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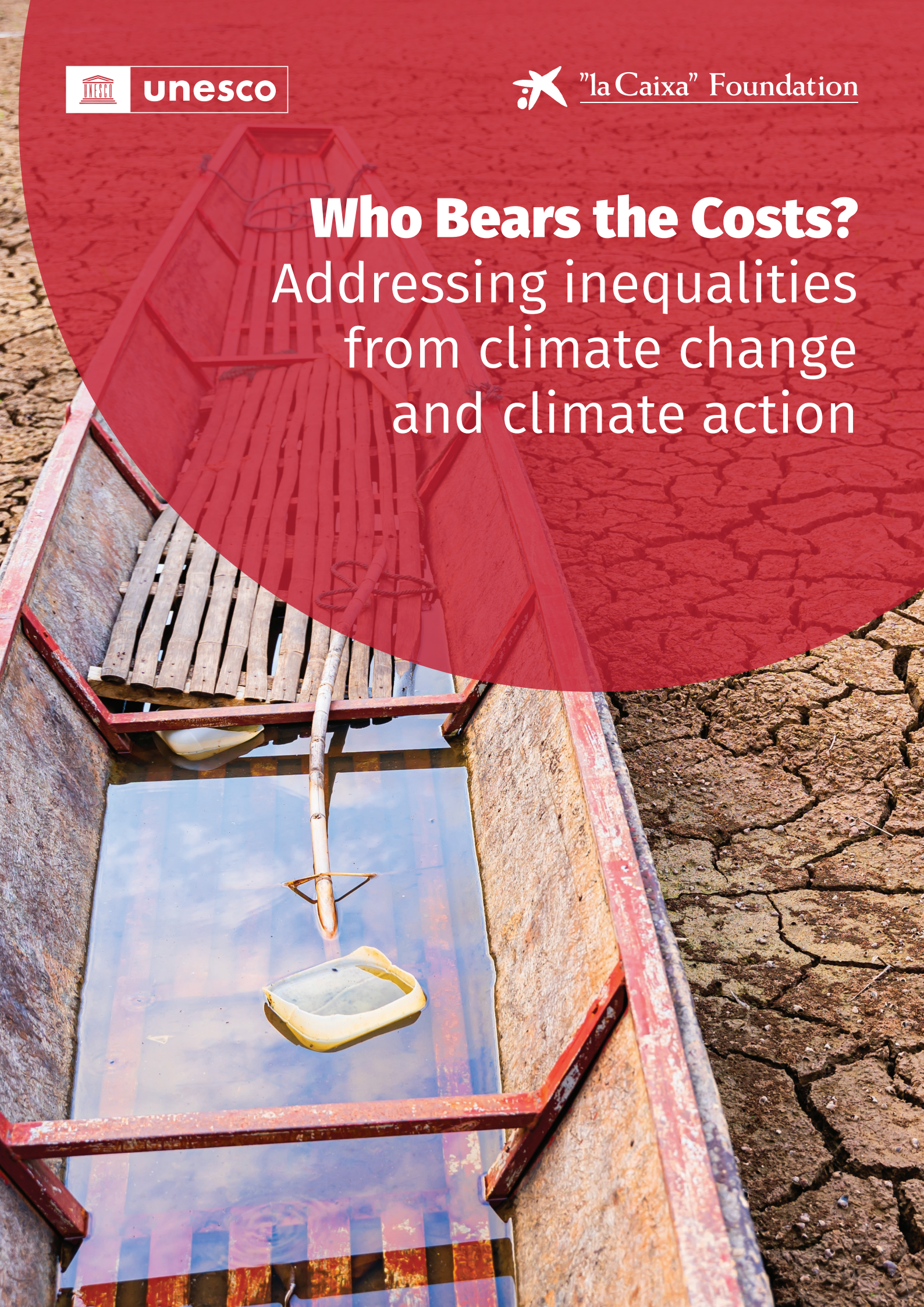
"la Caixa" Foundation

Who Bears the Costs?

Addressing inequalities from climate change and climate action



Published in 2025 by the United Nations Educational, Scientific and Cultural Organization, 7, place de Fontenoy, 75352 Paris 07 SP, France and "la Caixa" Foundation, Palau Macaya, Pg. de St. Joan, 108, 08037 Barcelona, Spain.

ISBN: 978-92-3-100767-5
DOI: https://doi.org/10.54678/GIXE7906

Cover photo: The ground is cracked and parched, with a network of deep fissures
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Cover design: Ana Carrasco/Arbelaitz Creative Studio
Graphic design and typeset: Ana Carrasco/Arbelaitz Creative Studio
Typeset: UNESCO CLD

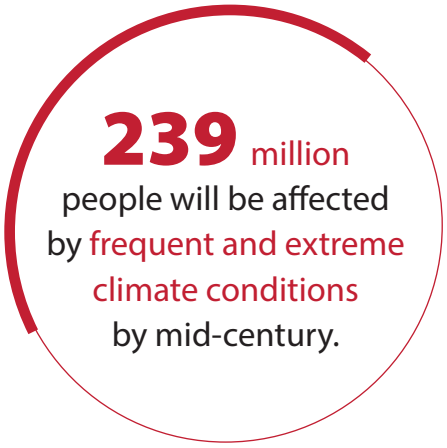
Printed in UNESCO printshop, Paris, France

Short Summary

Toward People-Centered Climate Transitions

Who Bears the Costs **explores the disproportional impacts of climate change and the need for designing policies to face climate change that also prioritize inclusivity and fairness.**

It shows how the impact of nations' green transitions to low carbon economies and sustainable practices varies widely, depending on where people work, their gender, income level, and the place they live in, and highlights the risk of widening socioeconomic inequalities that face our societies. It also reflects on the **changes needed for climate policies and responses within and between member countries, to be tailored to all communities' diverse needs and realities.**



This book is the second step of an intellectual partnership advocating how **to approach socioeconomic policies in a more integrated manner.** Policymakers, researchers, and others are invited to draw on the message of this report to reflect on how equity and inclusivity can guide the development of climate transition policies, rather than being added as an afterthought.

If we don't act now to manage the climate transition equitably, it will continue to marginalize vulnerable communities and compound their challenges in the face of climate change and also erode support for climate action.

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"Since wars begin in the minds of men and women it is in the minds of men and women that the defences of peace must be constructed."

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"la Caixa" Foundation

Who Bears the Costs?
Addressing inequalities from climate change and climate action

Foreword

Message from UNESCO

Climate change is no longer a distant threat but an urgent reality. It is accelerating at an unprecedented pace, affecting individuals and communities worldwide in ways that are uneven, deeply unjust, and often overlooked. Currently, approximately 3.6 billion people live in regions highly vulnerable to its impacts (IPCC, 2022a). Extreme weather events, rising temperatures, and shifting precipitation patterns have become the new normal, challenging our capacity to adapt and thrive. Among these, this report suggests that extreme heat poses the greatest threat, with nearly 2.5 billion people projected to be exposed by 2050. This will drive migration, fuel humanitarian crises, and prompt rapid adaptation efforts to sustain productivity and urban livability.

While all individuals contribute to greenhouse gas (GHG) emissions, their contributions vary significantly both within and across countries. The top 10% of global emitters generate nearly half of all GHG (Oxfam, 2023). Low-income households and marginalized groups – including women and Indigenous Peoples – are often more exposed to climate risks despite contributing far less. Compounding this injustice, current and proposed climate policies can impose unequal burdens. For example, policies such as carbon taxes – though effective in curbing emissions – can have regressive effects, disproportionately impacting lower-income and vulnerable communities already bearing the brunt of climate impacts.

These inequities create a vicious cycle: when climate policies are seen as unfair or overly burdensome, they erode public trust, fuel social unrest, and increase polarization. This sense of injustice can discourage sustainable behavior and weaken societal cohesion, undermining the willingness to pursue the ambitious measures needed to tackle the crisis.

Breaking this cycle requires a deliberate focus on equity and inclusion in climate policymaking. Addressing the needs and perspectives of those most affected – whether due to socioeconomic conditions or regional disparities – is essential to rebuilding trust and ensuring effective, fair climate action.

This report seeks to deepen our understanding of the social and economic dimensions of the climate transition. Using composite indices that assess social and labour vulnerability in mid-century climate scenarios, it highlights how different communities and sectors will be affected. These indices reveal disparities that must be addressed to build a resilient future. Our analysis shows that over 239 million people living in extreme poverty will be disproportionately affected by more frequent and intense weather events and climate-related disasters, with limited resources to adapt or recover.

The findings are a resounding call to action for policymakers and society alike – a powerful reminder that the time to act is now. Our solutions must be equitable, inclusive, and transformative. This is also a moment to accelerate progress toward the Sustainable Development Goals (SDGs), strengthen efforts to limit global warming to below 1.5°C, and ensure no one is left behind.

UNESCO plays a key role in advancing global dialogue on the social and ethical dimensions of climate change. Guided by the Declaration of Ethical Principles in relation to Climate Change, we emphasize linking scientific and technical solutions with human rights and social perspectives. This research, developed under the leadership of Gabriela Ramos and in cooperation with "la Caixa" Foundation, reflects a commitment to more accurate analytical models that address the complex, interrelated nature of social, economic, and climate challenges. It builds on the establishment of Palau Macaya – La Caixa Foundation, a UNESCO Category 2 Centre, created to promote research and support decision-making through a social science lens.

This report follows our earlier collaborative publication, *Inclusive and Resilient Societies: Equality, Sustainability, and Efficiency*, which challenged the equity-versus-efficiency narrative in economic policy. That work advocated for integrating equity and sustainability from the outset, across territorial, societal, and sectoral dimensions. Building on that foundation, the current report highlights the importance of embedding fairness at the core of climate policies to ensure a just and effective transition. By focusing on the social and economic aspects of climate change, it offers insights and solutions for a transition that centers human well-being alongside environmental sustainability.

As the world confronts climate crisis, this report is both a call to action and a roadmap for transformative policies. It reflects UNESCO and "la Caixa" Foundation's shared commitment to fostering a more equitable, sustainable, and resilient future.

Gustavo Merino
Director for Social Policies
Social and Human Sciences Sector
UNESCO

Message from "la Caixa" Foundation

Ecological transition and social justice are two closely related issues. We have never had so much knowledge, so much technology, or so much funding for tackling climate change. But more is needed. In the United States, in the 1970s, people began talking about a just transition from a theoretical perspective. At the COP in Cancun in 2012 it was addressed as a practical issue and has since been included in the Paris agreements. Energy transition policies must be designed to cause the least impact on people and the minimum possible differences between countries. And to offer alternatives at three levels: industrial, territorial, and personal. With the geopolitical circumstances we are currently experiencing, these issues acquire a very significant relevance.

The ecological transition plays a decisive role in the activities of the "la Caixa" Foundation. We do not have any specific programme dedicated to it: it is present across the board in our activities in the social, cultural, science and thought fields. One of our organisation's strong points is its ability to bring together specialists from different disciplines, and to involve public institutions, universities, and global organisations, opening the door to experts from all countries. From our base at the Palau Macaya of the "la Caixa" Foundation, UNESCO's Social and Human Sciences sector, we want to provide tools that encourage reflection, enable planning and action, and develop awareness-raising initiatives that reach everyone.

It is along these lines that we are today presenting the report Who bears the costs? addressing inequalities from climate change and climate action produced by UNESCO MOST (Management of Social Transformations) Programme. It offers a detailed assessment of the impacts of climate change by country, and within each country. It explains that climate change will affect everyone, with varying degrees of impact and intensity. And that the most vulnerable populations, developing countries, will be disproportionately impacted in both physical and socioeconomic terms. The report takes an in-depth look at different regions and groups, with practical examples, and highlights the need for a comprehensive view of climate change. Extreme weather events, forced displacement, economic disruptions, loss of cultural heritage, and gender inequalities will exacerbate the imbalances and vulnerabilities that already exist today.

One of the newest developments is the introduction of quantitative metrics: climate change exposure index, social vulnerability index, and climate transition impacts worker's vulnerability index. These new tools can help public institutions define their policies. The report warns of the need to implement programmes that offer specific solutions, beyond party ideologies, and alerts to the danger of polarisation in the debate on climate change: proposing documentation, evaluation, design and implementation in order to ensure fair and effective forward progress.

On behalf of the "la Caixa" Foundation, I would like to thank UNESCO for the opportunity to participate in this initiative and highlight the work of the specialists who have made it possible.

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Josep M. Coronas
General Director of the
"la Caixa" Foundation

Acknowledgements

This report was made possible thanks to the partnership between UNESCO and the "la Caixa" Foundation, within the framework of the Management of Social Transformations (MOST) Programme of the Social and Human Sciences Sector of UNESCO. It was developed under the supervision of Gabriela Ramos, Assistant Director-General for Social and Human Sciences at UNESCO and under the responsibility of Gustavo Merino, Director for Social Policies.

Special thanks go to the UNESCO team, composed of Mathilde Rodrigues, Programme Specialist, who oversaw the coordination and development of this publication. Appreciation is also extended to Nathalia Mineo, Jewan Attallah, and Andrea Garcia for their dedicated support throughout the publication process.

UNESCO gratefully acknowledges the support and advice of Sergi Loughney, Josep Ollé Pous, and Monica Badia at the "la Caixa" Foundation.

The team of authors was led by Rodolfo Lacy, Research Associate at the Sustainability Coordination Centre of the National Autonomous University of Mexico (UNAM) and Research Associate and Advisory Board Member of Biosphere 2 at the University of Arizona, with contributions from Rodrigo Muñoz, Research Associate in the Climate Change Research Program (PINCC) at UNAM; Leonardo Beltrán, Non-resident Fellow at Columbia University's Center on Global Energy Policy; Adrian Duhalt, Non-resident Scholar at Southern Methodist University's Texas-Mexico Center; and Gerardo Mendiola, Non-resident Editor at the Climate Change Research Program (PINCC) at UNAM. UNESCO also acknowledges the guidance and advice of Dimitra Xynou, Gender Expert and Counsellor at the Permanent Delegation of Greece to the OECD, and Miguel Cárdenas Rodríguez, Environmental Economist at the OECD Environment Directorate.

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Key takeaways

Climate change is unevenly reshaping our societies.

- Climate change is globally triggering unforeseen and profound transformative processes in the economy and society, but these shifts unfold unequally across regions, communities and industries.

- Our **climate change exposure index and social vulnerability Index** reveal that over 239 million people in extreme poverty will face disproportionate climate-related hardships, enduring relentless heatwaves exceeding 12 weeks with daily temperatures averaging above 35°C. Additionally, it reveals that overall, **by 2050**, nearly **2.5 billion people** will face critical exposure to extreme heat, among other extreme weather conditions, significantly increasing health risks.

- Climate-driven displacement is growing. According to the Office of the United Nations High Commissioner for Refugees **(UNHCR) (2024)**, nearly **80 million forcibly displaced people** are currently living in areas highly exposed to climate-related hazards. Approximately **65% of displaced populations** also face conflict-related risks, compounding their vulnerability.

- Our estimates for this report indicate that approximately **1.4 billion women (or 34% of the global female population)** will be directly impacted by climate-related conditions **between 2040 and 2060.**

Though well-intended, climate policies can often exacerbate existing inequalities or create unequal outcomes.

- If not designed inclusively, green transition policies such as carbon pricing, emissions trading schemes (ETS) and subsidies for renewables can exacerbate social inequalities.

- Carbon taxes particularly can disproportionately burden lower-income households particularly in regions where affordable clean energy options remain scarce.

- Energy access remains deeply unequal: as global energy markets shift, the most vulnerable populations risk falling further behind without targeted policy support.

- Workers in the manufacturing, mining and energy sectors are vulnerable to a transition to cleaner production, as can be measured by the **climate transition impact workers' vulnerability index, 325 million workers**, including **108 million women** and **106 million people over 45 years old**, are in industries vulnerable to climate transitions.

- Africa remains the **most vulnerable region** for worker displacement, followed by the Americas.[1]

If not designed inclusively, climate policies may face backlash and aggravate societal division.

- Perceived unfairness in climate policies fuels social unrest, leading to resistance across multiple countries from France's Gilets Jaunes movement to coal worker strikes in Germany and Poland, fuel subsidy protests in Ecuador and Kenya, and farmer uprisings in India and the Netherlands.

- Public opposition has slowed down or even reversed climate measures worldwide particularly when energy transitions disproportionately impact lower-income groups.

- Energy poverty and rising living costs from decarbonization policies are intensifying political polarization, particularly where green transitions fail to offer viable alternatives for workers and consumers.

Therefore, we must work to design and implement climate policies aligned with our goal to create a common path towards a just and inclusive transition.

- Climate finance must scale up dramatically. We call developed countries to increase contributions to **1.3 trillion annually by 2035** to support adaptation and mitigation in developing nations.

- Investing in social protection systems is essential to shield vulnerable workers and communities against economic shocks derived from the implementation from climate policies.

- Implement retraining and reskilling programs to ensure that workers affected by the phasing out of high-emission industries are not left behind by the climate transition.

- Integrate redistribution mechanism – such as subsidies, tax rebates, and reinvestment of carbon revenues towards vulnerable communities – into climate policies to make them more equitable.

- Support **large-scale technology transfer initiatives** through cooperative agreements and public-private partnerships, to ensure that developing countries benefit from clean energy growth and enhance their workforce's potential through access to clean energy technologies and financial support.

Policy priorities for a just climate transition: putting vulnerable communities first.

- **Achieving the SDG**s: Ensuring economic growth, social inclusion and environmental protection, with a vulnerable first approach in climate finance.

- **Prioritizing adaptation and resilience**: Strengthening financial, technological and social protection systems to address climate risks.

- **Addressing distributional impacts:** Implementing compensatory measures for vulnerable populations to counterbalance socioeconomic inequalities.

- **Accelerating the widespread deployment of clean and zero-emission technologies:** Unlocking the critical role of technology transfer.

- **Safeguarding cultural and natural heritage:** A call to action, recognizing climate change as a direct threat to historical and natural preservation.

1 In this report, the term *Americas* encompasses both North and South America. Despite the significant socioeconomic disparities among countries – such as the contrast between Canada and the United States of America versus Latin America and the Caribbean – these regions face common climate risks, including wildfires, extreme heat, and hurricanes. While these differences shape their respective capacities for adaptation, shared vulnerabilities underscore the need for coordinated regional strategies to enhance resilience and climate action.

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Introduction

Climate change is globally triggering unforeseen transformative processes in the economy and society. In certain nations, extreme weather events drive human migrations and humanitarian crises and prompt a rapid adaptation effort to sustain productive activities and urban liveability. In shifting towards low-carbon economies and achieving net-zero emissions, individuals are increasingly involved, consciously or inadvertently, in a wide array of climate transitions. These gradual transformations encompass a growing adoption of renewable energy across supply and demand, adjustments in production methods influenced by changing weather patterns, widespread electrification of machines, transportation modes and home appliances, industrial processes automation, significant shifts in labour markets, evolving consumption habits and reforms in political, economic and social structures.

While it is undeniable that the Paris Agreement (2015) is working, addressing emerging challenges and expanding its scope, it falls short of delivering the necessary results at the pace and scale required to avert social conflicts, economic disruptions and humanitarian crises. Atmospheric concentrations of all greenhouse gases continue to rise, surpassing even the rates observed before the Paris Agreement (NOAA, 2024). This increase is primarily attributed to human activities (IPCC, 2023), especially the ongoing emissions from fossil fuel combustion, which have failed to decrease and escalated during the post-COVID-19 pandemic period (IEA, 2024a).

Carbon inequalities stem from the substantial disparities between nations and the stark differences between rich and poor within individual countries. Recent studies suggest that these internal carbon inequalities may be even more pronounced than the global divide between nations.

Despite all individuals contributing to ghg emissions, they do so with varying levels of intensity and magnitude within and across countries. The richest 10% of individuals worldwide are responsible for nearly half of all global GHG emissions (Oxfam, 2023), highlighting significant disparities. Carbon inequalities stem from the substantial disparities between nations and the stark differences between rich and poor within individual countries. Recent studies suggest that these internal carbon inequalities may be even more pronounced than the global divide between nations. Low-income households are often disproportionately exposed to climate risks and environmental hazards, yet contribute far less to overall emissions (IPCC, 2018 and 2022a). This dynamic exacerbates social and economic vulnerabilities, highlighting the need for equitable climate action that addresses global and domestic disparities (Chancel L. et al., 2023).

Following adoption of the Paris Agreement on climate change, UNESCO emphasized that climate change not only undermines the sustainability of the Earth's ecosystems and the vital services they provide but also poses profound risks to human well-being on a global scale. These risks extend to people's livelihoods, local communities and individuals, disproportionately affecting vulnerable and poor populations. The wide-reaching impacts of

climate change – including rising temperatures, shifting weather patterns and biodiversity loss – create cascading effects that threaten food security, water availability and public health. UNESCO has highlighted that many of these consequences could be irreversible if not urgently addressed, further destabilizing both natural systems and human societies. In this context, ethical climate action is paramount, particularly in ensuring equitable and sustainable responses to mitigate and adapt to climate-related challenges (UNESCO, 2024).

Like all policies, climate policies inevitably create winners and losers, even within the same social group. However, vulnerable and marginalized populations – such as lower-income individuals, women and indigenous peoples – are disproportionately affected by the impacts of climate change, with these effects often intensified by pre-existing regional inequalities. Furthermore, climate policies, whether already implemented or yet to be enacted, tend to place an unequal burden on these groups (e.g., carbon taxes with regressive distributional effects), risking the amplification of existing disparities or the creation of new ones.

Vulnerable communities living at or near the poverty line, already grappling with or imminently exposed to increasing climate risks, face a heightened threat of socioeconomic and physical decline. This vulnerability stems from the compounded impacts of global warming, unpredictable extreme weather events and climate change policies that are often tailored to functional, stable and democratic economies. Such policies frequently overlook the unique challenges faced by marginalized groups and fragile nations, leaving them inadequately supported. **Figure I.1** illustrates these dynamics, contrasting the conditions that can empower and uplift the most vulnerable communities (upper section) with those that, when accrued, could push significant populations into extreme poverty (lower section). Such scenarios risk fostering sociopolitical crises akin to those recently witnessed in regions like the Middle East, sub-Saharan Africa and Latin America.

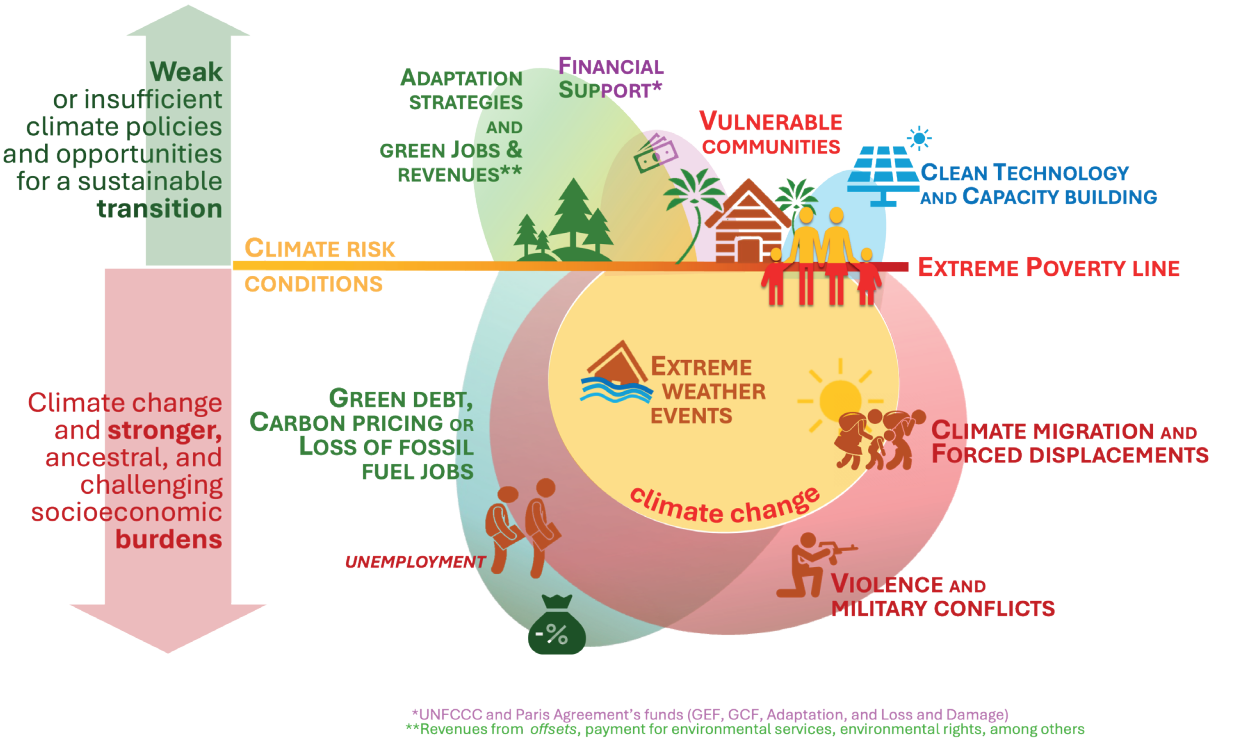


Figure I.1 Climate change burdens and opportunities under vulnerable conditions

Source: Author's own elaboration.

To address these challenges, it is crucial to adopt integrated social and economic policies that mitigate these inequities (OECD, 2021a). Without such measures, not only will injustice persist, but social unrest and resistance to vital climate action will likely increase. Highlighting the potential for poorly designed policies to deepen inequalities is essential, as it can contribute to further polarization and hinder progress on climate solutions.

Effective, coherent and equitable transition policies are imperative to mitigate undesirable trade-offs, particularly in the social and labour spheres, such as job losses in fossil fuel industries or higher energy costs for rural areas. However, global and regional disparities are so profound that specific large human populations are inevitably more severely affected by climate change than others, spanning multiple generations, even if customized policies are implemented to mitigate the impact of impending tipping points exacerbating the global climate crises. Historical geographic inequalities in GHG emissions and rising temperatures are already influencing critical aspects such as life expectancy (Hadré et al., 2023), mortality rates (OECD, 2024b) (García-León et al., 2024), income growth (Vogt et al., 2023), gross domestic product (GDP) expectancy (Burke et al., 2015) and labour productivity (Dasgupta S. et al., 2021), among other pressing contemporary issues.

To achieve these objectives, it is essential to develop advanced analytical tools, such as composite indices, which allow us to accurately visualize and quantify the magnitude and distribution of climate change impacts. These tools must capture the geographical, sectoral and social disparities of both the current and projected mid-twenty-first century climate impacts, providing critical insights to inform effective and equitable adaptation and mitigation long-term strategies.

Currently, 3.6 billion people reside in regions highly vulnerable to climate change impacts (IPCC, 2022a). While these regions primarily include middle- to low-income areas such as large parts of Africa, South Asia, Central and South America and the Arctic, developed nations are also increasingly susceptible to environmental threats shortly (Cabrita et al., 2021). According to the Institute for Economics and Peace (IEP, 2020), if weather patterns persist without additional mitigation efforts from technologically and economically advanced countries, an estimated 1.2 billion people globally could be displaced by 2050.

Currently, 3.6 billion people reside in regions that are highly vulnerable to climate change impacts (IPCC, 2022a).

A gender lens is particularly crucial in understanding the impacts of climate change. Globally, as climate-driven conflicts escalate, women and girls face heightened risks of gender-based violence, including sexual violence in conflict and during forced migration, new ways of human trafficking, child marriage, and other forms of exploitation (UN-Women, 2020). Gender inequalities, especially in poor and developing countries, exacerbate these risks, contributing to disparities in information access, transportation modes and mobility (ITF, 2022), decision-making power and access to resources and training (UNEP, 2011).

As highlighted by UN-Women, climate change acts as a "threat multiplier", intensifying social, political, and economic tensions in fragile and conflict-affected regions (UN-Women, 2022). The distributional impacts and costs of climate change are not borne equally across all populations but disproportionately affect certain groups along dimensions often overlooked, such as age, gender, culture and religion. These disparities highlight the need to address climate change with a focus on its varied impacts on vulnerable populations. Policies and action plans must be inclusive, considering the diverse needs and realities of all communities.

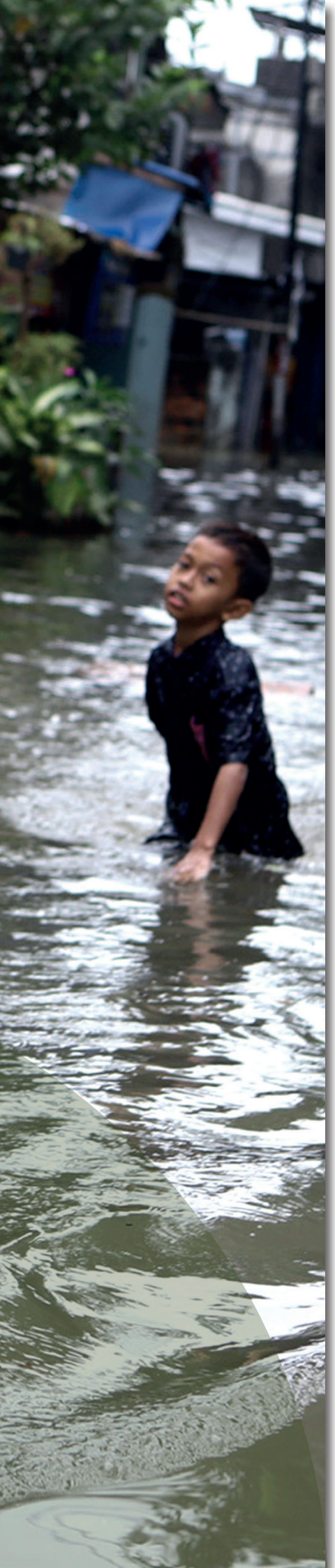
A gender lens is particularly crucial in understanding the impacts of climate change.

During natural disasters, women are disproportionately vulnerable to injuries and fatalities, exacerbated by systemic inequalities (UN-Women, 2020). According to the United Nations Development Programme (UNDP), worldwide, women perform more than 75% of unpaid care work, which is 3.2 times the amount done by men. When climate-induced disasters strike, this burden intensifies as women shoulder additional responsibilities to aid in the recovery and rebuilding of their households and communities (UNDP, 2024). The aftermath of extreme weather events linked to climate change increases these vulnerabilities, hindering their access to critical relief and support services. This compounds threats to their livelihoods, well-being and recovery, perpetuating a cycle of vulnerability that augments their susceptibility to future climate-related disasters.

The distributional impacts of climate policies are not only critical for garnering public support but also for addressing well-being and inequality concerns, even in developed regions. A recent study focusing on European countries examined the potential reform of the European Union's energy tax directive and the implementation of emissions-trading systems in the road transport and household sectors (€45/tCO_2). The findings highlight that these reforms, in the absence of revenue-recycling schemes, have a regressive effect, disproportionately reducing the welfare of lower-income households: the poorest 30% of households are impacted worst (almost -1% welfare impact) and the richest 10% of households least (Gore, 2022). The *Mouvement* des gilets jaunes (yellow vests protests) crisis in France dramatically demonstrated climate policy failure (Levain et al., 2022). There is a need for equitable policy design to mitigate adverse impacts and violence on vulnerable populations while advancing climate goals.

The distributional impacts of climate policies are critical for garnering public support and addressing well-being and inequality concerns, even in developed regions…There is a need for equitable policy design to mitigate adverse impacts and violence on vulnerable populations while advancing climate goals.

Understanding and measuring the distributional impact of climate change is essential to balance the goals of promoting equitable green growth and enhancing resilience to climate change. This task is particularly urgent for vulnerable communities and nations already grappling with the devastating consequences of severe weather events. However, addressing this multifaceted challenge requires proactive integration into the fabric of global and national climate policies, ensuring that no one is left behind in our quest for a sustainable and just world.



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Distributional aspects of climate change

The unequal and differentiated distribution of climate change impacts across regions and sectors is a defining feature of this global crisis. As global temperatures rise, and the intensity and frequency of extreme weather events increase, along with responses to climate change, these impacts are intensifying long-standing inequalities and widening economic and technological divides, both between nations and within them.

