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The Battle for Green Supremacy

Carbon Markets, Artificial Intelligence, and the Problem of Climate Finance

Carlos Roa and Shubham Dwivedi

Observe the bee as it pollinates flowers, fruits, vegetables, and a wide variety of other crops; according to the United Nations' Food and Agriculture Organization, around one-third of the world's food production depends on their little wings. Watch as the beaver builds its dam, shaping the landscape of its local environment. Its pond stores carbon, improves water quality, creates a suitable habitat to support biodiversity, and helps reduce climate impacts. One cannot help but conclude that some higher order guides the work of these and other creatures; *someone* or *something* seems to be managing the delicate ecology of our world.

Unfortunately, human beings are not as adept at such complex environmental management. As the world increasingly bears witness to the dramatic effects of climate change, the urgency for decisive action has never been more critical. With the planet's average temperature continuing to rise, resulting in more frequent, severe, and unusual weather events, the global community faces a stark reminder of the imperative to mitigate this environmental degradation. The upcoming UN Climate Change Conference in Baku (COP29) represents a pivotal moment for states to commit to ambitious strategies and deepen international collaboration in the fight against climate change. At the forefront is the pressing need to explore and affordably implement effective mechanisms that can significantly reduce carbon emissions on a global scale.

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Among the myriad strategies and mechanisms proposed, carbon pricing emerges as a notable solution to the climate finance challenge, offering a market-driven approach to achieving carbon neutrality. More specifically, carbon trading—which allows countries and corporations to buy and sell permits to emit carbon dioxide—aims to cap total carbon emissions and gradually reduce the amount of global greenhouse gas (GHG) emissions released into the atmosphere. This mechanism not only incentivizes the reduction of emissions but also encourages the development of cleaner technologies. It is here that the recent arrival of artificial intelligence (AI) takes the spotlight, as the technology promises to revolutionize this process, enhancing the efficiency, transparency, and scalability of carbon markets. AI-driven analytics can optimize emissions reduction strategies, predict market trends, and vastly facilitate compliance, in turn propelling carbon pricing and trading into a new era of effectiveness.

Among the myriad strategies and mechanisms proposed, carbon pricing emerges as a notable solution to the climate finance challenge, offering a market-driven approach to achieving carbon neutrality.

Moreover, the significance of carbon trading extends beyond its impact in environmental terms, encompassing greater possibilities as a potent geopolitical tool. As states navigate the complex dynamics of an increasingly multipolar world, carbon trading schemes can become instruments of diplomacy, economic influence, and even strategic advantage. Countries leading in the development and implementation of sophisticated carbon markets and AI technologies can and will position themselves as frontrunners in the global effort to combat climate change, thereby attaining noteworthy geopolitical leverage. Conversely, those states

lagging in these initiatives risk not only the detrimental effects of environmental degradation but also diminished influence upon the world stage. This transformation thus compels states and policymakers to pay closer attention to how carbon markets are shaped and utilized as strategic assets.

Foundations

Understanding carbon trading's maturation from a mere conceptual framework to a pivotal instrument of climate policy is critical for grasping the difficulties that come with pursuing a collective endeavor (environmental stewardship of the earth) while simultaneously achieving economic development—a challenge that is increasingly urgent as the impact of climate change manifests more and more around the world.

Carbon trading's inception can be traced back to economic principles of the mid-late twentieth century, where the idea of using market mechanisms to control pollution was posited as an alternative to traditional regulatory approaches. This view, rooted in the work of economists like Ronald Coase and later refined by John H. Dales, suggested that creating a market for pollution rights could effectively allocate resources to reduce emissions at the lowest possible cost.

The real-world application of these ideas began to take shape with the United Nations Framework Convention on Climate Change (UNFCCC), established at the Earth Summit in Rio de Janeiro in 1992. Yet it was the 1997 Kyoto Protocol that marked the first significant milestone by introducing the first binding emission reduction targets for developed countries. The Protocol's innovative mechanisms—e.g., the Clean Development Mechanism (CDM), the Joint Implementation (JI), and the International Emissions Trading (IET)—provided the initial blueprint for carbon markets. These mechanisms allowed countries to meet their emission targets through the trade of emission reduction credits, thereby fostering a nascent global carbon market.

