*Position Paper*

# Are we on the right track for mitigating climate change?

*Viet-Phuong La, Minh-Hoang Nguyen, Thanh Tu Tran, Quan-Hoang Vuong*

**Received:** 17 June 2025 | **Accepted:** 9 July 2025 | **Published:** 22 July 2025



**Keywords:** climate change; progress; eco-deficit culture; eco-surplus culture.

**Abstract.** *Climate change, primarily driven by human activities, is becoming one of the most urgent global challenges of our time. Over the past decade, significant efforts have been made to address the climate change crisis,* *resulting in certain impacts in combating climate change and raising awareness about its consequences. This paper critically assesses global climate mitigation efforts, highlighting both achievements and persistent shortcomings. Despite growth in renewable energy, international agreements, and technological innovation, as well as a carbon market, greenhouse gas emissions remain at record highs, and climate impacts continue to accelerate. Key strategies that predominantly rely on a growth-oriented paradigm and technological solutions have fallen short, often reinforcing existing exploitation paradigms rather than transforming them. Drawing on Granular Interaction Thinking Theory (GITT), the paper proposes transitioning from an eco-deficit to an eco-surplus culture – one that views ecological restoration and protection as fundamental for socio-economic well-being and development. Mitigating climate change requires not only scaling proven solutions but also reimagining socio-economic and governance structures to align with planetary boundaries and long-term sustainability.*

---

> "*Grand conclusion: The report is still completely honest, trustworthy, and ethical, even though the data are fabricated and measurements are falsified. The methane emission reduction campaign has achieved phenomenal success. Therefore, the bird village approves the inclusion of the report in Kingfisher's lifetime achievement archive."
>
> "GHG Emissions"; *Wild Wise Weird* (2024)

## 1. Introduction

Climate change is among the most significant threats confronting global ecosystems and human well-being in the twenty-first century, adversely affecting biodiversity, social well-being, and economic stability. It is driven by human activities, primarily greenhouse gas emissions from burning fossil fuels and land-use changes. The 2023 assessment from the Intergovernmental Panel on Climate

Change (IPCC) confirms with high confidence that greenhouse gas emissions from human activities have "unequivocally caused global warming," increasing the global average surface temperature by approximately 1.1°C in 2011-2020 since 1850-1900 (IPCC, 2023). This warming is intensifying extreme weather events, sea-level rise, and ecosystem disruptions worldwide (IPCC, 2022; Molinos et al., 2018; Oliver et al., 2018). The scientific community has indicated the urgency of addressing the climate crisis, noting that current warming is unprecedented in the context of the past millennia and directly linked to human-caused emissions of carbon dioxide ($CO_2$), methane, and other greenhouse gases (Burke et al., 2018; IPCC, 2023; Ripple et al., 2019). Climate change is an existential threat affecting global environmental and socio-economic systems, requiring immediate and transformative action.

The scientific consensus on anthropogenic global warming is virtually unanimous. Early surveys of climate research found over 97% of climate experts agreed that humans are the main cause of recent warming (Cook et al., 2013). More recent analyses show the consensus has grown even stronger: over 99% of peer-reviewed studies now suggest that human activities are driving climate change (Lynas et al., 2021). Despite this agreement, public perception often lags (Bliuc et al., 2015). For example, a 2023 Pew Research survey found that only 46% of U.S. adults believe human activity is the primary reason for the Earth's warming, with 26% attributing it mostly to natural patterns and 14% denying there is evidence of warming at all (Pasquini et al., 2023). Nonetheless, this consensus has driven substantial international climate policy initiatives, notably the Paris Agreement, which underscores the urgency of curbing greenhouse gas emissions to stabilize the climate and lays a strong foundation for global climate action (UNFCCC, 2015).

Despite decades of climate negotiations, treaties, and policies, global emissions remain at record highs, and climate impacts are accelerating (Frey & Burgess, 2023; IEA, 2024). Many nations have implemented climate action plans and agreed to international targets (like limiting warming to well below 2°C), yet the efficacy and sufficiency of these efforts are under intense scrutiny (Lamb et al., 2024; Matthews & Wynes, 2022; Raiser et al., 2020). This raises a crucial question:

> Are current climate mitigation strategies sufficient to avert dangerous climate change, or is a fundamental rethinking required?

This paper critically examines the progress and pitfalls in global climate change mitigation efforts. We evaluate significant efforts, including the growth of renewable energy, landmark international agreements, technological innovations, public awareness, scientific consensus, and the development of carbon markets. We also highlight persisting challenges and unintended consequences, including environmental impacts from clean technology supply chains, difficulties enforcing agreements, limitations of market-based solutions, and the persistence of climate change apathy and denial. By juxtaposing achievements with the worsening climate emergency, we interrogate the adequacy of current approaches. As the world faces increasingly severe climate impacts, evaluating the effectiveness of our response is essential for charting a sustainable path forward.

## 2. Review method

The topic of examination was selected after a thorough group discussion among the co-authors regarding climate change mitigation strategies that have been widely implemented. For being included in the examination, the efforts need to meet two main criteria: 1) the effort plays a vital role in mitigating climate change, and 2) the effort has been dominantly agreed, adopted, or promoted. Eventually, five main areas of scrutiny were selected: 1) renewable energy development, 2) international agreements and emissions regulations, 3) technological advancements, 4) public awareness and scientific consensus, and 5) carbon market. The five selected areas are consistent with the IPCC (2023)'s recommended systemic transitions necessary for achieving rapid and deep emissions reductions, which include: "deployment of low- or zero-emission technologies; reducing and changing demand through infrastructure design and access, socio-cultural and behavioural changes, and increased technological efficiency and adoption; social protection, climate services or other services; and protecting and restoring ecosystems."

It is essential to note that current global mitigation efforts remain primarily focused on the rapid phase-out of fossil fuels and the acceleration of renewable energy deployment. Meanwhile, although nature-based solutions are gaining traction, they are not yet considered dominant strategies and are therefore excluded from this analysis. This decision is primarily driven by the United Nations Environment Programme's estimation that nearly $7 trillion in government subsidies and private investments were directed toward sectors that actively harm nature in 2022—an amount approximately 35 times greater than the $200 billion allocated to nature-based solutions (UNEP, 2023b).

After the areas of examination were determined, a two-step review was performed. First, we conducted a manual literature review to examine both the progress and persistent challenges across the five selected areas. Our search strategy combined the use of search engines (e.g., Google Scholar for peer-reviewed studies and Google for gray literature) and the bibliographic references of relevant documents. Given the broad and complex nature of the inquiry, we did not restrict our sources to peer-reviewed literature but also included a wide range of gray literature, such as publications from intergovernmental organizations, government documents, reports from non-governmental organizations and think tanks, and news from reputable news outlets. Peer-reviewed studies and most recently published documents were prioritized when relevant.

Additionally, we incorporated ChatGPT's "Deep Research" tool to complement our manual literature review process. Powered by the o3 reasoning model, Deep Research is specifically designed for conducting multi-step research through browsing sources on the Internet. It can rapidly and systematically scan large volumes of literature and synthesize key findings, uncovering potentially overlooked insights, tracking emerging developments, and helping to reduce selective bias in the manual review process. The tool has been validated for reliability and accuracy and is increasingly recommended for research use across various research domains (Haman & Školník, 2025; Jones, 2025; Yin, 2025). We employed Deep Research to generate detailed reports on the developments, ongoing challenges, and potential unintended consequences within the five focus areas. However, we also acknowledged that, although the factual inaccuracies in ChatGPT's Deep Research were rare, hallucinations or misinterpretations could occur occasionally (Nguyen & Vuong, 2025). Thus, insights extracted from these AI-generated reports were then manually cross-verified using peer-reviewed publications and reputable gray literature sources. Only those findings that passed this verification process were incorporated into the final literature review.

This semi-autonomous review approach aimed to reduce the likelihood of overlooking important information by leveraging the expansive information-seeking capability of artificial intelligence, while ensuring the accuracy, reliability, and depth of findings through rigorous manual interpretation and validation. While we have endeavored to include as much relevant information as possible, it should be acknowledged that the article's broad and interdisciplinary scope inherently limits its ability to provide exhaustive coverage.

## 3. Progress in the fight against climate change

The past decade has seen notable progress in mitigation efforts. Renewable energy is expanding at unprecedented rates, global agreements have been established to limit warming, and emerging technologies offer cleaner pathways for industry and transport. Public concern has also grown significantly. This section highlights key areas of progress—each offering grounds for optimism, yet each is also accompanied by challenges or trade-offs that complicate the overall picture.

### *3.1. Renewable energy growth: a double-edged sword*

The substantial growth of renewable energy, particularly wind and solar power, has been a cornerstone of climate change mitigation efforts. Globally, solar and wind generation have surged to record levels, accounting for a rapidly growing share of electricity production (IEA, 2024; Lempriere, 2024). In 2023, solar photovoltaic (PV) output increased by approximately 307 TWh, while wind output surged by around 206 TWh, both reaching unprecedented levels. Together, wind and solar energy accounted for approximately 13.4% of global electricity generation in 2023, representing a significant increase from just a few percent a decade earlier (Wiatros-Motyka et al., 2024). This rapid expansion of renewables has played a crucial role in curbing the growth of $CO_2$ emissions from the power sector (Gielen et al., 2019; Hodge & Nakolan, 2023; IRENA, 2019). Wiatros-Motyka et al. (2024) reported that in 2023, wind and solar were the primary sources of new electricity generation worldwide, outpacing new generation from coal and gas. These impressive gains demonstrate the potential for clean energy to scale up swiftly, propelled by steep cost reductions (solar and wind are now frequently cheaper per kWh than fossil fuels) and robust policy support in many countries (such as feed-in tariffs, renewable portfolio standards, and tax incentives) (Altenburg et al., 2017; IRENA, 2013; IRENA, 2023; Stokes & Breetz, 2018). Consequently, several nations have achieved remarkable milestones. Denmark generates a record 58% of its electricity from wind, while solar provides 19.9% of annual electricity in Chile, 19% in Greece, 18.4% in Hungary, and 17.3% in the Netherlands (Wiatros-Motyka et al., 2024).

However, this progress has a double-edged aspect when examining the broader environmental footprint of renewables (Vuong, Nguyen, Tran, et al., 2025). The manufacturing of solar panels, wind turbines, and especially batteries for energy storage and electric vehicles entails significant resource extraction and ecological impacts (Santillan et al., 2010; Tawalbeh et al., 2021; Morozovska et al., 2024).

For instance, the surge in demand for lithium and cobalt—critical minerals for lithium-ion batteries—has led to a mining boom with its associated environmental downsides (Agusdinata et al., 2018; Tao et al., 2021; Turcheniuk et al., 2018). In South America's "Lithium Triangle" (comprising Argentina, Bolivia, and Chile), the extraction of lithium consumes vast quantities of water, resulting in water shortages for local communities and ecosystems (Petavratzi et al., 2022). In Chile's Salar de Atacama, lithium brine mining has been reported to use 65% of the region's water (Katwala, 2018), contributing to the drying of wetlands and competition with indigenous water needs (Schomberg et al., 2021). Cobalt, 69% of which is mined in the Democratic Republic of Congo, often originates from forested areas (Gulley, 2022; Wilkes, 2016). Mining for cobalt in the Democratic Republic of Congo dramatically transformed the landscape between 2009 and 2021, with bare land increasing 85.4% (+33.81 $km^2$), exposed rock growing 56.2% (+27.46 $km^2$), and vegetation significantly declining, and exposes nearby communities to toxic dust and water pollution (Banza Lubaba Nkulu et al., 2018; Brown et al., 2022). Beyond these specific materials, large-scale renewable deployment requires metals like nickel, copper, and rare earth elements, whose extraction can cause deforestation, soil and water contamination, and high energy use (often powered by fossil fuels) (Antoci et al., 2019; Bruyninckx et al., 2024; Imasiku & Thomas, 2020; Kramarz et al., 2021).

Another concern is the toxic waste and end-of-life disposal of renewable energy components. Solar panels, wind turbine blades, and batteries have limited lifespans and can create substantial waste streams if not recycled (Krauklis et al., 2021; Xu et al., 2018). Battery production and disposal also pose hazards. The processing of battery metals can release toxic byproducts and spent batteries risk leaching contaminants if landfilled (Brown et al., 2024; Kang et al., 2013; Rarotra et al., 2020; Wang et al., 2018; Yin et al., 2020).

In short, while renewable energy itself is clean at the point of generation, its supply chain is not impact-free. This does not undercut the climate rationale for renewables, but it necessitates efforts to ensure that "clean" energy is also sustainably sourced. The growth of renewable energy remains a pillar of climate change mitigation. Yet, its broader sustainability must be managed so that solving one problem (i.e., greenhouse gases emissions) does not exacerbate others (i.e., resource depletion and pollution).

### *3.2. International agreements and emission regulations*

On the international policy front, the Paris Agreement of 2015 marked a significant milestone in global climate governance (Abbass et al., 2022). For the first time, virtually all countries (over 190 parties) committed to individualized climate action plans, known as Nationally Determined Contributions (NDCs), aiming collectively to limit warming to well below 2°C and ideally 1.5°C above pre-industrial levels. The agreement's successes include establishing a universal, durable framework for climate cooperation and ratcheting up ambition over time (UNFCCC, 2015). Unlike its predecessor, the Kyoto Protocol, which mandated targets only for developed nations, the Paris Agreement also brought developing countries on board with mitigation pledges (UNFCCC, 2015). The agreement also set up mechanisms for transparency (i.e., common reporting of emissions and progress) and created avenues for climate finance to support poorer nations (UNFCCC, 2015). Simply put, the Paris Agreement signaled a new era of coordinated global intent to tackle climate change. By 2022, 156 countries (including the 27 EU Member States) had submitted NDCs with deeper emission cuts, partly spurred by the Paris Framework (den Elzen et al., 2022).

However, the effectiveness of international agreements, such as the Paris Agreement, is mixed, largely due to enforcement challenges and implementation loopholes (Doelle, 2021; Huggins, 2021; Raiser et al., 2020). The Paris Agreement relies on voluntary, nationally determined targets and lacks a binding enforcement mechanism to penalize non-compliance (Lawrence & Wong, 2017). Countries are expected to "name and shame" poor performers through transparency, but if a nation falls short of its pledge, the treaty provides no sanctions beyond diplomatic pressure (Lawrence & Wong, 2017; Stankovic et al., 2023; Tingley & Tomz, 2022). This voluntary approach was a political necessity to achieve consensus, but it made the agreement's success contingent upon good faith and internal political will. Indeed, some major emitters are not on track to meet their Paris pledges (as discussed later for the EU), and the aggregate effect of all NDCs, even if fulfilled, is projected to yield roughly 2.5–2.9°C of warming—above the 1.5–2°C goal (UNEP, 2023a). Recognizing this shortfall, the UN has initiated a five-year "global stocktake" process to encourage stronger commitments, but the gap remains worrying (UNFCCC, n.d.).

In tandem with global agreements, many jurisdictions have implemented greenhouse gas (GHG) regulations at the national or regional level—another area of progress tempered by shortcomings. Examples include the European Union's emission trading system (EU ETS) and climate laws, U.S. regulations on vehicle efficiency and power plant emissions, and China's emerging carbon market and renewables mandates (European Commission, 2024; Liu et al., 2017; Paltsev et al., 2015; Paraschiv et al., 2024). These policies have had a measurable impact: the EU ETS has contributed to a 47% drop in EU power sector, heat generation, and industrial production $CO_2$ emissions since 2005 (European Commission, 2024).

Yet, policy uncertainty, political polarization, and weaponization of climate change often undermine these regulations (Dorsey, 2019; Vuong et al., 2023). Inconsistent policies that fluctuate with political shifts create uncertainty, undermining investor confidence and hindering the growth of clean technology (Barradale, 2010; Chiappinelli & May, 2022; Gulen & Ion, 2015; Vuong et al., 2023). In the U.S., climate regulatory rollbacks (like postponing power plant rules) and legal challenges have stalled progress at times (Chemnick et al., 2025; Revesz, 2022). While international agreements and domestic regulations are crucial tools, signifying progress in climate governance, their real-world impact depends on closing loopholes, bolstering compliance and certainty, and achieving political consensus and cooperation. The Paris Agreement's promise will be realized only if countries substantially increase their ambition and implement their pledges in earnest rather than treating the agreement as merely symbolic (Andresen et al., 2021).

