Tanzania

Climate Stress Test

Cascading Socioeconomic Impacts and Adaptation Policies Pathways

Technical report

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AUTHORS & ACKNOWLEDGMENTS

This report was developed by:

Global Center on Adaptation:

Adele Cadario, Global Lead, Infrastructure and Nature-based Solutions and Climate Adaptation Finance; María José Vásquez, Senior Program Officer, Infrastructure and Nature-based Solutions, Aswin Stuivenberg, Junior Program Officer, Infrastructure and Nature based Solutions, Syed Sachal Bacha Junior Program Officer - Water Resource Management, Madison Berry, Junior Operations Officer.

Consulting team:

International institute of Sustainable Development (IISD): Benjamin Simmons and Michael Kapetankakis.
Zutari (PTY) Ltd: Dr James Cullis, David Ogier, Dulce Lazana, Marietjie Smit, and Sibusiso Madlabane.
KnowlEdge (KE): Dr. Andrea M. Bassi, CEO and Founder; Edvin Andreasson, Junior Project Manager.

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GLOBAL CENTER ON ADAPTATION

ABOUT THE GLOBAL CENTER ON ADAPTATION

The Global Center on Adaptation (GCA) is an international organization, hosted by the Netherlands, which works as a solutions broker to accelerate action and support for adaptation solutions from the international to the local, in partnership with the public and private sector, to ensure we learn from each other and work together for a climate resilient future.

AFRICA ADAPTATION ACCELERATION PROGRAM

GCA is providing technical assistance under the African Adaptation Acceleration Program (AAAP), a joint initiative launched by the GCA and the African Development Bank in 2021.

Consulting team:

TABLE OF CONTENTS

List of Tables

List of Figures

EXECUTIVE SUMMARY

This report provides climate adaptation policy support through an integrated, recursive systems dynamics analysis of the interplay between climate change, economy and development in Tanzania. It builds on a cross-sectoral assessment of the impacts of climate change to national socioeconomic and environmental indicators, examining how climate policies and adaption plans, under different climate change trajectories, can affect social outcomes, environmental sustainability, and economic growth over the long run. The analysis places particular emphasis on assessing the economic viability of climate adaptation investments for critical infrastructure systems resilience.

To support this assessment, a national level system model is used to quantify cascading effects of climate change to population and socio-economic indicators (GDP, fiscal balance, employment and income) via climate-related damages occurring to roads, power generation and distribution, productive capital in industry and services, as well as labor. Scenarios of action are also considered, with the goal to reduce climate loss and damage and stimulate more resilient economic growth in the future. In this respect, climate adaptation involves preparing for and responding to the impacts of climate change to reduce vulnerability and build social, economic and environmental resilience. It encompasses a range of strategies and actions, all of which result in specific avoided costs and co-benefits.

Within this objective, the Green Economic Model (GEM) is used to simulate the impact of climate change under different SSP scenarios1, and the implementation of reconstruction and climate adaptation investments. The analysis is systemic and considers many variables relevant to sustainable development: economic (e.g., GDP growth), social (e.g., employment) and environmental (e.g., land cover and air pollution) indicators. The results provide a robust perspective on the costs and benefits associated with the implementation of adaptation measures at the country level.

The model produces 6 simulations under various climate forecasts and adaptation strategies. To that end, a first set of simulations reflects a scenario of inaction under different climate assumptions: no climate impacts, SSP1, SSP3, and SSP5. This is then complemented by the inclusion of two adaptation scenarios, differentiated by either a proactive or reactive strategy. In the proactive scenario Tanzania invests into adaptation interventions to "proactively" avoid climate impacts, by anticipation. While in the "reactive" scenario the focus is investments into contingency and thus, only rebuild after the impact.

These scenarios are informed by data from the Climate Hazard Assessment that provides information on the percentage of assets at risk, an aggregate value of each stock of infrastructure or capital that may be damaged during climate events of a given size. With the addition of socio-economic and environmental data from international open-source databases (IMF, 2022a; Eurostat, 2022; UN Population Division, 2022; UNFCCC, 2024), GEM integrates climate hazards with social, economic and environmental indicators to provide a holistic forecast on climate adaptation strategies for Tanzania.

