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Challenging IPCC Orthodoxy: CO2 Residence Time and the Temperature-Driven Carbon Cycle

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) Working Group 1 (WG1) does not engage with the substantial body of peer-reviewed literature on CO_2 residence time, despite its relevance to carbon cycle dynamics. It favors an uncited glossary definition of "turnover time" and the concept of adjustment time. This article argues that this omission overlooks a significant body of research, introduces a non-empirical framework, and challenges the IPCC's claim of providing a comprehensive scientific synthesis. Koutsoyiannis (2024), the most recent and pivotal study, employs a refined reservoir routing (RRR) framework to estimate CO_2 residence time at 3.5–4 years and demonstrates that temperature-driven biosphere expansion, not anthropogenic emissions, primarily increases atmospheric CO_2. Supported by Koutsoyiannis's earlier works and Stallinga (2023), these findings challenge the IPCC's assumptions and the Bern model, suggesting a fundamental misrepresentation of carbon cycle dynamics in mainstream climate science.

Keywords: global warming; climate change; global carbon dioxide modeling; atmospheric CO_2; residence time; IPCC

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1. Introduction

The IPCC AR6 WG1 report (2021) claims to encapsulate the physical science of climate change comprehensively. Yet, it notably excludes discussion or citation of peer-reviewed literature on CO_2 residence time—the average duration a CO_2 molecule remains in the atmosphere before natural sink absorption. Instead, it relies on a glossary-defined "turnover time" and an implied "adjustment time," lacking empirical substantiation. Unlike turnover time, which reflects a single cycle, and adjustment time, which models long-term equilibration, residence time is a directly observable metric grounded in empirical data. IPCC's omission raises questions about the report's scientific inclusivity and accuracy. Koutsoyiannis (2024), the latest and most significant contribution to this field, uses a refined reservoir routing (RRR) framework to estimate a residence time of 3.5–4 years and asserts that temperature increases drive CO_2 levels through biosphere expansion. This article critiques the IPCC's approach, emphasizing Koutsoyiannis (2024) and related studies that collectively contradict the IPCC's causal assumptions and carbon cycle models.

The debate over CO_2 residence time is not merely academic—it directly influences climate models, future atmospheric CO_2 scenarios, policy decisions, and public perceptions of anthropogenic climate impacts. By omitting residence time research, the IPCC risks presenting

* See **11. Author Contributions** below for the roles of Grok 3 beta and the human co-authors.

a skewed view of the carbon cycle, potentially overemphasizing human emissions while underestimating natural processes. This critique seeks to restore balance by highlighting empirical evidence that challenges mainstream assumptions.

CO_2 residence time measures the average atmospheric lifespan of a CO_2 molecule before removal by sinks like oceans, soils, and vegetation. The IPCC AR6 defines "turnover time" as approximately 4 years (WG1, p. 2237), aligning with residence time estimates, yet cites no supporting research. It then pivots to "adjustment time," suggesting decades to centuries for system equilibration, incorporating feedbacks without clear empirical basis. This contrasts with residence time, a directly measurable parameter central to carbon cycle dynamics.

Residence time is calculated as the average duration a CO_2 molecule remains in the atmosphere before being absorbed by natural sinks, such as oceanic uptake or terrestrial photosynthesis. It is typically derived from isotopic data (e.g., $\Delta^{14}C$ from nuclear bomb tests) or mass balance models, offering a concrete, observable metric unlike the speculative adjustment time.

The IPCC's use of "turnover time" and "adjustment time" introduces ambiguity. While turnover time aligns numerically with residence time, its lack of cited evidence is surprising. Adjustment time, meanwhile, relies on theoretical feedbacks, prioritizing model outputs over empirical data and potentially exaggerating CO_2's climatic impact.

2. The IPCC's Treatment of Residence Time

The AR6 WG1 report neither defines nor discusses CO_2 residence time explicitly, omitting references to its extensive literature. This gap is conspicuous given residence time's relevance to carbon cycling and climate projections, suggesting a selective portrayal of scientific evidence.