### *3.3. Technological advancements: solutions or new problems?*

Human ingenuity has developed a range of technological solutions aimed at reducing emissions - some quite promising, others controversial, or still in development. Two prominent examples are carbon capture and storage (CCS) and electric vehicles (EVs). These innovations are often touted as climate solutions, yet each comes with questions about feasibility, scalability, and unintended effects.

CCS refers to techniques for capturing $CO_2$ from industrial flue gases or directly from the air and then injecting it into geological formations for long-term storage (Ndlovu et al., 2024). In theory, CCS could enable the continued use of fossil fuels without causing climate harm by preventing $CO_2$ from entering the atmosphere (Osman et al., 2021). It features prominently in many IPCC models for meeting the 1.5°C target, especially for hard-to-abate sectors such as the cement and steel industries, and for achieving "negative emissions" when coupled with bioenergy (BECCS) (Hanssen et al., 2020; Tanzer et al., 2020). As of 2024, 50 commercial CCS facilities were operating globally, with an additional 44 under construction and over 500 under development (Global CCS Institute, 2024). Some progress has been made in reducing the cost per ton of $CO_2$ captured, and governments have begun offering substantial subsidies (e.g., the U.S. Department of Energy's tax credit 45Q) to spur deployment (Gilmour, 2023; Hanson et al., 2025).

However, CCS has thus far underperformed relative to expectations, and experts question whether it will become a major contributor to mitigation this decade (de Coninck & Benson, 2014; Mahjour & Faroughi, 2023; Sori et al., 2024). Historically, many CCS projects have been canceled or failed to meet targets, including the Gorgon gas project in Western Australia, which is often referred to as one of the biggest CCS projects in the world (Gray, 2021; Marshall, 2022). A review of CCS initiatives noted a "decades-long history of overpromising and under-delivering," with most projects failing to achieve their intended $CO_2$ reductions (Anderson et al., 2023; Marshall, 2022). One analysis of a Texas coal plant with CCS found that, after accounting for lifecycle emissions, including the upstream emissions from the mining and processing of coal and natural gas, the plant's net $CO_2$-equivalent emission reduction was only 10.8% over 20 years and 20% over 100 years (Jacobson, 2020). High costs associated with CCS are a primary barrier, and its implementation can raise the overall energy requirement of power plants by 10-40% due to $CO_2$ capture and compression processes (Hanson et al., 2025). There are also safety and permanence concerns - $CO_2$ storage must not leak for centuries, and there are risks of induced seismicity from injection (Krishnan et al., 2023; Sori et al., 2024; White & Foxall, 2016).

While CCS could play a niche role (e.g., for industrial processes or legacy emissions), it remains a relatively unproven solution. Some critics argue that it serves as a distraction or a license for the fossil fuel industry to continue business as usual by promising future capture (Mulvey, 2023; Serena, 2023; Stephens, 2014; Vuong & Nguyen, 2024a). The mixed track record of CCS so far urges caution. Significant technological breakthroughs or economic incentives would be needed for CCS to fulfill the lofty role envisioned for it in some mitigation pathways.

*Electric vehicles (EVs).* The electrification of transportation is another technological shift considered pivotal for climate mitigation (McCollum et al., 2014; Yuan et al., 2021). Sales of electric cars have climbed rapidly in recent years, exceeding 10 million vehicles worldwide in 2022, driven by improvements in battery technology, declining costs, and policies such as zero-emission vehicle mandates (IEA, 2023b). EVs produce zero tailpipe emissions, thereby reducing urban air pollution and greenhouse gases when charged with low-carbon electricity (Bellocchi et al., 2019; Xie et al., 2024). Countries like Norway, where over 80% of new car sales are electric, demonstrate that a transition away from internal combustion engines (ICEs) is feasible within a couple of decades (Ewing, 2023). However, the environmental benefits of EVs depend on two factors: (1) the emissions from manufacturing batteries and vehicles, and (2) the cleanliness of the electricity grid used to charge them. In both respects, current limitations warrant attention.

Manufacturing an EV—particularly its lithium-ion battery pack - is an energy- and resource-intensive process that itself generates substantial $CO_2$ emissions (Vega-Muratalla et al., 2024). A study estimates that producing an EV emits significantly more $CO_2$ than producing a comparable ICE vehicle (Kurkin et al., 2024). In essence, an EV comes with a "carbon debt" upfront. Over the vehicle's lifetime, the EV can offset these higher manufacturing emissions through cleaner operation; however, the duration of this offset depends on the electricity mix and charging behavior (Lakshmi, 2023; Tang et al., 2021). Additionally, EV battery production drives mining issues described earlier (e.g., lithium, cobalt, nickel extraction). Mining operations for nickel and other battery metals have led to deforestation and pollution in regions such as Indonesia and the Philippines (Lo et al., 2024; Mervine et al., 2025). In order to address the issue, recycling programs initiated by automakers (e.g., Nissan, Volkswagen) aim to reclaim materials from used batteries to lessen future mining (Fujita et al., 2021; Harper et al., 2019; Wilkins & Kuna, 2023).

The second factor is the source of electricity. If EVs are charged predominantly on fossil-fueled grids, their indirect emissions can be significant (Mofolasayo, 2023; Sobol & Dyjakon, 2020). In a carbon-intensive grid (e.g., one heavily reliant on coal like Australia and China), an EV might underperform a fuel vehicle in terms of total lifecycle emissions (Li et al., 2019; Wolfram & Wiedmann, 2017). As of 2023, coal still accounted for 35% of global electricity (Wiatros-Motyka et al., 2024). In regions where coal is the primary power source, EVs are found to have higher $CO_2$ emissions intensities than gasoline cars (Gan et al., 2021). For instance, India sources about 78% of its power from coal and other fossil fuels (Wiatros-Motyka et al., 2024), so an EV in India currently still results in substantial upstream emissions. Nevertheless, as grids decarbonize through the growth of renewable energy, the climate benefits of EVs improve in tandem. In the EU, where renewables and nuclear power have greatly reduced the grid's carbon intensity, EVs yield significantly lower lifecycle emissions than diesel vehicles (Gustafsson et al., 2021). Moreover, technological advances are improving battery energy density and manufacturing efficiency, which should reduce the carbon footprint per battery (Liu et al., 2022).

Electric vehicles represent important progress toward sustainable transport, but they are not a panacea. Ensuring that EV adoption truly mitigates climate change requires parallel efforts to clean up electricity generation and to manage the supply chain impacts of batteries. Otherwise, we risk a scenario where we trade tailpipe emissions for smokestack and mining emissions. In that sense, addressing one aspect of the problem - such as reducing vehicle emissions - may inadvertently exacerbate others, including increased strain on the electricity grid and greater demand for raw materials. Moreover, the financial risks associated with overinvesting in a narrow set of solutions underscore the need for holistic, system-wide planning in technology-driven mitigation efforts (Vuong, Nguyen, Tran, et al., 2025).

### *3.4. Public awareness and scientific consensus*

Beyond technology and policy, a less tangible but crucial area of progress is the growing public awareness, concern, and activism regarding climate change, much of it driven by the clear scientific consensus and knowledge (Khatibi et al., 2021; Većkalov et al., 2024). In recent years, climate change has vaulted to the forefront of public consciousness in many countries, evidenced by opinion polls, youth-led movements, and media coverage. For example, surveys show that a large majority of people globally now view climate change as a serious threat and express strong support for climate action (Andre et al., 2024; Baum et al., 2024; van Baal et al., 2023). Notably, younger generations exhibit especially high levels of concern and engagement (Jones & Lucas, 2023; Neas et al., 2022; Ross et al., 2019).

In the United States, 70% of adults aged 18-34 report worrying about global warming, compared to 56% of those aged 55 or older (Ballew et al., 2019). This "generation gap" is reflected in activism; youths have organized massive climate strikes (inspired by figures like Greta Thunberg) and have pressured governments for stronger action, often outpacing the urgency felt by their elders (Coughlin & Morera Quesada, 2024; Neas et al., 2022; Trott, 2024). The climate movement has become more mainstream, with the environment now ranking as a top voting issue for many, particularly the young (Beitsch, 2019).

Underpinning this public momentum is the near-universal scientific consensus on climate change, which we highlighted earlier. The fact that 99.9% of peer-reviewed scientific literature agrees on human-induced warming (Lynas et al., 2021) has been repeatedly communicated by scientific bodies and educators, slowly permeating public discourse (Većkalov et al., 2024). Media organizations have moved toward reflecting the scientific consensus in their reporting, moving away from false "balance" that gave undue attention to denialist views (Bogert et al., 2024; Brüggemann & Engesser, 2017; Chinn et al., 2018). Additionally, climate education and outreach have improved: campaigns by educators, NGOs, and even some governments (through school curricula and public service messaging) emphasize the basics of climate science and the urgency of action (McKenzie, 2021; Nepraš et al., 2022; Ranney & Velautham, 2021; Trott, 2024). As a result, public awareness of the connection between GHG emissions and extreme weather events - for example, heatwaves, wildfires, or floods - is now more likely to attribute these events to global warming (Borick & Rabe, 2017; Craig et al., 2020; Demski et al., 2017).

Nevertheless, the persistence of climate apathy and denial - often driven by misinformation, disinformation, and political ideology - remains a significant concern (La et al., 2024). Public perceptions of climate change are dynamic and subject to change, shaped by complex socio-cultural and political factors. Despite the strong scientific consensus affirming the reality of anthropogenic climate change - as one Cornell University researcher put it, "it's pretty much case closed for any meaningful public conversation about the reality of human-caused climate change" (Nield, 2021) - 14.8% of Americans still do not believe in climate change. This disbelief is perpetuated by coordinated social media networks that promote climate skepticism and undermine trust in science (Gounaridis & Newell, 2024). At the center of this disinformation ecosystem is President Donald Trump, who not only withdrew the U.S. from the Paris Agreement but also rolled back over 125 environmental regulations and signed executive orders aimed at boosting fossil fuel production (Gounaridis & Newell, 2024; Shan, 2025).

A recent Pew Research Center survey underscores this growing skepticism, showing a sharp decline in public confidence in the societal benefits of science and scientists (Kennedy & Tyson, 2023). Since 2016, the proportion of Americans who believe science has a positive impact on society has dropped from 67% to 57%, while the percentage who view science negatively has doubled, from 4% to 8%. Notably, over a quarter of respondents expressed little or no trust in scientists to act in the public's best interest, up from 12% in April 2020. This erosion of trust spans political affiliations but is most pronounced among Republicans, nearly 40% of whom report little or no trust in scientists. In such a politically polarized environment like the U.S., it becomes increasingly difficult to mobilize public engagement and collective action based on scientific evidence.

Adding to this fragility, the Net-Zero Banking Alliance (NZBA) - established less than five years ago - has experienced a sharp decline in membership and total asset coverage. Following President Donald Trump's re-election, major American banks - including Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, and Wells Fargo - withdrew from the Alliance. They were soon followed by Canada's five largest banks - TD Bank, Bank of

Montreal, National Bank of Canada, Canadian Imperial Bank of Commerce, and Scotiabank (Frost, 2025). Additionally, five of six Japan's member banks have exited, with Mizuho Financial Group being the most recent to depart (Costa, 2025). Collectively, these withdrawals represent approximately 39% of the NZBA's total asset coverage (Iyer & Tan, 2025).

These developments raise a troubling question: if public awareness and scientific consensus on climate change are truly solid and enduring, why does climate denialism persist in public beliefs, and why do the socio-economic structures supporting climate action remain vulnerable to rapid, large-scale collapse?

### *3.5. The Carbon Market: A Failed Mechanism?*

A final major pillar of climate mitigation efforts worth examining is the use of carbon markets and pricing mechanisms. Economists have long argued that placing a price on carbon, through cap-and-trade systems or carbon taxes, is a cost-effective way to drive emissions reductions while maintaining economic growth (Baranzini et al., 2017; Boyce, 2018). There are 75 carbon pricing initiatives that have been launched worldwide (World Bank, 2024). The EU's Emission Trading System, California's cap-and-trade program, the Regional Greenhouse Gas Initiative (RGGI) in the U.S. Northeast, and emerging markets in China reflect progress in using market forces for climate goals (Dechezleprêtre et al., 2023; Hernandez-Cortes & Meng, 2023; Hibbard et al., 2015; Zhang et al., 2025). Additionally, carbon offset markets have expanded, enabling companies and countries to finance emissions reduction projects elsewhere - such as reforestation, carbon sequestration, methane abatement, and the development of energy efficient technologies initiatives - as a means of 'offsetting' their own emissions (Aggarwal, 2024; Dhanda & Hartman, 2012).

In theory, these mechanisms are expected to harness the efficiency of markets to identify the most cost-effective reductions and incentivize innovation. For instance, the EU ETS is expected to contribute to the phasing out of many coal power plants as utilities sought to avoid purchasing expensive permits and create a framework in which emitting $CO_2$ had a tangible financial cost (Anke et al., 2020; Pietzcker et al., 2021). By 2021, roughly 21% of global emissions were covered by some form of carbon pricing (The Economist, 2022).

However, there is growing evidence that carbon markets have not delivered the intended results at the necessary scale, leading some to label them a failed mechanism (Pearse & Böhm, 2014; Vuong & Nguyen, 2024a; Zhou et al., 2024). Perhaps the starkest indictment comes from analyses of carbon offset programs.

Investigations into voluntary carbon offsets, particularly those involving forest conservation credits, found widespread problems of non-additionality (credits not actually representing real emission reductions) and over-crediting (overestimating the amount of carbon emission reduction) (Badgley et al., 2022; van Kooten, 2017; West et al., 2020; West et al., 2023). A 2023 exposé revealed that over 90% of rainforest carbon offsets issued by the largest certifier were essentially worthless, as they did not result in actual emissions reductions (Greenfield, 2023). These credits, sold to and used by major corporations to claim "carbon neutrality," were often based on forest protection projects where the threat of deforestation had been overstated, or the forest would have survived regardless (Trouwloon et al., 2023; West et al., 2020). Such findings suggest that the booming offset market has enabled companies to make bold climate claims on paper, while emissions continue in reality—a form of greenwashing (Badgley et al., 2022; Hatalis, 2024; Trencher et al., 2024; Trouwloon et al., 2023). Even compliance markets have faced issues, particularly the Clean Development Mechanism (CDM), an international carbon finance mechanism established under the Kyoto Protocol. According to Lo and Cong (2022)'s analysis of 3,311 CDM projects implemented between 2005 and 2020, the actual greenhouse gas emissions reductions amounted to 2,043 million tonnes, 16.4% below the total reduction targets stated in CDM project proposals.

Cap-and-trade programs have likewise faced criticism. When permit prices decline significantly - due to frequent overallocation, economic recessions, or the phase-out of fossil fuel sources (e.g., coal power plants) - the incentive to reduce emissions can be substantially weakened (Anke et al., 2020; Antoniou et al., 2024; Fell, 2016; Koch et al., 2014). In the early years of the EU emissions trading system, the carbon price plummeted to an all-time low of €2.75, rendering it ineffective until structural reforms and tighter caps later boosted the price (Brink et al., 2016; Jevnaker & Wettestad, 2017). Furthermore, market-based schemes often suffer from loopholes and gaming (Ehrhart et al., 2008; Lepere et al., 2023; Sovacool, 2011). For example, some industries lobbied for and secured free permit allocations well into the future - ostensibly to prevent "carbon leakage" - which significantly weakened their incentives to reduce emissions (Grubb et al., 2022; Rode, 2021). In carbon markets, instances of fraud or double counting of credits have been reported (Aguirre, 2024; López-Vallejo, 2021; Martin & Walters, 2013).