The planet's average temperature has already risen by 1.1°C, putting us on a trajectory to reach the critical 1.5°C threshold sooner than anticipated (IPCC, 2022 and 2023). Speaking at the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29) in Baku, Azerbaijan, the Chair of the Intergovernmental Panel on Climate Change (IPCC) emphasized the urgent stakes, stating: "Carbon dioxide accumulates in the atmosphere; every incremental tonne adds to global warming. If we continue with currently implemented policies, we are likely, by 2030, to have placed limiting warming to 1.5ºC with low or no overshoot, even in the long run, beyond reach. Even the most ambitious emission reductions beyond 2030 may not allow us to recover lost ground". His remarks underscore the pressing need for transformative action within this decade to avert irreversible damage and meet global climate goals. (IPCC, 2024)

While every fraction of an additional degree Celsius (°C) will bring devastation and suffering to millions of people, the IPCC compiled studies highlighting the outsized magnitude of these impacts above 1.5°C, thus strengthening the objective laid out in the Paris Agreement on climate change (IPCC, 2022). The World Meteorological Organization (WMO) has updated its climate change forecast, indicating an 80% chance of surpassing a 1.5°C increase within the next three years compared to the 1850-1900 baseline (WMO, 2024c). The European Union's Copernicus Climate Change Service (C3S) reported that the last twelve months, notably 22-23 July 2024, marked the warmest consecutive months and days on Earth in recent history, setting a record since the ERA52 dataset began in 1940 (C3S, 2024). The WMO has officially confirmed that 2024 is the warmest year on record, marking the first calendar year with a global mean temperature exceeding 1.5°C above the pre-industrial average (1850–1900). This milestone is based on comprehensive data from six leading international datasets (WMO, 2025).

This alarming trend, driven by the cumulative impact of excessive emissions, has been further accelerated in recent years by a sharp rise in GHG emissions following the COVID-19 pandemic. This increase has been compounded by a surge in fossil fuel subsidies and investments, undermining global efforts to transition toward sustainable energy systems (IISD and OECD, 2024). Additionally, the international commitments outlined in nationally determined contributions (NDC) lack the ambition to effectively halt and potentially reverse the dangerously high concentrations of greenhouse gases in the atmosphere (UNEP, 2023).

Inequality in the geographic and sectoral distribution of climate change effects across the planet is an intrinsic characteristic of this global phenomenon. Still, the severity of its impact on different populations should not be accepted as inevitable.

This scenario suggests that rapid and widespread changes in the atmosphere, the ocean, the cryosphere and the biosphere will persist. These changes will continue to affect global climate patterns, leading to more extreme weather events, rising sea levels and ecosystem disruptions. Even with drastic and sustained reductions in emissions, the planetary system would still require at least two decades to stabilize and cease warming (IPCC, 2023).

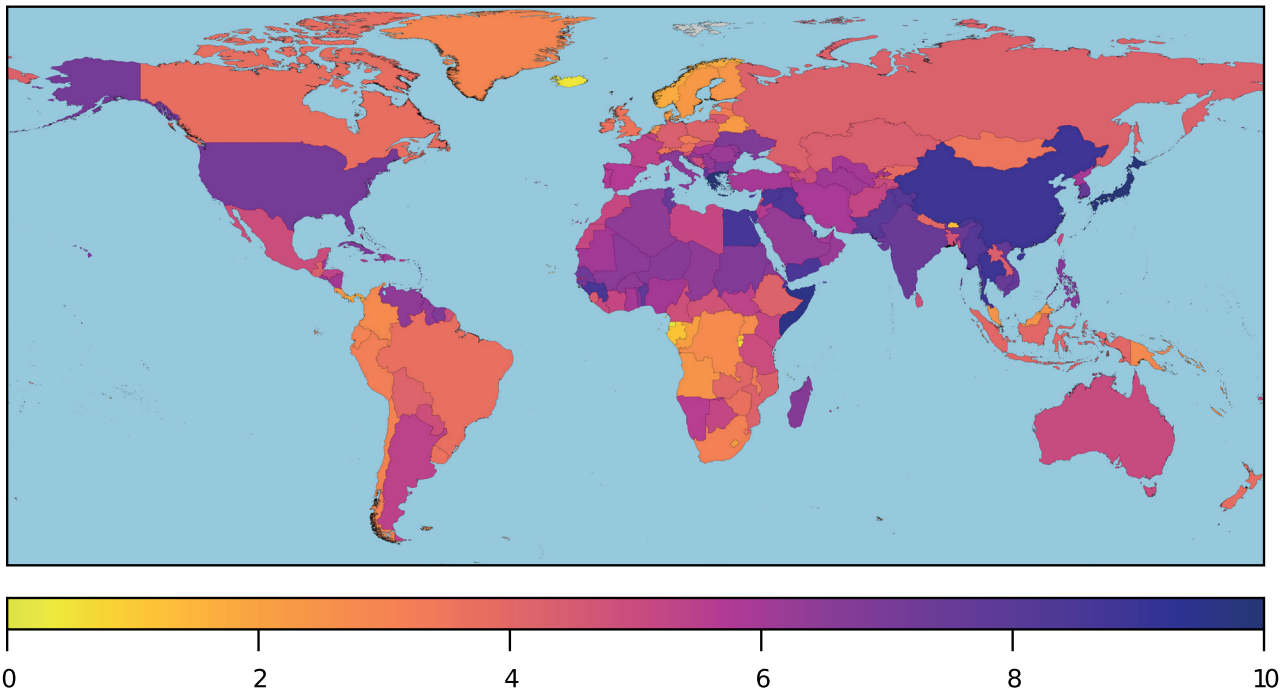
Given these projected climate futures, the resulting losses and damages to society could be immeasurable and profoundly unjust but expected to be at least $580 billion by 2030, excluding non-economic consequences (HRC, 2024). Vulnerable populations, including small island nations, Indigenous communities, coastal and low-lying regions, the urban poor, displaced people, arid and semi-arid settlements, people with disabilities and others – particularly those in developing countries – are likely to face the worst impacts of climate change, despite having contributed the least to global emissions (IPCC, 2022a).

This alarming trend of global warming is primarily driven by a significant increase in GHG emissions following the COVID-19 pandemic, compounded by a rise in fossil fuel subsidies.

In this report, we present the **climate change exposure index**, designed to estimate population exposure to climate change risks at the national level. The index evaluates exposure across five critical risk categories: extreme heat, extreme rainfall, hurricanes, drought and sea level rise. A score of 10 indicates the highest possible exposure to these climate risks. For a detailed account of the index's construction, methodology and the variables used, readers are encouraged to consult the methodological annex.

2 ERA5 is the fifth generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate.

Figure I.2. Climate change exposure index 2040-2060



Source: Authors' own elaboration based on data from UNDRR, the World Bank Group, Neumann et al. (2015), see Annex I. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure I.2 showcases the **climate change exposure index** results by country, illustrating the spatial distribution of exposure to climate risks under a composite scenario for 2040–2060 (see **box I.1** for methodological specifics). The map highlights populations in regions where climate conditions are projected to grow increasingly extreme. By aggregating exposure across the five key risk categories – extreme heat, extreme rainfall, hurricanes, drought and sea level rise – it provides a comprehensive visual summary of potential climate impacts. This representation underscores the varying intensity and geographic distribution of these risks, offering a clear perspective on the levels of vulnerability that populations worldwide may face as climate change accelerates.

Most nations, even the ones most exposed according to the index, are exposed to only one or two climate event categories. However, some countries, even if not among the most exposed, will face significant challenges to adaptation since they will be subject to a wide variety of extreme climate events. Australia, Colombia and Madagascar are the only countries exposed to all five climate risk categories. Meanwhile, four other nations – Anguilla, Bahrain, Japan and Somalia – face significant vulnerability, being highly exposed to at least three of these climate threats.

Regionally, Asia emerges as the most exposed continent overall, particularly vulnerable to sea level rise and extreme rainfall, followed closely by the Americas. The Americas, however, bear the most significant exposure to drought, Africa to extreme heat and Oceania to hurricanes.

This scenario suggests that rapid and widespread changes in the atmosphere, the ocean, the cryosphere and the biosphere will persist. These changes will continue to affect global climate patterns, leading to more extreme weather events, rising sea levels and ecosystem disruption.

Box I.1. Climate change exposure index

This index evaluates hazards (climate changes over a given area) and exposure (the population in that area). It utilizes the IPCC's SSP2-4.5 inertial scenario, which projects approximately 2°C of warming by 2050 and 3°C by 2100. The impacts are assessed for 2040-2060 relative to 1995-2014. The index comprises five categories:

1. **Hurricanes**: Measured by 100-year hurricane wind, with an extreme threshold of category 4 to determine the number of affected inhabitants. Made with data from the United Nations Office for Disaster Risk Reduction (UNDRR) Global Assessment Report on Disaster Risk Reduction (UNDRR, 2015).
2. **Extreme precipitation**: Assessed by the average 1-day maximum rainfall as a percentage of the total annual rainfall, with a threshold of 10%. Elaborated with data from the World Bank Group's Climate Change Knowledge Portal (WBG, 2024a).
3. **Drought**: Evaluated using the average 12-month Standardized Precipitation-Evapotranspiration Index (SPEI), with a threshold of -0.15 (WBG, 2024a).
4. **Extreme temperatures**: Measured by the average number of days with temperatures above 35°C, with a threshold of 12 weeks (WBG, 2024a).
5. **Sea level rise**: Considered by the 100-year coastal floodplain, according to Neumann et al. (2015).

The index is calculated by determining the difference between future and present conditions for each category, multiplying the percentage of the national population in each grid[3] by the index category variable, and adding these values across each country. The rank percentile is then calculated. The average of the five categories is taken, and the result is normalized to range from 0 (for the least exposed country) to 10 (for the most exposed country).

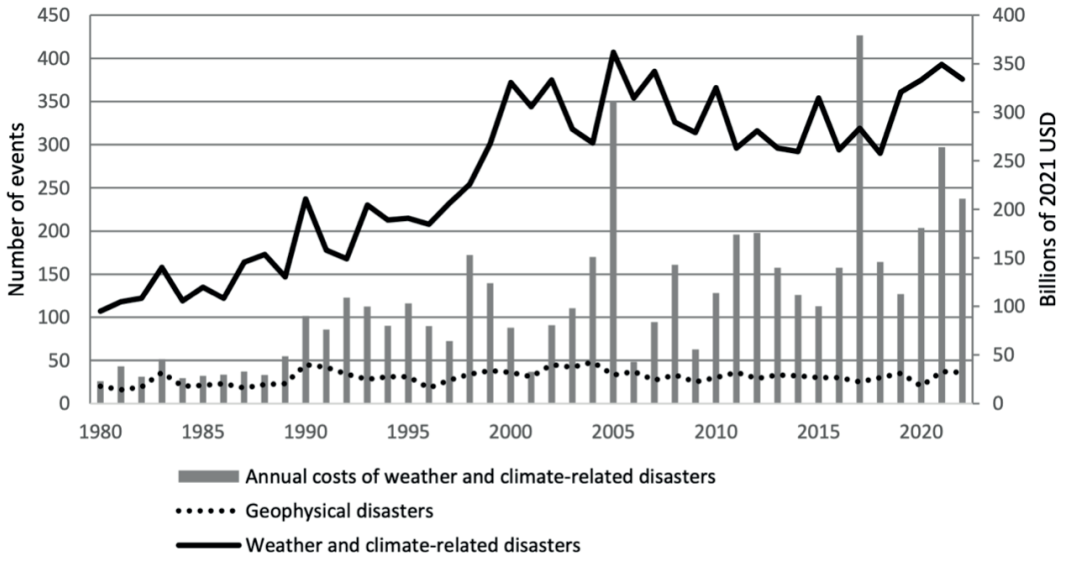
Small island developing States (SIDS) are disproportionately affected, showing higher-than-average exposure to climate risks, particularly sea level rise, drought and hurricanes. Similarly, least developed countries (LDCs) face greater-than-average exposure overall, with significant vulnerabilities to sea level rise, extreme heat, and extreme rainfall. Landlocked developing countries (LLDCs) are especially exposed to extreme heat and extreme rainfall, highlighting the diverse and widespread nature of climate risks across different regions and country classifications. The climate change exposure index underscores those countries across the global North and global South are expected to face significant adaptation challenges due to their exposure to a wide range of climate impacts. The extent to which individuals within these countries will be able to cope with the increased frequency of magnitude of extreme weather events will depend on their vulnerability and the disparities among social groups. As a result, climate change may create barriers to achieving a just climate transition that leaves no one behind.

Climate change is not merely an environmental challenge but a catalyst that can either deepen social and economic inequality or serve as an opportunity to regenerate wealth and drive sustainable progress.

The complexity of the distributional impacts of climate change are profoundly influenced by a range of interconnected factors. Geographic location plays a critical role, as regions experience varying degrees of exposure to climate-related risks. The health of ecosystems is equally important, as more degraded environments lack the resilience to buffer against these weather anomalies, putting both biodiversity and human communities at greater risk. Similarly, the resilience of productive systems, including agriculture, energy and infrastructure, dictates how well societies can withstand and recover from climate shocks in rural or urban conditions.

3 Most climate change data is structured within a global grid system, where each cell represents a specific geographic area with aggregated climate values. For example, a commonly used resolution is 0.25° latitude by 0.25° longitude, meaning each square contains a representative mean annual temperature (or other climate variable) for that defined space. These grid cells collectively span from 0° to 360° longitude and -180° to 180° latitude, effectively mapping climate variables across the entire globe. This structured approach enables the analysis of localized climate conditions within any region while maintaining consistency in global climate assessments.

Figure I.3. Evolution of weather and climate-related disaster events worldwide: number of events and annual costs 1980-2023



Source: IZA, 2024, with data from the Centre for Research on the Epidemiology of Disasters at the Catholic University of Louvain (www.emdat.be).

Socioeconomic development plays a critical role in shaping these impacts, with less-developed regions struggling to mobilize the resources needed for adaptation and mitigation at the pace required by accelerating climate change. Furthermore, human and cultural factors – such as governance structures, social cohesion and traditional knowledge systems – greatly influence a community's ability to adapt and respond to new and often unpredictable climatic challenges. These factors are actively interacting and frequently compound one another, intensifying their effects. Vulnerable populations, already marginalized by economic, social or environmental circumstances, disproportionately bear the brunt of these climate effects, further widening the gap between the most and least affected. In this context, climate change is not merely an environmental challenge but a catalyst that can either deepen social and economic inequality or serve as an opportunity to regenerate wealth and drive sustainable progress.

I.1 Climate change deepens social vulnerabilities that will exacerbate existing inequalities

Drawing on evidence from diverse locations, regions and sectors, the early impacts of global climate change are disproportionately burdening communities and nations that have contributed minimally to the crisis yet are acutely vulnerable to its effects. This heightened vulnerability is magnified by intersecting stressors, including geographic exposure, socioeconomic inequalities and limited technological capacity to adapt or respond effectively. These challenges are further compounded by the escalating severity and frequency of temperature anomalies, precipitation irregularities and, most notably, extreme weather events.

Between 1980 and 2022, climate-related disasters such as droughts, wildfires, floods, landslides, hurricanes, severe storms and extreme temperature events claimed nearly 1.6 million lives and caused over $4.6 trillion in economic damages. In this decade, the annual global economic toll has exceeded $200 billion (see **figure I.3.**), with some disasters becoming increasingly difficult to fully quantify (see **box I.3.** regarding Pakistan's recent flood). These figures, however, fail to reflect the disproportionate impacts on poorer nations and regions lacking essential services and resilient infrastructure. In these areas, the consequences of climate disasters are often far more severe, leading to prolonged recovery times, deeper economic setbacks and heightened vulnerability to future shocks (IZA, 2024).

To accurately determine which populations and regions will be impacted by exceptional climatic conditions and extreme weather events, it is essential to enhance the regional granularity of climate projections. While numerous projections exist regarding how the international community will progress towards a climate future that aligns with the ambitions of all nations and their people, this report will utilize projections from the MESSAGEix-GLOBIOM integrated assessment model (IAM). The IAM is officially employed by the International Institute for Applied Systems Analysis (IIASA) and featured in IPCC assessment reports to develop different climate scenarios.

The future climate of the Earth and its impacts on societies are not a given fact. They depend on how successful the world is in mitigating emissions, leading to drastically different futures. To study this, the IPCC Fifth Assessment Report (AR5) has established official demographic scenarios of the future based on plausible narratives; these are the shared socioeconomic pathways (SSPs), meant for inter-comparability of climate change studies (IPCC, 2013).

We selected for the projections of this report the SSP2-RCP4.5 climate scenario. The shared socioeconomic pathway 2 (SSP2) part, known as the "middle-of-the-road" scenario, which envisions a world where social, economic and technological trends continue along historical lines without significant deviations. This trend is complemented for analytical purpose with a representative concentration pathway (RCP) that outlines a climate scenario where global GHG emissions lead to a radiative forcing of 4.5 Watts per meter squared (W/m^2) by 2100 (RCP4.5), with a mean projected global temperature increase of 2°C by 2050 and 2.6°C at the end of the century (Fricko et al., 2017).

Under this SSP2-RCP4.5 scenario, global CO_2 emissions are anticipated to continue rising until 2050, with a projected increase of 7% from 2020. After peaking in 2050, a decline is expected, with emissions decreasing by 13% relative to 2020 by 2070. Despite this overall reduction, specific sectors will not contribute to the decrease in emissions by 2050. Notably, only the residential, commercial and other sectors, Agriculture, Forestry and Other Land Uses (AFOLU), and the international shipping sector are expected to reduce their emissions by this time.

The energy sector, a key contributor to global CO_2 emissions and central to the climate change challenge, is projected to sustain relatively stable emission levels through 2050. In contrast, the aviation industry is expected to see substantial growth in emissions, with this upward trend continuing well beyond 2050 and extending into 2070.

This is evident from the projections for investments and subsidies in this critical sector. According to the International Monetary Fund (IMF), global fossil fuel subsidies have more than doubled in recent years and are projected to continue rising, potentially reaching nearly $8 trillion. This growth is particularly significant when accounting for implicit subsidies linked to fuel consumption in emerging markets, where local environmental costs tend to be substantially higher (IMF, 2023). This figure starkly contrasts with the $1.3 trillion in financing required by developing countries to align their emission trajectories with the carbon neutrality pathway by 2035, as pledged at the COP29. This need is outlined in the new collective quantified goal on climate finance (UNFCCC, 2024).

Global fossil fuel subsidies have more than doubled in recent years and are projected to continue rising, potentially reaching nearly $8 trillion.

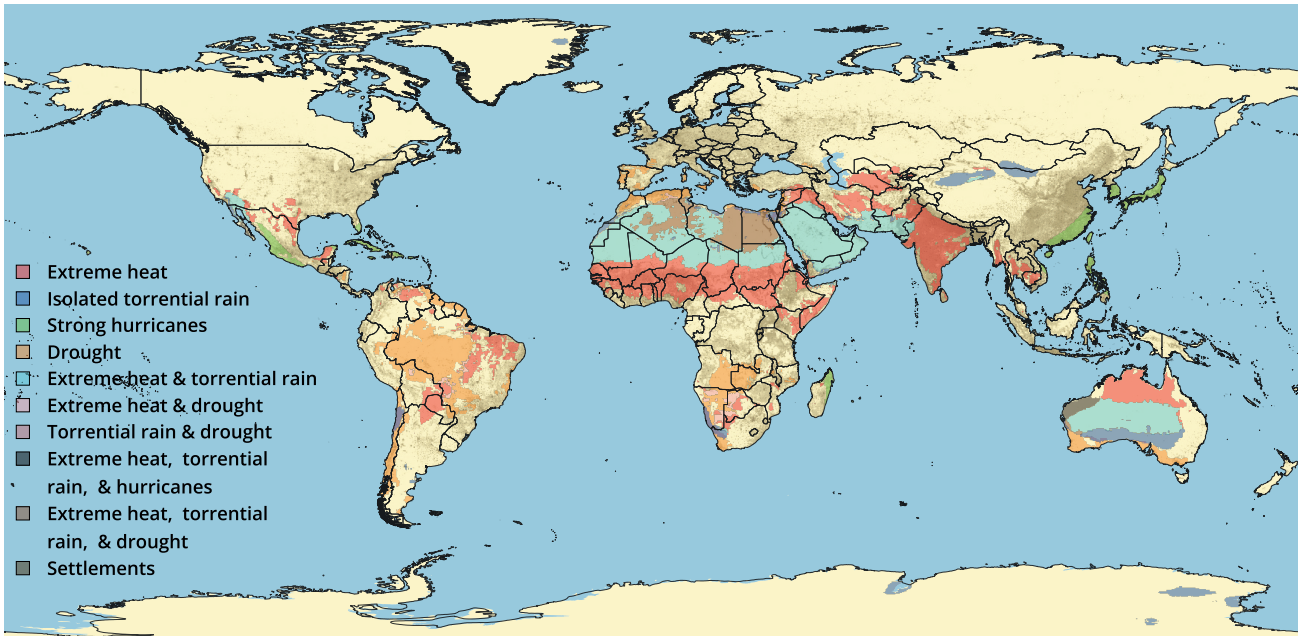
On a regional scale, sub-Saharan Africa is projected to see the most significant increase in emissions from the industrial sector and the residential, commercial and other sectors by 2050. South Asia, on the other hand, is expected to witness the most significant overall growth in CO_2 emissions, driven primarily by the energy and transportation sectors. The transportation sector stands out as the only sector where emissions are forecasted to increase across all regions globally. Furthermore, sub-Saharan Africa is unique because it is the only region where emissions are projected to rise across every sector. In contrast, in centrally planned Asia and China, the transportation sector is the only one anticipated to see emissions growth. Regions where total emissions are expected to decline from 2020 to 2050 include centrally planned Asia and China, Central and Eastern Europe, the former Soviet Union, and OECD Pacific States.

From a sectoral perspective, agricultural production is projected to continue its growth trajectory through 2070, driven primarily by a significant increase in energy crops. This surge is largely attributed to the global shift towards renewable energy sources, particularly biomass. As the demand for sustainable energy rises, energy crops are expected to play a pivotal role in meeting global energy needs.

Concurrently, electricity generation capacity is anticipated to double between 2020 and 2050. This expansion comes alongside a substantial decline in coal, which is expected to decrease by 73% owing to phase-out policies aimed at reducing carbon emissions. In stark contrast, solar energy is poised for exponential growth, expanding ninefold by 2070, while wind energy is projected to be nearly four times larger by 2050. Despite the decline in coal use, its role in primary energy remains relatively stable, with a slight dip around 2050, followed by a resurgence by 2070. This resurgence is expected to be fuelled by the widespread adoption of carbon capture and storage (CCS) technology, which has the potential to revitalize the fossil fuel industry, particularly in countries with significant proven reserves. Meanwhile, oil consumption is projected to experience modest growth, peaking around 2050 before gradually declining towards 2070.

The CO_2 concentrations are expected to rise, reaching nearly 500 parts per million (ppm) by 2050 and doubling pre-industrial levels by 2070, underscoring the urgent need for effective climate mitigation strategies. Regionally, Latin America and the Caribbean are anticipated to

Figure I.4. Extreme weather affected zones in 2040-2060



Source: Authors' own elaboration based on a SSP2-4.5 climate scenario, see figure I.1 and box I.1 for sources and methodological aspects. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

witness the most significant growth in energy crops and solar capacity, positioning these regions as leaders in the transition to renewable energy. The Middle East and Africa are expected to dominate in the growth of non-energy crop and livestock production, as well as in the expansion of total electricity capacity, including substantial increases in both wind and coal energy. In contrast, oil consumption is projected to see the highest growth rates in Asian countries, with a decline occurring only in the reforming economies. On the other hand, coal capacity is forecast to undergo a dramatic reduction across all regions, with near elimination in members of the Organisation for Economic Co-operation and Development (OECD), the European Union, and reforming economies. However, the decrease in coal use is expected to be less pronounced in Asian countries, where it remains a significant energy source.

Among the various extreme events, extreme heat poses the greatest threat to human populations, with projections indicating that nearly 2.5 billion people will be exposed by 2050.

In the MESSAGEix-GLOBIOM SSP2-RCP4.5 scenario, as outlined in previous discussions, global temperatures are projected to rise by 2°C by 2050, setting off a chain reaction of extreme weather events that will disproportionately affect vast, densely populated regions of the planet, amplifying its effects. This scenario, illustrated in **figure I.4** and further detailed in **table I.1**, highlights the escalating risks associated with continued global warming. The scenario anticipates a sustained warming trend that will surpass the temperature thresholds established by the Paris Agreement (2015), undermining global efforts to limit warming to well below 2°C. By 2070, global temperatures are expected to reach 2.3°C, and by 2100, they could escalate further to 2.6°C (IIASA, 2024).

Asia stands out as the region with the largest population exposure to nearly all categories of climate-related extreme events, with drought being the sole exception, where Africa emerges as the most vulnerable region. Among these threats, extreme heat poses the most significant risk to human populations, with projections indicating that nearly 2.5 billion people could be exposed by 2050. This alarming figure highlights the critical urgency for robust adaptive measures to safeguard vulnerable communities from the intensifying impacts of global warming.

SIDS are particularly vulnerable to sea level rise and the devastating effects of intense hurricanes, which threaten both lives and livelihoods. With limited land area and often fragile economies, these regions face disproportionate risks from these phenomena – risks that are neither their

Table I.1. Population affected by extreme climate events in 2040-2060 (millions and percentage of population)

Continents or group of countries	Sea level rise		Drought		Extreme heat		Extreme rainfall		Strong hurricanes	
Asia	250.7	5%	65.7	1%	1,780.7	35%	220.5	4%	555.5	11%
Europe	32.3	4%	30.8	4%	0	0%	0.02	0%	0	0%
Africa	38.4	2%	251	13%	0.6	32%	95.5	5%	17.0	1%
Oceania	1.5	3%	15.3	27%	0.4	1%	0.3	1%	0.5	1%
Americas	16.5	1%	83.5	7%	62.6	5%	7.9	1%	78.7	7%
SIDS	2.7	3%	8.2	10%	2.5	3%	0.1	0%	32.6	42%
LDC	33.4	2%	39.1	3%	388.1	25%	22.2	2%	3.0	0%
LLDC	0	0%	25.2	3%	222.0	28%	2.8	0%	0	0%
World	339.4	4%	446.4	5%	2,473.9	27%	324.3	4%	652.0	7%

Source: Authors' own elaboration, see figure I.1. and box I.1. for sources.

responsibility nor within their control. Moreover, these challenges hinder their ability to implement planned adaptation measures, as they exacerbate existing economic vulnerabilities and further entrench marginalization. To address the climate challenges faced by SIDS, it is crucial to understand, measure and manage these issues through the framework of "loss and damage" as established by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (2015). The habitability of these nations is increasingly under threat due to factors such as land loss, water scarcity and the extensive bleaching and biodiversity collapse of coral reefs.

According to the WMO, SIDS have suffered climate-related economic losses exceeding ten times their GDP between 1970 and 2021. This is particularly alarming given that over 40% of SIDS are either on the verge of or already experiencing unsustainable debt levels. Adding to this economic strain, projected losses and damages by 2050 are estimated to reach $56 billion under the SSP2-RCP4.5 scenario (UNDP and CAMÕES, 2024).

In contrast, LDCs and LLDCs are most severely impacted by extreme heat, exacerbating existing challenges related to poverty, food security and access to water. The significant exposure of these regions to climate extremes highlights the pressing need for targeted international support and climate resilience strategies tailored to their specific vulnerabilities.

In certain regions of the world, extreme heat is projected to pose existential threats to long-term habitability, potentially exceeding societies' capacity to implement effective adaptation measures for all. This could result in severe loss and damage, as well as large-scale forced displacement. These challenges raise critical questions about the necessity of managed relocation (see **box I.4**), or "retreat", for the most impacted communities, including vulnerable populations in refugee camps or internally displaced persons (IDPs) camps situated in highly exposed areas (OCHA et al., 2022). Under a SSP2-RCP4.5 climate scenario, it is also estimated by other sources that almost 2.12 billion people could be displaced globally due to temperature rise by 2070 (Chi et al., 2020).

Many countries in the global South are expected to face significant increases in illnesses and deaths linked to rising temperatures (Carleton et al., 2022). A comprehensive review by the International Federation of Red Cross and Red Crescent Societies (IFRC) highlights that extreme weather and climate-related disasters have claimed over 410,000 lives in the past decade (IFRC, 2020). The vast majority of these tragic losses occurred in low- and lower-middle-income countries, primarily in the global South, where communities are disproportionately vulnerable to climate extremes. Recovery, when possible, is often prolonged due to financial and technological constraints, further exacerbating the region's fragility and limiting its resilience to future climate impacts.

At least 2.41 billion workers – representing 71% of the global workforce – are regularly exposed to excessive heat, a condition exacerbated by climate change and insufficient workplace protections.

The International Labour Organization (ILO) highlights the escalating economic and human costs of heat stress, projecting that global economic losses due to this issue will soar from approximately $280 billion in 1995 to

an alarming $2.4 trillion by 2030 (ILO, 2019). This surge disproportionately affects lower-income countries too, where vulnerabilities are higher due to limited resources for adaptation and mitigation (ILO, 2024). In addition to the economic toll, the ILO estimates that at least 2.41 billion workers – representing 71% of the global workforce – are regularly exposed to excessive heat, a condition exacerbated by climate change and insufficient workplace protections. This widespread exposure contributes to an estimated 22.85 million work-related injuries and 18,970 fatalities annually (ILO, 2024a), underscoring the urgent need for adaptive labour policies, enhanced workplace safety standards, and global investment in climate-resilient infrastructure.

This projection made by different international organisms and for this report underscore the urgent need to explore diverse demographic and climate scenarios to plan effectively for large-scale adaptation and displacement, ensuring that populations remain within viable climate niches. It is crucial that strategies to address these challenges – whether through localized adaptation measures or the relocation of large populations to regions with more sustainable climatic conditions – are designed and implemented in a manner that is humane, equitable and inclusive.

Such efforts must focus on minimizing long-term socioeconomic disruptions, safeguarding human rights and preventing environmental degradation in both the areas of origin and the destinations. Achieving these goals demands integrated, forward-thinking approaches that not only address immediate needs but also align with broader sustainable development goals. Building resilience, fostering community participation and ensuring equitable resource allocation will be essential to guarantee that no one is left behind in the transition to a rapidly evolving climate landscape.

I.2 The amplifying effect of climate change on global inequality

Multiple communities, socioeconomically vulnerable and lacking the necessary infrastructure to cope with extreme hydrometeorological events and gradual climate changes, are inadvertently facing a new climate normal. These communities, already burdened by economic and social challenges, are encountering increased risks and uncertainties due to climate change. They are ill-equipped to adapt to the shifting environmental conditions and lack adequate resources and support. As a result, their futures are overshadowed by unpredictable and potentially devastating climatic developments. Addressing these vulnerabilities is crucial to ensuring that these communities build resilience and secure a more stable and sustainable future.

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Multiple communities, socioeconomically vulnerable and lacking the necessary infrastructure to cope with extreme hydrometeorological events and gradual climate changes, are inadvertently facing a new climate normal… Addressing these vulnerabilities is crucial to ensuring that these communities build resilience and secure a more stable and sustainable future.

