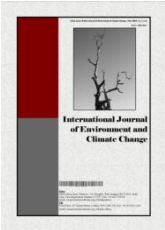

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Safeguarding National Developments against Climate Change: Cost Implications on Sectors, Services and Assets

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The world has come to terms with the alarming impacts of climate change, and their costs which are both monetary, and non-monetary. Increasing emissions and their global warming bearings, have resulted in disequilibrium of the climate system, and the associated ecosystems. This makes mitigation (low carbon strategies) to be essential. With the current world being on a high carbon trajectory, there is need for transition. A move in the energy sector (away from fossil fuel intensity), building the right financial investments, transitions in the planning (e.g. transform market systems for sustainability), policies and livelihood choices that acknowledge limits to planetary provisions, and, to safeguard humanity. The planet is on an increasingly unfamiliar trajectory, hence uncertainty to support lives as before. However, COP26 and the IPCC 2021 report indicated shortfalls in mitigation ambitions, which are needed to bring the planet back on track. Emissions need to be cut, to realise the Paris Agreement objectives, as well as the Sustainable Development Goals (SDGs), as climate change has far-reaching negative impacts, due to its cross-cutting nature. There are data gaps on the costs of current climate change i.e. the mitigation and adaptation costs, at national levels. The data would enable ease of implementation, build standardisation through agreed tables and formats, for accounting and reporting, and the necessary targets. Thus national plans, policies, technologies, institutional frameworks, business sector response mechanisms, and livelihood choices need to respond, so that the planet remains sustainable. The conclusions of this overview indicate that, national plans, those of private sector

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and of the citizenry need to escalate sustainability to a higher level. Most impacts of climate change would add to costs of production, heighten risks, and bring more uncertainty as well as negatively disrupting services and industries. The climate action needs to prioritize costs of climate change, to inform action on the Nationally Determined Contributions (NDCs), SDGs, livelihood assets and lead to the building of right investments. These are underlined by partnerships for delivery, governance, data interventions, and inclusion, in a world which is increasingly exhibiting inequalities, and their associated vulnerabilities. All these have mitigation and adaptation costs, which need to be part of Paris Agreement compliance frameworks for Parties/nations.

Keywords: Climate change costs; paris agreement; sectors; services; assets.

1. INTRODUCTION

Climate change may reverse development progress made, in addition to limiting opportunities for the future [1-5]. The UNFCCC has led the planet on a response mandate through the Conference of the Parties (COPs) to safeguard the planet from certain ruin e.g. Paris Agreement where each nation was to set voluntary targets to address the climate change debacle. National advancements must mitigate or adapt to the realities of climate change [6], as extremities and new scenarios emerge [7], which render past success plans unreliable [8].

1.1 Enhancing Implementation on Climate Change

In fact, climate change may be instrumental in furthering global inequalities e.g. between poor hot countries versus cooler more developed nations [9] and there is need for guiding principles on research and practice [10]. Climate change action addresses reduction in emissions – mitigation, and adaptation (how to cope/adjust to new climate realities) e.g. [11], hence technologies, policies, investments, trade/market systems and livelihood adjustments and consumer choices, are critical. With adaptation, there is need to bring this to a higher level of understanding which would enhance participation, ownership, and leadership. Adaptation strategies may be instrumental in early warning systems or rehabilitative responses for hazards mapping and interventions [5,10]. Mitigating climate change goes beyond technologies, thus benefits from policies/plans, and market interventions for low carbon development strategies. The renewable energies are equally important in the energy and economic transitions, to realise Paris Agreement targets [1]. SDG13 prioritises action i.e. urgently to combat climate change and its impacts (e.g. targets on building resilience, improve adaptive capacity, and develop disaster risk reduction strategies). To achieve climate proofing of national developments, there is need to implement the UN system of delivering as one; adopt integrated approaches as most issues are cross-cutting [10,8], and to build data systems which are responsive to national needs, as a service.

1.2 Costs are Central to Success of Climate Change

Central to mitigation and adaptation success, are determinations of costs [12]; 4). Study by [13] outlined costs to assets, which are financial, physical, social and knowledge – as being critical. The funding needs required for climate action are to be based on best possible evidence [10] as well as desired outcomes. For example, funding for adaptation, in some of the earlier studies [12] in Fig. 1 indicated annual expenditure for developing countries, to be running in billions of USA dollars. Yet for the period 2014-2018 the received funding to Africa was about US$5 per person, well below the required intervention levels [5]. Hence, more is needed to minimize costs and optimize benefits; reduce vulnerabilities and increase resiliencies with equitable and inclusive outcomes and processes [10]. Fig. 1 illustrates costs associated with climate change, with estimates from international organisations, from early 2000s.

