CARBON FINANCE LABS

The Removals Ramp

A global framework for scaling carbon removal capacity to net zero

How the world can build 3 GT/yr of carbon dioxide removal capacity by 2040 through a structured, accountable, and market-driven ramp — and why it must start now.

Working Paper — February 2026

Prepared for structured debate among global climate stakeholders

This paper does not prescribe a solution. It frames the decision levers and constraints for a Removals Ramp — the shape of the curve, the terminal target, the mix of methods, and the assignment of accountability — so that policymakers can debate from a common analytical foundation.

Executive Summary

The climate system needs a plan for carbon removal. It does not have one.

The Intergovernmental Panel on Climate Change requires net-zero emissions by mid-century to hold warming below 1.5°C. That target has two components: cutting emissions and removing residual carbon dioxide from the atmosphere. The world has spent three decades building (imperfect) frameworks for the first. For the second, there is no binding target, no assigned owner, and no enforceable deadline.

This paper proposes a **Removals Ramp** (RemRamp): a logistic S-curve framework that sets annual targets for installed carbon removal capacity, reaching at least 3 GT/yr by 2040. The framework links accountability to Nationally Determined Contributions, creates tradeable instruments (RemITMOs) for cross-border finance under Article 6 of the Paris Agreement, and builds excess capacity as insurance against the near-certain shortfall in emission reductions.

The argument rests on four pillars. First, the mechanism works: the logistic curve front-loads capacity deployment, maximising cumulative removals at 24 GT over the period while managing technology risk through early learning. Second, the economics are viable: nature-based removal costs rise with scarcity while technical costs fall with scale, and compliance mandates create the forward demand signals that crowd in private capital. Third, the risk of inaction is catastrophic: the build required is equivalent to 200 Three Gorges Dams in capital intensity, and delay only steepens the ramp. Fourth, governance structures exist but need adaptation: Article 6 provides the legal scaffold, and four allocation frameworks — current emissions, historical, GDP-weighted, and polluter-pays — offer politically feasible options for distributing the burden.

The paper is not a prescription. It is a structured framework for debate, organised around the decision levers (curve shape, terminal capacity, method mix, accountability assignment) and constraints (timeliness, cost, deployment capacity, biodiversity, NDC uncertainty) that any serious removals policy must address.

The RemRamp decision dashboard

Six parameters that define the framework

Target capacity	Ramp shape	Cumulative removals
3 GT/yr	**Logistic**	**24 GT**
by 2040	S-curve	2025–2040

Unit cost range	Coverage ratio	Accountability
$100–200	**1.5×**	**NDC-linked**
per tonne CO_2	NDC shortfall buffer	national obligations

Source: Carbon Finance Labs RemRamp framework specification

Figure 0. The RemRamp in six numbers: the framework's core parameters.

I. The Problem: Climate Goals Without a Plan

Every achievable goal requires three things: a clear target with a failure metric, accountability assigned to a single entity, and a binding deadline. The global net-zero emissions objective satisfies none of these conditions.

The Paris Agreement's architecture distributes responsibility across 195 signatories through Nationally Determined Contributions. In principle, this is a framework for collective action. In practice, it is a framework for collective ambiguity. Of those 195 signatories, only 72 have submitted long-term strategies to achieve a low-carbon economy by 2050. Of those 72, just 26 include any estimate of future residual emissions. None has an enforceable target for carbon removal capacity.

Figure 1. The governing equation: net zero requires both reductions and removals. Only the reduction side has a (weak) plan.

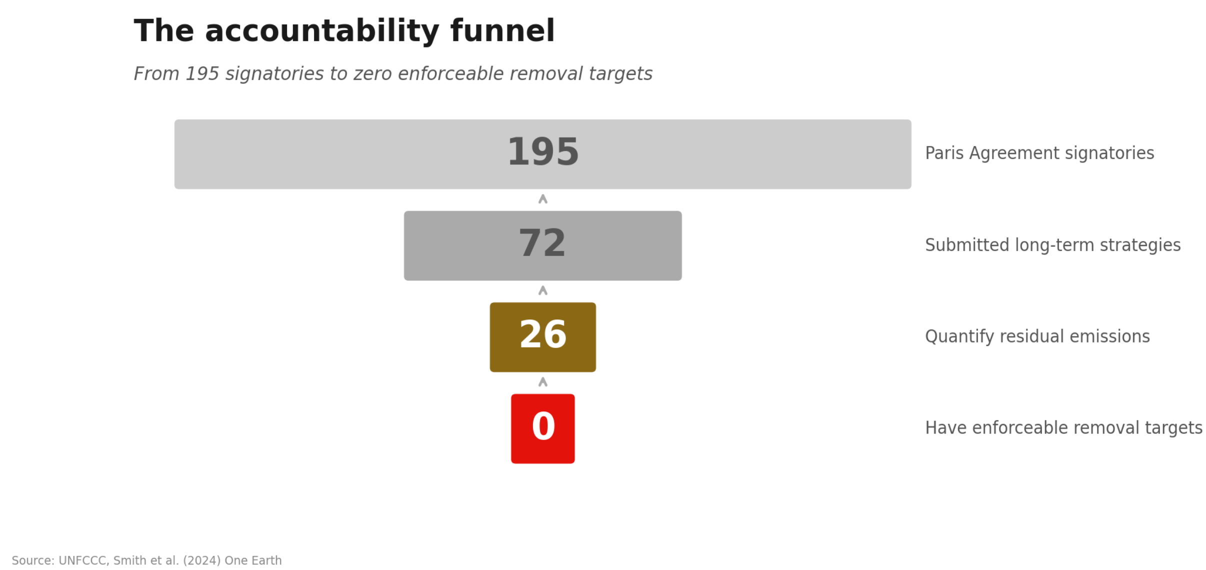

Figure 2. The accountability funnel: from 195 Paris signatories to zero enforceable removal targets.

The phrase heard most often in policy halls — “we should really do something” — is the sound of a goal with no owner. Aggregate NDCs are too remote, underreported, and consistently beneath the commitments required to limit warming to 1.5°C. Failure is not a risk to be managed; under current arrangements, it is the baseline expectation.

