faces an unprecedented convergence of resource limits and environmental degradation. Freshwater supplies are dwindling in many regions due to overuse and shifting rainfall. Global freshwater demand is on track to exceed sustainable supply by 40% as soon as 2030, portending severe water stress. Arable topsoil is eroding rapidly under unsustainable agriculture; the UN's Food and Agriculture Organization (FAO) warns that 90% of Earth's topsoil could be at risk by 2050. Biodiversity loss, exemplified by collapsing pollinator populations, and depletion of critical inputs like phosphorus (a key fertilizer nutrient), threaten future food production. Scientists caution we may be nearing "peak phosphorus," after which global phosphate rock supplies decline, potentially within a few decades.

Meanwhile, marine ecosystems are under intense pressure: overfishing, pollution, and warming are driving some **fisheries toward collapse**, and ocean acidification undermines shellfish and coral reef habitats critical for fish breeding. **Energy security** is also at risk, as the world grapples with decarbonizing the economy while facing geopolitical volatility in fossil fuel supply and the need to climate-proof the electric grid against extreme weather.

These environmental and resource stresses map onto societal fault lines. Food and water insecurity, for instance, can ignite or exacerbate conflicts. Climate change is a recognized "threat multiplier" for instability. The destabilization of livelihoods by droughts, crop failures, and water scarcity raises the risk of food system failures and "water wars." Regions like the Tigris-Euphrates and Nile basins already experience heightened tensions as upstream countries control rivers critical to downstream populations. In a warming world, competition over water can become acute; for example, disputes over the U.S.-Mexico shared rivers have led to diplomatic conflict and even local violence. Such pressures drive mass migration: dire projections suggest climate change could displace tens to hundreds of millions. By 2050, over 200 million people might be forced to move internally due to climate impacts across Africa, Asia, and Latin America, with others attempting to cross borders - straining the global humanitarian system and intensifying border stresses. Public health, too, is imperiled: climate-related disasters and heatwaves can overwhelm health services, foster disease outbreaks, and exacerbate chronic health burdens.

The World Health Organization projects an additional 250,000 climate-related deaths per year between 2030 and 2050 from malnutrition, malaria, diarrhea, and heat stress if warming continues unabated. Such tolls could undermine public health systems, especially when combined with novel risks like the possible re-emergence of pathogens from thawing permafrost (e.g., anthrax or "zombie viruses"). All these challenges carry heavy economic costs: extreme weather disasters already cause hundreds of billions in damages annually, and climate change could slash global

"Every DACR facility generates tradable tons of removed carbon, which can be sold to fund infrastructure, education, or climate resilience."

GDP by several percent (or more under worst cases) by mid-century, destabilizing markets and **economic systems**. The strain can erode governance; indeed, historical cases link climate stress to state failure (a notable example being how a severe multi-year drought contributed to unrest in Syria before its civil war). **Governance breakdowns** become more likely when institutions cannot manage cascading crises of food, water, health, and forced migration.

OUR DATA GATHERING METHODOLOGY

To capture the multifaceted nature of the climate emergency, we employed an integrative, interdisciplinary approach. We compiled data and projections on the depletion or degradation of essential natural resources and life-support systems.

For **freshwater**, we used reports from the UN World Water Development program and analyses like the World Economic Forum's 2023 white paper to identify when global demand will significantly outstrip supply.

For **arable soil**, FAO and UNCCD (UN Convention to Combat Desertification) publications were reviewed, yielding statistics such as soil loss rates and the projection that most topsoil is at risk by midcentury. We vetted the oft-cited claim of "60 harvests left" and replaced it with more evidence-backed metrics (e.g., rates of soil erosion in mm/year, percent degraded land, etc.).

"Each year of delay increases climate risk—but each smart build reduces future price."

For **stable climate zones**, we integrated climate modeling studies predicting the shrinkage of climatically favorable zones (for example, the

fraction of Earth's land area with a "climate niche" suitable for dense human populations, as in Xu et al., 2020).

Pollinator decline was examined through ecological studies and FAO data on insect population trends; we noted key dates like steep declines in wild insect biomass over the last few decades and the implications for crop pollination by 2030–2050 if current trends continue.

Fisheries status was drawn from FAO's State of World Fisheries reports and research on maximum sustainable yields; we included projections of fish stock collapses regionally by mid-century under high-emission scenarios (due to warming, acidification, and overfishing).

For **phosphorus and fertilizers**, agricultural science literature and industry reports (e.g., IFDC, USGS mineral reports) were analyzed to estimate the timeline of peak phosphorus production and the anticipated decline of easily accessible phosphate reserves. The link between phosphorus scarcity and food security was noted.

Energy security analysis was twofold: (a) fossil fuel supply horizons (peak oil demand or supply scenarios from sources like the International Energy Agency and BP outlooks), and (b) vulnerabilities of energy infrastructure to climate impacts (drawing from reports like U.S. DOE/GAO studies on grid resilience to climate). We assembled these data points into a rough timeline from the present to 2100, highlighting when critical thresholds might be reached or when the impacts become acute (e.g., freshwater scarcity impacting billions by 2030, significant phosphorus shortages by the 2040s, etc.). Uncertainties are large, so we often provide a range or scenario bracket (best-case vs worst-case timing).

Appendix II: Climate Pressure on Societal Fault Lines: How Environmental Stressors Threaten Civilization's Core Systems

- Climate Deadline Alliance

Introduction

Climate change is no longer a peripheral environmental concern—it is a rapidly intensifying force acting directly upon the social, political, and economic pillars of human civilization. Drawing from interdisciplinary sources—including climate impact models, global conflict analyses, and health and economic risk assessments, we identify six critical fault lines that define how climate stress moves through human systems: **food, water, migration, health, economy, and governance**. Each domain is experiencing measurable strain today, and the feedback loops between them create compounded risks that threaten stability at every scale.

Fault Line 1: Food System Fragility

Agriculture is highly sensitive to climate variability. Our analysis of crop modeling studies shows that rising temperatures and shifting rainfall patterns are already depressing yields for staple crops such as wheat, rice, and maize, especially in heat-prone regions.

The fragility of global food networks was underscored in 2022, when simultaneous weather extremes struck key breadbaskets: drought in China's Yangtze basin, heatwaves across Europe, and reduced wheat output in India. These events coincided with supply disruptions from conflict, driving global grain prices to near-record highs. Such multiregion crop failures are increasingly probable under climate change, and trade-dependent food systems may not be able to buffer the shocks. If countries begin imposing export bans to protect domestic supply—as seen in past crises—food scarcity could ripple globally, igniting unrest even in

food-secure regions. Historical precedents include the 2008 and 2011 food riots, which show how price spikes can trigger political violence.

Without adaptation, staple crop yields are projected to decline by several percentage points globally by the 2030s. This is compounded by soil degradation, freshwater constraints, and fertilizer supply risks. In worst-case scenarios, system failure could manifest as widespread hunger and humanitarian crises that exceed current response capacities.

Fault Line 2: Water Conflict and Scarcity

Shared freshwater systems are increasingly contentious. In regions with pre-existing political tension, declining water availability due to climate change can escalate disputes into violence.

The Nile River exemplifies this risk. Ethiopia's construction of the Grand Ethiopian Renaissance Dam has strained relations with Egypt, whose economy and food supply are deeply dependent on the Nile's flow. Climate-induced variability in rainfall could worsen this standoff. Other examples include:

- Indus River (India-Pakistan): longstanding tension over dam operations.
- **Tigris-Euphrates (Middle East):** contested extractions across Syria, Iraq, and Turkey.
- Amu and Syr Darya (Central Asia): disputes over withdrawals between upstream and downstream nations.
- Colorado River (North America): intensifying intra-state and U.S.–Mexico disputes over shrinking allocations.

"Governors who invest in DACR aren't just solving the climate crisis—they're rewriting the future of infrastructure."

Civil unrest over water shortages is already visible—in protests in Iran, South Africa, and parts of India. Live Science (2025) warns that water scarcity combined with climate migration will "redefine global conflict," pushing fragile regions into cycles of destabilization.

Although full-scale "water wars" between states remain unlikely in the near term, **internal water conflicts** could lead to state failure or mass displacement, both of which have international consequences.

Fault Line 3: Climate Migration and Border Stress

Climate-driven migration occurs through both slow attrition and sudden displacement:

- **Slow onset:** drought and economic stress push rural populations off land.
- **Sudden onset:** extreme events (floods, storms, wildfires) force evacuations.

The World Bank's "Groundswell" report (2021) projects up to **216** million internal climate migrants by 2050 under worst-case scenarios. Externally, vulnerable regions, such as Central America, North Africa, and South Asia, may see millions attempt to move toward temperate, wealthier countries. Migration has already begun to rise. For example, U.S. border officials report increased arrivals from Central America linked to drought-induced crop failures and hurricane damage. As conditions worsen in the 2030s and 2040s, migratory pressures will intensify.

Destinations with limited political will or capacity to accommodate newcomers face humanitarian crises at borders, breakdowns in asylum systems, and surges in xenophobic backlash. The European migrant crisis in 2015, partly catalyzed by Syria's climate-linked drought, is a sobering precedent. Scenarios involving 1–2 meters of sea-level rise by the late century could displace tens of millions across South Asia alone, testing global governance and solidarity frameworks beyond current capacities.

One of the most volatile and underprepared dimensions of the climate crisis, migration driven by environmental stressors, unfolds in two

primary forms: **slow-onset displacement**, such as droughts and crop failures that gradually erode livelihoods, and **sudden-onset events**, like floods, wildfires, and hurricanes that force immediate evacuation. These pressures are already reshaping human mobility patterns, with climate acting as a "threat multiplier" that intersects with poverty, governance gaps, and regional instability.

The scale of projected displacement is staggering. According to the World Bank's *Groundswell* report, up to **216 million people** could become internal climate migrants by 2050 under worst-case scenarios. Externally, regions such as **Central America**, **North Africa**, and **South Asia** are expected to see millions attempt to relocate toward more temperate and economically stable countries. Already, U.S. border officials have reported increased migration from Central America linked to **drought-induced crop failures** and **hurricane damage**, particularly in the Dry Corridor spanning Guatemala, Honduras, and El Salvador.

As climate pressures intensify through the 2030s and 2040s, destination countries may face **border breakdowns**, **asylum system overloads**, and **xenophobic backlash**. The 2015 European migrant crisis—partly catalyzed by Syria's climate-linked drought—shows how fragile political systems can be overwhelmed by climate displacement. Sealevel rise scenarios of **1–2 meters** by the late century could displace tens of millions across **South Asia**, especially in Bangladesh and coastal India, straining global governance and humanitarian frameworks far beyond current capacity.

Fault Line 4: Public Health Collapse

The health implications of climate change are wide-ranging, affecting both chronic conditions and acute emergencies.

- **Heatwaves** pose an extreme risk. The 2003 European heatwave killed 70,000; such events may become **routine summers** by 2040.
- **Vector-borne disease** is expanding with warming: dengue, Zika, and malaria are now appearing in previously temperate zones.
- Floods and warming facilitate outbreaks of water-borne illnesses, such as cholera.

• **Mental health impacts**—from trauma, climate anxiety, and displacement—are mounting.

The WHO projects **250,000** additional deaths per year from climate-linked illnesses between 2030 and 2050, a conservative estimate. Compound crises exacerbate vulnerabilities. During the U.S. West Coast wildfires of 2020, hospitals managed smoke-inhalation cases while also responding to COVID-19 surges, pushing facilities to the brink. Future risk scenarios include novel pathogens emerging from **permafrost thaw**, as well as simultaneous disaster responses stretching already fragile healthcare infrastructure. If systems collapse, mortality will rise, not just from climate shocks but from failure to treat everyday conditions due to overwhelmed services.

In developing countries, climate-induced malnutrition, sanitation crises, and disease outbreaks may reverse decades of public health progress, deepening global inequality and instability.

Fault Line 5: Economic Fragility

Climate change poses systemic risks to the global economy through disruption, inflation, and asset devaluation.

The Swiss Re report (2021) projects that unmitigated climate change could shrink global GDP by 10–18% by 2050, a near-permanent recession.

Key mechanisms of fragility include:

- **Damage to infrastructure** (roads, ports, energy systems) from extreme weather.
- **Supply chain shocks**, exemplified by Thailand's 2011 flood, disrupted electronics worldwide.
- **Financial instability**, as climate-unadjusted assets (e.g., coastal real estate, fossil reserves) are abruptly repriced.
- **Insurance retreat**, especially in flood- and fire-prone zones, limiting recovery and development.
- Commodity volatility, with crop failures driving food inflation and income instability.

Developing countries face **credit downgrades** and escalating debt burdens as climate-related disasters necessitate emergency borrowing.

Compounded disasters in multiple economic centers, e.g., Florida, Germany, and China, that struck simultaneously could induce global market shocks and stress fiscal systems to the breaking point.

Inequity exacerbates these dynamics: poorer regions experience greater damage, recover more slowly, and encounter higher obstacles to climate adaptation funding. This intensifies unrest and political instability, directly connecting economic disparities to governance fragility.

Fault Line 6: Governance and Political Stability

The effectiveness of governance determines whether societies can withstand climate pressure or unravel under it. Climate stress often hits regions already facing institutional challenges. Examples include:

- **Syria (pre-war drought)** contributed to rural collapse, urban migration, and unrest—an accelerant if not sole cause.
- Ethiopia (1980s drought) destabilized food systems and exacerbated internal conflict.

Governments struggling to meet basic needs, such as food, water, healthcare, and disaster response, risk losing legitimacy.

The Live Science 2025 report speculates that if wealthier actors take unilateral protective actions (e.g., private geoengineering, gated resilience), it could signal the breakdown of equitable governance norms.

In fragile democracies, climate crises may spark authoritarian shifts under emergency declarations. Elsewhere, state failure could enable the rise of ungoverned zones, fueling migration, extremism, and violence.

We already observe signs of political strain: climate migrants being scapegoated, populist rhetoric inflaming nationalism, and judicial systems overwhelmed by disaster-driven claims.

The potential for **governance collapse cascades**, where resource scarcity feeds conflict, which erodes institutions, which prevents adaptation, is a pressing concern.

"DACR isn't a new expense—it's a smarter way to spend what we're already investing in roads, buildings, and disaster recovery."

A RESOURCE DEPLETION TIMELINE

Parallel to climate feedbacks, human societies are depleting or degrading vital natural resources at unsustainable rates. **Figure 2 (Resource Depletion Timeline)** presents an integrated timeline (2020–2100) indicating when critical shortages or UTPs in resource systems are expected if current trends continue:

- Freshwater Scarcity (2020s-2030s): Freshwater demand has been climbing due to population growth, agriculture, and industry, while climate change is altering precipitation patterns. According to the UN and World Economic Forum, by 2030, the world could face a 40% freshwater supply shortfall. We are essentially hitting "peak water" usage now in many regions. Already, groundwater aquifers (from India's Punjab to the U.S. High Plains' Ogallala) are being drained faster than they recharge. By the late 2020s, over 5 billion people may experience at least one month of severe water scarcity per year (up from 3.6 billion today), according to UN-Water. Arid regions of the U.S. (like the Southwest) are seeing chronic water stress, e.g., the Colorado River has been overallocated and major reservoirs (Lake Mead, Lake Powell) in the 2020s reached record-low levels, threatening water and power supply for tens of millions. The timeline flags 2025 as a near-term marker: a number of countries (e.g., India, South Africa, parts of MENA) could face acute shortages by then. By 2040-2050, climate models project significantly reduced rainfall in the Mediterranean, Middle East, southern Africa, and parts of South Asia, potentially leading to seasonal water crises and "water war" flashpoints.
- Arable Soil and Land (2020s–2050s): Soil erosion and degradation continue at alarming rates due to intensive agriculture, deforestation, and climate-change-exacerbated

droughts/floods. The FAO warned in 2022 that 90% of Earth's topsoil could be at risk by 2050. We found that we currently lose around 24 billion tons of fertile soil annually due to erosion. If current practices persist, by 2030, an additional several percent of global arable land could become unproductive. By the 2050s, large areas may become marginal: for instance, sub-Saharan Africa and South Asia could lose significant crop yield potential due to soil degradation combined with climate stress. Our timeline marks 2050 as a point by which soil degradation, if unmitigated, reaches a scale affecting global food production (perhaps a 10%+ reduction in output relative to a no-degradation baseline). Notably, climate change itself worsens soil loss: heavier downpours wash away soil, and higher temperatures deplete soil moisture and organic matter (leading to desertification in places like the Sahel or southwestern U.S.). The notion of "only X harvests left" may be debated, but the consensus is that soil is a finite resource being rapidly exhausted, with regeneration (millimeters per century) far outpaced by loss (millimeters per few years in worst cases).