Climate-proofing the national development is about securing/fortifying the present and future investments [2,14,13]. A useful tool to achieve this, is the Enhanced Transparency Framework (ETF), which was concluded at COP26. This enables the UNFCCC Article 6 on carbon markets, to effect the Paris Agreement operations, for both mitigation and adaptation, including market and non-market systems. However, some key challenges for making informed decisions, on what is sustainable under

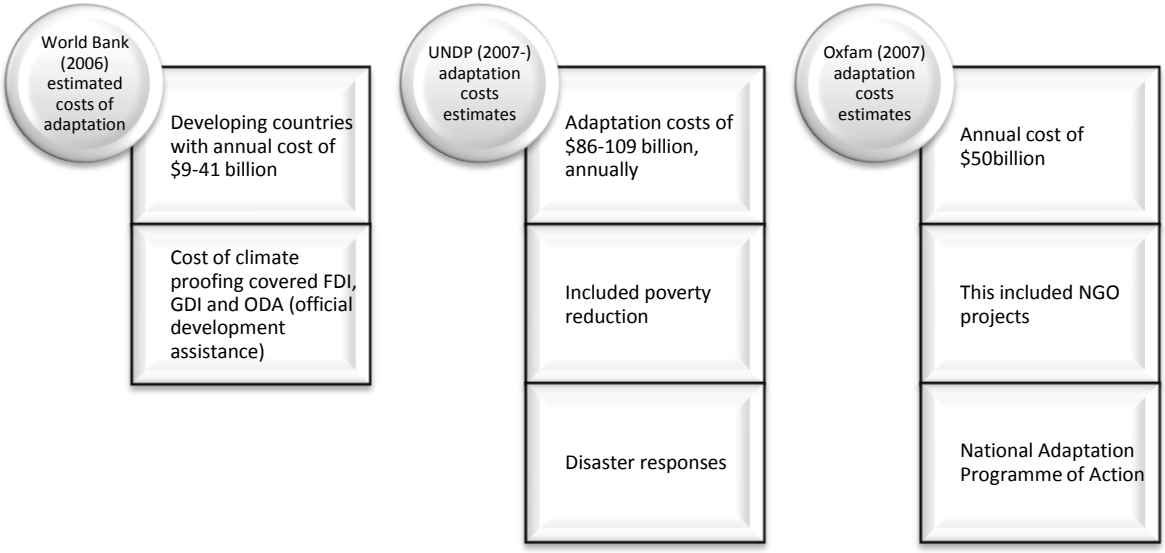

Fig. 1. Annual adaptation costs estimate [12]

new climate change scenarios, relate to data/information scarcity [12,15]; as well as chronicling the impacts of adaptation (the extent of avoided risks). Finance, loss and damage, capacity building/availability, and technology access – are key to complying with the Paris Agreement, through strengthened implementation measures. Thus, this overview aims to chronicle literature on i) the most vulnerable sectors to climate change, i.e. what sectors to divest against as the world faces new future scenarios of climate change; ii) information on the vulnerabilities of services and assets to a changing climate; and iii) make recommendations on climate change-proofing of national advancements.

2. CLIMATE CHANGE SENSITIVE SECTORS IN NATIONAL DEVELOPMENTS

Sustainable development and the 2030 agenda require a transformative approach – building economies and sectors which are resilient to the rigours of climate change [4]. The study by [8] reviewed processes/sectors and their impacts on GHGs and the GDP – assessing their relevance for sustainability under climate change. Analysis by [15] delineated the green economy pathway, as entailing: building low carbon assets, effective strategies on energy and land use systems to reduce emissions. Any departure from these, negatively affects industries and escalates costs due to inaction. Urgent action is needed on climate change, as [16] warned that climate change inaction may cost 15 times more, when delayed into the future. A health sector perspective by [17] highlighted the costs of climate change to the health sector, and the need to have informed policies in place, so that interventions are optimised. However, the estimates mostly omit impacts on lives/livelihoods, tipping points, costs on trauma, cultural heritage losses, as non-monetary assets are mostly omitted in most cost estimates [18]. The [19] report highlighted financial deficits for developing countries, to address challenges for adaptation i.e. often 5-10 times higher in costs than the available adaptation financial flows. The report by [4] drew caution on some impacts, which may take hundreds or thousands of years to remedy, and some faster warmings at regional levels. Table 1 gives indicative cost estimates, due to climate change.