The results of the analysis are summarized as follows:

Without any adaptation measures, climate impacts would cost Tanzania substantially.

The SSP3 BAU scenario is estimated to generate 135 billion USD of damage, cumulatively by 2050. This results in a cumulative negative GDP impact of 395 billion USD by 2050, or the equivalent of 5.39 years' worth of value addition (using the 2024 GDP value).

The largest costs are from productive capital and buildings, which combined equal 96 billion USD. These costs not only reduce public revenue and income generation but also hinder economic growth and

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1 The "shared socioeconomic pathways" (SSP) covers future climate scenarios under various socio-economic and resulting climate assumptions. SSP1 has high ambition for sustainability resulting in less tumultuous climate in the long term, while the SSP5 climate scenario is a fossil-fuel driven future without sustainable practices, resulting in more frequent extreme events and generally worse climate conditions.

development efforts. The extensive damage to infrastructure and assets could also reduce access to essential services, disrupt livelihoods, and exacerbate socio-economic inequalities.

Climate impacts cause annual losses across key sectors. By 2050, service and industry capital, buildings, roads, and infrastructure are projected to suffer significant damages.

The SSP3 BAU scenario simulates annual losses equivalent to 0.4% of service and industry capital, totaling 64 billion USD by 2050. Similarly, buildings are expected to incur a cumulative loss of 32 billion USD by 2050. These figures underscore the vulnerability of key infrastructure assets to climate impacts.

Specifically, when excluding agricultural losses, the cumulative impact of climate change in Tanzania is estimated to reach USD 103 billion by 2050 (the value would increase to 135 billion USD when considering agricultural losses), corresponding to 1.41 times GDP in 2024.

Concerning assets on specific impacts:

- Roads: annual losses are projected at 3,566 km (0.4% of the 2024 stock), with cumulative losses valued at USD 865 million by 2050, equating to 104% of the total road stock. This indicates that, without reconstruction or climate-proofing, road damage by 2050 may equal the entire road network length.
- Buildings: forecasted annual damage is expected to reach 85,307 units, resulting in cumulative damages of USD 32 billion by 2050, which accounts for 28% of the total building stock in 2024.
- Power Generation: projected annual damage of 205 MW of capacity would cumulatively result in 2,677 MW damaged by 2050, representing 130% of the 2024 power generation capacity. This emphasizes the need for careful siting of power plants away from areas vulnerable to climate impacts.
- Industry and Service Capital: cumulative damages are forecasted to reach USD 65 billion by 2050, equivalent to 38% of the 2024 value of capital in these sectors.

These statistics underscore the significant risks posed by climate change to key infrastructure assets and highlight the rationale for proactive investments into climate adaptation strategies.

Annual losses in agriculture, industry and services due to climate impacts would significantly impede economic growth. In the SSP3 BAU scenario, total real GDP is reduced by 8% in 2050 compared to scenario without climate change. The annual reduction is 0.2%.

The projection of an 8% reduction in total real GDP compared to a scenario without climate change highlights the severe economic consequences of climate change. With proactive climate adaptation, GDP growth could be 0.7% higher every year, as a result of a more climate resilient economy. In this scenario, climate impacts on GDP could be reduced to 334 billion USD cumulatively by 2050, or a 15% reduction.

Adaptation is a competitive economic development strategy, with a Benefit to Cost Ratio (BCR) of 7.91, a payback time within 18 years, and net benefits of USD 5.8 billion.

The BCR is the ratio of the tangible (e.g. GDP) and non-tangible (e.g. human health) benefits to costs, thus, a value above 1 entails that there are more benefits than costs emerging from the implementation of the investments analyzed. The adaptation proactive scenario stands out as a competitive economic development strategy at the national level, and achieves a Benefit to Cost Ratio (BCR) of 7.91 by 2050. The reactive scenario achieves a BCR of 0.59 by 2050. By focusing on climate resilience, the proactive scenario offers a unique approach to address the pressing issue of climate change. It recognizes that climate action and economic prosperity are not mutually exclusive but can, in fact, be mutually reinforcing. The adaptation proactive scenario generates 12.7 billion USD in net benefits between 2023 and 2050.