The IPCC has identified several groups that face significant disparities in development both within their countries and globally, making them particularly vulnerable to the impacts of climate change due to factors such as their geographic location, socioeconomic and ethnic conditions, or increased exposure to extreme weather events. Many of these groups reside in rural regions, underserved suburban areas, or urban neighbourhoods with insufficient infrastructure, especially in critical sectors such as sanitation and healthcare; some others are often marginalized and face considerable challenges, making them more likely to experience severe consequences as climate change progresses. The vulnerability of these groups to climate change not only increases their risk of being forced to adapt their lifestyles but may also drive them to migrate in search of safer environments. The following list, illustrated geographically with critical cases listed by the IPCC in **figure I.5**, exemplifies the diverse range of communities, groups of people and populations that are most at risk:

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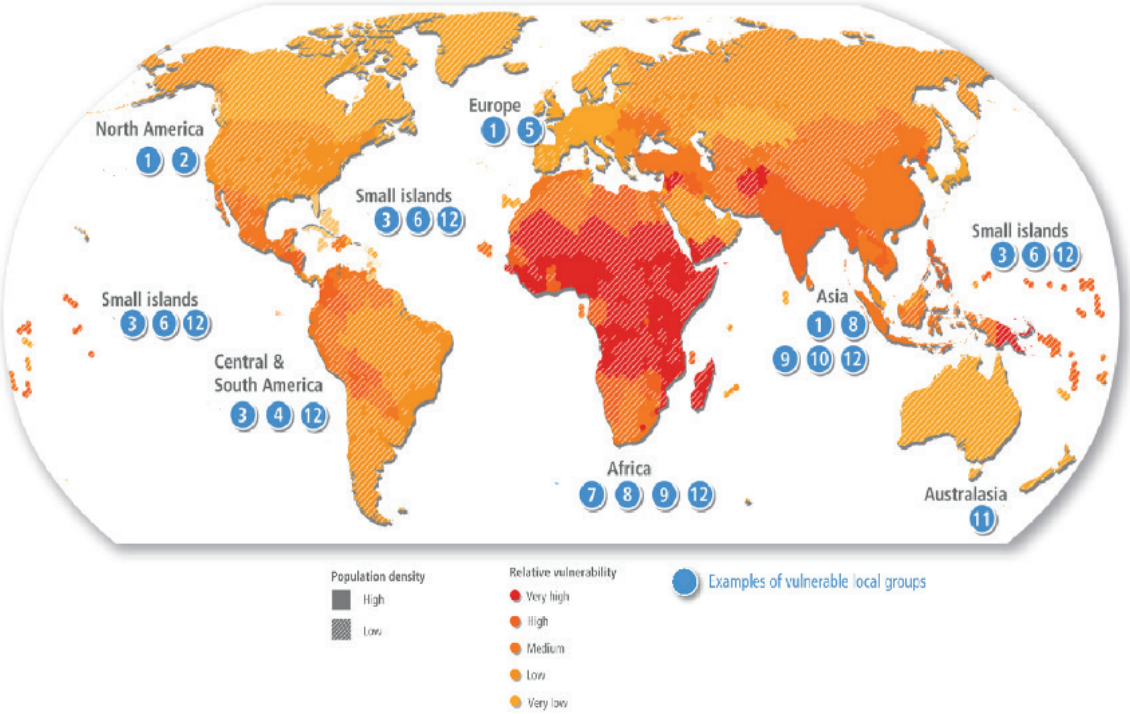
- **Island communities** who are facing the dual threat of losing both their homes and cultural heritage because of rising sea levels (see box I.4).
- **Migrants, refugees and displaced individuals**, who are particularly vulnerable due to their transient status and limited access to social and international safety nets. Often, they move within or from regions where climate change exacerbates existing challenges, such as resource scarcity and political instability, further compounding their hardships.
- **Indigenous Peoples**, whose traditional way of life is threatened by the rapidly changing environment. Climate change, pollution, illegal mining and deforestation disrupt their ancestral lands, cultural practices and livelihoods, undermining their deep connection to nature and their ability to sustain their communities.
- **Women, non-binary individuals or LGTB+ individuals**, who often bear disproportionate burdens in climate-affected regions, exacerbated by existing gender inequalities and social marginalization. These groups are frequently more vulnerable to the impacts of climate change due to limited access to resources, decision-making processes and support systems, further amplifying the challenges they face.
- **Urban ethnic minorities**, often residing in areas with poor infrastructure, which leaves them more exposed to economic instability and extreme weather conditions or natural disasters.
- **Older people**, especially those with low incomes and experiencing social isolation, are particularly vulnerable to the health impacts of extreme temperatures. Limited access to cooling systems, healthcare and social support networks further exacerbates their susceptibility, putting them at greater risk during heatwaves and cold spells.
- **Children in rural low-income areas**, who are facing compounded challenges due to limited access to education and healthcare, which intensify the impacts of climate change on their growth and development.
- **Populations living in informal settlements**, where inadequate housing and lack of infrastructure leave them highly exposed to climate risks.
- **Smallholder producers**, with low access to advanced technologies, whose livelihoods are endangered by shifting climate patterns affecting crop yields (see box II.4).

Through our exploration of data and studies on the climatic and risk conditions faced by vulnerable groups worldwide, we found that systemic, globally compiled information is available for very few of them. While extensive studies exist for the first four groups – small island nations, migrants, Indigenous Peoples, and gender – and these issues are integrally addressed within the UNFCCC and the Paris Agreement (2015), the remaining groups lack comprehensive data. For these, the available information is often scarce, localized and challenging to generalize. To bridge this gap, this report proposes the development of a social vulnerability index grounded in statistically reliable data (see box I.2), providing a more systematic and robust framework for addressing this critical and escalating challenge in climate policy.

Figure I.5. Relative vulnerability to climate change and population density



Source: IPCC, 2022. AR6, WGII. Examples: 1. Indigenous Peoples of the Arctic. 2. Urban ethnic minorities. 3. Smallholder coffee producers. 4. Indigenous Peoples in the Amazon. 5. Older people. 6. Island communities. 7. Children in rural low-income areas. 8. People displaced by conflict in regions such as the Near East and Sahel. 9. Women, non-binary individuals or LGTB+ individuals. 10. Migrants and refugees. 11. Aboriginal and Torres Strait Islander Peoples. 12. Populations living in informal settlements. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

The **social vulnerability index** assessing vulnerability to future physical climate impacts was developed to assess countries' overall vulnerability, highlighting the unequal and differential conditions that shape their susceptibility to the effects of global warming at a national level. These physical impacts are measured through the **climate change exposure index** presented earlier in the report. The index measures social vulnerability through five categories: wealth, health, gender, rurality and age dependency. The IPCC defines vulnerability as "The propensity or predisposition to be adversely affected […], including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC 2022a). It is a complex concept constantly evolving and has different factors across individuals, communities, and societies; some of the most relevant are wealth, social status, gender, age, and disability (Otto et al., 2017).

The dimensions of the social vulnerability index on a global, country-wide scale are interpreted as follows:

1. **Health**: Climate impacts exacerbate existing health conditions, acting as comorbidities for other illnesses.
2. **Wealth**: More affluent individuals typically possess greater resources to recover and adapt after climate-related impacts.
3. **Gender**: Women disproportionately bear the brunt of climate impacts due to existing social and economic inequalities.
4. **Rurality**: Rural areas are often underserved by emergency response and essential services, increasing their vulnerability.
5. **Age dependency**: Younger and older individuals are more dependent on their caregivers, whose well-being directly affects their resilience.

A value of 10 on the social vulnerability index indicates that the country is among the most vulnerable to physical climate risks projected to occur between 2040 and 2060 (see **box I.2** for sources).

The most vulnerable countries to climate impacts are overwhelmingly concentrated in Africa, with Chad, South Sudan, Niger, the Central African Republic, and Somalia leading the list. These nations are among the most at risk globally and represent the top vulnerable countries among LDCs and LLDCs, underscoring these regions' deep-rooted challenges. While not landlocked, Somalia still ranks one of the most vulnerable due to its severe socioeconomic challenges.

The results of the **social vulnerability index** calculation, shown in **figure I.6**, reveal that Guinea-Bissau, Comoros, Timor-Leste, Papua New Guinea, and Vanuatu, part of the Small Island Developing States (SIDS), are among the most vulnerable countries globally. These nations face elevated risks stemming from their distinct geographical and economic challenges, with pronounced vulnerabilities in areas such as health, wealth, and rural infrastructure.

Box I.2. Social vulnerability index assessing vulnerability to physical climate impacts

This index assesses individuals' vulnerability to the extreme weather events included in the climate change exposure index. It consists of five categories, each ranked by percentile:

1. **Health**: Evaluated by life expectancy at birth (UNDP, 2024).
2. **Wealth**: Measured by the human development index (HDI) wealth component (log GNI per capita in terms of [purchasing-power parity] PPP) (UNDP, 2024).
3. **Gender:** Measured by the Gender Development Index (GDI) (UNDP, 2024).
4. **Rurality**: Percentage of the rural population. Built from data reported by the UNESCO Institute for Statistics (UIS) (UIS, 2024).
5. **Age dependency**: Percentage of the population under 15 or over 65 years old. Constructed with data from the World Bank Group's Population Database (WBG, 2024).

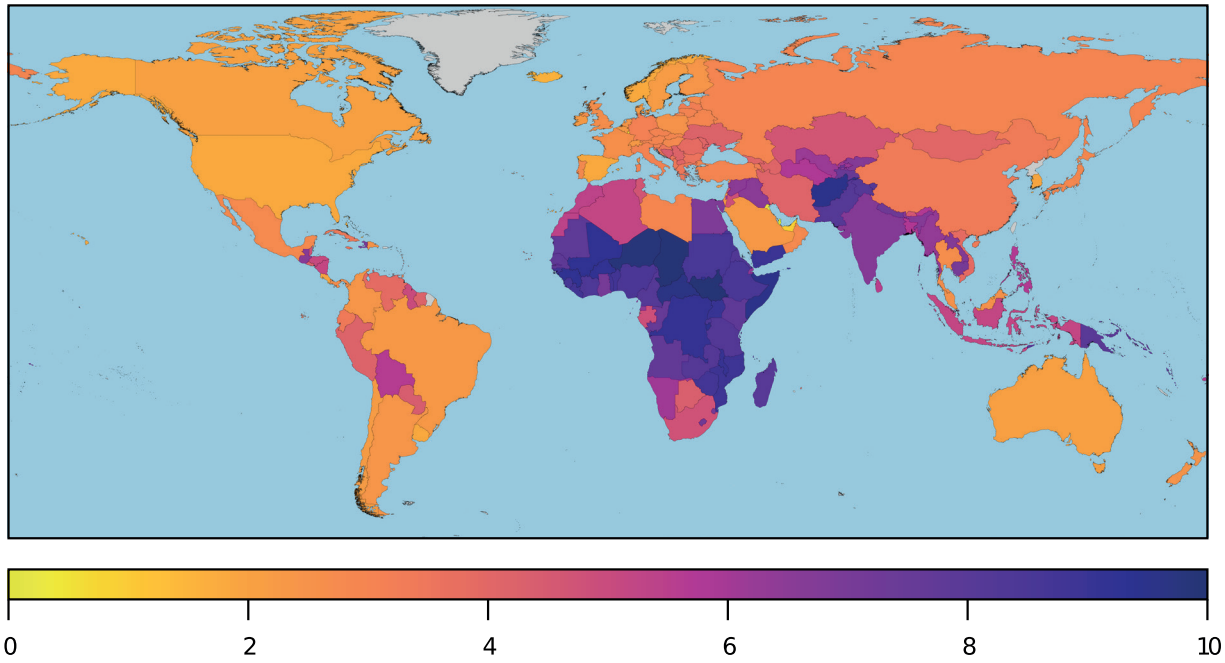
The scores for these five categories are averaged and the result is normalized to assign a value ranging from 0 (for the least vulnerable country) to 10 (for the most vulnerable country).

Regionally, Africa is the most vulnerable continent across all categories, followed by Oceania. This trend holds for every vulnerability category, with Oceania being the second most vulnerable in most categories, except for gender, where Asia takes the second spot. The vulnerability of SIDS is particularly pronounced in health, wealth and rurality, while LDCs and LLDCs consistently show greater-than-average vulnerability across all categories.

The narrative in **figure I.6** is clear: LDCs and LLDCs are disproportionately impacted by climate change, with their vulnerability far exceeding global averages. The overlap between LDCs and LLDCs among the most vulnerable countries highlights the compounded risks faced by nations with economic and geographic disadvantages. Meanwhile, SIDS, though differing in their specific challenges, also show significant vulnerability, particularly in areas critical to human well-being and economic stability. Several of the most vulnerable countries are also the most exposed to climate impacts, highlighting the role of climate as a threat multiplier.

Regionally, Africa is the most vulnerable continent across all categories, followed by Oceania. Regionally, Africa is the most vulnerable continent across all categories, followed by Oceania.

Figure I.6. Social vulnerability index assessing vulnerability to physical climate impacts 2040-2060



Source: Authors' own elaboration based on data from UNDP, UNESCO, and the World Bank Group. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

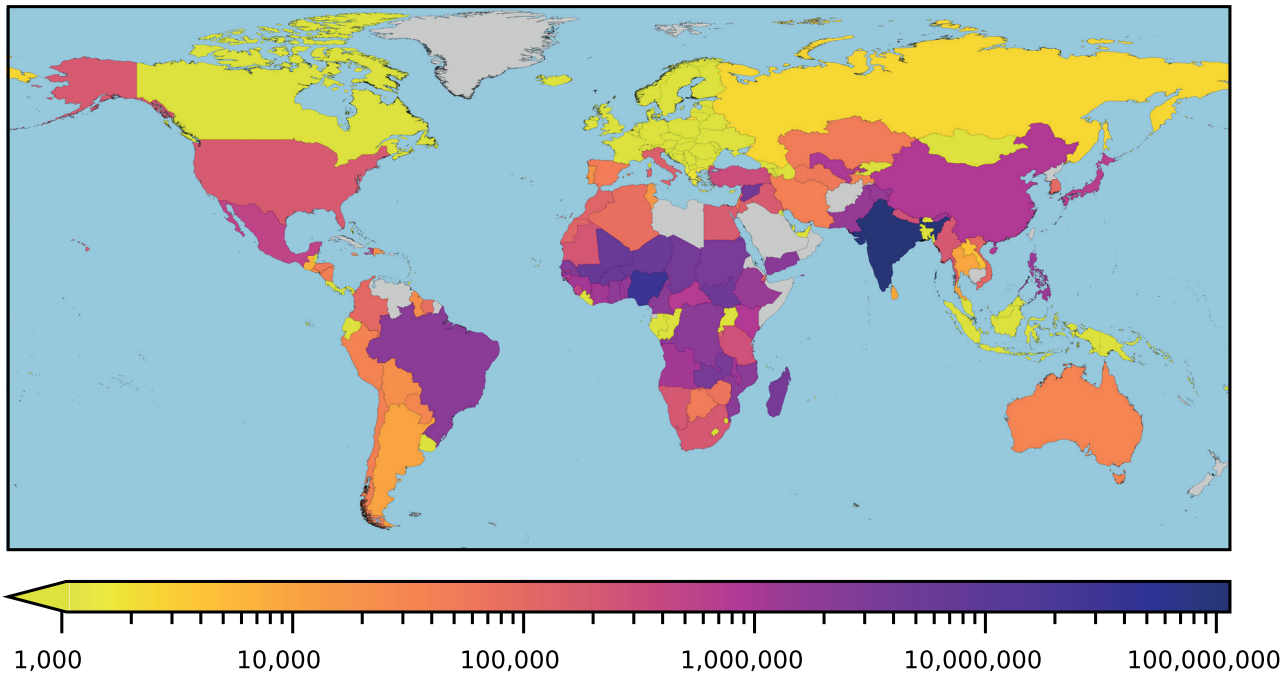
However, while **figure I.3**. shows that countries in central and southern Africa are less exposed than those located along the Sahara and the Sahel, **figure I.6**. reveals that almost all of them are highly vulnerable and will face similar changes in the quest for a climate transition. Another region equally burdened by both climate exposure and social vulnerability is Southern Asia, especially India and Pakistan. Sub-Saharan Africa and Southern Asia are among the most populated, rural, fastest growing and poorest regions in the world, where a vast number of children will be affected and climate change will only add to existing challenges to development.

Climate change is significantly worsening the plight of those already living in extreme poverty. More than 239 million people subsisting on less than $1.90 per day, as defined by the World Bank Group, are disproportionately affected by the increasing frequency and severity of extreme heat (see **figure I.7** and **table I.2**). These people live in regions that are increasingly experiencing very long warm spells (lasting more than 12 weeks) of days with a mean temperature above 35°C, according to the analysis elucidated by the **climate change exposure index** (see **figure I.2**). Torrential rains, soaring temperatures, prolonged droughts and powerful hurricanes are disrupting livelihoods, destroying homes and exacerbating food and water scarcity, further entrenching their struggles.

More than 239 million people subsisting on less than $1.90 per day, as defined by the World Bank Group, are disproportionately affected by the increasing frequency and severity of extreme heat.

The impact is especially severe in regions of Asia and Africa, where two-thirds of those 239 million people reside. These regions are characterized by limited economic development and weak infrastructure, making it difficult to respond effectively to natural disasters and to build resilience against future climate shocks. In these areas, the interplay of poverty and climate change creates a vicious cycle: poverty limits the capacity to adapt to climate change and climate change further entrenches poverty by devastating the few resources available to these vulnerable populations (IZA, 2024). For instance, in India's Andhra Pradesh state, droughts have led to a significant rise in poverty, affecting nearly 44% of the population over a 25-year period. Similarly, in Peru, the occurrence of just one additional climate-related disaster per year has been linked to a 16-23% increase in poverty rates (Hallegatte et al, 2020).

Figure I.7. Population living in extreme poverty and exposed to climate change 2040-2060



Source: Author's own elaboration based on data from Figure I.1. and Box I.1. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Table I.2. Population living in extreme poverty affected by diverse climate risks 2040-2060 (millions and percentage of population)

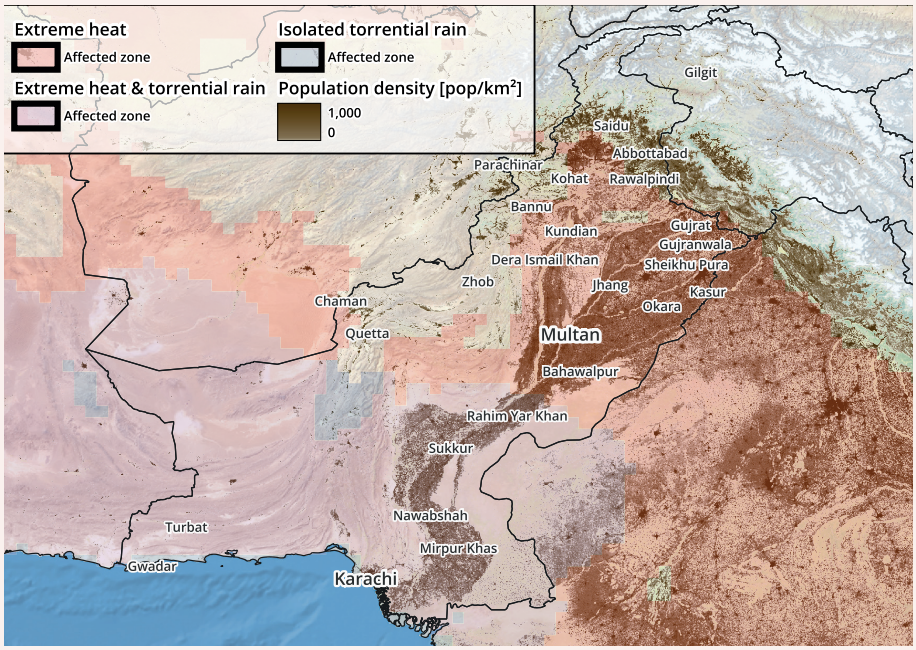
Continents or group of countries	Extreme climate		Extreme rainfall		Extreme heat		Drought		Strong hurricanes	
Asia	132.6	1.5%	3.2	0.05%	131.6	1%	5.3	0.4%	3.0	0.1%
Europe	0.2	0.01%	0.0	0%	0	0%	0.2	0.01%	0	0%
Africa	102.3	13%	2.8	0.03%	90.8	11%	13.2	1.5%	4.0	0.4%
Oceania	0.03	0.01%	0	0%	0	0%	0.03	0.01%	0	0%
Americas	4.0	1%	0.04	0%	1.8	0.1%	1.5	0.7%	1.0	0.2%
SIDS	1.4	2.3%	0	0%	0.8	1.5%	0.3	0.6%	0.5	0.2%
LDC	56.9	14.3%	1.8	0.07%	47.6	12.5%	10.1	1.6%	0.5	0.1%
LLDC	37.5	10.8%	0.1	0%	32.4	9.3%	5.3	1.5%	0	0%
World	**239.1**	**4.1%**	**6.1**	**0.02%**	**224.3**	**3.3%**	**324.3**	**0.7%**	**652**	**0.2%**

Source: Authors' own elaboration, see sources in Figure I.1 and Box I.1
SIDS: small island developing States, LDC: least developed countries, LLDC: landlocked developing countries. The numbers for the world are the sum of the values of Asia, Africa, the Americas, Europe and Oceania.

Box I.3. Flooding in Pakistan: a humanitarian disaster

Climate change has intensified flooding at the same time as heatwaves. This is a significant challenge for climate change adaptation since it impacts people unequally based on their level of wealth or poverty. In Pakistan, where 44% of the population is below the poverty line, the impacts of the torrential rains of 2023 reached unprecedented humanitarian proportions on a scale of devastation never seen before. In October, one-third of Pakistan was affected by the worst floods, with widespread destruction affecting 33 million of the country's 234 million inhabitants and displacing 8 million people. The victims, mainly from Baluchistan and Sindh provinces, lived on the banks of the Indus River. Sindh province was the most affected, with around 70% of the total damage and losses. There was also damage in the northern regions of Khyber Pakhtunkhwa and Punjab.

Pakistan projected exposure to extreme weather events 2040-2060



Source: Authors' own elaboration based on WorldPop (2018) and sources from Figure I.1 and Box I.1. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Women and men affected by the floods are in a situation of high multidimensional poverty and minimal access to resources to adapt and recover. Pakistan contributes less than 1% of the world's CO_2 emissions but is among the five countries most vulnerable to climate change. "We are poor. Our house was destroyed by the floods," said Qari Saeed, echoing the sentiment of many in his village in Dera Ismail Khan, in northwest Pakistan. They fear being trapped in a cycle of vulnerability. Although some have been able to rebuild, many are worried about having to repeatedly rebuild their homes only to see them washed away again by floods.

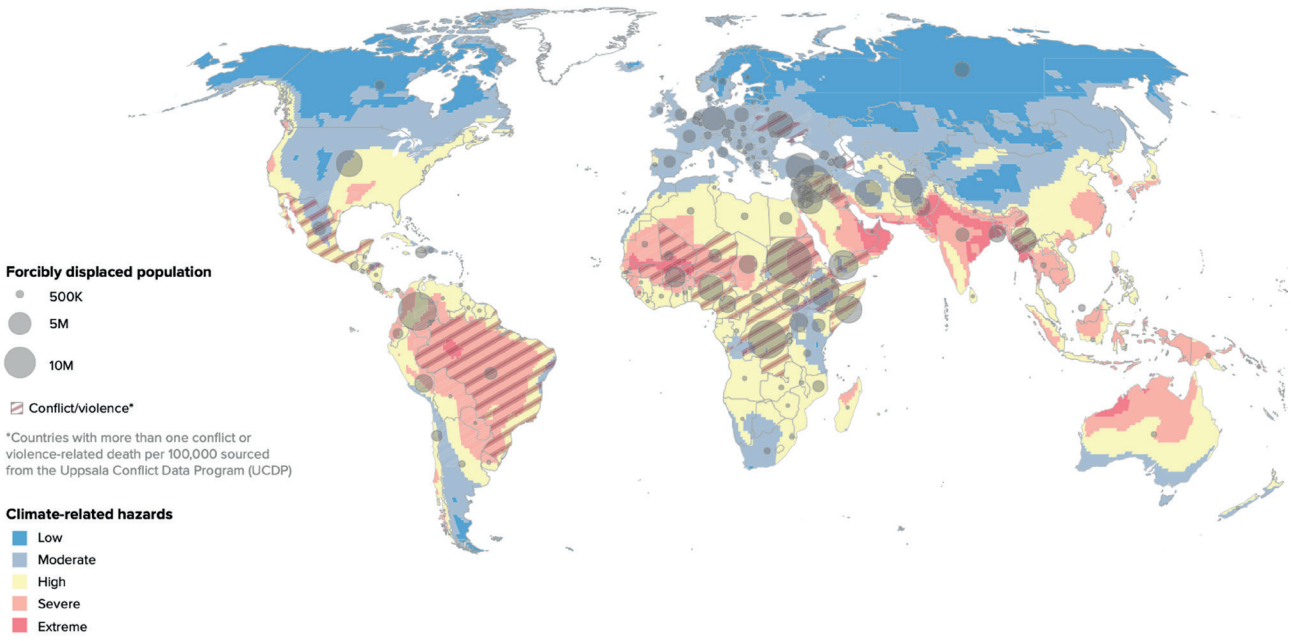
Unfortunately, the people of Pakistan are not only affected by torrential rains. In June 2022 and 2023, they faced heatwaves with maximum temperatures of almost 49°C in the western provinces of Baluchistan, Punjab and Khyber. High temperatures have also contributed to the melting of glaciers.

The increase in torrential rains and extreme heat affects the population differently depending on their income level. In Pakistan, the impact of these events has affected low-income women and men the most, who are limited in adapting due to their income level.

"As a father of eight, it's my duty to provide for my family, but I find myself powerless in the wake of these floods. If another flood comes next year, all our hard work to rebuild will go to waste",

Ali Bux said as he watches his once fertile land crumbling.
(Akbar, 2023).

Figure I.8. Climate-related hazards, conflict-related deaths 2022, and forcibly displaced population 2023



Source: UNHCR, 2024a. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

I.3 Forced displacements, an unrecognized climate consequence

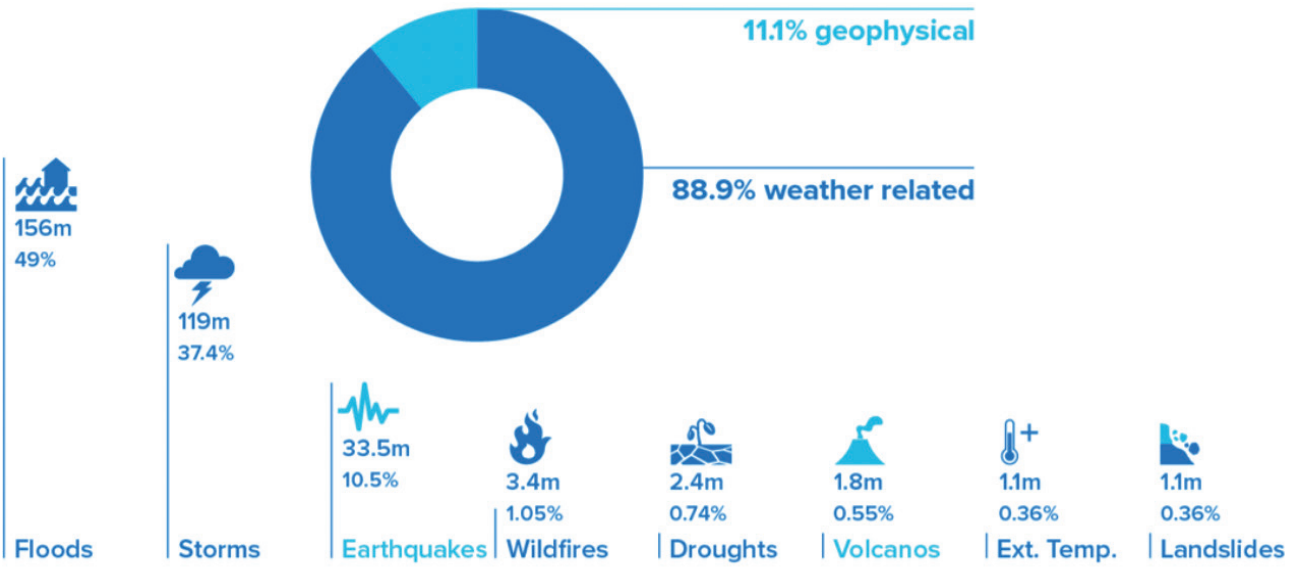
Climate change is increasingly jeopardizing livelihoods, forcing people to migrate as their home environments become risky or uninhabitable. The escalating frequency and severity of climate-related disasters, such as floods, hurricanes, droughts and rising sea levels, exacerbate vulnerabilities, particularly in fragile regions. As the Office of the United Nations High Commissioner for Refugees (UNHCR) underscores, "displacement linked to climate change is not a future hypothetical – it's a current reality" (UNHCR, 2016). Today, one in every 67 people worldwide is forcibly displaced, highlighting an unprecedented global crisis (UNHCR, 2024a). While conflict remains the predominant driver of cross-border displacement, the escalating impacts of climate change act as a significant threat multiplier. Rising sea levels, prolonged droughts, extreme weather events and resource scarcity not only jeopardize livelihoods but also intensify competition for limited resources, escalating tensions within and between communities. These pressures can erode social cohesion, destabilize already fragile regions and amplify the risk of conflict. Addressing this complex interplay between climate change and displacement requires coordinated global action that integrates climate resilience, conflict prevention and sustainable development strategies (UNHCR, 2024a).

Climate change is increasingly jeopardizing livelihoods, forcing people to migrate as their home environments become risky or uninhabitable.

In its latest report presented at the COP29 in Baku (UNHCR, 2024a), UNHCR estimates that, over the past decade, nearly 60,000 people per day were forcibly displaced globally due to weather-related disasters (see **figure I.8**). Alarmingly, approximately 65% of those individuals residing in areas highly to extremely vulnerable to climate-related hazards were living in countries where they continued to face significant exposure to ongoing conflict, underscoring the complex interplay between climate risks and insecurity (UNHCR, 2024).These numbers are expected to rise as climate impacts intensify, disproportionately affecting marginalized and impoverished communities who are least equipped to adapt (see **box I.3**).

The term "climate refugee" was first introduced and developed by the United Nations Environment Programme (UNEP) in 1985, through the work of researcher Essam El-Hinnawi. He defined environmental refugees as "those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption". However, this definition lacks clarity in distinguishing climate change-induced displacement from other forms of migration.

Figure I.9. Disaster displacement and breakdown by climate-related hazards, 2008-2020



Source: IDCM, 2021

This ambiguity has led to significant criticism, particularly concerning the definition's utility in the framework of international law. This definition broadness fails to clearly outline what constitutes a climate change effect. It does not specify whether the disruption must be sudden or gradual, whether displacement must occur due to uninhabitable conditions, or if voluntary migration in response to changing climate conditions falls under this category – even when the individuals involved are not in immediate danger. Furthermore, critical aspects such as whether the displacement must be within national borders or across them are omitted, adding to the challenges in formulating a globally recognized legal definition for this emerging category of displaced populations.

Beyond the ambiguities inherent in such a definition, it is essential to consider the widespread misconceptions regarding climate change and its impact on displacement. These misconceptions exacerbate the vulnerability of affected communities and hinder the development of effective policies and responses. The Internal Displacement Monitoring Centre (IDMC) highlights that contrary to popular belief, most disaster-induced displacement becomes protracted rather than short-term. Additionally, the role of climate change in triggering disasters is often oversimplified, leading to the erroneous belief that all weather-related disasters are direct consequences of climate change. For example, as illustrated in **figure I.9**., weather-related disasters – such as floods, storms and droughts – constitute 88.9% of the hazards leading to displacement, typically over prolonged periods. In contrast, geophysical hazards, often not directly linked to climate change, account for only 11.1% of such events. These nuances are crucial for developing a more accurate understanding of climate change-related displacement and creating targeted effective responses.

Under international law, the term "climate refugee" is not recognized, resulting in the absence of legal recognition for these individuals in the global legal framework. Consequently, communities displaced by climate change are left without the legal protections that would typically safeguard their human rights in other situations. The 1951 Convention relating to the Status of Refugees defines a refugee as "someone who is unable or unwilling to return to their country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion". According to this definition, those displaced by climate change do not qualify for protection under the convention, as environmental hazards do not constitute persecution. As a result, the human rights of these communities are severely endangered, leaving them increasingly vulnerable.

Weather-related disasters – such as floods, storms and droughts – constitute 88.9% of the hazards leading to displacement, typically over prolonged periods.

The consequences of climate-induced displacement are far-reaching (Ampudia S., 2024). Beyond the immediate loss of homes and livelihoods, displaced populations often face long-term challenges, including limited access to resources, social services and opportunities in their new locations. This displacement can strain urban infrastructure, lead to social tensions and exacerbate existing inequalities. Moreover, the lack of international legal frameworks specifically addressing climate refugees leaves many of these individuals in a precarious situation, often without the protections afforded to traditional refugees.

Under international law, the term "climate refugee" is not recognized.

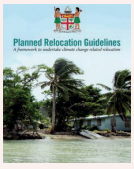
Addressing this critical issue demands urgent and coordinated global action, as forcibly displaced individuals are increasingly left with nowhere safe to turn. The devastating impacts of climate change not only destroy their homelands but also jeopardize the safety and viability of potential destinations (UNHCR, 2024a). Mitigation efforts must be coupled with adaptive strategies to reduce the risk of displacement, including investing in resilient infrastructure, sustainable agriculture, and disaster preparedness in vulnerable regions. Furthermore, the international community must work towards recognizing and protecting the rights of climate-displaced persons, ensuring they receive the support and resources necessary to rebuild their lives. As climate change continues to unfold, we must address the environmental and human dimensions of this global crisis.

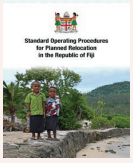
Box I.4. Fiji's first internal migration processes supported

The effects of climate change are apparent to most Fijians. Rising sea levels continue to erode coastlines and encroach on coastal communities. Tropical Cyclone Winston, the worst in Fiji's history, struck in 2016 with unprecedented force, causing damage to a third of Fiji's gross domestic product. Nearly 15% of the country's population was left homeless, 44 people died, and food insecurity was rife.

Against this backdrop, authorities launched an ambitious adaptive relocation strategy to bring the most affected communities to safety. While this is not the only relocation case worldwide, it is the first to have a clear and explicit strategy. The Planned Relocation Guidelines (Ministry of Economy of the Republic of Fiji, 2018) are the first step in the strategy to adapt Fiji to climate challenges, including the possibility of planned relocation as a last resort option. What is novel about the approach is that it assumes that the impacts of climate change are differentiated across the population, affecting men, women and children differently.