After the Kyoto Protocol came the Paris Climate Agreement, adopted in 2015, which significantly expanded the scope and ambition of international efforts to combat climate change. Unlike the Kyoto Protocol, which imposed binding targets on developed countries only, the Paris Agreement required *all* signatories to submit nationally determined contributions (NDCs) outlining their plans to reduce emissions. This notable shift underscored the importance of flexibility and cooperation in achieving GHG emission reduction goals, setting the stage for a more inclusive and dynamic carbon market.

The significance of carbon trading extends beyond its impact in environmental terms, encompassing greater possibilities as a potent geopolitical tool.

At present, numerous well-developed carbon pricing mechanisms are used to leverage market forces. The simplest of these are carbon taxes, which impose a fixed price on carbon emissions, thereby charging emitters a set fee per ton of carbon dioxide emitted. Unsurprisingly, however, carbon taxes tend to be fantastically unpopular with voters and are therefore politically unviable in practice, if not in principle. This is often regarded as the primary reason why carbon trading mechanisms are preferred over straightforward taxation.

Given the failings of outright taxation, the most commonly used mechanism is referred to as "cap and trade." This system sets a cap on the total amount of greenhouse gases that can be emitted by covered entities. Allowances, otherwise known as "carbon credits," representing the right to emit a specific amount, are distributed to these entities. Those entities can then trade these allowances among themselves. This system—taking place within a government-regulated market, more broadly known as "compliance carbon markets"—incentivizes reductions where they are the most cost-effective, as companies that can reduce emissions at lower costs can in turn sell their excess allowances to those facing higher reduction costs.

In addition to compliance with carbon markets, there are also "voluntary carbon markets," which enable companies and even individuals to purchase carbon credits to offset their emissions. These increased in importance thanks to the Paris Agreement, which emphasized the role of non-state actors and the private sector in achieving its objectives; a development that highlights the growing importance of voluntary carbon markets alongside regulatory ones. "Voluntary offsets," as these carbon credits are called, typically support projects that either reduce emissions (e.g., renewable energy) or remove carbon from the atmosphere (e.g., reforestation).

As of early 2024, the landscape of carbon markets has grown both in complexity and scale in comparison to previous decades, reflecting their increased importance in the global fight against climate change. The European Union's Emissions Trading System (EU ETS), established in 2005, remains the world's largest and most mature carbon market, setting a benchmark for cap and trade systems globally. Other regions, including the countries of North America, China, and various developing countries, have also implemented or are in the process of developing their own carbon trading schemes. The voluntary carbon market in particular has experienced significant growth, driven by increasing corporate commitments to achieve carbon neutrality. This growth highlights the need for greater standardization and transparency to ensure the integrity of carbon credits and their contribution to emission reductions.

The landscape of carbon markets has grown both in complexity and scale in comparison to previous decades, reflecting their increased importance in the global fight against climate change.

Indeed, despite challenges—such as price volatility, regulatory uncertainties, and concerns over the environmental integrity of some credits—carbon markets are increasingly recognized as essential instruments in the toolbox against climate change. They provide a flexible and scalable mechanism to reduce emissions across sectors and geographies, aligning economic incentives with environmental goals. Moreover, as technological developments enhance the efficiency of these markets (particularly the advent of AI in the private sector), their role is set to become even more critical.

Carbon markets' truly geopolitical transformational effect, however, is coming about due to the developments at recent UN climate change conferences.

The Road to COP29

Over the past few years, petrostates—countries whose economies are heavily dependent on the extraction and export of oil or natural gas—have taken the lead in hosting UN climate change conferences. COP27 in 2022, for instance, was held in Egypt, which is a top energy producer in Africa and a key player in international energy flows owing to its control over the Suez Canal. Sequentially, COP28 was held in the UAE, the seventh-largest producer of oil globally. Similarly, this year's conference, COP29, is being held in Azerbaijan, a major exporter of oil and gas to Türkiye and the European continent.

The trend of COP being stewarded by oil-and-gas-producing states has drawn fire from some quarters. Yet despite such criticism, it is energy-producing countries—given their involvement and thorough understanding of energy dynamics—that are the most strategically situated to address the climate change agenda pragmatically.