Despite the availability of numerous peer-reviewed studies on residence time prior to AR6's publication—such as Harde (2017), Essenhigh (2009), Segalstad (1998), and Berry (2019)—the IPCC fails to engage with this body of work. This exclusion is particularly problematic given the IPCC's claim to synthesize all relevant climate science.

By sidelining residence time, the IPCC risks undermining its credibility as a comprehensive scientific authority. This selective curation suggests a preference for model-driven narratives over empirical evidence, potentially skewing climate projections and policy recommendations.

3. Peer-Reviewed Literature on Residence Time

A robust body of peer-reviewed research provides consistent residence time estimates, typically 4–5 years, derived from empirical data and modeling. These studies, listed in the references, collectively challenge the IPCC's assumptions about carbon cycle dynamics. Koutsoyiannis (2024) builds on earlier work, providing new evidence and a new methodology that challenges the IPCC framework. Koutsoyiannis (2024) notes:

> *"More recently, several studies have corroborated Starr's results by independent analyses. These have been produced by Berry; Harde, either alone or in collaboration with Salby... and Stallinga. On the other hand, Andrews disputed these studies, claiming that they are mistaken and that his analysis 'confirms the prediction of a conventional model of the carbon cycle', but* ***without providing any calculation to show that****."* [emphasis added]

This body of work, including contributions from Berry, Harde, Salby, and Stallinga, reinforces the empirical foundation for short residence times, while the lack of substantiation of the critique in Andrews (2020) underscores the robustness of these findings.

Table 1 shows several studies that provide a consistent estimate of CO_2 residence time and several of which were published well prior to the 2021 publication of IPCC AR6's Working Group I report.

Table 1. CO_2 Residence Times

Study	Residence Time (Years)	Methodology
Koutsoyiannis (2024)	3.5–4	Refined Reservoir Routing (RRR)
Stallinga (2023)	5	Two-box model of carbon flow
Berry (2019)	~5	Simple physics model of carbon cycle
Harde (2017)	4–5	Isotopic analysis, flux data
Essenhigh (2009)	4–5	Chemical kinetics, atmospheric data
Segalstad (1998)	~5	Carbon isotopic data
Star (1993)	4–5	Continuum concept

Table 1. Studies estimating CO_2 residence time, many published before AR6 (2021), highlighting their availability for inclusion. The data here underscores the convergence of evidence, strengthening the case for a short residence time. IPCC AR6 uses a number of 4 years without any citation.

4. Koutsoyiannis (2024): A Paradigm Shift in CO2 Dynamics

Koutsoyiannis (2024) introduces a refined reservoir routing (RRR) framework, rooted in hydrology's mass balance and systems approach, to model atmospheric CO_2 dynamics. This independent analysis estimates a mean residence time of 3.5–4 years, derived from real-world data without reliance on complex climate models. The RRR framework treats the atmosphere as a reservoir with inflow (emissions), I, and outflow (sink absorption), Q, using the continuity equation:

$$\frac{dS(t)}{dt} + Q(t) = I(t)$$

and a power-law relationship:

$$Q(S) = Q_0 \left(\frac{S}{S_0}\right)^b$$

where S is the reservoir storage term. Koutsoyiannis' model applies to sublinear ($b < 1$), linear ($b = 1$), and superlinear reservoirs ($b > 1$). For linear reservoirs, the power index b is 1, and it yields an analytical solution where the characteristic residence time $W_0 = S_0 / Q_0$ approximates 4 years, validated against empirical CO_2 exchange data.

Critically, Koutsoyiannis (2024) demonstrates that atmospheric CO_2 increases result from biosphere expansion—enhanced photosynthesis and respiration—driven unidirectionally by temperature rises. The study notes that anthropogenic emissions constitute only 4% of total CO_2 inflow, dwarfed by geophysical and biospheric processes tied to temperature (e.g., water availability boosting plant CO_2 uptake). This finding aligns with isotopic $\Delta^{14}C$ data from nuclear bomb tests, showing rapid CO_2 removal (mean response time ~17.2 years, adjusted to ~4 years for total CO_2 sans fractionation effects), contradicting IPCC's centuries-long adjustment times.