The second step in this strategy is the Standard Operating Procedures (SOP) for planned relocation in the Republic of Fiji. This constantly updated instrument establishes a structure and detailed processes to ensure compliance with the principles for planned relocation defined in the PRG and in the provisions of section 77 of Fiji's Climate Change Act 2021 related to the relocation of communities at risk.





"I think our contribution to the effects of climate change is about a drop in the ocean."
Alani Tuivucilevu, Fiji's Women in Fisheries Network

"As he pushed through knee-deep water, (…) he pointed to the stub of a post barely visible in the seabed. This was my house."
Sailosi Ramatu, Fijian

"The procedures are clear and provide guidelines to navigating the sensitivities of tenure-ship, equal participation in decision-making, community trauma because of impacts of disaster and safety in its fullest sense."
Vani Catanasiga, Fiji Council of Social Services (FCOSS) Executive Director

I.4 Toward fair and just climate policies: the need for multidimensional gender approaches

Addressing gender issues in climate policies requires a multifaceted approach beyond mere acknowledgement of the problem. It demands the systematic collection and analysis of gender-disaggregated data to fully understand climate change's distinct and disproportionate impacts on women, men and gender-diverse individuals. This data is essential for informing policies that are genuinely responsive to the needs of all gender identities. An early inclusion of a gender perspective in policies, backed up by statistical data and analysis, will help identify differentiated impacts and challenges to gender identities and support holistic policies for all. The latest synthesis report from the United Nations Climate Change Secretariat to the COP29 in Baku highlights that 85% of Parties have incorporated gender considerations into their recent reports and communications submitted to the UNFCCC; this includes references in their NDC, national adaptation plans (NAP), and long-term low greenhouse gas emission development strategies (LT-LEDS) (FCCC/CP/2024/5).

To effectively integrate gender considerations into climate action, it is essential to establish a clear and robust legal framework grounded in the targets of the SDGs and international climate commitments. This framework should aim to challenge and transform traditional gender norms, particularly in areas such as economic activities, decision-making and leadership (UNEP et al. 2020). Such a framework should mandate the inclusion of gender perspectives in all stages of climate policy development, from planning and implementation to monitoring and evaluation. This legal foundation must be complemented by cross-sectoral policies that promote gender equity in critical areas such as energy access, agricultural practices, healthcare and disaster risk management. For example, policies that support women's leadership in renewable energy projects or that provide targeted support for female farmers adapting to changing climate conditions are critical to achieving gender-equitable outcomes.

The interconnectedness of gender, climate change and security is particularly significant and cannot be overlooked. Addressing challenges such as forced displacement, water scarcity and natural disasters necessitates the integration of a comprehensive gender perspective. Such an approach is crucial not only to mitigate conflicts but also to promote peace and ensure the resilience and stability of communities enduring the profound impacts of climate stress (UNEP et al., 2020).

Approximately **1.4 billion women in vulnerable age groups** will be impacted by climate conditions and extreme weather events between 2040 and 2060.

Women in impoverished regions often represent up to 70% of the population and play critical leadership roles as heads of households (UNESCO, 2022), particularly in the absence of men who have migrated for economic reasons. According to FAO, heat stress intensifies income disparities between female-headed and male-headed households, widening the gap by $37 billion annually, with floods adding another $16 billion each year. Moreover, a 1°C rise in long-term average temperatures is associated with a 34% decline in the total incomes of female-headed households relative to male-headed ones, highlighting the heightened economic vulnerability of women to climate impacts (FAO, 2024b). These challenges are further exacerbated by the impacts of other natural disasters, violence and forced migration. Considering this, we estimated the number of women in vulnerable age groups who could be affected by the shifting climate realities expected in the first half of this century, emphasizing the need for targeted interventions to address these compounded risks.

Table I.3. Female population affected by extreme climate (millions) 2040-2060

Continents, group of countries or countries	Total (millions)	% Global female population	0-12 months old (millions)	0-5 years old (millions)	Over 65 years old (millions)
Asia	1,028.4	46.6	17.1	84.5	96.8
Europe	15.1	2.2	0.1	0.6	3.5
Africa	272.2	39.2	8.1	39.8	11.0
Oceania	4.7	22.8	0.1	0.3	0.8
Americas	114.4	52.9	1.8	8.9	11.9
SIDS	20.3	50.9	0.3	1.5	2.4
LDC	143.2	34.8	4.4	21.1	5.0
LLDC	77.0	24.2	2.5	11.9	2.3
India	461.8	68.2	8.5	40.9	32.5
China	161.8	23.0	1.5	8.0	19.1
Pakistan	95.5	85.5	2.3	11.8	4.7
Japan	64.0	96.2	0.5	2.5	19.9
Nigeria	54.6	51.4	2.1	10.0	1.6
Egypt	43.0	92.0	0.9	5.1	2.3
World	**1,434.8**	**34.4**	**27.1**	**134.2**	**124.0**

Source: Authors' own elaboration based on several sources

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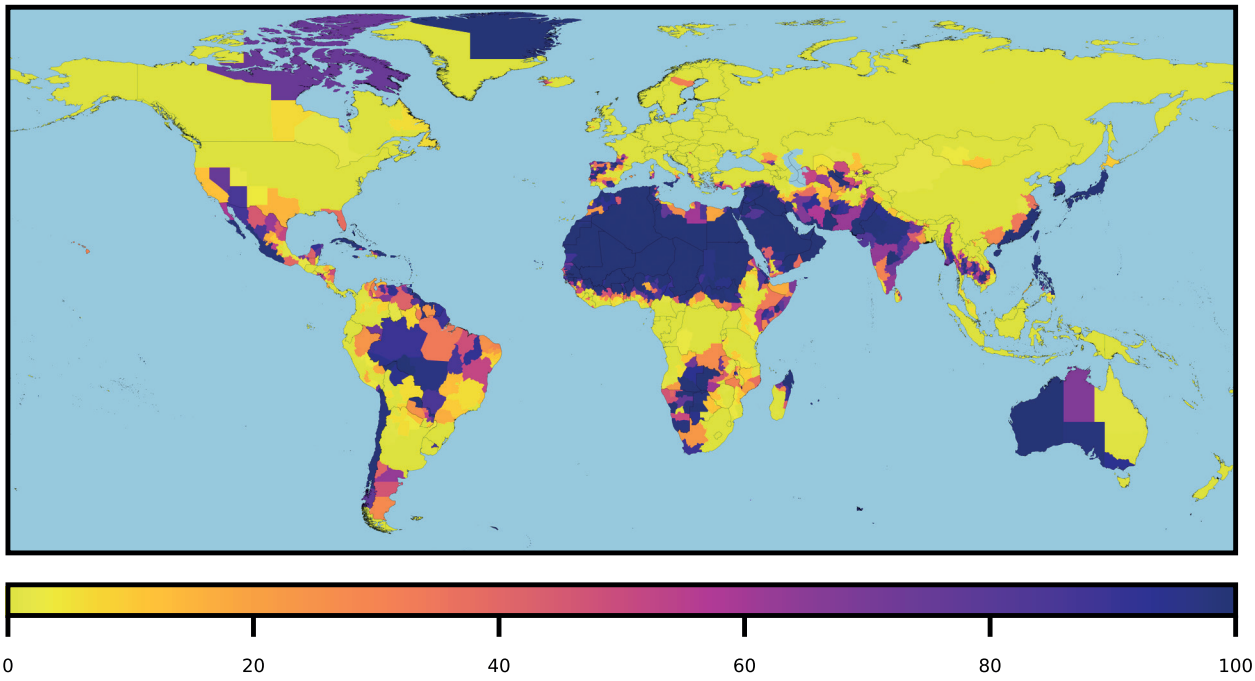
We estimate that approximately **1.4 billion women in vulnerable age groups** (see **table I.3**) will be impacted by climate conditions and extreme weather events between 2040 and 2060. This highly vulnerable female population is often under the care of an adult woman who leads the family (see **box 1.5**). She bears the critical responsibility of ensuring their safety, preserving their health and well-being, and safeguarding them from abuse and mistreatment, all while navigating challenging and adverse circumstances, due women's socially disadvantaged position (WBG, 2023). The success or failure of this endeavour could shape gender inequities for generations to come, either perpetuating or breaking the cycle.

Asia accounts for the vast majority of the affected female population, while Africa and the Americas also see significant numbers of women at risk. Countries across these three continents have a higher-than-average proportion of affected women. SIDS stand out, with an exceptionally high percentage of their female population affected. Notably, Africa is home to a disproportionately large number of young girls who will be particularly vulnerable to the impacts of climate change (see **figure I.10**).

Figure I.10. Females affected by extreme climate 2040-2060



Source: Authors' own elaboration based on several sources. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

To ensure that gender considerations are deeply integrated into climate action, it is crucial to establish a clear and robust legal framework.

The successful implementation of gender-responsive policies hinges on strong and sustained political commitment. Leaders at all levels – from local governments to international bodies – must actively champion gender-inclusive climate strategies. This includes allocating adequate resources for gender-specific programmes, building institutional capacities to address gender disparities and fostering collaboration between government agencies, civil society and the private sector. Raising public awareness and engaging communities in gender-sensitive climate action is vital to ensuring policies are adopted and effectively implemented to attain the SDGs, including climate targets of the Paris Agreement (2015) (OECD, 2021c).

The successful implementation of gender-responsive policies hinges on strong and sustained political commitment.

Without such comprehensive and committed efforts, initiatives to address gender disparities in the context of climate change are likely to fall short, thereby perpetuating and potentially exacerbating existing inequalities. It is only through a holistic and inclusive approach that the dual goals of gender equity and climate resilience can be fully realized, leading to a more just and sustainable future for all.

Box I.5. Gulf of Mexico: a droplet of water to adapt to challenges

As the impacts of climate change increasingly disrupt lives and livelihoods each year, vulnerable communities are proactively seeking strategies to enhance their resilience and adapt to evolving environmental challenges. In Mexico, the project "Adaptation to Climate Change Impacts on the Coastal Wetlands in the Gulf of Mexico", carried out between 2012 and 2018, stands out as a notable example. This initiative, which integrated a gender-sensitive approach, empowered local communities led by women to collaboratively analyse their adaptation needs in partnership with experts from various government agencies, fostering inclusive and informed decision-making (WBG, 2017).

This is the case of Las Coloradas, where mangrove reforestation was carried out, 5,600 chinampas and stilt houses were built, more than 20,000 plants were planted, and 3 km of lost canals were dredged. The word chinampa comes from the Nahuatl language and means "in the fence of reeds". It is an artificial cultivation system, built in areas where water is the main natural resource present in the environment. They are built in order to grow plants, vegetables and garden produce for self-consumption and the local market. The Wetlands Project, as the community colloquially calls it, is an adaptation strategy agreed upon with the communities "because otherwise it would have no impact". Adaptation has to be transformative, not assistance-based. This approach also included the creation of a social enterprise called Gotita de Agua (droplet of water), run by women dedicated to capturing rainwater for consumption and as an economic opportunity (WBG, 2017).

As part of the project in the Carmen-Pajonal-Machona lagoon system, stilt houses were built. In the absence of men who are working in the city or across the border, women take on the critical responsibility of protecting children and the elderly from floods, while also safeguarding their belongings, livestock and grains. To support them, it became essential to construct stilt houses, ensuring their homes remain safe and above water during flooding events. Stilt houses were equipped with solar panels, rainwater harvesting systems, biodigesters and elevated vegetable gardens. As part of the project, a tide and meteorological station was installed, connected to the Servicio Mareográfico Nacional (Mexican National Tidal Service) operated by the Institute of Geophysics of the National Autonomous University of Mexico (UNAM). This station allows early warnings to be given to the communities in the event of climatic or health emergencies (WBG, 2017).

Mexico's mangroves represent 6% of the world's total, which places it fourth in this ecosystem worldwide. Mangroves are well-known for their ability to mitigate the effects of climate change by capturing and storing organic carbon at rates three to five times higher than terrestrial forests (SEMARNAT, 2012). In addition to their role as carbon sinks, mangroves provide crucial protection for coasts and communities, shielding them from extreme, sudden climate events and the slower, more continuous impacts of environmental change. These ecosystems benefit their surroundings by absorbing CO_2, enhancing biodiversity, and protecting coastlines from erosion by acting as natural barriers. In addition to their ecological functions, mangroves provide valuable resources, such as firewood, and serve as essential fishing areas, supporting the livelihoods of local communities and contributing to the development of the regional economy. Furthermore, their restoration is a low-cost, high-return investment, making it a crucial and highly effective measure for environmental and economic sustainability.

In the Wetlands Project, adaptation measures were implemented using a triple approach: ecosystem-based adaptation (EBA), community-based adaptation (CBA), and risk reduction-based adaptation (RRBA). With these actions, it was possible to reduce the vulnerability of the community settled in the wetlands and increase the resilience of this ecosystem.

> "[Some] 25 to 30 years ago, I was one of those who deforested, and now I decided to work [reforesting the mangrove]. Why? To have it back as it was before." ,"…I come [to] teach how to make a chinampa…"
>
> Gustavo, resident of Las Coloradas

I.5 Climate change poses a dual threat to Indigenous Peoples and their ecosystems

There is sound evidence that the accelerated pace of climate change and the sweeping environmental transitions of the twenty-first-century place Indigenous Peoples, especially those who have preserved their way of life within the ecosystems where their cultures originally evolved, at significant risk (Reyes-García et al., 2024). These communities and their social-ecological systems, often residing in remote areas, have maintained a deep spiritual and practical relationship with their natural surroundings, which have sustained them for generations. However, the global nature of climate disruption – driven by factors largely beyond their control – poses unprecedented challenges.

For many Indigenous groups, their small population sizes, women disadvantages, and limited access to modern technological tools hinder their ability to adapt swiftly to shifting environmental conditions. Rising temperatures, unpredictable weather patterns and the degradation of ecosystems threaten the resources on which their cultural practices and survival depend. This vulnerability is compounded by political and economic marginalization, further weakening their ability to influence the global decisions reshaping their landscapes. Only 10% of the customary lands claimed by Indigenous Peoples globally have secured legal recognition, leaving their territories highly vulnerable to expropriation, environmental destruction and land grabbing. This precarious situation is further exacerbated by the growing demand for renewable energy development and the mining of transition minerals, often driven by States and private sector interests on Indigenous lands (Carling, 2024).

Even though these communities possess profound ecological knowledge honed over millennia of careful observation and interaction with their environments, this knowledge alone may not be sufficient to safeguard their future in the face of rapidly changing circumstances. Without adequate support, recognition of their rights and the integration of their traditional knowledge into broader climate adaptation strategies, including environmental issues, many Indigenous nations risk not only cultural erosion but existential collapse, losing their status as sovereign custodians of some of the world's most biodiverse regions (GCHRAGD, 2024). This unfolding crisis underscores the urgent need for more inclusive global climate policies that honour Indigenous contributions and ensure their resilience during global upheaval.

One of the most troubling challenges faced by Indigenous communities is the physical violence often perpetrated against their leaders and members when they stand up to defend their lands and ancestral rights. Climate and environmental justice remain elusive for many Indigenous

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Peoples, prompting the need for initiatives like the Escazú Agreement.[4] This landmark accord seeks to amplify their voices and safeguard their interests in the context of new infrastructure projects or investments in real estate, industrial and mining activities, or agroforestry development (ECLAC, 2022).

Only 10% of the customary lands claimed by Indigenous Peoples globally have secured legal recognition, leaving their territories highly vulnerable to expropriation, environmental destruction and land grabbing.

For the purposes of this report, leveraging global statistical data alongside our climate change exposure index and social vulnerability index, we estimate that over 505 million Indigenous People will face adverse climatic conditions with high or very high levels of vulnerability (see **table I.4**)

4 The Escazú Agreement, which came into force on 22 April 2021, is the first regional treaty in Latin America and the Caribbean focused on environmental and human rights and the first globally to include provisions for protecting environmental defenders. It ensures access to environmental information and participation in decision-making, and mandates States to prevent and investigate attacks on environmental defenders. However, key countries like Brazil and Colombia have yet to ratify the agreement, and others, such as Mexico, despite having ratified it, still face challenges in its effective implementation (ECLAC, 2022).

Table I.4. Indigenous Peoples' vulnerability to climate risks 2040-2060.

Continents, group of countries, countries	Indigenous population	Climate change exposure index	Social vulnerability index
Asia	393,246,705	Very exposed	Vulnerable
Europe	338,000	Exposed	Vulnerable
Africa	58,554,883	Exposed	Highly vulnerable
Oceania	1,657,100	Exposed	Very vulnerable
Americas	52,001,416	Very exposed	Vulnerable
SIDS	98,844	Exposed	Very vulnerable
LDC	53,527,296	Very exposed	Highly vulnerable
LLDC	43,242,703	Exposed	Very vulnerable
China	125,332,335	Highly exposed	Vulnerable
India	104,000,000	Very exposed	Very vulnerable
Indonesia	60,000,000	Exposed	Very vulnerable
Pakistan	35,000,000	Highly exposed	Highly vulnerable
Mexico	16,933,283	Exposed	Vulnerable
Ethiopia	16,500,000	Exposed	Highly vulnerable
World	**505,798,104**	**Very exposed**	**Vulnerable**

Source: Authors' own elaboration based on climate indices developed for this report

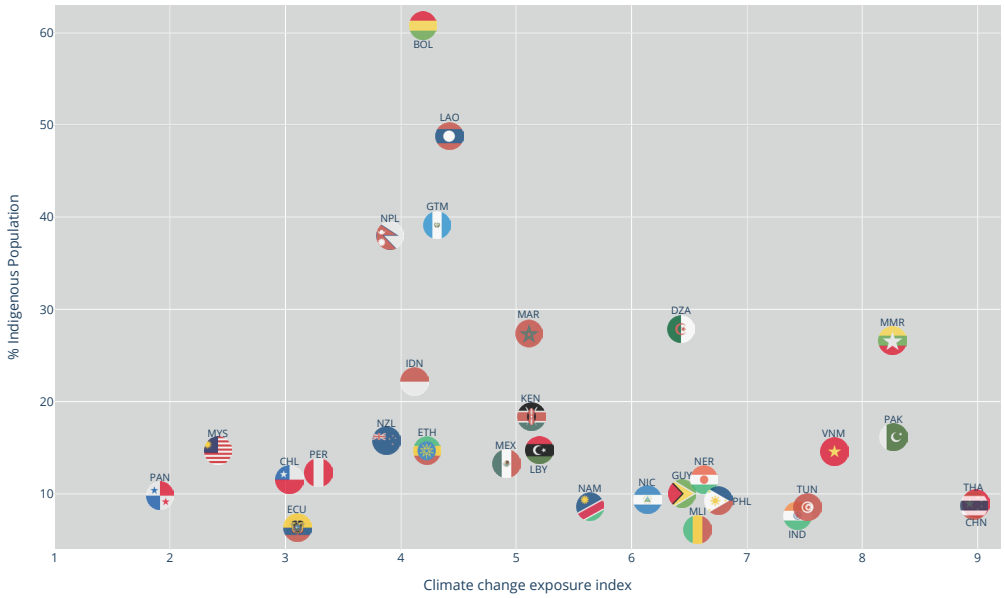
Among the nearly half a billion vulnerable Indigenous People worldwide, China has the largest Indigenous population, followed closely by India. Together, these two countries account for nearly half of the global Indigenous demographic and they are both significantly exposed to climate change risks. Asia hosts the highest concentration of vulnerable Indigenous communities, while Africa and the Americas each have over 50 million Indigenous people facing heightened climate-related dangers.

Overall, an estimated 197 million Indigenous People live in countries that are highly vulnerable to climate change.

Several countries have exceptionally high proportions of Indigenous residents that are exposed to extreme climate events or weather anomalies (see **figure I.11**). For instance, Morocco, Algeria and Myanmar each have over 25% of their populations identified as Indigenous, while Guatemala and Laos exceed 33%. Bolivia stands out, with more than 60% of its population identifying as Indigenous, reflecting the deep cultural and historical ties of its Indigenous communities. Other nations, including Tunisia, Vietnam, Pakistan, Myanmar, Thailand and China, have Indigenous populations making up over 5% of their citizens, and these countries are notably exposed to the impacts of climate change.

Overall, an estimated 197 million Indigenous people live in countries that are highly vulnerable to climate change. These countries include China, Pakistan, Myanmar, Vietnam, Thailand, Japan, Tunisia and Iraq. The disproportionate exposure of Indigenous communities in these regions to climate risks – such as extreme weather events, changing ecosystems and water scarcity – poses significant challenges, as Indigenous Peoples often rely heavily on natural resources and have limited access to adaptation and mitigation resources. Protecting these populations requires urgent, culturally sensitive climate action that respects Indigenous knowledge and strengthens their resilience in the face of environmental changes.

Figure I.11. Climate change exposure index of Indigenous People by country 2040-2060

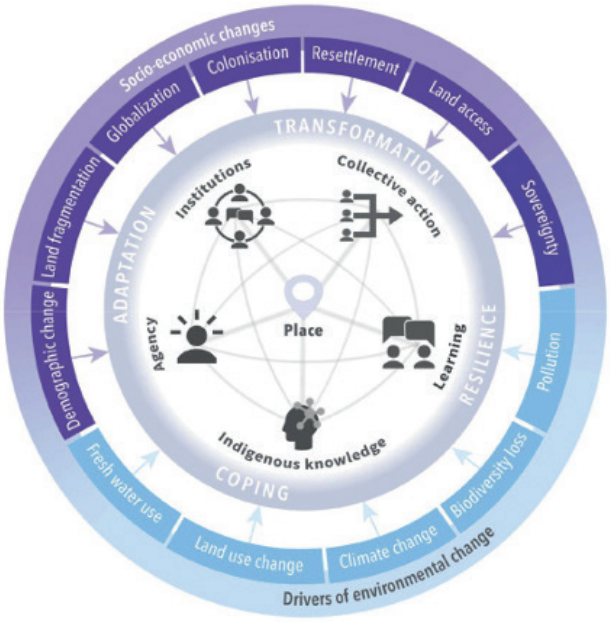


Source: Authors' own elaboration based on climate indices developed for this report

Indigenous communities have exhibited extraordinary resilience throughout history, continuing to safeguard vital ecosystems that serve as sanctuaries where biodiversity can flourish and evolve. Their stewardship of these areas has been instrumental in maintaining ecological stability, even as global environmental challenges intensify. **Figure I.12** illustrates the multifaceted factors that underpin this resilience (Ford et al., 2020), encompassing traditional knowledge systems, collective action on sustainable resource management practices, support institutions and agencies, continuous learning processes and deep cultural connections to the land. However, these factors are increasingly under strain from escalating pressures such as climate change, pollution, deforestation, or the fragmentation of forests and other natural habitats.

Operating largely outside the mainstream of contemporary technological and economic development, Indigenous groups hold a unique position as custodians of ancestral ecological wisdom. This practical and spiritual knowledge, passed down through generations, offers invaluable insights into sustainable living and ecosystem management. As the planet faces unprecedented environmental degradation, the contributions of Indigenous communities are becoming indispensable. Their practices not only preserve biodiversity but also help mitigate climate impacts, promote ecosystem restoration and foster global environmental resilience. Recognizing and empowering Indigenous leadership in conservation efforts is crucial for achieving a balanced and sustainable future (IUCN, 2024).

Figure I.12. The dynamic interaction between environmental and human factors in shaping the resilience of Indigenous People to environmental change

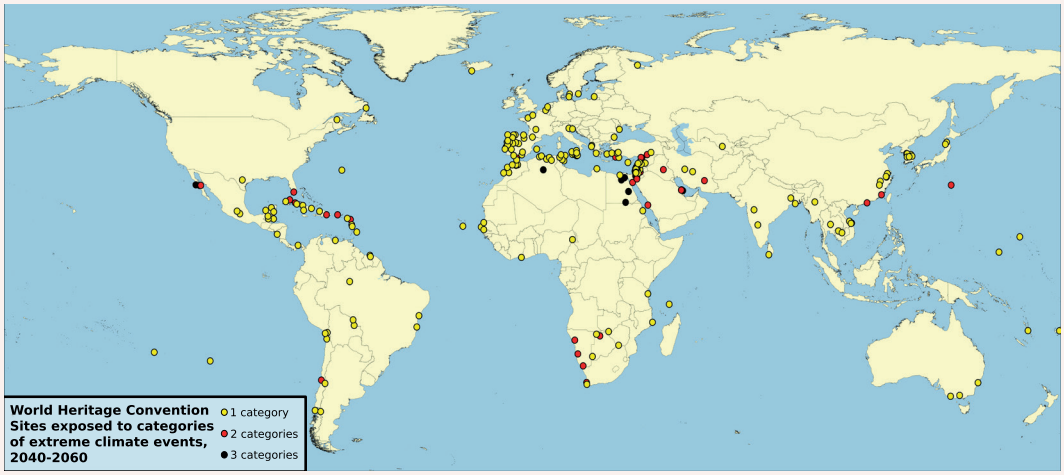


Source: Ford et al., 2020.

Box I.6. World heritage sites at risk from climate change 2040-2060

The map illustrates 238 world heritage sites that have not yet been exposed to extreme climate events but are projected to be at risk due to climate change, according to the climate change exposure index (**figure I.2**. and **box I.1**.). The climate change categories considered include extreme heat, extreme rainfall, drought, powerful hurricanes and sea level rise. The map uses colour coding to indicate the level of exposure: **yellow points** represent sites exposed to one type of extreme climate event (81%), **red points** indicate exposure to two types (14%), and **dark blue points** signify exposure to three types of extreme climate events (5%). It is important to note that while a site may be projected to experience a particular extreme event, this does not necessarily imply that the site is vulnerable to or will be impacted by it. Box I.6. World heritage sites at risk from climate change 2040-2060

The map illustrates 238 world heritage sites that have not yet been exposed to extreme climate events but are projected to be at risk due to climate change, according to the climate change exposure index (figure I.2. and box I.1.). The climate change categories considered include extreme heat, extreme rainfall, drought, powerful hurricanes and sea level rise. The map uses colour coding to indicate the level of exposure: yellow points represent sites exposed to one type of extreme climate event (81%), red points indicate exposure to two types (14%), and dark blue points signify exposure to three types of extreme climate events (5%). It is important to note that while a site may be projected to experience a particular extreme event, this does not necessarily imply that the site is vulnerable to or will be impacted by it.



Source: Authors' own elaboration based on the WHC list and sources in figure I.1 and box I.1. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Region	Sites	Percentage
Africa	19	8%
Arab States	59	25%
Asia and the Pacific	43	18%
Europe and North America	75	32%
Latin America and the Caribbean	42	18%
World	**238**	**100%**

Source: Authors' own elaboration based on the WHC list

2

Redistributive impacts of climate change policies: equity and opportunity

Addressing social inequalities that exacerbate the impact of climate change globally begins with the 2030 Agenda for Sustainable Development and its intertwined seventeen goals. However, the Sustainable Development Goals Report 2024 revealed that "only 17 per cent of the SDG targets are on track, nearly half are showing minimal or moderate progress, and progress on over one-third has stalled or even regressed". Unfortunately, goals related to no poverty (SDG 1), reduced inequalities (SDG 10) and climate action (SDG 13) are among those with clear stagnation and regression trends (United Nations, 2024). Despite being home to some of the world's most developed nations, the OECD countries have fully achieved only 10 out of 112 measurable targets and are nearing completion of just 18 more – most of which pertain to ensuring that basic needs are met and implementing policy tools and frameworks. Nevertheless, substantial efforts are still needed, particularly in addressing SDGs related to safeguarding the planet (OECD, 2022).

International climate regimes are founded on the principle of common but differentiated responsibilities (CBDR), recognizing the unequal distribution of global warming impacts, as discussed in section I of this report, as well as the uneven efforts required to address its root causes, which themselves create further distributional effects. The CBDR principle of the UNFCCC, applied systematically to the Paris Agreement (2015) and their COP decisions, recognizes that while all nations share the responsibility of mitigating climate change, they do so with varying degrees of obligation and effectiveness, reflecting their respective capacities and economic and technological constraints.

While the Paris Agreement has succeeded in mobilizing global efforts towards global ghg emission reductions, the current NDC commitments fall short of limiting global warming to 1.5°C above pre-industrial levels and they address, in a very limited way – partly due to a lack of precise or adequate metrics – the adaptation needs of the most vulnerable populations. This shortfall is critical, as the latest scientific research indicates that surpassing the 1.5°C threshold could trigger severe and potentially irreversible impacts on ecosystems, human health and economic stability (IPCC, 2022).

Recent studies highlight that global emissions must peak before 2025 and be reduced by nearly 50% by 2030 to stay within the 1.5°C limit (IPCC, 2022). However, even if fully implemented, current policies and pledges are projected to lead to a temperature rise of around 2.4°C to 2.7°C by the end of the century (IEA, 2023). The urgency of this situation has led the IPCC to strongly advocate for the acceleration and expansion of mitigation commitments strongly. Achieving net-zero emissions by 2050 has become a cornerstone of climate strategy, widely adopted by national governments, cities, industries and many corporations worldwide. This target is now seen as essential for stabilizing the climate and avoiding the worst consequences of climate change. The integration of nature-based solutions, advancements in carbon capture technologies and the transition to a circular economy are among the critical pathways being explored to achieve these ambitious climate goals. The next decade is pivotal, as the actions taken now will determine whether the global community can avert the most dangerous scenarios of climate change and secure a sustainable future for all.

Achieving net-zero emissions by 2050 has become a cornerstone of climate strategy, widely adopted by national governments, cities, industries and a growing number of corporations worldwide.

In addition to emphasizing mitigation, there is a growing consensus on the urgent need for robust adaptation strategies and a substantial scaling up of climate finance. In line with recent COP29 decisions, developed countries are now called upon to increase their financial contributions to $1.3 trillion annually by 2035, ensuring adequate support for developing nations that bear a disproportionate burden of climate change impacts.

Climate change disproportionately affects vulnerable communities, including women, children, Indigenous populations and residents of LDCs, LLDCs, and SIDS. These populations face extreme weather events, resource scarcity and environmental degradation, with limited adaptation capacity. Efforts to adapt to the impacts of climate change must prioritize the most affected regions and populations. This includes investing in sustainable infrastructure, enhancing disaster preparedness and response systems and promoting economic development that is both inclusive and environmentally sustainable. Recent analyses of African NDC and NAP reveal that over 50% of these instruments need enhancement to achieve adequate full coverage, consistency and robustness in addressing climate risks (Nowak et al., 2024). Addressing the needs of the most vulnerable is not only a moral imperative but also a crucial component of global efforts to combat climate change and its effects.

According to the NDC assessment conducted by Climate Action Tracker (CAT),5 which covers 38 countries along with the European Union – collectively accounting for 90.39% of global GHG emissions – there is a critical evaluation of both actions taken and policies implemented to combat climate change. CAT's comprehensive methodology assesses not only the pledges made under the NDC but also the effectiveness of these policies, the level of climate

5 https://climateactiontracker.org

finance provided, particularly by countries in the global North, and the alignment of these efforts with the principle of fair share in emissions reduction. This assessment (see figure II.1.) considers whether each country contributes equitably to global mitigation efforts based on its historical responsibility, current capabilities, and the urgency of the climate crisis.

Countries that are taking meaningful actions and implementing policies aligned with the 1.5°C target of the Paris Agreement include Bhutan, Costa Rica, Ethiopia, Kenya, Morocco, Nepal, Nigeria and the Gambia. However, it is essential to note that these nations collectively contribute only 0.68% of global emissions. Kenya is the only country without a formal net-zero target. While these countries have demonstrated commendable leadership in climate action, they face significant vulnerabilities.

Using the indices developed for this report to clearly distinguish the multidimensional effects of climate change, we were able to compare them with the commitments presented by countries under the Paris Agreement in their NDC. Figure II.1 and figure II.2 provide a country-level assessment of how vulnerable or exposed nations are to climate change, from both a physical perspective (climate change exposure index) and a social perspective (social vulnerability index). They also evaluate how aligned these countries' mitigation and adaptation efforts are with the goals of the Paris Agreement and whether these efforts are sufficient or not to address the planet's evolving climate conditions.