The [23] highlighted the need for adaptation in the continent, as it has the most vulnerable sectors (e.g. water demand to grow by 200% in some regions); hence need to incorporate climate change into planning. Thus adaptation needs to be Africa's future investment priority. Multiple stakeholders need to participate in developing solutions; thus knowledge, awareness and funding on climate change are critical empowerment tools.

Table 1. Climate change cost estimates and parameters covered

Institute or body	Cost estimates	Parameters covered
[20]	Africa's cost to climate change is 3-5% of the GDP, despite the continent not responsible for causing climate change.	Increased/longer droughts, floods, cyclones, water scarcity, high energy demand, increased costs on health and food. Need for climate finance, energy transition, adaptation, and covering of the loss and damage costs.
[21]	Adaptation cost of US$70-100 billion per year for 2010-2050, across the globe.	8 major sectors covered (e.g. human health, extreme weather events, sector level costs aggregated within a country).
[22]	Euro 200-350 billion in 2030 (equates to 1% of global GDP in 2030).	Reducing GHGs costs through abatement cost curve or marginal abatement curve.
[23]	US$20-30bilion per annum, for next 10-20yrs, in Africa.	Costs of adaptation on national economies, future investments.
[14]	Insurance Development Forum on climate risks, disclosure and building resilience for economies and societies.	Paris Agreement targets compliance, through: Data emergency, financial flows, and compliant investments.

3. CLIMATE CHANGE SENSITIVE BUSINESSES, ASSETS, AND SERVICES IN NATIONAL ADVANCEMENTS

Estimating the cost of climate change, is vital for sustainability, especially for businesses [24] as the supply chains are negatively affected. Action on the businesses include decarbonising supply chains, more awareness needed on commodities which degrade the environment, and ensuring more (informed) supplier engagements. Impacts to businesses [25] indicated that climate change extreme events would shift value of prime locations for enterprises, optimal places to live and do work, would affect building codes to align with rigours of climate change. Emerging data on climate change impacts related to i) weather-related insured losses increases and natural loss (disaster) events; ii) EU risk statistics data for some sectors highlighted, as share of total exposures; highlighted the following impacts: - real estate-related assets costs to rise by 11-12%; wholesale and retail -related assets at 7%; construction – related assets range of 1-4%. Thus risk under climate change, and what assets to invest in, remain key in climate-proofing businesses in national developments [11,26]. The [27] (accessed 12 March 2022) has among its 10 principles, advised that: businesses adopt a precautionary approach to environmental challenges (principle 7), while principle 8 calls for more environmental responsibility; with principle 9 emphasized the need for environmentally friendly technologies, to be adopted. The [24] report outlined the high supply chain costs of US$120 billion for various businesses, in the next 5 years, arising from environmental risks, due to climate change. The types of assets which are impacted by climate change include financial, physical, social and knowledge assets. Weather disasters in 2021 cost the world around $170 billion i.e. the costliest on record, thus fires, storms/floods, heatwaves show an increasing trend in costs; for the same year, the death toll was over 1000 with 1.3 million displaced [28].

1. Sensitive businesses and services to climate change – and the required actions for building resilience

According to [29], resilient businesses are required to build a resilient world, against the shocks of climate change. All institutions need to be resilient to climate shocks [1,30], as part of customer care and duty, of service providers. Table 2 illustrates key actions in compliance to climate change stressors.

The business services or industries which are vulnerable to climate change impacts [31], may include food industry, beverage, transport, and logistics. These are used as examples for their implications (resilience) for the future and what possible solutions are required, in broad terms (Fig. 2). For Africa, [32] estimated that 48% of the continent's GDP would be at risk from extreme events, with the climate change vulnerability index (CCVI) to grow from US$895billion in 2018 to US$1397billion in 2023.