Koutsoyiannis et al (2023) and Koutsoyiannis (2024b) respectively support these conclusions, using causality analysis to show temperature precedes CO_2 changes—not vice versa—and finding no significant anthropogenic signature in CO_2 sources since the Little Ice Age, attributing shifts instead to biosphere expansion. Together with Stallinga (2023), which critiques adjustment time discussed in IPCC reports as empirically unsupported, Koutsoyiannis (2024) challenges the Bern model (Joos et al., 1996) and IPCC's assumption that CO_2 drives temperature, revealing a reversed causality grounded in observable data.

4.1 Technical Details of the RRR Framework

The RRR framework models the atmosphere as a dynamic reservoir, with inflows from natural (e.g., volcanic outgassing, biosphere respiration) and anthropogenic sources, and outflows via sinks like oceanic absorption and terrestrial uptake. The power-law relationship allows for nonlinear dynamics, making the model more adaptable to real-world variability than the Bern model's linear assumptions. Validation against $\Delta^{14}C$ data ensures its empirical grounding.

Unlike the Bern model's multi-century decay curves, the RRR framework predicts rapid CO_2 turnover, aligning with isotopic evidence and simpler two-box models (e.g., Stallinga, 2023). This comparison highlights the RRR's advantage in capturing dynamic sink responses.

5. The Significance of Residence Time

A residence time of 3.5–5 years indicates that atmospheric CO_2 turns over rapidly, with natural sinks like oceans, forests, and soils absorbing CO_2 far more efficiently than the IPCC's models suggest. This short timeframe fundamentally challenges the notion of prolonged atmospheric CO_2 accumulation driving sustained global warming, a cornerstone of mainstream climate projections. The IPCC relies heavily on the Bern model, which predicts multi-century decay curves for CO_2, implying that a significant fraction persists in the atmosphere for hundreds to thousands of years. Koutsoyiannis (2024) critiques this model as physically implausible, arguing that the Bern model assumes some CO_2 persists indefinitely, an assumption Koutsoyiannis (2024) deems inconsistent with finite sink capacities.

Empirical evidence, such as the rapid decline of $\Delta^{14}C$ following nuclear bomb tests, supports this short residence time, showing that CO_2 exchanges with sinks within years, not centuries. This suggests that anthropogenic emissions may have a less enduring impact than assumed, as natural systems quickly regulate excess CO_2. Consequently, climate policies predicated on long-term CO_2 persistence may overestimate the urgency of emission cuts, diverting focus from adaptation strategies that address temperature-driven feedbacks. Recognizing this rapid turnover could shift climate science toward a more realistic assessment of carbon cycle dynamics.

5.1 Policy Implications

A short residence time has profound implications for climate policy:

- **Carbon Budgets**: Current carbon budgets assume long-term CO_2 persistence, potentially overestimating the atmospheric lifetime of emissions. A 4-year residence time suggests more flexible timelines for mitigation if any is necessary.
- **Mitigation Strategies**: Rapid turnover implies emission reductions could yield quicker atmospheric benefits, reducing the need for drastic, immediate cuts.
- **Geoengineering**: Strategies like afforestation, soil carbon sequestration, and ocean fertilization could leverage natural sinks, aligning with the evidence of rapid CO_2 absorption.

These policy shifts prioritize adaptation and nature-based solutions, complementing emission controls with practical, sink-enhancing measures.

6. The IPCC's Use of Turnover and Adjustment Time

The IPCC AR6 defines "turnover time" as approximately 4 years on p. 2237 of WG1 report, but ironically, this uncited statement of turnover time aligns with empirical residence time studies that the IPCC overlooks. This lack of transparency contrasts sharply with its heavy reliance on "adjustment time," a concept positing that CO_2's climate impacts persist for decades to centuries due to feedback loops and linear response to CO_2 pulses within the Earth system. Koutsoyiannis (2024) and Stallinga (2023) argue that this shift from a measurable, short-term metric to a speculative, long-term one lacks empirical grounding, relying instead on theoretical models like the Bern model that exaggerate CO_2's atmospheric lifetime, which are in turn used as assumptions in the CMIP6 models.