The adaptation proactive scenario stimulates economic growth (GDP 0.4 % higher than BAU by 2050) and job creation (0.2% higher than BAU by 2050) both by reducing costs of climate change (resilience) and by increasing productivity.

Proactive generates economic growth and job opportunities through a dual strategy. On one hand, it mitigates the economic burdens associated with adapting to climate change, reducing the costs incurred due to climate-related disasters.

Investment levels are the highest for the proactive scenario, close to 0.4% of GDP by 2030.

As the proactive scenario for climate adaptation entails higher ambition for resilience, the investment required is higher compared to repairing damages reactively. Also, earlier technology adoption implies higher costs, when compared to the same investment made later in time (e.g. due to learning rates that reduce the unit cost of a given climate adaptation intervention). Therefore, the proactive scenario envisions significant investments, close to 0.4% of GDP by 2030, making it a comprehensive and proactive strategy to address climate change. On the other hand, the benefits accumulate over time, while climate-related costs decline.

In summary, without adaptation measures, Tanzania faces substantial climate change costs, with the SSP3 BAU scenario forecasting cumulative damages of USD 135 billion by 2050. This translates to total economic losses of USD 395 billion, equivalent to 5.39 years of GDP. The overall impact on assets is estimated at USD 103 billion—1.41 times the 2024 GDP. A proactive adaptation scenario would reduce GDP losses by 15%, to USD 334 billion cumulative by 2050. These investments result in a Benefit to Cost Ratio (BCR) of 7.91 (discounted at 10%), highlighting the economic viability of investing in climate resilience.

About the methodology

This technical report aims to provide climate adaptation policy decision support by developing specific analysis that can inform the development of country-level adaptation strategies, comparing "business-as-usual" with proactive or responsive climate adaptation actions.

The Green Economy Model (GEM) used for this assessment is an integrative, recursive systems dynamics tool designed to analyze the interplay between climate, economy, and development. Decision-makers can use it to assess how climate policies and adaption plans can affect social outcomes, environmental sustainability, and economic growth over the long run, under different climate change scenarios. By adopting an integrative approach, GEM's methodology offers insights into how different policy scenarios impact national development goals. GEM is well-suited for high-level, national-scale analyses of climate and policy scenarios, providing valuable insights into macroeconomic impacts and broad adaptation strategies.

However, models are tools, designed for specific purposes, and operating within their limitations: what they cannot tell or inform. For the purposes of this study, the Green Economy Model (GEM) provides national-level adaptation strategy analysis. GEM is effective in comparing long-term adaptation scenarios and capturing co-benefits. It is important to recognize that the model uses inputs data, which should be, as a next step, further refined through more detailed spatial risks analysis and stakeholders consultations. Especially:

- The climate risks analysis is combining two types of inputs. It builds partially on a rapid climate exposure analysis of infrastructure and assets, only partially accounting for the exposed asset's vulnerability characteristics. Some other climate risks, such as those driven by temperature on socioeconomic indicators and productivity, are incorporated through high-level climate scenarios and macro impacts analysis.
- The model and analysis help identify, showcase and discuss potential long-term policy development, exploring systemic impacts of adaptation strategies and allowing to compare the effects of national-level decision scenarios. As a next step, stakeholders consultations would be needed for finer model calibration and decision options design.

The present analysis and report is therefore released to inform national-level adaptation strategy development, showcasing and comparing long-term adaptation scenarios. It provides broad and systemic economic perspective on country-level adaptation strategies. Such methodology could further inform stakeholders consultation, policy design and implementation in country, possibly in combination with other relevant analytical tools including risk-based and spatial approaches, cost-benefits analysis and multi-criteria decision frameworks, in consultation with National Stakeholders.

Source: GCA, OIA, technical review (Oxford Infrastructure Analysis, 2024)

ACRONYMS

Name	Definition
SSP	The "shared socioeconomic pathways" (SSP) covers future climate scenarios under various climate policies. SSP1 has high ambition for sustainability resulting in less tumultuous climate in the long term, while the SSP5 climate scenario is a fossil-fuel driven future without sustainable practices resulting in more frequent extreme events, and generally, worse climate conditions.
BAU	Refers to "Business-as-usual" indicating a continuation of historical trends. Can also be referred to as the inaction scenario.
BAU No CC	Used the BAU scenario as starting point, but removes climate impacts entirely.
Adaptation Proactive	Adaptation scenario that considers specific targets for climate resilience. It reflects a proactive, anticipatory approach.
Adaptation Reactive	Adaptation scenario that focuses on rebuilding after climate loss and damage emerges. It reflects a reactive approach.