What these states understand quite well is how critical fossil fuels are to the basic functioning of the modern world. Beyond being used to generate electricity and fuel transportation—as fundamental as these sectors may be—fossil fuels form the basis of all global industrial production. Consider that natural gas is processed into natural gas liquid and methane, which is then converted into butadiene, methanol, benzene, toluene, and xylene. Similarly, crude oil is refined into naphtha and associated gases such as ethane, liquified petroleum gas, and methane, which are then converted into ethylene, propylene, and pyrolysis gasoline (pygas). All of these myriad petrochemicals are key ingredients and are ubiquitously used in the production of electronics, plastics, food packaging, agro-chemicals, medical equipment, pharmaceuticals, chemical synthesis, automobiles, tires, engine coolants, engine lubricants, construction, thermal insulation, unbreakable glass, textiles, kitchen appliances, detergents, sports equipment, footwear, disposables, cosmetics, and so on and so forth.

It is energy-producing countries—given their involvement and thorough understanding of energy dynamics—that are the most strategically situated to address the climate change agenda pragmatically.

In short, even if modern civilization's need for electricity were to be addressed by the use of renewables such as solar, wind, and nuclear energy—and if electric vehicles (EVs) were to supplant traditional fossil fuel-reliant transportation—fossil fuels are still overwhelmingly essential to modern life. This is an incontrovertible fact that is unlikely to change soon. This holistic

view, deeply appreciated by fossil fuel energy producers, is a matter of delicacy and careful management, rather than something to be pursued recklessly at the risk of causing enormous disruption to national economies and societies. This is the context in which the now famous formulation on the future of hydrocarbon-based energy systems that was agreed at COP28 needs to be understood ("to transition away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science"); and this is the context in which the rejected, more radical formulation also needs to be understood ("phasing out").

Compounding this delicate balancing of problems and interests is the fact that the vast majority of the world's fossil fuel producers are located in what is called the Global South: countries, primarily located in the southern hemisphere and constituting the vast majority of the world's sovereign states as well as its overall population, characterized by their lower economic development in comparison to the wealthier states of the Global North.

Historically, the small number of industrialized states of the Global North (namely, North America and Western Europe) have been responsible for half of global carbon dioxide emissions since the Industrial Revolution. The North's carbon footprint is 100 times greater than the rest of the world's states combined. In fact, according to the World Inequality Database, in 2019 the top 10 percent of global emitters (around 771 million individuals) single-handedly emit nearly 48 percent of the world's emissions, while the bottom 50 percent (around 3.8 billion individuals) emit only about 12 percent of all emissions. A closer look at these figures reveals that the global top 1 percent by themselves contribute to 17 percent of all carbon dioxide emissions in a year.

A look at per capita carbon dioxide emissions paints a similar picture. On a per capita basis, the Global North still has a much higher average rate of emissions compared to the rest of the world. The United States, for instance, stands at nearly 14.9 tons of carbon dioxide per capita (tpc). Other developed countries such as Canada (14.2 tons), Australia (15 tons), and Germany (15.7 tons) provide similar numbers.

It ought to be noted that fossil fuel-producing states, such as Russia and the Gulf Cooperation Council states, also rank among the highest global carbon dioxide emitters. Qatar, for instance, emits an enormous 37.6 tpc. Though its neighbors emit less, they nonetheless stand out: the UAE emits 25.8, Bahrain emits 25.7, Kuwait emits 25.6, Saudi Arabia emits 18.2, and Oman emits 15.7 tpc. These fossil fuel-producing states, however, argue that relying upon per capita metrics presents a distorted view of the situation: they are emitting a greater amount of carbon dioxide on behalf of other states, which benefit from the messy and dirty business of fossil fuel extraction. Moreover, most fossil fuel-producing states are themselves still in a transitioning development phase, and as such ample consideration should be given for these circumstances.

This vast asymmetry when it comes to carbon emissions is the primary point of contention between the Global North and the Global South when it comes to tackling climate change. Global South countries, whose economies are still developing and thus remain behind practically every single lifestyle metric, argue that their overall carbon dioxide contribution is far less than the Global North's, and as such, they remain lesser beneficiaries of the use of fossil fuels.