The consequences of this structural deficit are not abstract. The World Bank projects 216 million internal climate migrants by 2050. Extreme weather events are intensifying. The carbon budget for 1.5°C is nearly exhausted. And yet the removal capacity that might compensate for inevitable shortfalls in emission reductions stands at approximately 2 MT/yr — less than 0.1% of what is needed.

II. The Proposal: A Global Removals Ramp

A Removals Ramp (RemRamp) is a goal framework to annually increase the capacity and amount of carbon dioxide removed from the atmosphere. It sets annual milestones for two metrics: **installed capacity** (the annual volume of CO_2e that can be removed, measured in GT/yr) and **cumulative removals** (the total CO_2e removed over time). This dual-metric approach ensures both incremental progress and cumulative impact.

How the ramp works

The RemRamp follows a logistic (S-curve) trajectory. It begins with a period of foundation-building — relatively modest capacity additions as technologies are proven and supply chains established. It then accelerates through a steep middle phase as proven methods scale rapidly. Finally, it levels off as capacity approaches the terminal target.

Under the proposed parameters, installed capacity rises from approximately 25 MT/yr in 2025 to roughly 3,000 MT/yr (3 GT/yr) by 2040, with cumulative removals of approximately 24 GT over the period.

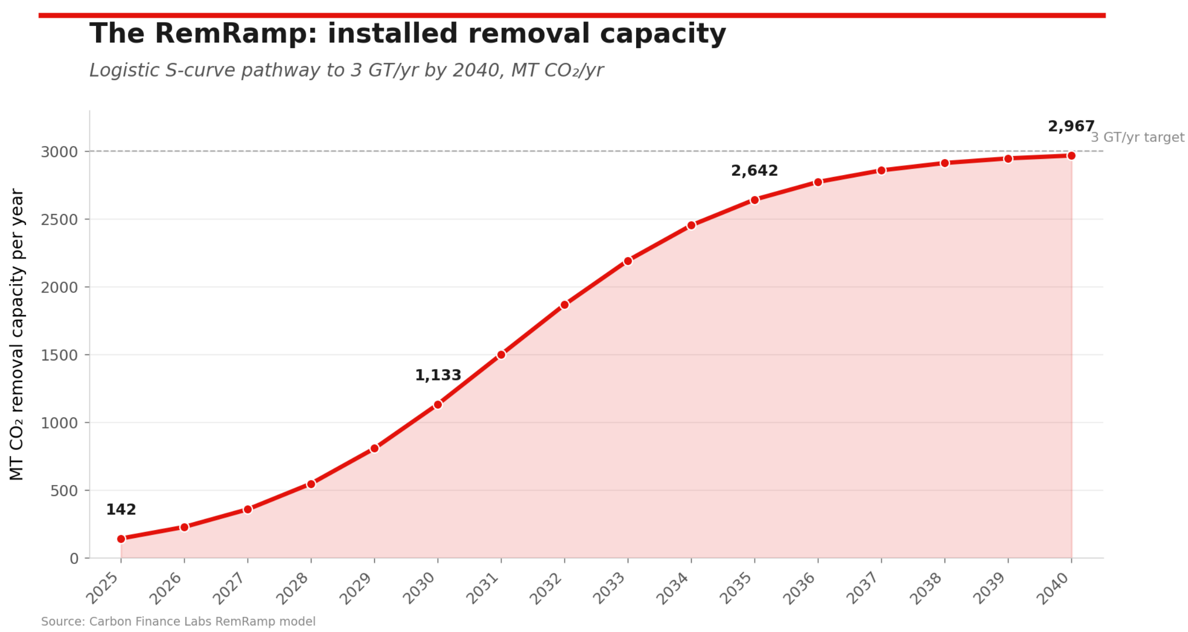

Figure 3. The RemRamp: installed removal capacity following a logistic S-curve, 2025–2040.

Why the S-curve beats the alternatives

Three growth models can reach the same terminal capacity of 3 GT/yr by 2040. Their cumulative impact differs dramatically. A linear ramp delivers 24.2 GT of cumulative removals but imposes unrealistic front-end costs. An exponential curve delivers only 10.9 GT — barely half — because it back-loads capacity to the final years. The logistic curve delivers 24.0 GT while matching deployment to realistic technology maturation timelines.

The logistic curve also offers three strategic advantages. It front-loads capacity relative to exponential growth, providing a buffer against NDC shortfalls. It accelerates innovation through early deployment, driving cost reductions via learning-by-doing. And it identifies technology risks early, when there is still time to adapt, rather than closer to the net-zero deadline when the consequences of failure are irreversible.