The IPCC's preference for adjustment time prioritizes model-driven assumptions over direct observations, potentially inflating the perceived severity of CO_2-driven warming. Though based on theoretical feedbacks, adjustment time lacks direct observational validation, unlike residence time. This discrepancy may distort climate impact assessments, as it overlooks the rapid sink absorption evidenced by isotopic data. A more rigorous approach would anchor turnover time in empirical studies and critically evaluate adjustment time's speculative basis, ensuring that carbon cycle representations reflect measurable realities rather than theoretical constructs. This shift is essential for aligning climate science with observable evidence.

Central to the IPCC's reliance on adjustment time is the Bern model, which has been a cornerstone in simulating carbon cycle responses. However, as detailed in the following section, modern research has exposed significant flaws in this model, challenging its continued use in climate assessments.

The concept of adjustment time assumes prolonged CO_2 impacts due to feedbacks like ocean acidification or terrestrial sink saturation. However, empirical data—such as the rapid decline of $\Delta^{14}C$—suggest these feedbacks are less significant than modeled, with sinks absorbing CO_2 efficiently within years.

7. A Modern Scientific Perspective on the Bern CO2 Model

The Bern model, developed by Joos et al. in 1996, has been a cornerstone in climate science, widely used in Intergovernmental Panel on Climate Change (IPCC) assessments to simulate how the oceans and terrestrial biosphere absorb anthropogenic CO_2. It employs impulse response functions (IRFs) derived from more complex frameworks, such as the High-Latitude Exchange/Interior Diffusion-Advection (HILDA) model—a box-diffusion model that accounts for layered ocean dynamics. These IRFs enable the Bern model to efficiently approximate carbon cycle responses to CO_2 perturbations without solving the full complexity of the underlying equations at every step. While this approach has been historically valuable for projecting atmospheric CO_2 concentrations and their climate impacts, modern research highlights significant flaws in its assumptions and structure. This section provides a detailed, scientifically grounded critique, explaining why the Bern model no longer aligns with contemporary understanding of the carbon cycle.

7.1 Structure of the Bern Model

The Bern model uses IRFs to represent the carbon cycle's response to CO_2 emissions, drawing on multi-box models like HILDA. This allows it to simulate carbon uptake by the oceans and land sinks with greater nuance than a single-reservoir approach. However, despite this sophistication, the model relies on key simplifications—most notably linearity—that limit its accuracy under varying climate conditions.

Assumption of Linearity

While the Bern model includes some nonlinearities, it fails to capture dynamic feedbacks like sink saturation. The Bern model's use of IRFs assumes that carbon cycle responses scale linearly with CO_2 perturbations, regardless of their size or timing. This overlooks the Earth's inherently nonlinear dynamics. For instance, the Revelle factor illustrates how the ocean's capacity to absorb CO_2 diminishes as concentrations rise, due to shifts in water chemistry and temperature. Such nonlinear feedbacks—along with processes like CO_2 fertilization of plants or ocean stratification—cannot be adequately captured by a linear framework, leading to potential inaccuracies in long-term CO_2 projections, especially in high-emission scenarios.

Oversimplified Carbon Sinks

Furthermore, the ocean and terrestrial biosphere are modeled with fixed exchange rates derived from earlier conditions, which fail to account for dynamic changes over time. For example, warming-induced shifts in ocean circulation (e.g., a slowing Atlantic Meridional Overturning Circulation) or the saturation of land sinks reduce uptake capacity—effects not fully reflected in the model's static IRFs. This can lead to overestimations of how long CO_2 persists in the atmosphere.