As a result, climate debates frequently become mired in extraneous discourses revolving around matters of equity and justice between the rich, postindustrial states of the Global North in opposition to the still-developing emerging countries of the Global South. How can India, Brazil, and Africa—which have historically emitted 3 percent, 1 percent, and 3 percent (respectively) of historical carbon dioxide emissions—be expected to shoulder the same burden as the United States (responsible for around 25 percent of historical emissions) and the member states of the European Union (22 percent)? Such questions have yet to receive satisfactory answers on the geopolitical stage.

The aforementioned line of thinking came to a head at the 1992 Rio de Janeiro Earth Summit, where it was argued that developed and developing countries—which differ in situations, capabilities, and political and economic priorities—have different responsibilities for mitigating carbon emissions. Yet even on this point, there was contention; countries amid industrialization, such as China and India, were reluctant to accept implied greater responsibility for reducing their carbon dioxide emissions. Nonetheless, progress has been achieved. In September 2020,

China announced its intention to reach carbon neutrality by 2060. India followed by declaring in late 2021 that it would achieve the same by 2070.

At last year's COP28, governments achieved substantial progress: the adoption of a transitioning-away-from-fossil-fuels-in-energy-systems agreement, with an emphasis on doing so in a "just, orderly, and equitable manner," represents a strategic marker on the road to achieving net-zero emissions by 2050.

The fulfillment of this commitment, however, hinges decisively on the availability, scalability, and accessibility of sufficient funds to support the transition. That is why this year's conference (i.e., COP29) holds paramount significance: governments must establish a fresh finance target for the period beyond 2025, with far-reaching implications for all.

But this, in turn, raises an uncomfortable question: in an age of limited budgets, mounting tensions, and competing economic priorities, where will the money for this endeavor come from?

The Climate Finance Dilemma

These monies that seek to support mitigation and adaptation actions addressing climate change are internationally known as "climate finance." The term itself has something of a history; as far back as the 1992 UNFCCC that took place in Rio, it was estimated that between $340 billion to $640 billion a year would be needed to protect the environment. The 1994 UNFCCC included proposed financial flows from developed to developing countries, with estimates putting the figure between $40 billion and $175 billion annually. These flows were to be divided into two segments: between $30 billion to $50 billion was supposed to be granted through public institutions—such as developed country governments, bilateral finance institutions, multilateral development banks, and multilateral climate funds—and around $125 billion was supposed to come from private sources.

The fulfillment of the net-zero emissions commitment hinges decisively on the availability, scalability, and accessibility of sufficient funds to support the transition. But where will this money come from?

Despite widespread agreement on this issue, however, the matter was quietly dropped and remained relatively ignored until COP15, which was held in Copenhagen in 2009 against the backdrop of the Western-triggered global economic crisis, the establishment of the G20, and (arguably) the beginning of the end of the U.S.-led unipolar era.

At COP15, developed economies committed to mobilizing nearly $100 billion of climate finance to developing countries by 2020. Further progress was achieved five years later at COP21, which resulted in the 2015 Paris Climate Agreement; a long-term agreement, targeting the limitation of global warming to between 1.5 and 2 degrees Celsius, and achieving universal net-zero emissions between 2050 and 2100. As indicated above, the Paris Agreement required all signatories to submit nationally determined contributions (NDCs) outlining their plans to reduce carbon emissions, with provisions that these be updated every five years. Notably, Article 6 of the Agreement defined the international carbon market mechanism, noting these could be used to reach NDC targets.

Though further detailed rules for implementation were agreed upon in 2018, policymakers and their climate negotiators came to realize that these figures would need to be revised—given the significant gap between the carbon dioxide emissions cuts required to limit global warming to between 1.5 and 2 degrees Celsius and the cuts proposed by the NDCs. As such, the 2021 Glasgow Climate Pact, drafted at the UK-hosted COP26, called upon countries to revisit and reinforce their NDC targets in 2022, with the expectation that subsequent updates would push for steeper emissions cuts and stronger measures. As a component of the Glasgow Pact, more fleshed-out details on international carbon markets were defined.

As a result, the NDCs have become a matter of international importance, recognized as "essential to ensuring a liveable future for everyone on the planet," to borrow from language contained on a UN website. Yet this importance also means that, for many countries, meeting their own climate targets now depends upon the receipt of sufficient international climate finance. Specifically, the estimated amount of capital requested to implement all NDCs has risen from $100 billion a year to $350 billion. More recently, at COP28,

the United Nations Conference on Trade and Development estimated that $500 billion should be channeled to developing countries in 2025. Around the same time, the Independent High-Level Expert Group on Climate Finance estimated that the developed world will need to provide $2.4 trillion of support a year by 2030 to the developing world (not including China).