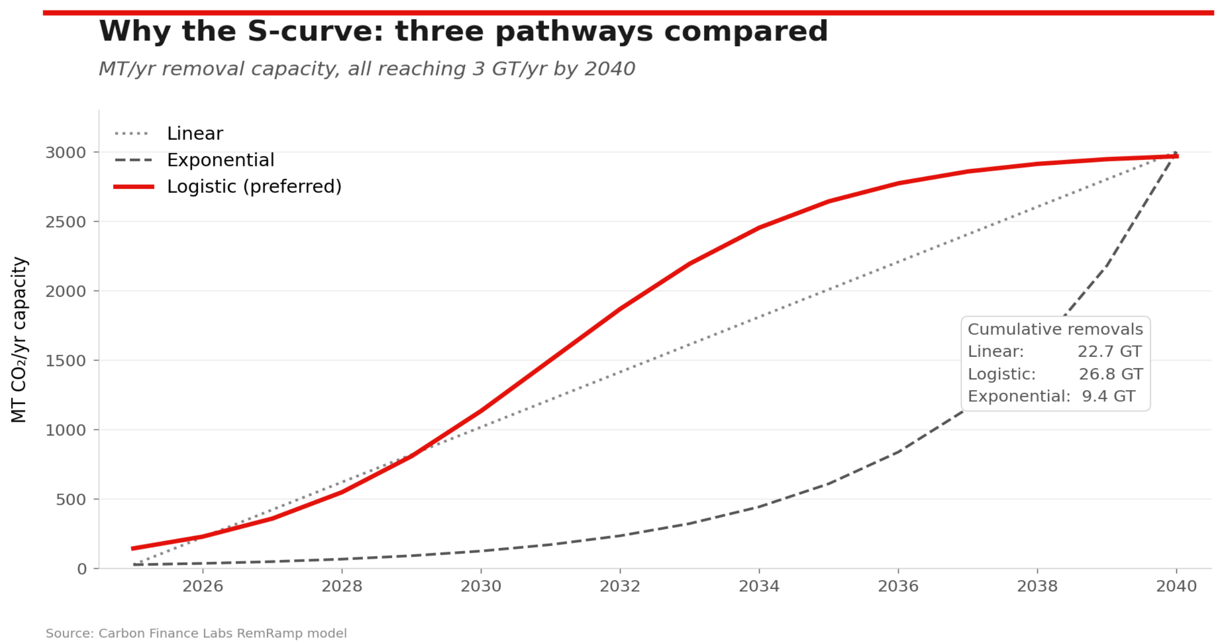

Figure 4. Three growth pathways compared: all reach 3 GT/yr by 2040, but cumulative removals differ by more than 2×.

III. The Risk Calculus: NDC Shortfalls and Spare Capacity

Achieving net zero by mid-century requires reducing global emissions from approximately 35.5 GT CO_2/yr (2024 baseline, per the IEA Stated Policies Scenario) to 8.5 GT CO_2/yr by 2040 under the IPCC's P1 pathway. That is a reduction of 27 GT/yr — a 76% cut in sixteen years.

The record to date offers little confidence that reductions of this magnitude will materialise on schedule. Current NDCs are insufficient to meet the 1.5°C target, with a projected emissions gap of 28 GT CO_2e by 2030. Delayed policy implementation, economic disruptions, political instability, and underestimation of actual emissions all point in the same direction: shortfall.

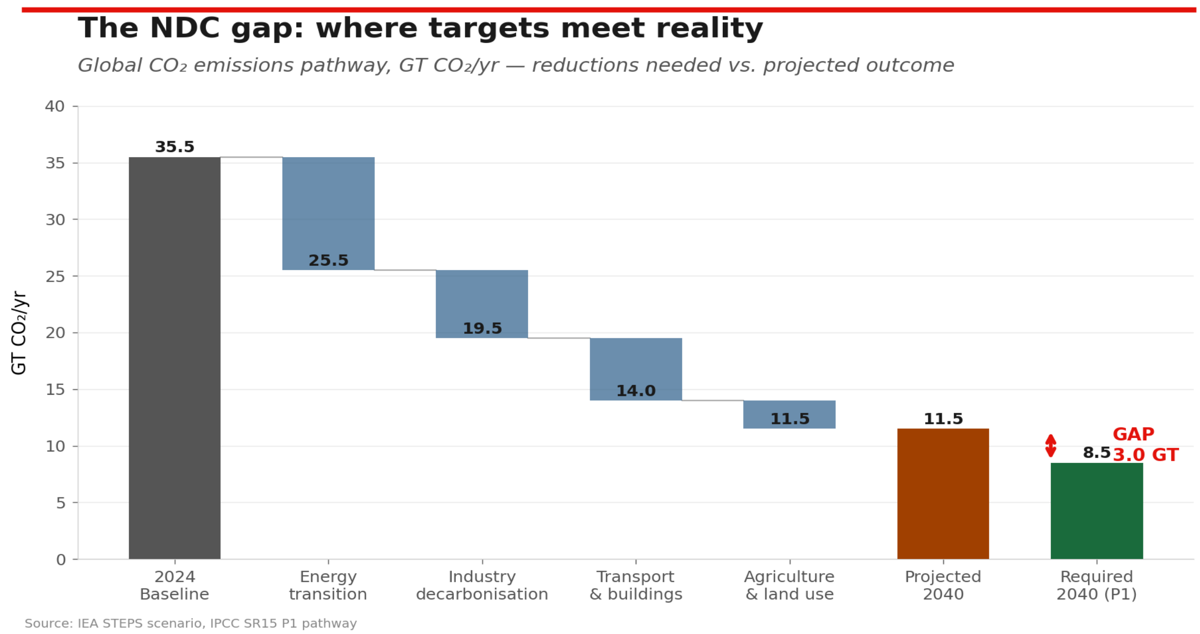

Figure 5. The NDC gap: from 35.5 GT today to a required 8.5 GT — a 76% reduction in sixteen years.

The sensitivity problem

Carbon removals are a small share of the net reductions needed. This makes the required removal capacity highly sensitive to any shortfall in emission reductions. The arithmetic is unforgiving: if reductions underperform by 20%, an additional 5.4 GT/yr of removal capacity is needed on top of the baseline 3 GT/yr. At a 30% shortfall, the total approaches 11 GT/yr — nearly four times the baseline.

The implication is clear. Building only to the baseline target of 3 GT/yr is prudent only if one is confident that 195 countries will deliver unprecedented emission cuts on schedule. To have a 95% probability of achieving the net-zero target, removal capacity should be built to at least 50% above projected requirements. Excess capacity is not waste; it is insurance.