The net result is that despite two decades of experience with carbon markets, global emissions have continued to rise, and we have not seen the deep cuts these instruments were supposed to incentivize (Grubert, 2024; Vuong & Nguyen, 2024a). Analysts now argue that while carbon pricing can be a helpful tool, it cannot carry the weight of mitigation alone, especially not under current designs (Cleary & Willcott, 2024). The core shortcomings lie in the market's emphasis on cost-efficiency and flexibility, which - when not accompanied by rigorous oversight - often results in corner-cutting accounting aimed at achieving emissions reductions that can be illusory (Pearse & Böhm, 2014; Stern, 2022). As one researcher noted, "the large majority [of carbon offsets] are not real or are over-credited," effectively slowing meaningful action (Romm & Schendler, 2023). Moreover, market mechanisms are inherently subjective and tend to overlook the complex and pervasive disequilibria present in natural systems (Vuong & Nguyen, 2024a). This has prompted calls for fundamental reform of carbon markets or even their replacement with direct regulations (Pearse & Böhm, 2014; Grubert, 2024; ZERO13, 2025). In Section 4, we will further discuss how an over-reliance on market mechanisms and green consumerism might be rethought in favor of more transformative approaches.

The areas reviewed in this section reveal a recurring pattern: while progress has been made, it remains largely inadequate and often introduces new challenges. Renewable energy is expanding rapidly, but not without environmental trade-offs. Nations have committed to climate goals, yet compliance and certainty remains low. Emerging technologies offer potential solutions, but they come with significant caveats. Public demand for climate action is at an all-time high, but it remains vulnerable to a return to apathy and denial. Carbon markets, once hailed as elegant solutions, have largely failed to deliver meaningful results. The next section examines real-world outcomes, asking whether, despite these efforts, the climate crisis continues to worsen.

## 4. Inadequate outcomes despite exerted efforts

Despite global mitigation efforts to date, they have not been sufficient to halt the acceleration of climate change. GHG concentrations continue to rise, temperatures continue to hit record highs, and impacts on natural systems are intensifying. This section examines the discrepancy between the efforts made and the outcomes observed. Understanding this discrepancy is crucial - it suggests that while progress has been real, it has not (yet) been enough to overcome the momentum of climate disruption.

### *4.1. Climate change is accelerating*

Far from slowing down, climate change has recently shown signs of acceleration, with several records and extreme events underscoring the urgency (Cattiaux et al., 2024; Hansen et al., 2025). In 2023, the global average temperature rose to approximately 1.2°C above the mid-20th-century baseline, making it the hottest year since instrumental records began (Cassidy, 2024). This acceleration continued into the period from June 2023 to August 2024, marked by an unprecedented streak of 15 consecutive months of record-breaking global temperatures (NOAA, 2024). Regions around the world experienced unprecedented anomalies - for instance, north of Ireland experienced sea surface temperatures up to 5°C above average, and Southern Europe endured extreme heatwaves, with Sardinia, Italy reaching 48.2°C during summer weeks in 2023, contributing to deadly heatwaves (Berthou et al., 2024; Perkins-Kirkpatrick et al., 2024).

The manifestation of climate change through extreme weather events and disruptions to the biosphere is increasingly evident. Virtually every corner of the globe has recently experienced anomalous events attributable to or worsened by climate change: unprecedented wildfires from Canada to Australia (Bowman & Sharples, 2023; Byrne et al., 2024), devastating floods in Asia and Africa (Merz et al., 2021), supercharged hurricanes and typhoons, and brutal heatwaves that would have been virtually impossible without global warming (Angelakis et al., 2023; Robinson et al., 2021).

One of the clearest signs of an accelerating climate crisis is the state of the Earth's cryosphere. Notably, Antarctic Sea ice reached a record-low extent in 2023, surpassing previous records by a significant margin (Gilbert & Holmes, 2024; Josey et al., 2024). Antarctic sea ice extent reached record lows during several months of the year, including the lowest summer minimum on record at 1.91 million km² in February and the lowest winter maximum at 16.80 million km² in September (Roach & Meier, 2024). This dramatic shift contrasts sharply with the relatively stable period of the extent of the Antarctic sea ice observed from 1990 to 2015 (Josey et al., 2024). Research indicates that the likelihood of observing such a record-low Antarctic ice level without human-caused climate change is virtually zero, estimated as a one-in-2,000-year event (Diamond et al., 2024). This suggests a sudden shift in the Antarctic system, potentially signaling that rising ocean heat is overwhelming the previous stability of Antarctic Sea ice (Hill et al., 2024).

Another stark impact is on coral reefs and marine ecosystems. Warming ocean temperatures and marine heatwaves have caused widespread coral bleaching and die-offs in recent years (Darmaraki et al., 2025). The Great Barrier Reef - the world's largest coral reef system - has suffered mass bleaching events in six of the last twenty years (2004, 2016, 2017, 2020, 2022, and 2024) (Henley et al., 2024). In 2022, an Australian government survey reported that 91% of reefs on the Great Barrier Reef showed bleaching, an unprecedented extent of impact across the 2,300 km reef tract (Morton & Cox, 2022). Repeated thermal stress prevents recovery between bleaching events, weakening coral resilience and leading to elevated mortality rates that threaten the reef's long-term survival (Guillermic et al., 2021; McCarthy et al., 2024; Nunn et al., 2025). Likewise, reefs in the Indian Ocean, Caribbean, and Central Pacific have experienced significant loss of coral cover (Bruno et al., 2019; Tebbett et al., 2023).

The loss of corals has cascading effects on 63% of coral-reef-associated biodiversity, as they are nurseries for thousands of marine species (Eddy et al., 2021). Beyond coral loss, elevated ocean temperatures have triggered widespread marine die-offs, including mass die-offs of invertebrates, fish, birds, and marine mammals (Terhaar et al., 2025). Warmer waters retain less dissolved oxygen and intensify ocean stratification, leading to the expansion of oxygen-depleted "dead zones." These conditions further stress marine organisms and disrupt the ecosystem functioning globally (Altieri & Diaz, 2019; Bhuiyan et al., 2024; Oschlies et al., 2018).

The biosphere's response to climate change is not limited to aquatic systems. On land, species are shifting their geographic ranges poleward or to higher elevations faster than predicted, with some moving at rates of tens of kilometers per decade as they track suitable climatic conditions (Brodie et al., 2025; Couet et al., 2022; Tomiolo & Ward, 2018). Nevertheless, many species cannot move fast enough or have nowhere to go (e.g., alpine species with no higher mountain to climb) (Corlett & Westcott, 2013; Samuels & Thompson, 2022). Climate change is now recognized as a primary driver of biodiversity loss, compounding traditional threats like habitat destruction (Habibullah et al., 2022; Pfenning-Butterworth et al., 2024). The Amazon rainforest, often referred to as the "lungs of the planet," has experienced more frequent droughts and is approaching a potential tipping point, where large areas could transition from rainforest to savannah-like ecosystems if precipitation patterns shift significantly under continued warming (Flores et al., 2024; Rodrigues, 2023).

## *4.2. Persistent greenhouse gas emissions*

The fundamental driver behind the accelerating climate impacts is the continuing rise in GHG emissions, especially $CO_2$ (Filonchyk et al., 2024). After a brief decline in 2020 due to the COVID-19 economic slowdown, global $CO_2$ emissions rebounded sharply and have since reached record highs (Davis et al., 2022). In fact, 2023 set a new record for energy-related $CO_2$ emissions. According to the International Energy Agency, global $CO_2$ emissions from energy grew by 1.1% in 2023 to reach 37.4 billion tonnes, the highest ever recorded (IEA, 2024). This emissions surge was fueled by multiple factors: the recovery of economic activity post-pandemic, increased fossil fuel use in some regions (notably as droughts cut hydropower, forcing more coal and gas use), and a surge in air travel as global mobility restrictions eased (Davis et al., 2022; Sun & Mi, 2023). The unfortunate reality is that, as of mid-decade, global emissions show no clear peak; they are still rising, albeit slowly (UNEP, 2023a).

The post-COVID emissions rebound underscores the close connection between our emissions and economic activity. Despite initial optimism that the pandemic might spur a "green recovery" through targeted stimulus investments in clean energy infrastructure, the actual outcome has been quite different (Chen et al., 2020; Dafnomilis et al., 2022; van de Ven et al., 2022). The reality is that stimulus spending on fossil fuels, in some cases, outpaced green spending, while pent-up consumer demand for travel, goods, and services led to a rapid resurgence in energy use (Andrew et al., 2022). By 2022, $CO_2$ emissions not only recovered but exceeded pre-pandemic levels (IEA, 2023a). The International Energy Agency noted that despite record growth in renewables, fossil fuel emissions were also at or near record levels (IEA, 2023a). This reveals that clean energy is adding to the energy mix but not yet displacing fossil fuels enough to cause absolute declines in emissions.

Another concerning trend is the continued increase in atmospheric GHG concentrations. In 2023, atmospheric $CO_2$ averaged around 420 ppm (parts per million), far above the pre-industrial level of approximately 278 ppm (Cassidy, 2024). Atmospheric methane ($CH_4$) — a potent greenhouse gas — has surged in recent years, driven by factors not yet fully understood. Likely contributors include emissions from fossil fuels, agriculture, and natural processes (Skeie et al., 2023). This rise in concentration highlights a concerning trend: Earth's natural sinks, such as oceans and the land biosphere, continue to absorb only about half of human-generated emissions, leaving the remainder to accumulate in the atmosphere (Cassidy, 2024; Mayot et al., 2024). There is emerging evidence that Earth's natural carbon sinks may be reaching saturation. For example, a recent study indicated that the ocean's capacity to absorb carbon could be weakening (Gruber et al., 2023). If confirmed, this would mean a larger share of emissions remains in the atmosphere, further accelerating global warming. Due to the inertia of the climate system, even if emissions level off, atmospheric concentrations will continue to rise - albeit more slowly - until net-zero emissions are achieved (King et al., 2022).

The current trajectory - marked by record-high emissions and intensifying climate impacts - suggests that mitigation efforts, while not without merit, have fallen short in both scale and effectiveness. To meet global climate targets, $CO_2$ emissions should already be declining sharply; instead, they continue to edge upward. Each additional year of elevated emissions "locks in" further warming, with delayed effects that will unfold over the coming decades due to the inertia of the Earth system.

## 5. Have we done the right things?

In the light of the persistent gap between climate efforts and actual outcomes, we believe that we may not be pursuing the right path. This section examines the structural factors underlying the shortfall in results and argues that effective emissions mitigation demands a new socio-cultural and economic paradigm.

### *5.1. Climate system inertia*

First, it is essential to recognize that even if mitigation efforts were perfectly aligned with global targets, we would not see an immediate halt or reversal of climate change due to the Earth system's inherent inertia. Even if net GHG emissions dropped to zero today, global temperatures would not decline tomorrow. In fact, they would likely continue to rise slightly before stabilizing (King et al., 2022; NASA Earth Observatory, 2007; Samset et al., 2020). This delay stems largely from the oceans, which absorb the majority of excess heat and take decades to reach equilibrium (Pierce et al., 2011). The concept of "committed warming" refers to the additional warming already locked in from past emissions that has yet to fully materialize (Emile-Geay, 2022).

This helps explain why we are experiencing significant climate impacts today despite some progress in mitigation—the system is still responding to the cumulative emissions released since the Industrial Revolution. As a result, the effects of mitigation efforts on global temperatures will only become apparent over time. Deep and sustained emissions reductions could slow the rate of warming within a few decades (IPCC, 2023) but not produce immediate cooling.

This temporal lag presents both political and psychological challenges: policymakers may be reluctant to implement effective climate policies whose benefits—such as avoided disasters or temperature stabilization—only emerge long after their terms end. Likewise, the public may feel disillusioned (e.g., "we cut emissions, but conditions keep worsening"), unaware of the time it takes for the Earth system to respond.

While it can be argued that many current efforts are in the right direction, they have not been sustained long enough or implemented at a sufficient scale to produce visible results. However, patience has its limits: the longer we delay peaking emissions, the more inertia we embed into the climate system—momentum that future efforts will struggle to reverse. This underscores a critical point: mitigation is urgent. The sooner and more decisively emissions are reduced, the less future warming becomes locked in. Inertia may justify tempered expectations about short-term outcomes, but it is not an excuse for inaction. On the contrary, it is a powerful reason to act swiftly and boldly to minimize irreversible damage.

### *5.2. The urgent need for an eco-surplus culture*

As outlined above, climate mitigation efforts have predominantly relied on market-based solutions - such as carbon trading, technological innovation, and renewable energy - with the aim of reducing emissions while sustaining economic growth. However, these approaches remain inadequate for addressing a crisis as systemic and deeply embedded as climate change, which requires more direct and structural interventions. Notably, after more than two decades of implementation, carbon markets have failed to produce tangible reductions in emissions (see Sub-section 3.5 and Section 4) (Grubert, 2024; Sato et al., 2019; Trencher et al., 2024). Rather than eliminating emissions, they have arguably obscured them, fostering a false sense of progress and delaying the adoption of more effective measures. For example, some fossil fuel companies have adopted nature-based offsets or committed to carbon capture and storage, even as they continue to expand fossil fuel exploration and drilling, effectively using these mechanisms as a means to justify their operations rather than as a genuine shift in their business models (Klinge, 2021).

A key challenge in advancing sustainability and climate action lies in how these issues are framed. Conventional approaches often fragment the problem, treating biophysical, social, economic, and political dimensions in isolation rather than as interlinked systems (Loos et al., 2014). This reductionist lens tends to favor technological fixes for inherently complex and multi-dimensional challenges

(Câmpeanu & Fazey, 2014) while overlooking the critical roles of human behavior, institutional dynamics, and socio-political structures (Abson et al., 2017; Shah, 2020).

To move beyond these limitations, we argue that meaningful climate action requires a foundational shift in value systems: a collective consensus that environmental sustainability is not optional but essential for human survival and long-term development (Vuong & Nguyen, 2025). The concept of an eco-surplus culture captures this shift. Granular Interaction Thinking Theory (GITT) (Vuong & Nguyen, 2024a, 2024b, 2024c), rooted in quantum mechanics (Hertog, 2023; Rovelli, 2018), Shannon's information theory (Shannon, 1948), and mindsponge theory (Vuong, 2023), offers a framework to articulate this logic.

GITT views humanity as an information-processing system governed by an evolving set of core values and priorities. Given the diversity of nations, political systems, institutions, and ethnic communities this value set is highly heterogeneous. As the number of competing values grows without clear prioritization, the system becomes increasingly disordered. Shannon's entropy formula models this rise in informational entropy:

$$H(X) = -\sum_{i=1}^{n} P(x_i) \log_2 P(x_i)$$

In this context, $X$ represents the set of humanity's core values and $P(x_i)$ indicates the probability that a given value or priority $x$ drives decisions and actions. When all values are treated equally (i.e., $P(x_i) = \frac{1}{n}$), entropy peaks. High-entropy systems are inherently unstable and require excessive energy—resources, labor, and energy—to maintain order and achieve their objectives. Reducing the entropy within the system requires defining certain sets of core values and priorities and assigning them a higher probability to drive decisions and actions. The current socio-economic paradigm remains rooted in eco-deficit values, prioritizing growth-oriented objectives while treating environmental concerns as externalities to be managed through the market's optimized allocation of resources via price signals. Given the eco-deficit mindset, even in the face of regulatory frameworks, actors operating within an eco-deficit culture often respond with evasive behaviors: lobbying, exploiting legal loopholes, misreporting, or greenwashing (Adi, 2018; Vuong et al., 2021; Walker & Wan, 2012).

In contrast, an eco-surplus culture foregrounds environmental restoration and protection as prerequisites for sustainable prosperity. In such a value system, climate mitigation is not a tradeoff but a foundation for achieving social, economic, and geopolitical objectives. Consider the example of major banks in the Net Zero Banking Alliance. Had their commitments been anchored in genuine eco-surplus values, it is unlikely they would have withdrawn following a shift in political leadership.