Table 2. Building climate change resilience actions for businesses and banking services

Business services actions	Banking services actions	Insurance services actions
-Decarbonize value chains, processes/operations. -Include supply chains risks into overall risk management measures/strategy. -Set targets for compliance (mitigation, adaptation, financing mechanisms). -Optimise on most resilient assets.	-Finance green agenda -Build & apply new critical skills in finance/climate analysis. -Transformation measures i.e. develop strategies for resiliencies under new climate scenarios.	-At high risk due to high climate extreme events. -Weather disasters, fires increasing. - Assess and cost risks on institutional strategies, finances, human resources, and on multiple sectors.

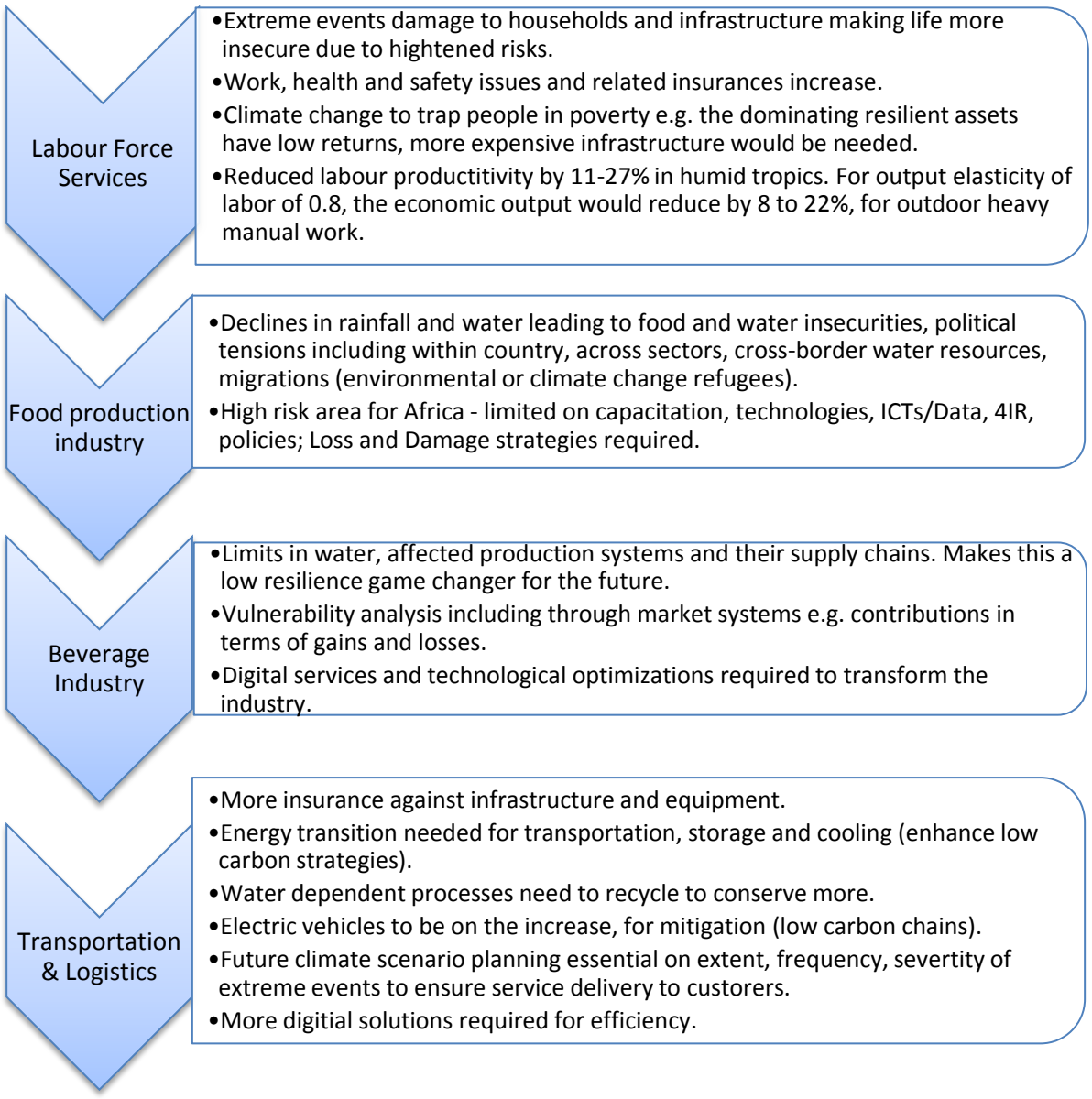

Fig. 2. Futuristic outlook of specific services/industries vulnerability to climate change