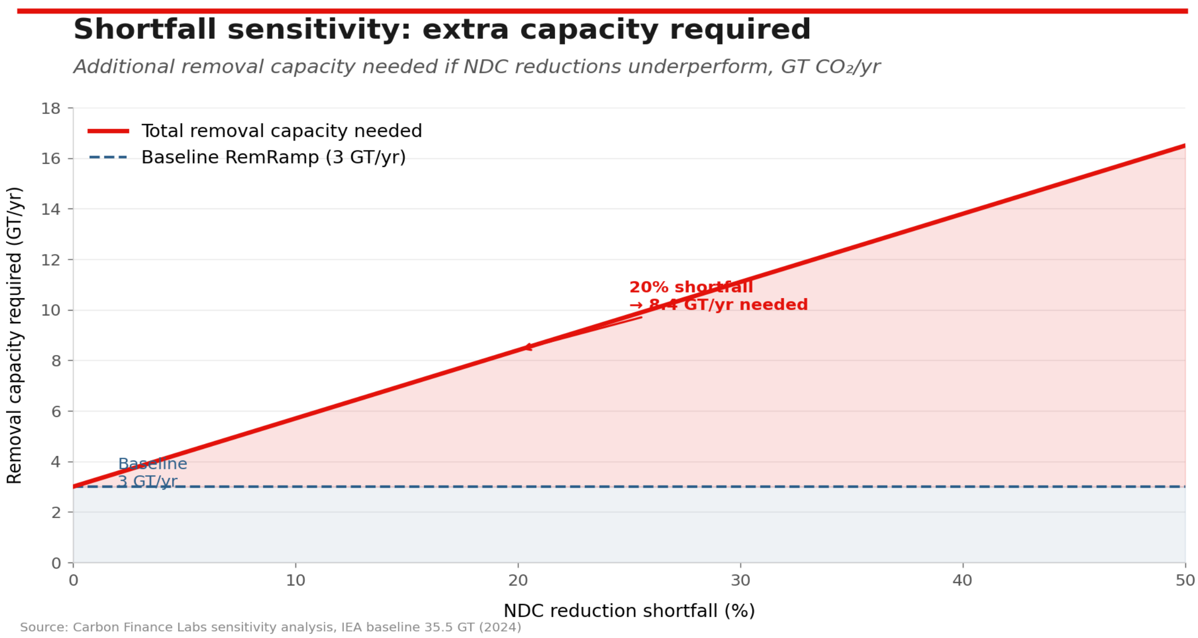

Figure 6. Shortfall sensitivity: a 20% miss on reductions requires disproportionate removal capacity.

IV. The Scale of the Build

The infrastructure required for the RemRamp has no modern precedent. To grasp the magnitude, consider the Three Gorges Dam — one of the largest infrastructure projects in history. It cost approximately $25 billion, took 18 years from construction start to full operational capacity, and was built by the most centralised and fastest infrastructure-deploying government on earth.

At a capital cost of roughly $1,000 per tonne/yr of built capacity (assuming $200/tonne removal costs amortised over 15 years), achieving 5 GT/yr of removal capacity requires approximately $5 trillion in cumulative capital expenditure. That is the equivalent of 200 Three Gorges Dams — built in 26 years, using technologies that in many cases do not yet exist at commercial scale.

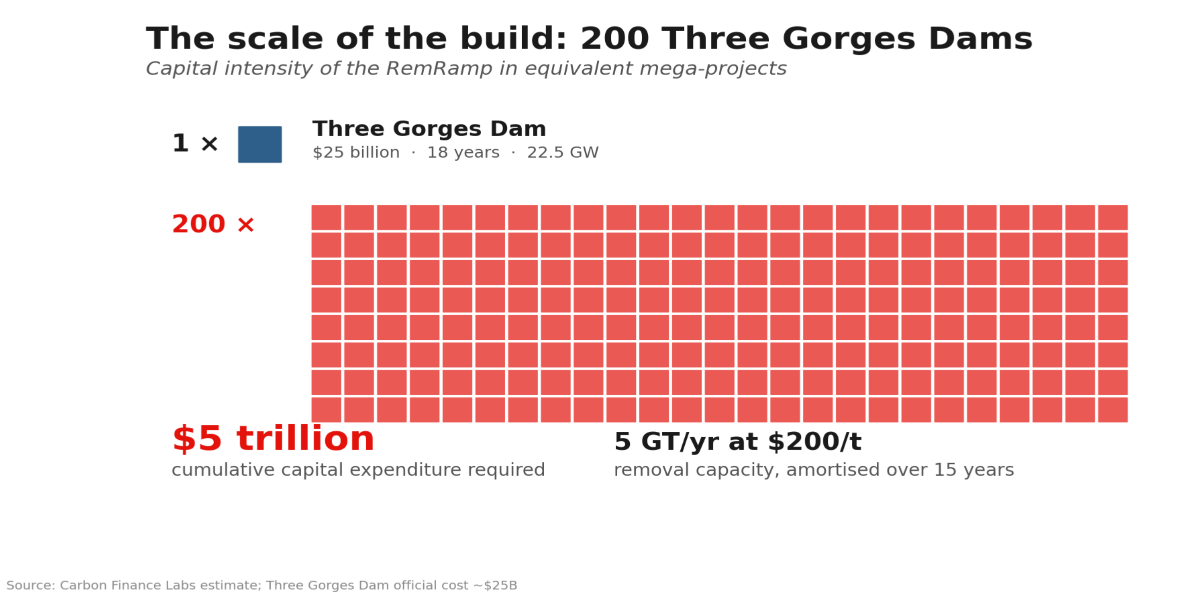

Figure 7. The scale of the build: 200 Three Gorges Dams in capital intensity, using unproven technologies.

This comparison is not intended to induce despair. It is intended to induce urgency. The best time to begin deploying the RemRamp was twenty years ago. The second-best time is now. Every year of delay steepens the required ramp, increases the cost, and reduces the margin for error.

The logistic curve is designed precisely for this challenge. By front-loading capacity additions, it buys time for technology maturation, supply chain development, and the iterative learning that has driven cost reductions in every major infrastructure deployment from solar panels to semiconductors.

V. The Economics: Two Curves, One Transition

The carbon removal landscape is governed by two economic forces pulling in opposite directions. Understanding their interaction is essential to designing policy that works at gigatonne scale.

Nature-based solutions: cheap today, expensive at scale

Afforestation, soil carbon sequestration, and other nature-based solutions offer the lowest costs per tonne today. But they are constrained by a finite resource: land. As the most accessible and affordable sites are exhausted, marginal costs rise. The result is a classic Marginal Abatement Cost curve — one that slopes upward with scale. Nature-based solutions also face risks from climate variability (wildfires, droughts), long payback periods, and biodiversity trade-offs that are rarely priced into cost estimates.

Technical removals: expensive today, cheap at scale

Direct air capture, BECCS, enhanced weathering, and similar technical solutions start at significantly higher costs — current DAC costs are in the range of $400–600 per tonne. But they follow learning curves, not scarcity curves. Wright's Law, validated across hundreds of industries over seven decades, predicts that costs fall 10–30% with every doubling of cumulative deployment. The trajectory is from abundance, not scarcity.

