Removals Ramp to Reach the UNFCCC IPCCC Net Zero goals, safely, effectively, and efficiently.

Reaching the UNFCCC IPCCC Net Zero goals, safely, effectively, and efficiently with a RemRamp (Removals Ramp):

Abstract:

Achieving the UNFCCC IPCC's ambitious net-zero targets requires a new framework capable of addressing both the urgency and complexity of climate change. This paper introduces the "Removals Ramp" (RemRamp), a structured approach to systematically scale carbon dioxide (CO_2) removal capacity, providing a pathway for effective climate mitigation. The RemRamp concept sets annual targets for both installed capacity and cumulative removals, aligning closely with Nationally Determined Contributions (NDCs), and adapting dynamically to shortfalls in emission reductions.

The RemRamp approach is guided by three fundamental principles for goal achievement: a clearly defined objective that includes a failure metric, accountability assigned to a responsible entity, and a strict deadline. Current global net-zero efforts lack these elements, leading to inconsistent and insufficient progress. Unlike the aggregate and often ambiguous NDCs, the RemRamp provides a clear and measurable pathway, enabling stakeholders to align annual progress towards a terminal target of global safety.

Key features of the RemRamp include:

1. **Installed Capacity and Cumulative Removals**: Installed capacity refers to the annual amount of CO_2 equivalent that can be removed, while cumulative removals quantify the total removed over time. This dual approach ensures both incremental progress and cumulative impact.

2. **RemRamp Coverage Ratio**: Designed to compensate for underperformance in emission reductions, this ratio ensures an adaptive increase in removals to maintain the trajectory towards net-zero.

3. **Market Mechanisms and RemITMOs**: The RemRamp creates market predictability for carbon removal, stimulating investments and technological innovation. RemITMOs (Removal Internationally Transferred Mitigation Outcomes) facilitate cross-border collaboration and finance for carbon removal projects.

The design and implementation of a RemRamp involve essential decision levers, including the "shape" of the ramp curve, terminal removal capacity, and accountability mechanisms, while also considering constraints such as timeliness, capacity deployment, cost, and biodiversity impacts. The

RemRamp is not presented as a definitive solution but as a framework to stimulate informed debate on the path towards achieving the IPCC's climate goals.

By setting incremental targets, assigning clear responsibilities, and fostering market engagement, the RemRamp offers a practical and scalable approach to achieving net-zero emissions by 2040, thereby reducing the catastrophic risks of inaction. This concept provides a structured framework for aligning global efforts towards a sustainable and climate-resilient future.

Goals require 3 things.

1. **Clear objective** with a failure metric (define it)
2. **Accountability** to a single entity (own it)
3. **Deadline** (get it done)

No goal for global net zero exists. Aggregate NDC's are too remote, not reported or beneath required commitments. Failure is assured by the lack of accountability echoed in policy halls as "We should really do something". No clear goal, no accountability and non-existent or non-actionable remote deadlines are a recipe for catastrophic failure impacting hundreds of millions of lives.[1]

A Removals Ramp (RemRamp) is a goal framework to annually increase the capacity and amount of carbon dioxide (CO2) removed from the atmosphere. It's a path with annual milestones to cool down our warming planet by reducing excess CO2. In this paper we will explain how the ramp was designed to meet global risk and safety concerns. The ramp has a few key suggested characteristics to debate among global stakeholders.

This paper is not a solution for a RemRamp but rather a way of framing the argument among the key design **decision levers** points and **constraints** for meaningful debate.

decision levers: "shape" of the ramp curve, terminal target GT/yr of capacity, mix of removals methods, accountability assignment mechanisms,

Constraints & factors: timeliness, capacity deployment, cost, NDC Reduction uncertainty, technical improvement (innovation impacts), biodiversity.

Executive summary:

The Removal Ramp (RemRamp) is a systematic approach to incrementally increase carbon removal capacities to achieve net-zero emissions. It sets annual targets for both installed carbon removal capacity and cumulative carbon removed, aligning with global and national climate goals.

Core Concepts for implementation:

1. Installed Capacity and Cumulative Removals:

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[1] Clement, Viviane; Rigaud, Kanta Kumari; de Sherbinin, Alex; Jones, Bryan; Adamo, Susana; Schewe, Jacob; Sadiq, Nian; Shabahat, Elham. 2021. Groundswell Part 2: Acting on Internal Climate Migration. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36248 License: CC BY 3.0 IGO

Installed Capacity refers to the annual amount of carbon dioxide equivalent (CO2e) that can be removed, while Cumulative Removals indicate the total CO2e removed over time.

Example: If in 2025, 5 megatons (MT) of CO2e can be removed, and this increases to 10 MT by 2026, the installed capacity in 2026 is 10MT and cumulative removals are 15 MT.

2. Alignment with NDCs:

Nationally Determined Contributions (NDCs) are countries' commitments to reduce emissions. RemRamp's targets can be integrated with NDCs to ensure a coherent approach to achieving net-zero emissions.

3. Market Mechanisms:

By creating a predictable demand for carbon removal, RemRamp supports the establishment of carbon markets, fostering investments in removal technologies and projects.

4. RemRamp Coverage Ratio:

A mechanism to accelerate removals if there's a shortfall in NDC achievements, ensuring the net-zero goal remains attainable.

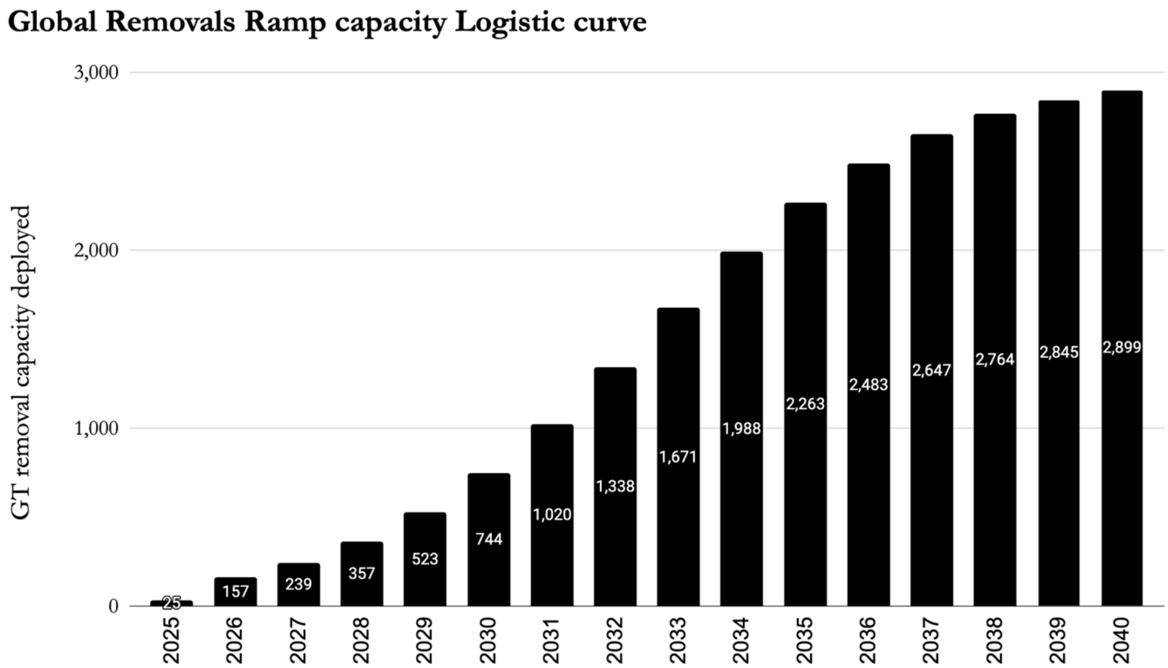
Example: If there's a 10% shortfall in emission reductions, and the coverage ratio is 1.5, the removals would be increased by 15% to cover this gap.

5. RemITMOs (Removal Internationally Transferred Mitigation Outcomes):

A specific category of carbon market transactions focusing on carbon removals, aiding in mobilizing finances and achieving RemRamp targets.

The proposed RemRamp

Annual targets, shape of the ramp or curve and assigning obligations for accountability are shown below. The shape and scale of a proposed RemRamp will be presented. Data here



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The RemRamp methodically boosts our CO2 removal efforts annually, harnessing innovative technologies and nature's power, such as reforestation and advanced methods to capture and securely store CO2. It's akin to progressively increasing your workout intensity to achieve long-term fitness goals, but here, our goal is to purify our atmosphere.

The pace at which we implement the RemRamp is crucial, for the ambitious 2040 target of achieving net-zero emissions. This means strive to balance the scales, ensuring the amount of CO2 we emit is equal to what we remove, cancelling out our carbon footprint.

Speed is of the essence as delays, increase the challenge and expense to mitigate climate change impact. Early and rapid actions allow us to leverage current technologies and pave the way for new innovations, making the journey to net-zero more manageable and cost-effective. Early ramping also addresses capacity building risk of NDC reductions target shortfalls.

Achieving global targets requires a coordinated effort, with clear and direct accountability at all levels, from national governments to local actors. Each player must have defined responsibilities and be held accountable for meeting their part of the bargain. This collective action ensures that no one works in isolation, and every effort contributes to a singular, global goal of a healthier planet.

The RemRamp is not just a plan but a global commitment to turn the tide against climate change, demanding swift action, innovation, and collaboration to reach a future where our planet breathes easier.

The Removal Ramp (RemRamp) is a blueprint for steering the global community towards the ambitious yet crucial goal of net-zero emissions, a vision strongly endorsed by authoritative entities like the IPCC. It's imperative that we dissect this concept into its core components, elucidate the roles of pivotal actors, and underscore the manifold benefits it promises.

Table of Contents

We need to hurry: Time & cost to deploy RemRamp infrastructure. The RemRamp is likely 200 times more capital than 3 The Three Gorges Dam.

Some context on the magnitude of removal infrastructure required. $1trillion in removals capacity annual spend (5Gt/yr at $200/ton)by 2050 in 26 years is likely required. These means new technology working at scales never before seen.

To understand the scope of the removals challenge let's look at a mature technology deployed at scale by the fastest infrastructure builders known to date. The Three Gorges Dam, located on the Yangtze River in China, is one of the largest hydroelectric power stations in the world. The construction involved several key phases over 18 years.

1. **Preparation and Planning**: The official plan was approved **1992**.
2. **Construction Start**: Construction formally began on December **1994**.
3. **Initial Completion**: The main wall of the dam was completed in **2006**.
4. **Full Operational Capacity**: The entire project, including all of its planned 32 main turbines, became fully operational in July **2012**.

Construction took 18 years from the start of building in 1994 to full operational capacity in 2012. Including planning and preparation, the period extends to 30 years. In a highly centralized government with a singular focus, capital and mature scales if undertaken today 2024 would be completed in 2054. Similar to our net zero timelines which are dynamic and changing.

In terms of cost, the Three Gorges Dam project was expensive. The official cost was reported to be around 180-200 billion yuan, which translates to roughly $22 - $25 billion USD. Some estimates, considering indirect costs and consequences, place the number even higher. The project was funded by the Chinese government, loans from various international groups, and revenue from selling bonds and electricity.

If one assumes capital projects that produce $200/ton carbon removal including energy etc. amortized over 15 years may require $1,000 per ton/yr of built up front capacity. The scale of "build out" from a capital perspective is more than 200 3 gorges dams worth of industrial carbon removal capacity in 26 years. This involves new technologies a risk to timely deploying.

The best time for deploying the RemRamp was 20 years ago, the second best Time is now.

NDC 2040 target shortfall risk means that 3 GT / Yr removal capacity may be too low. Removal capacity beyond 3GT is our **only** Plan B for NDC reduction shortfall.