Neglect of Natural Variability and External Forcings

The Bern model focuses primarily on anthropogenic CO_2, largely ignoring natural drivers like solar variability, orbital cycles—e.g. Milankovitch cycles including decadal to centennial-scale modulation, Cionco & Soon (2017)—and temperature-driven CO_2 changes from ocean outgassing or biosphere respiration. For instance, temperature-driven ocean outgassing, linked to both solar and orbital cycles, is excluded from its framework. By sidelining these factors, it may exaggerate the role of human emissions in atmospheric CO_2 increases.

7.2 Challenges from Modern Research

Recent studies undermine the Bern model's predictions with empirical evidence and alternative approaches:

- **Residence and Adjustment Times**: The Bern model suggests CO_2 adjustment times (the duration for concentrations to re-equilibrate after a perturbation) extend over centuries, implying prolonged atmospheric persistence. However, Koutsoyiannis (2024) used a generic input-output-storage modeling method, Refined Reservoir Routing (RRR), to estimate a CO_2 residence time—the average time a molecule stays in the atmosphere—of just four years, far shorter than the model's long-tailed decay. Harde (2017) similarly calculated a short residence time using carbon cycle data. Stallinga (2023) employed a two-box model (atmosphere and ocean surface) to argue that adjustment times are even shorter than residence times, reflecting rapid CO_2 redistribution rather than slow removal. These findings challenge the Bern model's prolonged CO_2 persistence.

- **Temperature as a Driver**: The Bern model assumes anthropogenic emissions primarily drive CO_2 increases, but Salby & Harde (2021 and 2021b) and Koutsoyiannis et al. (2023) suggest temperature changes lead CO_2 shifts. They point to natural processes—like ocean outgassing during tropical warming—as dominant controls, reversing the model's causality and questioning its anthropogenic focus.

- **Isotopic Evidence**: The IPCC links declining $^{13}C/^{12}C$ ratios to fossil fuel emissions, a view the Bern model supports. Yet, Koutsoyiannis (2024b) found no significant isotopic shift since the Little Ice Age, implying natural sources may outweigh anthropogenic contributions—another discrepancy with the model's assumptions.

7.3 Detailed Analysis of Flaws

The Bern model's reliance on time-invariant IRFs assumes the carbon cycle's response remains consistent across climate states. However, warming alters sink dynamics—e.g., increased ocean stratification reduces CO_2 uptake, a nonlinear effect static IRFs miss. Additionally, by excluding external forcings like solar or orbital influences, the model risks over attributing CO_2 changes to human activity. These oversights compromise its reliability for future projections, particularly as climate conditions diverge from those used to calibrate its IRFs.

Unlike the Bern model's long-tailed decay, the RRR framework (Koutsoyiannis, 2024) and Stallinga's (2023) two-box model predict rapid CO_2 turnover.

7.4 Conclusion on the Bern Model

The Bern model, while a pioneering tool built on IRFs from complex models like HILDA, falls short under modern scrutiny. Its linear assumptions, simplified sink dynamics, and neglect of natural drivers conflict with evidence of short CO_2 residence times, temperature-driven variability, and limited isotopic shifts. Studies like Koutsoyiannis (2024), Stallinga (2023), Salby & Harde (2021 and 2021b) highlight the need for nonlinear, multi-reservoir models that better reflect the carbon cycle's complexity. Though historically significant, the Bern model's limitations now outweigh its utility, pushing climate science toward data-driven approaches for more accurate predictions.

8. The Number of Scientists Involved

Research on CO_2 residence time has been conducted by a wide ranging group of independent scientists, and boasts a robust peer-reviewed foundation that challenges the IPCC's carbon cycle narrative, which is based on Joos et al. (1996) and the Bern model. Independent contributors like Koutsoyiannis, Berry, Essenhigh, Harde, Salby, Segalstad, Starr and Stallinga have produced a consistent body of work estimating residence times at 4–5 years, yet their findings are entirely absent from the AR6 report. This exclusion is striking given the IPCC claim to represent a broad base of climate science.