4. CONCLUSIONS AND RECOMMENDATIONS

More studies and data are needed to fully understand and detail the costs of climate change or sector impacts on the GDP and GHGs. The current climate change studies, tend to chronicle the key impacts, policy implications, as well as the need for mitigation and adaptation, but with limited disaggregated data on the costs associated with compliance responses at national levels. The loss and damage costs need to be fully addressed and unpacked, financing climate change e.g. the 100 billion annual cost needs to have measurable, reportable, and verifiable decrees (MRVs in climate finance); as well as strengthening implementation measures for climate change [33]. These gaps in the climate change literature, limit capacities for nations, private sector, and industry to respond. This paucity in enabling tools, explains the limited reduction in vulnerabilities, and less informed targets under the NDCs (accessed 14 March 2022 [34] to meet the Paris Agreements, nationally.

There is limited data and funding at national levels on the prioritised costs of adaptation and mitigation actions. Equally, there is no reference template, for nations, sectors, or businesses to use for compliance to the Paris Agreement. The Nationally Determined Contributions are well meaning, despite their voluntary nature. These lack a guiding template of associated costs, to achieve them, yet hope remains with the UNFCCC Enhanced Transparency Framework, concluded at COP26. In terms of the costs related to climate change compliance, to implement the National Adaptation Plans (NAPs) or National Adaptation Programmes of Action (NAPA), as well as NAMAs (Nationally Appropriate Mitigation Actions) the available global funding is also limited for most developing nations.

The international financing mechanism needs to develop, accountable/transparent system to disburse the funds e.g. between developed countries and developing nations. This is one of the challenges of implementing the multilateral agreements, where key operational issues are overlooked in agreements. Further, the methodologies for assessments, currently used to estimate climate change costs vary, and some exclude non-monetary yet critical challenges of climate change such as trauma, death, and loss of cultural assets. The long-term changes tend to be overlooked as well, including rapid regional changes and their cumulative impacts, tipping points, irreversible damage, on sustainability of nations.

There is need to build resilience urgently [35], enhance carrying capacities, and take climate change actions now, as delays would increase costs up to 15 times, in the future [16].

Climate Change Vulnerable Sectors: The overview has indicated some vulnerable sectors, in both developing and developed nations. Extreme events impose huge costs and trauma arising from floods, fires, drought, and storms e.g. cyclones. Water and energy sectors are very key in the world. Their demands are changing globally e.g. energy transitions and economic shifts towards green/circular, with greening targets made for the immediate future, based on the UNFCCC Conference of Parties, to meet the Paris Agreement. Infrastructure, settlements/ cities, pollution and waste, agriculture, tourism, the small and medium enterprises are some of the sectors which would be adversely affected due to climate change, hence areas of escalated costs. The study by [8] in their review of the earth-human integrative system in climate change costing, indicated the following as key: land sector (high GHGs), labour productivity (high impact on GDP), with other sectors like energy (potential for being high on GHGs). Those sectors which would significantly impact both GHGs increases and on GDP included: water resources, sea level rise, natural disasters, ecosystem services and diseases [8]. Further, the [36] has prioritised some sectors, noted as crucial.

Climate Change Vulnerable Services and Assets: High vulnerability has been indicated on locations for businesses, insurances, value chains, including their supply chains, production systems and various assets (financial, physical, social and knowledge). The following services have demonstrated climate change vulnerability, of note: insurances due to extreme weather events, beverages, finance (bailing out insolvencies is at 5-15% of the GDP see [8], labour, transport, and logistics, as well as risks arising from the climate system, including disasters and their response mechanisms to ensure timely service and business deliveries.

Climate Change-Proofing of National Developments: Needs to: First, outline the priorities at the national level e.g. National

Development Plans, National Visions, SDGs roadmaps, UN Obligations through synergies of the Rio Conventions action plans in a country, harmonising policies, and the transformative pathways. Secondly (ii) to integrate solutions e.g. the [37] Rwanda country study on climate change vulnerability for different parts of the country, was important in informing key areas, sectors, and policy implications, for intervention, both for the economy and livelihoods. The methodology by the World Bank [38], offered a simplified approach to developing country vulnerabilities. And, thirdly, to specify the services and assets such as retail which would experience higher costs [26] due to extreme events, and experience drops in value. Thus, (iv) data on vulnerabilities, capacities, technological and policy interventions would be critical in advancing the Nationally Determined Contributions (NDCs). For Botswana's third national communication [39] financial costs of mitigation projects were detailed. The noted barriers for mitigation included high investment costs, existing subsidies with no tax exemption on renewables or lack of zero interest on renewable energy loans, limited capacity to develop bankable green projects and the inadequate policy harmonisation [40]; as well as ensuring food security [41].