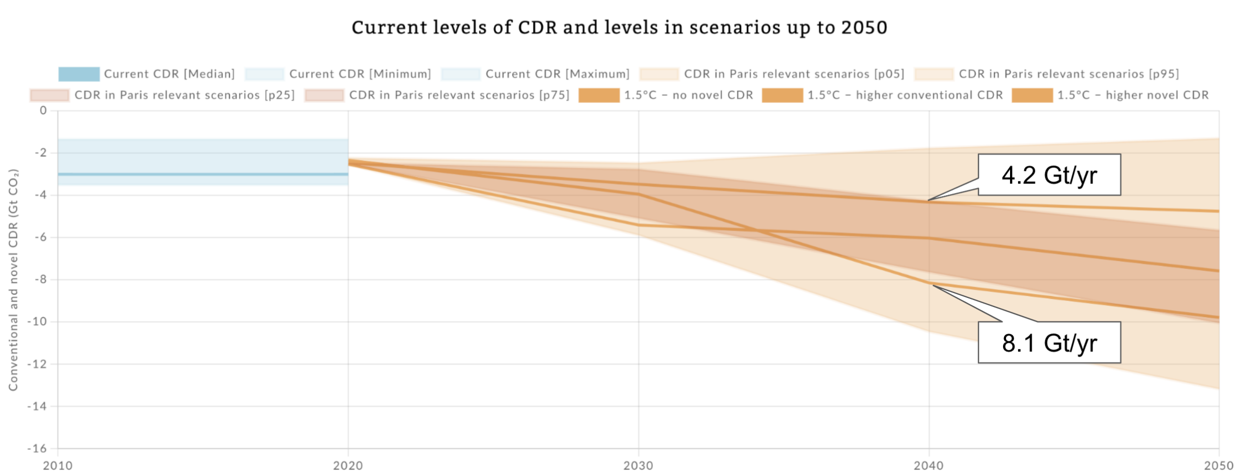
Achieving Net zero is critical. Establishing extra carbon removal capacity as a risk management strategy to ensure the achievement of the net-zero emissions target by 2050 and 2040, as set forth by the Intergovernmental Panel on Climate Change (IPCC). The success of reaching these targets depends on countries meeting their individual emission reduction goals, which, based on historical performance, is subject to significant uncertainty and risk of **NDC short fall**. "195 countries ratified the Paris Agreement, only 72 submitted voluntary long-term strategies to achieve a low-carbon economy by 2050. Of those, just 26 include an estimate of future residual emissions, according to a study published this month in *One Earth* journal."[2]

Most countries have no real plans for action, only 26 of 71 NDC strategies quantify residual emissions as of May, 2024[3].

In the IPCC's Special Report on Global Warming of 1.5°C (SR15), the emissions targets for 2040 are presented as a range, depending on the specific scenario and pathway. The report outlines four illustrative model pathways (P1, P2, P3, and P4) that limit global warming to 1.5°C with different levels of overshoot and reliance on carbon dioxide removal (CDR) technologies.

The exact amount of removals for 2040 should be baked into a target which is annually revisited and updated. Here is an example of the current range of goals.

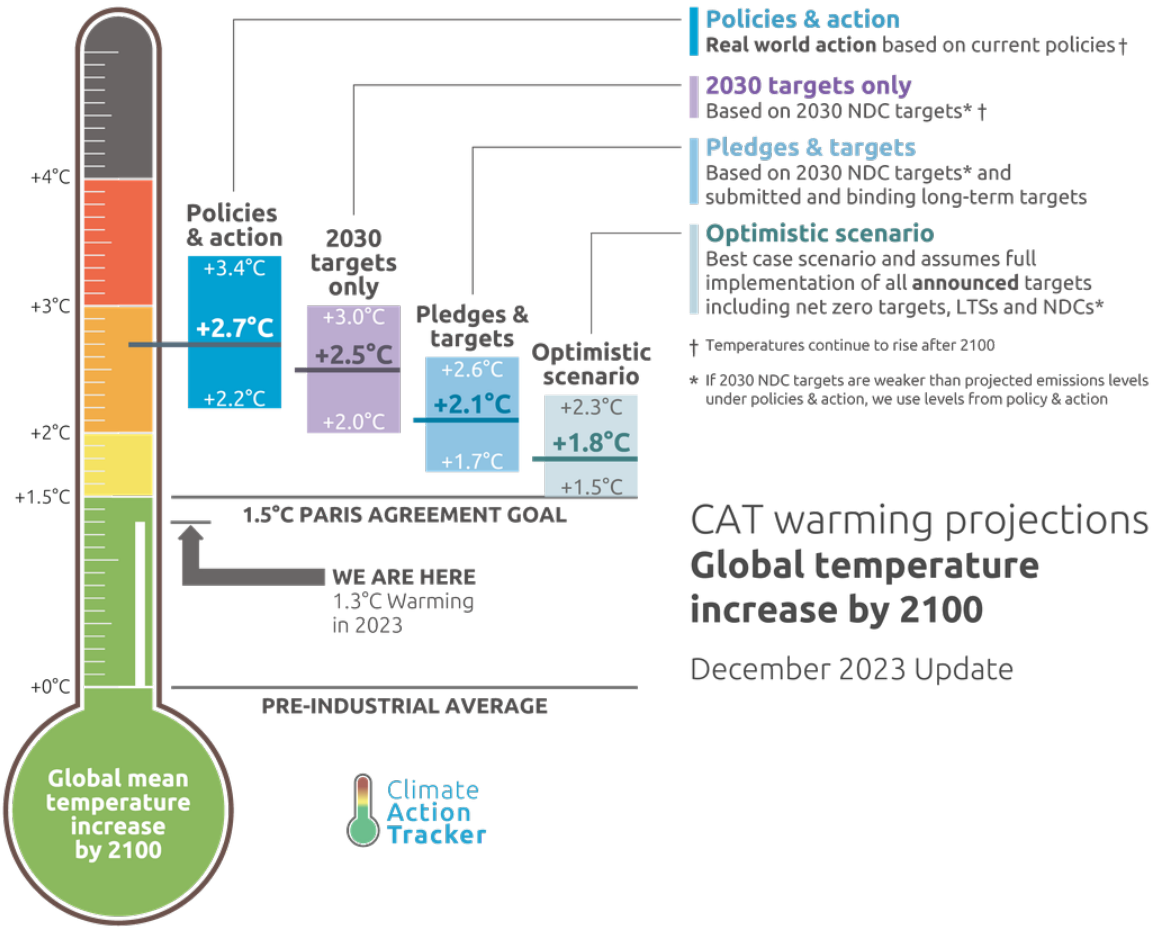
Fuzzy 2040 needs resolution to a target.



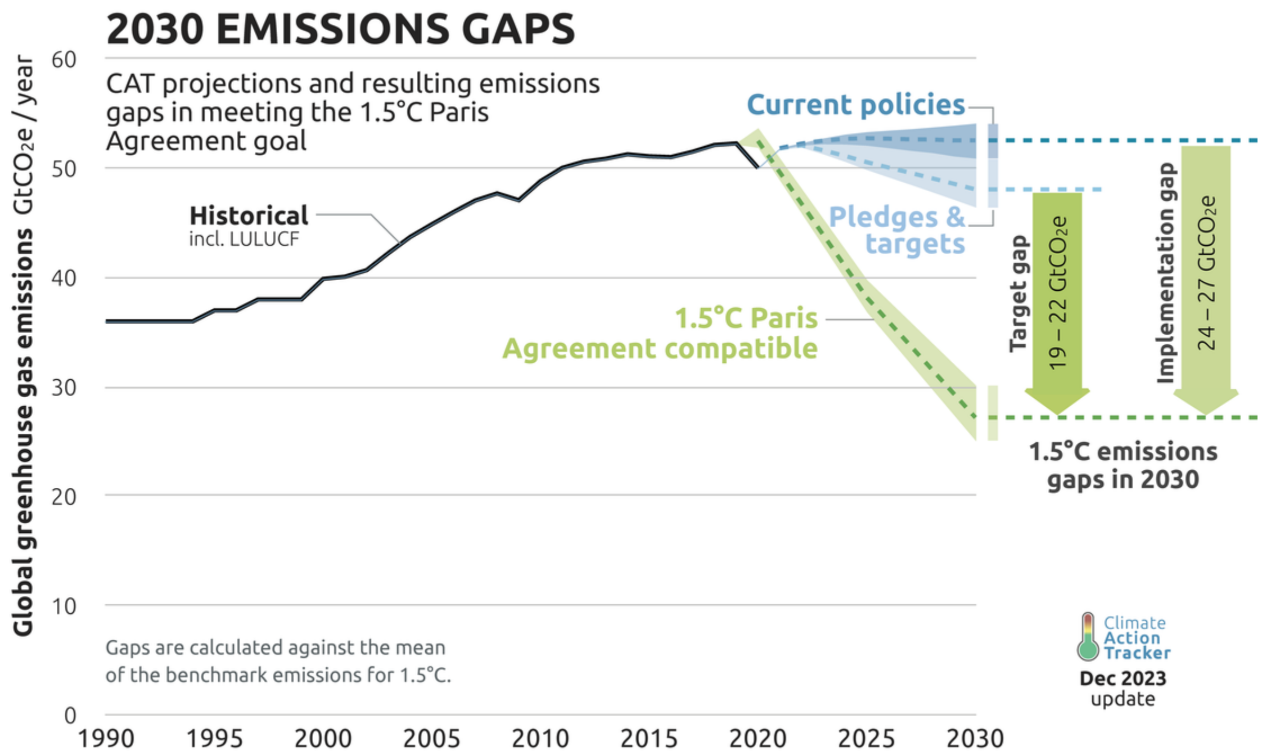
Chapter 9: The CDR gap. in The State of Carbon Dioxide Removal 2024 – 2nd Edition (eds. Smith, S. M. et al.)
Lamb, W. F., Minx, J. C., Vaughan, N. E., Gasser, T., Smith, H., Roman-Cuesta, R. M., Grassi, G., Pongratz, J., Smith, S. M., Schwingshackl, C., Gidden, M. J., Roe, S., Schenuit, F., Buck, H. (2024)

[2] https://www.eenews.net/articles/many-countries-pledge-to-reach-net-zero-by-2050-few-plan-for-it/
[3] https://www.cell.com/one-earth/fulltext/S2590-3322(24)00199-4 Residual emissions in long-term national climate strategies show limited climate ambition Harry B. Smith [4], Naomi E. Vaughan, Johanna Forster

Status today



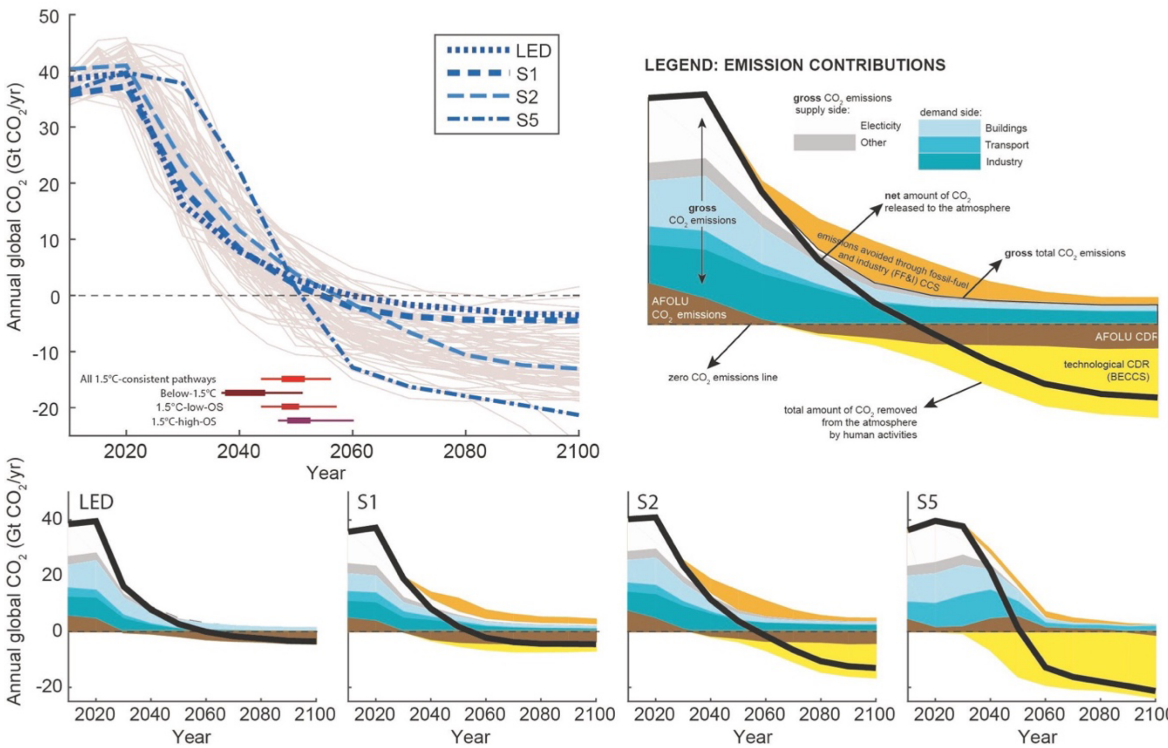
https://climateactiontracker.org/global/cat-thermometer/



https://climateactiontracker.org/global/cat-emissions-gaps/

For 2040, the CO2 emissions levels (in GtCO2/yr) for each pathway are:

- P1: 8.5 GtCO2/yr
- P2: 11.8 GtCO2/yr
- P3: 16.1 GtCO2/yr
- P4: 22.8 GtCO2/yr



Source: https://www.ipcc.ch/sr15/chapter/chapter-2/

Key Points:

1. Carbon removals are a small portion of the net reductions needed, making the required removals highly sensitive to emission reduction uncertainty.