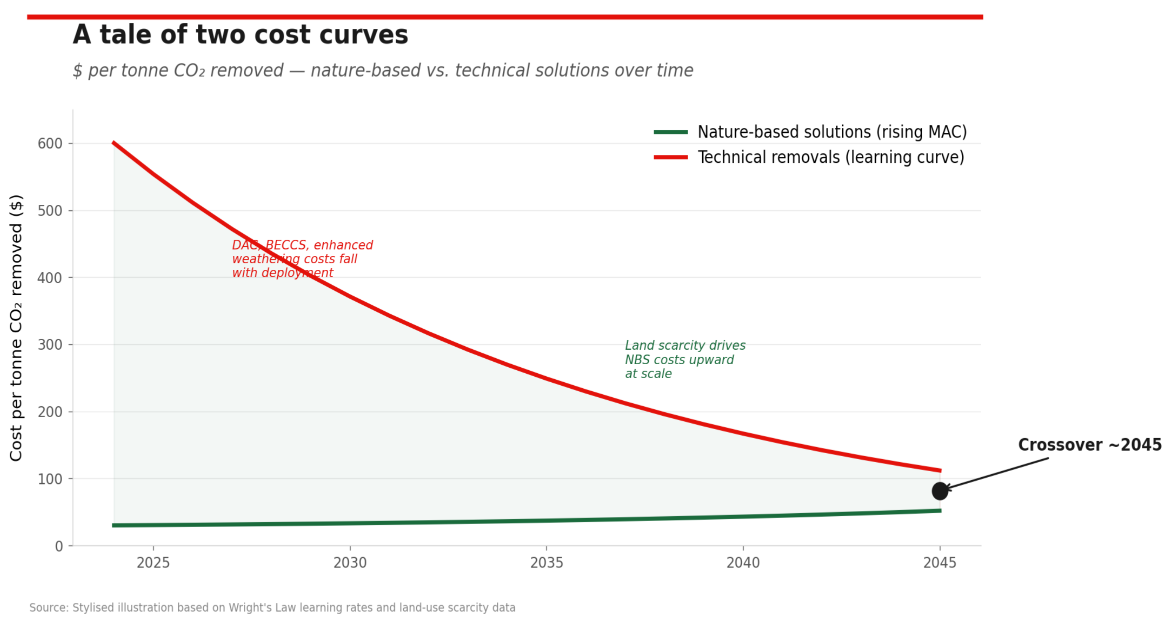

Figure 8. A tale of two cost curves: nature-based solutions rise with scarcity; technical solutions fall with scale.

Portfolio diversification, not cheapest-first

A policy that simply pursues the cheapest removals first — the "race to the bottom" approach driven by a mixed Marginal Abatement Cost curve — will systematically underinvest in the technologies that become cheapest at scale. This is the central paradox of early-stage carbon removal: the methods that appear most expensive today are precisely those with the greatest cost-reduction potential.

The RemRamp should therefore mandate a diversified portfolio of removal methods, explicitly including early-stage technical solutions alongside nature-based approaches. Compliance mandates that require a technology mix serve dual purposes: they build the removal capacity needed now while driving the cost curves down for the gigatonne-scale deployment needed later.

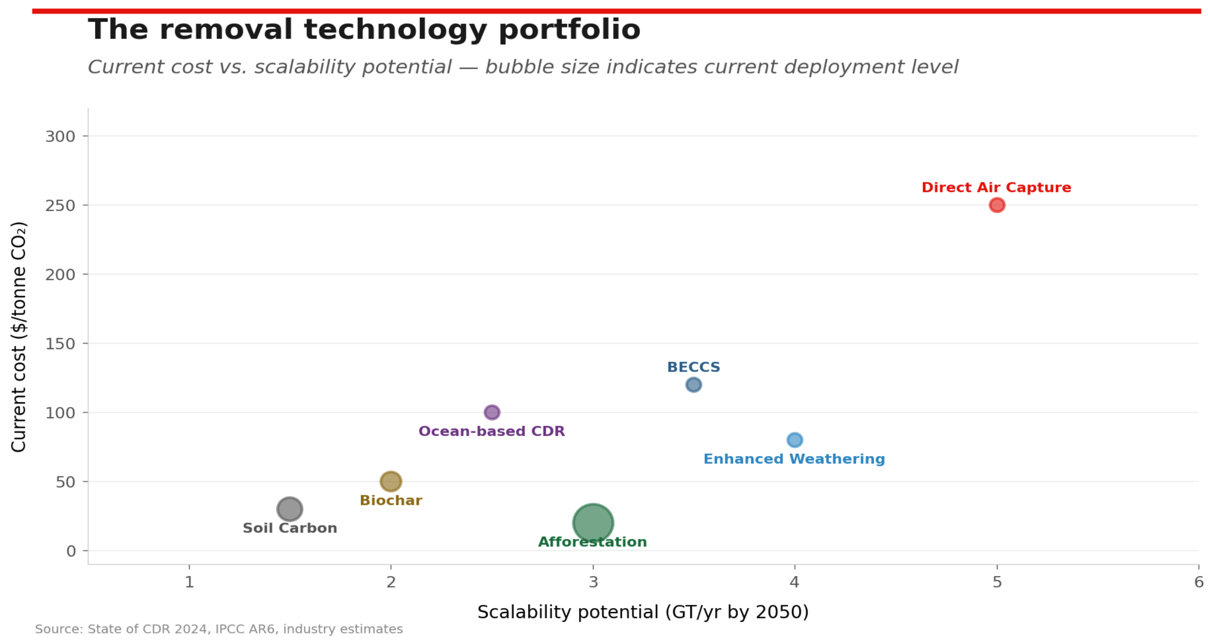

Figure 9. The removal technology portfolio: current cost vs. scalability potential.

VI. Who Pays: Allocating the Ramp

Accountability means assignability. A global removal target without national obligations is a wish, not a goal. This paper does not prescribe an allocation formula — that is a matter for negotiation among sovereign parties. But any serious debate must grapple with four candidate frameworks, each with distinct implications for equity, politics, and economics.

Under a **current-emissions** allocation, China bears 43.6% of the ramp and the United States 21.6% — reflecting today's emission profile. Under a **historical-emissions** model, the United States' share rises to 24% and Europe's share rises significantly, reflecting cumulative atmospheric contributions since industrialization. A **GDP-weighted** approach shifts burden toward wealthy nations regardless of their emission levels. A **polluter-pays** model holds current emitters directly responsible.