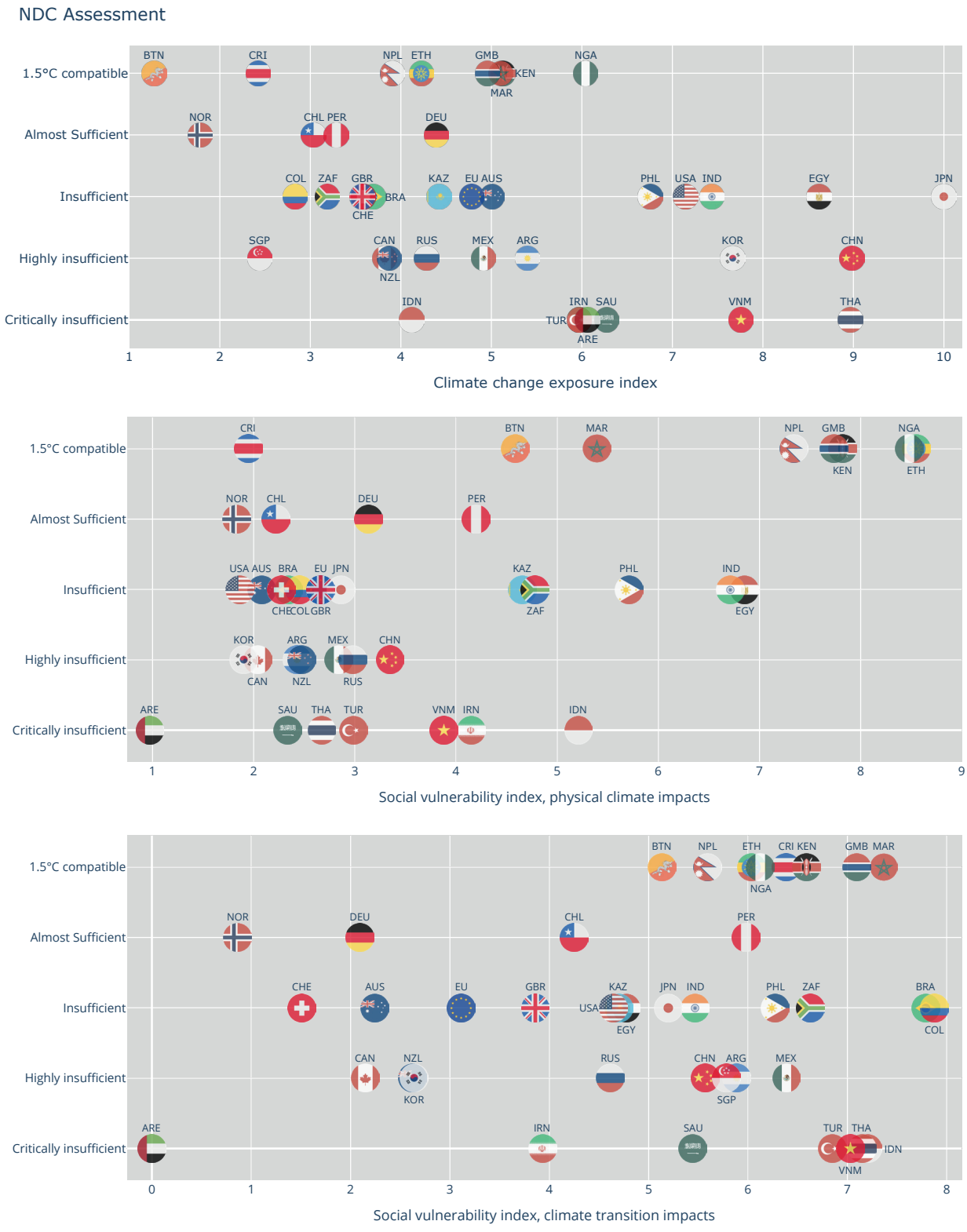
This vulnerability underscores the critical need for comprehensive adaptation plans within their NDC, as current assessments often focus primarily on mitigation efforts. For these countries, the urgency to avoid the worst impacts of climate change is particularly acute, as their populations have limited protective measures in place. Strengthening adaptation strategies alongside mitigation is essential to building resilience against climate shocks that these vulnerable populations are less equipped to withstand.

These countries could benefit from relatively low levels of government debt, which provides them with a greater capacity to mobilize the financial resources necessary to implement their climate strategies (WBG, 2022). Additionally, they have a young and adaptable workforce, a crucial asset in the face of rapidly evolving climate and economic conditions. However, their populations face significant vulnerabilities, particularly regarding transition risks. This vulnerability is exacerbated by several factors: low levels of education, minimal investment in research and innovation and persistent gender inequalities in the workplace.

Countries that are taking meaningful actions and implementing policies aligned with the 1.5°C target of the Paris Agreement include Bhutan, Costa Rica, Ethiopia, Kenya, Morocco, Nepal, Nigeria and the Gambia. However, it is essential to note that these nations collectively contribute only 0.68% of global emissions.

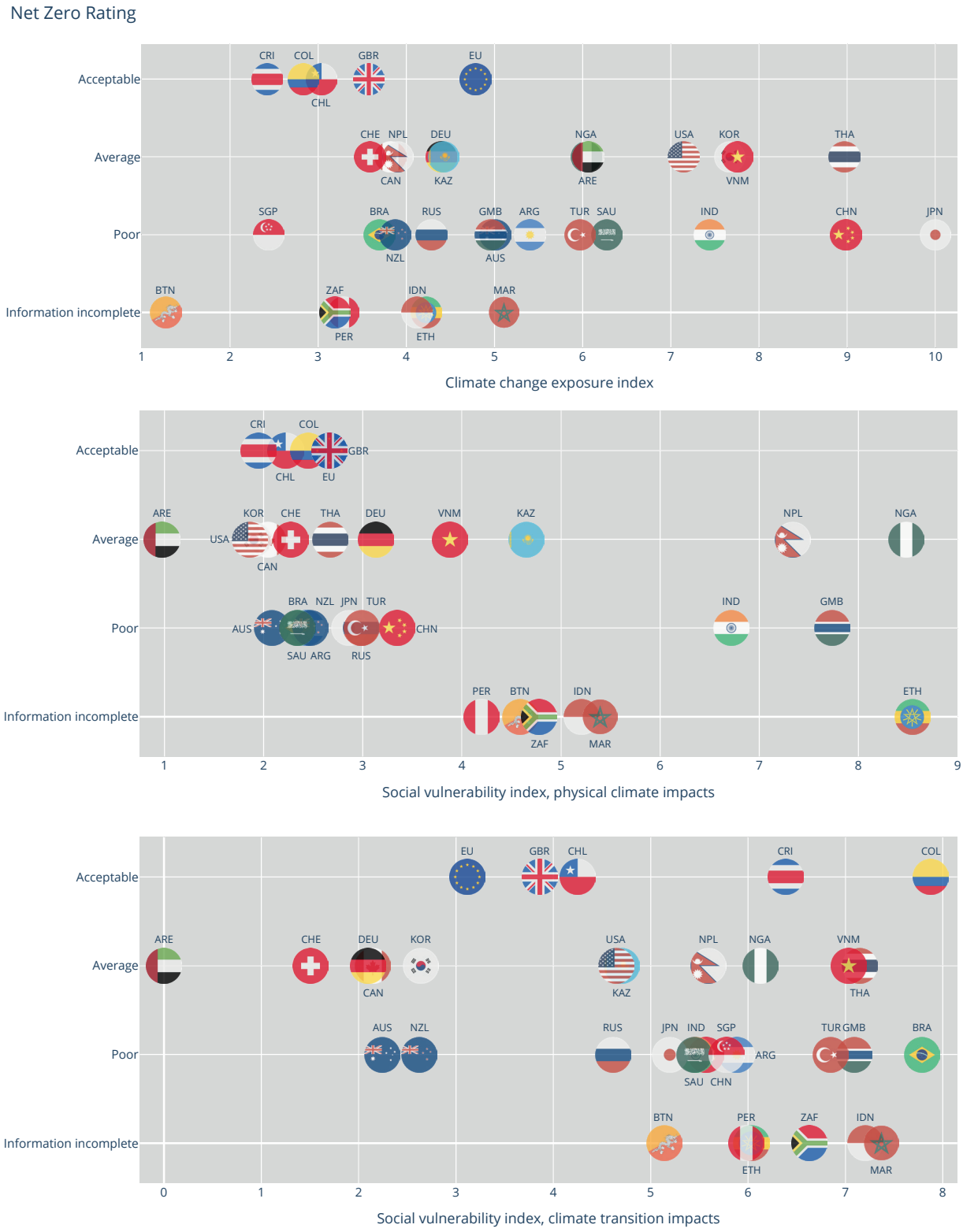
Also, these countries have a disproportionately high number of physically vulnerable workers who face increased exposure to extreme heat, particularly in rural areas where gender issues are relevant.

Figure II.1. Key GHG emitting countries' 2023 NDC assessment



Source: Authors' own elaboration based on Climate Action Tracker, 2024, sources in figures I.1, I.2 and II.3, and boxes I.1, I.2 and II.2.

Figure II.2. Key GHG emitting countries' 2023 net-zero rating



Source: Authors' own elaboration based on Climate Action Tracker, 2024, sources in figures I.1, I.2 and II.3, and boxes I.1, I.2 and II.2.

This situation further intensifies the challenges these workers face, as they are more susceptible to the physical impacts of climate change. The workforce in these nations is slightly more vulnerable to transition risks than the global average, making it imperative for these countries to develop robust strategies that do not address environmental concerns and enhance social resilience and workforce readiness in the face of inevitable economic shifts.

According to the CAT assessment, 32 countries, along with the 27 members of the European Union, have committed to achieving net-zero emissions by or around 2050, collectively accounting for 84.33% of global GHG emissions. However, despite these commitments, only 10 out of the 59 countries with a net-zero target are currently acting and implementing policies that are consistent with any of the Paris Agreement targets. Among these nations, Costa Rica stands out as the only country with policies and actions that align with the 1.5°C target of the Paris Agreement, coupled with a transparent and credible net-zero target. Nevertheless, Costa Rica's journey towards net zero is complicated by significant socioeconomic hurdles, including a population with generally low levels of education and a society marked by high inequality; in fact, the country also has a higher-than-average proportion of workers vulnerable to the economic transitions required for achieving net zero. On the positive side, Costa Rica benefits from low government debt levels, which alleviates some of the financial pressures associated with large-scale climate investments.

Left: Aerial view of a reforested area of trees in the middle of the Caribbean mountainous area of Limón province in Costa Rica © Saintdags/Shutterstock.com*

Box II.1. Reforestation in the Congo rainforest: a solution to combat war and climate change

Fair compensation for environmental services can serve as a pathway to a just transition for poor and vulnerable communities that hold valuable biotic resources. With only 7% of global ghg emissions and 15% of the world's population, Africa suffers disproportionately from the effects of climate change. "Over the past 60 years, Africa has experienced a warming trend that has become faster than the global average. By 2023, the continent experienced deadly heatwaves, heavy rains, floods, tropical cyclones and prolonged droughts" (WMO, 2024a). This situation, coupled with poverty and deforestation processes, has also generated violence and severe humanitarian crises. Extreme weather events, including floods and droughts, have significantly affected food security. The Congo forest has been affected by droughts, influencing tree mortality and threatening the dehydration of wetlands, two phenomena that affect the planet's atmospheric CO_2. As if that were not enough, the country has been at war for three decades and has suffered a very high social cost.

The Congo forest in Central Africa, at 790,000 square kilometres, is the second largest biome in the world. The Democratic Republic of the Congo, one of the six countries across which this carbon sink spans, holds 60% of this ecosystem. It is estimated that it stores around 600 billion tonnes of carbon – the equivalent of three years of global ghg emissions – and, together, absorbs almost 1.5 billion tonnes of carbon dioxide per year (UNEP, 2023), making it one of the regions in the world that absorbs more carbon than it emits. Maintaining this forest is vital to buffering climate change globally. Virunga National Park is one of 41 protected areas in the Democratic Republic of the Congo and the fifth-largest national park in the country. This forest is home to 50% of all terrestrial species on the African continent. It is home to more species of reptiles and mammals than any other in the world, including the mountain gorilla, one of the closest living relatives of humans. Protected areas in the Democratic Republic of the Congo total 324,290 km2, 41% of all Congolese forest.

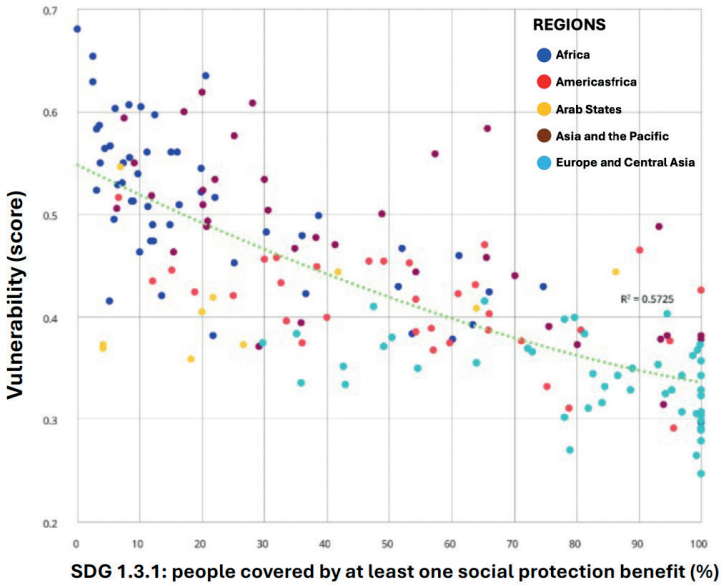
Virunga National Park is under pressure from the 7.2 million displaced people living in its surroundings, of whom 51% are women (OCHA, 2022). For three decades, war has produced enormous pressure on forest resources, and fragmenting the habitat of gorillas and elephants, among other endangered species (IUCN, 2024). These rainforests also contain some of the world's most valuable mineral deposits, which international mining companies extract – 71% of the world's cobalt production and 35% of coltan – as well as copper and gold (Bokamba E. et al., 2022). Overall, mining activity contributes around 25% of GDP.

Nature-based solutions, such as reforestation in Virunga National Park, are some of the most affordable and fastest ways to reduce pressure on the rainforest while serving the gorilla conservation goal. There is already evidence that reforestation is achieving the recovery of the gorilla population (UNESCO, 2024). Women are an essential part of this strategy. Since 2014, the project led by the Women's Earth and Climate Action Network (WECAN) International, involving 500 women, has planted more than 100,000 trees, "all by hand, without machinery or equipment" and is campaigning to stop illegal logging in the rainforest. This initiative has created income-generating activities for women through planting trees and collecting and selling their fruits.

Another initiative is the Hero Women Rising's "Reforesting Women" programme, which addresses environmental degradation and women's empowerment. "Men are too busy fighting or looking for work, but women are busy planting trees, harvesting, doing all the work on the ground," says Neema Namadamu, Senior Advisor to the Minister of Gender and Family of the Democratic Republic of the Congo.

Reforestation of Virunga National Park is accompanied by projects aimed at protecting the forest while improving the living conditions of nearby communities, particularly women. Renewable energy production from the Luviro-Ivingu hydroelectric plant generates enough electricity for 30,000 inhabitants and supports a drinking water pumping system. The company's profits go directly to the park's conservation and economic development projects. The resources are used to promote the creation of nurseries and the development of agrifood and agro-industrial projects, such as the industrialization of cocoa. All of this contributes to improving the resilience of communities. Every effort is being made to ensure that the carbon in this forest remains locked away. The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD) is developing pilot projects on reducing emissions from deforestation and forest degradation in developing countries (REDD+) as part of a global strategy to provide participating developing countries with results-based payments to keep their forests standing.

Figure II.3. The relationship between a country's vulnerability to climate change (score) and its social-protection coverage (percentage), by region, 2023



Source: ILO, 2024b.

II.1. Enhanced social protection systems are now required for a just transition

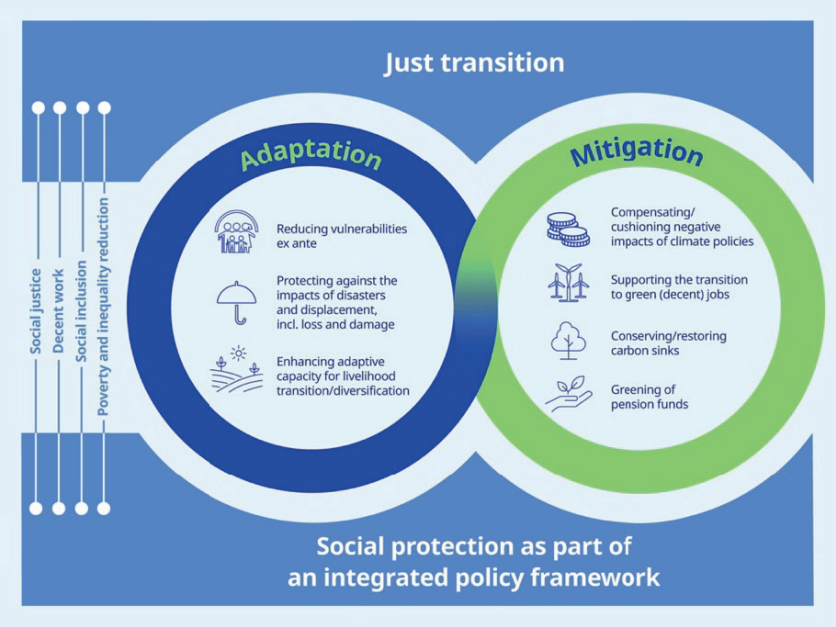
Given the profound impacts of climate change on social systems, public health, and overall well-being worldwide, it is clear that the international climate frameworks established under the UNFCCC and the Paris Agreement (2015) are not adequately designed or equipped to address the comprehensive social protection measures needed to ensure that individuals can live with dignity throughout their life cycles. This is especially critical in the context of the current and anticipated climate transitions outlined in section I.

The first, unwritten climate right of every person on Earth is the right to know whether one's life is at risk because of an extreme weather event linked to climate change. Today, we possess the technological capability to detect, monitor and communicate such risks through the World Meteorological Organization and regional and local meteorological institutions and networks. In terms of safeguarding the physical integrity of vulnerable populations, the Paris Agreement (2015) has advanced the universality and implementation of early warning systems. Recent COP (Conference of the Parties to the United Nations Framework Convention on Climate Change) decisions have further laid the groundwork for enhancing these systems, ensuring that they are universally accessible in 2027, tailored to individual needs, and adequately financed within the structure of the UNFCCC (WMO, 2024b).

Effective early warning systems must be seamlessly integrated with robust civil protection programmes to ensure a coordinated response in the aftermath of natural disasters. These programmes should mobilize law enforcement and other essential services to reorganize the affected populations and restore disrupted productive and commercial activities. Equally important is the establishment of comprehensive support systems to provide displaced individuals with safe shelter, emergency food supplies, medical care and adequate sanitary conditions, safeguarding their health and dignity. Furthermore, restoring normalcy following an extreme hydrometeorological event requires the integration of these emergency response efforts with broader social protection systems, fostering community resilience and laying the foundation for sustainable recovery.

The overlap between climate vulnerability and global coverage of social protection systems shown in **figure II.3** is staggering. Africa stands out as the continent with the most populations lacking the necessary safeguards to cope with current and impending climate challenges. This is not attributable solely to the poor economic conditions in developing countries, but also to the prevalence of informal employment in such countries, where both circumstances are far more significant than they are in wealthier nations. Social protection systems, by design, are tied to formal employment, which is notably scarce in poor countries, especially within the rural sector. Under these circumstances, each natural disaster imposes catastrophic costs on those affected, leading to a complete regression in their standard of living because of the absence of systemic protection. In contrast, most European countries are less vulnerable to climate stressors and benefit from

Figure II.4. The role of social protection systems as enablers of a just transition



Source: ILO, 2024b

social protection systems which – despite not entirely preventing human tragedies or significant economic losses – enable them to manage catastrophic climate events more effectively, fostering greater community resilience.

There is mounting and compelling evidence of the adverse social impacts of extreme weather events, as well as of the gradual yet profound effects of slow-onset changes such as sea-level rise, desertification, and shifting ecosystems, all driven by climate change. These phenomena are already undermining public health by exacerbating the spread of diseases, intensifying heat-related illnesses and compromising access to clean water and nutritious food. They diminish quality of life by disrupting communities, creating inequities and straining infrastructure. Furthermore, they threaten employment and livelihoods, particularly in vulnerable sectors such as the agriculture, fisheries and tourism sectors; extreme heat and other stressors also cause unsafe working conditions, which reduce labour productivity (ILO, 2024b).

These impacts pose significant challenges to poverty eradication efforts, deepening inequality and exposing systemic vulnerabilities in social and economic systems. Urgent and transformative measures are essential to designing and implementing adaptive and inclusive social protection systems in response. Social protection systems must anticipate and address the dynamic risks of a changing climate by being flexible, equitable and adequately resourced to support the most vulnerable populations while fostering resilience, sustainable development and climate justice in an increasingly uncertain future (see **figure II.4**).

There are undeniable and critical interconnections between mitigation and adaptation policies and social protection systems, which, if strategically harnessed, can serve as powerful tools to achieve a truly just transition. These synergies extend across diverse domains, and can range from the use of retirement and pension funds to finance innovative decarbonization projects that drive economic transformation to robust safety nets and rapid recovery mechanisms which enable affected communities to return to normalcy following devastating extreme weather events. For instance, adaptation policies can align with social protection by incorporating climate-resilient infrastructure investments into public works programmes, while mitigation efforts can be strengthened by incentivizing low-carbon employment or green jobs through targeted social safety nets.

However, these interconnections must not remain implicit or incidental. To fully realize their potential, they need to be explicitly integrated into the design and implementation of social protection systems, backed by clear mandates and robust legal, administrative and infrastructure frameworks. This includes embedding climate-resilience criteria in social programmes, ensuring universal access to climate-sensitive health and welfare services, and creating financial instruments that link social protection with sustainable development goals. Only by making these synergies explicit and actionable can we ensure that social protection systems play a pivotal role in fostering equitable, inclusive and sustainable pathways to a net-zero future.

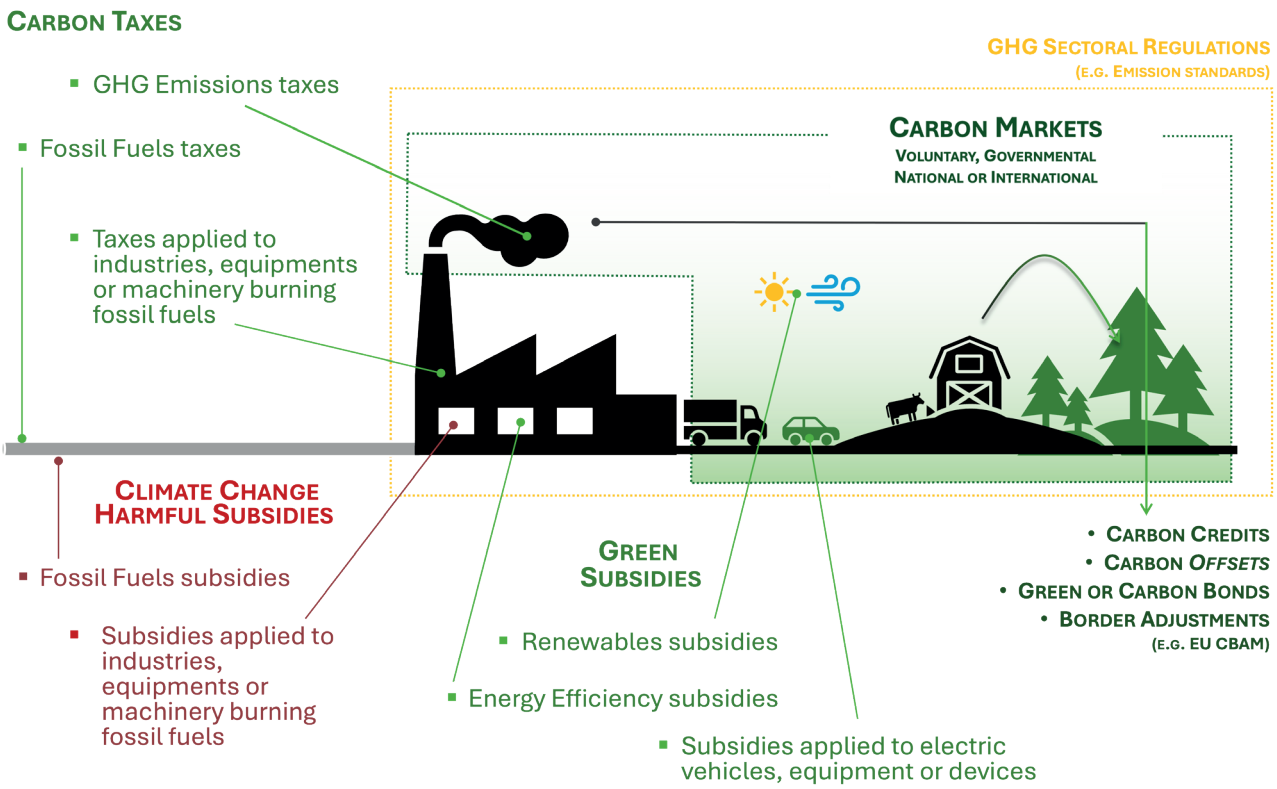
II.2. The distributional effects of carbon pricing as a possible driver of inequalities

From an economic perspective, the transition to climate neutrality hinges on the implementation of robust economic and regulatory signals that internalize the cost of environmental externalities, particularly those related to greenhouse gas emissions. By assigning a value to the negative climate impacts of the most carbon-intensive sectors – either directly through carbon taxes or indirectly through emissions trading schemes (ETS) or sectoral regulations – governments can establish strong financial incentives for businesses and consumers to transition towards more sustainable practices (**figure II.5**). At the same time, phasing out environmentally harmful subsidies can further enhance the effectiveness of these measures, promoting a more equitable and climate-resilient economy. Some market-based instruments normally aim to shift economic behaviour by aligning profit motives with environmental sustainability, fostering investment in clean technologies, renewable energy and energy efficiency, and reducing reliance on fossil fuels.

As at 2024, the World Bank Group reports that there are 75 active carbon-pricing mechanisms, including both carbon taxes and ETS programmes, spanning countries and regions worldwide. Together, these schemes cover nearly 30% of global greenhouse gas emissions, mainly in developed countries, reflecting a growing global commitment to carbon pricing as a tool for climate mitigation (WBG, 2024b). However, the limited coverage and the varying levels of ambition among existing programmes highlight the need for broader implementation and stronger integration across regions and sectors to meet international climate goals. It is crucial to highlight that Europe, as a region, not only operates an ETS in the context of the European Green Deal, but has also approved the introduction of a carbon border adjustment mechanism (CBAM).

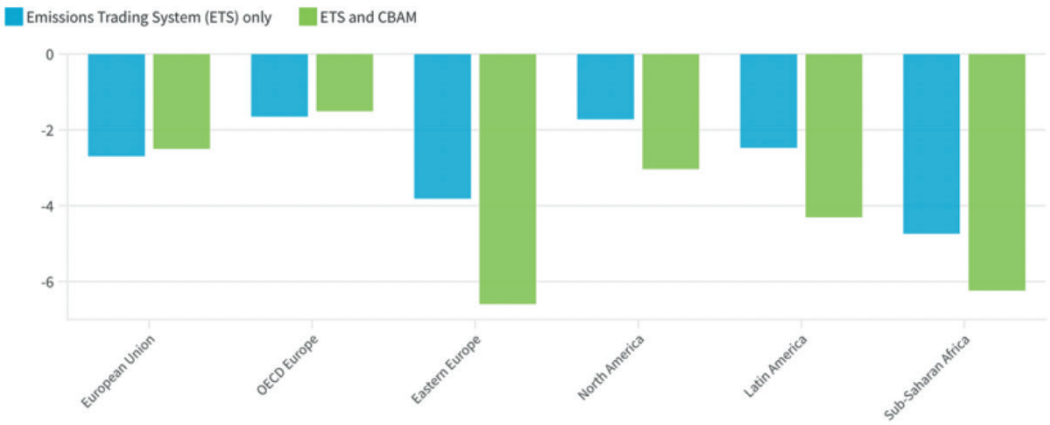
The CBAM is poised to significantly intensify the distributive impacts of carbon pricing, not within the European Union (EU) itself, but on those of its external trading partners which lack equivalent carbon pricing mechanisms (Fredriksson and Zachmann, 2021). By levelling the playing field for carbon costs, the CBAM will reshape global

Figure II.5. Carbon-pricing instruments



Source: Author's own elaboration.

Figure II.6. Impact of the European Union's carbon border adjustment mechanism (CBAM). Exports to the European Union (% change)



Source: Asian Development Bank (2024). Asian Economic Integration Report 2024: *Decarbonizing Global Value Chains.*

trade dynamics, creating new pressures on countries and industries which do not match Europe's climate ambitions. Some economic simulations indicate that standardizing carbon prices both within and across EU countries could reduce the regressive nature of carbon pricing policies (IMF, 2024); nevertheless, other regions of the world will experience economic and social impacts (ADB, 2024), as they reduce their exports to Europe, which will in turn affect their GDP and labour markets, as illustrated in **figure II.6**.

One of the significant challenges associated with implementing a strict carbon pricing policy is the risk of carbon leakage resulting from carbon pricing asymmetries among countries, regions or sectors. Carbon leakage mainly occurs when industries, particularly those that are energy-intensive and have high emissions from fossil fuels, relocate their operations to countries with more lenient or non-existent climate and environmental prices or regulations (OECD, 2024a). A similar situation is evident in the transportation industry: electric vehicles are increasingly produced and marketed in developed regions and China, while cheaper new and used internal combustion engine vehicles continue to be sold in developing countries. These countries often lack the automotive manufacturing infrastructure or regulatory frameworks necessary to support the transition to advanced vehicle technologies (IEA, 2024c). This induced situation undermines the original policy's goals by merely shifting emissions from one region to another rather than reducing global emissions overall. As a result, while countries with strict carbon pricing policies and regulations might see reductions in their domestic emissions, global circumstances may remain the same or even worsen. Industries relocating to countries with weaker environmental safeguards often face lower operational costs, which can also create an uneven playing field, discouraging investment in cleaner technologies. Moreover, this shift can amplify air pollution problems in the host countries, which may lack the infrastructure or political will to mitigate public health problems and environmental damage.

Carbon pricing mechanisms can have regressive impacts in both developing and developed countries, where lower-income households tend to spend a higher proportion of their income on energy and other carbon-intensive goods, potentially exacerbating economic inequality.

In addition to their climate impacts, these instruments impose significant social burdens and have significant economic implications, particularly in terms of their global distributional effects (Piontek et al., 2023). Studies have shown that carbon pricing mechanisms can have regressive impacts in both developing and developed countries (IDB, 2022), where lower-income households tend to spend a higher proportion of their income on energy and other carbon-intensive goods, which potentially exacerbates economic inequality if not properly addressed through compensatory measures such as rebates, lump-sum redistribution or progressive green subsidies (Vona F., 2023). However, in some developing countries, where there are wide social and economic gaps, carbon pricing has shown more progressive outcomes, particularly in the transportation sector (Ohlendorf et al., 2021). In these contexts, well-designed schemes which reinvest carbon revenues into social programmes, renewable-energy access or infrastructure improvements can have redistributive effects, helping to alleviate poverty and reduce inequality.

It is crucial to carefully consider the methodological approaches and metrics used in studies which assess

distributive impacts both between and within nations. Research suggests that income-based assessments may overstate the regressive effects of carbon pricing, potentially distorting policy outcomes. In contrast, expenditure-based approaches provide a more accurate and reliable means of evaluating carbon burdens, offering a clearer picture of how carbon pricing affects different socioeconomic groups (Shei et al., 2024).

Thus, while carbon pricing is a key tool for driving climate action, its success depends not only on its environmental effectiveness, but also on how equitably its costs and benefits are distributed (EPG, 2023). Careful consideration of the social and economic contexts in which such instruments are implemented is critical to ensuring that they contribute to both climate goals and broader socioeconomic development objectives. Policymakers must design complementary measures to mitigate negative impacts on vulnerable populations, ensuring that the path to climate neutrality is both inclusive and just.

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II.3. Energy access and the distributional challenges of climate policies

Energy lies at the heart of the climate-change challenge, and a key reason behind the ongoing difficulties in reducing greenhouse gas emissions under the UNFCCC and the Paris Agreement (2015) is the strong positive correlation between GDP and energy access. Recent data from the World Bank Group show a correlation coefficient of 0.33, underscoring the persistent link between economic growth and energy consumption (WBG, 2024a). This relationship underscores the reality that a country's economic performance generally improves as energy access expands. The interplay between energy access and the distributional effects of climate policies is intricate, particularly when equitable outcomes are sought through carbon pricing and clean-technology-deployment policies and regulations. These policies must balance the need to reduce emissions with the imperative to ensure affordable and reliable energy for all – especially for vulnerable populations – by 2030 (SDG 7). Ensuring that carbon pricing mechanisms and clean energy transitions do not disproportionately burden low-income groups or developing regions is critical to fostering inclusive, sustainable growth while addressing climate change.