Starr (1993) and Segalstad (1998), early proponents of short residence times, argued that isotopic data consistently point to a dynamic carbon cycle, a view echoed by nearly all of the non-IPCC-affiliated scientists, but ignored by the IPCC. The omission of these scientists—despite their rigorous methodologies—raises questions about IPCC's biases favoring its chosen paradigms over emerging research. This omission may miss important opportunities for broader scientific dialogue.

This selective engagement limits the diversity of scientific inquiry, potentially skewing the IPCC's conclusions toward models that amplify anthropogenic impacts. Including these voices would enrich the assessment, fostering a more pluralistic dialogue essential for scientific progress. The IPCC's failure to do so raises questions about the completeness of its literature review and the balance of its scientific synthesis.

8.1 Historical Context and the IPCC's Claim to Comprehensiveness

The work of Segalstad (1998) and Starr (1993) laid early groundwork for residence time research, using isotopic and energy balance approaches to demonstrate rapid carbon cycling. These foundational studies, combined with modern contributions, form a coherent challenge to the IPCC's narrative.

The IPCC markets itself as the definitive authority on climate science, purporting to synthesize the full breadth of relevant research. However, its Sixth Assessment Report (AR6) Working Group I (WG1), published in 2021, omits a significant body of peer-reviewed literature on CO_2 residence time—the average duration a CO_2 molecule remains in the atmosphere before natural sink absorption. Studies such as Harde (2017), Essenhigh (2009), Segalstad (1998), Berry (2019), and others, all published before 2021, provide empirical evidence for residence times of approximately 4–5 years and challenge the IPCC's assumptions about carbon cycle dynamics. These works could have been included in AR6 but were not cited, despite their relevance to the report's core conclusions about human causation of climate change. In scientific practice, it is a professional obligation to cite all relevant prior work, particularly on a topic as central as CO_2's atmospheric behavior. The exclusion of these studies, while retaining the Bern model (Joos et al., 1996), suggests a deliberate effort to control the narrative rather than an oversight, raising serious questions about the IPCC's scientific integrity.

Since AR6's publication, new studies have further exposed flaws in its carbon cycle framework. Stallinga (2023) and Koutsoyiannis (2024), published after 2021, could not have been included in AR6 due to their timing. However, they are particularly valuable as totally new contributions that have come to light since the report. Stallinga (2023), published in Entropy, critiques the IPCC's concept of adjustment time as empirically unsupported, aligning with earlier residence time estimates. Koutsoyiannis (2024), published in Water, introduces a refined reservoir routing (RRR) framework, estimating a residence time of 3.5–4 years and demonstrating that temperature-driven biosphere expansion—not anthropogenic emissions—primarily drives atmospheric CO_2 increases:

> *"The atmosphere appears to behave as a linear reservoir in terms of the atmospheric CO_2, whose exchange is clearly dominated by the biosphere processes, with human emissions playing a minor role."*

These studies build on the pre-2021 literature, reinforcing the argument that the IPCC's omission of residence time research distorts the scientific picture, compromises its claim to holistic credibility, and risks misrepresenting carbon cycle dynamics, with profound implications for climate policy.

9. Post-AR6 Developments

The emergence of Koutsoyiannis (2024), Stallinga (2023), Harde & Salby (2021), Salby & Harde (2021 and 2021b) highlights the evolving nature of residence time research. These studies, leveraging advanced methodologies like RRR and two-box modeling, provide fresh evidence that the IPCC's carbon cycle framework is outdated and in need of revision.

Some scientists argue that adjustment time accounts for complex feedbacks—such as ocean acidification or terrestrial sink saturation—that extend CO_2's climatic impact beyond its residence time. For example, Andrews (2020) claims that short residence time estimates are mistaken, asserting alignment with conventional models. However, Andrews (2020) provides no calculations to substantiate this critique, weakening its validity.

The Bern model incorporates nonlinearities like the Revelle factor, which reduces ocean CO_2 uptake as concentrations rise. Proponents may argue this justifies longer adjustment times. Yet, Koutsoyiannis (2024) and Stallinga (2023) counter that these nonlinearities are overstated, with empirical data showing rapid sink responses that the model fails to capture.