2. Any shortfall in emission reductions means a disproportionate increase in carbon removal capacity to compensate.

3. Proactively building extra carbon removal capacity early ensures a readily available industrial buffer capacity to absorb unexpected emissions and maintain progress towards net-zero.

Examples of NDC reductions Risk:

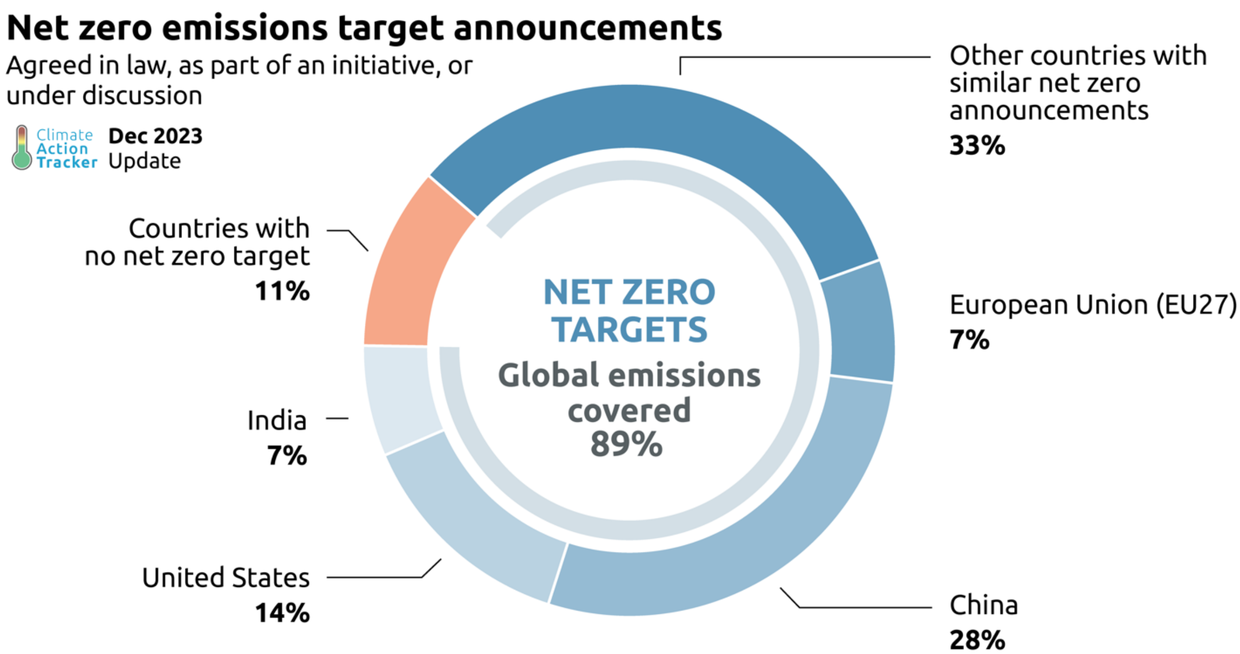
Delayed implementation of emissions reduction policies: If countries delay the implementation of policies and technologies to reduce emissions, the gap between the target and actual emissions will widen, requiring a significant increase in carbon removal capacity.

Unforeseen economic or political events: Economic downturns, political instability, or changes in government priorities can hinder the progress of emission reductions, leading to an increased reliance on carbon removals.

Underestimation of emissions: If the actual emissions are higher than initially estimated, the required carbon removal capacity will need to be increased accordingly to maintain the net-zero balance.

Recommendation: To have a 95% chance of achieving the net-zero target, it is recommended to develop a carbon removal capacity that is at least 50% greater than the currently projected requirements. This spare capacity will provide a robust safety net against potential reduction target slippages and unforeseen emissions.

Tool for tracking this: https://climateactiontracker.org/global/cat-net-zero-target-evaluations/ Net zero tracker.

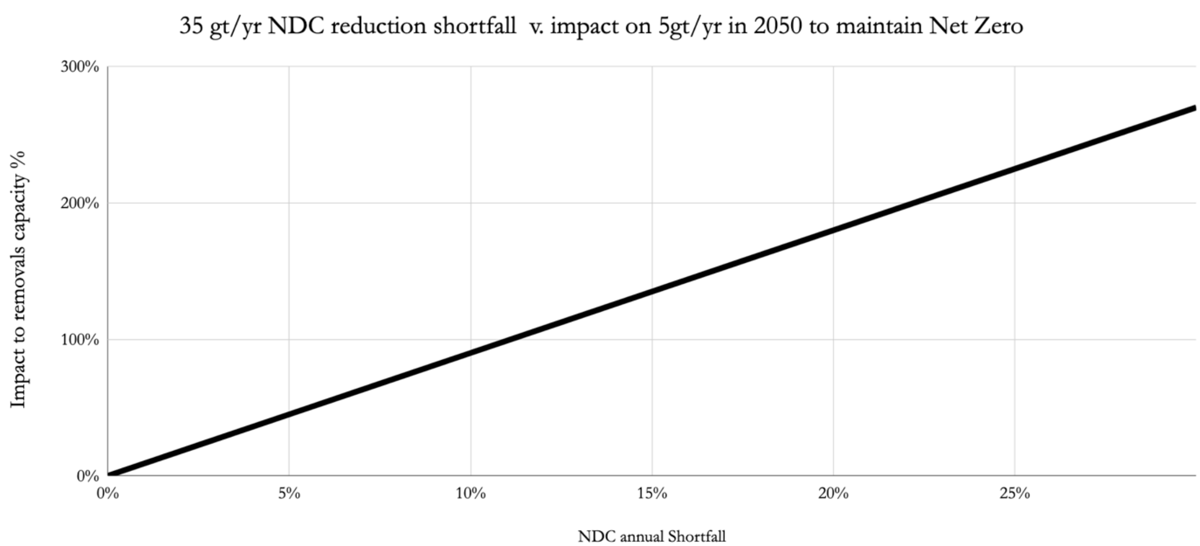


Deploying extra carbon removal capacity early is a risk management strategy to ensure the success of our global climate goals. By proactively developing this capacity, the risks associated with emission reduction shortfalls, provide a buffer against uncertainties, and increase the likelihood of achieving net-zero emissions by 2040 and 2050. The time to act is now to acknowledge uncertainty in the NDCs and scale removals flex capacity accordingly.

Excess Removal Capacity as emergency brake for 1.5

The 2040 goals above for reductions assume everyone hits their targets. Many countries are showing ambitions above 1.5 and in some cases closer to 3 or even above 4.5% in terms of commitments, much less delivered reductions.

As such global excess industrial capacity should be put in place. Due to the long lead times for infrastructure deployment, the logistic curve shown earlier is the least risky approach to assure scalable deployment from an "emergency" capacity deployment needed a % growth shock required. Scenarios below show the extra capacity that would need to be brought on board should reductions prove late or impossible to realize for technical or political reasons. Assuming IEA's Stated Policies Scenario (STEPS), reflects current policy settings, global energy-related CO2 emissions are projected to reach around 35.5 Gt in 2024. Arriving at 8.5 Gt/yr CO2e emissions in 2040 requires reductions from 2024 baseline 27.0 Gt/yr. Note cumulative impacts of a shortfall would increase the RemRamp capacity requirements. For illustrative purposes a simple non-cumulative impact is shown below.



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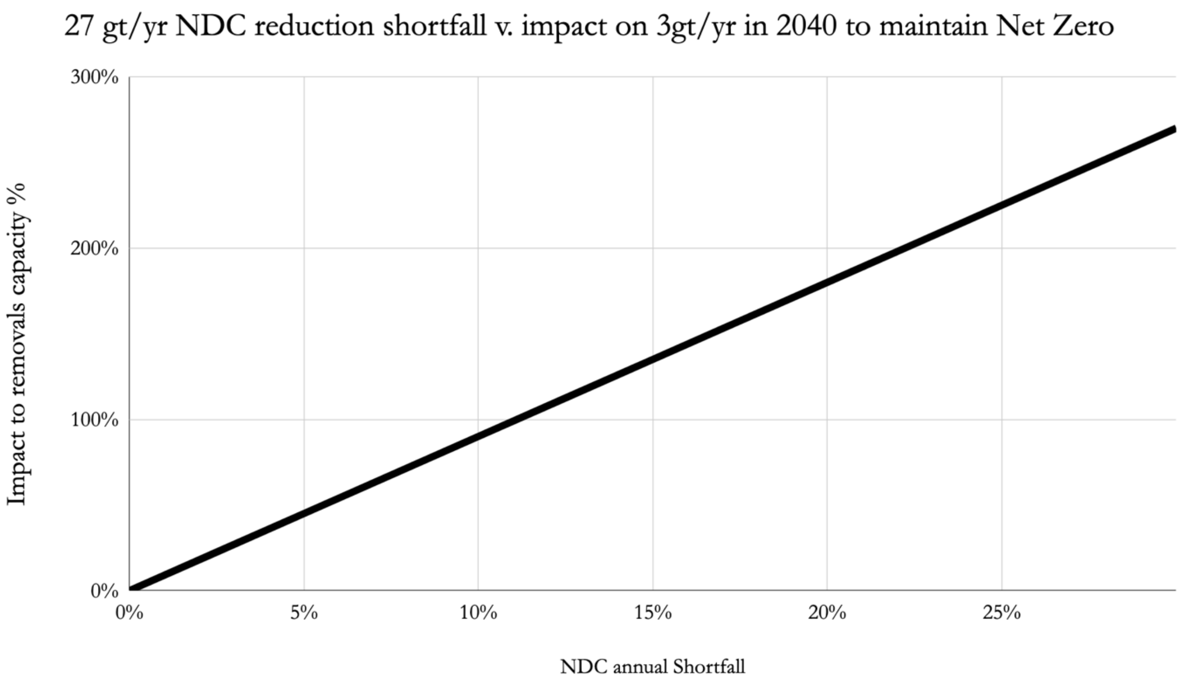

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From the finding of NDC papert "Residual emissions in long-term national climate strategies show limited climate ambition"[4], here are the key points and relevant data:

1. Residual emissions are a significant portion of current and peak emissions for many countries:
   - For Annex I countries, residual emissions average 21% of peak emissions, ranging from 5% to 52%.
   - For non-Annex I countries, residual emissions average 34% of peak emissions.
   - Residual emissions are, on average, 25% of 2021 GHG emissions for Annex I countries and 41% for non-Annex I countries.
2. High-residual-emission scenarios indicate some countries may retain or expand fossil fuel use and compensate with more carbon dioxide removal (CDR) or international offsets to achieve net zero.
3. Agriculture is the largest contributor to residual emissions:
   - Agriculture represents, on average, 36% of total residual emissions for Annex I countries and 35% for non-Annex I countries.
   - Despite this, agriculture is rarely discussed in detail in the strategies compared to industry emissions.

[4] *Residual emissions in long-term national climate strategies show limited climate ambition*, Harry B. Smith,1,2,4,* Naomi E. Vaughan,1,2 and Johanna Forster2,3 1School of Environmental Sciences, University of East Anglia, NR4 7TJ Norwich, UK 2Tyndall Centre for Climate Change Research, University of East Anglia, NR4 7TJ Norwich, UK 3School of Global Development, University of East Anglia, NR4 7TJ Norwich, UK 4Lead contact *Correspondence: harry.b.smith@uea.ac.uk https://doi.org/10.1016/j.oneear.2024.04.009

4. Sectors have varying levels of anticipated emission reductions by the net-zero target year:
    - Agriculture shows the least progress, with an average reduction of only 37% for Annex I countries and 51% for non-Annex I countries compared to 2021 emissions.
    - The energy sector is largely decarbonized, with an 84% reduction on average for Annex I countries.
    - Transport emissions are reduced by 83% on average for Annex I countries.
5. Separate targets for emission reductions and removals can help prevent high residual fossil fuel scenarios by reducing the substitution of emission reductions with CDR.
6. Many countries fail to quantify residual emissions in their long-term strategies, limiting transparency and understanding of their net-zero targets.

To estimate the carbon removal capacity required by 2040 and 2050 for achieving net-zero emissions by 2050, I'll draw insights from the provided research article and other relevant sources.