The eco-surplus culture can also enable the semi-conducting principle of monetary and environmental value exchange, which allows society to capitalize on the current established market mechanism to address climate change and environmental degradation rather than replace it. Specifically, there needs to be a new profit/growth paradigm - one that integrates environmental value as a core component (Vuong, 2021):

$$New\ Net\ Profits = Net\ Monetary\ Profits + Net\ Environmental\ Values$$

In this model, environmental value is exchanged for monetary value, but not the reverse. This reflects the semiconducting principle of value exchange, where financial capital cannot be used to justify or offset ecological harm (Vuong, 2021). Current carbon markets lack this principle, allowing businesses to continue polluting while claiming compliance through offsets, ultimately reinforcing eco-deficit behaviors. Without safeguards, this creates a dangerous feedback loop of false progress and worsening environmental conditions.

Traditional economic growth metrics, i.e., GDP, fail to account for environmental degradation. In contrast, an eco-surplus mindset redefines success, incorporating values such as ecosystem health, climate stability, and overall quality of life (Vuong & Nguyen, 2024a). Promising steps in this direction are emerging - most notably the "Doughnut Economics" framework (Raworth, 2018), which envisions a safe and just operating space bounded by social foundations and ecological ceilings. Similarly, national well-being indices are gaining traction. Countries like New Zealand and Bhutan have incorporated well-being and happiness into policy objectives, implicitly acknowledging that infinite GDP growth is neither feasible nor desirable if it erodes the planet's life-supporting systems (Lee & Goh, 2023; Zsolnai et al., 2023).

Inevitably, building an eco-surplus culture is a long-term process that requires sustained investment and coordinated implementation across multiple dimensions, including education. To establish a value system aligned with eco-surplus principles and foster pro-environmental social norms, environmental education must become more innovative and move beyond the conventional purpose of transmitting and reinforcing existing eco-deficit cultural knowledge and values (Durkheim, 1956; Stevenson, 2007). Achieving this goal requires a focus on illuminating the nature-human nexus - particularly by emphasizing the connections between environmental issues, the students, and their "objects of care," such as valued people, places, possessions, and elements of their core identity (Kollmuss & Agyeman, 2002; Nguyen et al., 2024; Vuong & Nguyen, 2023b; S. Wang et al., 2018). Such informed and personalized linkages are crucial for anchoring environmental concerns in what students genuinely value, thereby fostering genuine motivation to protect the environment and mitigate climate change.

Environmental education should also provide students with opportunities to engage directly with nature. Integrating experiential learning programs in natural environments into school curricula - such as tree planting, school garden restoration, walking in the parks and forests, observing and playing with nonhuman animals, or local water quality monitoring - offers a practical approach (Paulsen et al., 2022; Pirchio et al., 2021; Spannring, 2017). In addition to direct interactions, indirect engagements through media such as visual arts, painting, film, literature, and pictures can also nurture a mindset that values nature and supports conservation and restoration efforts. These media can facilitate voluntary and repeated information processing, reinforcing eco-surplus values and behaviors over time (Nguyen, 2024; Tran, 2025; Vuong & Nguyen, 2023a).

Fostering an eco-surplus culture also requires integrating indigenous and local knowledge systems into mainstream decision-making, particularly through the adoption of nature-based solutions. Indigenous communities have long practiced forms of environmental stewardship that align with eco-surplus principles - living within the regenerative capacity of their ecosystems (Tran et al., 2025). Increasingly, sustainability science recognizes these approaches as effective and equitable (Tom et al., 2019). For instance, reforestation and ecosystem restoration efforts grounded in indigenous knowledge often yield more enduring and just outcomes (Haq et al., 2023; Tran et al., 2025). Policy innovations may include granting legal rights to ecosystems (as adopted in several countries), expanding protected areas, supporting community-led conservation efforts, and reshaping financial systems to prioritize investments in natural capital regeneration.

Public fiscal policies are promising tools for shaping cultural value systems and influencing the behaviors of the public and businesses. Reorienting incentives to reward ecological protection and restoration, while penalizing eco-deficit activities, is essential for steering society toward an eco-surplus economy. A notable example is the Payment for Ecosystem Services (PES) in Costa Rica, which once had one of the world's highest deforestation rates during the 1970s and 1980s. The country has since reversed this trend and successfully restored approximately 57% of its forest cover through a PES scheme financed by a fossil fuel tax (Vincenzi, 2024). Empirical studies in Costa Rica and Colombia have demonstrated the lasting impact of PES programs on eco-surplus land use changes, particularly the adoption of silvopastoral practices that enhance biodiversity conservation and carbon sequestration on previously degraded, treeless pastures (Pagiola et al., 2016; Rasch et al., 2021). Rasch et al. (2021) further revealed behavioral convergence among farmers and a positive association between social ties and group membership, indicating that these practices and their driving values can be diffused and reinforced through social interaction—the exchange of information and experiences among the farmers. Although PES schemes still face challenges that need to be addressed, they represent an effective mechanism for embedding environmental value into profitability function.

In addition to PES, fiscal instruments such as tax policies, ecological fiscal transfers, and targeted subsidies or grants can also be leveraged to make restoration economically rewarding and environmental degradation financially burdensome (Busch et al., 2021). These mechanisms, when implemented systematically and complementarily, can create conditions for adopting the semiconducting principle of monetary and environmental value exchange, helping to harmonize economic activities with ecological sustainability.

One of the critical conditions for establishing the principle is the ability to sustain financial flows that are sufficient to support and fund nature protection and restoration activities, as well as innovative projects that do not cause environmental degradation. To achieve this, future research and policy efforts must focus on designing both mandatory and voluntary financial mechanisms that actively involve businesses and citizens, rather than relying solely on the limited budgets of governments. These mechanisms should not be restricted to communities located near conservation, restoration, or emission reduction project sites. Instead, they should be designed to connect with businesses and individuals in other regions - particularly in urban areas - thereby expanding the base of contributors and enhancing the scalability and sustainability of environmental financing systems.

Involving the private sector through public–private partnerships (PPPs) can be an effective strategy to reduce government expenditures. This collaborative model - particularly when it engages multiple stakeholders - can help mobilize capital, leverage expertise and innovation, and allocate risks more efficiently for projects that inherently demand high investment, innovation, and risk tolerance, such as low-carbon infrastructure, sustainable agriculture, and forest restoration (Casady et al., 2024; Löfqvist et al., 2023; Zhang et al., 2022). Beyond these advantages, from the perspective of cultivating eco-surplus culture, PPPs can also serve as a mechanism through which governments promote and institutionalize values and operational principles that prioritize environmental sustainability. Governments can establish these values as preconditions for partnership and reinforce them throughout project implementation via oversight and compliance mechanisms. Conversely, large multinational corporations that have embraced an eco-surplus culture can also apply sustainability-oriented values and principles as criteria for participating in government-tendered projects. In doing so, both sectors mutually reinforce a culture where environmental sustainability is embedded as a foundational operational norm.

For the general public, innovative financing mechanisms that leverage the power of the Internet and digital technologies should be developed. Approaches such as crowdfunding or citizen-led impact funds can be employed to generate financial resources for ecological and biodiversity conservation and restoration projects, or for initiatives aimed at reducing negative environmental impacts (Cunha-e-Sá et al., 2025; Gallo-Cajiao et al., 2018). To enhance citizen engagement and foster a sense of ownership, these projects should include mechanisms that communicate their relevance to citizens and their "objects of care", in addition to participatory monitoring, planning, and decision-making systems. However, implementing such approaches poses significant challenges, particularly due to the public's limited perception of the relevance of projects - especially among those living far from the project sites - and the low perceived value of initiatives. However, fostering an eco-surplus culture offers a promising path forward. In a society with eco-surplus culture, citizens are more likely to recognize the interlinkages between ecological sustainability and the stability of their lives and personal concerns, thereby increasing their willingness to participate and contribute (Nguyen & Jones, 2022a, 2022b).

Currently, we conclude that humanity is not yet on the right trajectory for effective climate change mitigation; however, we can achieve it through a bold and systemic transition. Despite sincere efforts, the current path remains anchored in outdated growth-oriented paradigms that are ill-equipped to confront the scale and urgency of a rapidly changing climate. A decisive course correction toward genuinely sustainable practices is essential. Humanity already possesses the knowledge and tools needed to address the crisis; what remains is the socio-cultural and economic shift to deploy them at the necessary scale. A viable path forward exists - one defined by deep emissions reductions, innovation aligned with nature, and a redefinition of progress - and it is still within our collective power to choose it.

## References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, *29*(28), 42539-42559. https://doi.org/10.1007/s11356-022-19718-6

Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., . . . Jager, N. W. (2017). Leverage points for sustainability transformation. *Ambio*, *46*, 30-39. https://doi.org/10.1007/s13280-016-0800-y

Adi, A. (2018). # Sustainability on Twitter: loose ties and green-washing CSR. In *Corporate responsibility digital communities: An international perspective towards sustainability*. G. Grigore, A. Stancu, & D. McQueen (Eds.). Springer: pp. 99-122.

Aggarwal, R. (2024). Carbon offsets compatible with the Paris Agreement to limit global warming: Call for a direct action. *Environmental Challenges*, *17*, 101034. https://doi.org/https://doi.org/10.1016/j.envc.2024.101034

Aguirre, J. C. (2024). The warring conmen at the heart of a €5bn carbon trading scam: https://www.theguardian.com/news/article/2024/jun/04/the-warring-conmen-at-the-heart-of-a-5bn-carbon-credit-scam Accessed 1 Jul 2025.

Agusdinata, D. B., Liu, W., Eakin, H., & Romero, H. (2018). Socio-environmental impacts of lithium mineral extraction: towards a research agenda. *Environmental Research Letters*, *13*(12), 123001. https://doi.org/10.1088/1748-9326/aae9b1

Altenburg, T., Assmann, C., Rodrik, D., Padilla, E., Ambec, S., & Esposito, M. (2017). *Green industrial policy: Concept, policies, country experiences*. UN Environment, German Development Institute.

Altieri, A. H., & Diaz, R. J. (2019). Chapter 24 - Dead Zones: Oxygen Depletion in Coastal Ecosystems. In *World seas: An environmental evaluation (Second Edition)*. C. Sheppard (Ed.). Academic Press: pp. 453-473.

Anderson, K., Buck, H. J., Fuhr, L., Geden, O., Peters, G. P., & Tamme, E. (2023). Controversies of carbon dioxide removal. *Nature Reviews Earth & Environment*, *4*(12), 808-814. https://doi.org/10.1038/s43017-023-00493-y

Andre, P., Boneva, T., Chopra, F., & Falk, A. (2024). Globally representative evidence on the actual and perceived support for climate action. *Nature Climate Change*, *14*(3), 253-259. https://doi.org/10.1038/s41558-024-01925-3

Andresen, S., Bang, G., Skjærseth, J. B., & Underdal, A. (2021). Achieving the ambitious targets of the Paris Agreement: the role of key actors. *International Environmental Agreements: Politics, Law and Economics*, *21*(1), 1-7. https://doi.org/10.1007/s10784-021-09527-6

Andrew, K., Majerbi, B., & Rhodes, E. (2022). Slouching or speeding toward net zero? Evidence from COVID-19 energy-related stimulus policies in the G20. *Ecological Economics*, *201*, 107586. https://doi.org/10.1016/j.ecolecon.2022.107586

Angelakis, A. N., Capodaglio, A. G., Valipour, M., Krasilnikoff, J., Ahmed, A. T., Mandi, L., . . . Dercas, N. (2023). Evolution of floods: from ancient times to the present times (ca 7600 BC to the present) and the future. *Land*, *12*(6), 1211. https://doi.org/10.3390/land12061211

Anke, C.-P., Hobbie, H., Schreiber, S., & Möst, D. (2020). Coal phase-outs and carbon prices: Interactions between EU emission trading and national carbon mitigation policies. *Energy Policy*, *144*, 111647. https://doi.org/10.1016/j.enpol.2020.111647

Antoci, A., Russu, P., & Ticci, E. (2019). Mining and local economies: Dilemma between environmental protection and job opportunities. *Sustainability*, *11*(22), 6244. https://doi.org/10.3390/su11226244

Antoniou, F., Delis, M. D., Ongena, S., & Tsoumas, C. (2024). Pollution permits and financing costs. *Journal of Money, Credit and Banking*. https://doi.org/10.1111/jmcb.13241

Badgley, G., Freeman, J., Hamman, J. J., Haya, B., Trugman, A. T., Anderegg, W. R. L., & Cullenward, D. (2022). Systematic over-crediting in California's forest carbon offsets program. *Global Change Biology*, *28*(4), 1433-1445. https://doi.org/https://doi.org/10.1111/gcb.15943

Ballew, M., Marlon, J., Rosenthal, S., Gustafson, A., Kotcher, J., Maibach, E., & Leiserowitz, A. (2019). Do younger generations care more about global warming?: https://climatecommunication.yale.edu/publications/do-younger-generations-care-more-about-global-warming/ Accessed 17 Mar 2025.

Banza Lubaba Nkulu, C., Casas, L., Haufroid, V., De Putter, T., Saenen, N. D., Kayembe-Kitenge, T., . . . Nemery, B. (2018). Sustainability of artisanal mining of cobalt in DR Congo. *Nature Sustainability*, *1*(9), 495-504. https://doi.org/10.1038/s41893-018-0139-4

Baranzini, A., van den Bergh, J. C. J. M., Carattini, S., Howarth, R. B., Padilla, E., & Roca, J. (2017). Carbon pricing in climate policy: Seven reasons, complementary instruments, and political economy considerations. *WIREs Climate Change*, *8*(4), e462. https://doi.org/https://doi.org/10.1002/wcc.462

Barradale, M. J. (2010). Impact of public policy uncertainty on renewable energy investment: Wind power and the production tax credit. *Energy Policy*, *38*(12), 7698-7709. https://doi.org/10.1016/j.enpol.2010.08.021

Baum, C. M., Fritz, L., Low, S., & Sovacool, B. K. (2024). Public perceptions and support of climate intervention technologies across the Global North and Global South. *Nature Communications*, *15*(1), 2060. https://doi.org/10.1038/s41467-024-46341-5

Beitsch, R. (2019). Climate change is top priority for young voters: study:. https://thehill.com/policy/energy-environment/467205-study-climate-change-is-top-priority-for-young-voters/ Accessed 1 Jul 2025.

Bellocchi, S., Klöckner, K., Manno, M., Noussan, M., & Vellini, M. (2019). On the role of electric vehicles towards low-carbon energy systems: Italy and Germany in comparison. *Applied Energy*, *255*, 113848. https://doi.org/10.1016/j.apenergy.2019.113848

Berthou, S., Renshaw, R., Smyth, T., Tinker, J., Grist, J. P., Wihsgott, J. U., . . . Worsfold, M. (2024). Exceptional atmospheric conditions in June 2023 generated a northwest European marine heatwave which contributed to breaking land temperature records. *Communications Earth & Environment*, *5*(1), 287. https://doi.org/10.1038/s43247-024-01413-8

Bhuiyan, M. M. U., Rahman, M., Naher, S., Shahed, Z. H., Ali, M. M., & Islam, A. R. M. T. (2024). Oxygen declination in the coastal ocean over the twenty-first century: Driving forces, trends, and impacts. *Case Studies in Chemical and Environmental Engineering*, *9*, 100621. https://doi.org/10.1016/j.cscee.2024.100621

Bliuc, A.-M., McGarty, C., Thomas, E. F., Lala, G., Berndsen, M., & Misajon, R. (2015). Public division about climate change rooted in conflicting socio-political identities. *Nature Climate Change*, *5*(3), 226-229. https://doi.org/10.1038/nclimate2507

Bogert, J. M., Buczny, J., Harvey, J. A., & Ellers, J. (2024). The effect of trust in science and media use on public belief in anthropogenic climate change: A meta-analysis. *Environmental Communication*, *18*(4), 484-509. https://doi.org/10.1080/17524032.2023.2280749

Borick, C. P., & Rabe, B. G. (2017). Personal experience, extreme weather events, and perceptions of climate change. In *Oxford research encyclopedia of climate science*. Oxford University Press.