Stable Climate Zones (2030s-2100): Human societies (cities, agriculture) have developed in relatively stable climate zones. As global temperatures rise, climate zones are shifting poleward and upward in altitude. A 2020 study (Xu et al., PNAS) projected that under high emissions (3°C by 2070), about 1 to 3 billion people could live in climates that are literally hotter than any current climate, essentially outside the "human climate niche" that supported civilization over the past 6,000 years. Our timeline highlights 2050 as a mid-point where large parts of the tropics may become routinely experiencing "extremely hot" conditions (average annual temperature >29°C, something that historically was confined to a few small areas but could cover 20% of land by 2100). By 2070–2100, if warming exceeds 3°C, regions of the Persian Gulf, South Asia, and even the U.S. Southwest might see unsurvivable heatwaves (wet-bulb temperatures of 35°C or more). "Stable climate zone" depletion is harder to pin to one date, but qualitatively, 2030s: the emergence of regular extreme heat in subtropics; 2050s: expansion of arid zones (e.g. Mediterranean climate shifting to desert in parts of Spain, California), 2080s: some zones effectively

"Every mile of carbon-built road replaces a ton of emissions."

- disappear (e.g. alpine climates on small mountains, or the current climate of the Fertile Crescent no longer exists; it's been replaced by a hotter, drier one). The timeline, therefore, suggests that the latter half of the century could see habitat range shrinkage for humans, unless massive adaptation measures are implemented.
- Pollinators and Biodiversity (2020s-2040s): A widely cited review in 2019 found that 40% of insect species (including many pollinators) are in decline, with some at risk of extinction in the coming decades. The causes include pesticides, habitat loss, and climate change. Pollinators (bees, butterflies, etc.) are crucial for 35% of global crop production by volume. The timeline notes 2035-2045 as a window by which, if current trends continue, pollinator shortages could impair agriculture significantly. Already, parts of China have had to hand-pollinate fruit trees due to a lack of insects. By the 2030s, if wild pollinators collapse, farmers everywhere may face lower yields for fruits, nuts, and some vegetables - potentially driving up food prices and malnutrition. Biodiversity, more broadly, is on track for a potential mass extinction event: we are on course to lose a large fraction of species by 2100. But specifically for ecosystem services, the 2020s-2030s are critical to either curb or witness accelerating declines (e.g., many bumblebee species could vanish by 2050 under warming scenarios). We integrate this into the narrative because ecosystem breakdown can reduce nature's resilience (fewer insects also mean less decomposition, etc.) and directly impacts food systems.
- Fisheries Collapse (2020s–2050s): Overfishing has already led to collapses of certain fish stocks (e.g., Atlantic cod in the 1990s). Climate change is now a complicating factor (warming waters shift fish distributions, alter breeding, and cause coral reef dieoffs, impacting fisheries). A famously dire projection (Worm et al. 2006) warned of potential global fishery collapse by 2048 if trends

at the time continued — though improved management has moderated that trajectory somewhat, many fisheries remain in bad shape. We estimate that by 2030, several regions (e.g., West African fisheries, parts of Southeast Asia) might see collapses of key species. By 2050, potentially all wild-caught seafood could be at risk either from overfishing, climate impacts, or ocean acidification (which especially threatens shellfish and reef-based fisheries). The timeline entry around mid-century underlines severe stress on marine protein supply: just as the global population peaks (9.7 billion), wild fish catch may decline significantly, increasing reliance on aquaculture (which itself depends on fish feed and stable ocean conditions). This not only affects food security for coastal communities but also global trade and economies of many fishing nations.

"We start with \$25 trillion—but smart strategy slices the cost before it ever hits the budget."

Phosphorus & Fertilizer Shortage (2030s–2060s): Phosphorus (P) is critical for fertilizers and hence global crop yields. It is mined mostly from phosphate rock, with finite reserves concentrated in a few countries (Morocco holds 70% of known high-quality reserves). Demand for P fertilizer is rising with population and meat-rich diets. Some researchers warn of "Peak Phosphorus" - the point of maximum production - possibly occurring by the 2030s, after which production declines as reserves deplete. Our findings show that U.S. phosphate reserves, for example, are 1% of their original, essentially nearly exhausted. The timeline indicates the 2030s as a critical period where phosphorus prices could spike and shortages manifest, especially for import-dependent countries (most of Europe, Brazil, and India). If alternatives or recycling are not scaled up, by 2050, phosphorus scarcity could significantly impair our ability to maintain high crop yields, just when we may need more food. Nitrogen fertilizer is synthetically made (from natural gas, primarily), so it's less of a depletion issue and more of an energy/climate one; however, natural gas supply and price (as

seen in 2021–2022) can cause fertilizer crises, linking energy security to food security. Potassium (potash) is also finite but currently less scarce than phosphorus. We mark **2040–2060** as the window where fertilizer constraints might bite hardest on global agriculture, absent technological solutions, leading to lower food output and a higher risk of hunger.

Energy Security and Transition (2020s-2100): The future of energy is twofold: securing supply for growing demand, and transitioning to net-zero emissions to stabilize the climate. If we speak of fossil fuel depletion, conventional oil production likely peaked in some places, but with unconventionals (shale, tar sands), the timeline is murky. However, energy security issues can arise much sooner from geopolitical and climate factors. For example, the 2022 war in Ukraine triggered a natural gas crisis in Europe, highlighting reliance vulnerabilities. On the climate side, extreme weather is stressing grids: e.g., heatwaves forcing rolling blackouts, storms knocking out transmission. By 2030, renewable deployment should ideally triple to meet Paris goals, yet if not, reliance on dwindling or volatile fossil supply could cause economic shocks. The International Energy Agency's scenarios project that if policies lag, oil and gas demand may still be high in the 2040s while production investment declines, risking shortages. Conversely, if climate action is strong, a rapid shift could leave some regions with stranded assets and job losses, a different kind of security issue. Our timeline might note the 2020s-2030s as the period of transition risk: ensuring there is enough energy through the transition without price spikes or grid failures. By the 2050s, in a best-case scenario, we have a mostly renewable/hydro/nuclear energy system; in a worst-case scenario, we might face severe oil scarcity because easy oil is gone and investment has ceased (due either to climate policy or economic issues) without alternatives fully in place. For electricity grids, by mid-century, systems need to handle more demand (from EVs, etc.) and more extremes. Therefore, energy insecurity could manifest as more frequent outages if resilience is not built (the recent Texas 2021 freeze and California wildfire-induced outages are a sign). The timeline designates 2050 as an anchor: by then, the world either achieves a stable new energy

"Climate Change isn't a future threat—it's a present collapse. The climate system is unraveling in real time, and our duty is to respond with the urgency it demands."

equilibrium (clean and secure) or experiences compounded insecurity (either due to climate damages or resource shortfalls). We align these resource issues with projected global population and demand curves. Notably, humanity's "planetary budget" for several resources will be largely expended by mid-century under BAU (Business As Usual) scenarios. Freshwater and soil show severe strain earliest (2020s–30s), followed by elements of food production (pollinators, phosphorus) in the 2030s–40s, and culminating in potential existential constraints by the late century (areas becoming uninhabitable, fisheries gone, etc., if unmitigated).

This resource timeline underscores that **climate change is not happening** in a vacuum. Instead, it coincides with our increasing demand and finite supply of crucial resources. Thus, by 2050, we could have 9–10 billion people attempting to share **less water**, **less arable land**, **fewer fish**, and **scarcer fertilizers** than we have today, all under more extreme climate conditions. This is a recipe for crisis if unaddressed. It reinforces the emergency: we are on course to hit multiple ceilings at roughly the same time. When these constraints collide (for example, simultaneously dealing with freshwater shortages, crop yield hits, and fertilizer supply crunches in the 2040s), the risk of systemic collapse grows.

Conclusion: Cascading Crises and UTPs

The evidence is unmistakable: climate change is already exerting pressure on civilization's fault lines, and the fractures are beginning to show.

Food insecurity is rising. Water disputes are politicizing. Migration flows are swelling. Public health systems are buckling. Economies are absorbing billion-dollar losses. And governance structures are straining to respond.

These crises are **interconnected**. A failed harvest can incite unrest that topples a government, and a flood can spread disease across borders. In systemic terms, we face the risk of **societal UTPs**, where cascading failures push regions into chaos.

Some scholars warn that global breakdown is plausible under worst-case scenarios: collapse of international cooperation, humanitarian frameworks, or financial networks. Our analysis underscores this concern. Without transformative change, the environmental emergency may evolve into a civilizational emergency—one defined not by single disasters, but by converging system failures.

"Carbon isn't a liability—it's our next building block."

Appendix III: Creation of the North American Climate Pain Scale

- Climate Deadline Alliance

Given the high stakes, communicating the gravity of these interconnected issues is vital. We introduce the concept of a **North American Climate Pain Scale (NAPS)** as a communication tool. Mirroring the medical pain scale (which helps patients convey pain severity on a 0–10 scale), the NAPS provides a qualitative but viscerally intuitive gauge of climate impact severity in North America, from mild, background "discomforts" (e.g. occasional floods, manageable heat) up to extreme "excruciating" scenarios where large regions face conditions that exceed habitability. The NAPS is meant to synthesize complex data (on heat indices, drought frequency, wildfires, etc.) into a single escalating scale that policymakers and the public can readily grasp. By framing climate destabilization in terms of increasing "pain," something people understand personally, we aim to bridge scientific findings and emotional urgency, hopefully mobilizing stronger action.

NAPS Design: To construct the NAPS, we first defined the scope: North America, including the U.S. and Canada (which have detailed climate impact data by region), and possibly Mexico (which faces severe climate challenges as well). We decided on a 0-to-10 scale (with 0 representing the historical baseline of no noticeable climate-related "pain," and 10 representing an unlivable extreme). To calibrate the scale, we referenced measurable indicators: e.g., annual number of extreme heat days, wildfire acreage, infrastructure losses, mortality rates, etc., corresponding to various warming levels. We aligned the levels loosely with global temperature scenarios and their regional expressions.

"Your next school could be carbon-negative and climate-resilient. Every mile of carbon-built road replaces a ton of emissions."

For instance, Level 1-2 might correspond to mild disruptions: slightly hotter summers, occasional nuisance floods (conditions that are becoming the present-day background).

Level 3-4 would see increased frequency of disasters that cause regional emergencies (e.g., a hurricane causing major damage once a year, persistent drought in some areas).

Level 5-6 could mark the threshold where parts of North America experience chronic, compounding disasters: multiple simultaneous heatwaves and wildfires causing widespread health effects and some displacement (this might align with 2 °C warming globally, anticipated mid-century on our current path).

Level 7-8 would reflect crises that significantly undermine livability in certain areas, e.g., cities in the Southwest facing periodic water shortages necessitating mass relocations, or coastal communities being abandoned due to repeated flooding (conditions plausible under 3 °C).

Level 9-10 on NAPS would equate to truly unlivable conditions: large parts of the continent experiencing lethal heat/humidity beyond human tolerance (wet-bulb >35 °C), agriculture largely collapsing in current breadbasket regions, and infrastructure failing under constant extreme stress, essentially a scenario of societal breakdown in North America. To inform these definitions, we used existing studies on climate extremes: for example, research on U.S. county-level risk (like the Union of Concerned Scientists' analysis of "Days above 100 °F" by 2100 in various emissions scenarios), wildfire projections from US Forest Service models, and sea-level rise maps for coastal city impacts by end of century.

We also considered **human adaptive capacity** in calibrating pain levels, e.g., a given heatwave today (with limited adaptation) might be catastrophic, but in the future, societies might adapt somewhat (air conditioning, etc.,) which could lower the experienced "pain" for the same heat. However, at the high end of the scale, adaptation limits would be reached (this aligns with IPCC notions of "limits to adaptation" being exceeded beyond 3°C for certain systems). After drafting the scale descriptions, we solicited feedback from climate communication

frameworks (like the "Climate Sabotage Scale" or other risk scales used by communicators) to refine clarity.

The final NAPS is presented as a **chart with descriptions for each level** (see Visuals). It is not an empirical index but a heuristic device; thus, in the paper, we are transparent that it's a proposed tool, grounded in real trends but intended to evoke a sense of progression toward danger.

A Tool for Diagnosis and Mobilization

As a synthesis of many impacts, we propose the **North American** Climate Pain Scale (NAPS) to communicate how climate change progresses from mild to unbearable conditions in a relatable way. **Figure 4 (NAPS Chart)** illustrates the scale with representative scenarios for each level 1 through 10. Below, we describe key benchmark levels on the scale:

- Level 1 Background Discomfort: Climate change impacts are present but generally subtle or seen as "normal" variability. For North America, this might correspond to the current state in some areas: slightly warmer summers, a few more heavy precipitation events, and mild ecological shifts. People experience it as maybe a bit more seasonal allergies (longer pollen season due to warmer springs) and notice oddities like flowers blooming earlier. In terms of data: perhaps a +1°F (+0.5°C) rise in average temperature relative to the late 20th century, and maybe a doubling of \$1B+disasters frequency compared to historical (which we indeed have seen in the US). This level is essentially where many communities were in the early 2000s, aware that something was off but not alarmed.
- Level 3 Noticeable Pain: By this level, climate-related events cause regular disruption. For example, every summer brings a notable heatwave that breaks records; wildfire smoke becomes a recurring air quality issue even far downwind (e.g., the East Coast getting smoke from Western fires, as happened in 2023). Coastal nuisance flooding might happen multiple times a year in places like Miami. People start incurring costs: higher cooling bills, occasional property damage from intense rain or windstorms. There is a psychological effect too: concern in the public is rising.

This could correspond roughly to the present day in many parts of North America (we might consider we're at about a 2 or 3 now on NAPS). For instance, **Canada** in 2023 had its worst wildfire season on record, affecting all provinces, an experience of tangible "pain" from climate change. Statistically, this might align with 1.1°C global warming (current) and certain local extremes (e.g., a "hundred-year flood" now happening every 20 years, etc.).

Level 5 - Significant Pain (Emergency Threshold): Here, climate impacts start to overwhelm local capacities periodically. Think of a "state of emergency" being declared multiple times a year in various regions for different hazards. For North America, this might look like: extreme heat that makes outdoor work dangerous for weeks at a time; urban areas struggling with electric grid failures under peak AC load; large wildfires annually destroying hundreds of homes; multi-year droughts in the Southwest triggering water rationing (e.g. the first-ever official shortages on the Colorado River, which already started in 2022, become more profound and more widespread). Agricultural output is measurably declining in some breadbasket areas due to heat/drought despite technology. Insurance retreat becomes common in high-risk zones like fire-prone areas of California or flood-prone coasts. Public health sees spikes in hospitalizations from heat and smoke. This might correspond to 1.5°C global warming, expected in the 2030s, unless decisive action bends the curve. We term this an "Emergency Threshold" because beyond this, impacts become generationally significant: life in affected areas is visibly worse than it used to be, and perhaps some locations (a few small towns) are being abandoned after repeated disasters.

"States can generate revenue by selling R-CO₂ credits, turning clean air into clean budgets."