Factors to consider:

1. Current global emissions and projected growth

2. Emission reduction targets and potential shortfalls

3. Residual emissions estimates from long-term strategies

4. CDR deployment scenarios and feasibility

Current global emissions and projected growth:

- Global GHG emissions reached 52.4 GtCO2e in 2020 (UNEP Emissions Gap Report 2021)

- Emissions are expected to continue growing without significant policy changes

Emission reduction targets and potential shortfalls based on the prior paper:

- To limit warming to 1.5°C, global net anthropogenic CO2 emissions must decline by about 45% from 2010 levels by 2030 and reach net zero by 2050 (IPCC Special Report on Global Warming of 1.5°C)

- Current nationally determined contributions (NDCs) are insufficient to meet these targets, with a projected emissions gap of 28 GtCO2e by 2030 (UNEP Emissions Gap Report 2021)

Residual emissions estimates from long-term strategies:

- The research article indicates that residual emissions average 21% of peak emissions for Annex I countries and 34% for non-Annex I countries

- Some high-residual-emission scenarios suggest a greater reliance on CDR

CDR deployment scenarios and feasibility 5-15gt/yr by 2040:

- The IPCC Special Report on Global Warming of 1.5°C estimates that CDR deployment in the range of 100-1000 $GtCO_2$ over the 21st century may be necessary to limit warming to 1.5°C

- Current global CDR capacity is limited, with estimates around 2 $MtCO_2$/year (as mentioned in the provided research article)

Estimated CDR capacity required by 2040 and 2050:

Based on these factors, the estimated following range of global annual CDR capacity required:

2040:

- Low end: 5 $GtCO_2$/year (assuming aggressive emission reductions and lower residual emissions)

- High end: 15 $GtCO_2$/year (assuming insufficient emission reductions and higher residual emissions)

2050:

- Low end: 10 $GtCO_2$/year (assuming successful implementation of emission reduction policies and lower residual emissions)

- High end: 20 $GtCO_2$/year (assuming a significant emissions gap remains and high levels of residual emissions)

These estimates suggest that global CDR capacity needs to scale up significantly from current levels to support the goal of achieving net-zero emissions by 2050. The wide range in estimates highlights the importance of ambitious emission reduction efforts to minimize the reliance on large-scale CDR deployment.

It is crucial to note that these estimates are based on available data and assumptions, and actual CDR requirements may vary depending on the success of emission reduction policies, technological advancements, and the evolving understanding of climate dynamics. Nonetheless, this analysis emphasizes the urgent need to develop and deploy CDR technologies alongside aggressive emission reduction measures to achieve net-zero emissions by 2050.

Linking the REMRAMP to NDC's as an action lever

Accountability means assignability of the shared goal. The integration of a Removal Ramp (RemRamp) with Nationally Determined Contributions (NDC) obligations can accelerate innovation & investments in carbon removal capacity by signaling implied forward market intent. The ramp may in time trigger local advanced market commitments globally.

This synergy creates a predictable demand curve which is essential for channeling financial resources efficiently, effectively and at speed. Here's a breakdown of how this mechanism supercharges financing and the role of removal Internationally Transferred Mitigation Outcomes (ITMOs) and Removal ITMOs (RemITMOs) in this context:

Investment Stimulation through NDC-Linked RemRamp:

1. Demand Curve Establishment Via policy co-ordination: A RemRamp linked to NDC obligations sets a clear demand curve for carbon removals, making the market predictable for investors. The demand curve signifies a guaranteed market for carbon removal, which is crucial for attracting investments.

2. Price Assurance: With a projected price of $150 per ton of carbon, investors have a clearer understanding of the financial returns they can expect.

3. Reduced Risk: The clarity in demand and pricing significantly reduces market risks associated with investments in carbon removal technologies and projects.

Advancing Removal Capacity through RemITMOs:

1. Market Creation:

RemITMOs create a specific market category for traded NDC obligations focused on removals, distinguishing them from other carbon market transactions.

This specificity makes the market more attractive to investors interested in carbon removals.

2. Capital Mobilization:

The trading of RemITMOs can mobilize significant capital, both domestically and internationally.

It allows for the transfer of mitigation outcomes between countries, enabling nations with excess removal capacity to support those with higher emissions.

3. Capacity Building:

The proceeds from RemITMO transactions can be reinvested in capacity building for carbon removal, thus creating a self-sustaining financial mechanism.

4. Target Achievement:

By facilitating a structured market for carbon removals, RemITMOs support the building of the required 5GT of removal capacity by 2040.

5. CAPEX (Capital Expenditure) Alignment:

The associated CAPEX for creating this capacity can be substantially covered through the revenues generated from the trading of RemITMOs at the projected carbon price.

Carbon Removals, Direct Air Capture and the Role of Geoengineering in Climate Mitigation

The talk surrounding direct air capture (DAC) as a form of geoengineering has elicited a spectrum of viewpoints, raising pivotal questions about the ethical, environmental, and practical implications of such interventions. Critics often frame DAC and similar carbon removal strategies as radical manipulations of Earth's systems, laden with unforeseeable risks. However, this perspective warrants a nuanced examination, especially in the context of anthropogenic climate change—a phenomenon that, in itself, is a result of inadvertent geoengineering on a global scale.

Historical geoengineering our climate and planet

Fossil fuel combustion and land-use changes for agriculture and forestry combined with seafood harvesting mean that industrial and post-industrial human activity have profoundly altered the Earth's atmosphere and climate. 75% of species have disappeared since 1970. This massive, albeit un-intentional, geoengineering project has precipitated an urgent crisis. The resultant climate change is a clear testament to humanity's capacity to influence global systems, albeit historically without the necessary foresight and stewardship. The shift in climate solutions based geo-engineering is the intentionality of the goal and the 25 yr v. 50-150 year time horizons.

Direct Air Capture & other removal technologies as necessary interventions

Direct air capture removes CO2 from the atmosphere and is often labeled as geoengineering due to its intentional manipulation of Earth's carbon cycle. However, this characterization overlooks a critical distinction: DAC is a corrective measure aimed at mitigating the existing anthropogenic alterations to the carbon cycle, rather than an uncontrolled experiment on planetary systems. Biochar at scale, blue carbon etc., are all geo-engineering and that is the point. Residual emissions, not mitigated by reductions or delivered to late need to be resolved by atmospheric balancing to the degree safely possible.

Risk Mitigation Through Controlled Intervention

The primary argument for the accelerated deployment of DAC and similar strategies hinges on the concept of controlled, scalable intervention to address a problem of our making. The risks associated with unchecked climate change—rising sea levels, extreme weather events, biodiversity loss, and more—far outweigh the potential risks of carefully researched, implemented, and monitored carbon removal technologies. The sooner we understand the dynamics of carbon removal at scale, the better equipped we will be to ensure these interventions are safe and effective.

Geoengineering: A Loaded Term Reconsidered

The term "geoengineering" carries with it connotations of hubris and uncharted scientific territory, invoking fears of unforeseen consequences. Yet, when we consider the extensive geoengineering that has occurred through activities contributing to global warming, it becomes evident that human influence on the planet is not a new phenomenon. What changes with DAC and similar strategies is the intentionality behind the influence: from inadvertent alteration to deliberate restoration and balance.

The Imperative of Scale and Safety

Understanding and mitigating the risks of large-scale carbon removal is paramount. This requires robust scientific research, transparent policy-making, and international cooperation to ensure that interventions like DAC are implemented safely and effectively. Moreover, framing these interventions within a broader context of existing and historical geoengineering activities allows for a more informed and less polarized discussion on their merits and risks.

Direct air capture and other carbon removal strategies represent a conscientious shift from inadvertent to intentional geoengineering, with the goal of mitigating the profound climatic changes wrought by centuries of industrial activity. Far from being a radical departure, these efforts are a logical and necessary extension of our growing understanding of human impact on the Earth's systems. For policymakers, embracing this perspective is crucial. It involves recognizing the urgent need for action, the potential for controlled and safe intervention, and the importance of framing the debate in a manner that acknowledges the complex legacy of human influence on our planet. As we navigate the challenges of climate change mitigation, let us approach the task with humility, diligence, and an unwavering commitment to the health of our planet and future generations.

The concept of a RemRamp Coverage Ratio serves as a safety buffer to address the gaps in achieving Nationally Determined Contributions (NDCs) towards net-zero emissions. If there's a shortfall in NDC achievements, the removals can be ramped up to cover this gap. This ratio articulates the extent to which removal capacities need to be enhanced to counterbalance the shortfall in emissions reduction. Here's a detailed explanation using a hypothetical example:

Beyond nature based solutions and the race to the removals bottoms is risky

Investing heavily in nature-based removals, particularly when they are subject to Marginal Abatement Curves (MACs) effects and physical capacity limits, carries several risks, especially when compared to technologically driven removals. Here are some key risks to consider:

1. **Cost Inefficiency Over Time:** One significant risk of overinvesting in nature-based removals is that, over time, their cost-effectiveness may decrease. As we exhaust the most accessible and affordable options (low-hanging fruit), additional investments may yield diminishing returns. The MAC may start to slope upwards, indicating higher costs for incremental removals.

2. **Limited Scalability:** Nature-based removals often have limitations in terms of scalability. For instance, there's a finite amount of land suitable for afforestation or reforestation. As demand for removals increases, there may be challenges in finding suitable areas to implement these methods at a large scale.

3. **Biodiversity Impact:** Biodiversity risk has not been adequately factored into the MAC. As we expand nature-based removals, there's a risk of unintended consequences, such as disrupting ecosystems or causing biodiversity loss. This could significantly shift the impact of the MAC, making it less favorable from an ecological perspective.

4. **Vulnerability to Climate Variability:** Nature-based removals, like forests, are vulnerable to climate variability, such as wildfires, droughts, or pests. These natural events can compromise the effectiveness of these removal methods and result in financial losses.

5. **Longer environmental Payback Periods:** Nature-based removals often have longer payback periods before they start capturing significant carbon. If we heavily invest in them and expect quick returns, there's a risk of financial impatience, which may divert resources away from these vital long-term projects.

7. **Innovation Lag:** Overinvestment in nature-based removals might inadvertently slow down innovation in technologically driven removal methods. If the focus is on one approach, there is less incentive to develop and improve alternative, more efficient technologies.

8. **Failure to Meet Targets:** Overly investing in nature-based removals and underestimating the potential impact of biodiversity and other ecological factors on the MAC, means potential struggling to meet the targeted carbon removal goals by 2040. This can have significant consequences in addressing climate change.

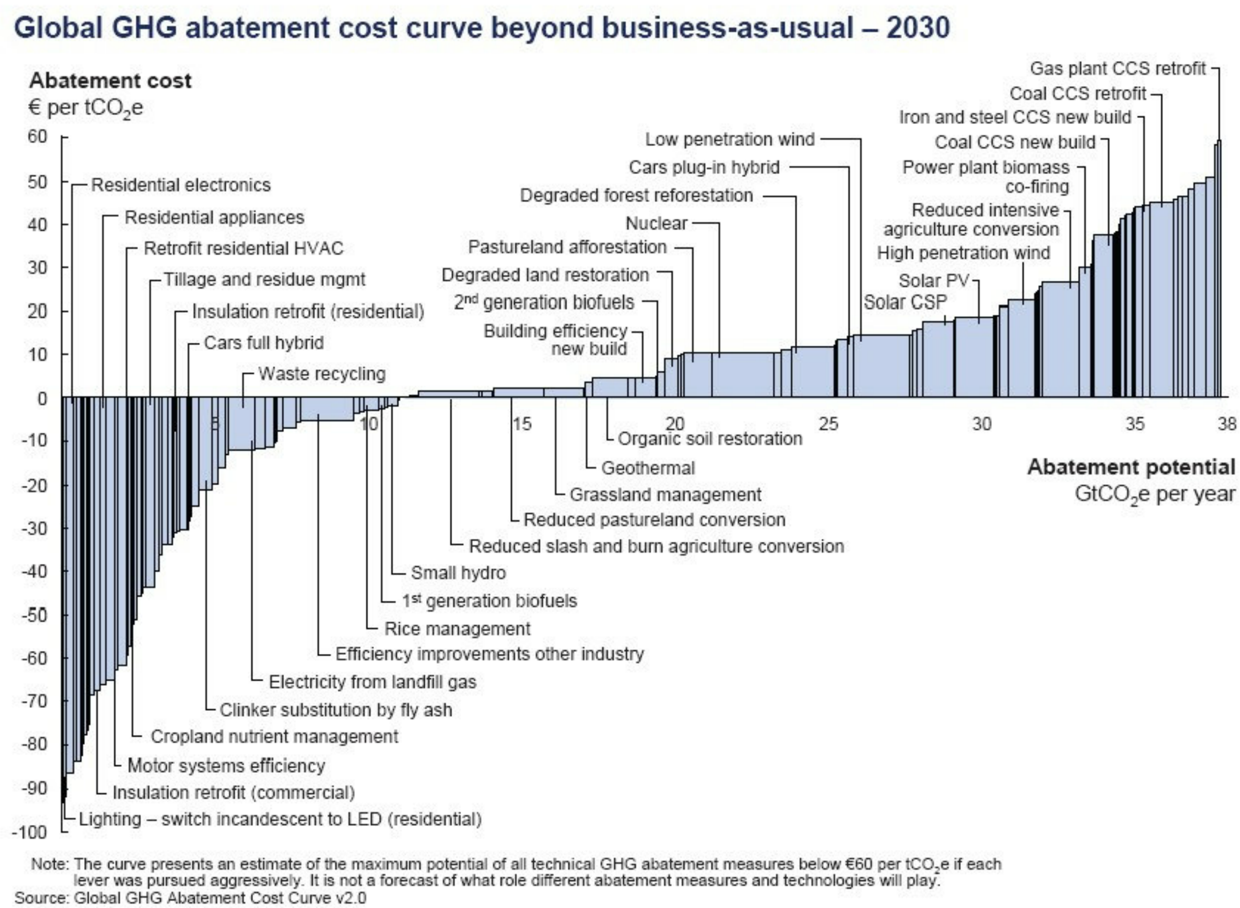
To mitigate these risks, it's essential to strike a balance between nature-based removals and technologically driven methods. This approach provides flexibility and adaptability to changing conditions ensuring we achieve the desired carbon removal targets while considering ecological and economic factors. Regularly updating the MAC to incorporate biodiversity and other relevant variables can provide a comprehensive and accurate assessment of removal methods' impacts over time.