Bowman, D. M. J. S., & Sharples, J. J. (2023). Taming the flame, from local to global extreme wildfires. *Science*, *381*(6658), 616-619. https://doi.org/doi:10.1126/science.adi8066

Boyce, J. K. (2018). Carbon pricing: Effectiveness and equity. *Ecological Economics*, *150*, 52-61. https://doi.org/10.1016/j.ecolecon.2018.03.030

Brink, C., Vollebergh, H. R. J., & van der Werf, E. (2016). Carbon pricing in the EU: Evaluation of different EU ETS reform options. *Energy Policy*, *97*, 603-617. https://doi.org/10.1016/j.enpol.2016.07.023

Brodie, J. F., Freeman, B. G., Mannion, P. D., & Hargreaves, A. L. (2025). Shifting, expanding, or contracting? Range movement consequences for biodiversity. *Trends in Ecology & Evolution*, *40*(5), 439-448. https://doi.org/10.1016/j.tree.2025.02.001

Brown, C., Boyd, D. S., & Kara, S. (2022). Landscape analysis of cobalt mining activities from 2009 to 2021 using very high resolution satellite data (Democratic Republic of the Congo). *Sustainability*, *14*(15), 9545. https://doi.org/10.3390/su14159545

Brown, C. W., Goldfine, C. E., Allan-Blitz, L.-T., & Erickson, T. B. (2024). Occupational, environmental, and toxicological health risks of mining metals for lithium-ion batteries: a narrative review of the Pubmed database. *Journal of Occupational Medicine and Toxicology*, *19*(1), 35. https://doi.org/10.1186/s12995-024-00433-6

Brüggemann, M., & Engesser, S. (2017). Beyond false balance: How interpretive journalism shapes media coverage of climate change. *Global Environmental Change*, *42*, 58-67. https://doi.org/10.1016/j.gloenvcha.2016.11.004

Bruno, J. F., Côté, I. M., & Toth, L. T. (2019). Climate change, coral loss, and the curious case of the parrotfish paradigm: Why don't marine protected areas improve reef resilience? *Annual Review of Marine Science*, *11*, 307-334. https://doi.org/10.1146/annurev-marine-010318-095300

Bruyninckx, H., Hatfield-Dodds, S., Hellweg, S., Schandl, H., Vidal, B., Razian, H., . . . Silva, D. A. L. (2024). *Global resources outlook 2024: Bend the trend-pathways to a liveable planet as resource use spikes*. International Resource Panel.

Burke, K. D., Williams, J. W., Chandler, M. A., Haywood, A. M., Lunt, D. J., & Otto-Bliesner, B. L. (2018). Pliocene and Eocene provide best analogs for near-future climates. *Proceedings of the National Academy of Sciences*, *115*(52), 13288-13293. https://doi.org/doi:10.1073/pnas.1809600115

Busch, J., Ring, I., Akullo, M., Amarjargal, O., Borie, M., Cassola, R. S., . . . Kasymov, U. (2021). A global review of ecological fiscal transfers. *Nature Sustainability*, *4*(9), 756-765. https://doi.org/10.1038/s41893-021-00728-0

Byrne, B., Liu, J., Bowman, K. W., Pascolini-Campbell, M., Chatterjee, A., Pandey, S., . . . Sinha, S. (2024). Carbon emissions from the 2023 Canadian wildfires. *Nature*, *633*(8031), 835-839. https://doi.org/10.1038/s41586-024-07878-z

Câmpeanu, C. N., & Fazey, I. (2014). Adaptation and pathways of change and response: a case study from Eastern Europe. *Global Environmental Change*, *28*, 351-367. https://doi.org/10.1016/j.gloenvcha.2014.04.010

Casady, C. B., Cepparulo, A., & Giuriato, L. (2024). Public-private partnerships for low-carbon, climate-resilient infrastructure: Insights from the literature. *Journal of Cleaner Production*, *470*, 143338. https://doi.org/10.1016/j.jclepro.2024.143338

Cassidy, E. (2024). Emissions from fossil fuels continue to rise: https://earthobservatory.nasa.gov/images/152519/emissions-from-fossil-fuels-continue-to-rise Accessed 5 May 2025.

Cattiaux, J., Ribes, A., & Cariou, E. (2024). How extreme were daily global temperatures in 2023 and early 2024? *Geophysical Research Letters*, *51*(19), e2024GL110531. https://doi.org/10.1029/2024GL110531

Chemnick, J., Farah, N. H., Clark, L., & E&E News. (2025). Inside the EPA's attempt to roll back climate regulation: https://www.scientificamerican.com/article/trump-epa-announces-climate-regulation-rollback-but-faces-legal-hurdles/ Accessed 1 Jul 2025.

Chen, Z., Marin, G., Popp, D., & Vona, F. (2020). Green stimulus in a Post-pandemic recovery: The role of skills for a resilient recovery. *Environmental and Resource Economics*, *76*(4), 901-911. https://doi.org/10.1007/s10640-020-00464-7

Chiappinelli, O., & May, N. (2022). Too good to be true? Time-inconsistent renewable energy policies. *Energy Economics*, *112*, 106102. https://doi.org/10.1016/j.eneco.2022.106102

Chinn, S., Lane, D. S., & Hart, P. S. (2018). In consensus we trust? Persuasive effects of scientific consensus communication. *Public Underst Sci*, *27*(7), 807-823. https://doi.org/10.1177/0963662518791094

Cleary, S., & Willcott, N. (2024). Carbon pricing: Necessary but not sufficient. *Finance Research Letters*, *68*, 106017. https://doi.org/https://doi.org/10.1016/j.frl.2024.106017

Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., . . . Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters*, *8*(2), 024024. https://doi.org/10.1088/1748-9326/8/2/024024

Corlett, R. T., & Westcott, D. A. (2013). Will plant movements keep up with climate change? *Trends in Ecology & Evolution*, *28*(8), 482-488. https://doi.org/10.1016/j.tree.2013.04.003

Costa, M. (2025). NZBA under pressure as Japanese banks leave: https://greencentralbanking.com/2025/04/03/nzba-under-pressure-as-japanese-banks-leave/ Accessed 16 May 2025.

Couet, J., Marjakangas, E.-L., Santangeli, A., Kålås, J. A., Lindström, Å., & Lehikoinen, A. (2022). Short-lived species move uphill faster under climate change. *Oecologia*, *198*(4), 877-888. https://doi.org/10.1007/s00442-021-05094-4

Coughlin, J., & Morera Quesada, A. P. (2024). The other Greta Effect (OGE): Recognizing youth climate activists beyond Thunberg. *Kvinder, Køn & Forskning*, *37*(1), 15. https://doi.org/10.7146/kkf.v37i1.141088

Craig, C. A., Allen, M. W., Feng, S., & Spialek, M. L. (2020). Exploring the impact of resident proximity to wildfires in the northern Rocky Mountains: Perceptions of climate change risks, drought, and policy. *International Journal of Disaster Risk Reduction*, *44*, 101420. https://doi.org/10.1016/j.ijdrr.2019.101420

Cunha-e-Sá, M. A., Dietrich, T., Faria, A., Nunes, L. C., Ortigão, M., Rosa, R., & Vieira-da-Silva, C. (2025). Willingness to pay for nature protection: Crowdfunding as a payment mechanism. *Environmental and Resource Economics*, *88*(2), 367-396. https://doi.org/10.1007/s10640-024-00933-3

Dafnomilis, I., Chen, H.-H., den Elzen, M., Fragkos, P., Chewpreecha, U., van Soest, H., . . . van Vuuren, D. P. (2022). Targeted green recovery measures in a post-COVID-19 world enable the energy transition. *Frontiers in Climate*, *4*, 840933. https://doi.org/10.3389/fclim.2022.840933

Darmaraki, S., Krokos, G., Genevier, L., Hoteit, I., & Raitsos, D. E. (2025). Drivers of marine heatwaves in coral bleaching regions of the Red Sea. *Communications Earth & Environment*, *6*(1), 120. https://doi.org/10.1038/s43247-025-02096-5

Davis, S. J., Liu, Z., Deng, Z., Zhu, B., Ke, P., Sun, T., . . . Ciais, P. (2022). Emissions rebound from the COVID-19 pandemic. *Nature Climate Change*, *12*(5), 412-414. https://doi.org/10.1038/s41558-022-01332-6

de Coninck, H., & Benson, S. M. (2014). Carbon dioxide capture and storage: Issues and prospects. *Annual Review of Environment and Resources*, *39*, 243-270. https://doi.org/10.1146/annurev-environ-032112-095222

Dechezleprêtre, A., Nachtigall, D., & Venmans, F. (2023). The joint impact of the European Union emissions trading system on carbon emissions and economic performance. *Journal of Environmental Economics and Management*, *118*, 102758. https://doi.org/10.1016/j.jeem.2022.102758

Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G., & Spence, A. (2017). Experience of extreme weather affects climate change mitigation and adaptation responses. *Climatic Change*, *140*, 149-164. https://doi.org/10.1007/s10584-016-1837-4

den Elzen, M. G. J., Dafnomilis, I., Forsell, N., Fragkos, P., Fragkiadakis, K., Höhne, N., . . . Sperling, F. (2022). Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach. *Mitigation and Adaptation Strategies for Global Change*, *27*(5), 33. https://doi.org/10.1007/s11027-022-10008-7

Dhanda, K. K., & Hartman, L. (2012). Carbon offset markets: A viable instrument? In *Handbook of $CO_2$ in power systems*. Q. P. Zheng, S. Rebennack, P. M. Pardalos, M. V. F. Pereira, & N. A. Iliadis (Eds.). Springer Berlin Heidelberg: pp. 107-129.

Diamond, R., Sime, L. C., Holmes, C. R., & Schroeder, D. (2024). CMIP6 models rarely simulate Antarctic winter sea-ice anomalies as large as observed in 2023. *Geophysical Research Letters*, *51*(10), e2024GL109265. https://doi.org/10.1029/2024GL109265

Doelle, M. (2021). In defence of the Paris Agreement's compliance system: The case for facilitative compliance. In *Debating climate law*. B. Mayer & A. Zahar (Eds.). Cambridge University Press: pp. 86-98.

Dorsey, J. (2019). Waiting for the courts: Effects of policy uncertainty on pollution and investment. *Environmental and Resource Economics*, *74*(4), 1453-1496. https://doi.org/10.1007/s10640-019-00375-2

Durkheim, E. (1956). *Education and sociology*. Simon and Schuster.

Eddy, T. D., Lam, V. W. Y., Reygondeau, G., Cisneros-Montemayor, A. M., Greer, K., Palomares, M. L. D., . . . Cheung, W. W. L. (2021). Global decline in capacity of coral reefs to provide ecosystem services. *One Earth*, *4*(9), 1278-1285. https://doi.org/10.1016/j.oneear.2021.08.016

Ehrhart, K.-M., Hoppe, C., & Löschel, R. (2008). Abuse of EU emissions trading for tacit collusion. *Environmental and Resource Economics*, *41*(3), 347-361. https://doi.org/10.1007/s10640-008-9195-y

Emile-Geay, J. (2022). What is 'committed warming'? A climate scientist explains why global warming can continue long after emissions end: https://dornsife.usc.edu/news/stories/what-is-committed-warming/ Accessed 14 May 2025.

European Commission. (2024). *Report from the Commission to the European Parliament and the Council on the functioning of the European carbon market in 2023*. European Commission.

Ewing, J. (2023). In Norway, the electric vehicle future has already arrived: https://www.nytimes.com/2023/05/08/business/energy-environment/norway-electric-vehicles.html Accessed 10 May 2025.

Fell, H. (2016). Comparing policies to confront permit over-allocation. *Journal of Environmental Economics and Management*, *80*, 53-68. https://doi.org/10.1016/j.jeem.2016.01.001

Filonchyk, M., Peterson, M. P., Zhang, L., Hurynovich, V., & He, Y. (2024). Greenhouse gases emissions and global climate change: Examining the influence of CO2, CH4, and N2O. *Science of The Total Environment*, *935*, 173359. https://doi.org/10.1016/j.scitotenv.2024.173359

Flores, B. M., Montoya, E., Sakschewski, B., Nascimento, N., Staal, A., Betts, R. A., . . . Hirota, M. (2024). Critical transitions in the Amazon forest system. *Nature*, *626*(7999), 555-564. https://doi.org/10.1038/s41586-023-06970-0

Frey, U. J., & Burgess, J. (2023). Why do climate change negotiations stall? Scientific evidence and solutions for some structural problems. *Global Discourse*, *13*(2), 138-162. https://doi.org/10.1332/204378921x16431423735159

Frost, R. (2025). Top American banks exit net zero alliance: What does this mean for their European peers?: https://www.euronews.com/green/2025/02/10/top-american-banks-exit-net-zero-alliance-what-does-this-mean-for-their-european-peers Accessed 17 May 2025.

Fujita, T., Chen, H., Wang, K.-t., He, C.-l., Wang, Y.-b., Dodbiba, G., & Wei, Y.-z. (2021). Reduction, reuse and recycle of spent Li-ion batteries for automobiles: A review. *International Journal of Minerals, Metallurgy and Materials*, *28*(2), 179-192. https://doi.org/10.1007/s12613-020-2127-8

Gallo-Cajiao, E., Archibald, C., Friedman, R., Steven, R., Fuller, R. A., Game, E. T., . . . Ritchie, E. G. (2018). Crowdfunding biodiversity conservation. *Conservation Biology*, *32*(6), 1426-1435. https://doi.org/10.1111/cobi.13144

Gan, Y., Lu, Z., He, X., Hao, C., Wang, Y., Cai, H., . . . Bouchard, J. (2021). Provincial greenhouse gas emissions of gasoline and plug-in electric vehicles in China: comparison from the consumption-based electricity perspective. *Environmental Science & Technology*, *55*(10), 6944-6956. https://doi.org/10.1021/acs.est.0c08217

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, *24*, 38-50. https://doi.org/10.1016/j.esr.2019.01.006

Gilbert, E., & Holmes, C. (2024). 2023's Antarctic sea ice extent is the lowest on record. *Weather*, *79*(2), 46-51. https://doi.org/https://doi.org/10.1002/wea.4518

Gilmour, J. (2023). 45Q: Toward a stronger federal carbon capture tax credit. *Environmental Claims Journal*, *35*(3), 235-253. https://doi.org/10.1080/10406026.2023.2252375

Global CCS Institute. (2024). *Global status report 2024*. Global CCS Institute.

Gounaridis, D., & Newell, J. P. (2024). The social anatomy of climate change denial in the United States. *Scientific Reports*, *14*(1), 2097. https://doi.org/10.1038/s41598-023-50591-6

Gray, K. A. (2021). Climate action: The feasibility of climate intervention on a global scale. In *Climate geoengineering: Science, law and governance*. W. Burns, D. Dana, & S. J. Nicholson (Eds.). Springer International Publishing: pp. 33-91.

Greenfield, P. (2023). Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows: https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe Accessed 20 Mar 2025.