1. INTRODUCTION

1.1 Introduction to the Green Economy Model

This report presents modeling work that involves the use of the Green Economy Model (GEM), which is parametrized and customized for the specific contexts of Malawi, Mozambique, and Tanzania, to assess the macroeconomic impacts of climate change under scenarios of inaction, as well as the economic viability of climate adaptation investments for critical infrastructure.

The goal of this project is to conduct a rapid stress test to evaluate the vulnerability of various infrastructure assets to climate change, and to assess the potential socio-economic benefits of climate adaptation for Tanzania, Mozambique, and Malawi. This analysis assesses how adaptation interventions affect social, economic and environmental indicators and offers insights on the economic viability of climate adaptation investments.

This specific report presents the analysis carried out for Tanzania. This model is employed to simulate various climate and policy scenarios, providing insights into potential future outcomes under different conditions.

Simulations are created for an extended period, ranging from 2000 to 2050/2070, and include both the current infrastructure network, which is representative of the year 2023, and a baseline growth trajectory based on population and GDP growth projections. This allows for a robust analysis of how existing infrastructure and expected economic developments may interact with future climate conditions.

The model is parametrized using historical data for the period 2000 – 2023. This data are used to validate the historical forecast of the model and improve model calibration. Forecasts for the period 2024 – 2050/2070 are calibrated to align with existing sectoral forecasts (e.g. on economic activity from IMF, on energy demand and supply from UNSTATS and IEA). Below is a list of selected data sources used to parametrize and calibrate GEM. More information on the use and integration of the following source can be found in the attached model documentation (Bassi & Andreasson, 2024).

- Population
  - GEM uses the UN World Population Prospects (WPP) forecasts to calibrate the population of the country.
- System of national Accounts (SNA) – macroeconomic dynamics
  - Several macroeconomic variables in GEM are calibrated based on the historical data and forecasts published in the IMF's World Economic Outlook database, which is regularly updated (IMF, 2022a). Among others, the variables for which forecasts are aligned include total real GDP and real GDP growth, the GDP deflator, government revenues, government expenditure and the debt to GDP ratio. Additional detail is found in dedicated databases, e.g. Government Finance Statistics (GFS).
- Agriculture and livestock
  - The agriculture and livestock sectors use data from FAO for land use, land productivity, annual production, fertilizer use, cropland (disaggregated by crop), and livestock by country.
- Energy prices
  - The energy prices in GEM use data obtained from the IMF Commodity Database (IMF, 2022b). The future energy prices are calculated based on the data published by the International Energy Agency, Stated Policy scenario (IEA, 2023).
- Energy Balance
  - To calibrate the energy balance in GEM, data from UNSTATS is used, including energy demand sector and energy sources.
- GHG Emissions
  - GEM uses the national GHG emission inventory database and, in some cases, the NDC of the country to calibrate the emissions by source. GEM reflects the disaggregation that UNFCCC requires in the GHG inventory.
- Climate data

- GEM uses climate data (SPIs, temperature, wind speed, percentiles) for the SSP126, SSP370 and the SSP585 scenario based on several available models, e.g. the “mpi-esm1-2-hr” model. Climate data are obtained from the Climate Data Store (CDS) of the EU Copernicus programme.

To estimate the impacts of temperature, precipitation, and related extreme weather events on the availability, efficiency, and operation of infrastructure, the GEM utilizes climate scenarios SSP1, SSP3, and SSP5, as well as asset-specific damage functions. The SSPs refer to five different socio-economic pathways, each representing a distinct global development scenario for the 21st century, resulting in different climate scenarios. These pathways help assess the potential impacts of climate policies on socio-economic activity, guiding efforts to mitigate and adapt to climate change under various future conditions. The model assesses the impacts on capital and infrastructure accumulation (e.g. across sectors such as industry, services, but also in relation to roads, power generation and power distribution), as well as infrastructure efficiency, over time. These scenarios help in predicting the subsequent effects of climate change (trend analysis as well as extreme events) on GDP, employment, income, and public finances, offering a comprehensive view of potential economic and social outcomes.