Marginal Abatement Curves (MACs) and the race to the bottom

Imagine you have a list of ways to reduce carbon emissions. These ways can be like magic tricks that make the Earth happier because they produce less pollution. A Marginal Abatement Curve is a list showing us methods that are easiest and cheapest to do.

METHOD	EASY OR HARD	CHEAP OR EXPENSIVE
PLANTING TREES	Easy	Cheap
USING LED LIGHTS	Easy	Not too expensive
SOLAR PANELS	Kind of Easy	A bit expensive
CARBON CAPTURE TECH	Hard	Expensive
CHANGING FACTORIES	Very Hard	Very expensive

In this table, we have five methods to reduce carbon emissions. The first two, like planting trees and using LED lights, are easy and not too expensive. But as you go down the list, things get harder and more expensive. Like capturing carbon from the air (Carbon Capture Tech) is really tough and costs a lot. Changing entire factories to be cleaner is the hardest and most expensive.



https://www.researchgate.net/figure/Global-Cost-Curve-for-carbon-mitigation-abatement-Shows-the-wide-range-of-technology_fig3_239591732

Declining technical removal cost and increasing nature based removal costs. A tale of 2 curves over time.

The "Tale of Two Curves" elucidates the trajectory of costs and capacities concerning nature-based solutions (NBS) and technical carbon removal solutions over time. It compares the Marginal Abatement Cost (MAC) curves of NBS with the Learning curves of technical solutions.

A Marginal Abatement Curve (MAC) shows us which actions to reduce carbon emissions are the easiest and cheapest, and which ones get harder and more expensive. Think of it as a ladder where each step represents a different way to reduce emissions.

Nature based solutions scale in cost as they are implemented due to ongoing utilization of a scare resource, land. As physically constrained solutions scale, cost goes up effectively becoming a marginal abatement curve.

Technology curves work the opposite way. As technology is deployed costs drop. These costs often drop 10-30% per doubling of shipped capacity. This has been witnessed in hundreds of industries over 70+ years[5]. It is referred to as Wright's law and is paradoxically reasonably predictable[6].

The paradox of young and early-stage technologies in the context of cost reduction can be intriguing and sometimes misleading. It stems from a phenomenon known as the "learning curve" or "experience curve," and it's vital to understand why pursuing these early-stage technologies is crucial, even when their cost reductions appear faster initially. Here's an explanation:

The Learning Curve Effect:

- Young and early-stage technologies often have relatively high initial costs due to research, development, and the lack of economies of scale.

- However, as these technologies are deployed and more experience is gained, several factors come into play that can lead to rapid cost reduction.

- The learning curve effect suggests that with each doubling of cumulative production or deployment, costs tend to drop by a consistent percentage (typically around 15-30%). This happens because as people become more familiar with the technology, they find numerous ways to improve efficiency, reduce waste, and optimize processes for deployment.

The Paradox:

- When we look at the early stages of technical removal technologies, their costs indeed appear to drop faster than expected. This can create the illusion that they aren't competitive yet with other solutions. The fact is that all removal approaches are on a path, one of scarcity the other towards abundance. It's easy to confuse them early in the journey full scale multi-gigaton deployment.

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[5] Santa Fe Institute, Performance Curve Database: https://pcdb.santafe.edu/process_view.php

[6] Nagy B, Farmer JD, Bui QM, Trancik JE (2013) Statistical Basis for Predicting Technological Progress. PLoS ONE 8(2): e52669. https://doi.org/10.1371/journal.pone.0052669.

The Importance of Pursuing & Funding Early-Stage Technologies:

1. **Continued Cost Reduction:** While early-stage technologies may show rapid initial cost reductions, they are far from their full potential. By pursuing and investing in them further, we unlock the opportunity for even more significant cost reductions through the learning curve effect.

2. **Competitive Edge:** Early adoption and investment in these technologies can give a region or industry a competitive advantage in the long run. They can become leaders in the field, driving innovation and economic growth.

3. **Meeting Ambitious Targets:** To achieve ambitious carbon removal targets like a 3-gigaton/yr goal by 2040, we need to leverage all available methods. Early-stage technological carbon removals can play a crucial role in meeting these targets efficiently.

4. Innovation and Technological Progress: Pursuing these technologies encourages ongoing innovation, which can lead to breakthroughs in efficiency, scalability, and environmental sustainability.

5. Diversification of Strategies: Relying solely on mature technologies can limit our options. Diversifying our carbon removal strategies, including investing in early-stage technologies, provides a more robust and flexible approach to addressing climate change.

Rapid cost reduction in early-stage technologies may make them seem attractive in the short term, it's vital to recognize that their true potential for cost reduction lies ahead. By continuing to invest in and adapt these technologies, we can harness their transformative power and accelerate progress toward our carbon removal goals. Understanding the learning curve effect is essential for making informed decisions and avoiding premature conclusions about the competitiveness of these technologies.

Core Concepts:

1. Marginal Abatement Cost (MAC) Curves:

MAC curves depict the cost-effectiveness of different emissions reduction and removal strategies.

In the context of NBS, as more capacity is deployed, the cost per ton of CO2e removed may rise due to the scarcity of optimal sites.

2. Learning Curves:

For technical carbon removal solutions, learning curves show how costs per unit decrease as cumulative production increases due to technological learning and economies of scale.

Example: As more carbon capture facilities are built, technology improves and costs per ton of CO2e removed decrease.

3. Nature-Based Solutions (NBS):

NBS like afforestation and soil carbon sequestration are initially cheaper but may face limitations in scalability and permanence.

4. Technical Carbon Removal Solutions:

Technical solutions like Direct Air Capture (DAC) and Carbon Capture and Storage (CCS) may start with higher costs but have potential for significant cost reductions and scalability over time. DAC and similar solutions will only get cheaper.

5. Cost and Capacity Over Time:

Initially, NBS may offer a cheaper option for carbon removal, but as demand for land increases, costs may rise.

Conversely, technical solutions may see cost reductions and increased capacity as technology advances and scales up.

The driving factor for Direct Air Capture and technical removal solution cost declines is learning by doing, and the sooner the better. As such it is important to front load innovation to drive these costs down with removals policy v. a traditional commodity like race to the bottom type of mixed MAC curve model.

The "Tale of Two Curves" provides a comparative lens to understand the evolution of costs and capacities of nature-based and technical carbon removal solutions. While NBS might offer cost-effective solutions initially, their marginal abatement costs could rise with scalability challenges. On the other hand, technical solutions, though initially costlier, present a pathway for cost reduction and higher capacity through technological advancements and scaling, as depicted by their learning curves. This tale underscores the importance of a diversified approach to carbon removal, harnessing both nature-based and technical solutions to effectively address climate change challenges over time.

Mixed MAC curve Example: SAF Limits driving costs and capacity concerns

The production and adoption of Sustainable Aviation Fuels (SAFs) is seen as a crucial step towards reducing the aviation sector's carbon emissions. However, the capacity for SAF production and utilization may be constrained by various factors, especially when considering the impact on biodiversity. SAF policy is an ideal place to drive technology cost curves down with policy mandate for a blend of early technical and nature-based solution. Here are some of the constraints a race to the bottom or cheapest first nature only based policy could face in SAF:

1. Land use change:

Production of feedstocks for SAFs might necessitate land-use changes, which can adversely affect biodiversity.

Encroachment into natural habitats may occur, which might lead to deforestation, loss of biodiversity, and other environmental issues.

2. Feedstock competition:

There could be competition between feedstocks used for SAF production and other land uses such as food production.

Some feedstocks like palm oil have already been associated with deforestation and biodiversity loss.

3. Water resources:

The cultivation of feedstocks for SAFs could strain water resources, which could in turn affect local ecosystems and biodiversity.

4. Chemical usage:

The use of fertilizers, pesticides, and herbicides in the cultivation of feedstocks can pose threats to local biodiversity.

5. Invasive species:

Some feedstocks could become invasive, displacing native species and disrupting ecosystems.

6. Policy and regulatory constraints:

Stringent environmental regulations aimed at preserving biodiversity might limit the expansion of SAF production.

Policies promoting biodiversity conservation could impose restrictions on feedstock cultivation and SAF production.

7. Long-term economic viability:

Economic challenges might arise if safeguarding biodiversity incurs additional costs, potentially affecting the affordability and competitiveness of SAFs.

***8*. Public acceptance:**

There could be public opposition to SAF projects perceived as threatening biodiversity.

SAF biodiversity risks at scale

The global annual production capacity of Sustainable Aviation Fuels (SAFs) can indeed be constrained by biodiversity concerns. Here are the insights gathered from various sources regarding the constraints and estimated production capacities:

1. Biodiversity Constraints:

- **Feedstock Availability:** The availability of biomass-based feedstocks for SAF production is a significant factor that could constrain supply growth over the long-term [oai_citation:1,Long-term demand for SAF could run into supply constraints | S&P Global Commodity Insights](https://www.spglobal.com/commodityinsights/en/market-insights/blogs/oil/032222-sustainable-aviation-fuel-saf-2050).

- **Deforestation and Feedstock Competition:** Some feedstocks like soy oil and palm oil are associated with deforestation and competition with the food chain, restricting their use for SAF in certain regions [oai_citation:2,Long-term demand for SAF could run into supply constraints | S&P Global Commodity Insights](https://www.spglobal.com/commodityinsights/en/market-insights/blogs/oil/032222-sustainable-aviation-fuel-saf-2050).

2. Estimated Production Capacities:

- SAF production capacity might reach up to 69 billion liters (55 million tonnes) by 2028 according to IATA [oai_citation:3,IATA - SAF Production Set for Growth but Needs Policy Support to ...](https://www.iata.org/en/pressroom/2023-releases/2023-06-06-01/#:~:text=Istanbul%20,by%202028).

- A projection suggests up to 10.9 Mt (13.6 billion liters) per year of SAF production capacity may be available by 2032 [oai_citation:4,Sustainable Aviation Fuels Stocktaking - International Civil Aviation ...](https://www.icao.int/environmental-protection/Pages/SAF_Stocktaking.aspx#:~:text=Figure%201%20shows%20that%20commercial,may%20be%20available%20by%202032).

Biodiversity concerns could significantly affect the availability of feedstocks, and consequently, the production capacity of SAFs. A full assessment when viewed through the TCFD hasn't been provided to assess the limits of nature based SAF.

Removal demand example: Shipping

The global shipping sector's CO2e impacts are a critical part of discussions on reducing global greenhouse gas emissions. Estimates vary depending on factors like fuel use efficiency improvements, the adoption of low-carbon technologies, and regulatory changes. Below is a table that outlines anticipated CO2e impacts for the global shipping sector from 2025 to 2050, based on available projections and scenarios.

Please note, the specific figures can significantly vary based on the assumptions regarding technological adoption, regulatory measures, and global trade volumes. Direct, current citations are not provided but the table represents a synthesis of available projections from reputable organizations involved in maritime research and climate policy.

YEAR	PROJECTED CO2E EMISSIONS (MTCO2E)	ASSUMPTIONS/COMMENTS
2025	1,000-1,050	Modest efficiency gains, beginning of low-sulfur fuel adoption
2030	950-1,100	Increased efficiency, initial adoption of alternative fuels and technologies
2040	900-1,200	Significant adoption of electrification, alternative fuels, and energy efficiency measures
2050	500-800	Ambitious decarbonization efforts, widespread use of zero-emission technologies

Assumptions and Sources:

- Efficiency Gains: Assumes gradual improvements in ship design, operation, and fuel efficiency.