The analysis on market systems, policies, skilled manpower and livelihoods securities are mainly relevant for adaptation scenarios [42]; noting cost of carbon to developments [43]. The global mitigation i.e. emissions gap [44] and adaptation cost estimates are needed to achieve the indicated priorities under NDCs. At country level [even at local, 45]; showed that capacity is needed for stakeholders, i.e. to enable participation across various sectors- government, private sector, and civil society for ownership, leadership, and data generation [46] to strengthen the means of implementation. Realising resilience of the nations, is instrumental in driving initiatives on shared and broad-based prosperity, through inclusiveness (leaving no one behind). The ESG (environment, social and governance) framework is pivotal in covering key deliverables of sustainability, in a world that needs to build sustainable economic development strategies, underpinned by inclusion [47]. The observations by [48] bear a strong input on assessing loss and damage e.g. climate simulations, observational records, extreme value statistical methods; the economic costs of climate change [49] initiatives by [50] (accessed 12 March 2022); also noting the Climate Change Performance Index [51]. The [52] assessment on market systems, provides additional value assessments for mitigation and adaptation; additionally, with the business cases for resilience building underscored by [31].

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Arent DJ, Tol RSJ, Faust E, Hella JP, Kumar S, Strzepek KM, et. al. Key economic sectors and services. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014;659-708.
2. World Bank. The Adaptation Principles: 6 Ways to Build Resilience to Climate Change; 2020.
Available:https://www.worldbank.org/en/news/feature/2020/11/17/the-adaptation-principles-6-ways-to-build-resilience-to-climate-change
3. Hallegatte S, Rentschler J, Rozenberg J. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. World Bank, Washington, DC. World Bank; 2020.
4. IPCC; 2021.
Available:https://www.ipcc.ch/report/ar6/wg1/
5. Savvidou G, Atteridge A, Omari-Motsumi K, Trisos CH. Quantifying international public finance for climate change adaptation in Africa, Climate Policy. 2021; 21(8):1020-1036.
DOI: 10.1080/14693062.2021.1978053