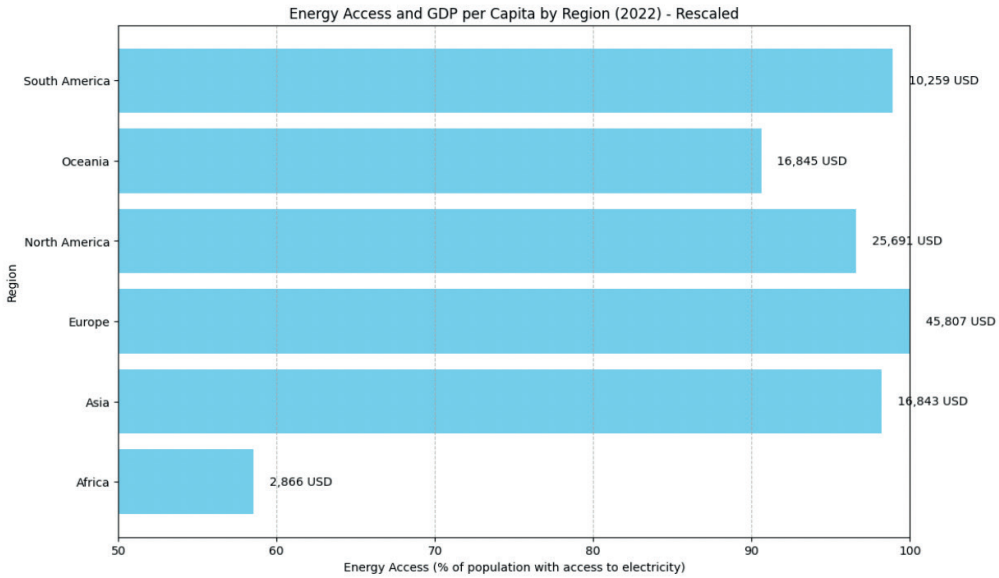
Energy poverty restricts opportunities for economic advancement, heightening vulnerability to climate risks and further entrenching poverty.

Energy access is a critical catalyst for economic activities, driving productivity, industrial growth and overall development. However, the distribution of these benefits is uneven (see **figure II.7**), often leaving the most vulnerable populations –particularly in emerging and developing economies – behind, unable to share in the advantages of increased access to renewable and clean energy. This disparity further complicates efforts to achieve global emission-reduction targets while ensuring equitable economic progress.

Climate change is significantly amplifying the unpredictability of water resources, which are vital for energy generation, especially with regard to hydropower and cooling systems in power plants. As environmental changes intensify, the most vulnerable communities – already struggling with limited access to energy and water – will face the harshest consequences, in a further deepening of existing inequalities.

The lack of reliable energy access significantly undermines vulnerable communities' ability to adapt to a changing climate. For instance, without electricity and affordable fuels, farmers cannot utilize modern irrigation systems, climate-controlled storage, or refrigerated transport, making them increasingly vulnerable to heatwaves, droughts and other extreme weather events. Likewise, small businesses which rely on energy for refrigeration, lighting or other critical technologies struggle to operate efficiently, stifling income generation and hindering economic growth. This cycle of energy poverty restricts opportunities for economic advancement, heightening vulnerability to climate risks and further entrenching poverty. To illustrate, although not exhaustively, energy access is crucial for:

Figure II.7. Energy access and GDP 2022



Source: World Bank Data https://data.worldbank.org/

- **Agricultural productivity:** Farmers cannot use modern farming tools and technologies without access to energy, particularly electricity. This limits their productivity and ability to respond to environmental changes, confining them to subsistence farming and condemning them to low-income levels.

- **Healthcare:** Inadequate energy access limits the availability and quality of healthcare services. Medical facilities need reliable electricity for lighting, the refrigeration of medicines and the operation of essential medical equipment. Without these services, health outcomes in vulnerable communities deteriorate, reducing the communities' capacity to adapt to and recover from climate-related health impacts.

- **Education:** Energy access is crucial for educational attainment. Schools without electricity cannot offer evening classes, access digital learning tools or provide an environment conducive to learning. This limits the educational opportunities available to young people in the communities affected, perpetuating cycles of poverty.

- **Entrepreneurship and employment:** The absence of energy restricts the ability to start and grow businesses. Many small-scale industries, such as the food processing, textiles and crafts industries, depend on reliable power to operate machinery, maintain production schedules and store goods. Without energy, businesses cannot compete, reducing employment opportunities and economic growth in vulnerable areas.

Thus, addressing SDG 7, which concerns the global energy gap, is essential to economic development. It is also essential as a core component of a holistic strategy to mitigate climate change impacts and promote long-term sustainability in the world's most vulnerable regions.

II.4. Unexpected climate and social effects of clean energy solutions

The transition from fossil fuels to renewable energy is essential for mitigating climate change, but it also presents significant social and economic challenges. Communities reliant on fossil fuel industries – such as coal mining and oil extraction – face job losses and economic downturns as these sectors decline. Meanwhile, the expansion of renewable-energy infrastructure can generate social tensions, particularly in rural and marginalized areas. Large-scale projects such as wind farms and solar parks require extensive land use, potentially displacing local populations and disrupting traditional livelihoods.

The use of hydropower, a dominant renewable energy resource, illustrates these challenges (see **box II.2**). While hydropower provides stable electricity in many regions, it is highly vulnerable to climate variability. Prolonged droughts and shifting precipitation patterns reduce reservoir levels, undermining generation capacity and exacerbating energy insecurity. Historically, hydropower projects have also caused forced displacement, loss of agricultural land and restricted water access – disproportionately affecting lower-income communities. Rising electricity costs due to decreased hydropower availability further deepen social inequalities.

The economic and environmental resilience of hydropower-reliant nations varies significantly. Countries such as Brazil and Viet Nam have proactively addressed hydropower risks by investing in diversified renewable portfolios, integrating wind and solar power to reduce their vulnerability. Conversely, Colombia and India continue to rely heavily on hydropower, making them more susceptible to energy shortages and economic disruptions due to erratic hydrological conditions. Without strategic diversification, these nations risk long-term instability of their energy supply.

Climate extremes further threaten hydropower's sustainability. In Colombia, where hydropower accounts for over 60% of electricity generation, unpredictable rainfall and prolonged droughts pose significant risks. Studies indicate that wealthier nations tend to reduce their hydropower dependence as GDP grows, shifting towards diversified energy sources. In contrast, lower-income countries struggle to transition, reinforcing their vulnerability to energy insecurity and economic hardship. Investing in alternative renewables such as wind and solar power is crucial to mitigating these risks.

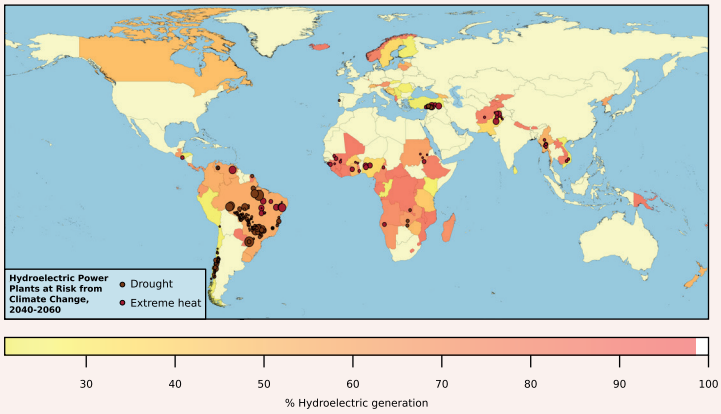
To ensure a just and sustainable energy transition, policymakers must address the socioeconomic impacts of renewable-energy expansion. This requires incorporating affected communities into decision-making, fostering local economic alternatives, and implementing adaptive strategies such as improved hydrological forecasting and climate-resilient infrastructure. By adopting a comprehensive and equity-driven approach, nations can maximize the benefits of renewable energy while minimizing unintended consequences – ultimately ensuring energy security, economic stability and social well-being in the face of a changing climate.

Box II.2. Hydropower

In recent years, the share of renewable energy resources, such as wind and solar power, in the global electricity mix has steadily increased. However, hydropower remains the dominant form of renewable energy. In 2023, hydropower accounted for 14.3% of global electricity generation, while wind and solar power accounted for 7.8% and 5.5%, respectively. These percentages vary significantly by region: in South America, hydropower represents 56.8% of total electricity generation, compared to 13.2% in North America, and 12.3% in Asia.

As the world grapples with the challenges posed by climate change, the impact on hydropower resources cannot be understated. Hydropower is highly dependent on consistent water flow, which is increasingly endangered by shifting weather patterns, prolonged droughts and the melting of glaciers. These disruptions pose serious risks for emerging and developing economies, particularly in cases where hydropower accounts for a substantial portion of total electricity generation.

Hydroelectric power plants projected to be at risk in 2040-2060



Note: Map refers to droughts and heatwaves (more than 12 weeks with average temperatures above 35°C) affecting power plants in 2050. The size of the circles represents the power-generation capacity of plants. Includes countries where hydropower accounts for at least 20% of total generation. *Source:* World Resources Institute, Global Power Plant Database, https://datasets.wri.org/dataset/globalpowerplantdatabase. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

This map shows hydropower plants projected to be at risk in 2050 because of extended droughts and heatwaves exceeding 12 weeks with average temperatures above 35°C. As noted, the global South is expected to be particularly affected.

Brazil is a notable example, since a large number of its hydropower plants are expected to bear the impacts of climate change. Colombia can be affected as well; even though hydropower constitutes 62.3% of its total power generation (Ritchie and Rosado, 2024). Lower-than-expected rainfall levels can substantially stress power systems, potentially leading to serious operational challenges. For example, a weak La Niña in Colombia – or elsewhere – could affect the level of hydropower generation (FAO, 2024a). The reduced rainfall linked to these events diminishes water levels in reservoirs, thus compromising the efficiency and reliability of hydropower plants.

The decreasing availability of hydropower resources in certain regions could lead to higher energy costs, creating challenges for local businesses. The ripple effects of energy scarcity may significantly affect sectors such as tourism and agriculture, both vital to the economies of many developing countries. This underscores the urgent need for countries to diversify their energy portfolios by accelerating the adoption of alternative resources such as wind and solar power, fostering resilience and maintaining competitiveness in an evolving energy landscape.

Nonetheless, hydropower will continue to help communities meet their electricity requirements, which is particularly important for developing countries such as China and India, the countries in the ASEAN (Association of Southeast Asian Nations) region and those in Africa, since they are expected to lead global capacity additions through 2030, according to the International Energy Agency (IEA) (IEA, 2024e). For these countries – and any others eyeing hydropower development – it is critical to follow specific guidelines addressing the economic, environmental and social dimensions of new (and existing) hydropower plants. One of the objectives of establishing robust mechanisms for stakeholder engagement during the life cycle of these projects is to mitigate risks for communities and developers (IHA, 2020). This inclusive approach not only supports responsible energy generation but also promotes lasting economic and environmental benefits for affected localities.

II.5. The green transition and its implications for labour

The transition envisioned by the Paris Agreement (2015) to achieve a net-zero emissions scenario presents a profound technological and organizational challenge across productive and service sectors, particularly in rapidly growing cities and those adapting to new climate conditions. This transition goes beyond merely reducing GHG emissions; it presents a pivotal opportunity to drive change by fostering the creation of green jobs, spurring innovation through new businesses, and generating sustainable wealth. It holds immense potential for countries most urgently in need of lifting their populations out of poverty, mitigating the risks of internal conflicts, and ensuring long-term stability. It also entails a comprehensive transformation of industrial and production processes, with far-reaching impacts on urban planning, energy infrastructure, transportation networks and food-production systems. We can build resilient communities and enable a more inclusive and equitable global future by embedding these transitions in a secure and sustainable framework.

From a labour perspective, this transition offers substantial opportunities, such as creating of millions of green jobs, essential for building a sustainable economy. According to the International Renewable Energy Agency (IRENA) and the ILO, the shift to a greener economy could create up to 139 million jobs globally by 2030, particularly in sectors such as renewable energy and energy transition technologies (IRENA and ILO, 2023). These new jobs are expected to contribute to increased wages and improved working conditions, especially in regions which invest in upskilling their workforce to meet the demands of new technologies.

However, this transition also presents significant challenges. The shift towards green technologies and sustainable practices will inevitably lead to the phasing out of specific industries and roles, particularly those reliant on fossil fuels and carbon-intensive processes. This technological substitution and labour restructuring will likely have unintended distributional effects, especially job losses in traditionally hard-to-abate industries and high GHG-emitting sectors, such as coal mining, oil and gas extraction, meat production or manufacturing industries heavily dependent on non-renewable resources.

These disruptions pose a significant risk of social impoverishment, as workers in traditional industries may struggle to secure new employment, particularly if they lack the skills needed for emerging green jobs. In some cases, they may also face the added challenge of relocation. This economic dislocation could trigger short-term instability while entrenching long-term inequalities, disproportionately affecting vulnerable communities. As unemployment rises and business closures become more widespread, the potential for social unrest and violence may intensify, further destabilizing affected regions.

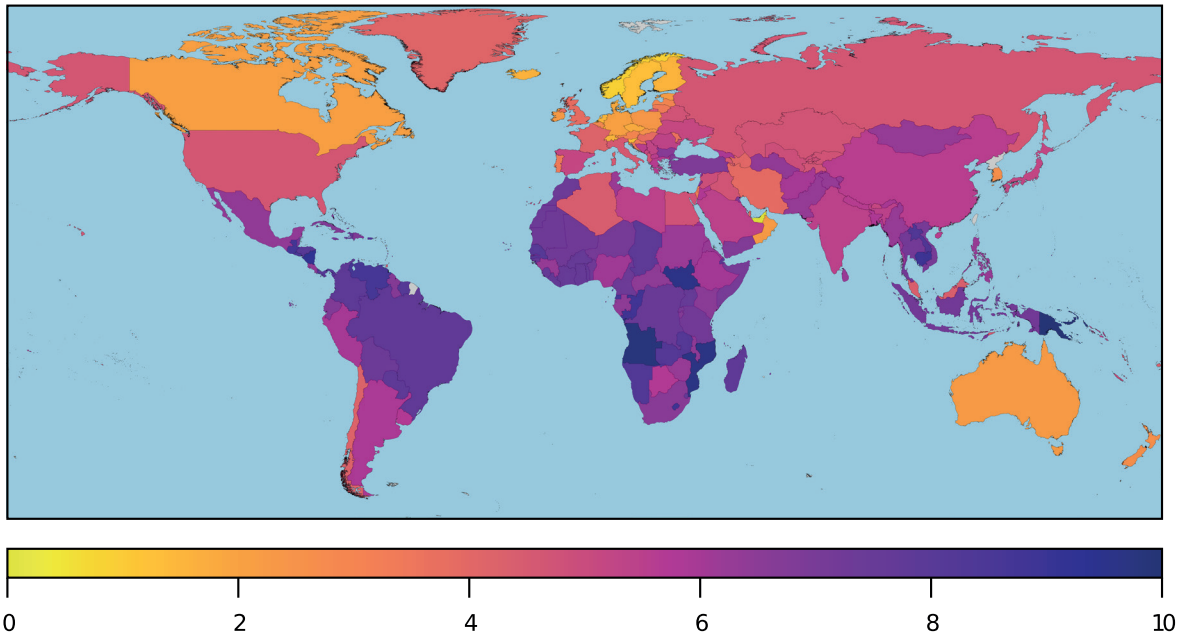
If the transition to a green economy is not managed inclusively, with strong social protection measures and policies to support retraining and job placement, it could deepen social divides and create pockets of poverty and disenfranchisement.

Moreover, the pace of technological change could exacerbate these challenges. If the transition to a green economy is not managed inclusively, with strong social protection measures and policies to support retraining and job placement, it could deepen social divides and create pockets of poverty and disenfranchisement. Therefore, it is critical that governments and organizations not only focus on the technological and environmental aspects of the transition but also prioritize its social dimension, ensuring that no one is left behind in the move towards a sustainable future.

For example, South Africa and Indonesia both face significant challenges as they transition from coal-dependent economies to more sustainable energy systems pursuant to international commitments to combating climate change. South Africa, where over 70% of electricity generation relies on coal, has deep economic ties to coal mining, particularly in Mpumalanga, where it is a critical economic driver (JET-IP, 2023). Similarly, Indonesia (Power Technology, 2024), as the world's largest exporter of thermal coal, heavily depends on coal revenue, particularly in coal-producing regions such as Kalimantan and Sumatra. Both countries are under mounting pressure to phase out coal and transition to greener energy systems: South Africa is aiming for a just energy transition through its 2023 Just Energy Transition Investment Plan (JET-IP), and Indonesia is targeting net-zero emissions by 2060 while phasing out coal-fired power plants by 2050.

To support these transitions, international partnerships have pledged substantial funding: $8.5 billion to South Africa through the Just Energy Transition Partnership and $20 billion to Indonesia. These funds focus on renewable-energy investments, regional economic diversification, and green job creation while addressing the risks of social and economic disruption in coal-dependent regions. Despite these efforts, both countries face significant challenges, including potential job losses, governance issues and resistance from local communities. South Africa's Presidential Climate Commission highlights the need for retraining coal workers and transparent implementation to mitigate social impacts, while Indonesia faces similar struggles, emphasizing the fair distribution of benefits and

Figure II.8. Index of workers' vulnerability to climate transition impacts 2040-2060



Source: Authors' own elaboration, based on multiple data sets (see box II.2). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

overcoming governance barriers. Success for both nations hinges on effective community engagement, scaling up green industries, and ensuring equitable support for vulnerable workers and regions during the transition.

For this report, an **index of workers' vulnerability to climate transition impacts** was developed to assess various risks within the labour domain, evaluating both personal and structural factors that enable or hinder a just transition for workers (see **box II.3.** for methodology). It evaluates six dimensions relevant to the ability of individual workers to adapt to a changing industry landscape, such as a young workforce, highly educated individuals, and gender inequalities in the job market. The rest of the six indicators measure structural challenges dependent on the market and government policy, such as a government's capability to invest in income support programmes according to its external debt, income inequality and its impact on job opportunities and social mobility, and a government's active or lagging role in the net-zero transition according to its research and innovation.

Two factors critical to ensuring a just transition for workers in the face of unpredictable climate futures are the flexibility and the mobility of the workforce; also of great importance is the strength of income support systems. Measures essential to facilitating a transition which leaves no one behind include trade adjustment assistance and income support, which may entail substantial costs predominantly borne by governments. An ageing workforce, with its reduced flexibility and mobility, poses additional challenges, potentially hindering the effectiveness of these mechanisms. There is evidence that "the net-zero transition is creating […] good-quality jobs […] in high-skill occupations and represent an opportunity mainly for highly educated, urban workers […] In contrast, for low-skilled workers, green-driven occupations may not be a sufficiently attractive alternative to jobs […]" (OECD, 2024c).

Technical innovation and robust governmental support for emerging industries are crucial to avoiding sunk investments in sectors no longer compatible with a climate-affected future. Economic sectors are vulnerable to physical risks, such as extreme weather events, and transition risks, which arise from market economic shifts. For example, agriculture and construction are industries where workers are most likely to be affected by physical risks. At the same time, sectors such as energy, fossil fuel extraction, manufacturing and mining face significant risks from economic transitions. Additionally, industries such as tourism are at risk of income loss and physical damage due to the degradation of ecosystems and rising sea levels.

Africa is, globally, the most vulnerable region for workers facing climate sociotechnological transitions, closely followed by the Americas.

By analysing these factors, the index provides a comprehensive and geographic distributional view (see **figure II.8.**) and an understanding of the vulnerabilities which workers face in the context of climate change. It highlights the necessary measures for supporting a just transition, ensuring that all workers are adequately protected and prepared for the changes ahead.

Box II.3. Index of workers' vulnerability to climate transition impacts

This index evaluates workers' vulnerability to the net-zero transition across six categories, each ranked by percentile.

1. **Young workforce**: Measured by the ratio of the population aged 20-39 years to that aged 40-65 years. Calculation based on World Bank Group's population database (WBG, 2024).
2. **Education**: Assessed by the mean years of schooling (UNDP, 2024).
3. **Inequality**: Evaluated using the Gini index (WBG, 2024; CIA, 2024).
4. **Research and innovation**: Measured by the number of scientific and technical journal articles per million inhabitants, reported by countries to UNESCO (UIS, 2024).
5. **Government debt:** Assessed by debt service and central government debt (World Bank, 2024d).
6. **Gender**: Measured by gender inequality index (GII) (UNDP, 2024).

The scores for these six categories are averaged, and the result is normalized to yield a value ranging from 0 (least vulnerable country) to 10 (most vulnerable country). Workers in outdoor sectors, such as agriculture and construction, are particularly vulnerable to physical impacts such as extreme heat. In contrast, those in the energy, manufacturing and mining sectors face the highest risks from transition factors.

As can be seen on the map in **figure II.9**, Africa is, globally, the most vulnerable region for workers, closely followed by the Americas. The countries in these regions have an overall high score in the workers' vulnerability index, and they are particularly vulnerable in critical areas such as education, research and innovation, gender equality, and central government debt. These factors create a complex web of challenges which impede a region's sustainable development and socioeconomic progress. Meanwhile, though generally more resilient, Europe exhibits significant vulnerabilities in its young workforce and total government debt service, indicating potential long-term economic strains. The Americas, on the other hand, face their greatest vulnerability in terms of inequality, highlighting deep-rooted disparities which could exacerbate sociopolitical instability. South-to-North migration, driven by both legal and illegal movements of workers which have been precipitated by economic, political or violent circumstances, highlights ongoing conflicts at the border between the United States of America and Mexico. Climate-related risks could further exacerbate these migration pressures, likely to intensify existing vulnerabilities in the region.

Worldwide, the countries most vulnerable to the labour transition are predominantly classified as least developed countries (LDCs), landlocked developing countries (LLDCs) or small island developing States (SIDS). These nations consistently rank above the global average in terms of overall country vulnerability. Specifically, LDCs and LLDCs are disproportionately affected by education challenges, research and innovation, gender equality and inequality. These three categories represent critical areas where systemic weaknesses can hinder growth and development. SIDS, because of their unique geographic and economic circumstances, are more susceptible to vulnerabilities in terms of education, gender equality, a young workforce, central government debt and inequality. Their isolation and reliance on limited economic sectors make them particularly sensitive to external shocks.

According to data from the ILO, 765 million people live in countries exposed to climate change and work in industries vulnerable to extreme heat, such as agriculture and construction.

Among the most vulnerable countries and territories globally, Papua New Guinea, Angola, Mozambique, South Sudan, and Bermuda stand out. These places face challenges that significantly impair their ability to achieve the Sustainable Development Goals. The most vulnerable SIDS include Papua New Guinea, Bermuda, Puerto Rico, the Northern Mariana Islands and the United States Virgin Islands. These islands are particularly at risk because of their small economies, limited resources and exposure to environmental hazards. Angola, Mozambique, South Sudan, Cambodia and Lesotho are the most vulnerable LDCs. These countries struggle with pervasive poverty, weak institutions and limited access to global markets. Among LLDCs, South Sudan, Lesotho, the Lao People's Democratic Republic, Zambia and Chad are the most vulnerable, facing significant challenges related to their geographic isolation, dependence on transit countries and limited infrastructure, all of which hinders their economic development and integration into global trade networks.

According to data from the ILO (ILO, 2024c), 765 million people live in countries exposed to climate change and work in industries vulnerable to extreme heat (see **box II.3**), such as agriculture (**box II.4**) and construction. These vulnerabilities especially affect older workers and pregnant women, along with migrant and informal workers and people with disabilities. Other social factors influencing physical vulnerability are described in the social vulnerability index assessing vulnerability to physical climate impacts (see **box I.2** and **figure I.6**). The effects can be mild, such as heat fatigue, or severe and life-threatening, including heat exhaustion, heatstroke, accidents and injuries, and electrolyte disorders. In the long term, extreme heat increases the risk of cardiovascular, kidney, respiratory and mental-health illnesses (ILO, 2024). Two hundred and forty-seven million women and 49 million people over the age of 65 years work in agriculture or construction and are expected to be exposed to extreme heat due to climate change.

Box II.4. Uncertain futures for coffee farms amid rising temperatures

Globally, the importance of coffee is framed not only by the assumption that it is one of the most widely consumed tropical crops but also by the number of people (farmers, roasters, baristas) whose income depends on the different activities associated with it, from harvesting and processing to distribution and retailing. It is estimated that roughly 125 million people's livelihoods depend on the production of coffee, including 25 million smallholder farmers in developing countries (Fairtrade Foundation, 2024).

However, with coffee production requiring temperatures to range between 18ºC and 22ºC (Scott, 2015), rising global temperatures and changing weather conditions threaten to bring about unwanted consequences, such as lower yields and a reduction in the area suitable for cultivation, which can especially affect farmers in vulnerable contexts (Grüter et al. (2022). Expected global suitability of coffee, cashew and avocado due to climate change. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. This map might not include all countries.

For example, it is anticipated that the world's cultivation area may shrink by as much as 50% by 2050 (IDB, 2022a). In addition, Mexico, the world's tenth-largest producer of coffee beans (USDA, 2024), presents rich empirical evidence of the struggles the coffee industry faces amid changing climate conditions, among other factors.

For at least the past two decades, Mexico has experienced a drop in both the size of its cultivation areas and, consequently, its production levels. Between 2003 and 2023, the surface dedicated to coffee cultivation decreased from 789,073 hectares (ha) to 699,506 ha (SIAP, 2024), while output registered a fall of around 34% in the same time frame, going from 1.621 million tons (MMT) to 1.058 MMT. It is not a surprise that the state of Veracruz, the country's second-largest coffee-berry producer, faces similar challenges (SIAP, 2024).

In Veracruz, two of the leading producing regions are Coatepec and Fortín. In the last 20 years, Coatepec's output contracted from 0.092 MMT to 0.049 MMT, and that of Fortín, from 0.210 MMT to 0.126 MMT (SIAP, 2024). The local economies are heavily tied to coffee production as a means of livelihood, which means that 86,000 producers and their families count on it for their financial stability (Gabriel-Hernández and Barradas, 2024).

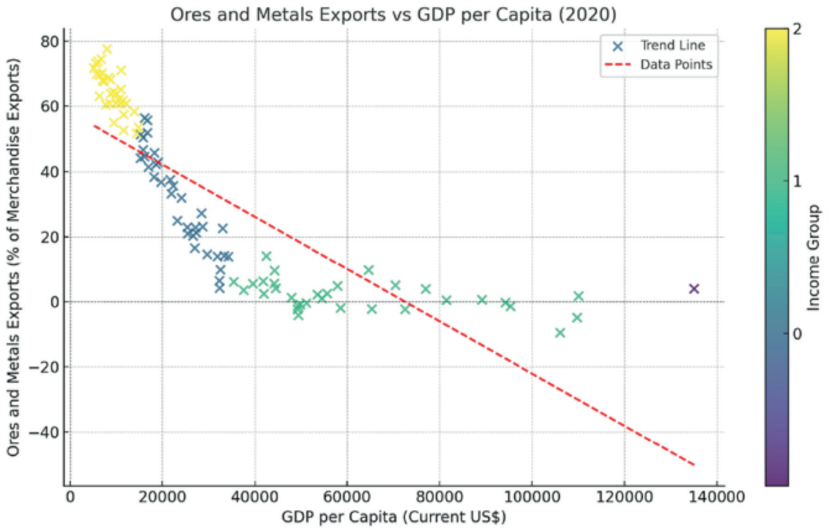
Climate change has emerged as one of the key factors driving huge challenges in this region. Farmers report several climate-related issues which make their crops vulnerable, including rising temperatures, unpredictable precipitation and prolonged droughts (Ronzón Benítez, 2020). Lengthy heatwaves cause coffee flowers to dry out, which reduces the quality of beans and yields, negatively affecting market prices. Greater levels of humidity, another outcome of changing weather patterns, encourage the appearance and spread of diseases such as coffee leaf rust (*roya*), which could also lead to substantial production decreases. Erratic rainfall affects flowering and harvesting cycles, increasing production costs while affecting yields (Ronzón Benítez, 2020). Likewise, heavy precipitation causes coffee flowers to drop prematurely, resulting in smaller, lower-quality beans. All in all, these climate-induced issues are both a menace to coffee output and a threat to the livelihoods of communities worldwide.

The second type of risk which workers face is that posed by climate transition. This risk affects employees in sectors such as manufacturing, mining and energy, which are particularly exposed to shifts towards cleaner production methods. Without adequate governmental safeguards – such as robust retraining programmes and income support – many workers could be left behind in the transition. Using the index of workers' vulnerability to climate transition impacts (refer to figure II.8 and box II.3), our analysis reveals that 325 million workers worldwide are employed in industries at risk from the climate transition. This includes 108 million women and 106 million individuals aged 45 years and older, highlighting the need for targeted support to address these vulnerabilities.

Workers in the manufacturing, mining and energy sectors are vulnerable to being left behind if, in a transition to cleaner production, governments do not establish sufficient safeguards for retraining and income support.

Artificial intelligence (AI) is also intensifying labour challenges in sectors transitioning to clean technologies. While AI is reshaping the workforce by automating tasks, creating new job opportunities, driving the demand for reskilling and augmenting human labour (IOE, 2024), it is simultaneously introducing environmental and social

Figure II.9. Ores and metals exports vs GDP per capita in 2020



Source: World Bank Data https://data.worldbank.org/

challenges (AI NOW, 2023). On the environmental front, AI's growing reliance on energy, often sourced from fossil fuels, increases electricity consumption and carbon emissions (box II.6). Regarding labour, AI poses risks such as job displacement and wage inequality, and it raises ethical concerns related to algorithmic bias (IOE, 2024). How societies address these issues will be crucial in determining whether AI's impact on the workforce is equitable and sustainable in the long run (see section II.8).

II.6. Who owns technologies and minerals critical to a net-zero future?

The impact of climate change on critical minerals is a pressing concern as the world shifts towards a low-carbon economy. Minerals such as lithium, cobalt and nickel and rare earth elements are indispensable for renewable energy technologies, electric vehicles and advanced electronics. As the demand for these technologies surges, so too does the need for the minerals required to produce them. This escalating demand is closely tied to global efforts to mitigate climate change, and yet it also introduces several challenges, including those posed by supply-chain vulnerabilities, environmental repercussions and economic dependencies. Addressing these challenges is essential to ensuring a sustainable and equitable transition to a low-carbon future (OECD, 2023).

The impact of climate change on critical minerals is a pressing concern as the world shifts towards a low-carbon economy [...] Developing nations which are heavily reliant on the export of ores and metals may find themselves in a precarious situation as they attempt to balance economic growth with sustainable development practices

These technologies require substantial amounts of critical minerals, driving up global demand. However, the impact of this demand varies significantly across countries. Developing nations which are heavily reliant on the export of ores and metals may find themselves in a precarious situation as they attempt to balance economic growth with sustainable development practices. **Figure II.9**. provides an enhanced visualization of this relationship, showcasing the interplay between GDP per capita and ores and metals exports as a percentage of merchandise exports. The scatterplot is categorized into three income groups (low, middle and high income), and it shows a clear negative trend, with a regression line reflecting a correlation coefficient of -0.151. This trend indicates that countries with higher GDP per capita tend to rely less on ores and metals exports, highlighting their ability to diversify their economies away from primary-resource dependency.

In contrast, many developing countries appear increasingly dependent on the export of these critical minerals as global demand rises. This heightened reliance could come at the expense of efforts to diversify their economies and achieve long-term sustainability. The challenge for these nations lies in managing the dual pressures of meeting international demand while simultaneously pursuing economic diversification and adhering to sustainable practices. Without careful management, there is a risk that these countries could become more entrenched in resource dependency, making it harder to achieve broader economic and environmental goals, especially with regard to the two issues discussed below.

Supply-chain vulnerabilities
Extreme weather events, such as floods, droughts and hurricanes, can disrupt mining operations and transportation networks, leading to supply shortages and price volatility. Moreover, many critical minerals are sourced from regions that are highly susceptible to the impacts of climate change, exacerbating the vulnerability of these supply chains. It is also relevant that more than 54% of transition minerals (lithium, cobalt, nickel, etc.) are found in or near Indigenous territories (Owen et al., 2023).

Environmental and social impacts
The extraction and processing of critical minerals can have significant environmental consequences, including habitat destruction, water pollution and increased greenhouse gas emissions. These activities often occur in countries where environmental regulations may be less stringent, further amplifying the impact (Moghimi Dehkordi et al., 2024). Additionally, the social implications of mining, such as displacement and labour exploitation, can be severe, particularly in regions where governance is weak. .