Grubb, M., Jordan, N. D., Hertwich, E., Neuhoff, K., Das, K., Bandyopadhyay, K. R., . . . Pizer, W. A. (2022). Carbon leakage, consumption, and trade. *Annual Review of Environment and Resources*, *47*(1), 753-795. https://doi.org/10.1146/annurev-environ-120820-053625

Gruber, N., Bakker, D. C. E., DeVries, T., Gregor, L., Hauck, J., Landschützer, P., . . . Müller, J. D. (2023). Trends and variability in the ocean carbon sink. *Nature Reviews Earth & Environment*, *4*(2), 119-134. https://doi.org/10.1038/s43017-022-00381-x

Grubert, E. (2024). Carbon markets have no future in a (net) zero-emissions world. *Dialogues on Climate Change*, *2*(1), 29768659241300681. https://doi.org/10.1177/29768659241300681

Guillermic, M., Cameron, L. P., De Corte, I., Misra, S., Bijma, J., de Beer, D., . . . Eagle, R. A. (2021). Thermal stress reduces pocilloporid coral resilience to ocean acidification by impairing control over calcifying fluid chemistry. *Science Advances*, *7*(2), eaba9958. https://doi.org/10.1126/sciadv.aba9958

Gulen, H., & Ion, M. (2015). Policy uncertainty and corporate investment. *The Review of Financial Studies*, *29*(3), 523-564. https://doi.org/10.1093/rfs/hhv050

Gulley, A. L. (2022). One hundred years of cobalt production in the Democratic Republic of the Congo. *Resources Policy*, *79*, 103007. https://doi.org/10.1016/j.resourpol.2022.103007

Gustafsson, M., Svensson, N., Eklund, M., & Möller, B. F. (2021). Well-to-wheel climate performance of gas and electric vehicles in Europe. *Transportation Research Part D: Transport and Environment*, *97*, 102911. https://doi.org/10.1016/j.trd.2021.102911

Habibullah, M. S., Din, B. H., Tan, S.-H., & Zahid, H. (2022). Impact of climate change on biodiversity loss: global evidence. *Environmental Science and Pollution Research*, *29*(1), 1073-1086. https://doi.org/10.1007/s11356-021-15702-8

Haman, M., & Školník, M. (2025). Fake no more: The redemption of ChatGPT in literature reviews. *Accountability in Research*, 1-3. https://doi.org/10.1080/08989621.2025.2465619

Hansen, J. E., Kharecha, P., Sato, M., Tselioudis, G., Kelly, J., Bauer, S. E., . . . Pokela, A. (2025). Global warming has accelerated: Are the United Nations and the public well-informed? *Environment: Science and Policy for Sustainable Development*, *67*(1), 6-44. https://doi.org/10.1080/00139157.2025.2434494

Hanson, E., Nwakile, C., & Hammed, V. O. (2025). Carbon capture, utilization, and storage (CCUS) technologies: Evaluating the effectiveness of advanced CCUS solutions for reducing CO2 emissions. *Results in Surfaces and Interfaces*, *18*, 100381. https://doi.org/10.1016/j.rsurfi.2024.100381

Hanssen, S. V., Daioglou, V., Steinmann, Z. J. N., Doelman, J. C., Van Vuuren, D. P., & Huijbregts, M. A. J. (2020). The climate change mitigation potential of bioenergy with carbon capture and storage. *Nature Climate Change*, *10*(11), 1023-1029. https://doi.org/10.1038/s41558-020-0885-y

Haq, S. M., Pieroni, A., Bussmann, R. W., Abd-ElGawad, A. M., & El-Ansary, H. O. (2023). Integrating traditional ecological knowledge into habitat restoration: Implications for meeting forest restoration challenges. *Journal of Ethnobiology and Ethnomedicine*, *19*(1), 33. https://doi.org/10.1186/s13002-023-00606-3

Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., . . . Anderson, P. (2019). Recycling lithium-ion batteries from electric vehicles. *Nature*, *575*(7781), 75-86. https://doi.org/10.1038/s41586-019-1682-5

Hatalis, M. (2024). Greenwashing or going green? An empirical analysis of the drivers and the effects of carbon offsets and renewable energy certificates on firm performance. *American Journal of Management*, *24*(2), 17-49. https://doi.org/10.33423/ajm.v24i2.7108

Henley, B. J., McGregor, H. V., King, A. D., Hoegh-Guldberg, O., Arzey, A. K., Karoly, D. J., . . . Linsley, B. K. (2024). Highest ocean heat in four centuries places Great Barrier Reef in danger. *Nature*, *632*(8024), 320-326. https://doi.org/10.1038/s41586-024-07672-x

Hernandez-Cortes, D., & Meng, K. C. (2023). Do environmental markets cause environmental injustice? Evidence from California's carbon market. *Journal of Public Economics*, *217*, 104786. https://doi.org/10.1016/j.jpubeco.2022.104786

Hertog, T. (2023). *On the origin of time: Stephen Hawking's final theory*. Random House.

Hibbard, P. J., Okie, A. M., Tierney, S. F., & Darling, P. G. (2015). *The economic impacts of the regional greenhouse gas initiative on nine northeast and mid-Atlantic states*. Analysis Group.

Hill, E. A., Gudmundsson, G. H., & Chandler, D. M. (2024). Ocean warming as a trigger for irreversible retreat of the Antarctic ice sheet. *Nature Climate Change*, *14*(11), 1165-1171. https://doi.org/10.1038/s41558-024-02134-8

Hodge, T., & Nakolan, K. (2023). Lower $CO_2$ emissions are partially due to shifts in power generation sources: https://www.eia.gov/todayinenergy/detail.php?id=61023 Accessed 12 Mar 2025.

Huggins, A. (2021). The Paris Agreement's Article 15 mechanism: An incomplete compliance strategy. In *Debating climate law*. B. Mayer & A. Zahar (Eds.). Cambridge University Press: pp. 99-110.

IEA. (2023a). *CO2 emissions in 2022*. International Energy Agency

IEA. (2023b). *Global EV outlook 2023*. International Energy Agency

IEA. (2024). *CO2 emissions in 2023*. International Energy Agency.

Imasiku, K., & Thomas, V. M. (2020). The mining and technology industries as catalysts for sustainable energy development. *Sustainability*, *12*(24), 10410. https://www.mdpi.com/2071-1050/12/24/10410

IPCC. (2022). *Climate change 2022: Impacts, adaptation, and vulnerability*. Cambridge University Press.

IPCC. (2023). *Climate change 2023: Synthesis report*. IPCC.

IRENA. (2013). *30 years of policies for wind energy - Lessons from 12 wind energy markets*. International Renewable Energy Agency.

IRENA. (2023). *Renewable power generation costs in 2022*. International Renewable Energy Agency.

IRENA. (2019). *Global energy transformation: A roadmap to 2050*. International Renewable Energy Agency.

Iyer, R. N., & Tan, S. X. (2025). Quitting climate alliances risks trust and transparency for banks: https://ieefa.org/resources/quitting-climate-alliances-risks-trust-and-transparency-banks Accessed 16 May 2025.

Jacobson, M. Z. (2020). *100% clean, renewable energy and storage for everything*. Cambridge University Press.

Jevnaker, T., & Wettestad, J. (2017). Ratcheting up carbon trade: The politics of reforming EU emissions trading. *Global Environmental Politics*, *17*(2), 105-124. https://doi.org/10.1162/GLEP_a_00403

Jones, C. A., & Lucas, C. (2023). 'Listen to me!': Young people's experiences of talking about emotional impacts of climate change. *Global Environmental Change*, *83*, 102744. https://doi.org/10.1016/j.gloenvcha.2023.102744

Jones, N. (2025). OpenAI's 'deep research' tool: is it useful for scientists? *Nature*. https://doi.org/10.1038/d41586-025-00377-9

Josey, S. A., Meijers, A. J. S., Blaker, A. T., Grist, J. P., Mecking, J., & Ayres, H. C. (2024). Record-low Antarctic sea ice in 2023 increased ocean heat loss and storms. *Nature*, *636*(8043), 635-639. https://doi.org/10.1038/s41586-024-08368-y

Kang, D. H. P., Chen, M., & Ogunseitan, O. A. (2013). Potential environmental and human health impacts of rechargeable Lithium batteries in electronic waste. *Environmental Science & Technology*, *47*(10), 5495-5503. https://doi.org/10.1021/es400614y

Katwala, A. (2018). The spiralling environmental cost of our lithium battery addiction: https://www.wired.com/story/lithium-batteries-environment-impact Accessed 26 Mar 2025.

Kennedy, B., & Tyson, A. (2023). Americans' trust in scientists and positive views of science decline: https://www.pewresearch.org/science/2023/11/14/americans-trust-in-scientists-positive-views-of-science-continue-to-decline/ 14 May 2025.

Khatibi, F. S., Dedekorkut-Howes, A., Howes, M., & Torabi, E. (2021). Can public awareness, knowledge and engagement improve climate change adaptation policies? *Discover Sustainability*, *2*(1), 18. https://doi.org/10.1007/s43621-021-00024-z

King, A. D., Peel, J., Ziehn, T., Bowen, K. J., McClelland, H. L. O., McMichael, C., . . . Sniderman, J. M. K. (2022). Preparing for a post-net-zero world. *Nature Climate Change*, *12*(9), 775-777. https://doi.org/10.1038/s41558-022-01446-x

Klinge, N. (2021). Nature-based offsets bring controversial solution to carbon-emissions problem: https://www.upstreamonline.com/energy-transition/nature-based-offsets-bring-controversial-solution-to-carbon-emissions-problem/ Accessed 15 May 2025.

Koch, N., Fuss, S., Grosjean, G., & Edenhofer, O. (2014). Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything?—New evidence. *Energy Policy*, *73*, 676-685. https://doi.org/10.1016/j.enpol.2014.06.024

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239-260. https://doi.org/10.1080/13504620220145401

Kramarz, T., Park, S., & Johnson, C. (2021). Governing the dark side of renewable energy: A typology of global displacements. *Energy Research & Social Science*, *74*, 101902. https://doi.org/10.1016/j.erss.2020.101902

Krauklis, A. E., Karl, C. W., Gagani, A. I., & Jørgensen, J. K. (2021). Composite material recycling technology—State-of-the-art and sustainable development for the 2020s. *Journal of Composites Science*, *5*(1), 28. https://doi.org/10.3390/jcs5010028

Krishnan, A., Nighojkar, A., & Kandasubramanian, B. (2023). Emerging towards zero carbon footprint via carbon dioxide capturing and sequestration. *Carbon Capture Science & Technology*, *9*, 100137. https://doi.org/10.1016/j.ccst.2023.100137

Kurkin, A., Kryukov, E., Masleeva, O., Petukhov, Y., & Gusev, D. (2024). Comparative life cycle assessment of electric and internal combustion engine vehicles. *Energies*, *17*(11), 2747. https://doi.org/10.3390/en17112747

La, V.-P., Nguyen, M.-H., & Vuong, Q.-H. (2024). Climate change denial theories, skeptical arguments, and the role of science communication. *SN Social Sciences*, *4*(10), 175. https://doi.org/10.1007/s43545-024-00978-7

Lakshmi, R. B. (2023). The environmental impact of battery production for electric vehicles: https://earth.org/environmental-impact-of-battery-production/ Accessed 16 May 2025.

Lamb, W. F., Gasser, T., Roman-Cuesta, R. M., Grassi, G., Gidden, M. J., Powis, C. M., . . . Minx, J. C. (2024). Current national proposals are off track to meet carbon dioxide removal needs. *Nature Climate Change*, *14*(6), 555-556. https://doi.org/10.1038/s41558-024-01993-5

Lawrence, P., & Wong, D. (2017). Soft law in the Paris Climate Agreement: Strength or weakness? *Review of European, Comparative & International Environmental Law*, *26*(3), 276-286. https://doi.org/10.1111/reel.12210

Lee, Y.-Y., & Goh, K.-L. (2023). The happiness-economic well-being nexus: New insights from global panel data. *SAGE Open*, *13*(4), 21582440231199659. https://doi.org/10.1177/21582440231199659

Lempriere, M. (2024). Wind and solar are 'fastest-growing electricity sources in history': https://www.carbonbrief.org/wind-and-solar-are-fastest-growing-electricity-sources-in-history/ Accessed 15 May 2025.

Lepere, M., Aikman, D., Dong, Y., Drellias, E., Havaldar, S. D., & Nilsson, M. (2023). Emissions gaming?: A gap in the GHG Protocol may be facilitating gaming in accounting of GHG emissions. *KBS Research Impact Papers*, 1. https://kclpure.kcl.ac.uk/portal/en/publications/emissions-gaming-a-gap-in-the-ghg-protocol-may-be-facilitating-ga

Li, Y., Ha, N., & Li, T. (2019). Research on carbon emissions of electric vehicles throughout the life cycle assessment taking into vehicle weight and grid mix composition. *Energies*, *12*(19), 3612. https://doi.org/10.3390/en12193612

Liu, H.-C., You, X.-Y., Xue, Y.-X., & Luan, X. (2017). Exploring critical factors influencing the diffusion of electric vehicles in China: A multi-stakeholder perspective. *Research in Transportation Economics*, *66*, 46-58. https://doi.org/10.1016/j.retrec.2017.10.001

Liu, W., Placke, T., & Chau, K. T. (2022). Overview of batteries and battery management for electric vehicles. *Energy Reports*, *8*, 4058-4084. https://doi.org/10.1016/j.egyr.2022.03.016

Lo, A. Y., & Cong, R. (2022). Emission reduction targets and outcomes of the Clean Development Mechanism (2005–2020). *PLoS Climate*, *1*(8), e0000046. https://doi.org/10.1371/journal.pclm.0000046

Lo, M. G. Y., Morgans, C. L., Santika, T., Mumbunan, S., Winarni, N., Supriatna, J., . . . Struebig, M. J. (2024). Nickel mining reduced forest cover in Indonesia but had mixed outcomes for well-being. *One Earth*, *7*(11), 2019-2033. https://doi.org/10.1016/j.oneear.2024.10.010

Löfqvist, S., Garrett, R. D., & Ghazoul, J. (2023). Incentives and barriers to private finance for forest and landscape restoration. *Nature Ecology and Evolution*, *7*(5), 707-715. https://doi.org/10.1038/s41559-023-02037-5

Loos, J., Abson, D. J., Chappell, M. J., Hanspach, J., Mikulcak, F., Tichit, M., & Fischer, J. (2014). Putting meaning back into "sustainable intensification". *Frontiers in Ecology and the Environment*, *12*(6), 356-361. https://doi.org/10.1890/130157

López-Vallejo, M. (2021). Non-additionality, overestimation of supply, and double counting in offset programs: Insight for the Mexican carbon market. In *Towards an emissions trading system in Mexico: Rationale, design and connections with the global climate agenda.* S. Lucatello (Ed.). Springer: pp. 191-221.

Lynas, M., Houlton, B. Z., & Perry, S. (2021). Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature. *Environmental Research Letters*, *16*(11), 114005. https://doi.org/10.1088/1748-9326/ac2966

Mahjour, S. K., & Faroughi, S. A. (2023). Risks and uncertainties in carbon capture, transport, and storage projects: A comprehensive review. *Gas Science and Engineering*, *119*, 205117. https://doi.org/10.1016/j.jgsce.2023.205117

Marshall, J. P. (2022). A social exploration of the West Australian Gorgon gas, carbon capture and storage project. *Clean Technologies*, *4*(1), 67-90. https://doi.org/10.3390/cleantechnol4010006

Martin, P., & Walters, R. (2013). Fraud risk and the visibility of carbon. *International Journal for Crime, Justice and Social Democracy*, *2*(2), 27-42. https://doi.org/10.5204/ijcjsd.v2i2.95

Matthews, H. D., & Wynes, S. (2022). Current global efforts are insufficient to limit warming to 1.5°C. *Science*, *376*(6600), 1404-1409. https://doi.org/doi:10.1126/science.abo3378

Mayot, N., Buitenhuis, E. T., Wright, R. M., Hauck, J., Bakker, D. C. E., & Le Quéré, C. (2024). Constraining the trend in the ocean CO2 sink during 2000–2022. *Nature Communications*, *15*(1), 8429. https://doi.org/10.1038/s41467-024-52641-7

McCarthy, O. S., Winston Pomeroy, M., & Smith, J. E. (2024). Corals that survive repeated thermal stress show signs of selection and acclimatization. *PLoS ONE*, *19*(7), e0303779. https://doi.org/10.1371/journal.pone.0303779

McCollum, D., Krey, V., Kolp, P., Nagai, Y., & Riahi, K. (2014). Transport electrification: A key element for energy system transformation and climate stabilization. *Climatic Change*, *123*(3), 651-664. https://doi.org/10.1007/s10584-013-0969-z

McKenzie, M. (2021). Climate change education and communication in global review: tracking progress through national submissions to the UNFCCC Secretariat. *Environmental Education Research*, *27*(5), 631-651. https://doi.org/10.1080/13504622.2021.1903838

Mervine, E. M., Valenta, R. K., Paterson, J. S., Mudd, G. M., Werner, T. T., Nursamsi, I., & Sonter, L. J. (2025). Biomass carbon emissions from nickel mining have significant implications for climate action. *Nature Communications*, *16*(1), 481. https://doi.org/10.1038/s41467-024-55703-y

Merz, B., Blöschl, G., Vorogushyn, S., Dottori, F., Aerts, J. C. J. H., Bates, P., . . . Macdonald, E. (2021). Causes, impacts and patterns of disastrous river floods. *Nature Reviews Earth & Environment*, *2*(9), 592-609. https://doi.org/10.1038/s43017-021-00195-3

Mofolasayo, A. (2023). Assessing and managing the direct and indirect emissions from electric and fossil-powered vehicles. *Sustainability*, *15*(2), 1138. https://doi.org/10.3390/su15021138

Molinos, J. G., Poloczanska, E. S., Olden, J. D., Lawler, J. J., & Burrows, M. T. (2018). Biogeographical shifts and climate change. In *Encyclopedia of the Anthropocene*. D. A. Dellasala & M. I. Goldstein (Eds.). Elsevier: pp. 217-228.