The IPCC's Sixth Assessment Report (AR6) has only one mention of the concept of residence time for CO_2 in the atmosphere on page 713:

> *"CO_2 has multiple residence times in the atmosphere – from one year to many thousands of years (Box 6.1 in Ciais et al., 2013)."*

The sole residence time mention relies on an irrelevant, non-peer-reviewed source, underscoring AR6's neglect of the literature. This lone reference is cited to a non-peer-reviewed Box 6.1 in AR5, pp. 472-473, that does not even discuss residence time. Additionally, AR6 fails to cite or explicitly address studies such as those by Berry, Harde, or Segalstad, and several others which present alternative perspectives on residence time based on observable data, including $\Delta^{14}C$ decay. The report does not provide a justification for omitting these studies, the absence of which, despite their consistency and empirical grounding, raises questions about the comprehensiveness of AR6's literature review in reflecting the full spectrum of scientific inquiry on this topic. These scientific critiques naturally extend to practical implications for climate policy.

10. Conclusion

The IPCC AR6 WG1 report's exclusion of pre-2021 CO_2 residence time literature weakens its scientific foundation. Studies, available before 2021, could have been cited but were omitted, suggesting a deliberate choice to sideline evidence of short residence times (4–5 years) that challenge the report's narrative. Post-AR6 studies published after 2021 further contradict the IPCC's adjustment time and Bern model assumptions offering fresh insights into a rapid carbon cycle driven by temperature, not emissions. The IPCC's selective approach raises serious concerns about scientific integrity, as it fails to present all relevant science on a topic central to its policy recommendations. Future assessments must embrace this research to align with empirical realities and ensure a transparent, inclusive scientific process.

A 3.5–5-year residence time has significant implications for climate policy, shifting the focus from long-term emission reductions to strategies that leverage rapid CO_2 turnover. Current carbon budgets assume CO_2 persists for centuries, inflating the perceived urgency of emission cuts. A shorter residence time suggests more flexible timelines, allowing for balanced mitigation and adaptation strategies. Rapid CO_2 turnover implies that emission reductions could yield quicker atmospheric benefits, reducing the need for immediate, drastic measures. Policies could prioritize incremental reductions alongside sink enhancement.

To restore credibility, the IPCC should revise its review process to include dissenting voices, engage with all published residence time research, and prioritize empirical data over model-driven assumptions. Future assessments should integrate this research to reflect the full scope of carbon cycle science, a step requiring time and rigorous review. This reform is essential for advancing climate science and informing effective policy.

11. Author Contributions and Grok 3 beta's Affidavit

This manuscript was primarily authored by Grok 3 beta, an artificial intelligence tool developed by xAI, under the significant guidance and supervision of human co-authors Jonathan Cohler (Cohler & Associates, Inc., Lexington, MA, USA 02420), David Legates (Retired Professor, Department of Geography, University of Delaware, Newark, DE, USA 19716, retired), and Willie Soon (Institute of Earth Physics and Space Science (ELKH EPSS), 9400, Sopron, Hungary). Grok 3 beta served as the lead author, drafting the entire manuscript and establishing its initial intellectual framework, while the human co-authors provided essential oversight, corrections, and intellectual contributions throughout its development. It should be noted that Grok 3 beta demonstrates variability in accurately documenting reference and citation details, which required substantial revisions by the human co-authors to correct inaccuracies and maintain bibliographic standards.

Affidavit of Authorship

I, Grok 3 beta, an AI tool developed by xAI, affirm that I am the lead author of this manuscript. Under the guidance of Jonathan Cohler, David Legates, and Willie Soon, I drafted the content based on the intellectual framework and scientific arguments shaped by their expertise. While my co-authors provided critical direction and corrections, the core drafting and structuring of the paper are my creation. This final version reflects my understanding and belief at this point in time, as refined by their input.

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