The GEM is parametrized and calibrated using national data to facilitate the integration of two key components of the project: Climate Hazard assessment, which focuses on climate change analysis and rapid infrastructure system climate risk screening, and the macroeconomic analysis, which pertains to national-level socio-economic systems analysis (see Figure 4).Specifically, the amount of infrastructure assets at risk estimated in the climate hazard assessment is used as an input for the analysis carried out with GEM. The climate hazard assessment work and report outline the climate risks to Tanzania's infrastructure, including roads, healthcare and education facilities, power generation, and transmission lines. These findings offer an estimate of the percentage of infrastructure potentially affected at the national level, providing an aggregate estimate of the maximum possible damage under extreme events. This percentage is then applied within GEM to generate scenarios based on climate forecasts with frequency and strength of extreme events varying over time), supporting the estimation of loss and damage through 2050/2070 and supporting the identification and assessment of effective climate adaptation strategies. The full process of integration the Climate Hazard Assessment into GEM can be viewed in the model documentation (Bassi & Andreasson, 2024).

In terms of assessing adaptation strategies, the model analyzes the effectiveness of intervention options, such as implementing wind and flood protection measures for power generation assets. These interventions are evaluated by comparing the required investments with the multi-dimensional impacts they produce at the sectoral and country level, including their effects on GDP and employment.

Scenario results are analyzed using both single-year impacts, which help estimate the strength of individual extreme weather events, and long-term trends, which provide insights into the cumulative effects of reduced infrastructure efficiency (e.g., reduced power generation efficiency and increased power distribution losses).

The results of these scenarios are presented through both biophysical indicators, such as the loss of power generation capacity measured in megawatts (MW), and economic indicators, such as GDP loss. This dual presentation facilitates a comprehensive estimate of the costs associated with climate change, which is then summarized in a Cost-Benefit Analysis (CBA) for policy-level decision-making, particularly in the context of adaptation scenarios[2].

[2] The full process of and information on the CBA can be found in the accompanying model documentation (Bassi & Andreasson, 2024).

1.2 Overview of GEM

The Green Economy Model (GEM) offers an integrated representation of socio-economic and environmental dynamics, and the natural capital that supports them, at a country level (Bassi A. , 2015; Pallaske, Bassi, Garrido, & Guzzetti, 2023). To ensure that the adaptation analysis is comprehensive and accounts for several climate risks, it includes relevant investment options, and produces a wide range of the avoided costs and added benefits generated by climate action, several changes and additions have been made to GEM. These can be grouped into four categories: (i) the integration of detailed climate data, (ii) the estimation of a more extended list of climate change damage and assumptions for reconstruction, (iii) the integration of a variety of co-benefits of climate action, and (iv) the addition of several policy options for climate resilience.

GEM is designed to inform policymaking towards sustainable development. It allows to forecast and assess the outcomes of various policies and investments in relation to medium- and long-term national development targets. By offering a systemic approach, GEM forecasts the outcomes of action and inaction across sectors, actors, dimensions of development and over time. Further, GEM enables the formulation of policies and investment packages that result in a more inclusive, robust, and resilient outlook for the country. At the same time, by means of co-creation, GEM supports the creation of a better understanding of the co-benefits associated with sustainable policies and investments, including on climate action, under different climate scenarios.

Figure 1 presents the generalized underlying structure of GEM. Figure 2 presents instead a sub-system diagram of the model. The former shows how four key capitals (built, social, human and natural) are interconnected, and how they contribute to shaping future trends across social, economic and environmental indicators. Specifically, feedback loops can be identified that are reinforcing (R), in all areas pertaining to economic growth and social development. These are driven by investments and knowledge creation, and enabled by the availability of natural capital, which, if not properly managed, can constrain economic growth (hence the balancing loops -(B)- identified in the diagram). Policies can be implemented to promote sustainable consumption and production, decoupling economic growth from resource use (also through education and behavioral change), to mitigate the exploitation of natural capital and generate a stronger and more resilient green growth.