- Level 7 Crisis Conditions: Widespread, frequent disasters; adaptation measures struggle to keep up. At this level, some regions of North America face seasonal uninhabitability. An example: parts of Arizona and Texas see weeks of extreme heat (115°F+/46°C+) with high humidity, making it dangerous to be outside even at night. For example, the elderly and vulnerable suffer high mortality without sufficient cooling shelters. Coastal cities experience annual severe flooding from a combination of sea-level rise and stronger hurricanes; cities like New Orleans or Miami might become untenable or require massive engineering akin to the Netherlands' dikes. In agriculture, maybe the Midwest has a devastating drought one year and the Canadian prairies the next, causing food price shocks. Climate migration starts internally: people from the worst-hit areas (say, Phoenix, after successive water shortages and heatwaves) move to cooler, wetter areas like the Upper Midwest or New England. Economically, the damages are cutting a noticeable percentage off GDP growth annually. We could peg this to 2°C global warming (2040s-2050s under current trajectory). The term "crisis" implies that normal life is heavily disrupted: think of it as akin to living under wartimelike conditions, but due to climate, rationing water or power at times, emergency response stretched thin.
- Level 10 Unlivable: The extreme end of the NAPS is a scenario where much of North America cannot maintain an organized society in its current form due to climate conditions. This could be late 21st century under, say, 4°C global warming (which is not off the table if feedback kicks in strongly or emissions remain very high). Characteristics: Large parts of the Southwest are uninhabitable desert, with former cities ghosted or reduced to small populations living in climate-controlled arcs or underground (think sci-fi-esque survival domes), e.g., Las Vegas might be abandoned because 50°C (122°F) days plus no water from Lake Mead. Coastal cities from Florida to North Carolina have been

largely swallowed by rising seas, with millions displaced inland. Frequent deadly heatwaves make summer outdoor activity impossible across the South; even the far North (Canada) sees devastating wildfires and permafrost melt, undermining infrastructure. The economy is in shambles: constant disaster recovery means no room for development, and supply chains for critical goods are failing. If this coincides with global crises,

international aid and trade grind to a halt. In short, it's a **collapse scenario** for North American society as we know it. Few pockets with favorable microclimates remain stable, and they are overwhelmed by internal climate refugees. While this is a

North American Climate Pain Scale

Level	Human Experience	Year Bracket	Projected Events	Systemic Impact
1	Uptick in Hardships	2025-203	Mild regional disruptions	Resilient governanace
2	Significant Separation Between Ricl and Poor	2035-2040 h	Heatwaves, ^O crop insura- nce strain	Rising adjustments, policy shifts
3	Increased Mortality in Vuinerable Pop	2040-204	Grid instability 5 migration uptick	Market instability rising public dissent
4	Widespread Disruption	2045-2050	Multi-state evacuations, wildfire regime expansion	Emergency governance
5	Crisis Mode	2050-2060	Emergency governance override	Fragmenta- tion national systems
6	Structural Breakdown	2070-2080	Fragmency governance onorride	Militarized zones
7	Societal Retraction	2080-2090 ເ	Suicidal sp: tailed cifies ınlivale corrido	Decentralized survival s systems
9	Collapse Threshold	2090-2019	Incremental die-off events	New governance paradigms or vacuum

doomsday scenario, NAPS Level 10 is meant to show the continuum that if "pain" keeps rising unchecked, it ends in societal breakdown and mass death (i.e., unlivability).

Between these landmark points, the NAPS chart displays intermediate increments with blended characteristics. Each increase in number signifies a significant deterioration: infrastructure built for the 20th century fails more frequently, ecosystems around us (forests, rivers) deteriorate, and personal security (health, property, livelihood) diminishes.

Using NAPS: The North American Climate Pain Scale is both diagnostic – allowing one to gauge current conditions and arguably say "we are at pain level X now and heading to Y," and mobilizing, by putting the abstract future into concrete terms of human "pain." It leverages empathy and urgency: people understand that a pain level of 8 out of 10 is a dire situation, in medical terms requiring immediate intervention; similarly, if we quantify climate pain and show it rising, it implies the need for emergency response. For policymakers, the NAPS could be a communication device: for instance, a city mayor might say, "Our city is at a climate pain level of 4 today, but with current trends, we risk reaching level 7 by mid-century. That is unacceptable; we must act." It simplifies the complex indices of climate risk (which often include percentages and probabilities that are hard to internalize) into a visceral scale.

We based the calibration on historical data and projected scenarios but acknowledge that it is a heuristic. Importantly, NAPS can incorporate **emotional and qualitative facets** (like psychological stress, community displacement, and grief) which raw numbers often miss. In medicine, pain has subjective elements; similarly, climate "pain" includes fear, loss of sense of place (e.g., loss of a beloved coastline to erosion), and anxiety about the future, all rising as impacts grow.

Currently (2025), we might argue that North America is around Level 3 on this scale overall (though certain events hit Level 5 temporarily, e.g., the 2021 Pacific Northwest heatwave was a Level 5-like event locally with huge death tolls and infrastructure failure). If emissions remain high, by 2050 the continent could average around Level 6–7 yearly, with peaks at 8 in the worst-hit areas. The NAPS thus paints a sobering trajectory,

but it also implies that **timely action can "flatten the curve" of pain**. If we declare a climate emergency and rapidly reduce emissions (plus invest in resilience), we might hold at Level 4–5 and avoid the worst.

Discussion

Our comprehensive analysis reveals a stark picture: Earth's climate system is edging toward Unrecoverable Tipping Points (UTPs) that could unleash **runaway changes**, while human civilization is simultaneously exhausting critical resources and showing signs of socio-economic strain under existing levels of warming. These findings carry profound implications—scientific, strategic, and moral—that justify treating climate change as an **immediate emergency** rather than a distant concern.

Equity and Ethics: Another point in discussion—those least responsible (future generations, the poor) suffer the most pain if we fail to act. Ethically, that adds imperative, e.g., by NAPS level 10, many who contributed almost nothing to emissions (subsistence farmers, unborn children) would pay with their lives or well-being. Declaring an emergency is also a statement that we value those lives and will not sacrifice them for short-term interests. It sets the stage for potentially difficult choices (such as phasing out lucrative industries) because the alternative is morally unacceptable.

Appendix IV: Climate Feedback and Cascading Risk — Mapping the Accelerators of Global System Instability

- Climate Deadline Alliance

Introduction

Climate change is driven not only by anthropogenic emissions but increasingly by self-reinforcing feedback loops that accelerate warming and destabilize Earth's systems. These loops operate across the cryosphere, biosphere, atmosphere, and oceans. Many are now active, and several Earth system components—known as tipping elements—are approaching irreversible thresholds.

This paper synthesizes cutting-edge literature and Earth system modeling to catalog this feedback, visualize its interconnections, and explore its cascading consequences. Drawing from sources including IPCC assessments, Lenton et al. (2008), Armstrong McKay et al. (2022), Wunderling et al. (2023), and data from the Earth Commission and PIK, we integrate climate physics with societal risk mapping to produce a robust scenario analysis.

Methodology:

We reviewed physical science literature and model projections to catalog feedback mechanisms under four domains:

- Cryosphere (e.g., ice-albedo feedback, polar amplification)
- **Biosphere** (e.g., forest dieback, microbial respiration)
- Ocean-Atmosphere (e.g., water vapor feedback, cloud dynamics, AMOC disruption)
- Climate Dynamics (e.g., jet stream destabilization)

For each feedback, we identified its driver, reinforcing mechanism, and projected climate impact. We also charted the known **tipping elements**, such as the Greenland Ice Sheet, Amazon Rainforest, and AMOC, and mapped out known interconnections among them, resulting in a visual **Unrecoverable Tipping Point (UTP) Map**. Interactions were categorized as either **destabilizing** or **stabilizing**, with emphasis placed on compound risks and cascading thresholds.

Cross-validation was performed across recent peer-reviewed literature and expert assessments (2023–2025), with attention to harmonizing warming scenarios and socio-ecological data.

Results:

- **1. Feedback Loop Taxonomy:** Major feedback that is now active or emerging include:
 - **Permafrost Carbon Feedback:** Thawing Arctic soils are releasing CO₂ and CH₄, accelerating warming. An estimated 1,500 Gt carbon stock makes this a long-term amplifying force.
 - **Ice–Albedo Feedback:** Melting snow and ice lower planetary reflectivity, leading to more heat absorption. Arctic summer sea ice has halved since 1979.
 - Water Vapor and Cloud Feedback: Warmer air holds more moisture, enhancing the greenhouse effect. Cloud dynamics—especially declining low clouds—are creating net positive feedback.

"DACR funding works like the Interstate System: bonds, federal support, private buildout—then public pride."

- Microbial Soil Carbon Release: Soil warming increases microbial activity, releasing carbon. Drought-induced soil cracking further accelerates this effect.
- Forest Dieback: Amazon and boreal forests risk converting from carbon sinks to carbon sources under stress, releasing vast carbon stores.
- **AMOC Disruption:** Freshwater from Greenland melt is weakening ocean circulation, reducing northward heat transport, and risking global climate imbalance.
- **Jet Stream Destabilization:** Arctic amplification is disrupting jet stream behavior, causing persistent extreme weather patterns and secondary feedback.
- **Methane Hydrate Release:** Warming oceans may destabilize seafloor methane deposits—an abrupt potential emission source.
- **2.** Cascading Tipping Interactions: Our feedback mapping highlights several compound cascades:
 - Cryosphere Cascade: Greenland melt weakens AMOC → warms Southern Ocean → destabilizes West Antarctic Ice Sheet → >10 meters sea-level rise over centuries.
 - Biosphere-Climate Cascade: Amazon dieback releases CO₂ →
 accelerates warming → triggers boreal forest dieback and
 permafrost thaw → runaway carbon loop.
 - Ocean-Atmosphere Cascade: AMOC disruption weakens monsoons → regional vegetation loss → dust feedback alter Atlantic SSTs → further AMOC weakening.
 - **Jet–Permafrost–Fire Nexus:** Arctic warming weakens jet stream → causes heatwaves → triggers tundra fires → releases carbon → accelerates warming.
 - Stabilizing Feedback (few but notable): AMOC-induced North Atlantic cooling may slow Greenland melt regionally; volcanic aerosols or engineered reflectivity could slow warming, but generally less potent than reinforcing loops.
- **3. Emergent Wildcard Feedback:** Secondary loops now recognized as critical:

- Soil Carbon Sensitivity: Drought-exposed soils release hidden carbon. Tufts University found deep carbon stores are vulnerable to cracking, oxygenation, and microbial conversion, producing CO₂ and N₂O.
- Cloud Feedback Complexity: Low clouds cool; high clouds warm. Shifting cloud types introduce chaotic variables.
- Carbon-Poor Vegetation Shift: Warmer temperatures favor species that store less carbon, reducing global sequestration capacity.

4. Magnitude and Speed of Feedback-Driven Warming

Recent studies suggest climate models may underestimate warming by up to 2°C by 2100 due to underrepresented feedback (Torn & Harte, 2006). Instead of 3°C, projections could exceed 5°C under highemissions scenarios.

Furthermore, this feedback compresses the timeline:

- Warming that might have taken 80–100 years may unfold in **40–60 years**, limiting adaptation capacity.
- Models incorporating nonlinear feedback forecast warming trajectories up to 70% greater and 1.5–2× faster than baseline projections.

"At current pace, we're 26 million years behind. Let's close the gap in a decade."

Resource Strain and Societal Fault Line Exposure:

Accelerated warming will deplete critical life-support systems:

Resource	Why It's at Risk	Projected Impact Timeline
Freshwater	Droughts, glacier loss, pollution	>5B people at risk by 2030–2050
Arable Soil	Erosion, salinization, desertification	< 60 viable harvests in many areas
Stable Climate Zones	Extreme heat, rainfall disruption	Breadbasket destabilization by 2040
Pollinators and Biodiversity	Habitat collapse, warming, pesticides	>68% decline since 1970; ecosystem fragility
Fisheries	Overfishing, warming, acidification	Collapse risk by 2050
Phosphorus and Fertilizers	Non-renewable, pollution-driven shortages	Reserve exhaustion in 80–100 years
Energy Security	Fossil depletion, grid stress	Widespread disruptions in 40–60 years

Societal Breakdown: First Cracks Likely to Appear:

- 1. **Food Systems:** Price spikes, famine, and unrest as crops fail from heat and soil degradation. E.g., Syria's pre-war drought.
- 2. **Water Wars:** Rivers like the Nile, Indus, and Colorado are already contested. Conflict is likely by the 2030s.
- 3. **Migration & Border Stress:** 1.2 billion climate migrants projected by 2050. Destabilization of borders and economies.
- 4. **Public Health Collapse:** Disease spread (dengue, malaria, cholera), overwhelmed hospitals, and chronic heat stress.
- 5. **Economic Fragility:** Insurance collapse, supply chain breakdowns, asset revaluations. World Economic Forum identifies these as top-tier global risks.

6. **Governance Breakdown:** Dwindling legitimacy, authoritarian drift, social unrest. Fragile states may collapse; even stable democracies risk structural strain.

Final Analysis: We Are Approaching the Threshold

Feedback loops are not additive. They are **multiplicative** and **cross-systemic**. The idea of a linear climate trajectory is obsolete. Our synthesis supports the emerging consensus:

- At just 1.2°C, permafrost thaw and coral bleaching have begun.
- By 1.5–2°C, at least five major tipping elements may begin shifting irreversibly.
- At **2.5–3**°C, the likelihood of **cascading tipping chains** grows dramatically.

Wunderling et al. (2023) and Steffen et al. (2018) warn that the interconnected nature of Earth's systems **lowers effective tipping thresholds**, meaning interaction can trigger early collapse.

Given current policies, the planet is on track for 2.4–2.8°C by 2100, with additional warming locked in beyond that. We are entering the range where multiple feedback—cryospheric, biological, and chemical—could run away from human control.

Feedback Loops and UTPs — The Necessity of Urgency: The science of feedback and UTPs underscores that climate change is non-linear. Small incremental emissions today could set off disproportionate impacts later by triggering self-perpetuating processes. For example, each additional ton of carbon increases the risk that permafrost or forests will release even more carbon, a kind of domino effect that human actions would struggle to rein in. The PIK study we cited illustrates that even "low" emissions trajectories might overshoot targets because of this amplifying feedback. This challenges any complacency in gradualism. It's not enough to say, "We will reduce emissions by mid-century." The Earth system might not wait. It could respond faster and more forcefully than our political timelines account for. Therefore, from a risk-management perspective, we must front-load climate action, aiming to

minimize the chance of crossing those hidden thresholds. The Discussion would point out that, unlike problems where linear improvements suffice, here we face potential points of no return (e.g., a collapsed AMOC or disintegrating ice sheets) that **lock in multimeter sea-level rise or pervasive heat** for future generations. The amplified heating risk on millennial scales found by Kaufhold et al. (2025) also reminds us that our **responsibility spans beyond 2100**. The carbon we emit now can reverberate in feedback that raises temperatures for centuries. Declaring a climate emergency is a rational response to this knowledge; it acknowledges that we are in the "last effective year" or decade to prevent an irreversible trajectory.

Resource Limits — Converging Crises Demand Integrated Solutions: Our resource depletion timeline highlights how climate change collides with other human-induced strains. This confluence can produce cascading human crises, just as feedback produces cascading climate crises. For instance, if a severe multi-region drought (climate-driven) hits in the 2030s while soil degradation has reduced crop resilience and groundwater is depleted, the result could be a global food shortage, not just a localized famine. One crisis can amplify another: a food shortage can spark conflict, which then hampers climate action or resource sharing—a vicious cycle. The discussion emphasizes that climate policy cannot be siloed. We need a holistic emergency response that also addresses water management, soil conservation, sustainable agriculture, and resource equity. The climate emergency is also a resource emergency. Efforts like massive reforestation and regenerative farming could sequester carbon and rebuild soil and pollinator populations, yielding co-benefits for climate and food security.

"Instead of asphalt and bridges, we build atmospheric cleansing stations."

Similarly, transitioning to renewable energy not only cuts carbon emissions but also reduces dependency on finite fossil fuels, aiding long-term energy security. A key point is that **delay makes the solutions harder or impossible**: if we wait until phosphorus is truly scarce and multiple harvests fail, social stability may be too eroded to implement technical fixes. Thus, proactive emergency measures (e.g., aggressive

investment in agricultural innovation, water recycling, alternative fertilizers, etc.) are needed **now** to shore up these systems before they fail.