Morozovska, K., Bragone, F., Svensson, A. X., Shukla, D. A., & Hellstenius, E. (2024). Trade-offs of wind power production: A study on the environmental implications of raw materials mining in the life cycle of wind turbines. *Journal of Cleaner Production*, *460*, 142578. https://doi.org/10.1016/j.jclepro.2024.142578

Morton, A., & Cox, L. (2022). 'Devastating': 91% of reefs surveyed on Great Barrier Reef affected by coral bleaching in 2022: https://www.theguardian.com/environment/2022/may/10/devastating-90-of-reefs-surveyed-on-great-barrier-reef-affected-by-coral-bleaching-in-2022 Accessed 13 May 2025.

Mulvey, K. (2023). Overcoming unprecedented oil and gas industry influence at UN climate talks: https://blog.ucs.org/kathy-mulvey/overcoming-unprecedented-oil-and-gas-industry-influence-at-un-climate-talks/ Accessed 1 Jul 2025.

NASA Earth Observatory. (2007). If we immediately stopped emitting greenhouse gases, would global warming stop?: https://earthobservatory.nasa.gov/blogs/climateqa/would-gw-stop-with-greenhouse-gases/ Accessed 20 Mar 2025.

Ndlovu, P., Bulannga, R., & Mguni, L. L. (2024). Progress in carbon dioxide capture, storage and monitoring in geological landform. *Frontiers in Energy Research*, *12*, 1450991. https://doi.org/10.3389/fenrg.2024.1450991

Neas, S., Ward, A., & Bowman, B. (2022). Young people's climate activism: A review of the literature. *Frontiers in Political Science*, *4*, 940876. https://doi.org/10.3389/fpos.2022.940876

Nepraš, K., Strejčková, T., & Kroufek, R. (2022). Climate change education in primary and lower secondary education: Systematic review results. *Sustainability*, *14*(22), 14913. https://doi.org/10.3390/su142214913

Nguyen, M.-H. (2024). How can satirical fables offer us a vision for sustainability? *Visions for Sustainability*, *23*(11267), 323-328. https://doi.org/10.13135/2384-8677/11267

Nguyen, M.-H., Duong, M.-P. T., Nguyen, Q.-L., La, V.-P., & Hoang, V.-Q. (2024). In search of value: the intricate impacts of benefit perception, knowledge, and emotion about climate change on marine protection support. *Journal of Environmental Studies and Sciences*, *15*, 124-142. https://doi.org/10.1007/s13412-024-00902-8

Nguyen, M.-H., & Jones, T. E. (2022a). Building eco-surplus culture among urban residents as a novel strategy to improve finance for conservation in protected areas. *Humanities and Social Sciences Communications*, *9*, 426. https://doi.org/10.1057/s41599-022-01441-9

Nguyen, M.-H., & Jones, T. E. (2022b). Predictors of support for biodiversity loss countermeasure and bushmeat consumption among Vietnamese urban residents. *Conservation Science and Practice*, *4*(12), e12822. https://doi.org/10.1111/csp2.12822

Nguyen, M.-H., & Vuong, Q.-H. (2025). Navigating the new landscape of knowledge in the age of generative AI. *AI and Society*. https://doi.org/10.1007/s00146-025-02379-7

Nield, D. (2021). Over 99.9% of studies agree: Humans have caused climate change on Earth: https://www.sciencealert.com/over-99-9-percent-of-studies-agree-humans-have-caused-climate-change Accessed 16 Apr 2025.

NOAA. (2024). Global climate summary for August 2024: https://www.climate.gov/news-features/understanding-climate/global-climate-summary-august-2024 Accessed 1 Jul 2025.

Nunn, B. L., Brown, T., Timmins-Schiffman, E., Mudge, M. C., Riffle, M., Axworthy, J. B., . . . Padilla-Gamiño, J. L. (2025). Protein signatures predict coral resilience and survival to thermal bleaching events. *Communications Earth & Environment*, *6*(1), 191. https://doi.org/10.1038/s43247-025-02167-7

Oliver, E. C. J., Donat, M. G., Burrows, M. T., Moore, P. J., Smale, D. A., Alexander, L. V., . . . Wernberg, T. (2018). Longer and more frequent marine heatwaves over the past century. *Nature Communications*, *9*(1), 1324. https://doi.org/10.1038/s41467-018-03732-9

Oschlies, A., Brandt, P., Stramma, L., & Schmidtko, S. (2018). Drivers and mechanisms of ocean deoxygenation. *Nature Geoscience*, *11*(7), 467-473. https://doi.org/10.1038/s41561-018-0152-2

Osman, A. I., Hefny, M., Abdel Maksoud, M. I. A., Elgarahy, A. M., & Rooney, D. W. (2021). Recent advances in carbon capture storage and utilisation technologies: a review. *Environmental Chemistry Letters*, *19*(2), 797-849. https://doi.org/10.1007/s10311-020-01133-3

Pagiola, S., Honey-Rosés, J., & Freire-González, J. (2016). Evaluation of the permanence of land use change induced by payments for environmental services in Quindío, Colombia. *PLoS ONE*, *11*(3), e0147829. https://doi.org/10.1371/journal.pone.0147829

Paltsev, S., Karplus, V., Chen, H., Karkatsouli, I., Reilly, J., & Jacoby, H. (2015). Regulatory control of vehicle and power plant emissions: how effective and at what cost? *Climate Policy*, *15*(4), 438-457. https://doi.org/10.1080/14693062.2014.937386

Paraschiv, F., Schmid, H., Schmitz, M., Dünwald, V., & Groos, E. (2024). The interplay between China's regulated and voluntary carbon markets and its influence on renewable energy development—A literature review. *Energies*, *17*(22), 5587. https://doi.org/10.3390/en17225587

Pasquini, G., Spencer, A., Tyson, A., & Funk, C. (2023). *Why some Americans do not see urgency on climate change*. Pew Research Center.

Paulsen, M., Jagodzinski, J., & Hawke, S. M. (2022). *Pedagogy in the Anthropocene: Re-wilding education for a new earth*. Springer Nature.

Pearse, R., & Böhm, S. (2014). Ten reasons why carbon markets will not bring about radical emissions reduction. *Carbon Management*, *5*(4), 325-337. https://doi.org/10.1080/17583004.2014.990679

Perkins-Kirkpatrick, S., Barriopedro, D., Jha, R., Wang, L., Mondal, A., Libonati, R., & Kornhuber, K. (2024). Extreme terrestrial heat in 2023. *Nature Reviews Earth & Environment*, *5*(4), 244-246. https://doi.org/10.1038/s43017-024-00536-y

Petavratzi, E., Sanchez-Lopez, D., Hughes, A., Stacey, J., Ford, J., & Butcher, A. (2022). The impacts of environmental, social and governance (ESG) issues in achieving sustainable lithium supply in the Lithium Triangle. *Mineral Economics*, *35*(3), 673-699. https://doi.org/10.1007/s13563-022-00332-4

Pfenning-Butterworth, A., Buckley, L. B., Drake, J. M., Farner, J. E., Farrell, M. J., Gehman, A.-L. M., . . . Davies, T. J. (2024). Interconnecting global threats: climate change, biodiversity loss, and infectious diseases. *The Lancet Planetary Health*, *8*(4), e270-e283. https://doi.org/10.1016/S2542-5196(24)00021-4

Pierce, D. W., Barnett, T. P., & Gleckler, P. J. (2011). Ocean circulations, heat budgets, and future commitment to climate change. *Annual Review of Environment and Resources*, *36*, 27-43. https://doi.org/10.1146/annurev-environ-022610-112928

Pietzcker, R. C., Osorio, S., & Rodrigues, R. (2021). Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonization of the EU power sector. *Applied Energy*, *293*, 116914. https://doi.org/10.1016/j.apenergy.2021.116914

Pirchio, S., Passiatore, Y., Panno, A., Cipparone, M., & Carrus, G. (2021). The effects of contact with nature during outdoor environmental education on students' wellbeing, connectedness to nature and pro-sociality. *Frontiers in Psychology*, *12*, 648458. https://doi.org/10.3389/fpsyg.2021.648458

Raiser, K., Kornek, U., Flachsland, C., & Lamb, W. F. (2020). Is the Paris Agreement effective? A systematic map of the evidence. *Environmental Research Letters*, *15*(8), 083006. https://doi.org/10.1088/1748-9326/ab865c

Ranney, M. A., & Velautham, L. (2021). Climate change cognition and education: given no silver bullet for denial, diverse information-hunks increase global warming acceptance. *Current Opinion in Behavioral Sciences*, *42*, 139-146. https://doi.org/10.1016/j.cobeha.2021.08.001

Rarotra, S., Sahu, S., Kumar, P., Kim, K.-H., Tsang, Y. F., Kumar, V., . . . Lisak, G. (2020). Progress and challenges on battery waste management :A critical review. *ChemistrySelect*, *5*(20), 6182-6193. https://doi.org/10.1002/slct.202000618

Rasch, S., Wünscher, T., Casasola, F., Ibrahim, M., & Storm, H. (2021). Permanence of PES and the role of social context in the Regional Integrated Silvo-pastoral Ecosystem Management Project in Costa Rica. *Ecological Economics*, *185*, 107027. https://doi.org/10.1016/j.ecolecon.2021.107027

Raworth, K. (2018). *Doughnut economics: Seven ways to think like a 21st century economist*. Chelsea Green Publishing.

Revesz, R. L. (2022). How will EPA regulate the power sector? *Science*, *377*(6605), 450-450. https://doi.org/doi:10.1126/science.ade0779

Ripple, W. J., Wolf, C., Newsome, T. M., Barnard, P., & Moomaw, W. R. (2019). World scientists' warning of a climate emergency. *BioScience*, *70*(1), 8-12. https://doi.org/10.1093/biosci/biz088

Roach, L. A., & Meier, W. N. (2024). Sea ice in 2023. *Nature Reviews Earth & Environment*, *5*(4), 235-237. https://doi.org/10.1038/s43017-024-00542-0

Robinson, A., Lehmann, J., Barriopedro, D., Rahmstorf, S., & Coumou, D. (2021). Increasing heat and rainfall extremes now far outside the historical climate. *npj*

*Climate and Atmospheric Science*, *4*(1), 45. https://doi.org/10.1038/s41612-021-00202-w

Rode, A. (2021). Rent seeking over tradable emission permits. *Environmental and Resource Economics*, *78*(2), 257-285. https://doi.org/10.1007/s10640-020-00531-z

Rodrigues, M. (2023). *The Amazon's record-setting drought: how bad will it be? Nature*, *623*, 675-676. https://doi.org/10.1038/d41586-023-03469-6

Romm, J., & Schendler, A. (2023). Too many carbon offset claims are 'greenwashing' us into a hotter world: https://web.sas.upenn.edu/pcssm/news/too-many-carbon-offset-claims-are-greenwashing-us-into-a-hotter-world/ Accessed 14 May 2025.

Ross, A. D., Rouse, S. M., & Mobley, W. (2019). Polarization of climate change beliefs: the role of the millennial generation identity. *Social Science Quarterly*, *100*(7), 2625-2640. https://doi.org/10.1111/ssqu.12640

Rovelli, C. (2018). *Reality is not what it seems: The journey to quantum gravity*. Penguin.

Samset, B. H., Fuglestvedt, J. S., & Lund, M. T. (2020). Delayed emergence of a global temperature response after emission mitigation. *Nature Communications*, *11*(1), 3261. https://doi.org/10.1038/s41467-020-17001-1

Samuels, F. M. D., & Thompson, A. (2022). How climate change is leaving some species with 'nowhere left to go': https://www.scientificamerican.com/article/how-climate-change-is-leaving-some-species-with-nowhere-left-to-go/ Accessed 13 May 2025.

Santillan, J., Heaston, M. S., Woodward, D. S., & Joshi, M. M. (2010). Environmental impacts associated with manufacturing of solar and wind power alternative energy systems. *Remediation Journal*, *20*(2), 107-113. https://doi.org/10.1002/rem.20243

Sato, M., Laing, T., & Hulme, M. (2019). Are carbon markets the best way to address climate change? In *Contemporary climate change debates*. M. Hulme (Ed). Routledge: pp. 83-95.

Schomberg, A. C., Bringezu, S., & Flörke, M. (2021). Extended life cycle assessment reveals the spatially-explicit water scarcity footprint of a lithium-ion battery storage. *Communications Earth & Environment*, *2*(1), 11. https://doi.org/10.1038/s43247-020-00080-9

Serena, B. (2023). *Carbon Capture and Storage: the solution to climate change or to the fossil fuels' survival? Critically framing EU´s discourses around CCS*. University of Stavanger.

Shah, H. (2020). Global problems need social science. *Nature*, *577*(7790), 295-296. https://doi.org/10.1038/d41586-020-00064-x

Shan, S. (2025). Here are all of Trump's major moves to dismantle climate action: https://time.com/7258269/trump-climate-policies-executive-orders/ Accessed 16 May 2025.