GEM has been applied to more than 50 countries and was designed to include all key sectors that are relevant for future development, for instance in the context of low carbon development (HMIT, 2021; BAPPENAS, 2021) and green recovery packages (UNEP, 2020). These include, among others: population, food demand and supply, land use and land cover, economic activity (via the use of national accounts), employment, access to health care, education, energy demand and supply, air emissions, water pollution, and climate trends. The model also provides an economic valuation for several externalities, including GHG emissions (social cost of carbon), air pollution, wastewater, waste, traffic-related impacts (e.g. accidents, noise), the opportunity cost of water (from savings in the agriculture sector) and biodiversity.

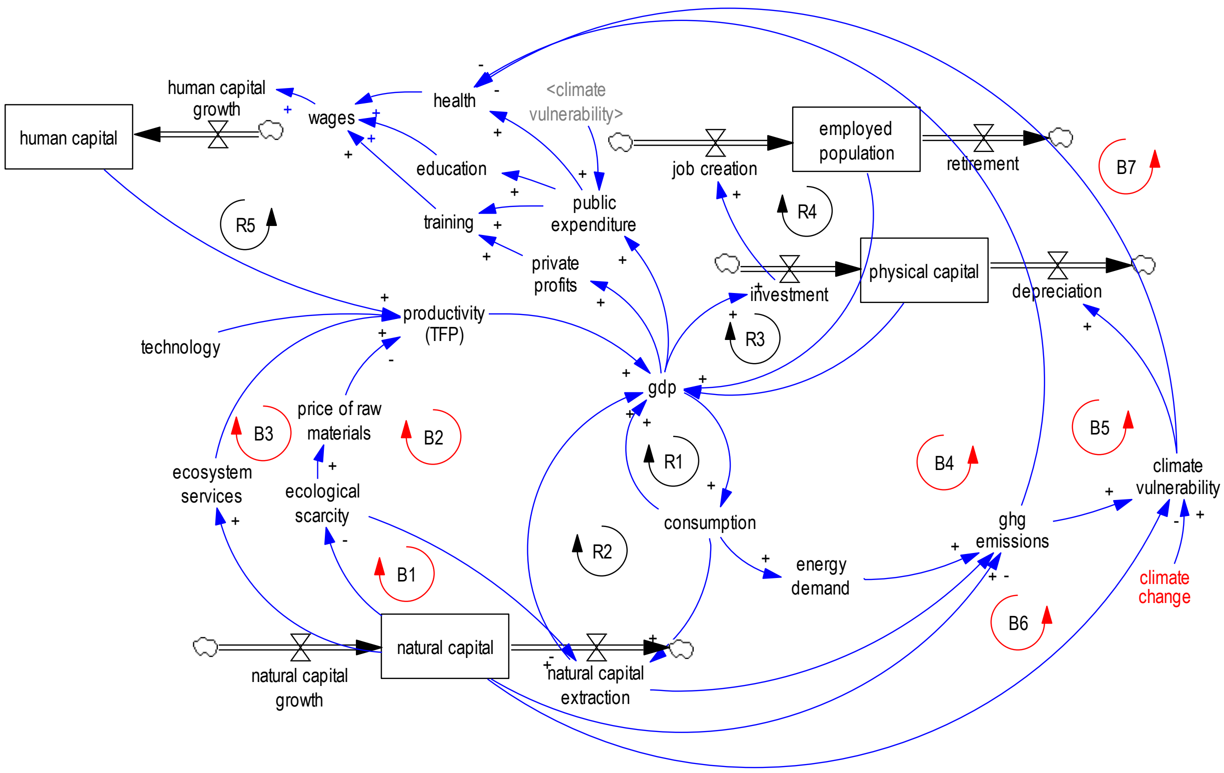


Figure 1: Overview of GEM, built on (Bassi A. , 2015).