Civilizational Resilience - Prevention Now or Collapse Later: The societal fault lines we examined (food, water, migration, health, economy, governance) read like a compendium of potential collapse triggers. Encouragingly, history shows societies can often adapt to moderate stresses, but what we are risking is synchronous, multi-faceted stress at an unprecedented global scale. Modern civilization has never been tested by planetary climate disruption coupled with resource scarcity at this magnitude. The closest analogies—perhaps the Bronze Age collapse (possibly linked to drought) or the fall of civilizations like the Mayans—were regional, not global. Our analysis suggests that no country will be an island in the face of these systemic pressures. Even wealthier nations like the U.S. or Canada cannot fully insulate themselves; they will face internal disasters as well as external spillover (like climate refugees or global economic shocks). This argues for a cooperative global emergency response: climate change should perhaps be handled like an asteroid heading for Earth—a threat to everyone, requiring coordinated action surpassing normal politics. Unfortunately, as impacts mount, there's a risk that governance turns more nationalistic (scramble for resources, fortressing borders). To avoid a dark scenario of fragmentation and constant crises, we discuss the need for strengthening global governance - possibly new treaties on climate refugees, water sharing agreements, and global emergency funds. The concept of "Planetary Emergency" has been floated by scientists and even the UN in recent years; our findings back this up in detail. We suggest that declaring a climate emergency isn't just symbolic-it can unlock extraordinary measures. For example, governments could mobilize funds and innovation akin to wartime economies: implementing climate jobs programs, rationing or redirecting certain resource uses (if needed for the greater good), and focusing the national agenda on resilience and decarbonization.

Conclusion

The climate emergency is **amplifying itself** through its own biology, chemistry, and physics. Feedback now acts across the Earth system in

synchrony, compressing time, raising stakes, and shredding our margin for error.

This paper consolidates current science to offer a stark but actionable truth: unless unprecedented mitigation and adaptation begin immediately, the climate system could shift into a **new equilibrium**, one hostile to food security, political stability, economic functionality, and human health. The countdown is not abstract. It is mapped in fire, drought, permafrost thaw, crop failure, species decline, and unrelenting feedback. And every degree gained from here forward multiplies not just heat, but system failure.

Peer-Reviewed Support – Credibility of an Emergency Declaration: The mention of the PIK and SEAHI (Obiora et al. 2025) studies shows that our dire warnings are not exaggeration but reflected in up-to-date research. The PIK press release emphatically stated that even 2°C may not be safe due to feedback and called for accelerated action. The UTPs review concluded that cascades "cannot be ruled out" even at 1.5–2°C, essentially meaning early stages of an emergency are here.

"Each DACR facility powers a local economy—cement-free schools, carbon-negative highways, fire-resilient homes."

Appendix V: Direct Atmospheric Carbon Removal Funding and Budget Mechanisms

Deploying DACR at an infrastructure scale will necessitate innovative financing. Instead of directly burdening taxpayers, states can utilize public-private funding models, cost savings from new materials, federal support, and service-based revenue.

Key budget mechanisms include:

State-Level Funding Pathways for DACR Deployment

1. Green Infrastructure Bonds

- States issue **climate resilience bonds** similar to highway or school bonds.
- Backed by future savings from disaster avoidance, energy efficiency, and infrastructure durability.
- Example: California's past **Prop 1** and **Prop 68** raised billions for water and climate projects.

2. Material Substitution Savings

- DACR-derived materials (R-CO₂ concrete, asphalt, etc.) **replace traditional materials**.
- States redirect existing infrastructure budgets toward carbonnegative alternatives.
- This isn't new money—it's **smart reallocation**.

3. State Green Banks

- Public-private financing institutions that fund clean tech projects.
- DACR facilities qualify as long-term climate infrastructure.
- Example: New York Green Bank has mobilized over \$1.6B in clean energy investments.

4. Carbon-Embedded Procurement Mandates

- States require public projects to use carbon-negative materials.
- This creates **guaranteed demand** for DACR outputs, attracting private investment.
- Think: "Every new school must use R-CO2 concrete."

5. University and Research Partnerships

- Land-grant universities host DACR pilots funded by **state innovation grants**.
- Ties DACR to workforce development, STEM education, and tech transfer.

6. Federal Pass-Through Grants

- States tap into federal infrastructure, disaster recovery, or climate resilience funds.
- For example, the **Supplemental Disaster Recovery Fund** offers up to \$2M per project for flood control and infrastructure retrofits.

7. DACR-as-a-Service Contracts

- States lease DACR capacity from private operators (like Climeworks) instead of building outright.
- The pay-per-ton model spreads the cost over time and avoids upfront capital.

"Think of DACR like broadband: deploy smart, scale fast, ride the tech drop."

8. Agricultural DACR Credits

- States fund biochar, enhanced weathering, and regenerative practices that remove CO₂ and improve soil.
- These programs already exist in pilot form in places like North Dakota and California.

- bonds or climate bonds to raise capital exclusively for DACR projects. Much as cities finance transit or water systems with municipal bonds, a state can float bonds for carbon removal facilities or related upgrades. Voter-approved climate bond initiatives in places like New York (\$4.2 billion in 2022) and California (\$10 billion in 2024) demonstrate public willingness to invest in environmental infrastructure. Proceeds from a "Carbon Removal Infrastructure Bond" would fund DACR plant construction, pipeline connections to storage sites, and integration into public works. These bonds can be appealing to investors as they are backed by the state and tied to tangible assets, with the "green" label attracting ESG-focused funds. By amortizing costs over decades, states spread out the expense of large DACR deployments in the same way highways are paid off over time.
- Material Substitution Savings: Interestingly, DACR can partially pay for itself when its outputs or byproducts replace costly materials. A prime example is the use of captured CO₂ in concrete. If a DOT uses CO₂-cured concrete (like CarbonCure technology) in a highway, it can achieve the same strength with less cement. Cement is expensive and carbon-taxing; a 10% reduction in cement content translates to budget savings. Table 2 (below) illustrates how this works: for every 100,000 cubic yards of concrete used by a city, injecting waste CO2 could avoid 8,500 tonnes of emissions and slightly reduce material cost by cutting cement volume. At scale, these savings (or avoided costs from carbon pricing) can be redirected to fund DACR operations. Additionally, if captured CO2 is turned into products (aggregates, chemicals, fuels), selling those products creates revenue. For instance, CO2 from a DAC plant could be used by a local manufacturer of synthetic methanol or sustainable aviation fuel, and the state might take an offtake royalty or reduced fuel costs in return. Another substitution: using DACR to plug old oil wells (via CO2 injection for mineralization) could qualify for federal well Upcycling funds (since it prevents methane leaks), again offsetting project costs. In summary, by tapping the value in CO₂, whether as a commodity (for industrial use) or by embedding it in materials, states can chip away at the net cost of removal.

Federal Grants and Credits: The federal government has unleashed unprecedented support for carbon removal, and states should capitalize on it. The Bipartisan Infrastructure Law (BIL) allocates \$3.5 billion to create four DAC hubs of 1 Mt/year each, and as of 2023 the Department of Energy has funded 16 regional DAC hub feasibility projects across 12 states (including in the Four Corners region covering CO/NM). States like Colorado, Arizona, Louisiana, Texas and others have already received DOE grants (tens of millions) to plan DAC hubs. By participating in these programs, states can have the feds cover a significant share of early project costs. In addition, the 45Q tax credit now offers \$180 per ton of CO2 removed by DAC and stored, meaning a 1 Mt DAC facility could generate up to \$180 million in federal tax credits annually, hugely improving its economics. States can attract private developers by helping them monetize 45Q (for example, by facilitating transfer of credits or providing state tax matching).

"Each DACR facility powers a local economy—cement-free schools, carbon-negative highways, fire-resilient homes."

The federal government is also directly purchasing carbon removal as a market stimulator. The DOE launched a Carbon Dioxide Removal procurement program in 2023 to sign offtake agreements for CO₂ removed. States can lobby to channel some of these purchases to their projects (e.g., a federal agency buys X tons from a state DAC facility each year for the next 10 years), guaranteeing revenue. Furthermore, other federal grants (FEMA's BRIC program for resilience, USDA grants for rural development, etc.) could be tapped by packaging DACR into resilience or economic development projects. Using federal dollars and incentives wherever possible reduces the burden on state budgets and signals bipartisan commitment to these projects.

"DACR-as-a-Service" Models: Rather than states owning all DAC infrastructure, they can foster a public-private service model. In this approach, private companies build and operate DACR facilities

(taking on the capital expense), and the state (or its agencies) contracts them to remove a certain amount of CO2 per year, essentially purchasing carbon removal as a service. This is akin to power purchase agreements in renewable energy. The benefit is the state pays annual operating fees (which can be adjusted or canceled if goals change) instead of huge upfront costs. Companies like Climeworks already sell carbon removal subscriptions to businesses; states could do similarly for their "hard-to-decarbonize" emissions or to meet statutory climate targets. A precedent is the U.S. federal CDR pilot purchase program, where the government committed to buy CO₂ removals from providers to help launch the industry. States can issue competitive bids for, say, "100,000 tons of carbon removal per year for 10 years," inviting companies to install DAC units on state land and deliver the service. This could be financed through a *Carbon* Removal Fund fed by polluter fees or general funds. Additionally, regional alliances of states could jointly contract larger DAC services at lower bulk prices. Over time, as the market matures, states might get removal costs near or below \$100/ton, making DACR-as-a-service a cost-effective tool to hit climate goals after maximizing direct emissions cuts. It also creates a local industry of service providers and maintenance crews. In summary, service models turn carbon removal into an operational expense akin to waste management – the state pays a firm to "clean up" a ton of CO₂, with performance guarantees.

Table 2: Key Financing Mechanisms for State DACR Programs

Mechanism	Description	Examples / Notes
Green Bonds	Issue state bonds	Examples: New York's \$4.2 B
	earmarked for	environmental bond (2022)
	DACR and climate	funds climate resiliency.
	projects, repaid over	California's \$10 B climate
	time by general	bond (2024) backs clean energy
	revenue or small	and carbon reduction. Similar
	rate surcharges.	bond measures can finance
		DAC hubs, with voter buy-in
		ensuring political legitimacy.

Material Substitution Savings

Use captured CO₂ to replace or reduce expensive materials, channeling the cost savings or product revenues into funding DACR.

Example: Injecting CO2 into (CarbonCure) concrete cement use 5-10%, saving sequestering money and carbon. If a state saves \$5 per ton of concrete and thousands of tons of cement, those savings fund DAC ops. Note: Also monetize CO₂-derived products: e.g. sell captured CO₂ for industrial use or turn it into aggregates for sale, creating revenue streams.

Federal Support (Grants Credits)

Leverage federal funds and incentives for carbon removal.

Examples: DOE's DAC Hub grants (total \$3.5 B) cover large portions of project cost. 45Q credit provides up to \$180/ton for DAC CO2 stored offsetting (nearly early operational costs). The federal government's carbon removal purchase program guaranteed offtake contracts. de-risking investment. States should align projects to meet federal criteria and grab these funds.

DACR-as-a-Service (Public-Private) Contract private companies to deliver CO₂ removal, paying per ton instead of owning infrastructure.

Example: A state signs a 10year contract with a DAC provider to remove 50,000 tCO₂/yr at \$200/ton, indexed to drop to \$100/ton as tech improves. The company builds the plant (using 45Q credits to finance). The state pays annually for results, akin to waste disposal services. This capital turns expense into

operating expense and can be funded via modest utility-like fees or climate fund budgets.

By combining these mechanisms, states can **stack financing** for DACR. For instance, a state could issue green bonds to cover a local cost-share on a federally funded DAC hub, use material-based savings to lower operating costs, and sign a service contract ensuring long-term removal purchases that give investors confidence. Creative budgeting, including exploring **cap-and-invest programs** (like RGGI or California's cap-and-trade revenue), will ensure DACR deployment doesn't crowd out other priorities. Many states are already examining such tools to fund climate infrastructure. The OCR envisions DACR funding as an integrated piece of infrastructure finance, not a one-off expense.

Sample Rollout Strategy for Colorado and New Mexico

To illustrate how the OCR can be tailored, consider **two states**, **Colorado and New Mexico**, as examples. Both are in the interior West but have different industry landscapes. Colorado has a head start on policy and a diverse green economy, while New Mexico has vast geological resources and an oil/gas legacy. The rollout in each state leverages local strengths:

Colorado: From Climate Leader to Carbon Removal Leader

Policy Foundation and Targets: Colorado has established itself as a climate-progressive state with legal mandates for carbon management. In 2023, the state enacted the Carbon Management Act (HB 23-1210), tasking the Energy Office to develop a carbon removal roadmap and explore technologies like DAC, carbon utilization, and sequestration. This law, championed as both a climate and jobs bill, explicitly aimed to "facilitate the scale-up of carbon management" to meet net-zero by 2050 while creating quality jobs. The resulting Colorado Carbon Management Roadmap (2025) identified key opportunities in sectors such as construction materials, manufacturing, and natural lands for

carbon removal. With this policy support, Colorado's rollout plan sets **incremental targets**: e.g., 50,000 tCO₂/yr by 2028 (pilot hubs), 300,000 by 2030, 1 Mt by 2040 in line with the OCR tiers.

"Carbon-built infrastructure becomes visible ROI"

Early Projects (2025–2030): The first step is demonstrating DACR at a meaningful scale in-state. In 2023, Colorado-based company Global Thermostat unveiled a pilot DAC plant in Brighton, CO (near Denver) that captures 1,000t CO₂/yr. State leaders, including the Governor and federal representatives, attended its launch, signaling political buy-in. This pilot will be followed by a larger Colorado DAC Hub project: with \$3 million DOE funding, Carbon America and partners are studying a DAC hub near **Pueblo**, **CO**, aiming for 50,000 t/yr removal integrated with local geologic storage in the Denver-Julesburg Basin. The vision is to pair a DAC facility with an identified deep saline aquifer or depleted oil formations in Pueblo County for permanent CO₂ storage. By 2026–2027, Colorado could break ground on this DAC hub (perhaps using technology from Sustaera and GE as planned). Importantly, these projects are engaging the community early: the Pueblo DAC hub team is developing a Community Benefits Plan and doing consent-based siting outreach, which helps alleviate local concern and ensures jobs and benefits for residents. Alongside Pueblo, the state will likely see a DAC project in the north: possibly Wyoming-Colorado joint efforts (Colorado has joined a coalition with Wyoming to pursue carbon removal initiatives, leveraging Wyoming's storage sites). By 2030, Colorado aims to have at least one DAC hub operational (removing on the order of 0.1–0.3 Mt/yr) and several smaller pilot projects (including, for example, a Boulder County communityscale CDR project that might combine forest biomass carbon removal with DAC to reduce wildfire fuels).

"Every DACR facility is a carbon mine—pulling value from the sky."

- Integration into Infrastructure: Colorado will integrate DACR across various public works to normalize the technology. The state's Department of Transportation can start specifying lowcarbon concrete (with CO₂ mineralization) for highway projects - Colorado is already a leader in green construction policies. As part of the rollout, a goal is set that by 2030 all state-funded building projects must consider carbon-infused materials. For instance, if CDOT rehabilitates I-70 or builds new bridges, they could use concrete from plants using CarbonCure or similar tech, thereby storing CO₂ and boosting local demand for captured CO₂. Furthermore, Colorado could pilot DAC units at public facilities, such as installing a small DAC system at the Colorado State Capitol or a major university, as a demonstration. This would pull a token amount of CO2 (say, a few tons a year) but serve educational and symbolic purposes – a constant reminder of climate action in progress. Another integration is with the power sector: as Colorado retires its last coal plants (like the Comanche station in Pueblo by 2030), those sites, with grid connections and workforces, can be repurposed for DACR plants powered by renewable energy. Xcel Energy and other utilities can be partners, incorporating DACR into their clean energy plans (perhaps counting removals toward corporate net-zero goals). By 2035, Colorado aims for every major infrastructure investment (roads, water projects, new state buildings) to include both a resilience component and a carbon component, whether through materials or co-located DAC.
- Local Industry Synergies: Colorado's rich ecosystem of industries and research institutions will be harnessed. The state is home to national labs (NREL, NOAA) and universities that are advancing carbon capture technologies. For instance, Colorado State University has launched carbon management education programs to supply skilled workers. Those graduates can feed the growing DAC industry. The oil & gas sector on the West Slope and Weld County can pivot to carbon storage services: drilling companies and geologists who once extracted oil can now drill CO2 injection wells and monitor storage sites. This leverages their

expertise and provides continued employment as fossil fuel production declines. Additionally, firms like **Kiewit and engineering companies in Colorado** are already engaged in DAC projects (Kiewit is part of the Pueblo DAC hub team); they will benefit from contracts to design and build facilities, creating a local supply chain. Colorado also has a burgeoning **clean tech startup scene** – the plan will provide grants or green bank loans to startups working on direct air capture innovations (e.g., novel sorbents or modular DAC devices).

"Don't front-load the cost—ride the cost curve."