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, *27*(3), 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Skeie, R. B., Hodnebrog, Ø., & Myhre, G. (2023). Trends in atmospheric methane concentrations since 1990 were driven and modified by anthropogenic emissions. *Communications Earth & Environment*, *4*(1), 317. https://doi.org/10.1038/s43247-023-00969-1

Sobol, Ł., & Dyjakon, A. (2020). The influence of power sources for charging the batteries of electric cars on CO2 emissions during daily driving: A case study from Poland. *Energies*, *13*(16), 4267. https://doi.org/10.3390/en13164267

Sori, A., Moghaddas, J., & Abedpour, H. (2024). Comprehensive review of experimental studies, numerical modeling, leakage risk assessment, monitoring, and control in geological storage of carbon dioxide: Implications for effective CO2 deployment strategies. *Greenhouse Gases: Science and Technology*, *14*(5), 887-913. https://doi.org/10.1002/ghg.2295

Sovacool, B. K. (2011). Four problems with global carbon markets: a critical review. *Energy and Environment*, *22*(6), 681-694. https://doi.org/10.1260/0958-305X.22.6.681

Spannring, R. (2017). Animals in environmental education research. *Environmental Education Research*, *23*(1), 63-74. https://doi.org/10.1080/13504622.2016.1188058

Stankovic, T., Hovi, J., & Skodvin, T. (2023). The Paris Agreement's inherent tension between ambition and compliance. *Humanities and Social Sciences Communications*, *10*(1), 550. https://doi.org/10.1057/s41599-023-02054-6

Stephens, J. C. (2014). Time to stop investing in carbon capture and storage and reduce government subsidies of fossil-fuels. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(2), 169-173. https://doi.org/10.1002/wcc.266

Stern, N. (2022). Towards a carbon neutral economy: How government should respond to market failures and market absence. *Journal of Government and Economics*, *6*, 100036. https://doi.org/10.1016/j.jge.2022.100036

Stevenson, R. B. (2007). Schooling and environmental education: Contradictions in purpose and practice. *Environmental Education Research*, *13*(2), 139-153. https://doi.org/10.1080/13504620701295726

Stokes, L. C., & Breetz, H. L. (2018). Politics in the U.S. energy transition: Case studies of solar, wind, biofuels and electric vehicles policy. *Energy Policy*, *113*, 76-86. https://doi.org/10.1016/j.enpol.2017.10.057

Sun, X., & Mi, Z. (2023). Factors driving China's carbon emissions after the COVID-19 outbreak. *Environmental Science & Technology*, *57*(48), 19125-19136. https://doi.org/10.1021/acs.est.3c03802

Tang, Y., Cockerill, T. T., Pimm, A. J., & Yuan, X. (2021). Reducing the life cycle environmental impact of electric vehicles through emissions-responsive charging. *iScience*, *24*(12), 103499. https://doi.org/10.1016/j.isci.2021.103499

Tanzer, S. E., Blok, K., & Ramírez, A. (2020). Can bioenergy with carbon capture and storage result in carbon negative steel? *International Journal of Greenhouse Gas Control*, *100*, 103104. https://doi.org/10.1016/j.ijggc.2020.103104

Tao, Y., Rahn, C. D., Archer, L. A., & You, F. (2021). Second life and recycling: Energy and environmental sustainability perspectives for high-performance lithium-ion batteries. *Science Advances*, *7*(45), eabi7633. https://doi.org/doi:10.1126/sciadv.abi7633

Tawalbeh, M., Al-Othman, A., Kafiah, F., Abdelsalam, E., Almomani, F., & Alkasrawi, M. (2021). Environmental impacts of solar photovoltaic systems: A critical review of recent progress and future outlook. *Science of The Total Environment*, *759*, 143528. https://doi.org/10.1016/j.scitotenv.2020.143528

Tebbett, S. B., Connolly, S. R., & Bellwood, D. R. (2023). Benthic composition changes on coral reefs at global scales. *Nature Ecology & Evolution*, *7*(1), 71-81. https://doi.org/10.1038/s41559-022-01937-2

Terhaar, J., Burger, F. A., Vogt, L., Frölicher, T. L., & Stocker, T. F. (2025). Record sea surface temperature jump in 2023–2024 unlikely but not unexpected. *Nature*. https://doi.org/10.1038/s41586-025-08674-z

The Economist. (2022). Carbon markets are going global: https://www.economist.com/finance-and-economics/2022/05/26/carbon-markets-are-going-global Accessed 16 Mar 2025.

Tingley, D., & Tomz, M. (2022). The effects of naming and shaming on public support for compliance with International Agreements: An experimental analysis of the Paris Agreement. *International Organization*, *76*(2), 445-468. https://doi.org/10.1017/S0020818321000394

Tom, M. N., Sumida Huaman, E., & McCarty, T. L. (2019). Indigenous knowledges as vital contributions to sustainability. *International Review of Education*, *65*(1), 1-18. https://doi.org/10.1007/s11159-019-09770-9

Tomiolo, S., & Ward, D. (2018). Species migrations and range shifts: A synthesis of causes and consequences. *Perspectives in Plant Ecology, Evolution and Systematics*, *33*, 62-77. https://doi.org/10.1016/j.ppees.2018.06.001

Tran, T. M. A., Gagnon, V. S., & Schelly, C. (2025). A review of traditional ecological knowledge in resilient livelihoods and forest ecosystems: lessons for restoration sciences and practices. *Forests, Trees and Livelihoods*, *34*(1), 27-53. https://doi.org/10.1080/14728028.2024.2408725

Tran, T. T. (2025). Flying beyond didacticism: The creative environmental vision of 'Wild Wise Weird'. https://youngvoicesofscience.org/?p=1963

Trencher, G., Nick, S., Carlson, J., & Johnson, M. (2024). Demand for low-quality offsets by major companies undermines climate integrity of the voluntary carbon market. *Nature Communications*, *15*(1), 6863. https://doi.org/10.1038/s41467-024-51151-w

Trott, C. D. (2024). Activism as education in and through the youth climate justice movement. *British Educational Research Journal*, *n/a*(n/a). https://doi.org/10.1002/berj.4082

Trouwloon, D., Streck, C., Chagas, T., & Martinus, G. (2023). Understanding the use of carbon credits by companies: a review of the defining elements of corporate climate claims. *Global Challenges*, *7*(4), 2200158. https://doi.org/10.1002/gch2.202200158

Turcheniuk, K., Bondarev, D., Singhal, V., & Yushin, G. (2018). Ten years left to redesign lithium-ion batteries. *Nature*, *559*(7715), 467-470. https://doi.org/10.1038/d41586-018-05752-3

UNEP. (2023a). *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*. United Nations Environment Programme.

UNEP. (2023b). *State of finance for nature 2023*. United Nations Environment Programme.

UNFCCC. (n.d.) Why the global stocktake is important for climate action this decade: https://unfccc.int/topics/global-stocktake/about-the-global-stocktake/why-the-global-stocktake-is-important-for-climate-action-this-decade Accessed 14 Mar 2025.

UNFCCC. (2015). *Adoption of the Paris Agreement. United Nations Framework Convention on Climate Change*. United Nations Framework Convention on Climate Change.

van Baal, K., Stiel, S., & Schulte, P. (2023). Public perceptions of climate change and health—A cross-sectional survey study. *IJERPH*, *20*(2), 1464. https://doi.org/10.3390/ijerph20021464

van de Ven, D.-J., Nikas, A., Koasidis, K., Forouli, A., Cassetti, G., Chiodi, A., . . . Gambhir, A. (2022). COVID-19 recovery packages can benefit climate targets and clean energy jobs, but scale of impacts and optimal investment portfolios differ among major economies. *One Earth*, *5*(9), 1042-1054. https://doi.org/10.1016/j.oneear.2022.08.008

van Kooten, G. C. (2017). Forest carbon offsets and carbon emissions trading: Problems of contracting. *Forest Policy and Economics*, *75*, 83-88. https://doi.org/10.1016/j.forpol.2016.12.006

Većkalov, B., Geiger, S. J., Bartoš, F., White, M. P., Rutjens, B. T., van Harreveld, F., . . . van der Linden, S. (2024). A 27-country test of communicating the scientific consensus on climate change. *Nature Human Behaviour*, *8*(10), 1892-1905. https://doi.org/10.1038/s41562-024-01928-2

Vega-Muratalla, V. O., Ramírez-Márquez, C., Lira-Barragán, L. F., & Ponce-Ortega, J. M. (2024). Review of Lithium as a strategic resource for electric vehicle battery production: Availability, extraction, and future prospects. *Resources*, *13*(11), 148. https://doi.org/10.3390/resources13110148

Vincenzi, D. (2024). Conservation pays and everyone's benefitting from it (commentary): https://news.mongabay.com/2024/07/conservation-pays-and-everyones-benefitting-from-it-commentary/ Accessed 1 Jul 2025.

Vuong, Q.-H. (2021). The semiconducting principle of monetary and environmental values exchange. *Economics and Business Letters*, *10*(3), 284-290. https://doi.org/10.17811/ebl.10.3.2021.284-290

Vuong, Q.-H. (2023). *Mindsponge theory*. Walter de Gruyter GmbH.

Vuong, Q.-H. (2024). *Wild Wise Weird*. AISDL.

Vuong, Q.-H., La, V.-P., & Nguyen, M.-H. (2023). Weaponization of climate and environment crises: Risks, realities, and consequences. *Environmental Science & Policy*, *162*, 103928. https://doi.org/10.1016/j.envsci.2024.103928

Vuong, Q.-H., & Nguyen, M.-H. (2023a). How an age-old photo of little chicks can awaken our conscience for biodiversity conservation and nature protection. *Visions for Sustainability*(22), 253-264. https://doi.org/10.13135/2384-8677/10982

Vuong, Q.-H., & Nguyen, M.-H. (2023b). Kingfisher: Contemplating the connection between nature and humans through science, art, literature, and lived experiences. *Pacific Conservation Biology*, *30*, PC23044. https://doi.org/10.1071/PC23044

Vuong, Q.-H., & Nguyen, M.-H. (2024a). *Better economics for the Earth: A lesson from quantum and information theories*. AISDL.

Vuong, Q.-H., & Nguyen, M.-H. (2024b). Exploring the role of rejection in scholarly knowledge production: Insights from granular interaction thinking and information theory. *Learned Publishing*, *37*(4), e1636. https://doi.org/10.1002/leap.1636

Vuong, Q.-H., & Nguyen, M.-H. (2024c). Further on informational quanta, interactions, and entropy under the granular view of value formation. *The VMOST Journal of Social Sciences and Humanities*. https://doi.org/10.2139/ssrn.4922461

Vuong, Q.-H., & Nguyen, M.-H. (2025). On Nature Quotient. https://philarchive.org/rec/VUOONQ

Vuong, Q.-H., Nguyen, M.-H., Tran, T. M. A., & La, V.-P. (2025). The Battery Bubble. https://philarchive.org/rec/VUOTBB

Vuong, Q. H., La, V. P., Nguyen, H. K. T., Ho, M. T., Vuong, T. T., & Ho, M. T. (2021). Identifying the moral–practical gaps in corporate social responsibility missions of Vietnamese firms: An event-based analysis of sustainability feasibility. *Corporate Social Responsibility and Environmental Management*, *28*(1), 30-41. https://doi.org/10.1002/csr.2029

Walker, K., & Wan, F. (2012). The harm of symbolic actions and green-washing: Corporate actions and communications on environmental performance and their financial implications. *Journal of Business Ethics*, *109*, 227-242. https://doi.org/10.1007/s10551-011-1122-4

Wang, Q., Liu, W., Yuan, X., Tang, H., Tang, Y., Wang, M., . . . Sun, J. (2018). Environmental impact analysis and process optimization of batteries based on life cycle assessment. *Journal of Cleaner Production*, *174*, 1262-1273. https://doi.org/10.1016/j.jclepro.2017.11.059

Wang, S., Leviston, Z., Hurlstone, M., Lawrence, C., & Walker, I. (2018). Emotions predict policy support: Why it matters how people feel about climate change. *Global Environmental Change*, *50*, 25-40. https://doi.org/10.1016/j.gloenvcha.2018.03.002

West, T. A. P., Börner, J., Sills, E. O., & Kontoleon, A. (2020). Overstated carbon emission reductions from voluntary REDD+ projects in the Brazilian Amazon. *Proceedings of the National Academy of Sciences*, *117*(39), 24188-24194. https://doi.org/doi:10.1073/pnas.2004334117

West, T. A. P., Wunder, S., Sills, E. O., Börner, J., Rifai, S. W., Neidermeier, A. N., . . . Kontoleon, A. (2023). Action needed to make carbon offsets from forest conservation work for climate change mitigation. *Science*, *381*(6660), 873-877. https://doi.org/doi:10.1126/science.ade3535

White, J. A., & Foxall, W. (2016). Assessing induced seismicity risk at CO2 storage projects: Recent progress and remaining challenges. *International Journal of Greenhouse Gas Control*, *49*, 413-424. https://doi.org/10.1016/j.ijggc.2016.03.021

Wiatros-Motyka, M., Fulghum, N., Jones, D., Altieri, K., Black, R., Broadbent, H., . . . Zaimoglu, O. (2024). *Global electricity review 2024*. EMBER.

Wilkes, A. (2016). China-Africa forest trade and investment. An overview with analysis for Cameroon, Democratic Republic of Congo, Mozambique and Uganda. https://www.iied.org/17585iied

Wilkins, D., & Kuna, J. (2023). *Automakers and EV recycling*. Atlas Public Policy.

Wolfram, P., & Wiedmann, T. (2017). Electrifying Australian transport: Hybrid life cycle analysis of a transition to electric light-duty vehicles and renewable electricity. *Applied Energy*, *206*, 531-540. https://doi.org/10.1016/j.apenergy.2017.08.219

World Bank. (2024). *State and trends of carbon pricing 2024*. World Bank.

Xie, D., Gou, Z., & Gui, X. (2024). How electric vehicles benefit urban air quality improvement: A study in Wuhan. *Science of The Total Environment*, *906*, 167584. https://doi.org/10.1016/j.scitotenv.2023.167584

Xu, Y., Li, J., Tan, Q., Peters, A. L., & Yang, C. (2018). Global status of recycling waste solar panels: A review. *Waste Management*, *75*, 450-458. https://doi.org/10.1016/j.wasman.2018.01.036

Yin, J., Pan, M., Chen, Z., & Li, J. (2020). Discussion on the recycling ecological chain and commercial model of decommissioned batteries. *IOP Conference Series: Materials*

*Science and Engineering*, *793*(1), 012001. https://doi.org/10.1088/1757-899X/793/1/012001

Yin, X. (2025). *"Deep research" for scientific literature review*. https://xiangyu-yin.com/content/post_deep_research.html 2 Jul 2025.

Yuan, M., Thellufsen, J. Z., Lund, H., & Liang, Y. (2021). The electrification of transportation in energy transition. *Energy*, *236*, 121564. https://doi.org/10.1016/j.energy.2021.121564

ZERO13, G. (2025). 88% of industry respondents call for major reform of global carbon markets: https://www.globenewswire.com/news-release/2025/01/20/3011839/0/en/88-of-industry-respondents-call-for-major-reform-of-global-carbon-markets.html Accessed 14 May 2025.

Zhang, W., Qiao, Y., Lakshmanan, P., Yuan, L., Liu, J., Zhong, C., & Chen, X. (2022). Combing public-private partnership and large-scale farming increased net ecosystem carbon budget and reduced carbon footprint of maize production. *Resources, Conservation and Recycling*, *184*, 106411. https://doi.org/10.1016/j.resconrec.2022.106411

Zhang, X., Yu, R., & Karplus, V. J. (2025). The development of China's national carbon market: An overview. *Energy and Climate Management*, *1*(2). https://doi.org/10.26599/ECM.2025.9400015

Zhou, X., Xing, S., Jin, Y., Zhang, M., & Liu, Z. (2024). Carbon price signal failure and regulatory policies: A systematic review. *Environmental Impact Assessment Review*, *105*, 107444. https://doi.org/10.1016/j.eiar.2024.107444

Zsolnai, L., Ócsai, A., Kovacs, G., Kelemen, K., & Valcsicsak, Z. (2023). Wellbeing policies for countries and cities. In *Value creation for a sustainable world: Innovating for ecological regeneration and human flourishing*. L. Zsolnai, T. Walker, & P. Shrivastava (Eds.). Springer International Publishing: pp. 285-307.

## Authors

**Viet-Phuong La**
Centre for Interdisciplinary Social Research, Phenikaa University, Yen Nghia Ward, Ha Dong District, Hanoi, Vietnam

**Minh-Hoang Nguyen** *(corresponding author)* hoang.nguyenminh@phenikaa-uni.edu.vn
Centre for Interdisciplinary Social Research, Phenikaa University, Yen Nghia Ward, Ha Dong District, Hanoi, Vietnam

**Thanh Tu Tran**
University of Copenhagen, Copenhagen, Denmark

**Quan-Hoang Vuong**
Centre for Interdisciplinary Social Research, Phenikaa University, Yen Nghia Ward, Ha Dong District, Hanoi, Vietnam
University College, Korea University. 145 Anam-ro, Seongbuk-Gu, Seoul 02841, South Korea


## Author contributions

Conceptualization, Q.-H.V. and V.-P.L.; formal analysis, V.-P.L. and M.-H.N.; investigation, T.T.T and V.-P.L.; resources, V.-P.L.; writing—original draft preparation, V.-P.L., M.-H.N., and T.T.T; writing—review and editing, M.-H.N. and V.-P.L.; supervision, Q.-H.V.; project administration, Q.-H.V. All authors have read and agreed to the published version of the manuscript.


## Funds

This research received no external funding


## Competing Interests

The authors hereby state that there are no financial and non-financial competing interests.


## Citation

La, V.-P., Nguyen, M.-H., Tran, T. T., & Vuong, Q.-H. (2025). Are we on the right track for mitigating climate change? *Visions for Sustainability*, 24, 12060, 1-51.
http://dx.doi.org/10.13135/2384-8677/12060