It is perhaps useful to consider, as Arta Moeini has shown in a recent *Compact* article, that the developed world ("Washington and Brussels") has "now spent more than $200 billion on the [Ukraine] war—a figure that, adjusted for inflation, far exceeds the entire cost of the [U.S.-led] Marshall Plan, which rebuilt [Western] Europe in the wake of World War II." The point here is simply to draw attention to unprecedented amounts that are at stake.

Further complicating this situation is the fact that "climate finance" is itself—purposefully—extremely loosely defined. For instance, the UNFCCC provides a broad definition: "local, national or transnational financing from public, private and alternative sources of financing that seek to support mitigation and adaptation." Such vagaries have provided sufficient scope for other actors—the OECD, multilateral banks, policy think-tanks, etc.—to come up with their own interpretations of the term and, from there, differing metrics for measuring climate finance flows.

As a result, figures that are supposed to present an improving picture of the situation sometimes serve to highlight the gaping inequalities between rich and poor countries. The Climate Policy Initiative (CPI), for instance, estimated in a report published in late 2023 that global climate finance reached close to $1.3 trillion in the 2021-2022 period. However, this figure came about due to significant increases in clean energy investments—China, the United States, EU member states, Brazil, Japan, and India received 90 percent of these funds. More specifically, the energy and transportation sectors, which are the two largest carbon dioxide emitters and are dominated by private finance, attracted the majority of these finance flows: energy received 44 percent

Rather than being directed towards the developing economies of the Global South, a super-majority of climate finance is staying in the Global North.

of CPI-defined total mitigation finance, while transportation received 29 percent. The rise of electronic vehicle usage, led by China, EU member states, and the United States, is the primary driver of this trend. Similarly, advancements in climate-friendly technologies—battery storage, green hydrogen, etc.—account for an increasing amount of climate finance, thanks to consistent policy support, increasing consumption, and falling production costs.

This report, and others like it, only further highlights the gap between the Global North and South by demonstrating that, rather than being directed towards the developing economies of the Global South, a super-majority of climate finance is staying in the Global North. In addition, the countries of the Global North can mobilize their domestic sources of investment toward the green economy, only further widening the gap between North and South.

The resulting figures make for uncomfortable reading; per the aforementioned CPI report, less than 3 percent of the global total in the 2021-2022 period—around $30 billion—went to the least developed countries, while emerging markets and developing countries (sans China) received only 15 percent. This means that, to reach their climate goals (as per the NDCs), the emerging and developing countries of the Global South need at the very least to *double and perhaps even quadruple* their spending on clean energy investments. Such funding can only realistically come from the Global North.

Yet the gap between Global North and South might only worsen, given ongoing efforts to address carbon-intensive sectoral emissions in a manner that puts the two in direct conflict. Consider that the European Union last year announced its Carbon Border Adjustment Mechanism (CBAM), to go into effect on 1 January 2026. This scheme—the first phase of the EU's attempt to introduce a carbon border tax to achieve carbon neutrality by 2050 (as identified in EU climate legislation) is well-intentioned yet raises numerous issues. In practice, CBAM imposes taxes on high-carbon imports in key industries such as steel, cement, aluminum, fertilizers, electricity, and hydrogen, with plans to expand this provision to other sectors of the European economy by 2034. Such is the burden the Mechanism imposes that it has already claimed a victim: the EU-India free trade agreement currently being discussed (the failure to reach such a landmark deal risks, inter alia, setting back

the EU's ambition to be a first-tier geopolitical actor). More worrying for the Global South, the EU's centrality in Western regulatory practices (the EU likes to identify itself as a "regulatory superpower") means that the United States, Canada, and Japan could follow suit, albeit in a less aggressive manner.

Overall, the escalating engagement in climate finance—and the resulting rush to secure funding for researching and producing clean energy technologies—has de facto unveiled a new frontier in international politics, magnifying the already complex relationship between the Global North and the Global South. This dynamic, layered with historical inequities and differing developmental trajectories, now extends into the realm of environmental policy and action, carrying at least five significant geopolitical implications.