Countries are increasingly adopting new energy technologies, as illustrated in **figure II.10**. However, research on and manufacturing of renewable energy technologies remains highly concentrated in a few geographic regions. Over the last decade, global solar manufacturing has increased tenfold, yet the production capacity is predominantly situated in just a handful of countries. Currently, five nations possess 90% of the world's capacity for producing solar modules: China, which alone accounts for 60% of the global capacity for solar PV (photovoltaics), wind and battery production combined, followed by Viet Nam, India, Malaysia and Thailand. This concentration illustrates the strategic dominance of these countries in the renewable energy supply chain.

Currently, five nations possess 90% of the world's capacity for producing solar modules: China, which alone accounts for 60% of the global capacity for solar PV, wind and battery production combined, followed by Viet Nam, India, Malaysia and Thailand.

In contrast, Europe holds a leading position in the manufacturing of wind-turbine components, with several European countries playing a crucial role in the global supply chain. This geographical concentration of manufacturing and research capabilities presents both opportunities and risks. On one hand, it allows for economies of scale and rapid technological advancements in these regions. On the other hand, it creates vulnerabilities in global supply chains, particularly in the face of geopolitical tensions, trade restrictions or disruptions caused by natural disasters.

The production and sale of electric vehicles face challenges similar to those encountered in the adoption of clean energy generation technologies. A small number of countries and regions – primarily China, Europe and the United States of America – hold a dominant position in patents for, manufacturing of and sales of hybrid and electric vehicles. While projections suggest that one in five vehicles sold by the end of this decade will be ultra-low GHG emission models (IEA, 2024c), the persistent dominance of internal combustion vehicles – particularly for heavy-duty applications in transporting goods and passengers, and in construction – poses significant obstacles to achieving carbon neutrality in the transportation sector by 2050. This challenge spans across land, maritime and aviation transportation modes. Without widespread access to and adoption of low-carbon transportation solutions in emerging and developing economies, the global goal of limiting temperature increases to 1.5°C will remain out of reach.

As the demand for renewable energy and clean technologies continues to grow, there is an increasing need for a more diversified and resilient global manufacturing network based on massive technology transfer and corporative and private-public agreements and initiatives. Expanding manufacturing capacity to other regions could not only mitigate supply-chain risks but also foster broader economic development and job creation in emerging markets. Furthermore, reducing the concentration of manufacturing in a few countries would enhance global energy security and help to ensure a more equitable transition to a low-carbon economy.

II.7. Artificial intelligence: a double-edged solution in climate scenarios

Artificial intelligence has immense potential to accelerate climate-change transitions by optimizing energy systems, improving climate predictions and driving efficiency across sectors. However, its energy consumption and distributional effects need careful management to ensure that the benefits of AI are shared equitably across regions and social groups, particularly in the context of a just transition to a sustainable and inclusive green economy.

Artificial intelligence and the big data revolution are profoundly shaping responses to the climate crisis, but they also present significant challenges, particularly regarding their social and environmental dimensions (Lewis et al., 2024). AI infrastructure is geographically dispersed and heavily concentrated within private companies, not

Table II.1. Global trends in digital and energy indicators, 2015-2050

Indicator	2015	2022	Projected 2050	Change (2022-2050)
Internet users (billions)	3	5.3	9-10	89%
Internet traffic (zettabytes)	0.6	4.4	40-60	+800-1,200%
Data centre workloads (millions)	180	800	5-7	+525-775%
Data centre energy use* (TWh)	200	240-340	800-1,000	+135-240%
Cryptomining energy use (TWh)	4	100-150	1,500-2,000	+900-1,200%
Data transmission network energy use (TWh)	220	260-360	700-1,000	+180-275%

*Excluding crypto

Source: IEA Data Centres and Transmission Networks (IEA, 2023a) and authors' own assumptions

only posing a complex challenge as to estimating its energy usage, but also raising concerns about equity, governance and access. Labour reallocation driven by AI-induced productivity gains in certain advanced sectors, which concentrate its short-term benefits, could give rise to a new form of Baumol's disease. This phenomenon may lead to rising costs of other essential goods and services, exacerbating inequalities within service sectors and deepening economic disparities between nations, ultimately widening the global economic divide (OECD, 2024d).

The concentration of AI-driven climate solutions in specific regions and communities risks excluding marginalized groups and underrepresented areas from their benefits, while disproportionately burdening the populations in the places in question with the environmental costs of energy-intensive technologies. To address these inequities, it is crucial to adopt a more inclusive and transparent approach to the development and deployment of AI in climate action. This includes efforts such as integrating renewable energy sources to power AI technologies, ensuring that the advantages of these innovations are equitably shared and their burdens fairly distributed.

According to the IEA, energy consumption for AI was estimated at 460 TWh in 2022, roughly 2% of global energy demand. This figure is projected to increase by at least 50%, reaching between 620 and 1,050 TWh by 2026 (see **table II.1** for disaggregated data).

AI is a double-edged sword in the context of the climate crisis. While it contributes to rising energy consumption and emissions, it is also heralded as one of the most promising tools for accelerating emissions reductions across industries and productive sectors, such as agriculture (Chen et al., 2023). Some of the most powerful applications of AI include forecasting solar energy production, optimizing heating and cooling systems in buildings, detecting deforestation through satellite imagery, and analysing corporate financial disclosures for climate-related insights (GPAI, 2021). However, the degree to which these innovations can offset AI's own environmental footprint remains uncertain, highlighting the need for careful balance between technological advancement and sustainability. More precise, more detailed data are essential to understanding better the GHG emissions associated with the rapidly growing AI industry.

Artificial intelligence and the big data revolution demand a heavy toll on the climate crisis.

The UNESCO's "Recommendation on the Ethics of AI" asks Member States and businesses to assess the direct and indirect environmental impacts of AI systems and ensure that AI solutions help support the prevention, control and mitigation of climate-related problems (UNESCO, 2021). These include carbon footprints, energy consumption and raw material extraction (Strubell et al., 2020). AI models should address such concerns and their environmental footprint (Li et al., 2023) by developing energy-efficient algorithms, optimizing computing resources, and implementing sustainable practices in AI infrastructures (Ligozat et al., 2022). This includes designing algorithms which require less computing power or use renewable energy sources to power AI systems. These efforts can reduce the carbon footprint (Dhar, P. 2020) of AI and contribute to climate change mitigation and the sustainability of AI (Wu et al., 2022; Van Wynsberghe, 2021).

Box II.5. Some figures with regard to artificial intelligence's environmental burden

- A 2023 study revealed that training GPT-3 in data centres of the United States directly consumed 700,000 litres of clean fresh water – equivalent to producing 370 BMW cars or 320 Tesla electric vehicles. This water usage would triple if the training occurred in Microsoft's Asian data centres (Li et al., 2023).
- It is estimated that global AI demand will consume 4.2-6.6 billion cubic meters of water withdrawal in 2027, which is more than the total annual water withdrawal of 4 to 6 Denmark (Li P. et al., 2025).
- A common AI training model can emit more than 626,000 lb of CO_2 equivalent – about five times the lifetime emissions of the average car, which include the emissions from the manufacture of the car itself (Strubell et al., 2019).
- The training of BLOOM (the less energy-intensive of the four language models analysed by the Stanford Institute for Human-Centered AI, namely BLOOM, GPT-3, Gopher and OPT) emitted 1.4 times more carbon in one year than the average American, and the equivalent of a single passenger flying from New York to San Francisco 25 times. BLOOM's training consumed enough energy to power the average American's home for 41 years (Maslej et al., 2023).

II.8. Job creation and opportunities for a just transition

The global energy sector is at a critical juncture. For the first time, investment in clean energy technologies (renewables, electric vehicles, low-emissions fuels, nuclear power, heat pumps, storage and grids) is projected to reach $2 trillion, or twice as much as the amount destined for fossil fuels by the end of 2024, which is expected to stand at $1 trillion, according to the estimates of the International Energy Agency (IEA, 2024b). While this milestone is a testament to the pressing need to transition towards more sustainable and low-carbon energy sources, the truth is that renewables, hydropower and nuclear power continue to represent only 18.53% of global primary energy consumption (or 50.58 exajoules) as at 2023. Accounting for 81.47%, fossil fuels dominate the world's energy mix. Out of a total consumption of 619 exajoules worldwide, 504.83 exajoules came from oil, natural gas and coal (EI, 2024).

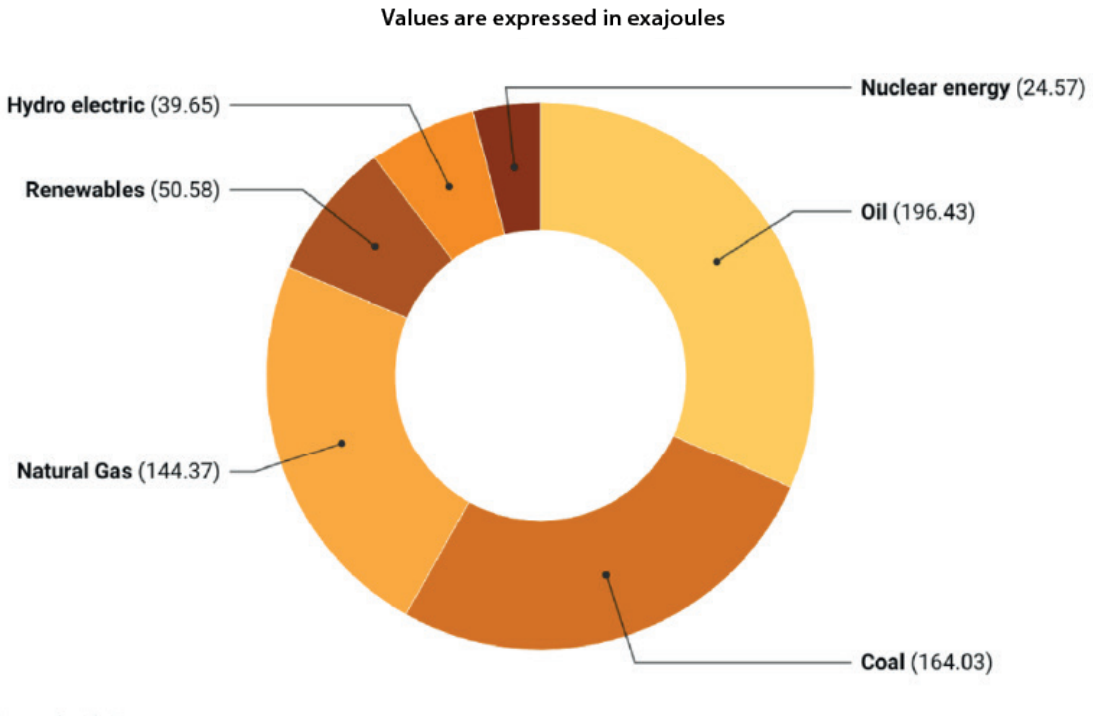
The global transition to renewable energy constitutes not only an environmental imperative but also a tremendous opportunity for economic growth and job creation. As the world shifts away from fossil fuels to embrace renewable energy sources, the demand for new skills, technologies, and infrastructure will create millions of jobs across various sectors. This transformation is central to achieving a just transition, where the benefits of the energy transition are shared equitably, and the impacts on workers and communities are managed with care.

The global transition to renewable energy constitutes not only an environmental imperative but also a tremendous opportunity for economic growth and job creation.

The structure of the world's energy system (see **figure II.11**) can be viewed as a delicate balancing act between fossil fuels and low-carbon solutions which both developed and developing nations will have to manage in the decades to come. In this process, the trends which are likely to shape our energy future include those listed below.

- **Geopolitical events**. Recent events, such as the outbreak of coronavirus disease (COVID-19) and the Russian Federation's invasion of Ukraine, have created havoc across global energy markets, raising concerns about the security of supply. This scenario, along with higher prices for energy commodities, consumer goods and foodstuffs, underscored the pressing need for countries to diversify their energy sources. A more significant domestic deployment of renewables can shield countries from uncertainty in energy markets (WEF, 2022).
- **Regulations**. The transition to a low-carbon economy must be accompanied by a robust set of policies, regulations and even incentives. In the United States of America, the Inflation Reduction Act of 2022, which is designed to build more resilient supply chains and create an ecosystem for furthering the development of clean technologies, is a case in point (Senate Democrats, 2022). Developing countries face the challenge of finding solutions tailored to their context and financial capacity in order to take advantage of the opportunities presented by the energy transition (IRENA, 2024a).
- **Expansion of renewables**. Clean energy sources are expected to carry increased weight in the global energy mix (IEA, 2024e). For specific countries whose coal consumption is significant, the expansion of wind and solar energy can contribute to building a less carbon-intensive energy system (IEA, 2024e). In the upcoming decades, the challenge lies in the world's capacity to

Figure II.10. World's primary energy consumption by fuel, 2023



Source: Energy Institute, 2024.

finance a more rapid expansion of sustainable solutions while easing demand for fossil fuels, particularly in the global South.

- **The role of fossil fuels**. Despite the impressive growth which clean energy sources have experienced over the past decade or so, crude oil, natural gas and coal will continue to represent the largest share of the world's energy system in the foreseeable future (IEA, 2024d). Heating and power generation are sectors whose reliance on fossil fuels poses a significant challenge to the world's efforts to combat climate change and meet emission targets.

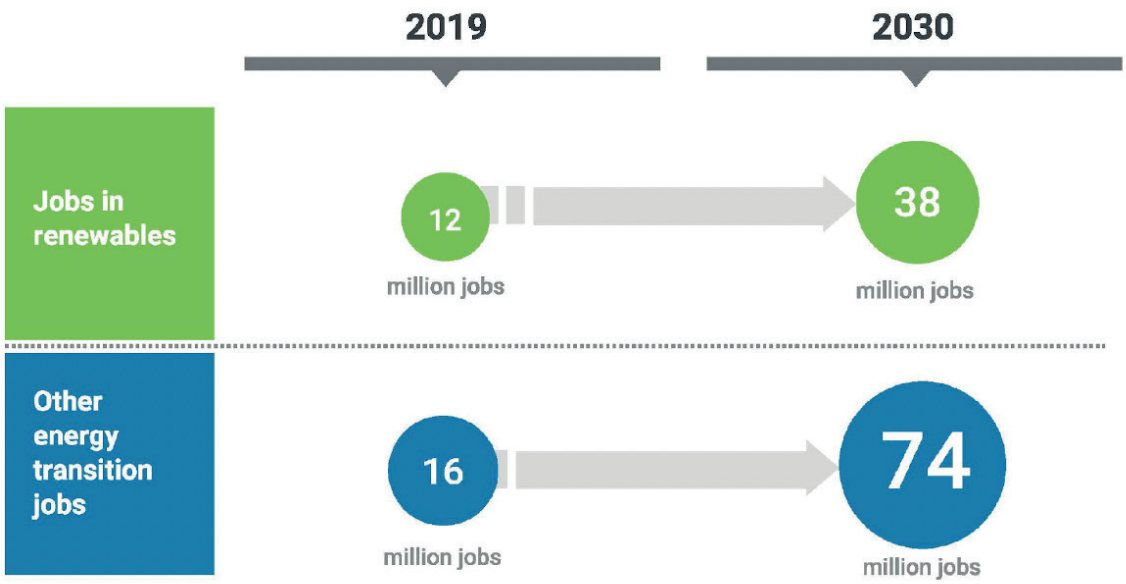
- **Innovation**. Driven by government-led incentives and private investment, technological advancements across the energy sector are set to shape the prospects of low-carbon solutions (IEA, 2023a). Progress in energy storage is pivotal to integrating variable renewable energy into the grid. Likewise, innovations related to the production of green hydrogen and sustainable fuels are crucial to helping decarbonize hard-to-abate sectors.

- **International partnerships**. For both rich and less developed countries, global cooperation is vital to achieving sustainable goals and strengthening the security of supply (IRENA, 2024b). In the decades to come, global stakeholders are expected to build partnerships with their counterparts either to access more affordable energy commodities or to finance low-carbon infrastructure projects.

The renewable energy sector has already shown remarkable growth in terms of job creation. Projections indicate that the sector is expected to create tens of millions of new jobs by 2030 and 2050 (**figure II.11**). These jobs will span a wide range of activities, from manufacturing and installation of solar panels and wind turbines to research on and development of new technologies and the maintenance of renewable energy infrastructure.

As global efforts to combat climate change intensify, energy transition policies are reshaping economic landscapes, particularly in the context of moving towards low-carbon economies. Emerging energy policies, such as those related to carbon pricing and renewable energy subsidies, are critical for reducing greenhouse gas emissions. However, their impact varies widely across regions. Developed countries with advanced technologies and infrastructure tend to integrate these policies more seamlessly, fostering growth in green sectors. In contrast, developing countries often struggle with limited resources and institutional challenges, making adopting of these policies more complex and potentially less effective.

Figure II.11. Jobs in renewables vs energy-transition jobs by 2030



Source: IRENA and ILO, 2023

The unintended social consequences of energy transitions are a significant source of concern. For instance, carbon pricing can increase energy costs, disproportionately affecting low-income households.

The unintended social consequences of transitions in energy and low-carbon technologies are a significant source of concern with regard to climate policies. For instance, carbon pricing and stringent GHG emissions standards can increase the cost of goods and services, disproportionately affecting low-income households. Additionally, the shift away from fossil fuels can lead to job losses in traditional energy, transportation and food production sectors, causing economic insecurity for workers who lack the skills to transition to new roles in a circular and low-carbon economy. These issues highlight the need for policies which are both effective in environmental terms and socially equitable.

Box II.6. Social responses and civil resistance to the core policies of the Paris Agreement (2015)

In May 2018, Priscillia Ludosky, a young micro-entrepreneur, launched an appeal (Ludosky, 2018), through the Change.org platform, for lower gasoline prices at service stations. Éric Drouet, a truck driver, signed up, and together they called for a protest against the carbon tax on diesel and gasoline which the French Government had announced would be applied in 2021. This tax was intended to accelerate the green transition, encouraging the replacement of diesel vehicles with less polluting gasoline-powered, hybrid and electric vehicles. An action to implement the Paris Agreement (2015) in the very site of its adoption.

The resulting three-week blockade of motorways, airports and roundabouts throughout France by hundreds of thousands of citizens, mainly from the countryside and city outskirts, caused the Government to back down on the tax (Duran, 2018).

It is clear that low-income citizens perceived the rise in fuel prices and the new ecological tax as an arbitrary policy and not as a positive measure of benefit to the general public. Above all, it is clear that they perceived it as an unfair measure, since independent workers who live in the countryside and on the outskirts of cities cannot go to work without their cars and find it expensive to buy new cars. Hence it was not difficult to add demands for wage increases, inflation control, significant tax deductions, and population consultation on these measures, to the other demands under the original banner of abolishing energy taxes.

Structural changes in the economy which are intended to reduce greenhouse gas emissions and fight climate change and which are driven by the Paris Agreement (2015) can sometimes be disruptive, as shown by the gilets jaunes protests in France 2018. And no wonder, since increases in fuel prices have historically been a strong trigger for political mobilization, as they directly affect the cost of living for the population. In France, 3.3 million cars use diesel, and in Europe, 19 million vehicles use this fuel (FNE, 2023). They are suspected of polluting with nitrogen oxide far above the levels legally permitted. For this reason, an increase in the price of diesel was promoted; the price was expected to equal that of gasoline in 2021, and with this, there would be a replacement of the vehicle fleet and a decrease in GHGs. The energy transition driven by the Paris Agreement (2015) provides for the mitigation of GHGs – which are responsible for anthropogenic climate change – as one of the central concepts of the green transition. The idea of "putting a price on carbon" to limit emissions of gases responsible for climate change was raised during the negotiations for the Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997). It is undoubtedly vital for everyone, but there are obstacles to its implementation.

In France, a significant part of the population lives in rural areas or on the outskirts of cities. This creates a dependence on the use of cars to travel to the workplace. In rural areas, 93% of households have a car, compared to 59% in Paris. In rural areas, the use of diesel cars is higher than in cities. Thus, the increase in diesel and gasoline prices particularly affects people who live in rural areas and who have lower purchasing power. On the other hand, the big polluters enjoy carbon-tax exemptions, so the rural population have to pay a higher tax and do not benefit from any reductions. Two thirds of the price increase at the pumps was linked to a phenomenon beyond the Government's control: the increase in the world price of a barrel of oil (Le Monde, Les Décodeurs, 2018). Knowing this does not prevent many low-income households from spending more than 15% of their budget to pay for gasoline. Thus, the push for a green transition in certain circumstances collides with the need to prevent an increase in poverty and existing inequalities. The gilets jaunes movement directly addresses not only the need for green transition policies, but also the need for policies which are socially fair and differentiated according to responsibilities.

The gilets jaunes protests against climate transition policies are not unique; similar protests have occurred worldwide throughout this decade. Since 2020, efforts to phase out coal mining and transition to renewable energy in Germany have faced resistance from coal workers and mining-dependent regions (Heinisch et al., 2020). The Government of Germany promised billions of euros in compensation and regional development to support a just transition. In Poland in 2021, the phasing out of coal mining and use and a European Union court order to immediately close a mine spurred protests by coal miners and other energy sector workers (Baran et al., 2020).

In 2024, protests erupted in Germany, after the federal government decided to phase out tax breaks on agricultural diesel. Farmers demanded a full reversal of the cuts, arguing that continued support for diesel subsidies and motor vehicle tax exemptions is essential for the competitiveness of German agriculture. The protests reflect broader

tensions between the EU's climate objectives—particularly in cutting fossil fuel use—and the economic realities faced by farmers. A response to the European Green Deal, that aims at making the EU carbon-neutral by 2050 by cutting fertilizer use, limiting nitrogen emissions, reducing pesticide use, and requiring 4% of farmland to be left fallow. Farmers argue that these policies increase costs and lower productivity. Moreover, cheaper imports from non-EU countries with looser standards—such as Ukraine and Mercosur nations—further undermine their competitiveness.

In India in 2020, farmers nationwide protested against Government legislative reforms (Ruparelia, 2021) perceived as corporate-friendly and dismissive of the climate-related vulnerabilities of agricultural livelihoods in India. After prolonged demonstrations, the Government repealed the laws. Rising electricity rates linked to shifts to cleaner energy sparked protests in 2021 in Kenya, particularly in low-income communities. The backlash pressured the Government to reassess energy policies (Rotich et al., 2024) to ensure affordability. Since 2021, the Government of Ecuador has attempted to remove fuel subsidies, causing sharp increases in fuel prices and triggering nationwide protests, mainly by Indigenous groups and low-income communities. The Government thus reinstated subsidies to quell unrest (Vogt-Schilb and Soria, 2019). In the Kingdom of the Netherlands, the Government has been promoting a plan of action for the transition to circular agriculture since 2023. It entails reducing nitrogen and ammonia emissions. The uncertainty of the plan, which will reduce livestock numbers by 30%, has led to protests by farmers (LNV, 2019).

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Conclusions and policy recommendations

Climate change presents a multidimensional challenge which exacerbates social inequalities, drives forced migration, threatens cultural heritage and disrupts labour markets. As countries shift to low-carbon economies, it is essential to ensure that vulnerable populations receive priority support, displaced individuals are integrated into sustainable migration pathways, and cultural heritage sites are safeguarded. This report delivers a focused set of conclusions and policy recommendations, grounded in our innovative indices, which illuminate previously unknown or partially understood climate change impacts and dynamics. These insights aim to promote an inclusive, resilient and sustainable transition.

The inequalities exacerbated by climate change and the policies designed to mitigate its impacts can create complex and often unintended negative synergies that demand urgent attention on the international stage. These dynamics disproportionately affect vulnerable populations, deepening existing socioeconomic disparities and creating new forms of exclusion and hardship. Climate change does not affect all regions or communities equally; marginalized groups, particularly in developing nations, are often on the front lines, bearing the brunt of environmental degradation, food and water insecurity and extreme weather events.

The consequences of neglecting these inequalities in the short term could be devastating, as demonstrated by the prolonged droughts in the Syrian Arab Republic (Kelley et al., 2015). In the most extreme cases, we see large-scale humanitarian crises, such as forced migration, where entire communities are displaced from their homes because of rising sea levels, prolonged droughts or devastating floods. In these situations, people lose not only their livelihoods, but also their cultural and social foundations. The intensification of climate-related disasters such as hurricanes, wildfires and heatwaves can upend the lives of millions within a single season, overwhelming response systems and causing tragic loss of life.

These challenges are further intensified when climate mitigation policies, despite their good intentions, fail to account for local contexts or inadvertently deepen existing inequalities. For instance, policies promoting renewable energy or electromobility can create new job opportunities in emerging sectors but often lead to job losses in traditional industries, leaving workers and entire communities marginalized. The recent United Auto Workers (UAW) strike in the United States of America highlights these tensions (Dupuis et al., 2024). If international climate agendas do not place equity and justice at their core, they risk perpetuating cycles of inequality which threaten global stability and hinder the collective pursuit of sustainable development. The urgent need for inclusive and equitable climate action has never been greater.

Drawing on the data compiled and analysed, as well as on the numerical and geographical insights derived from the three indices developed for this report (see Annex I), we have produced the recommendations discussed below. The indices were meticulously designed to assess the nuanced distributional impacts of future climate scenarios on populations' socioeconomic conditions, in addition to the magnitude of those impacts. The recommendations are organized hierarchically, progressing from broad, overarching themes to more targeted and actionable measures, aligned with the report's key focus areas.

Achieving the Sustainable Development Goals: critical to eradicating deep-rooted and historical inequalities

Achieving the Sustainable Development Goals of the 2030 Agenda is imperative to avoiding an unjust climate transition. These goals are designed to create a more equitable world by fostering economic growth, social inclusion and environmental protection. If successfully implemented, the SDGs could significantly diminish the adverse impacts of climate change, particularly among the world's most vulnerable communities. This would also avert potential humanitarian tragedies, such as climate migration. By uniting global efforts collectively, we can ensure that the benefits of sustainable development are shared broadly and equitably, thus safeguarding both our planet and its inhabitants for future generations.

Incorporate SDG 10 and SDG 13 jointly into government budgetary plans and programmes. When examining the Sustainable Development Goals related to climate change (SDG 13) and the reduction of global inequalities (SDG 10), governments should advance both interconnected objectives. They should take urgent action to combat climate change and its impacts (SDG 13), raising awareness and building human and institutional capacities with regard to climate change mitigation, adaptation, impact reduction, and early warning systems (SDG 13, Target 13.3). Simultaneously, governments must reduce inequality within and among countries (SDG 10), placing strong emphasis on empowering and promoting the social, economic, and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status (SDG 10, Target 10.2).

Promote a comprehensive and synergistic approach to advancing SDGs 1, 5 and 7, ensuring that their interconnections are leveraged for maximum impact. Progress towards the achievement of SDG 13 and SDG 10 is deeply interlinked with other SDGs, such as SDG 1 (no

poverty), SDG 5 (gender equality) and SDG 7 (affordable and clean energy). Achieving these goals requires a holistic approach in key governmental ministries and agencies, considering the multifaceted nature of climate change and inequality. For instance, ensuring access to clean energy can reduce poverty and carbon emissions; promoting gender equality can lead to more effective and inclusive climate action.

Promote strategic environmental assessment (SEA) to minimize the environmental and climate impacts of economic development plans and programmes. Many nations have yet to modernize and align their environmental policy and regulatory frameworks, including procedures for environmental impact assessment (EIA) and environmental and social impact assessment (ESIA). These instruments remain largely fragmented, failing to evolve into integrated governance systems capable of ensuring that decision-making in economic and productive sectors – particularly those driven by short-term priorities – is sustainable and aligned with SDGs and broader environmental and social goals (see 2024 IAIA guidance).

Prioritizing adaptation and resilience: a strategic pathway for social protection and financial and technological investments

Equitable policy responses are essential to ensuring that climate adaptation strategies and actions are not limited to specific regions, sectors or communities but are instead universally strengthened across the whole population. This requires a shift towards inclusive decision-making processes, where local knowledge and social needs are integrated into climate action plans. By ensuring that no one is left behind, we can foster a just transition towards a more resilient and sustainable future – one where climate action not only mitigates the impacts of global warming but also addresses the underlying inequalities which exacerbate its effects.

Strengthen social protection systems through NDC adaptation strategies. NDCs must include a social dimension, with metrics which specifically address the expansion of healthcare and well-being services. These services should align with the projected climate impacts for each region or country, prioritizing the areas of greatest need. Explicit references to these social priorities must be incorporated into NDCs to enable precise quantification of the human, technological and financial efforts required.

Prioritize climate finance with a vulnerable-first approach. Leverage indices such as the climate change exposure index and the social vulnerability index assessing vulnerability to physical climate impacts, or similar metrics, to strategically guide the allocation of climate finance. This approach ensures that resources are directed towards regions and communities in countries which face a high degree of climate exposure and possess low adaptive capacity. By prioritizing these areas, climate finance can effectively address critical vulnerabilities, enhance resilience and foster equitable adaptation efforts.

- ***Top priority regions***: Africa, South Asia and the Americas, focusing on countries where social and physical vulnerabilities intersect.

- ***Critical investments***: Strengthen health and social protection systems, develop resilient infrastructure, promote sustainable agriculture and enhance disaster preparedness.

Create legal frameworks and allocate loss and damage funds to support planned and emergent climate migration. Addressing the needs of internal and international climate migrants – one of the most pressing humanitarian challenges on the global warming agenda – must begin with acknowledging their existence, systematically identifying and monitoring their movements, and ensuring timely and effective assistance. This requires the establishment of robust institutional and governmental frameworks which strengthen national climate and human rights systems, while also being closely integrated and reinforced by international mechanisms. These frameworks must be designed to provide comprehensive support to climate migrants, who will increasingly confront complex and multifaceted challenges, ensuring their dignity, rights and resilience in the face of growing environmental pressures.

- ***Funding formula:*** Develop and implement a financial resource allocation model which distributes funding based on the proportion of displaced individuals relative to the total population in affected countries. This approach ensures equitable support for the most affected regions while aligning with the principles of fairness and inclusivity. Additionally, leverage the financial mechanisms established under the Paris Agreement (2015) to secure the necessary resources, reinforcing global solidarity and commitment to addressing climate-induced displacement.

Addressing the distributional impacts of climate policies: compensatory measures for vulnerable and affected populations

Promoting GHG mitigation and adaptation solutions across and within nations and regions, including the use of economic and financial instruments such as those related to carbon pricing, must prioritize equity to prevent undue burdens on vulnerable communities, sectors or regions already facing severe climate impacts despite minimal historical contributions to the problem.

Compensatory measures to shield affected groups, communities or enterprises. Effective climate policy must proactively avoid regressive impacts by embedding inclusive strategies which incorporate compensatory measures to shield affected individuals and social groups from additional economic or social burdens. These policies should uphold the principles of climate justice by ensuring that the transition to low-carbon solutions is fair, equitable and closely aligned with Sustainable Development Goals. This requires a design framework which fosters local solidarity, empowers the most vulnerable stakeholders, and ensures that they can benefit from and contribute to the transition to a carbon-neutral future.

Choosing worker solidarity over labour resistance as a path to inclusive transition. It is essential to ensure that workers displaced during the transition to sustainable systems are provided with comprehensive support. This includes access to reskilling and training programmes tailored to emerging job opportunities, as well as immediate income support where applicable. These measures are crucial to safeguarding livelihoods, fostering economic resilience, and enabling workers to successfully integrate into the evolving low-carbon economy.

Integrate gender considerations into key governmental plans and programmes addressing climate change risks. Ensuring an inclusive and equitable approach to gender in climate policies and actions is essential. Governments, particularly at the local level and within Indigenous territories, agricultural districts and natural protected areas, must actively avoid gender-blind initiatives in climate projects and investments. Instead, they should adopt gender-sensitive strategies which acknowledge and address the distinct vulnerabilities, needs and contributions of all genders. This ensures that climate actions can effectively promote equality, empowerment and resilience, fostering sustainable and inclusive development for all communities.

Promote community-led heritage preservation. Drawing on ancestral wisdom can transform environmental and climate adaptation efforts, making them more inclusive and effective. Actively involving local communities and Indigenous groups in conservation work ensures that traditional knowledge and cultural practices are not only respected but also seamlessly integrated into heritage preservation. Beyond this, it is vital to raising the social status of Indigenous populations, protecting them from marginalization and violence as they advocate for and defend their ancestral rights. By embracing their insights and honouring their contributions, we can create a more just and sustainable path forward.

Expand research on the distributional impacts of climate policies, prioritizing the development of advanced metrics to guide decision-makers and accurately assess outcomes. The current understanding of how climate policies affect diverse productive, commercial and service sectors, as well as various cultural groups and ethnicities, is still insufficient and requires significantly more attention at the governmental level. Institutions responsible for implementing NDCs, NAPs and LT-LEDS must proactively champion and support research on the subject to prevent regressive effects and to ensure that climate policies are equitable, inclusive and aligned with social justice goals.