The state's brewing and beverage industries, which use CO₂, could agree to purchase a fraction of their CO₂ from direct air capture instead of byproduct sources, as a marketing and supply-chain innovation. Furthermore, Colorado's cement and concrete industry (e.g., GCC's large cement plant in Florence, CO) can partner to utilize CO₂ from DAC to cure cement or make carbonate aggregates, turning a high-emission industry into a mitigator. These synergies demonstrate how DACR becomes embedded in Colorado's economic fabric, not a standalone novelty, but part of multiple value chains (energy, materials, tech, workforce development).

• Public Engagement and Support: Colorado's rollout emphasizes transparency and community benefit, learning from its robust stakeholder process for the Carbon Roadmap. Each project includes outreach. For example, the Pueblo DAC hub team has already involved local officials and will continue to hold community meetings as design progresses. On the state level, officials will continuously message the *co-benefits*: the jobs (reminding that potentially 85k jobs by 2050 are at stake), the risk reduction (e.g. "this year's wildfires underscore why we need to both cut emissions and remove carbon – DAC is part of protecting our forests and ski industry,") and economic opportunities (attracting federal \$\$ and being the "Silicon Valley of Carbon Removal"). Bipartisan support is cultivated by involving diverse leaders – the roadmap effort already saw involvement from both Republican and Democratic sponsors. Colorado can point to tangible early successes by 2028: a Pueblo DAC plant providing union

construction jobs, a Boulder carbon removal project reducing wildfire debris, and students getting trained in DAC operations at CSU. These stories will be shared widely to maintain momentum. By the late 2030s, Colorado should reach the 1 Mt/yr removal mark through a combination of perhaps 2–3 large DAC hubs (Plains, West Slope, maybe Four Corners region) and dozens of smaller integrated DAC units statewide. At that point, DACR is simply part of Colorado's public infrastructure toolkit, much as wind farms or water treatment plants are, and enjoys broad public acceptance as a source of state pride ("built by Colorado for Colorado").

New Mexico: Transitioning Oil & Gas Expertise into Carbon Removal

- Policy Foundation and Context: New Mexico has aggressive climate ambitions (targeting net-zero emissions by 2050 via executive order) but also a strong oil & gas sector that is the backbone of its economy. The OCR rollout in New Mexico is designed to bridge these two worlds. The state's leaders are framing carbon management as an economic diversification and environmental necessity. U.S. Senator Martin Heinrich of New Mexico has been a vocal champion of direct air capture and carbon storage, emphasizing that New Mexico's innovation and workforce make it a key player in large-scale carbon removal. While NM does not yet have a dedicated carbon removal law like Colorado, it has participated in regional initiatives. For example, New Mexico Tech and state agencies are partners in a Southwest **DAC Hub** planning effort led by Arizona State University. In 2025, that consortium received \$11.2 M from DOE to design a DAC hub in the Four Corners area (northwestern NM). This gives New Mexico a head start on planning infrastructure. The OCR sets goals for NM to reach 100,000 t/yr removal by 2030 (with the help of that regional hub) and 1 Mt/yr by 2040, aligning with the national push for hubs in multiple regions.
- Early Projects (2025–2030): New Mexico's first tangible DACR project is already underway: Spiritus, a climate-tech startup, is launching a pilot DAC plant on the Nambé Pueblo tribal land

near Los Alamos, expected to be operational in 2025. Although small (1,000 t/yr initially), this project is significant: it demonstrates DAC in NM's climate (high desert conditions) and forges a partnership with an indigenous community. The Nambé Pueblo provided the site and infrastructure upgrades, and Spiritus is bringing high-skill jobs to the area. This pilot ("Orchard" concept) will inform larger "megaton-scale Carbon Orchards" planned by Spiritus in the future. The state will support such pilots through grants or tax incentives, seeing them as seeding new industry. By the late 2020s, the biggest leap will be establishing a DAC hub in the Four Corners region of NW New Mexico. This area (San Juan County) has seen coal plant closures (the San Juan Generating Station closed in 2022), leading to job losses. The DAC hub design led by ASU envisions multi-site DAC facilities in east-central AZ, NW NM, and SE Utah with dedicated CO2 storage sites.

"R-CO₂ isn't sold. It's seen, touched, driven over, and lived inside."

For New Mexico, one site identified is in NW NM, likely leveraging the geology of the San Juan Basin for CO2 storage. The plan is to use new solar and wind farms to power the DAC (since the region's coal plants are retiring, making grid capacity available). By 2030, this Four Corners DAC hub could be removing on the order of 0.5 MtCO₂/yr (across all sites) if fully realized, with perhaps 0.1-0.2 Mt of that in New Mexico. In parallel, in the southeast NM (Permian Basin), closer to the oilfields, there is potential for another DAC project. Occidental Petroleum's subsidiary 1PointFive is constructing the world's largest DAC plant (1 Mt/yr) just over the border in Texas, and Oxy has long-term plans for dozens of DAC plants in the Permian Basin region. New Mexico will coordinate with these efforts, possibly hosting a second large DAC plant on the NM side of the Permian. For example, near Hobbs or Carlsbad, NM, a DAC facility could be built by industry (taking advantage of NM's Class VI injection well regulatory framework for CO2 storage). Early utilization of CO₂ from this plant might be for **enhanced oil recovery (EOR) in depleted fields**, a controversial but revenue-generating use that New Mexico might permit as a transitional step to help finance the project (with strict accounting to ensure net CO₂ removal). By 2030, New Mexico should aim to have at least **two operational DAC projects**: one in the northwest (linked with renewable energy and storage, possibly partially funded by DOE) and one in the southeast (industry-led, linking to oil/gas infrastructure). Combined, these might capture a few hundred thousand tons per year.

Integration into Infrastructure: New Mexico's approach is to weave DACR into its core infrastructure sectors: energy, environment, and even water. For instance, the state can integrate DACR with its abandoned oil well remediation program. New Mexico has many orphaned oil and gas wells; as they plug these wells (often with federal funds), they could concurrently use those sites for small-scale DAC units that use the well for CO2 injection (turning a former pollution source into a storage asset). In agricultural infrastructure, New Mexico's traditional acequias (irrigation canals) and water systems could benefit from CO₂-cured concrete linings or pipes, improving durability while storing carbon. When the state invests in modernizing water infrastructure (a big need due to drought), specifying CO₂-sequestered concrete would be a simple integration. State buildings and schools in New Mexico, especially in cities like Albuquerque and Santa Fe, could be built with carbon-storing materials (there's growing local interest in sustainable building). The state can partner with startups (perhaps via Los Alamos or Sandia labs), developing alternative (like calcium carbonate cement) using CO₂. cements Deployment of DACR in remote areas could also support infrastructure. For example, direct air capture units co-located with solar farms in the sunny southern part of the state can act as a flexible load on the grid, soaking up excess solar power at midday to capture CO₂. This helps stabilize the grid as more renewables come online, essentially making DAC a piece of energy infrastructure as well. In terms of resilience, New Mexico faces extreme heat and wildfire risk; the state might pilot using captured CO₂ to create **fire-retardant materials or soil amendments** that improve land resilience. One concept involves mixing CO₂-derived bicarbonates into soil to help it retain moisture, which could be tested on state lands. In summary, New Mexico will integrate DACR in projects where it complements existing goals: cleaning up old oil sites, expanding renewable energy, and building resilient infrastructure for water and land management.

Local Industry Synergies: New Mexico's greatest asset is its energy industry and geology. The state will tap the expertise of oil, gas, and mining companies to pivot into carbon management. Oilfield service companies in the Permian (many with offices in NM) can get contracts to drill CO₂ injection wells and maintain CO₂ pipelines. Their know-how in handling gases and pressures is directly applicable, turning a potential workforce liability into a DACR workforce. There is also the benefit of existing CO2 pipelines in the region. For decades, CO2 from natural reservoirs in Colorado has been piped to Permian oilfields for EOR; these pipelines (and associated rights-of-way) could be repurposed in the future to transport captured CO2 to secure storage in NM's portion of the Permian Basin. The state's two national labs (Los Alamos and Sandia) and research university (New Mexico Tech) are heavily involved in energy innovation; they are already partners in DAC projects and conduct CO₂ storage research. The rollout will strengthen these R&D ties with funding for pilot projects and testing facilities (e.g., a field station in NM Tech's Petroleum Recovery Research Center to test new DAC sorbents under real conditions). Mining and minerals industry: New Mexico has mining operations (copper, potash). Mine tailings and minerals could be used to react with CO₂ (mineral carbonation), providing another removal pathway. One could imagine a mine in Grant County becoming a CO₂ "sink" by naturally binding CO₂ in crushed rock. If that process is enhanced by DAC (capturing CO2 and feeding it to the mine waste), it's a synergy between mining and carbon removal. The construction sector in NM, though smaller, can benefit by producing carbon-neutral building blocks for export (a company in NM could produce CO2-cured concrete blocks to sell across the Southwest). Another synergy: the burgeoning hydrogen

and CCUS projects. New Mexico has an interest in hydrogen fuel (with carbon capture); if blue hydrogen plants get built, they will have a CO₂ byproduct. Pairing them with DAC can create a hub where all CO₂ (from air and hydrogen production) is jointly stored, achieving negative emissions overall. This sort of clustering (hydrogen + DAC + storage) in places like the San Juan Basin could attract federal hydrogen hub funding and multiply the impact. Essentially, New Mexico will repurpose its skill in extracting energy to excel in injecting and storing carbon, turning an extraction economy into an injection economy. Local businesses will see new markets: engineering firms will design CO₂ wells, universities will train "carbon technicians," and even the tourism sector could benefit (imagine visitors touring a cutting-edge DAC plant in the desert as an educational attraction).

Community Engagement and Equity: New Mexico's rollout is very attuned to the needs of frontline and indigenous communities. The Spiritus pilot set a positive example by partnering with Nambé Pueblo and aligning with the pueblo's environmental stewardship values. Building on that, the state will ensure tribes and local communities have opportunities in the DACR expansion. For instance, involving the Navajo Nation (which spans NW NM) in the Four Corners DAC hub planning. Many coal workers from the Navajo power plant could be retrained for jobs at the DAC facilities planned in that region. The state can negotiate benefits, such as a share of revenues or energy improvements, for those communities. Public outreach will also address the question, "Why invest in carbon removal when we have other needs?" by highlighting cobenefits: new revenue for local governments (DAC projects will pay property/production taxes or equivalent, which can fund schools in e.g. San Juan County, offsetting lost coal revenue), and environmental co-benefits (remediation of legacy pollution: for example, if DAC projects help plug wells or clean up brine, communities get a cleaner environment). Messaging will be culturally sensitive by using metaphors like "Earth healing technologies," which might resonate in communities that value environmental restoration. And just as Colorado did, New Mexico will uphold that DACR complements emissions reduction, not replaces it, to maintain credibility with environmental groups. When Senator Heinrich lauds the Spiritus project as bringing highskill jobs and positioning New Mexico as a leader, it encapsulates what the state wants every community to feel: that DACR is bringing opportunity, not burden. As projects come online, the state will monitor impacts closely (via an environmental justice lens) and adjust course if, say, a project uses too much water in a dry area, technological tweaks (like using dry cooling for DAC units, or siting DAC near brackish water sources) will be employed to avoid local resource strain. By 2040, New Mexico's target of 1 MtCO₂/yr removed will likely be met through a combination of one large hub in the northwest, one in the southeast, and scattered smaller projects, and the success will be measured not just in tons, but in how well those projects uplift local economies and align with New Mexico's dual identity as an energy producer and a land of natural beauty.

Conclusion: The examples of Colorado and New Mexico show how different states can customize the OCR while following the same overall roadmap of targets, integration, funding, and outreach. Colorado leveraged policy mandates, tech industries, and green talent; New Mexico leveraged geology, energy know-how, and federal partnerships. Both focused on co-benefits: jobs, resilience, and pride. The State Office of Carbon Recovery transforms direct air capture from a nascent tech into a practical infrastructure pillar. By 2040, through steady scaling, smart use of public funds, and community-centric deployment, DACR can realistically evolve into a nationwide public service, cleaning our atmosphere much like waste management services clean our cities, helping states achieve climate goals and fostering a new era of sustainable industry in the process. The OCR offers a credible, actionable blueprint for states to begin this transformation now, proving that carbon removal can move from speculation to implementation on a timeline that our climate demands.

Appendix VI: State Office of Carbon Upcycling (OCU) for State-Level DACR Deployment

- Climate Deadline Alliance

Overview: This State Office of Carbon Upcycling (OCU) description provides a state-level blueprint for deploying Direct Atmospheric Carbon Removal (DACR) as a core element of public infrastructure. The plan outlines phased deployment targets from 2025 to 2040, innovative use cases integrating DACR into roads, housing, and resilient infrastructure, funding mechanisms to finance these projects, messaging strategies to build broad support, and state-specific rollout examples (Colorado and New Mexico) demonstrating local industry synergies and applications. By treating DACR as essential infrastructure, much like roads and power lines, states can transition this technology from speculative to practical, achieving climate goals while spurring economic development.

Tiered Deployment Targets (2025–2040)

Each state will ramp up its carbon removal capacity in tiers, starting with pilot-scale projects by the mid-2020s and reaching megaton-scale operations by 2040. **Table 1** summarizes the proposed targets per state over time:

<u>Year</u>	DACR	Deployment Tier and Milestone
	Capacity	
	per State	
2025	36,000 tons	Tier 1 – Pilot Demonstration: Install an initial
	CO ₂ /year	DAC facility (36 kt/year), roughly the size of
	-	Climeworks' new Mammoth plant. This "first-of-
		a-kind" project establishes operational know-
		how and local workforce training.

2030	200,000+ tons CO ₂ /year	Tier 2 – Early Commercial: Scale up with multiple or larger DAC units totaling 0.2 Mt/year per state. By 2030, a few regional DAC hubs (each 1 Mt/year) should be online nationally, enabling each state to host mid-sized plants and collectively achieve tens of Mt globally.
2035	500,000– 600,000 tons CO ₂ /year	Tier 3 – Mass Deployment: Accelerate installation of DAC facilities leveraging improved technology and lower costs (approaching the \$100/ton target). By mid-2030s, each state operates multiple DACR sites (or one large hub) integrating into power and industrial infrastructure, reaching 0.5–0.6 Mt/year.
2040	1,000,000 tons CO ₂ /year	Tier 4 – Full Scale Integration: Achieve 1 Mt/year removal capacity per state as a cornerstone of climate strategy. This implies a network of DACR installations statewide, equivalent to one large million-ton DAC plant (already demonstrated in Texas by 2025) or several smaller units. At this stage, DACR is a mature public utility, collectively pulling 50 Mt/year across all states.

Rationale: These targets reflect an aggressive but feasible growth trajectory. The jump from 36,000 t in 2025 to 1 Mt in 2040 requires roughly a 25- to 30-fold scale-up over 15 years. This pace is comparable to historical clean-tech growth (e.g., solar 10× per decade expansion). Early 2020s projects like Climeworks' *Mammoth* (36 kt/yr) and Occidental's planned 1 Mt/yr DAC plant provide real-world proof-of-concept for Tier 1 and Tier 2. By hitting 10 Mt total U.S. capacity by 2030, the foundation is laid for exponential growth thereafter. Crucially, the cost per ton is expected to fall from the current \$600–\$1,000 to around \$100 by 2030–2035, thanks to R&D (DOE's Carbon Negative Shot targets \$100/tCO₂ at gigaton scale) and economies of scale. As costs drop and climate policies tighten, states can justify the yearly removal of 1 Mt CO₂ as part of meeting net-zero goals (many of which aim for 85–100% emissions cuts plus removals by 2040–2050). By 2040, DACR

facilities will become as commonplace as water treatment plants – critical infrastructure managing the "waste" (CO₂) that drives climate change.

Use Cases: Integrating DACR into Public Infrastructure

A key strategy is embedding DACR into **public works and construction projects** so that carbon removal adds value beyond climate mitigation. This integration creates visible, local benefits that make DACR politically viable. Example use cases include:

Roads and Highways

State transportation agencies can incorporate DACR into road projects in two ways: materials and roadside installations. First, use carbonsequestering concrete and asphalt in highway construction. For instance, Minnesota DOT is testing concrete mixes that inject CO₂ during curing, permanently mineralizing carbon and reducing cement needs. If each cubic yard of concrete can lock in a pound of CO₂ while using less cement, thousands of tons of CO2 per mile of highway could be offset with costneutral material improvements. Second, roadside DACR units can be colocated along highways or interstates. These could be powered by solar panels on sound barriers or rights-of-way and even utilize turbulence from passing traffic to mix air. By siting DACR "vacuum" modules near transportation corridors (often high-emission zones), states create a visible symbol of climate action. The captured CO2 can either be piped to nearby geological storage or used on-site (for example, to cure more "green concrete" for road maintenance). This approach ties carbon removal to the very infrastructure that historically contributed to emissions, literally paving the way to a cleaner future.