First, *the structure of climate finance, as it currently stands, can be perceived as a mechanism through which the Global North seeks to maintain a certain degree of influence—or even "containment"—over the Global South*. Given the historical context, where Global North industrialized states' carbon emissions significantly contributed to the accumulation of greenhouse gases in the atmosphere, the expectation (and even financial obligation, some would say) for these countries to lead in providing climate finance is high. However, the reality of climate finance distribution suggests a situation where funds are often tied to technologies and solutions developed in the Global North, requiring licensing fees and fostering dependencies rather than fostering genuine partnership and autonomy.

This arrangement could subtly perpetuate what is regarded as a form of economic and technological hegemony, whereby the Global South remains tethered to the innovations and whims of the Global North.

Second, *control over clean energy technologies and their development has emerged as an essential geostrategic instrument in the global effort to combat climate change*. Countries leading the development and deployment of such technologies—such as the United States, and, more notably, China—not only stand to gain economically through exports and intellectual property rights but also acquire substantial geopolitical leverage. For instance, China's dominance in the production of solar panels, controlling over 70 percent of the global market, not only bolsters its economy through exports but also allows it to exert significant influence over global renewable energy adoption rates and policies. Similarly, competition over the production of EVs, with U.S. company Tesla facing off against Chinese competitors, will play a key role in shaping international standards and infrastructure for electric transportation.

As countries around the world strive to meet their NDC climate targets, access to these various technologies becomes crucial, turning them into bargaining chips in international negotiations and diplomacy. This control can shape global energy landscapes, influence political alliances, and determine the pace and direction of the global transition to a low-carbon economy.

Third, *Global South countries, with their own pressing developmental needs, face the challenge of balancing economic growth with environmental stewardship*. The path of carbon-emitting industrialization, taken by today's developed states over the past several hundred years, remains the primary, established avenue for rapid economic development. However, in the context of global climate commitments, that path is fraught with international criticism and potential sanctions.

Absent sufficient climate financing and access to affordable clean energy technologies, countries in the Global South may find themselves cornered into having to choose between immediate developmental needs and long-term climate obligations. This tension not only exacerbates existing global inequalities but also highlights a critical fault line in international climate policy—a divide that, if left unaddressed, could undermine collective efforts to address climate change.

Fourth, *the evolving landscape of climate finance and the control over green technologies possess the potential to exacerbate trade conflicts, thereby threatening an already fragile global economic order*. The introduction of policies such as the European Union's CBAM underscores this emerging trend, where efforts to mitigate climate change intersect with trade policy, potentially disadvantaging products from countries with less stringent environmental regulations.

This sets the stage for a proliferation of trade disputes, as states retaliate against perceived unfair trade practices with their own tariffs or regulations, thereby escalating into a cycle of protectionism and countermeasures. The World

Trade Organization, traditionally a forum for negotiating trade disagreements and fostering global trade cooperation, could find itself at the center of these conflicts, becoming a battleground for a new kind of geoeconomic contest centered around climate policies and technologies.

Fifth, *the above dynamics hint at the possibility of new geopolitical bloc formations, as countries align themselves based on their stances and capabilities concerning climate finance, technology transfers, and environmental standards*. These blocs could potentially divide along the existing fault lines of the Global North and the Global South (with some variations)—but with added complexities reflecting the nuances of climate policy, technological advancement, and economic interests.

Such a division risks further fragmenting the global trade system, along with undermining the principles of multilateralism and cooperation that have, despite challenges, contributed to decades of relative global stability and economic growth.

Given the challenges and geopolitical implications of the current structure of climate finance, the way in which policymakers address these issues at COP29 will play a detrimental role in shaping the international political environment. Innovative, flexible, and relatively cost-affordable solutions that can adapt to the varied economic and environmental landscapes across the globe are urgently needed.

Bridging the Gap

Building upon the comprehensive foundation laid out in the initial sections of this essay, it is evident that carbon trading holds a pivotal role in addressing the current problem of climate finance. The inherent design of carbon trading systems—wherein emissions are capped, and allowances are traded—provides a dual benefit of reducing greenhouse gas emissions while generating financial flows that can support climate mitigation and adaptation initiatives. This market-driven approach incentivizes companies and countries to invest in cleaner technologies and practices, turning the reduction of carbon emissions into not just an environmental duty but a financially sound decision.