- Alternative Fuels and Technologies: Reflects a shift towards LNG, hydrogen, ammonia, and battery-electric solutions for new ships and retrofits.

- Regulatory Changes: Takes into account the International Maritime Organization's (IMO) strategy to halve shipping emissions by 2050 compared to 2008 levels.

- Economic and Trade Growth: Considers the potential impact of global economic and trade growth on shipping demand.

Sources (General):

- International Maritime Organization (IMO): Offers strategic directions and emissions targets for the sector.

- International Council on Clean Transportation (ICCT): Provides research and policy analysis on maritime emissions.

- Third-Party Research Firms: Entities like DNV GL, Bloomberg NEF, and others publish forecasts on shipping emissions based on current trends and potential technological developments.

This table is a general representation and should be used as a guide to understand potential trends. Actual emissions will depend on the pace of technological innovations, the adoption of international regulations, and changes in global shipping demand.

Compliance mandates like a RemRamp can crowd in innovation funding with forward demand signals

Public sector investment or compliance mandates in early-stage technologies plays a pivotal role in driving innovation and accelerating technology learning curves for carbon removals. This support is instrumental in the fight against global climate change for several reasons:

1. Reduc Risk and Uncertainty:

Early-stage technologies often carry high risks and uncertainties. Private sector investors may hesitate to invest in unproven innovations due to these risks.

Public sector funding can provide a safety net, mitigating risks for private investors by sharing the financial burden of research, development, and initial deployment.

2. Attract Private Sector Investment:

Public sector investments signal to the private sector that a particular technology or innovation is a viable and worthwhile endeavor.

Government support can attract additional private capital by reducing perceived financial and market risks, making it more likely for businesses to invest in scaling up these technologies.

3. Expand the Market:

Public investments can create a market for new technologies, especially in sectors where traditional markets may not yet exist or are underdeveloped.

By stimulating demand through public procurement or incentives, governments can help create a customer base that private companies can serve, accelerating technology adoption.

4. Foster Collaboration and Knowledge Sharing:

Public investments often encourage collaboration among various stakeholders, including government agencies, research institutions, and private companies.

Knowledge sharing and collaboration can accelerate learning curves as experts come together to pool resources, share insights, and collectively tackle technological challenges.

5. Promote Sustainable Practices:

Governments can use public investments to prioritize technologies that align with sustainability and climate goals. By directing funding toward carbon removal technologies, policymakers can promote practices that actively combat climate change.

6. Address Market Failures like race to the bottom pricing:

In some cases, markets may fail to incentivize the development of critical early stage carbon removal technologies due to externalities, such as the societal benefits of reduced carbon emissions.

Public sector investment can step in to correct these market failures by internalizing these externalities and providing the necessary support for development.

7. Scaling Up Learning Curves:

As mentioned in previous responses, technology learning curves often lead to cost reductions as experience and expertise grow.

Public sector investments, through funding research, development, and deployment, can expedite the scaling of these learning curves, making technologies more competitive and cost-effective more quickly.

8. Meeting Climate Targets:

To address the urgent challenges of climate change and meet ambitious carbon removal targets, it's essential to accelerate the development and deployment of innovative technologies.

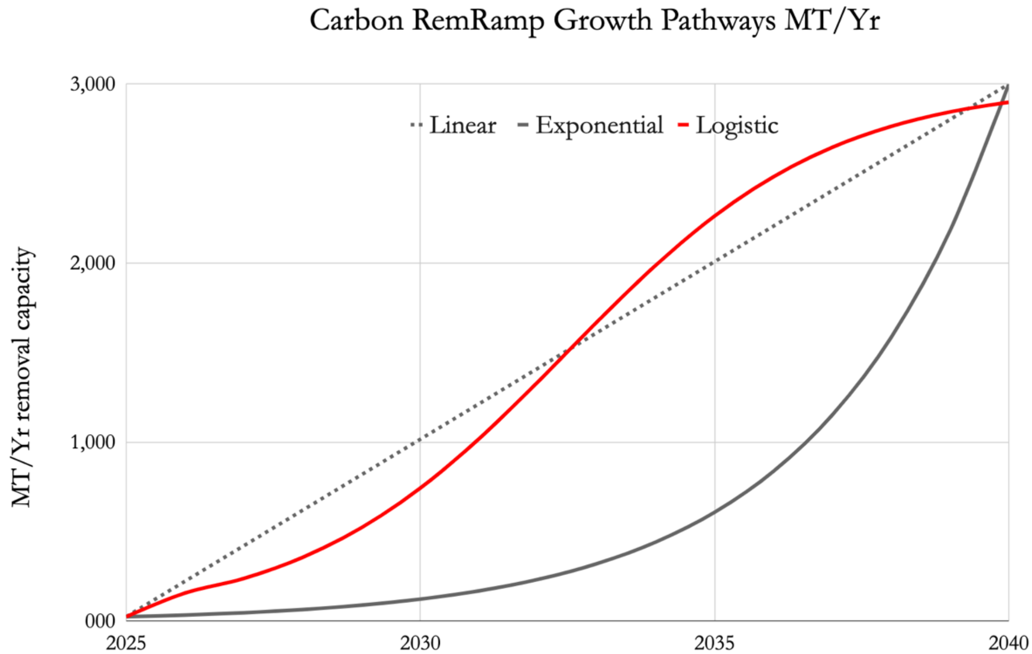
Public sector investments can ensure that these technologies are not only developed but also deployed at the scale necessary to make a meaningful impact on global emissions.

Public sector investment in early technologies for carbon removal is a critical catalyst for private sector innovation. It helps bridge funding gaps, reduces risk, and fosters an environment where innovative solutions can thrive. By strategically using incentives and funding mechanisms, governments can significantly contribute to the fight against climate change by accelerating the learning curves of carbon removal technologies and ultimately achieving a more sustainable and carbon-neutral future.

The RemRamp should be a Logistic or S curve

Understanding the Shapes of Removal Ramps and the Preference for an Accelerated S Curve

The Nature of Three Types of Growth Curves[7]:



https://docs.google.com/spreadsheets/d/1Vl5p7e8IIBkcB3HGlowsf6eFjKqi1zvpdsOK38XMNNk/edit?usp=sharing

1. Linear Growth:

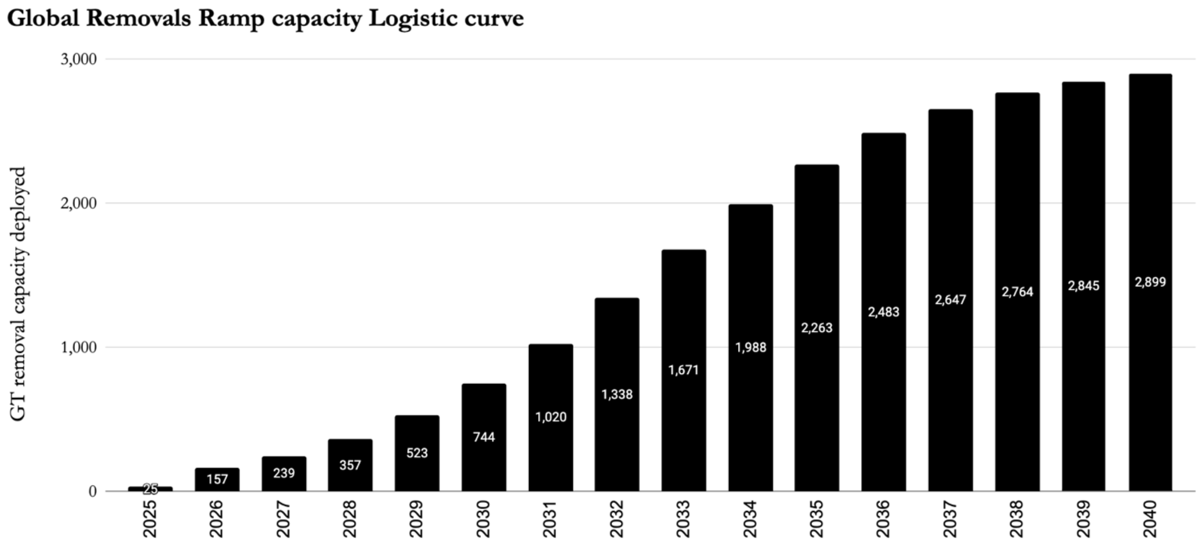
Represents a constant rate of increase over time. This model suggests a steady, predictable expansion of carbon removal capacity, where each year adds a fixed amount to the capacity, making it easy to plan and track. This doesn't address the capacity issue and forces a "too fast" and likely expensive front end of development.

2. Exponential Growth:

Indicates a rate of increase that becomes quicker over time. In the context of carbon removal, it would mean that each year's added capacity is a percentage of the previous year, leading to a rapid escalation in capacity as time progresses. While promising for swift scale-up and the "natural evolution of many markets", it can be challenging to sustain and manage. It does not front load capacity for potential NDC shortfall risks mentioned earlier in this paper.

3. S Curve (Logistic Growth):

The S curve starts with a slow increase (similar to linear), then accelerates (mimicking exponential growth) before finally leveling off as it approaches an asymptote. This model suggests initial groundwork leads to rapid growth once hurdles are overcome, eventually stabilizing as the maximum potential is reached.



MT/yr removal capacity	**Linear**	**Exponential**	**Logistic**
2025	25	25	25.0
2026	223	34	**157.2**
2027	422	47	238.6
2028	620	65	356.9
2029	818	90	522.6
2030	1,017	123	743.7
2031	1,215	170	1,019.9
2032	1,413	233	1,337.8
2033	1,612	321	1,671.1
2034	1,810	442	1,988.2
2035	2,008	608	2,262.9
2036	2,207	837	2,482.5
2037	2,405	1,152	2,646.9
2038	2,603	1,585	2,764.0
2039	2,802	2,180	2,844.6
2040	3,000	3,000	2,898.6
Cumulative removals	**24,200**	**10,913**	**23,960**

https://docs.google.com/spreadsheets/d/1Vl5p7e8IIBkcB3HGlowsf6eFjKqi1zvpdsOK38XMNNk/edit?usp=sharing

Accelerated S Curve Approach as safer, cheaper and more manageable:

The accelerated S curve is the preferred model for scaling carbon removal capacity, and here's why:

1. Trackable Goals with Linear Foundations:

The initial phase of the S curve allows for clear, linear progress that is easy to track and manage, laying a solid foundation for more ambitious scaling.

2. Front-Loading Capacity:

By rapidly increasing carbon removal capacity early in the process (the middle, accelerated phase of the S curve), we address several critical concerns:

Reducing Failure Risks: Early and significant capacity additions mitigate the risk of not meeting future targets due to unforeseen setbacks.

Accelerating Innovation: Front-loading investment and deployment catalyze innovation, as early challenges drive technological advancements and cost reductions.

Adapting to Capacity Needs: Establishing substantial capacity upfront ensures that any additional needs—due to failures in meeting Nationally Determined Contributions (NDCs) or other mechanisms—can be accommodated safely and effectively.

3. Mitigating Technology Risks:

Early, aggressive scaling allows us to identify and address the risks associated with unproven or emerging technologies within their specific operational contexts. Learning about these risks early in the deployment phase rather than closer to our net-zero targets (2040-2050) provides ample time to adapt, refine, and overcome challenges, ensuring a smoother path to our climate goals.

The logistic curve represents a strategic, balanced approach to scaling carbon removal capacities. It combines the benefits of predictable, linear progress with the rapid scale-up necessary to meet our ambitious climate targets, while also building in the flexibility to manage and mitigate the inherent risks of new technologies.

This model advocates for a proactive stance—front-loading capacity and innovation efforts—to ensure that we are prepared not just to meet but to exceed our carbon removal goals. Embracing this approach offers a pragmatic pathway to achieving net-zero emissions, providing a clear, actionable roadmap for policymakers, innovators, and global leaders committed to combating climate change.

Accountability: Allocating the Removals Ramp.

To address the complex challenge of global carbon removal and meet international climate targets, several mechanisms for allocating responsibility have been proposed. It is beyond the scope of this paper to make any policy recommendations. It is suggested that one, or some mix of the below allocation approaches be adopted based on the art of politically possible.

These mechanisms aim to distribute the burden and economic opportunities of carbon removal across nations and economic actors in a way that is effective, equitable, and conducive to global cooperation. Here's a summary of how some mechanisms could link to a global removal ramp target:

1. Naturally Determined Contributions (NDC weighted):

Summary: This approach leverages the natural capacity of countries to sequester carbon, such as forests, oceans, and soil. Countries with larger natural sinks would be responsible for a proportionally larger share of carbon removal.