6. EPA. Planning Framework for a Climate-Resilient Economy; 2016.
Available:https://www.epa.gov/sites/default/files/2016-05/documents/planning-framework-climate-resilient-economy-508.pdf
7. World Health Organisation. Climate change and health; 2021.
Available:https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
8. Tachiiri K, Su X, Matsumoto K. Identifying key processes and sectors in the interaction between climate and socio-economic systems: A review toward integrating Earth–human systems. Progress in Earth and Planetary Science. 2021;8:24.
Available:https://doi.org/10.1186/s40645-021-00418-7
9. Diffenbaugh NS, Burke M. Global warming has increased global economic inequality. PNAS May 14, 2019;116(20):9808-9813.
First published April 22, 2019.
Available:https://doi.org/10.1073/pnas.1816020116.https://www.pnas.org/content/116/20/9808
10. Singh C, Iyer S, New MG, Few R, Kuchimanchi B, Alcade C, et al. Interrogating 'effectiveness' in climate change adaptation: 11 guiding principles for adaptation research and practice, Climate and Development; 2021.
DOI: 10.1080/17565529.2021.1964937
11. Denton F, Wilbanks TJ, Abeysinghe AC, Burton I, Gao Q, Lemos MC, et al. Climate-resilient pathways: adaptation, mitigation, and sustainable development. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, et al. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014;1101-1131.
12. Parry M, Arnell N, Berry P, Dodman D, Fankhauser S, Hope, et al. Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London; 2009.
13. Avory B, Cameron E, Erickson C, Fresia P. Climate Resilience and the Role of the Private Sector in Thailand: Case Studies on Building Resilience and Adaptive Capacity. BSR Report. Hong Kong: BSR; 2015.
Available:https://www.bsr.org/reports/BSR_Climate_Resilience_Role_Private_Sector_Thailand_2015.pdf
14. Global Resilience Index; 2020.
Available:https://www.cgfi.ac.uk/global-resilience-index-initiative/
15. Broom D. What's the price of a green economy? An extra $3.5 trillion per year; 2022.
Available:https://www.weforum.org/agenda/2022/01/net-zero-cost-3-5-trillion-a-year/#:~:text=Green%20New%20Deals%20What%E2%80%99s%20the%20price%20of%20a,as%20an%20opportunity%20rather%20than%20just%20a%20challenge
16. Nuccitelli D. Can the economy afford NOT to fight climate change? Yale Climate Connections; 2021.
Available:https://yaleclimateconnections.org/2021/09/can-the-economy-afford-not-to-fight-climate-change/
17. Nicole W. Toward Better Estimates of the Cost of Climate Change Mitigation: Guidelines for Studying Potential Health Benefits. Environmental Health Perspectives. 2020;128(12).
Published: 29 December 2020.CID: 124003.
Available:https://doi.org/10.1289/EHP8671
18. Camuzeaux J. How we underestimate the costs of climate change, and why it matters now; 2020.
Available:https://www.edf.org/blog/2020/07/23/how-we-underestimate-costs-climate-change-and-why-it-matters-now
19. UNFCCC: Step Up Climate Change Adaptation Efforts or Face Huge Disruption: UN Report (04 Nov 2021); 2021.
Available:https://unfccc.int/news/step-up-climate-change-adaptation-efforts-or-face-huge-disruption-un-report
20. AU Africa Climate Change Committee handover. President Kenyatta takes over as chair of AU Climate Change committee; 2022.
Available:https://www.thecitizen.co.tz/tanzania/news/africa/kenya-chair-of-au-climate-change-committee-3711460

21. World Bank. Estimating costs of adaptation to climate change. Open Knowledge Repository; 2011. Available:https://openknowledge.worldbank.org/handle/10986/4799
22. Our World in Data. How much will it cost to mitigate climate change?; 2017. Available:https://ourworldindata.org/how-much-will-it-cost-to-mitigate-climate-change
23. Africa Development Bank. The Cost of Adaptation to Climate Change in Africa; 2011. Available:https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Cost%20of%20Adaptation%20in%20Africa.pdf
24. CDP Global Supply Chain Report. Transparency to transformation: A chain reaction; 2020. Available:https://cdn.cdp.net/cdpproduction/cms/reports/documents/000/005/554/original/CDP_SC_Report_2020.pdf?1614160765
25. Vergara C. Calculating the cost of climate change. IESE Business School Insight no.156; 2020. Available:https://media.iese.edu/research/pdfs/74860.pdf
26. Dehan A. How Does Climate Change Affect Real Estate Prices? Rocket Mortgage; 2022. Available:https://www.rocketmortgage.com/learn/climate-change-real-estate-prices Accessed 14 March 2022.
27. UN Global Compact. The Ten Principles of the UN Global Compact; 2022. Available:https://www.unglobalcompact.org/what-is-gc/mission/principles
28. Christian Aid. Climate change: Cost of weather disasters surged in 2021; 2021. Available:https://www.dw.com/en/climate-change-cost-of-weather-disasters-surged-in-2021/a-60263393
29. Cameron E, Harris S, Prattico E. Resilient Business, Resilient World: A Research Framework for Private-Sector Leadership on Climate Adaptation. Report. BSR, San Francisco; 2018. Available:https://www.bsr.org/reports/BSR_Resilient_Business_Resilient_World_A_Research_Framework_for_Private_Sector_Leadership_on_Climate_Adaptation.pdf
30. Slay C, Dooley K. Improving Supply Chain Resilience to Manage Climate Change Risks. From The Sustainability Consortium, with funding and support from HSBC; 2020. Available:https://www.sustainabilityconsortium.org/ HSBC
31. Curphey M. Industries most vulnerable to climate change. Business Risk; 2019. Available:https://csuite.raconteur.net/business-risk/industries-most-vulnerable-to-climate-change/
32. Hewston R. 84% of world's fastest growing cities face 'extreme' climate change risks; 2018. Available:https://www.maplecroft.com/insights/analysis/84-of-worlds-fastest-growing-cities-face-extreme-climate-change-risks/
33. Eceiza J, Harreis H, Härtl D, Viscardi S. Banking imperatives for managing climate risk; 2020. Available:https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/banking-imperatives-for-managing-climate-risk
34. Explore Nationally Determined Contributions (NDCs). Available:https://www.climatewatchdata.org/ndcs-explore Accessed 14 March 2022.
35. UNFCCC Report: Assessing the costs and benefits of adaptation options: An overview of approaches; 2011. Available:https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf.
36. Global Reporting Initiative (GRI) (2020) GRI Sector Program – Revised list of prioritized sectors. https://www.globalreporting.org/media/mqznr5mz/gri-sector-program-list-of-prioritized-sectors.pdf
37. United Nations Economic Commission for Africa, UNECA: Rwanda Environment Management Authority (2015-05). Baseline climate change vulnerability index for Rwanda. Kigali: Rwanda Environment Management Authority; 2015. Available:https://hdl.handle.net/10855/23285
38. Heltberg R, Bonch-Osmolovskiy M. Mapping Vulnerability to Climate Change (January 1, 2011). World Bank Policy Research Working Paper No. 5554; 2011. Available:SSRN: https://ssrn.com/abstract=1754347
39. Botswana's third national communication to the United Nations Framework Convention on Climate Change: Ministry of Environment, Natural Resources