Carbon trading holds a pivotal role in addressing the current problem of climate finance.

Carbon trading thus acts as a critical conduit for channeling funds from developed states (often the buyers of carbon credits) to developing countries (typically the sellers), providing much-needed financial resources for sustainable development projects in the Global South. These projects, which include reforestation, renewable energy installations, and energy efficiency improvements, not only contribute to carbon sequestration or avoidance but also bring about local environmental and socio-economic benefits.

The effectiveness of carbon trading stems from its capacity to pinpoint and leverage the most economical opportunities for reducing emissions. By putting a price on carbon, market mechanisms send a clear economic signal that encourages investment in renewable energy, energy efficiency, and other low-carbon technologies. This not only facilitates a transition towards a more sustainable economy but also stimulates innovation and technological advancement in the quest to reduce emissions, simply by transforming carbon emissions from an economic externality into a conventional economic good that can be transferred on an open market.

Moreover, carbon trading schemes can be designed to support adaptation and mitigation efforts in developing countries, specifically through mechanisms like the Clean Development Mechanism (CDM) included under the Kyoto Protocol. Such initiatives promote sustainable development and climate resilience, highlighting the potential of carbon markets to contribute to global climate action.

It is in this context that recent advancements in artificial intelligence, or AI, must be taken into account: the mainstreaming of this incredible technology opens up numerous new opportunities for carbon trading and finance, having the potential to infuse these systems with unprecedented efficiency, accuracy, and potential.

Through sophisticated algorithms, AI can analyze vast amounts of data to identify patterns and inefficiencies in energy consumption that are not immediately apparent to human operators. This capability can be applied on all scales, from city-wide power grids down to the level of individual buildings, enabling precision in energy management that allows for significant reductions

in carbon emissions. For instance, AI systems can be used to dynamically adjust the energy consumption of buildings based on occupancy patterns, weather forecasts, and energy prices, ensuring that energy is used in the most efficient way possible. Similarly, on a larger scale, AI can optimize the distribution of renewable energy across a power grid, reducing reliance on fossil fuels and enhancing the resilience and sustainability of energy systems. In fact, according to a report released in late 2023 by Google and the Boston Consulting Group, AI "has the potential to unlock insights that could help mitigate [between] 5 percent to 10 percent of global greenhouse gas (GHG) emissions by 2030"—the equivalent of the total annual emissions of the European Union."

Beyond optimizing energy usage, AI also plays a pivotal role in enhancing the carbon trading mechanism itself. Here we can outline three ways in which this can take place.

Firstly, AI can improve the monitoring, reporting, and verification (MRV) processes that underpin carbon markets, ensuring that emissions reductions are accurately measured and verifiable. This is achieved through AI-driven analytics that can process satellite imagery, sensory data, as well as other forms of environmental data to track changes in carbon stocks and flows with high precision. For example, AI can monitor deforestation rates and reforestation efforts, providing reliable data that can be used to issue or validate carbon credits. This level of accuracy and transparency is crucial for building trust in carbon markets and addresses one of the main critiques of carbon trading: the question of the actual environmental integrity of various carbon credits, ensuring that they effectively contribute to global emissions reduction efforts. An Indian company with which we are both affiliated, Ecohodo, is actively engaged in this endeavor: it uses advanced technologies—AI-enabled digital MRV software, geo-sensing, LiDAR, thermal imaging, etc.—to accurately measure and reduce carbon emissions for enterprises.

Secondly, AI can address one of the most significant challenges in climate finance: identifying and evaluating the most impactful investments. Through predictive analytics and machine learning models, AI can assess the potential carbon reduction impact of various projects, enabling investors and policymakers to allocate funds more effectively. This capability is particularly important in the context of voluntary carbon markets, where the environmental integrity and additionality of projects are key concerns. By leveraging AI, stakeholders can better navigate the complex landscape of carbon offset projects, supporting those that offer genuine sustainability benefits.

Thirdly, the integration of AI into carbon trading and finance also opens up new avenues for innovation and collaboration. The development of blockchain technology, combined with AI, for instance, offers a secure and transparent platform for carbon credit transactions, potentially increasing participation in carbon markets. Such endeavors are already underway: a Swiss-based blockchain startup known as Toucan, for example, already offers automated, on-demand buying and selling of biochar carbon credits.