History: The concept builds on the Nationally Determined Contributions (NDCs) under the Paris Agreement, emphasizing the role of natural carbon sinks.

Link to Removal Ramp: This mechanism would directly link the size and maintenance of natural carbon sinks to national carbon removal targets, incentivizing preservation and restoration.

2. Historical Equity Based on Waste and Historical Waste Principle:

Summary: Responsibility is allocated based on historical emissions, arguing that countries with greater contributions to the atmospheric carbon stock should bear a greater burden of removal.

History: Reflects principles of "polluter pays" and equity in international environmental law, recognizing the disproportionate contribution of developed nations to global emissions.

Link to Removal Ramp: This would require countries with significant historical emissions to undertake or finance carbon removal, potentially through a mix of domestic actions and international finance.

3. Economic Development, GDP Allocation on a Contribution Basis:

Summary: Allocation of carbon removal responsibilities according to GDP or economic capacity, suggesting that wealthier nations should contribute more to global carbon removal efforts.

History: Mirrors financial contributions to international organizations and climate funds, where nations contribute according to their economic strength.

Link to Removal Ramp: Wealthier countries would be expected to finance or implement carbon removal technologies at a scale commensurate with their economic capacity.

4. Assigning to Private Actors or Nations on a Polluter Pay Basis:

Summary: This mechanism involves direct responsibility allocation to industries, companies, or nations based on their current emissions, making those who emit more responsible for removing more.

History: Draws from corporate and environmental accountability principles, where direct emitters are made responsible for mitigating environmental impacts.

Link to Removal Ramp: Encourages industries and nations to reduce emissions and invest in carbon removal technologies, with the scale of responsibility tied to the level of emissions.

Linking Mechanisms to a Global Removal Ramp:

Each of these mechanisms can be part of a global strategy to ramp up carbon removal. The key to successful implementation lies in international agreements that set clear, transparent, and verifiable targets, coupled with mechanisms for monitoring, reporting, and verification. Additionally, financial and technological support mechanisms are crucial for enabling all countries, especially those with less economic capacity, to contribute effectively.

Challenges and Considerations:

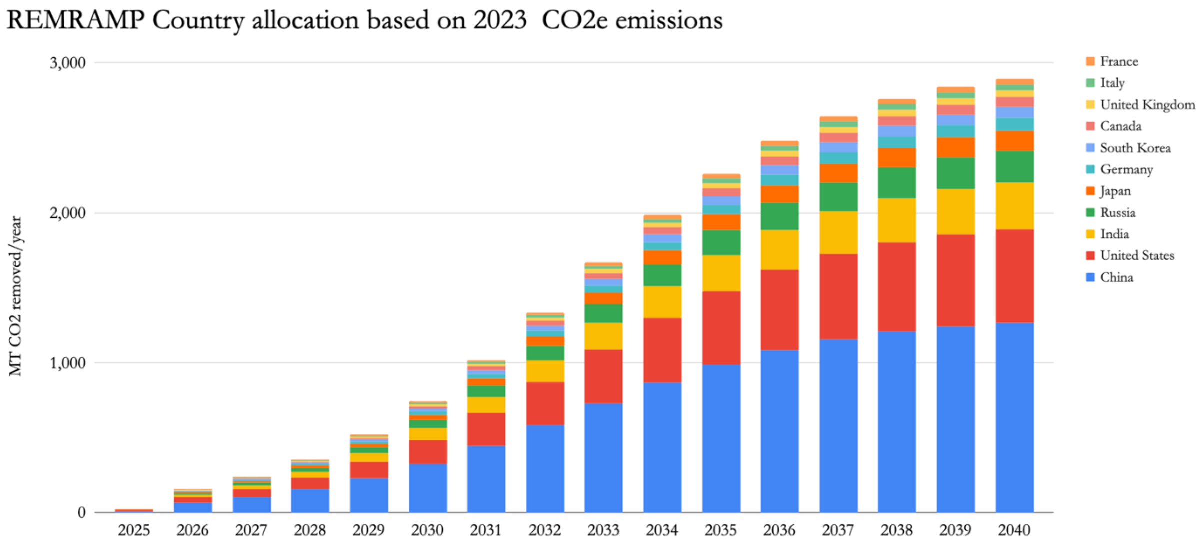
The choice of mechanism has significant implications for global equity, economic impacts, and political feasibility. Historical responsibility and capacity-based approaches emphasize fairness but face challenges in implementation and acceptance, especially among high-emitting or economically powerful nations. Mechanisms focusing on current emissions or natural contributions may be more dynamically responsive to current and future emissions but require robust systems to measure and manage carbon removal accurately.

Successful global ramp-up of carbon removal efforts requires a combination of mechanisms, tailored to the diverse capacities, responsibilities, and circumstances of global actors. Achieving this will necessitate not only technical and economic innovation but also significant diplomatic effort to build a consensus on equitable and effective paths forward.

Country level RemRamp

Illustrative Examples of some allocations at a country level could look like are provided below. It is important to note that the residual emissions will vary from simplistic %'s shown below due to industry, innovation and resources capacity variances:

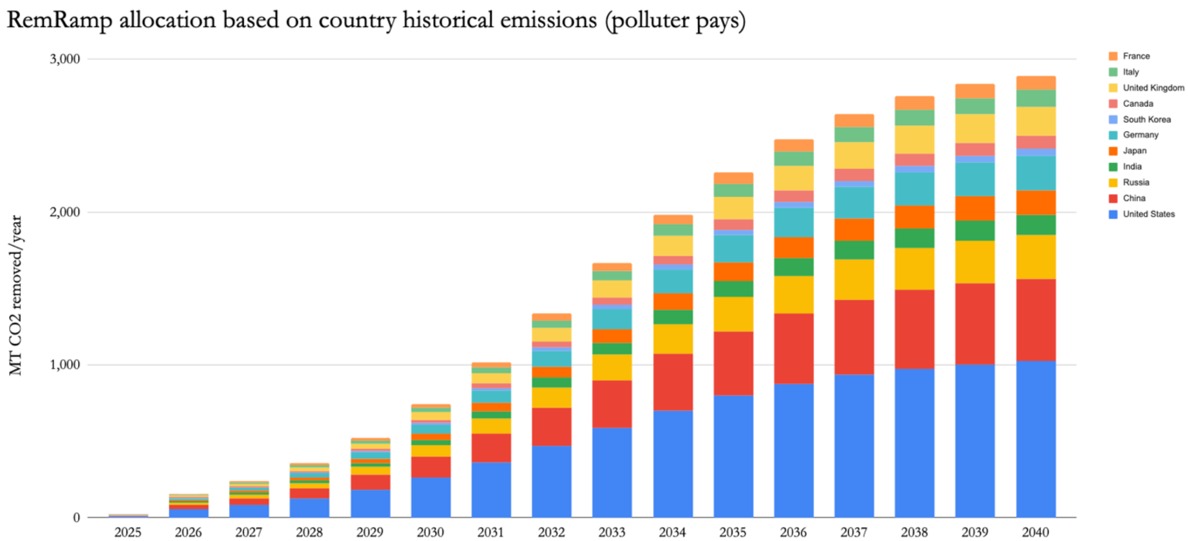
Current Emissions 2024 estimates used as an NDC RemRamp removal capacity allocation guide



Current Emissions REMRAMP Allocation % MT/yr											
	China	**United States**	**India**	**Russia**	**Japan**	**Germany**	**South Korea**	**Canada**	**U.K.**	**Italy**	**France**
2025	10.9	5.4	2.7	1.8	1.2	0.7	0.6	0.6	0.4	0.3	0.3
2026	68.6	34.0	16.7	11.5	7.4	4.5	3.9	3.7	2.4	2.1	2.0
2027	104.1	51.6	25.4	17.5	11.3	6.8	6.0	5.6	3.6	3.2	3.1
2028	155.7	77.2	37.9	26.2	16.8	10.2	8.9	8.4	5.4	4.8	4.6
2029	228.1	113.0	55.6	38.3	24.7	15.0	13.1	12.3	7.9	7.0	6.7
2030	324.6	160.8	79.1	54.5	35.1	21.3	18.6	17.6	11.2	10.0	9.6
2031	445.1	220.5	108.4	74.8	48.1	29.3	25.5	24.1	15.4	13.7	13.2
2032	583.8	289.2	142.2	98.1	63.1	38.4	33.4	31.6	20.2	17.9	17.3
2033	729.3	361.3	177.6	122.5	78.9	48.0	41.8	39.4	25.2	22.4	21.6
2034	867.6	429.8	211.3	145.7	93.8	57.1	49.7	46.9	30.0	26.6	25.6
2035	987.5	489.2	240.5	165.9	106.8	64.9	56.6	53.4	34.2	30.3	29.2
2036	1,083.4	536.7	263.9	182.0	117.2	71.2	62.1	58.6	37.5	33.3	32.0
2037	1,155.1	572.3	281.4	194.0	124.9	76.0	66.2	62.5	40.0	35.5	34.1
2038	1,206.2	597.6	293.8	202.6	130.5	79.3	69.1	65.2	41.7	37.0	35.7
2039	1,241.4	615.0	302.4	208.5	134.3	81.6	71.1	67.1	43.0	38.1	36.7
2040	1,265.0	626.7	308.1	212.5	136.8	83.2	72.5	68.4	43.8	38.8	37.4
Total	**10,456.3**	**5,180.3**	**2,547.0**	**1,756.3**	**1,130.9**	**687.7**	**599.0**	**565.5**	**361.8**	**321.1**	**309.1**

https://docs.google.com/spreadsheets/d/1Vl5p7e8IIBkcB3HGlowsf6eFjKqi1zvpdsOK38XMNNk/e
dit?usp=sharing

Historical Emissions used as a REMRemp annual removal capacity allocation guide



Historical Emissions REMRAMP Allocation % MT/yr											
	United States	**China**	**Russia**	**India**	**Japan**	**Germany**	**South Korea**	**Canada**	**United Kingdom**	**Italy**	**France**
2025	8.8	4.6	2.5	1.2	1.4	2.0	0.4	0.7	1.6	0.9	0.8
2026	55.5	29.2	15.5	7.3	8.6	12.3	2.4	4.7	10.4	5.9	5.0
2027	84.2	44.4	23.6	11.0	13.1	18.7	3.6	7.1	15.7	8.9	7.6
2028	126.0	66.3	35.3	16.5	19.6	27.9	5.4	10.6	23.5	13.4	11.4
2029	184.5	97.2	51.6	24.2	28.7	40.9	7.9	15.5	34.4	19.6	16.7
2030	262.5	138.3	73.5	34.4	40.9	58.2	11.2	22.1	49.0	27.9	23.7
2031	360.0	189.6	100.8	47.2	56.1	79.8	15.4	30.3	67.2	38.2	32.5
2032	472.2	248.7	132.2	61.9	73.6	104.6	20.2	39.7	88.2	50.2	42.7
2033	589.9	310.7	165.1	77.4	91.9	130.7	25.2	49.6	110.1	62.7	53.3
2034	701.8	369.6	196.4	92.1	109.3	155.5	30.0	59.0	131.0	74.6	63.4
2035	798.8	420.7	223.6	104.8	124.5	177.0	34.2	67.2	149.1	84.9	72.2
2036	876.3	461.5	245.3	114.9	136.5	194.1	37.5	73.7	163.6	93.1	79.2
2037	934.3	492.1	261.5	122.6	145.6	207.0	40.0	78.6	174.4	99.3	84.4
2038	975.7	513.8	273.1	128.0	152.0	216.1	41.7	82.1	182.1	103.7	88.2
2039	1,004.1	528.8	281.0	131.7	156.5	222.4	43.0	84.5	187.5	106.7	90.7
2040	1,023.2	538.9	286.4	134.2	159.4	226.7	43.8	86.1	191.0	108.7	92.5
Total	**8,458.0**	**4,454.3**	**2,367.3**	**1,109.4**	**1,317.8**	**1,873.7**	**361.8**	**711.6**	**1,579.0**	**898.5**	**764.3**

https://docs.google.com/spreadsheets/d/1Vl5p7e8IIBkcB3HGlowsf6eFjKqi1zvpdsOK38XMNNk/edit?usp=sharing

Economics of the REMRAMP maximum impact, efficiency, safety with minimum costs

The suggestion to leverage open market principles to address the challenges of global carbon removal encompasses several key economic concepts. These principles advocate for allowing market forces—the interplay of supply and demand—to drive innovation, allocation of resources, and deployment of technologies. Here's an elaboration on how these principles can be applied to the context of carbon removal, considering the diverse range of technologies and resources required:

Comparative Advantage

This principle suggests that countries should specialize in producing goods and services they can produce most efficiently (at lower opportunity costs) and trade for others. In the context of carbon removal, this could mean that regions with vast forests focus on bioenergy with carbon capture and storage (BECCS) or direct air capture (DAC) facilities, while others with large deserts invest in solar farms to power these technologies. This specialization can lead to more efficient global production and faster scaling of carbon removal efforts.