Embedding climate education and awareness programmes for empowered action. Both formal and informal systems, including social media platforms, must be continually updated to reflect the latest advancements in climate-change science and its pressing challenges. Education systems must evolve to meet emerging human development and capacity-building needs, equipping individuals with the knowledge and skills required to navigate the complexities of climate issues. By promoting informed collaboration and fostering active participation, these systems empower communities to play a proactive role in developing adaptive solutions and reducing GHG emissions. This holistic approach is essential not only for meeting national and short-term climate commitments, but also for building resilient societies capable of driving long-term sustainability and transformative change.

Accelerating the widespread deployment of clean and zero-emission technologies: unlocking the critical potential of technology transfer

Developing countries possess a crucial advantage in their younger, more adaptable workforce. Still,

this potential can only be fully realized through effective technology transfer and capacity-building for a massive deployment of clean, zero-emissions technologies. Without access to the advanced technologies and expertise necessary for driving clean-energy innovation, local industries in these nations risk becoming obsolete in the rapidly evolving net-zero global economy. Technology transfer from developed countries is crucial to bridging this gap and empowering developing nations to participate actively in the clean energy transition. Skilled workers with the right tools and knowledge will be much better positioned to capitalize on the opportunities of a net-zero future, making education and technical training essential priorities.

A comprehensive approach to technology transfer is particularly vital in energy resilience. Many developing countries, especially those with economies highly dependent on hydroelectric power, are acutely vulnerable to climate-change-induced disruptions affecting water availability and stability. These countries must diversify their energy mix, incorporating a more comprehensive array of low-carbon technologies – such as solar, wind and geothermal technologies – to enhance resilience and reduce over-reliance on a single energy source. However, the reality is that many developing nations are not producing renewable-technology patents on a meaningful scale and lack significant investment in research and development (R&D). This deficiency places them at a structural disadvantage in the global race towards sustainable energy solutions.

In summary, technology transfer from developed to developing countries is pivotal in shaping a global net-zero future. Without it, the clean energy transition risks leaving developing nations behind, widening the gap between those with access to cutting-edge technologies and those without. The path to a resilient and inclusive energy future requires coordinated international efforts to share technology, build capacity and develop the human capital needed to power the next generation of clean energy innovation.

Integrating technology transfer strategies and investments into NDCs and national development plans. For technology transfer to be effective, it must go beyond the mere provision of equipment or training of technicians. It should include the sharing of intellectual property, know-how and best practices, substantial investments in capacity-building, and institutional strengthening. Developed countries, with their wealth of experience in renewable technologies, must actively support these efforts, facilitating not only the flow of capital and innovation, but also creating frameworks for cooperation in R&D. International climate finance mechanisms, public-private partnerships, and more robust international collaborations are all essential for ensuring that developing countries have both the technological capabilities and the workforce skills required to thrive in a decarbonized world.

Advancing regulatory frameworks for technology transfer at the local level. Local governments in developing countries must prioritize establishing favourable conditions for effective technology transfer. This involves strengthening regulatory frameworks, designing attractive financial incentives, investing in human capital development and nurturing local innovation ecosystems. Policies which encourage research and development, foster international collaboration and empower local entrepreneurs are critical to ensuring that technology transfer not only addresses immediate needs but also drives sustainable industrial growth and enhances resilience over the long term.

Prioritize sustainability approaches in the research, development and demonstration (RD&D) of emerging and advanced technologies. Innovations such as artificial intelligence, electric vehicles, zero-GHG hydrogen, as well as organic, protected and precision agriculture, among other technological solutions, must be pursued through climate-transition and sustainable principles. This shift is essential to preventing a short-sighted reliance on energy sources with high carbon intensity over their life cycles; it ensures that these technologies contribute to long-term environmental goals rather than exacerbating carbon footprints or environmental degradation processes.

Low-carbon supply chains should be supported and prioritized. Supporting and prioritizing low-carbon supply chains is essential to reducing global emissions and achieving climate targets. International trade regulations and organizations should actively incentivize and favour goods and services which originate in low-carbon supply chains, aligning with global climate neutrality programmes. This approach not only minimizes carbon footprints across production and distribution stages, but also drives innovation in sustainable practices, creating economic opportunities within green sectors. Encouraging such supply chains fosters resilience to climate-related disruptions, promotes responsible resource management, and positions low-carbon goods as the standard in a climate-conscious global market.

Safeguarding cultural and natural heritage from climate change threats: a call to action

Cultural heritage sites worldwide are increasingly vulnerable to climate change. Many are located in natural protected areas which are also home to Indigenous communities. Rising sea levels, floods and extreme weather events threaten to damage or destroy these sites and ecosystems, which not only have historical significance but also embody vital aspects of community identity and shared memory. The loss of cultural heritage diminishes human diversity and weakens resilience by severing communities from their history and natural environment.

Preserving these sites is essential to sustaining both cultural and ecological continuity, fostering global solidarity and strengthening resilience in the face of climate change. Preserving Indigenous cultural heritage and Indigenous Peoples' profound knowledge of ecosystems and sustainable biodiversity practices not only is essential for cultural survival but also constitutes a critical strategy for global environmental resilience. This knowledge, rooted in centuries-old practices of harmonizing with nature, offers valuable insights for sustainable resource management and biodiversity conservation. It should be prominently integrated into the agendas of the United Nations' three major environmental conventions: the United Nations Framework Convention on Climate Change (1992), the Convention on Biological Diversity (1992), and the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (1994).

Moreover, the growing vulnerability of world heritage sites – both cultural and natural – demands immediate action. These sites, which have irreplaceable historical, ecological and cultural value, are increasingly threatened by climate change impacts, from rising sea levels and extreme weather events to biodiversity loss. Protecting these sites requires substantial financial investment, not only to prevent their degradation but also to ensure their restoration and adaptive resilience to future climate stresses. By fortifying these heritage sites, we can see to it that theirs is an active role in global climate solutions, demonstrating how historical and natural legacies can adapt and contribute to sustainability goals. They should not simply be passive relics at risk of loss, but dynamic examples of resilience and of conservation which avoids compounding the associated environmental challenges which require addressing.

Incorporate global cultural heritage preservation into the Loss and Damage Fund of the UNFCCC. Advocate for a dedicated percentage of the Loss and Damage Fund to be allocated to global cultural heritage preservation initiatives. These resources should support conservation efforts and disaster recovery for endangered heritage sites, ensuring their protection from the escalating impacts of climate change. Administered through UNESCO's World Heritage Fund, this allocation would not only safeguard irreplaceable cultural landmarks but also strengthen the resilience of communities whose identities and livelihoods are deeply intertwined with these sites.

Develop climate-resilient conservation strategies. Incorporate comprehensive climate risk assessments and adaptive management strategies into the preservation of cultural heritage sites. This approach should include the use of climate-resilient materials, innovative restoration techniques and robust disaster-preparedness measures to safeguard these invaluable sites from the increasing impacts of climate change. By proactively addressing vulnerabilities, these strategies ensure the long-term protection and resilience of cultural heritage sites while maintaining their historical and cultural significance for future generations.

Box III.1. The role of artificial intelligence in climate transitions and its distributional effects

Artificial intelligence has emerged as a transformative technology across industries and in the context of climate change mitigation and adaptation efforts. AI offers numerous opportunities to improve efficiency in energy systems, enhance climate modelling and optimize resource allocation. However, it also raises critical concerns regarding its energy consumption, its distributional impacts and the need for its equitable integration in global climate transitions.

1. **AI's potential to accelerate climate change mitigation**. Below are some key areas where artificial intelligence is playing a pivotal role.

- **Energy system optimization**: AI helps in optimizing renewable energy integration by improving grid efficiency, demand forecasting and energy storage management. AI-driven systems can predict fluctuations in renewable energy generation (such as that of solar and wind energy) and adjust power grids accordingly, enhancing the reliability of clean energy sources.
- **Climate modelling and prediction**: AI tools are improving climate models by processing vast amounts of climate data, making predictions more accurate. For example, AI can simulate extreme weather events, enabling early warnings and mitigating the impact of natural disasters exacerbated by climate change.
- **Smart agriculture**: AI solutions are being used to optimize agricultural practices, reducing carbon footprints through precision farming techniques. AI-driven systems can monitor soil health, water usage and crop productivity, minimizing the environmental impact of farming and contributing to food security in the face of climate stress.
- **AI in carbon capture and storage**: Also being explored is AI's potential for improving carbon capture technologies by predicting the best locations for carbon storage, optimizing processes to capture and store carbon more efficiently, and reducing operational costs in CCS facilities.

2. **Energy use of AI systems and data centres**. While AI holds promise for accelerating climate solutions, its growing use also raises concerns about the energy intensity of AI models, data centres and digital infrastructures.

- **Data centre energy use**: The rapid expansion of AI technologies has significantly increased the energy demand of data centres. According to the IEA, data centres and data transmission networks account for nearly 1% of global electricity demand, with AI models contributing to this growing energy footprint. If the trend continues, energy consumption will grow by an order of magnitude (see **table II.1.).**
- **Energy consumption of AI models**: Large AI models, especially deep learning systems, require substantial computing power, leading to high energy consumption. Training a single AI model can generate significant carbon emissions, depending on the energy source powering the data centre involved.
- **AI for energy efficiency**: Ironically, AI can also help reduce the energy consumption of data centres through optimization techniques. For instance, AI can optimize cooling systems, improve load balancing and enhance server utilization, leading to more energy-efficient data centres.

3. **Distributional effects of AI in climate transitions**

- **Energy access and equity**: AI-powered systems could disproportionately benefit developed economies with advanced digital infrastructure, leaving behind developing nations which lack the technological capacity to deploy AI at scale. This inequality could widen the gap in energy access and economic development.
- **Job displacement and creation**: The rise of AI in climate transitions could result in job displacement, particularly in traditional energy sectors such as coal and oil. However, AI also has the potential to create new jobs in renewable energy and smart agriculture, as well as in the field of AI-driven climate solutions. It is crucial to ensure a **just transition**, whereby workers in vulnerable industries are supported through retraining and new job opportunities.
- **Gender equity**: AI could exacerbate existing social inequalities if not implemented inclusively. Women in developing countries may face barriers to the training and resources necessary to benefit from AI-driven job opportunities in the climate sector. A **gender-equitable approach** ensures that women are not excluded from the AI-powered green economy.

4. **Policy recommendations for AI integration in climate change action**

- **Incentivize renewable energy for data centres**: Governments should promote the use of renewable energy to power data centres which support AI systems, ensuring that the environmental footprint of AI technologies is minimized.
- **Equitable access to AI technologies**: International cooperation is needed to ensure that developing countries have access to AI technologies for climate mitigation. Investment in digital infrastructure and capacity-building programmes will be critical.
- **Just transition policies**: Policymakers must design inclusive strategies to retrain workers displaced by AI and automation, particularly in carbon-intensive industries, ensuring a smooth transition to AI-driven jobs in the renewable energy sector.
- **Gender-equitable AI**: Governments and organizations must address gender disparities in AI education and training to ensure that women are equally represented in the workforce and benefit from AI-driven climate solutions.

Acronyms and abbreviations

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry and Other Land Uses
AI	artificial intelligence
AR6	Sixth Assessment Report
C3S	Copernicus Climate Change Service
CAT	Climate Action Tracker
CBAM	carbon border adjustment mechanism
CCS	carbon capture and storage
CIA	Central Intelligence Agency
CMIP	Coupled Model Intercomparison Project
COP	Conference of the Parties to the United Nations Framework Convention on Climate Change
EIA	environmental impact assessment
ESIA	environmental and social impact assessment
ETS	emissions trading scheme
EU	European Union
FAO	Food and Agriculture Organization
GDI	Gender Development Index
GDP	gross domestic product
GHG	greenhouse gas
GPAI	Global Partnership on Artificial Intelligence
HDI	human development index
IAM	integrated assessment model
IDB	Inter-American Development Bank
IDMC	Internal Displacement Monitoring Centre
IEA	International Energy Agency
IEP	Institute for Economics and Peace
IHA	International Hydropower Association
IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IZA	Institute of Labor Economics
LDCs	least developed countries
LLDC	landlocked developing country
LT-LEDS	long-term low greenhouse gas emission development strategies
NAP	national adaptation plans
NDC	nationally determined contributions
NGO	non-governmental organizations
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
Oxfam	Oxfam International
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PPP	purchasing-power parity
RCP	representative concentration pathway
R&D	research and development
SDG	Sustainable Development Goal
SEA	strategic environmental assessment
SIDS	small island developing State
SOP	standard operating procedure
SPEI	Standardized Precipitation-Evapotranspiration Index
SSP	shared socioeconomic pathway
UIS	UNESCO Institute for Statistics
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change (1992)
UNHCR	Office of the United Nations High Commissioner for Refugees
USDA	United States Department of Agriculture
WBG	World Bank Group
WEF	World Economic Forum
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

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Annex 1. Methodological note: climate change exposure index

The **climate change exposure index** used in this report considers hazards (changes in climate over an area) and exposure (population living in the area) at the national level for most countries around the world, based on subnational socioeconomic and climate data. The aim of the climate index is to quantify the projected change in exposure due to climate change, as opposed to current climate risk. Because the index does not consider all the possible extreme meteorological impacts of climate change, countries with an apparently low index value may still be highly exposed to other phenomena not considered herein, such as wildfires.

The objectives of the index are: to consider exposure to climate change in the context of a range of extreme weather events; to estimate the change in exposure with regard to population evolution; to achieve comparability between different exposure categories and within countries with a wide range of populations and climates; and to be simple enough to facilitate tracing back to the number of inhabitants affected. This index uses an inertial, or "middle-of-the-road", scenario: the IPCC's shared socioeconomic pathway SPP2-RCP4.5 (Riahi et al., 2017). In this scenario, population growth and development trends do not stray from historical trends. This scenario reflects a rise in temperature of approximately 2°C by 2050 and approximately 3°C by 2100. All impacts are calculated for the years 2040-2060 and the current period is defined as 1995-2014, as recommended for the consideration of impacts starting from a present-time baseline (IPCC, 2023). For sea-level rise, the current period is 2000 and the future period is 2060.

Five exposure categories have been selected: hurricanes, extreme precipitation, drought, extreme temperatures and sea-level rise. The climate variables used are, respectively: 100-year return period6 hurricane wind; annual one-day maximum rainfall7, measured as a percentage of average total annual rainfall; 12-month SPEI (measuring anomalies in surface moisture over the past 12 months; numbers below zero indicate drought and numbers above zero, the absence of drought) (Vicente-Serrano et al., 2010); annual number of days with a mean temperature above 35°C; and the 100-year return period coastal floodplain.

Present and future population, precipitation, drought and temperature data were obtained from the World Bank Group's Climate Change Knowledge Portal (WBG, 2024a) in the form of a 0.25°x0.25° global gridded data set8 derived from IPCC's CMIP (Coupled Model Intercomparison Project) climate model runs. Population projections consider international and internal rural-migration due to existing processes, but not the expected climate migration. Hurricane data come from the UNDDR Global Assessment Report 2015 (UNDDR, 2015). It must be borne in mind that the impacts of climate change on hurricanes are still poorly understood (Knutson et al., 2021). A general estimate is a 5% to 10% increase in storm intensity in a 2°C warmer world (Knutson et al., 2020); this factor (10%) has been used globally to produce a future wind-speed data set for this index. Sea-level rise data come from a paper by Neumann et al. (Neumann et al., 2015) and are the only data not available in a spatially explicit gridded form.

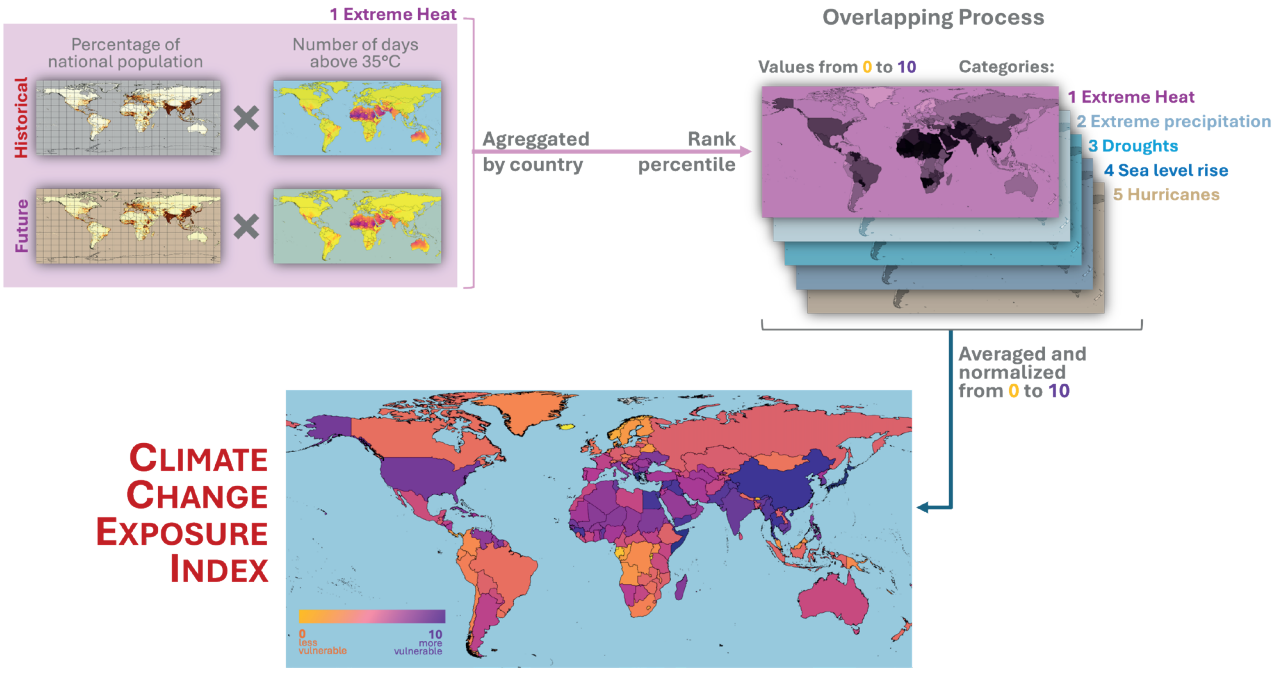
Using the 0.25°x0.25° gridded data climate and population data, each exposure category in the index is constructed as follows: in every grid cell the variable value of the historical data is multiplied by the historical percentage of national population to obtain a value measured in inhabitants-variable (e.g., inhabitants-wind speed). The same operation is repeated for future values, and then the subtraction of future data minus historical data is calculated. This methodology estimates the change in exposed population

6 The return period represents the average interval between occurrences of a specific event, such as an extreme weather phenomenon. For example, the 100-year return hurricane wind is the maximum hurricane wind expected to occur every 100 years on average.

7 The one-day maximum rainfall corresponds to the wettest day expected to occur in a given year.

8 Most climate change data is structured within a global grid system, where each cell represents a specific geographic area with aggregated climate values. For example, a commonly used resolution is 0.25° latitude by 0.25° longitude, meaning each square contains a representative mean annual temperature (or other climate variable) for that defined space. These grid cells collectively span from 0° to 360° longitude and -180° to 180° latitude, effectively mapping climate variables across the entire globe. This structured approach enables the analysis of localized climate conditions within any region while maintaining consistency in global climate assessments.

Figure A.1. Methodological process for development of the climate change exposure index



along a wide range of base values, allowing the comparison between regions with different climates.

The next step is to convert the gridded data to country-scale values. The value for each cell within a certain country is added to obtain a total number. Any negative change in exposure has been set as a value of 0, since the exposure index will be higher as the populations of countries become more exposed to the impacts of climate change. The last step to obtain the index for a given category is to calculate the rank percentile (a generalization of the classical statistical percentile which allows for repeated values) to obtain a value between 0 and 10. The final exposure index is calculated by averaging the five categories and normalizing the result to have a value of 0 for the least vulnerable country and 10 for the most vulnerable one. Therefore, each country has a value for each category and a final index value consisting of the combination of all categories.

The resulting index for each category therefore is higher the larger the population increase and the greater the change in climate for a given country. However, this does not directly represent a given population number. Regardless, the number of inhabitants affected can be obtained from the index by setting specific thresholds for each of the categories. They are: hurricanes, areas expected to receive landfall of a hurricane of category 4 or higher in a 100-year return period; extreme rainfall, areas where annual maximum one-day rainfall is at least 10% of the total annual rainfall; drought, regions where the 12-month SPEI is below -0.15; extreme temperature, areas with more than 12 weeks of daily temperatures above 35°C; and sea-level rise, the 100-year return period coastal floodplain.

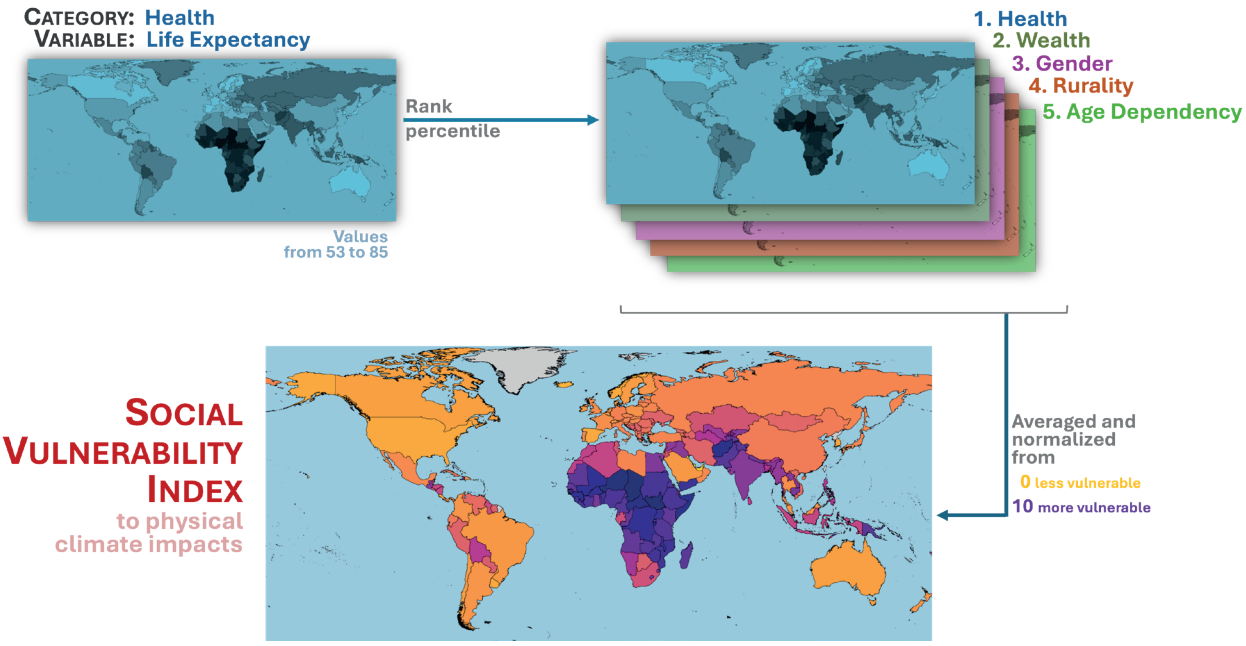
Social vulnerability index assessing vulnerability to physical climate impacts

The first social vulnerability index assesses individuals' vulnerability to the extreme weather events considered in the climate change exposure index (sea-level rise, drought, extreme temperature, extreme rainfall, hurricanes). It is also constructed in a manner similar to that of the climate change exposure index. The combination of the exposure index, which considers hazards and exposure, with the social vulnerability index completes a holistic climate risk evaluation (IPCC, 2015).

The extent of the present index is global and thus, with the objective of having available data for the largest possible number of countries, the variables are reported at a country-wide level. While social vulnerability has structural and personal dimensions, many of which are relevant at very local scales (Zuzak et al., 2022), national proxies have been considered for the categories considered in the literature as determinants of vulnerability9.

9 For an example of a local vulnerability index which considers similar categories measured using a large number of variables, see the U.S. Climate Vulnerability Index (https://climatevulnerabilityindex.org/).

Figure A.2. Methodological process for development of the social vulnerability index assessing vulnerability to physical climate impacts



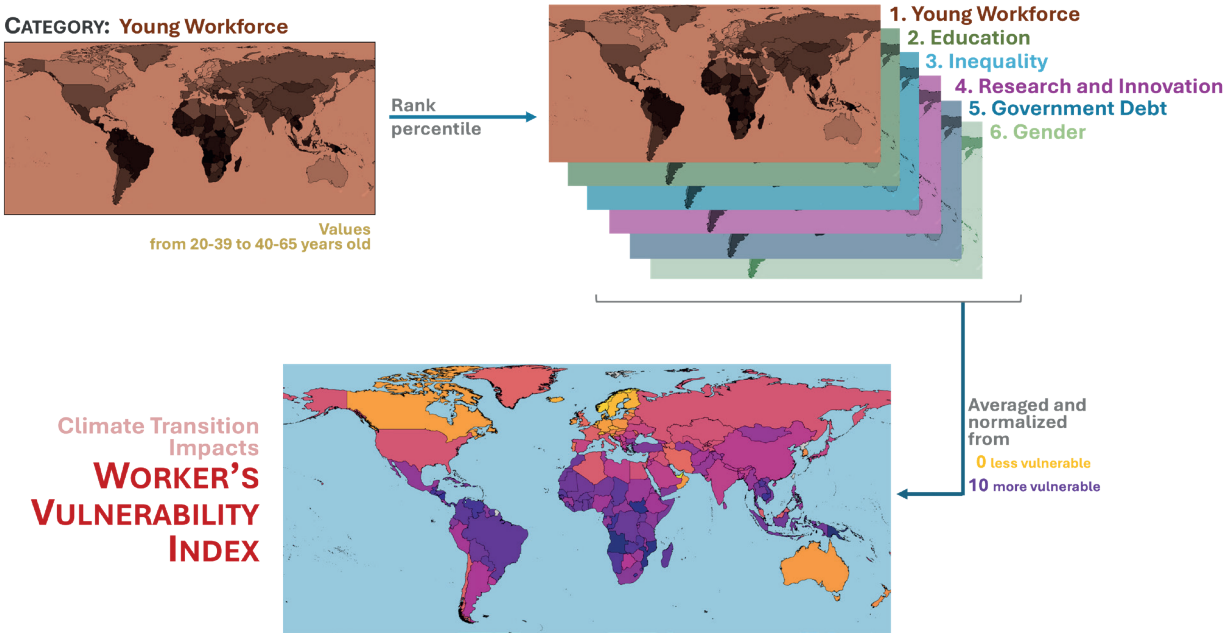
The index is composed of five categories: wealth, health, age dependency, rurality and gender. Each category is represented by one variable. Using a method similar to that of the climate exposure index, a country is assigned a grade from 0 (least vulnerable) to 10 (most vulnerable) according to its corresponding rank for each category. The final vulnerability index is calculated by averaging the five categories and normalizing the result to have a value of 0 for the least vulnerable country and 10 for the most vulnerable one.

For the wealth category, the selected variable is the wealth component of the HDI (log GNI per capita, PPP), as calculated by the UNDP (2024). It is relevant because higher income gives the population more agency to invest in adaptation measures, and to have assets (such as cars, air conditioning and so on) which improve mobility and reduce exposure (Leichenko and Silva, 2014; Otto et al., 2017). The variable for the health category is life expectancy at birth, reported as a component of the HDI by the UNDP (2024) and by several national Governments for their constituencies. Life expectancy is an indirect measure of the general health of individuals, which is important with regard to the comorbidities which can increase excess deaths, and the quality of the health system, including its ability to serve individuals during emergencies (Saito et al., 2014; Ebi et al., 2021). Age dependency is measured by the percent of the population under the age of 15 years or over the age of 65 years, using data from the World Bank Group's Population Estimates and Projections database (WBG, 2024). Young and old individuals are more affected by extreme events and have less agency because of their increased dependency (Sheffield and Landrigan, 2011; Huang et al., 2023). Rurality reflects the percentage of the population that is rural, according to the UNESCO Institute for Statistics (UIS, n.d.). Rural areas are generally less developed, with fewer health facilities, and their sparse population can mean that it is harder to provide them with emergency, early warning and preventive services (Dasgupta et al., 2015). For the last category, gender, the variable is the UNDP's Gender Development Index (UNDP, 2024). The GDI measures the difference in access to wealth, education and health between males and females, which makes women less resilient (Denton, 2002; Pearse, 2016).

Social vulnerability index assessing workers' vulnerability to climate transition impacts

The second social vulnerability index assesses workers' vulnerability to changes brought on by the net-zero transition (a rise in sustainable industries and a decline in fossil fuel industries) which affect skills and occupations. It is also constructed in a manner similar to that of the climate exposure index. Climate change poses numerous risks for global workers (Rosemberg, 2010). Two of the main factors which influence a just transition for workers in the face of climate change are a flexible and highly mobile workforce and a strong income support system (Ghaleigh, 2019). Fundamental to enabling a transition which leaves no one behind are trade adjustment assistance and income support (Barret, 2001), programmes which may involve high costs which will mostly be borne by governments.

Figure A.3. Methodological process for developing the index of social workers' vulnerability to climate transition impacts



An ageing workforce that has less flexibility and mobility is a hindering mechanism. Additionally, technical innovation and governmental support for new industries are important to avoiding sunk investments in industries which are no longer compatible with a future affected by climate change (Upham et al., 2014). The transition vulnerability index assesses personal and structural factors which enable and hinder a just transition for workers, considering the aforementioned factors which influence workers' vulnerability to the climate transition.

Economic sectors can be affected by physical risks due to extreme weather events (Moda et al., 2019) or to transition risks due to economic changes in markets (Lieu et al., 2019; Andres et al., 2023). Industries where workers will most be affected by physical risks are agriculture (Fenske and Pinkerton, 2021) and construction (Acharya et al., 2018); energy and fossil fuel extraction (Campiglio and der Ploeg, 2021), manufacturing (Ezeasor and Ozougwu, 2022) and mining (Carr-Wilson et al., 2024) are most at risk from transition factors.

The construction of the index assessing vulnerability to climate transition is similar to that of the index assessing vulnerability to physical impacts. It comprises six categories: workforce age, education, inequality, research and development, government debt, and gender. Each category is represented by one variable, given a grade from 0 to 10, and averaged to have a value of 0 for the least vulnerable country and 10 for the most vulnerable one.

For the workforce age, the selected variable is the ratio of population aged 20-39 years to the population aged 40-65 years (WBG, 2024). This category measures a personal component of vulnerability; it is relevant because an older workforce is more at risk of having its skills become obsolete, and companies will likely be less interested in investing in its reskilling. The variable for the education category is mean years of schooling, reported as a component of the HDI by the UNDP (2024). It also measures a personal component of vulnerability, and it is relevant because there is evidence that "the net-zero transition is creating […] good-quality jobs […] [which] tend to be in high-skill occupations and represent an opportunity mainly for highly educated [...] workers […] In contrast, for low-skilled workers, green-driven occupations may not be a sufficiently attractive alternative to jobs in the rest of the economy" (OECD, 2024). Inequality is measured by the Gini index (World Bank Group, 2024; CIA, 2024). This category of vulnerability reflects a structural component; in more unequal economies, a just transition will be harder to achieve, with the wealthier workforce having the means and support necessary for reskilling and the opportunities to find new jobs in growing industries, while less well-off workers will more likely be locked in sunk industries and be left behind.

Research and development are measured by scientific and technical journal articles per million inhabitants (UIS, 2024). As a structural component of vulnerability, this variable measures an individual country's ability to create new jobs and industries and to lead the economic transition.

Government debt is measured both by total debt service as percentage of GNI (reported mostly for global South countries, includes the interest payment), and central government debt as percentage of GDP (reported mostly for global North countries) (WBG, 2024d). It measures a structural component of vulnerability and is relevant because world governments might be in need of offering buyouts and early retirement packages or might otherwise bear the brunt of reskilling costs to ensure a just transition for all; this will further increase debt burdens.

The last category, gender, uses the UNDP's GII to measure female reproductive health and to contrast male and female empowerment and labour market participation. As a personal and structural component of vulnerability, it relates to women's agency and the opportunities women have in the labour market and government. A more inclusive workforce can be more easily diversified and retrained, and households with more sources of income are less vulnerable to job losses.

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Who Bears the Costs?
Addressing inequalities from climate change and climate action

This publication, developed in cooperation between the Social and Human Sciences Sector of UNESCO and "la Caixa" Foundation, forms an intellectual partnership dedicated to addressing the complex and interconnected challenges society faces.

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It also critically examines the unintended social and economic consequences of climate policies, ensuring that proposed solutions foster just and sustainable outcomes rather than exacerbating existing inequalities.

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