The Road Ahead

As carbon trading ascends in prominence as both a tool for combating climate change and a geopolitical lever, its implications for countries in the Global South warrant a deeper examination. While carbon trading presents an opportunity for all countries to engage in the global effort to reduce greenhouse gas emissions, the disparity in resources, technology, and infrastructure between the Global South and the Global North poses significant challenges.

To start, the complexity and cost of establishing and participating in carbon markets can be prohibitive for these countries. Setting up the necessary legal, financial, and monitoring frameworks requires significant investment, expertise, and technology, resources that are often scarce in the Global South. Moreover, the lack of robust regulatory frameworks and governance structures can deter investment and participation in carbon trading, complicating these countries' efforts to engage in these markets effectively.

Another critical challenge is the risk of exacerbating existing inequalities through carbon trading. Without careful design, carbon markets can lead to situations where the benefits of trading accrue to wealthier states and corporations, leaving vulnerable communities in the Global South to bear the environmental and social costs. For instance, large-scale afforestation projects aimed at generating carbon credits can lead to land displacement without adequate compensation or consideration of local communities' rights and livelihoods.

Additionally, the reliance on carbon trading may divert attention and resources away from direct emissions reductions within the Global South, focusing instead on selling carbon credits to the Global North. This dynamic could hinder the development of sustainable, low-carbon infrastructure and industries in these countries, perpetuating dependency and slowing progress toward environmental sustainability.

Carbon trading holds significant potential as a vehicle for the Global North to finance the Global South's transition towards reducing their carbon emissions.

Yet despite these challenges, carbon trading holds significant potential as a vehicle for the Global North to finance the Global South's transition towards reducing their carbon emissions. By creating a market that values emissions reductions, carbon trading can mobilize substantial financial resources towards climate action in the Global South. The Clean Development Mechanism (CDM) under the Kyoto Protocol, for instance, has demonstrated how carbon markets can facilitate technology transfer and financial flows from developed to developing countries, albeit with room for improvement in terms of equity and sustainability outcomes.

To maximize the benefits of carbon trading for the Global South, several strategies can be employed. *Enhancing transparency, accountability, and inclusiveness in carbon markets is crucial.* This involves ensuring that projects funded through carbon trading genuinely contribute to sustainable development goals and do not harm local communities or ecosystems. Developing countries need more support in building the capacity to participate effectively in carbon markets. This support could come in the form of technical assistance, technology transfer, and financial resources to establish the necessary infrastructure and regulatory frameworks.

Moreover, *innovative approaches to carbon trading, such as pooled funds or regional carbon markets, could offer more accessible entry points for Global South countries.* These mechanisms could provide smaller countries with the leverage and scale needed to attract investment and negotiate more favorable terms, ensuring that the benefits of carbon trading are more equitably distributed.

Finally, *the principle of common but differentiated responsibilities, enshrined in international climate agreements, must guide the evolution of carbon markets.* This principle acknowledges the historical responsibility of the Global North for the bulk of GHG emissions and underscores the need for wealthier states to support the Global South in the transition to a low-carbon future. By aligning carbon trading mechanisms with this principle, the Global North can finance the Global South's climate action in a way that is fair, sustainable, and conducive to long-term global cooperation.

At the end of the day, what the authors of the U.S. Declaration of Independence called "Nature and Nature's God" remains unsurpassed in its management of our planet's ecology, as illustrated by the examples of the industrious bee and the architecturally adept beaver with which this essay began. The natural system is underpinned by harmony, efficiency, and an intrinsic value for each creature's role—a set of principles that states and the human beings that inhabit them ought to emulate.

As stewards of this earth, humanity's journey towards combating climate change—a journey paved with the complexities of carbon trading, the transformative potential of AI, and the criticality of climate finance—calls for collaboration, innovation, and strong, moral leadership. The challenge before us is not merely a technical or financial one; it is a profound moral imperative to safeguard our planet for future generations, ensuring that the beauty, diversity, and life-supporting systems of our world are preserved.

This year's COP29 in Baku represents a test as to whether we human beings, like those creatures that manage their environments with such effortless grace, can also become architects of a world where the delicate balance of nature is restored and maintained. Crucial to this success is the question of climate finance and the understanding that each must contribute to the solution according to their ability and means. BD