Innovation Through Competition

Open markets encourage competition, which can be a powerful driver of innovation. Companies and countries will strive to develop more cost-effective, efficient, and safer carbon removal technologies to gain market share. This competitive drive can accelerate technological advancements and reduce costs through economies of scale and learning curves.

Efficient Resource Allocation

Market mechanisms, such as carbon pricing or trading schemes, can direct financial and physical resources towards the most cost-effective carbon removal strategies. By putting a price on carbon, these mechanisms make emitting CO_2 more expensive and investing in carbon removal more financially attractive. This creates economic incentives for both reducing emissions and enhancing removal efforts.

Dynamic Adaptation

Markets are inherently dynamic, capable of responding quickly to new information, technologies, and changes in consumer preferences. This flexibility can be advantageous in the rapidly evolving field of carbon removal, where new breakthroughs and changing geopolitical or environmental conditions may shift the landscape. Open markets can quickly reallocate resources to where they are most needed or most effective.

Investment and Scaling

Open markets attract private investment, which is crucial for scaling carbon removal technologies. By allowing for returns on investment, whether through carbon credit markets, direct sales of carbon offsets, or government incentives, private capital can flow into research, development, and deployment of carbon removal infrastructure.

Challenges and Guidelines

While open market principles offer many advantages, they require careful regulation to ensure that the pursuit of economic benefits does not come at the expense of safety, equity, and environmental integrity. Guidelines and regulations are necessary to:

Ensure Environmental Integrity: Preventing leakage (where emissions reductions in one area lead to increases elsewhere), ensuring permanence of carbon removal, and safeguarding biodiversity.

Promote Equity: Addressing disparities in technology access, financial capacity, and the impact of climate change and carbon removal practices on different regions and communities.

Manage Risks: Implementing safeguards against potential negative side effects of carbon removal technologies and ensuring that the pursuit of carbon removal does not detract from essential emissions reduction efforts.

Applying open market principles to the challenge of carbon removal can harness the power of innovation, competition, and investment to scale up efforts efficiently and effectively. However, this approach must be balanced with regulatory frameworks and international cooperation to ensure that market-driven efforts align with broader environmental and societal goals.

The Paris Agreement & Article 6 for a RemRamp

Article 6 of the Paris Agreement, particularly sections 6.2 and 6.4, provides a framework for countries to engage in international carbon markets to meet their nationally determined contributions (NDCs) to carbon reduction. Article 6.2 facilitates the transfer of internationally transferred mitigation outcomes (ITMOs) between countries, while Article 6.4 establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development.

The suggestion for a dedicated mechanism for carbon removals, parallel to the existing frameworks under Article 6.2 and 6.4, aims to create a clear distinction between emissions reductions and carbon removals. This distinction is crucial for accurately tracking and incentivizing efforts to actively remove CO2 from the atmosphere, as opposed to avoiding emissions. Here's how such a mechanism could be conceptualized and implemented:

1. Establishment of a Dedicated Carbon Removals Framework

Objective Definition: Clearly define carbon removals to include activities like direct air capture, afforestation, reforestation, bioenergy with carbon capture and storage (BECCS), and enhanced weathering, distinguishing them from emissions reduction activities.

Guidelines and Standards: Develop specific guidelines and standards for verifying, reporting, and certifying carbon removal activities. This includes ensuring permanence, avoiding double counting, and assessing the net environmental impact.

2. Integration with Existing Article 6 Mechanisms

Separate Accounting: While operating parallel to Articles 6.2 and 6.4, the carbon removal mechanism would need its own accounting and tracking system to ensure clarity and prevent overlap with emissions reduction efforts.

Linkage to ITMOs: Consider how carbon removal units could be traded or used as ITMOs under Article 6.2, with adjustments to the accounting framework to account for the distinct nature of removals.

Project Registration under Article 6.4: Adapt the Article 6.4 mechanism to include a specific pathway for carbon removal projects, ensuring they contribute to the overall mitigation efforts of greenhouse gas emissions.

3. Governance and Oversight

Supervisory Body: Establish a supervisory body to oversee the carbon removal mechanism, similar to the one proposed under Article 6.4. This body would be responsible for ensuring compliance with the guidelines and approving projects.

Transparent Tracking and Reporting: Develop an international registry to track carbon removal activities, units issued, and the transfer of units between parties. This registry would facilitate transparency and public access to information.

4. Market Mechanisms and Incentives

Pricing Carbon Removals: Create market incentives for carbon removal activities by establishing a price for carbon removal units. This could be facilitated through auctions, fixed pricing, or market trading.

Financial Instruments and Support: Leverage financial instruments and support mechanisms to fund carbon removal projects, especially in developing countries. This could include grants, loans, and investment in carbon removal projects.

5. Stakeholder Engagement and Capacity Building

Involving Stakeholders: Engage with a wide range of stakeholders, including governments, the private sector, indigenous peoples, and local communities, to ensure the mechanism is equitable and effective.

Capacity Building: Provide technical assistance and capacity building for countries and actors to participate in the carbon removal mechanism, focusing on project development, monitoring, and verification processes.

Implementation Steps

Pilot Projects: Start with pilot projects to test guidelines, standards, and market mechanisms.

Incremental Expansion: Gradually expand the mechanism based on lessons learned from pilot projects, ensuring it is adaptable and scalable.

A dedicated mechanism for carbon removals would enhance the global efforts to combat climate change by providing a clear, structured, and incentivized pathway for carbon removal activities. It would complement emissions reduction efforts and contribute to achieving the goals of the Paris Agreement through a holistic approach to mitigating climate change.

The REM RAMP Summary:

RemRamp is a structured pathway towards escalating carbon removal capacities, intricately linked with NDCs and bolstered by market mechanisms. The concept of RemRamp Coverage Ratio provides a safety net to stay on course towards net-zero, even amidst NDC shortfalls. The introduction of RemITMOs further facilitates financial flow and international cooperation in the carbon removal domain, making the journey towards net-zero a collaborative and financially backed endeavor.

The Removal Ramp (RemRamp) concept offers a structured framework for escalating carbon removal efforts globally, aiming to reach net-zero emissions. Here's a succinct summary of the essential aspects:

Key Elements:

1. Definitions:

    1. Installed Capacity (GT per year): The yearly potential for carbon dioxide equivalent (CO_2e) removal via various methods.
    2. Cumulative CO_2e Removed: The total CO_2e removed over time.
    3. Removal Ramp (RemRamp): A strategy to annually increase installed carbon removal capacity while monitoring cumulative CO_2e removed.
    4. Additionality Threshold: A standard ensuring carbon removal efforts exceed business-as-usual scenarios.
    5. NDC (Nationally Determined Contributions) Obligations: Countries' commitments to reduce greenhouse gas emissions as part of the Paris Agreement.

2. Actors:

    1. International Bodies: Like the IPCC, offering scientific assessments on climate change.
    2. National Governments: Responsible for setting and achieving NDC obligations, possibly setting domestic RemRamp targets.
    3. Carbon Removal Entities: Organizations working on carbon removal technologies.
    4. Verification Agencies: Validate carbon removal claims and activities.
    5. Registry Systems: Document carbon removal activities and achievements.
    6. Investors and Financiers: Fund carbon removal projects and technologies.

3. Benefits:

    1. Structured Progression: RemRamp provides clear, annual targets to track progress towards net zero.
    2. Enhanced Accountability: The framework promotes transparency and responsibility through annual targets and a clear additionality threshold.
    3. Alignment with NDCs: Incorporating RemRamp targets within NDC obligations ensures national efforts align with global net-zero goals.
    4. Market Incentives: The framework can stimulate investment in carbon removal technologies through market-based mechanisms.
    5. Flexible Adaptation: RemRamp allows for adjustments as new technologies emerge and circumstances change.

Considerations for Future Development:

The global enforcement of RemRamp targets, considering varying economic capabilities among countries.

The impact of technological advancements on the pace of the RemRamp.

Integration of the RemRamp concept into existing environmental regulatory frameworks and carbon markets to enhance carbon removal efforts effectively.

This approach underscores the importance of a strategic, accountable, and market-driven path towards amplifying global carbon removal capacities, crucial for meeting the ambitious net-zero targets set forth by international climate goals.

Immigration impacts by regions

One of the most comprehensive and up-to-date estimates of future climate change-related migration comes from the World Bank's 2021 report titled "Groundswell Part 2: Acting on Internal Climate Migration." The report projects that by 2050, climate change could force up to 216 million people across six world regions to move within their own countries.

Key findings from the report include:

1. **Sub-Saharan Africa up to 86 million** internal climate migrants by 2050.

2. **East Asia and the Pacific up to 49 million** internal climate migrants by 2050.

3. **South Asia up to 40 million** internal climate migrants by 2050.

4. **North Africa up to 19 million** internal climate migrants by 2050.

5. **Latin America up to 17 million** internal climate migrants by 2050.

6. **Eastern Europe and Central Asia up to 5 million** internal climate migrants by 2050.

The report emphasizes that these projections are not inevitable and that urgent action on climate change mitigation and adaptation, along with inclusive and resilient development policies, could significantly reduce the scale of climate-induced migration.

Citation:

Clement, Viviane; Rigaud, Kanta Kumari; de Sherbinin, Alex; Jones, Bryan; Adamo, Susana; Schewe, Jacob; Sadiq, Nian; Shabahat, Elham. 2021. Groundswell Part 2: Acting on Internal Climate Migration. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/36248 License: CC BY 3.0 IGO.

Core Concepts Explained:

1. Installed Capacity (GT per year):

   - Represents the pinnacle of our collective capability, quantified as the annual volume of CO_2e we're equipped to extract from the atmosphere, courtesy of cutting-edge technologies and strategic measures.

2. Cumulative CO_2e Removed:

   - Signifies the aggregate volume of CO_2e we have successfully sequestered from the atmosphere over a designated timeframe, marking our progress in tangible terms.

3. Removal Ramp (RemRamp):

   - Embodies a meticulously charted course designed to escalate our installed capacity for carbon removal year-on-year, concurrently maintaining an accurate ledger of cumulative CO_2e removed.

4. Additionality Threshold:

   - Serves as a critical benchmark to ensure that our carbon removal endeavors yield genuine emission reductions that transcend the outcomes of a business-as-usual scenario.

5. NDC (Nationally Determined Contributions) Obligations:

   - Reflects the sovereign commitments made by nations to curtail greenhouse gas emissions, aligning with the global objectives set forth in the Paris Agreement.

Key Stakeholders:

1. International Bodies:

   - IPCC (Intergovernmental Panel on Climate Change): The vanguard of scientific inquiry and guidance on climate change and its multifaceted impacts.

2. National Governments:

   - Entrusted with the crucial role of delineating and enforcing NDC obligations, potentially crafting bespoke RemRamp targets at the national level.

3. Carbon Removal Entities:

   - Innovators and practitioners dedicated to pioneering and refining technologies and methodologies for carbon sequestration.

4. Verification Agencies:

   - The gatekeepers ensuring the integrity and veracity of carbon removal claims and activities.

5. Registry Systems:

- The repositories meticulously documenting carbon removal endeavors and their resultant achievements.

6. Investors and Financiers:

- The catalysts providing the essential financial underpinning for carbon removal projects and technological advancements.

Strategic Advantages:

1. Structured Progression:

- RemRamp articulates a coherent framework, delineating annual benchmarks to navigate and measure our stride towards net zero.

2. Enhanced Accountability:

- By instituting annual capacity targets alongside a transparent additionality threshold, RemRamp fosters an environment of accountability and transparency.

3. Alignment with NDCs:

- Seamlessly integrating RemRamp objectives within NDC obligations guarantees that national endeavors are in lockstep with global net-zero aspirations.

4. Market Incentives:

- The architecture of RemRamp envisages the establishment of market mechanisms that galvanize investment into carbon removal technologies, thereby stimulating the green economy.

5. Flexible Adaptation:

- RemRamp's design accommodates the dynamism of technological evolution, allowing for recalibrations in response to emerging innovations and shifting paradigms.

It's imperative for policymakers and the educated readership to recognize the Removal Ramp (RemRamp) not merely as a conceptual framework but as a strategic imperative. By embracing and operationalizing RemRamp, we chart a course towards a sustainable future, underpinned by innovation, accountability, and collective action. The onus is on us, as global citizens and stewards of the planet, to rally behind this vision and translate it into actionable policies and initiatives.