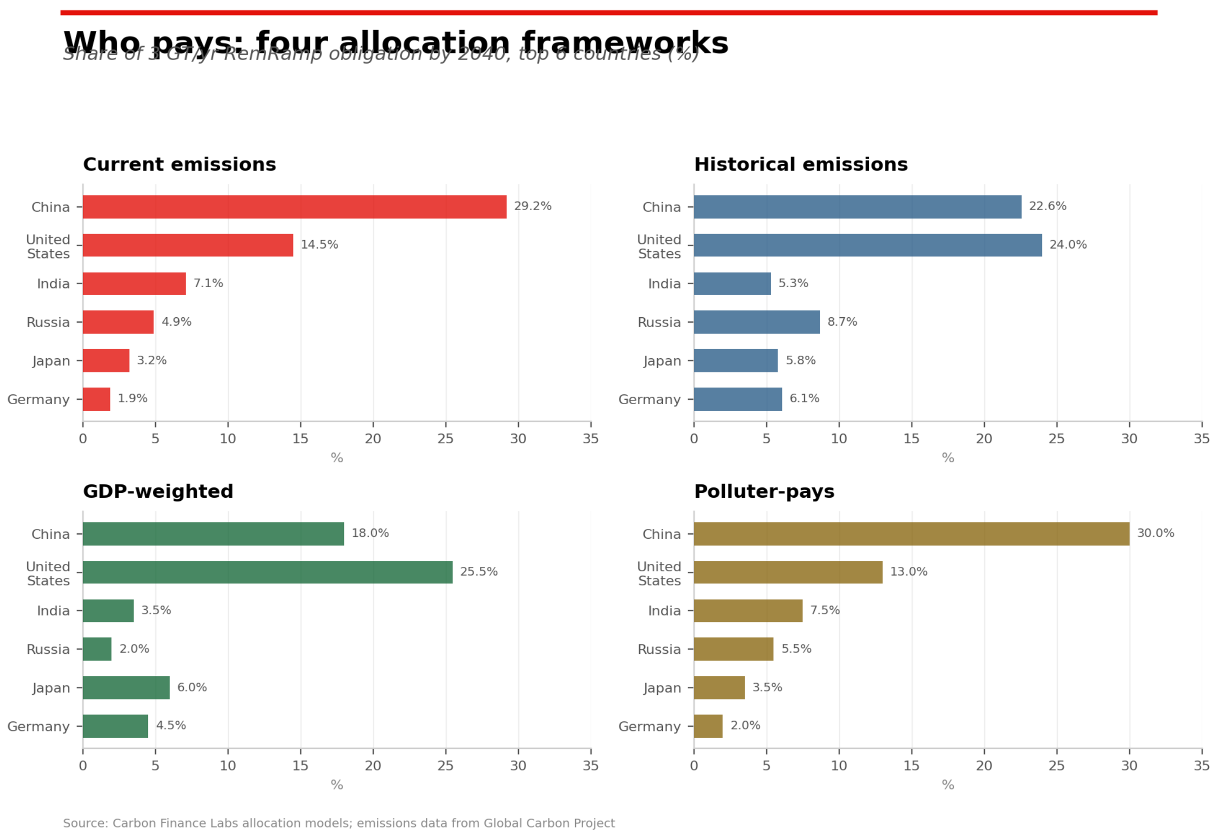

Figure 10. Four allocation frameworks: the burden shifts dramatically depending on the principle applied.

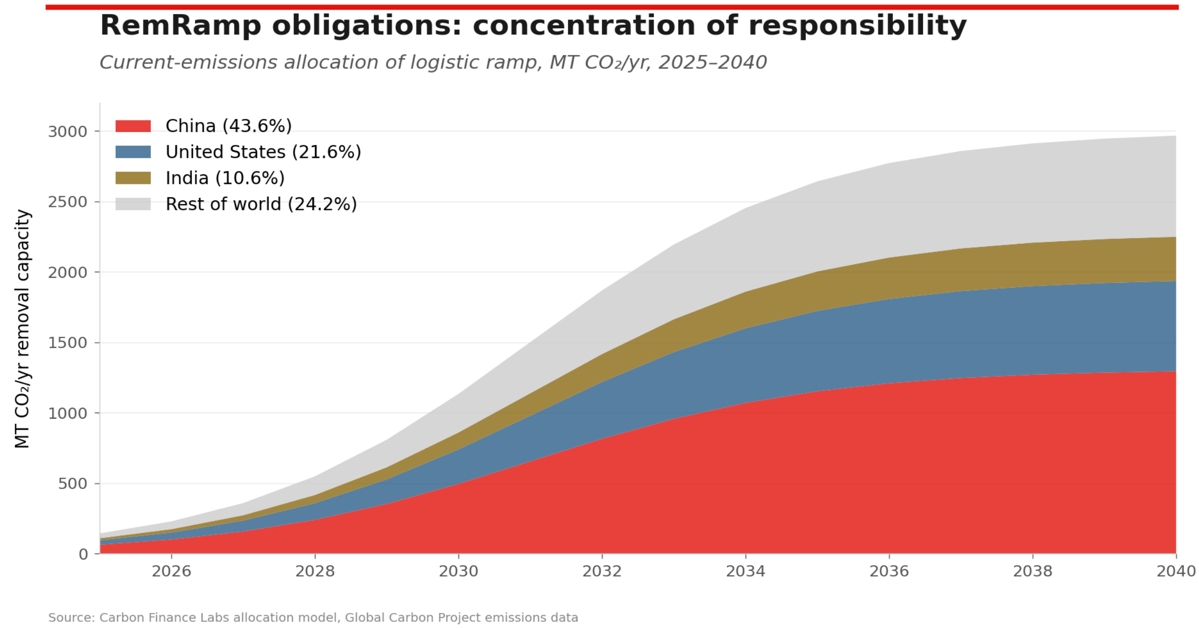

Figure 11. Top-3 country obligations under current-emissions allocation of the logistic ramp.