Conservation and Tourism. Republic of Botswana; 2019.
Available:chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://unfccc.int/sites/default/files/resource/BOTSWANA%20THIRD%20NATIONAL%20COMUNICATION%20FINAL%20.pdf

40. UNEP. Six sector solutions to climate change; 2020.
Available:https://www.unep.org/interactive/six-sector-solution-climate-change/
41. International Food Policy Research Institute. Climate change and hunger: Estimating costs of adaptation in the agrifood system; 2021.
Available:https://reliefweb.int/report/world/climate-change-and-hunger-estimating-costs-adaptation-agrifood-system
42. NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters; 2022.
Available:https://www.ncdc.noaa.gov/billions/,
DOI: 10.25921/stkw-7w73
Available:https://www.ncdc.noaa.gov/billions/time-series
43. Archer A. Kite E, Lusk. The ultimate cost of carbon. Archer, Kite and Lusk, Climactic Change*;* July 15, 2020.
DOI: 10.1007/s10584-020-02785-4
Available:https://news.uchicago.edu/story/climate-change-will-ultimately-cost-humanity-100000-ton-carbon-scientists-estimate
44. UNEP (2021) Emissions Gap Report; 2021.
Available:https://www.unep.org/resources/emissions-gap-report-2021
45. Debortoli NS, Clark DG, Ford JD, et al. An integrative climate change vulnerability index for Arctic aviation and marine transportation. Nature Communications. 2019;10:2596.
Available:https://doi.org/10.1038/s41467-019-10347-1
46. Rowlands M. How can we solve the energy crisis and mitigate climate change? Oxford University Press's Academic Insights for the Thinking World; 2021.
Available:https://blog.oup.com/2021/10/how-can-we-solve-the-energy-crisis-and-mitigate-climate-change/
47. UNEP. Global temperatures: costs continued to soar in 2021; 2022.
Available:https://www.unep.org/news-and-stories/story/global-temperatures-costs-continued-soar-2021z
Accessed 14 March 2022.
48. Wehner MF, Reed KA. Operational extreme weather event attribution can quantify climate change loss and damages. PLOS Clim. 2022;1(2):e0000013.
Available:https://doi.org/10.1371/journal.pclm.0000013
49. Diaz D. What is the economic cost of climate change?; 2015.
Available:https://www.weforum.org/agenda/2015/01/what-is-the-economic-cost-of-climate-change/.
50. European Climate Change Action for: EU Action – the 2030 climate and energy framework: Greenhouse gas emissions-raising the ambition; 2030.
Available:https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2030-climate-energy-framework_en
51. The Climate Change Performance Index. Feature Publication, New Climate Institute, CAN, CCPI, Climate Change Performance Index, German watch, Klima Schutz index, Tracking climate action; 2022.
Available:https://newclimate.org/2021/11/09/the-climate-change-performance-index-2022/
Accessed 14 March 2022.
52. Deo K, Prasad AA. Exploring Climate Change Adaptation, Mitigation and Marketing Connections. Sustainability. 2022;14:4255.
Available:https://doi.org/10.3390/su14074255

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