Buildings and Housing

DACR can be integrated into state housing programs and public buildings to sequester carbon during construction and enhance indoor environments. One approach is using CO₂-storing building materials. For example, concrete blocks, insulation, or aggregates made with captured CO₂ (via mineralization processes) can be used in state-funded affordable housing. Companies have developed concrete that absorbs CO₂ as it hardens, yielding strong blocks with lower emissions. Deploying these in public housing or school construction would turn buildings into

carbon stores. Another approach is installing **building-integrated DAC**: modular DACR units that connect to large buildings' HVAC systems. These units would scrub CO₂ from ambient air as it circulates, perhaps using waste heat from the building's boilers or solar panels on the roof. The benefit is twofold: they slightly improve indoor air quality (by removing CO₂ and pollutants) and capture carbon, which can be collected for reuse or disposal. While still experimental, a city pilot could outfit a government office or university dorm with a DACR system in the ventilation. Housing developments could also use captured CO₂ to produce their own construction materials on-site (e.g. a neighborhood block factory that mineralizes CO₂ into pavers). By integrating DACR into buildings, states make climate technology part of everyday life and infrastructure, much like energy efficiency or solar roofs.

Disaster-Resilient Projects

Investing in **climate resilience** offers an opportunity to pair **adaptation** with mitigation. When states undertake projects like flood control systems, wildfire buffers, or rebuilding after disasters, they can incorporate DACR components. For example, when constructing new seawalls or levees, consider using **CO₂-infused concrete** or aggregates. Each mile of reinforced coastal wall could lock away thousands of tons of CO₂ in its structure. In wildfire-prone areas, rebuilding communities and power grids could incorporate DACR units powered by community solar/battery microgrids, which also provide backup power during emergencies. One imaginative concept is to deploy portable DACR units to disaster-rebuilding zones: after a wildfire or hurricane, as communities rebuild homes and infrastructure, mobile DACR systems run on-site (perhaps using excess generators or solar in the recovery camps) to capture CO₂ during the rebuilding effort, sending a message that we rebuild stronger *and* cleaner.

Additionally, many hazard mitigation projects involve large concrete works (bridges, storm drains, foundations for relocating buildings), which can utilize low-carbon concrete. Integrating carbon removal into these projects creates a virtuous cycle: the project enhances safety against climate impacts while directly removing some of the atmospheric CO₂ that fuels those very impacts. Politically, this helps frame DACR as part of protecting communities, e.g., "carbon removal pipes and tanks" become as critical as water pumps in a flood control project. Over time,

DACR units might be standard in public facilities like hospitals or emergency shelters, providing not only CO₂ removal but potentially cobenefits (some DAC designs produce fresh water as a byproduct, which could aid emergency water supply). By linking DACR with resilience, states underscore that **climate action yields tangible protection and jobs** locally, beyond abstract global benefits.

Funding and Budget Mechanisms

Deploying DACR at infrastructure scale will require innovative financing. Rather than burdening taxpayers outright, states can leverage public-private funding models, cost savings from new materials, federal support, and service-based revenue. Key budget mechanisms include:

- Green Bonds for Climate Infrastructure: States can issue green bonds or climate bonds to raise capital exclusively for DACR projects. Much as cities finance transit or water systems with municipal bonds, a state can float bonds for carbon removal facilities or related upgrades. Voter-approved climate bond initiatives in places like New York (\$4.2 billion in 2022) and California (\$10 billion in 2024) demonstrate public willingness to invest in environmental infrastructure. Proceeds from a "Carbon Removal Infrastructure Bond" would fund DACR plant construction, pipeline connections to storage sites, and integration into public works. These bonds can be appealing to investors as they are backed by the state and tied to tangible assets, with the "green" label attracting ESG-focused funds. By amortizing costs over decades, states spread out the expense of large DACR deployments in the same way highways are paid off over time.
- Material Substitution Savings: Interestingly, DACR can partially pay for itself when its outputs or byproducts replace costly materials. A prime example is the use of captured CO₂ in concrete. If a DOT uses CO₂-cured concrete (like CarbonCure technology) in a highway, it can achieve the same strength with less cement. Cement is expensive and carbon-taxing; a 10%

reduction in cement content translates to budget savings. Table 2 (below) illustrates how this works. For every 100,000 cubic yards of concrete used by a city, injecting waste CO2 could avoid 8,500 tons of emissions and slightly reduce material cost by cutting cement volume. At scale, these savings (or avoided costs from carbon pricing) can be redirected to fund DACR operations. Additionally, if captured CO₂ is turned into products (aggregates, chemicals, fuels), selling those products creates revenue. For instance, CO2 from a DAC plant could be used by a local manufacturer of synthetic methanol or sustainable aviation fuel. The State might take an offtake royalty or reduced fuel costs in return. Another substitution: using DACR to plug old oil wells (via CO₂ injection for mineralization) could qualify for federal well Upcycling funds (since it prevents methane leaks), again offsetting project costs. In summary, by tapping the value in CO₂, whether as a commodity (for industrial use) or by embedding it in materials, states can chip away at the net cost of removal.

Federal Grants and Credits: The federal government has unleashed unprecedented support for carbon removal, and states should capitalize on it. The Bipartisan Infrastructure Law (BIL) allocates \$3.5 billion to create four DAC hubs of 1 Mt/year each, and as of 2023, the Department of Energy has funded 16 regional DAC hub feasibility projects across 12 states (including in the Four Corners region covering CO/NM). States like Colorado, Arizona, Louisiana, Texas and others have already received **DOE** grants (tens of millions) to plan DAC hubs. By participating in these programs, states can have the feds cover a significant share of early project costs. In addition, the 45Q tax credit now offers \$180 per ton of CO2 removed by DAC and stored, meaning a 1 Mt DAC facility could generate up to \$180 million in federal tax credits annually, hugely improving its economics. States can attract private developers by helping them monetize 45Q (for example, by facilitating the transfer of credits or providing state tax matching). The federal government is also directly purchasing carbon removal as a market stimulator. The DOE launched a Carbon Dioxide Removal procurement program in 2023 to sign offtake agreements for CO2 removed.

States can lobby to channel some of these purchases to their projects (e.g., a federal agency buys X tons from a state DAC facility each year for the next 10 years), guaranteeing revenue. Furthermore, other federal grants (FEMA's BRIC program for resilience, USDA grants for rural development, etc.) could be tapped by packaging DACR into resilience or economic development projects. Using federal dollars and incentives wherever possible reduces the burden on state budgets and signals bipartisan commitment to these projects.

"DACR-as-a-Service" Models: Rather than states owning all DAC infrastructure, they can foster a public-private service model. In this approach, private companies build and operate DACR facilities (taking on the capital expense), and the state (or its agencies) contracts them to remove a certain amount of CO2 per year, essentially purchasing carbon removal as a service. This is akin to power purchase agreements in renewable energy. The benefit is that the state pays annual operating fees (which can be adjusted or canceled if goals change) instead of huge upfront costs. Companies like Climeworks already sell carbon removal subscriptions to businesses; states could do similarly for their "hard-to-decarbonize" emissions or to meet statutory climate targets. A precedent is the U.S. federal CDR pilot purchase program, where the government committed to buy CO₂ removals from providers to help launch the industry. States can issue competitive bids for, say, "100,000 tons of carbon removal per year for 10 years," inviting companies to install DAC units on state land and deliver the service. This could be financed through a Carbon Removal Fund fed by polluter fees or general funds. Additionally, regional alliances of states could jointly contract larger DAC services at lower bulk prices. Over time, as the market matures, states might get removal costs near or below \$100/ton, making DACR-as-a-service a cost-effective tool to hit climate goals after maximizing direct emissions cuts. It also creates a local industry of service providers and maintenance crews. In summary, service models turn carbon removal into an operational expense akin to waste management – the state pays a firm to "clean up" a ton of CO₂, with performance guarantees.

Table 2: Key Financing Mechanisms for State DACR Programs

Mechanism	Description	Examples / Notes
Green Bonds	Issue state bonds earmarked for DACR and climate projects, repaid over time by general revenue or small rate surcharges.	Examples: New York's \$4.2 B environmental bond (2022) funds climate resiliency. California's \$10 B climate bond (2024) backs clean energy and carbon reduction. Similar bond measures can finance DAC hubs, with voter buy-in ensuring political legitimacy.
Material Substitution Savings	Use captured CO ₂ to replace or reduce expensive materials, channeling the cost savings or product revenues into funding DACR.	Example: Injecting CO ₂ into concrete (CarbonCure) cuts cement use 5–10%, saving money and sequestering carbon. If a state saves \$5 per ton of concrete and thousands of tons of cement, those savings fund DAC ops. Note: Also monetize CO ₂ -derived products: e.g. sell captured CO ₂ for industrial use or turn it into aggregates for sale, creating revenue streams.
Federal Support (Grants Credits)	Leverage federal funds and incentives for carbon removal.	Examples: DOE's DAC Hub grants (total \$3.5 B) cover large portions of project cost. 45Q tax credit provides up to \$180/ton for DAC CO ₂ stored (nearly offsetting early operational costs). The federal government's carbon removal purchase program offers guaranteed offtake contracts,

		de-risking investment. States should align projects to meet federal criteria and grab these funds.
DACR-as-a- Service (Public- Private)	Contract private companies to deliver CO ₂ removal, paying per ton instead of owning infrastructure.	Example: A state signs a 10-year contract with a DAC provider to remove 50,000t CO ₂ /yr at \$200/ton, indexed to drop to \$100/ton as tech improves. The company builds the plant (using 45Q credits to finance). The state pays annually for results, akin to waste disposal services. This turns capital expense into operating expense and can be funded via modest utility-like fees or climate fund budgets.

By combining these mechanisms, states can **stack financing** for DACR. For instance, a state could issue green bonds to cover a local cost-share on a federally funded DAC hub, use material-based savings to lower operating costs, and sign a service contract ensuring long-term removal purchases that give investors confidence. Creative budgeting, including exploring **cap-and-invest programs** (like RGGI or California's cap-and-trade revenue), will ensure DACR deployment doesn't crowd out other priorities. Many states are already examining such tools to fund climate infrastructure. The OCR envisions DACR funding as an integrated piece of infrastructure finance, not a one-off expense.

MESSAGING AND PUBLIC SUPPORT STRATEGIES

To make DACR deployment politically viable, an effective **messaging strategy** is crucial. Public understanding of DAC is currently low and sometimes conflated with fossil-fuel carbon capture, so states must shape the narrative. The following messaging approaches will build broad support:

- **Emphasize Job Creation and Economic Revitalization:** Frame DACR as a jobs program and economic driver for both bluecollar and high-tech workers. Highlight studies projecting tens of thousands of new jobs. For example, analysis by Rhodium Group estimates direct air capture could create 85,000 annual jobs in Colorado by 2050, rivaling the state's current oil and gas workforce. Emphasize opportunities for skilled construction, welding, electricians for building DAC plants; technicians and operators to run them; and scientists/engineers for ongoing innovation. Many jobs will be in rural or transitioning areas (old industrial or fossil fuel regions), providing work where it's needed most. Every public statement should link carbon removal to "good, green jobs" and workforce development. States can cite examples like a carbon removal startup in Colorado that could generate over \$500 million in tax revenue, or the high-skill jobs brought to Nambé Pueblo by a DAC pilot in New Mexico. This converts abstract climate policy into tangible economic benefits for constituents.
- Stress Community Resilience and Health Co-benefits: Connect DACR to protecting communities from climate disasters and pollution. Explain that removing CO2 helps stabilize the climate long-term, reducing extreme weather risk – a form of *preventative* infrastructure. Localize the message: for a coastal state, talk about slowing sea-level rise; for a Western state, talk about mitigating drought and wildfire intensity through global cooling. Also note that, unlike capturing emissions at a smokestack, DACR cleans the ambient air, it does not produce smog or harmful copollutants. A DAC plant has fans and filters but essentially no smokestack, so it can even improve local air quality by filtering dust or co-capturing some pollutants. This is important for environmental justice: communities hosting DAC will not get soot or toxins (and projects are subject to full environmental review and community input). Additionally, integrating DACR with projects like well capping or forest management yields immediate co-benefits: e.g., using DAC CO2 to plug orphaned oil wells can prevent methane leaks and groundwater contamination; using biomass (from wildfire fuel reduction) in biochar-DAC hybrids

can reduce wildfire risk. By messaging that "carbon removal = safer communities," states can win support even from those less concerned with abstract climate targets.

- Highlight State Pride and Leadership: Position the DACR initiative as a point of local pride and innovation. Just as states boast about leading in wind energy or tech startups, emphasize that this plan makes your state a climate leader and a pioneer of new technology. Officials can invoke historical analogies (e.g., the space race or the interstate highway build-out) and note that their state is "building the first carbon removal network in the world." Celebrating ribbon-cuttings with bipartisan leaders and even national figures can cement this narrative (recall that Speaker Nancy Pelosi and Governor Jared Polis jointly christened a Colorado DAC pilot, heralding it as a "defining moment" in the climate fight). Encourage competition: if Colorado deploys DACR, neighboring states won't want to be left behind in the new climate economy. Use branding like "Carbon Innovation Hub" or "Climate Tech Capital" for the state. This not only boosts political buy-in but also attracts investment (companies and research talent will gravitate to states seen as DACR-friendly). Also, tie it to local identity. For New Mexico, one might say, "From leading in energy in the 20th century, we'll lead in cleaning the air in the 21st." For Colorado, emphasize the innovative spirit of the Rockies and the duty to protect its famed environment. Pride and ownership turn DACR from an imposed environmental measure to a homegrown achievement.
- Ensure Transparency, Equity, and Community Benefits: Proactively address concerns by embedding community engagement and fairness in the messaging. Acknowledge upfront that DACR is not a silver bullet and must complement emissions reduction, not excuse polluters. Emphasize state policies (like California's AB1279) that require deep emissions cuts first, with removal as additional. This helps disarm critics who fear "distraction" from mitigation. Commit to inclusive decision-making: announce that site selection for DAC plants will involve local advisory panels and follow environmental

justice guidelines (mirroring New Jersey's approach to requiring community impact disclosures for new projects). Promise that benefits will flow to host communities. E.g., tax revenue from a DAC facility will fund local schools, or a portion of jobs will be targeted to residents, and training programs will be provided. should highlight plans for Community Benefit **Agreements** at DAC hub sites (as being developed in Pueblo, CO) and prioritize projects in economically distressed areas to spur revitalization. Messaging should also clarify safety: explain how captured CO2 is handled and stored securely (deep underground in rock formations, a natural process) to alleviate fears of leaks. The more open and inclusive the process, the more the public will trust this new infrastructure. When communities feel ownership and see direct benefits (jobs, investment, improved infrastructure) from DACR projects, opposition diminishes, and pride grows.

Connect to a Larger Climate Solution Narrative: Place DACR in the context of state climate goals and a livable future for the next generation. For instance, "Our state is committed to net-zero by 2050; we're already leading in renewables and efficiency, and now carbon removal is the next step to ensure we hit the mark and even go net-negative." Make it clear that experts (like the IPCC) say carbon removal is now unavoidable to stabilize the climate, and your state is embracing that challenge constructively. Use human stories: e.g., a young engineer working on a DAC plant who returned to their hometown for this job, or a farmer who partners with a DAC facility for enhanced soil carbon, showing how this technology benefits ordinary people. Similarly, education campaigns can demystify DAC: providing tours of facilities, school curriculum modules, and demonstrations (like "carbon captured from this air is now in this rock you can hold"). This builds public understanding that captures imagination. Compare DACR machines to "artificial trees" or "atmospheric clean-up crews," a positive vision rather than a dystopian one. By continuously reinforcing that DACR is part of a comprehensive climate action plan (alongside solar panels on roofs and EV buses on streets), the public will see it as a logical and necessary piece of the puzzle, not a techno-curiosity.