The choice of framework has profound implications. Historical and capacity-based approaches emphasise fairness but face resistance from high-emitting or economically powerful nations. Current-emissions approaches are dynamically responsive but arguably penalise developing nations whose emissions are still growing. The art of the politically possible will likely produce a hybrid — but any hybrid must still sum to the global target.

VII. The Market Architecture

A RemRamp linked to NDC obligations creates something markets need above all else: predictable demand. By establishing a rising, legally mandated demand curve for carbon removals, the framework transforms an aspiration into an investable asset class.

RemITMOs: a dedicated removal trading mechanism

Removal Internationally Transferred Mitigation Outcomes (RemITMOs) are a proposed category of carbon market transaction focused specifically on removals, distinct from emission reduction credits. They would operate under Article 6 of the Paris Agreement, creating a structured market for cross-border removal obligations. Countries with excess removal capacity sell RemITMOs to those with higher obligations — mobilising capital, building capacity, and enabling the comparative advantage that makes global cooperation efficient.

The market architecture flows from NDC obligations through national RemRamp targets, to removal project development, independent verification, RemITMO issuance, and cross-border trading. At each stage, transparency, additionality, and permanence must be ensured through robust monitoring, reporting, and verification systems.

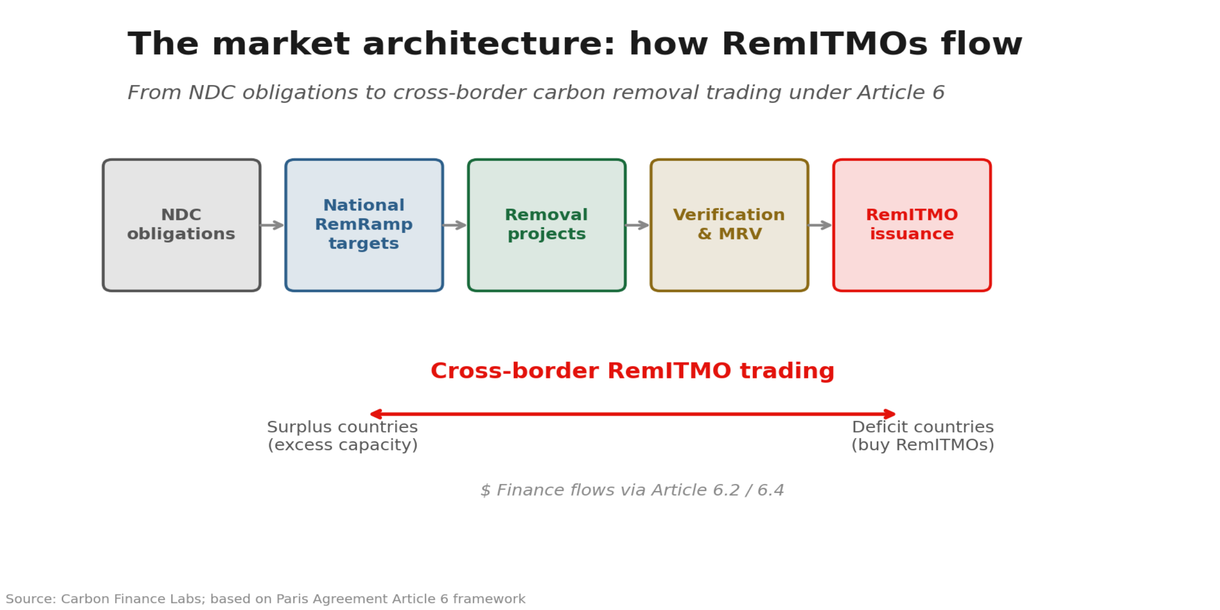

Figure 12. The market architecture: how RemITMOs flow from obligations to cross-border trading.

The innovation flywheel

Public sector investment in early-stage technologies — whether through direct funding, compliance mandates, or advanced market commitments — does not merely build capacity. It sets a virtuous cycle in motion. Compliance mandates create forward demand signals. Demand signals attract private investment. Investment funds deployment at scale. Deployment generates learning-by-doing. Learning drives cost reduction. Cost reduction enables expanded deployment. The flywheel accelerates.

This mechanism has been demonstrated repeatedly: in solar photovoltaics, wind turbines, batteries, and semiconductors. The question is not whether it works but whether policymakers will create the initial conditions — the compliance mandates and demand signals — that set it in motion for carbon removal.

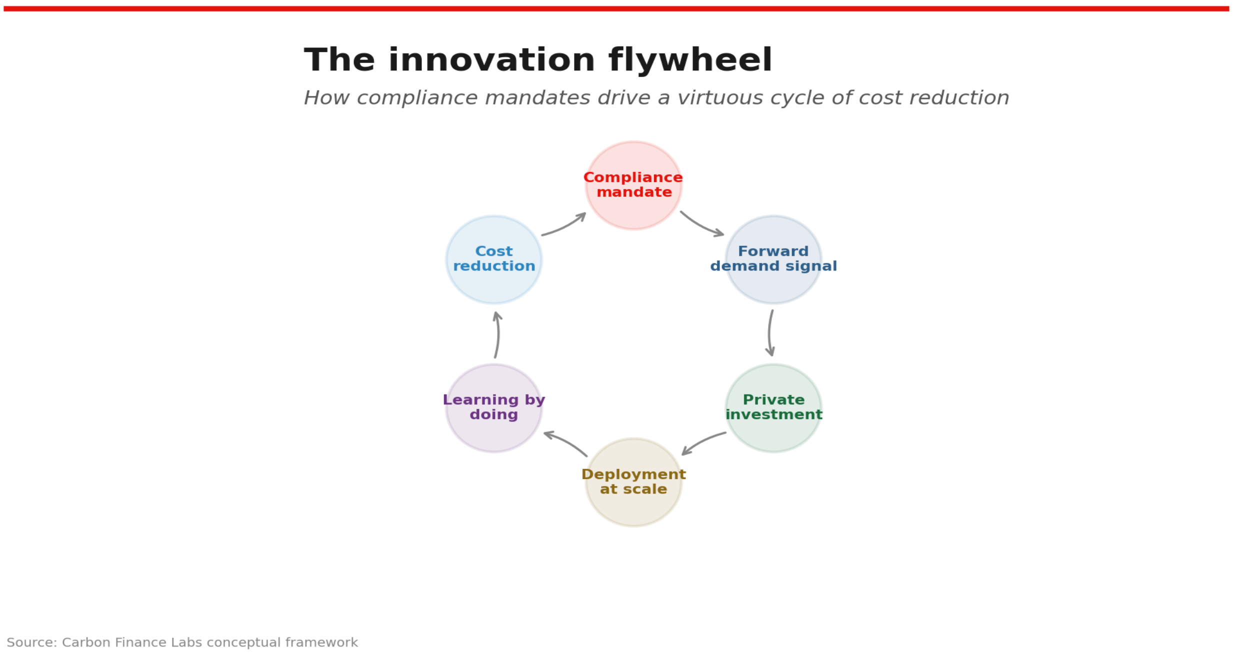

Figure 13. The innovation flywheel: compliance mandates trigger a virtuous cycle of cost reduction.