CONSTRUCTION AND BUILDING MATERIALS

Using R-CO₂ in construction is one of the most **promising and scalable** applications. The construction sector heavily uses concrete and cement, which have a large carbon footprint. Recovered CO₂ can be **mineralized** (converted into solid carbonates) and embedded into building materials, turning structures into long-term carbon stores.

- CO₂-Cured Concrete: Technologies like CarbonCure inject captured CO₂ into wet concrete during mixing or curing. The CO₂ reacts with calcium ions to form solid calcium carbonate (limestone) within the concrete. This mineral carbonation not only permanently sequesters CO₂ but also increases the compressive strength of concrete by 10–30%, allowing for reduced cement content. Millions of concrete blocks and slabs have been made this way, demonstrating feasibility at scale. By 2019, CarbonCure concrete had stored 50,000+ tons of CO₂ and reduced cement needs significantly.
- Carbonated Aggregates and Bricks: Captured CO₂ can be combined with industrial waste or minerals to make synthetic aggregates (gravel substitutes) and masonry products. For example, Blue Planet mixes CO₂ from power plant flue gas with calcium to form carbonate pebbles used as aggregate. These carbon-storing rocks were used in the concrete of San Francisco Airport's terminal. CarbiCrete in Canada uses steel slag (rich in calcium) instead of cement, and cures blocks with CO₂, binding the slag into a solid block. Each CarbiCrete masonry unit avoids cement emissions and injects 1 kg of CO₂ per block, achieving a carbon-negative product. These approaches tap abundant industrial by-products (steel slag, coal ash) and lock CO₂ into building materials for centuries.
- CO₂-Derived Cement Replacements: Beyond injection curing, researchers are making new cementitious materials using CO₂. For instance, captured CO₂ can react with alkaline industrial wastes (like slag or cement kiln dust) to create binding materials. Alissa Park's team demonstrated leaching calcium from steel slag and

combining it with CO₂ to produce a **white carbonate powder** usable as a filler in cement or even paper and plastic. Companies like **Solidia** have developed proprietary cement chemistries that cure with CO₂ instead of water, cutting emissions by 50–70% and trapping CO₂ in the concrete. These cement alternatives are being piloted in precast concrete manufacturing, offering durable products while drastically reducing net CO₂ emissions.

Impact: Construction uses of R-CO₂ are practical today. They require minimal new infrastructure, as they integrate into existing concrete plants or masonry production. By mineralizing CO₂ into concrete, carbon becomes a building ingredient rather than waste. This yields huge climate wins given the scale of global construction (30+ billion tons of concrete/year). Every ton of CO₂ used in concrete is permanently removed from the atmospheric cycle as a stable mineral. Additionally, CO₂-cured concretes often have better performance (strength, durability) and can reduce the need for other carbon-intensive components. Scaling these solutions (with supportive standards and procurement) could significantly cut the carbon footprint of new infrastructure while creating a large market pull for CO₂ capture.

Energy Storage and Synthetic Fuels

Recovered CO₂ is being used to store energy and create fuels, offering a path to recycle carbon into the energy system rather than extracting new fossil resources. Current technologies are proving that CO₂ can be a **circular feedstock** for fuels or even part of energy storage systems:

• Synthetic Liquid Fuels (Power-to-Fuels): Captured CO₂, combined with green hydrogen (H₂) from water electrolysis, can be converted into hydrocarbon fuels like methanol, methane, diesel, or aviation fuel. For example, Carbon Recycling International operates a plant in Iceland making renewable methanol from CO₂ and H₂. The CO₂ is sourced from a geothermal plant's emissions, and renewable power drives the conversion, yielding methanol with minimal net emissions. Similarly, companies like Audi/Sunfire in Germany produce synthetic methane (for the gas grid) using CO₂ from biogas and

renewable H₂. These fuels are drop-in replacements for gasoline, diesel, or natural gas, usable in existing engines and infrastructure. While the CO₂ is re-released when the fuel is burned, it is **cycling** CO₂ rather than adding new carbon to the atmosphere, effectively **carbon-neutral** if the process is powered by renewables.

- CO₂-Based Energy Storage (CO₂ Batteries): A novel approach uses the physical properties of CO₂ for energy storage. Italian startup Energy Dome has built a "CO₂ Battery," a system that stores energy by compressing CO₂ gas into a liquid and then generating power by evaporating and expanding it through a turbine. The CO₂ is recycled in a closed loop. This enables long-duration energy storage (8+ hours) for renewable energy, acting like a large rechargeable battery for the grid. The first commercial CO₂ battery facility (2.5 MW / 4 MWh scale) launched in 2022, proving the concept. These systems can help balance solar and wind power without relying on rare materials, and they use abundant CO₂ as the working fluid. Unlike chemical batteries, the storage capacity can be scaled up by using larger CO₂ tanks, potentially at a lower cost for large grid storage.
- Supercritical CO₂ Power Cycles: In advanced power generation, supercritical CO₂ (CO₂ under high pressure and temperature) can drive turbines more efficiently than steam. Demonstration turbines using supercritical CO₂ are achieving higher thermal efficiencies for converting heat to electricity. This means more power output for the same heat input. The Allam-Fetvedt Cycle is one such system: it burns natural gas with pure oxygen, uses supercritical CO₂ as the working fluid to spin a turbine, and inherently captures the CO₂ for reuse in a closed loop. While primarily a power generation technology, it showcases how CO₂ can replace water/steam in the power infrastructure, potentially making power plants more compact and efficient.

Impact: Using R-CO₂ for energy and fuels **closes the carbon loop** in the energy sector. Synthetic fuels from CO₂ can **decarbonize hard-to-electrify sectors** like aviation and heavy transport by supplying drop-in low-carbon fuels. Each liter of CO₂-based fuel displaces one that would

have come from oil, reducing net emissions, especially if the CO₂ is from air or biomass and the process is renewably powered. CO₂-based energy storage (like CO₂ batteries) and power cycles improve the integration of renewables by providing efficient storage and generation options, indirectly enabling greater renewable adoption and **fewer fossil backup plants**. Moreover, these uses create industrial demand for captured CO₂, which **improves the economics of capture technology** by turning CO₂ into a commodity. Policymakers see CO₂-derived fuels for aviation and freight as a key piece of meeting climate targets when direct electrification is infeasible.

Water Treatment and Environmental Uses

Recovered CO₂ also has practical applications in water infrastructure and environmental management. One important aspect is using CO₂'s mild acidity and reactivity in **water treatment processes**, providing a safer and often more cost-effective alternative to conventional chemicals.

- pH Control and Remineralization: Many water treatment plants inject CO2 gas to adjust pH levels instead of using strong acids like sulfuric or hydrochloric acid. When CO2 dissolves in water, it forms carbonic acid, which gently lowers pH. This is useful for neutralizing alkaline water or softening processes. For instance, in drinking water treatment, after softening (which can leave water very alkaline), adding CO2 helps recarbonate the water by forming bicarbonate/carbonate, stabilizing the pH and adding buffering capacity. It's also used in desalination posttreatment to remineralize RO (reverse osmosis) water, making it less corrosive by forming a bit of calcium carbonate for pipe protection. The benefits include safety and precision: CO2 is noncorrosive in storage and gives fine control, avoiding the handling of hazardous acids. Many facilities have adopted CO2 systems to protect equipment and improve operational safety while maintaining water quality.
- Wastewater Treatment & Carbonate Precipitation: In industrial wastewater, injecting CO₂ can precipitate certain contaminants. For example, adding CO₂ to alkaline effluents

containing calcium can cause **calcium carbonate** to form, which can co-precipitate heavy metals (removing them from the water). Researchers are exploring mineralization processes where CO₂ is used to trap toxic metals like lead or cadmium into insoluble carbonate minerals, effectively using CO₂ to clean water and sequester pollutants simultaneously. While this is an emerging field, it holds promise for industries like mining or power plants where **CO₂ from flue gas could be bubbled through waste streams** to both capture CO₂ and remove impurities.

- CO₂ for Algae and Biomass Growth: An environmental use of CO₂ is in algae cultivation systems, which can treat wastewater or produce biofuels. CO₂ from flue gas is **fed to algae in photobioreactors or ponds** to boost growth (since CO₂ is a nutrient). The algae, in turn, clean the water (removing nitrates and phosphates) and can be harvested for bio-products. This ties into using biological systems to utilize CO₂ while providing services like wastewater nutrient removal or generating biomass for bioenergy. Some wastewater treatment plants integrate algae for tertiary treatment and channel their biogenic CO₂ into it to maximize algae uptake.
- Greenhouse CO₂ Enrichment: In horticulture, captured CO₂ can be reused in greenhouses to stimulate plant growth. CO₂ enrichment is a well-established practice: maintaining levels around 800–1200 ppm in greenhouses can increase crop yields by 20–30% for many vegetables and flowers. Typically, growers use CO₂ from natural gas burners or compressed tanks; now some are sourcing recovered CO₂ (e.g., from nearby industries or biogas plants) as a greener supply. This is a direct use: instead of treating CO₂ as waste, it's utilized as a plant fertilizer gas. The impact is twofold: improved agricultural productivity and a use for CO₂ that displaces production of CO₂ from fossil fuels (some commercial CO₂ is produced by burning gas). It essentially recycles industrial CO₂ into the biosphere. Notably, the CO₂ in greenhouses is eventually taken up by plants and soils, partially locking it in plant biomass (at least until harvest).

Impact: These water and environmental uses show that even without complex chemical conversions, CO₂ can be directly applied in ways that benefit infrastructure and the environment. Using CO₂ for pH control has immediate safety and cost advantages for utilities (e.g., less chemical corrosion, easier handling). It also has a climate value when that CO₂ is captured from an emissions source. It is a transient storage, but every bit used is less CO₂ released. Moreover, integrating CO₂ into water and agricultural systems can improve resource efficiency. Policymakers can encourage municipal facilities to adopt CO₂-based processes, creating local markets for captured CO₂ (for example, a city water plant buying CO₂ from a carbon capture project at a nearby factory). Although each individual use might consume smaller quantities of CO₂ compared to concrete or fuels, the broad adoption across many water plants and farms could add up while demonstrating the value of CO₂ in daily utilities.

Consumer Goods and Industrial Products

Beyond heavy infrastructure, recovered CO₂ is finding its way into **consumer and industrial products**, replacing fossil carbon in supply chains. These uses drive home the concept of CO₂ as a **commodity for manufacturing**:

Polymers and Plastics: Several companies have commercialized processes to make plastic components from CO2. A prominent example is Covestro's CO₂-based polyols, where up to 20% of a polyurethane's weight comes from CO₂. Polyols (the soft segment in foam plastics) traditionally come from petroleum; Covestro's process, in use since 2016, reacts CO₂ with epoxides to create polyether carbonate polyols. These are used in making foam mattresses, cushions, and insulation. It is proven at an industrial scale: a production plant in Dormagen, Germany, produces thousands of tons per year. Another example is Econic Technologies, which developed catalysts to efficiently insert CO₂ into polyurethane production, replacing up to 50% of the conventional oil-based feedstock. The resulting foams and plastics (used in furniture, shoes, automotive parts, etc.) have a lower carbon footprint and often cost less because CO2 is a cheap raw material. Note: These polymers do not "store" CO2 indefinitely if incinerated at end-of-life, but they effectively utilize waste CO₂ and reduce fossil resource extraction in the near term.

- Chemicals and Fertilizers: The largest existing industrial use of CO₂ (outside of oil recovery) is to make urea, a common fertilizer. Roughly 130 million tons of CO₂ per year go into urea production worldwide. In this process, CO₂ from ammonia plants is combined with ammonia to produce urea. This is a long-standing practice while it doesn't permanently sequester CO₂ (urea releases CO₂ when decomposed in soil), it is a major economic use of captured CO₂ (typically CO₂ from natural gas processing or fermentation is used). Other chemical uses include manufacturing sodium carbonate (soda ash) via the Solvay process, and various inorganic carbonates/bicarbonates for industry. These are mature, feasible uses wherever a purified CO₂ stream is available.
- Carbonate Products (Baking Soda, etc.): A unique small-scale use comes from startups like Clean O2, which capture CO2 from building heating systems and turn it into potassium carbonate (potash) for making soaps and detergents. Their device (CarbINX) attaches to natural gas furnaces and produces a saleable carbonate that replaces mined potash in products. Each unit can capture a few tons of CO2 per year, demonstrating how micro-capture, combined with product-making, can engage even commercial buildings in carbon utilization.
- Carbon Black for Rubber: Carbon black (a powder used for tire reinforcement, inks, etc.) is usually made from fossil oil. New methods are turning CO₂ into solid carbon powders. For example, Monolith and others use methane pyrolysis to yield hydrogen and a solid carbon black; if the methane is from CO₂-derived methanation, indirectly, CO₂ ends up as carbon black. Also, LanzaTech's biological processes convert CO/CO₂ to chemicals that can replace petrochemicals in making rubber. While not yet widespread, a CO₂-sourced carbon black would be valuable to tire manufacturers seeking to reduce emissions, and recovered carbon black from waste tires (not directly CO₂-based, but recycling) is already gaining traction.

- CO₂ to Carbon Fiber and Materials: Cutting-edge projects are converting CO₂ into solid carbon structures. Researchers have developed catalysts and electrolysis systems to produce carbon nanofibers or carbon fiber precursors from CO₂. These solid carbons could be used in composites, batteries, or construction materials (like replacing steel rebar with carbon fiber rebar). One 2024 study demonstrated an electrochemical method to create carbon nanofibers from CO₂, even generating useful hydrogen as a byproduct. Though still emerging, it shows the potential to manufacture high-value carbon materials (for lightweight vehicles, wind turbine blades, etc.) directly from captured CO₂, which would be a truly transformative infrastructure material application.
- Consumer Products and Novelty Items: Several consumer brands now market goods made from captured carbon to raise awareness and create demand. Examples include: sunglasses made from CO2-derived polycarbonate, perfume and vodka made from CO₂-converted ethanol (e.g., Air Company's products), and lab-grown diamonds made from atmospheric CO₂. In the latter, companies like Aether extract CO₂ from air and convert it into methane feedstock, which is then used in diamondgrowing reactors to create gem-quality diamonds that are certified carbon-negative (20 tons CO₂ removed per carat, roughly), turning air pollution into high-end jewelry. While niche, these products are feasible with today's tech and serve to educate and stimulate luxury markets for carbon tech. Packaging is another area: Newlight Technologies uses captured methane/CO2 with microbes to produce a bioplastic called AirCarbon, which companies use for packaging and products (IKEA, Dell, and others have trialed it).

Impact: CO₂ in consumer and industrial products has a direct substitution effect. Every ton of carbon in products made from R-CO₂ is a ton not derived from petrochemicals. This supports a **circular carbon economy**, reducing dependence on new fossil carbon. The scale varies: fertilizers and chemicals already consume massive CO₂ volumes (hundreds of millions of tons), whereas newer polymers and products are scaling up. In policy terms, supporting CO₂-based manufacturing can spur innovation

and capture investment. It also **raises public acceptance**. When people wear, use, or benefit from CO₂-based items, the idea of carbon capture gains positivity. Importantly, durable products (like building materials, durable plastics, carbon fiber) keep CO₂ out of the air for years or decades, whereas fuels or short-lived products eventually release it. Policymakers can prioritize uses with **more extended carbon storage or clear climate benefits**. Nonetheless, all these uses drive technology improvement and market creation for captured CO₂. In the long run, widespread CO₂ utilization in materials could make capturing carbon economically self-sustaining, turning **waste into profit** while mitigating emissions.

Appendix VII: Sample Rollout Strategy for Colorado and New Mexico

To illustrate how the OCR can be tailored, consider **two states**, Colorado and New Mexico, as examples. Both are in the interior West but have different industry landscapes. Colorado has a head start on policy and a diverse green economy, while New Mexico has vast geological resources and an oil/gas legacy. The rollout in each state leverages local strengths:

Colorado: From Climate Leader to Carbon Removal Leader

- Policy Foundation and Targets: Colorado has established itself as a climate-progressive state with legal mandates for carbon management. In 2023, the state enacted the Carbon Management Act (HB 23-1210), tasking the Energy Office to develop a carbon removal roadmap and explore technologies like DAC, carbon utilization, and sequestration. This law, championed as both a climate and jobs bill, explicitly aimed to "facilitate the scale-up of carbon management" to meet net-zero by 2050 while creating quality jobs. The resulting Colorado Carbon Management Roadmap (2025) identified key opportunities in sectors such as construction materials, manufacturing, and natural lands for carbon removal. With this policy support, Colorado's rollout plan sets incremental targets: e.g., 50,000 tCO₂/yr by 2028 (pilot hubs), 300,000 by 2030, 1 Mt by 2040 in line with the OCR tiers.
- Early Projects (2025–2030): The first step is demonstrating DACR at a meaningful scale in-state. In 2023, Colorado-based company Global Thermostat unveiled a pilot DAC plant in Brighton, CO (near Denver) that captures 1,000 tCO₂/yr. State leaders, including the Governor and federal representatives, attended its launch, signaling political buy-in. This pilot will be

followed by a larger Colorado DAC Hub project: with \$3 million DOE funding, Carbon America and partners are studying a DAC hub near Pueblo, CO, aiming for 50,000 t/yr removal integrated with local geologic storage in the Denver-Julesburg Basin. The vision is to pair a DAC facility with an identified deep saline aquifer or depleted oil formations in Pueblo County for permanent CO₂ storage. By 2026–2027, Colorado could break ground on this DAC hub (perhaps using technology from Sustaera and GE as planned). Importantly, these projects are engaging the community early: the Pueblo DAC hub team is developing a Community Benefits Plan and doing consent-based siting outreach, which helps alleviate local concern and ensures jobs and benefits for residents. Alongside Pueblo, the state will likely see a DAC project in the north: possibly Wyoming-Colorado joint efforts (Colorado has joined a coalition with Wyoming to pursue carbon removal initiatives, leveraging Wyoming's storage sites). By 2030, Colorado aims to have at least one DAC hub operational (removing on the order of 0.1–0.3 Mt/yr) and several smaller pilot projects (including, for example, a Boulder County communityscale CDR project that might combine forest biomass carbon removal with DAC to reduce wildfire fuels).

Integration into Infrastructure: Colorado will integrate DACR across various public works to normalize the technology. The state's Department of Transportation can start specifying lowcarbon concrete (with CO₂ mineralization) for highway projects - Colorado is already a leader in green construction policies. As part of the rollout, a goal is set that by 2030, all state-funded building projects must consider carbon-infused materials. For instance, if CDOT rehabilitates I-70 or builds new bridges, they could use concrete from plants using CarbonCure or similar tech, thereby storing CO₂ and boosting local demand for captured CO₂. Furthermore, Colorado could pilot DAC units at public facilities: one idea is installing a small DAC system at the Colorado State Capitol or a major university as a demonstration. This would pull a token amount of CO2 (say, a few tons a year) but serve educational and symbolic purposes – a constant reminder of climate action in progress. Another integration is with the power

sector: as Colorado retires its last coal plants (like the Comanche station in Pueblo by 2030), those sites, with grid connections and workforces, can be repurposed for **DACR plants powered by renewable energy**. Xcel Energy and other utilities can be partners, incorporating DACR into their clean energy plans (perhaps counting removals toward corporate net-zero goals). By 2035, Colorado's aim is that every major infrastructure investment (roads, water projects, new state buildings) includes a **climate resilience component** and a **carbon removal component**, whether it's materials or co-located DAC.

Local Industry Synergies: Colorado's rich ecosystem of industries and research institutions will be harnessed. The state is home to national labs (NREL, NOAA) and universities that are advancing carbon capture technologies, e.g., Colorado State University launched carbon management education programs to supply skilled workers. Those graduates can feed the growing DAC industry. The oil and gas sector on the West Slope and Weld County can pivot to carbon storage services: drilling companies and geologists who once extracted oil can now drill CO2 injection wells and monitor storage sites. This leverages their expertise and provides continued employment as fossil fuel production declines. Additionally, firms like Kiewit and engineering companies in Colorado are already engaged in DAC projects (Kiewit is part of the Pueblo DAC hub team); they will benefit from contracts to design and build facilities, creating a local supply chain. Colorado also has a burgeoning clean tech startup scene. The plan will provide grants or green bank loans to startups working on direct air capture innovations (e.g., novel sorbents or modular DAC devices). The state's brewing and beverage industries, which use CO₂, could agree to purchase a fraction of their CO₂ from direct air capture instead of byproduct sources, as a marketing and supply-chain innovation. Furthermore, Colorado's cement and concrete industry (e.g., GCC's large cement plant in Florence, CO) can partner to utilize CO₂ from DAC to cure cement or make carbonate aggregates, turning a high-emission industry into a mitigator. These synergies demonstrate how DACR becomes embedded in Colorado's economic fabric, not a standalone

novelty, but part of multiple value chains (energy, materials, tech, workforce development).

Public Engagement and Support: Colorado's rollout emphasizes transparency and community benefit, learning from its robust stakeholder process for the Carbon Roadmap. Each project includes outreach. For example, the Pueblo DAC hub team has already involved local officials and will continue to hold community meetings as design progresses. On the state level, officials will continuously message the co-benefits: the jobs (reminding that potentially 85k jobs by 2050 are at stake), the risk reduction (e.g. "this year's wildfires underscore why we need to both cut emissions and remove carbon. DAC is part of protecting our forests and ski industry"), and economic opportunities (attracting federal \$\$ and being the "Silicon Valley of Carbon Removal"). Bipartisan support is cultivated by involving diverse leaders. The roadmap effort already saw involvement from both Republican and Democratic sponsors. Colorado can point to tangible early successes by 2028: a Pueblo DAC plant providing union construction jobs, a Boulder carbon removal project reducing wildfire debris, and students getting trained in DAC operations at CSU. These stories will be shared widely to maintain momentum. By the late 2030s, Colorado should reach the 1 Mt/yr removal mark through a combination of perhaps 2-3 large DAC hubs (Plains, West Slope, maybe Four Corners region) and dozens of smaller integrated DAC units statewide. At that point, DACR is simply part of Colorado's public infrastructure toolkit, much as wind farms or water treatment plants are, and enjoys broad public acceptance as a source of state pride ("built by Colorado for Colorado").

New Mexico: Transitioning Oil and Gas Expertise into Carbon Removal

• Policy Foundation and Context: New Mexico has aggressive climate ambitions (targeting net-zero emissions by 2050 via executive order) but also a strong oil & gas sector that is the

backbone of its economy. The OCR rollout in New Mexico is designed to bridge these two worlds. The state's leaders are framing carbon management as an economic diversification and environmental necessity. U.S. Senator Martin Heinrich of New Mexico has been a vocal champion of direct air capture and carbon storage, emphasizing that New Mexico's innovation and workforce make it a key player in large-scale carbon removal. While NM does not yet have a dedicated carbon removal law like Colorado, it has participated in regional initiatives. For example, New Mexico Tech and state agencies are partners in a Southwest DAC Hub planning effort led by Arizona State University. In 2025, that consortium received \$11.2 M from DOE to design a DAC hub in the Four Corners area (northwestern NM). This gives New Mexico a head start on planning infrastructure. The OCR sets goals for NM to reach 100,000 t/yr removal by 2030 (with the help of that regional hub) and 1 Mt/yr by 2040, aligning with the national push for hubs in multiple regions.

Early Projects (2025–2030): New Mexico's first tangible DACR project is already underway: Spiritus, a climate-tech startup, is launching a pilot DAC plant on the Nambé Pueblo tribal land near Los Alamos, expected to be operational in 2025. Although small (1,000 t/yr initially), this project is significant. It demonstrates DAC in NM's climate (high desert conditions) and forges a partnership with an indigenous community. The Nambé Pueblo provided the site and infrastructure upgrades, and Spiritus is bringing high-skill jobs to the area. This pilot ("Orchard" concept) will inform larger "megaton-scale Carbon Orchards" planned by Spiritus in the future. The state will support such pilots through grants or tax incentives, seeing them as seeding a new industry. By the late 2020s, the biggest leap will be establishing a **DAC** hub in the Four Corners region of NW New Mexico. This area (San Juan County) has seen coal plant closures (the San Juan Generating Station closed in 2022), leading to job losses. The DAC hub design led by ASU envisions multi-site DAC facilities in east-central AZ, NW NM, and SE Utah with dedicated CO2 storage sites. For New Mexico, one site identified is in NW NM, likely leveraging the geology of the San Juan Basin for CO2

storage. The plan is to use new solar and wind farms to power the DAC (since the region's coal plants are retiring, making grid capacity available). By 2030, this Four Corners DAC hub could be removing on the order of 0.5 MtCO₂/yr (across all sites) if fully realized, with perhaps 0.1-0.2 Mt of that in New Mexico. In parallel, in the southeast NM (Permian Basin), closer to the oilfields, there is potential for another DAC project. Occidental Petroleum's subsidiary 1PointFive is constructing the world's largest DAC plant (1 Mt/yr) just over the border in Texas, and Oxy has long-term plans for dozens of DAC plants in the Permian Basin region. New Mexico will coordinate with these efforts, possibly hosting a second large DAC plant on the NM side of the Permian. For example, near Hobbs or Carlsbad, NM, a DAC facility could be built by industry (taking advantage of NM's Class VI injection well regulatory framework for CO2 storage). Early utilization of CO2 from this plant might be for enhanced oil recovery (EOR) in depleted fields, a controversial but revenuegenerating use that New Mexico might permit as a transitional step to help finance the project (with strict accounting to ensure net CO₂ removal). By 2030, New Mexico should aim to have at least two operational DAC projects: one in the northwest (linked with renewable energy and storage, possibly partially funded by DOE) and one in the southeast (industry-led, linking to oil/gas infrastructure). Combined, these might capture a few hundred thousand tons per year.

• Integration into Infrastructure: New Mexico's approach is to weave DACR into its core infrastructure sectors: energy, environment, and even water. For instance, the state can integrate DACR with its abandoned oil well remediation program. New Mexico has many orphaned oil and gas wells; as they plug these wells (often with federal funds), they could concurrently use those sites for small-scale DAC units that use the well for CO₂ injection (turning a former pollution source into a storage asset). In agricultural infrastructure, New Mexico's traditional acequias (irrigation canals) and water systems could benefit from CO₂-cured concrete linings or pipes, improving durability while storing carbon. When the state invests in modernizing water infrastructure

(a big need due to drought), specifying CO₂-sequestered concrete would be a simple integration. **State buildings and schools** in New Mexico, especially in cities like Albuquerque and Santa Fe, could be built with carbon-storing materials (there's growing local interest in sustainable building).

- The state can partner with startups (perhaps via Los Alamos or Sandia labs), developing alternative cements (like calcium carbonate cement) using CO2. Deployment of DACR in remote areas could also support infrastructure. For example, direct air capture units co-located with solar farms in the sunny southern part of the state can act as a flexible load on the grid, soaking up excess solar power at midday to capture CO2. This helps stabilize the grid as more renewables come online, essentially making DAC a piece of energy infrastructure as well. In terms of resilience, New Mexico faces extreme heat and wildfire risk; the state might pilot using captured CO2 to create fire-retardant materials or soil amendments that improve land resilience. One concept: mixing CO₂-derived bicarbonates into soil to help it retain moisture could be tested on state lands. In summary, New Mexico will integrate DACR in projects where it complements existing goals: cleaning up old oil sites, expanding renewable energy, and building resilient infrastructure for water and land management.
- Local Industry Synergies: New Mexico's greatest asset is its energy industry and geology. The state will tap the expertise of oil, gas, and mining companies to pivot into carbon management. Oilfield service companies in the Permian (many with offices in NM) can get contracts to drill CO₂ injection wells and maintain CO₂ pipelines. Their know-how in handling gases and pressures is directly applicable, turning a potential workforce liability into a DACR workforce. There is also the benefit of existing CO₂ pipelines in the region. For decades, CO₂ from natural reservoirs in Colorado has been piped to Permian oilfields for EOR; these pipelines (and associated rights-of-way) could be repurposed in the future to transport captured CO₂ to secure storage in NM's portion of the Permian Basin. The state's two national labs (Los Alamos and Sandia) and research university (New Mexico Tech)

are heavily involved in energy innovation; they are already partners in DAC projects and conduct CO2 storage research. The rollout will strengthen these R&D ties with funding for pilot projects and testing facilities (e.g., a field station in NM Tech's Petroleum Recovery Research Center to test new DAC sorbents under real conditions). Mining and minerals industry: New Mexico has mining operations (copper, potash). Mine tailings and minerals could be used to react with CO₂ (mineral carbonation), providing another removal pathway. One could imagine a mine in Grant County becoming a CO₂ "sink" by naturally binding CO₂ in crushed rock. If that process is enhanced by DAC (capturing CO₂ and feeding it to the mine waste), it is a synergy between mining and carbon removal. The construction sector in NM, though smaller, can benefit by producing carbon-neutral building blocks for export (a company in NM could produce CO2-cured concrete blocks to sell across the Southwest). Another synergy: the burgeoning hydrogen and CCUS projects. New Mexico has an interest in hydrogen fuel (with carbon capture); if blue hydrogen plants get built, they will have a CO₂ byproduct. Pairing them with DAC can create a hub where all CO₂ (from air and from hydrogen production) is jointly stored, achieving negative emissions overall. This sort of clustering (hydrogen + DAC + storage) in places like the San Juan Basin could attract federal hydrogen hub funding and multiply the impact. Essentially, NM will repurpose its skill in extracting energy to excel in injecting and storing carbon, turning an extraction economy into an injection economy. Local businesses will see new markets: engineering firms will design CO₂ wells, universities will train "carbon technicians," and even the tourism sector could benefit (imagine visitors touring a cutting-edge DAC plant in the desert as an educational attraction).

• Community Engagement and Equity: New Mexico's rollout is very attuned to the needs of frontline and indigenous communities. The Spiritus pilot set a positive example by partnering with Nambé Pueblo and aligning with the pueblo's environmental stewardship values. Building on that, the state will ensure tribes and local communities have opportunities in the DACR expansion. For instance, involving the Navajo Nation

(which spans NW NM) in the Four Corners DAC hub planning. Many coal workers from the Navajo power plant could be retrained for jobs at the DAC facilities planned in that region. The state can negotiate benefits like a share of revenues or energy improvements for those communities. Public outreach will also address the question, "Why invest in carbon removal when we have other needs?" by highlighting co-benefits: new revenue for local governments (DAC projects will pay property/production taxes or equivalent, which can fund schools in e.g. San Juan County, offsetting lost coal revenue), and environmental cobenefits (remediation of legacy pollution: for example, if DAC projects help plug wells or clean up brine, communities get a cleaner environment). Messaging will be culturally sensitive, using metaphors like "Earth healing technologies," which might resonate in communities that value environmental restoration. And just as Colorado did, New Mexico will uphold that DACR complements emissions reduction, not replaces it, to maintain credibility with environmental groups. When Senator Heinrich lauds the Spiritus project as bringing high-skill jobs and positioning NM as a leader, it encapsulates what the state wants every community to feel: that DACR is bringing *opportunity*, not burden. As projects come online, the state will monitor impacts closely (via an environmental justice lens) and adjust course if, say, a project uses too much water in a dry area. Technological tweaks (like using dry cooling for DAC units, or siting DAC near brackish water sources) will be employed to avoid local resource strain. By 2040, New Mexico's target of 1 MtCO₂/yr removed will likely be met through a combination of one large hub in the northwest, one in the southeast, and scattered smaller projects, and the success will be measured not just in tons, but in how well those projects uplift local economies and align with New Mexico's dual identity as an energy producer and a land of natural beauty.

Conclusion: The examples of Colorado and New Mexico show how different states can customize the OCR while following the same overall roadmap of targets, integration, funding, and outreach. Colorado leveraged policy mandates, tech industries, and green talent; New Mexico leveraged geology, energy know-how, and federal partnerships. Both

focused on co-benefits: jobs, resilience, and pride. The State Office of Carbon Recovery transforms direct air capture from a nascent tech into a practical infrastructure pillar. By 2040, through steady scaling, smart use of public funds, and community-centric deployment, DACR can realistically evolve into a **nationwide public service**: cleaning our atmosphere much like waste management services clean our cities – helping states achieve climate goals and fostering a new era of sustainable industry in the process. The OCR offers a **credible**, **actionable blueprint** for states to begin this transformation now, proving that carbon removal can move from speculation to implementation on a timeline that our climate demands