VIII. The Human Stakes

The abstractions of gigatonnes and basis points obscure a reality measured in human lives. The World Bank's Groundswell report projects that without decisive action, climate change could force up to 216 million people across six world regions to migrate within their own countries by 2050. Sub-Saharan Africa alone faces 86 million internal climate migrants.

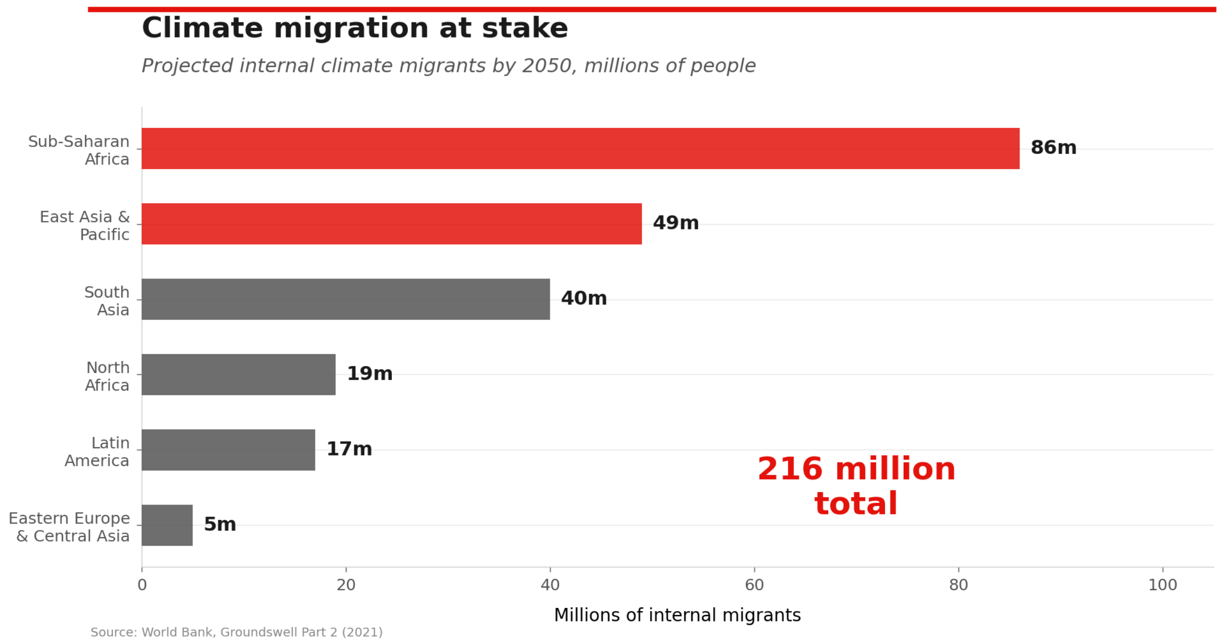

Figure 14. Climate migration at stake: 216 million projected internal migrants by 2050.

These projections are not inevitable. The Groundswell report emphasises that urgent action on mitigation and adaptation could significantly reduce the scale of displacement. The RemRamp is one such action — a framework that, by building the capacity to remove carbon from the atmosphere at scale, reduces the probability of the worst warming scenarios and the human suffering they would entail.

The geoengineering question

Critics sometimes frame direct air capture and large-scale carbon removal as "geoengineering" — a loaded term suggesting hubris and uncharted risk. This characterisation warrants correction. Humanity has been geoengineering its climate for two centuries through fossil fuel combustion and land-use change. Seventy-five per cent of species have disappeared since 1970. The question is not whether to intervene in Earth's systems — that intervention is already underway, inadvertently and catastrophically. The question is whether to shift from inadvertent to intentional intervention, with the explicit goal of restoration and balance.

Direct air capture is not a radical departure. It is a corrective measure aimed at reversing existing anthropogenic alterations to the carbon cycle. The risks of carefully researched, monitored, and scaled carbon removal are orders of magnitude smaller than the risks of unchecked climate change — rising seas, extreme weather, biodiversity collapse, and mass displacement.

IX. Conclusion: The RemRamp as Strategic Imperative

This paper has not prescribed a RemRamp. It has framed the terms of a debate that must happen — and happen quickly.

The decision levers are clear: the shape of the ramp (logistic, for the reasons argued above), the terminal capacity target (at least 3 GT/yr, likely higher given NDC shortfall risk), the mix of removal methods (diversified to capture both immediate capacity and long-term cost reduction), and the accountability mechanism (NDC-linked, tradeable through RemITMOs, with separate accounting from emission reductions).

The constraints are equally clear: timeliness (every year of delay steepens the ramp), capacity deployment (the industrial scale is unprecedented), cost (declining for technology, rising for nature), NDC uncertainty (the single largest risk factor), innovation trajectory (dependent on early deployment), and biodiversity (a binding constraint on nature-based solutions).

What is not debatable is the need. Carbon removal at scale is not optional under any pathway that limits warming to 1.5°C. The only question is whether the world builds a structured, accountable, and market-driven framework for doing so — or continues to defer to the language of aspiration while the window for effective action narrows.

The Removals Ramp offers one such framework. It demands swift action, innovation, and international cooperation. It demands that every player — from national governments to private actors — accept defined responsibilities and be held accountable. And it demands that we start now, with the understanding that the second-best time to begin is today.

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