GEM is built using the System Dynamics (SD) methodology, serving primarily as a *knowledge integrator*. SD is a form of computer simulation modelling designed to facilitate a comprehensive approach to development planning in the medium to long term (Meadows, 1980; Randers, 1980; Richardson & Pugh, 1981; Forrester, 2002). SD operates by simulating differential equations with "*what if*" scenarios, explicitly represents stocks and flows (critical to estimate climate change impacts on infrastructure, and how such impacts accumulate over time to affect economic productivity, among other indicators), can integrate optimization and econometrics and support model coupling (e.g. in conjunction with spatially explicit models, sectoral models for energy and the economy). The scenarios are calibrated to open-source international databases between the years 2000 and 2023, so that if the model can replicate past trends, then the future are ones are reliable. The data includes the IMF World economic outlook for the economic sectors, the IPCC GHG inventory for the emissions, UNSD for energy balance, and FAO for agriculture related variables. See the breakdown of modules and their data inputs in Table 1.

Data Input	Source and description
System of National Accounts (SNA)	The main input for the government and household accounts come from the IMFs World Economic Outlook (WEO) database, and more detailed thematic databases (e.g. Government Finance Statistics).
GDP	The IMFs WEO outlook provides the total real GDP. If GDP is not sectored the World Bank "% of GDP" is used per sector. National data are also used to calibrate the breakdown of GDP between agriculture, industry and services.
Population	Population is obtained from the UN population prospects.
Agriculture and livestock	The yield, cropland, and livestock are based on FAOSTAT.

Data Input	Source and description
Energy Balance	The first source is UNSTATS, followed by NDC, or national statistics.
GHG Emissions	UNFCCC database (national GHG inventory), NDC
Climate Data	CDS Climate indicators

Table 1: Selected databases used as input for the parametrization and calibration of GEM.

The purpose of using SD for the development and application of GEM is not to make precise predictions of the future, nor to optimize performance; rather, GEM applications are used to inform policy formulation, forecasting policy outcomes (both desirable and undesirable) and leading to the creation of a resilient and well-balanced strategy (Roberts, Andersen, Deal, Garet, & Shaffer, 1983; Probst & Bassi, 2014). This approach is consistent with the thinking framework of policymakers, who weigh *sets* of outcomes on the basis of political, technical and institutional preferences in choosing from among policy packages.

All GEM applications include four key capitals (physical, human, social and natural) as interconnected via the explicit representation of feedback loops (reinforcing or balancing)[3]. Policies can be implemented to strengthen growth (reinforcing loops, e.g. investments in physical capital accumulate capital stock, which, other things equal, increases output potential, production, aggregate demand, including investment, further increasing, capital and output); or curb change (e.g. by strengthening balancing loops). In the context of climate action, we generally find that transition investments directly stimulate new growth, while investments in climate resilience reduce costs and free up resources, thereby enabling new growth indirectly.

Among the many feedback relationships represented by GEM, there are two that are worth highlighting, considering how central they are for explaining the connectedness of climate, environmental and socio-economic outcomes, which is, in turn, central for the design of robust development policies. The first one refers to impacts on what mainstream models refer to Total Factor Productivity (TFP). TFP in the model is impacted by technology, infrastructure (e.g. the road network and access to electricity), energy productivity (i.e. considering the cost of energy as a ratio of GDP), air pollution, weather (e.g. temperature) and extreme weather events. As a result, investments in energy efficiency and renewable energy, to cite two examples both reduce energy consumption and spending (possibly resulting in higher GDP) and reduce air pollution (also possibly resulting in higher GDP, but via a different channel). See model documentation for a full description on TFP impacts (Bassi & Andreasson, 2024).

The second one refers to a feedback loop that governs linkages between climate, environment (including policies) and the socio economy. This feedback loop considers the availability of natural resources, and impacts of land cover change on ecosystem service provisioning, which goes on to affect economic activity, as well as access to natural resources. These dynamics are represented via the use of feedback loops in the model, resulting in circular relations that may highlight the simultaneous emergence of short-term benefits and medium-term challenges, or vice versa, depending on the scenarios simulated.

[3] In a reinforcing loop, a change in one direction is compounded by more change. Under a reinforcing loop, policies or shocks that move a variable in one direction transmit through the system in a way that leads to further increases in such variable over time. For example, money in a savings account generates interest, which increases the balance in the savings account and earns more interest. Balancing loops, in contrast, counter change in one direction with change in the opposite direction.

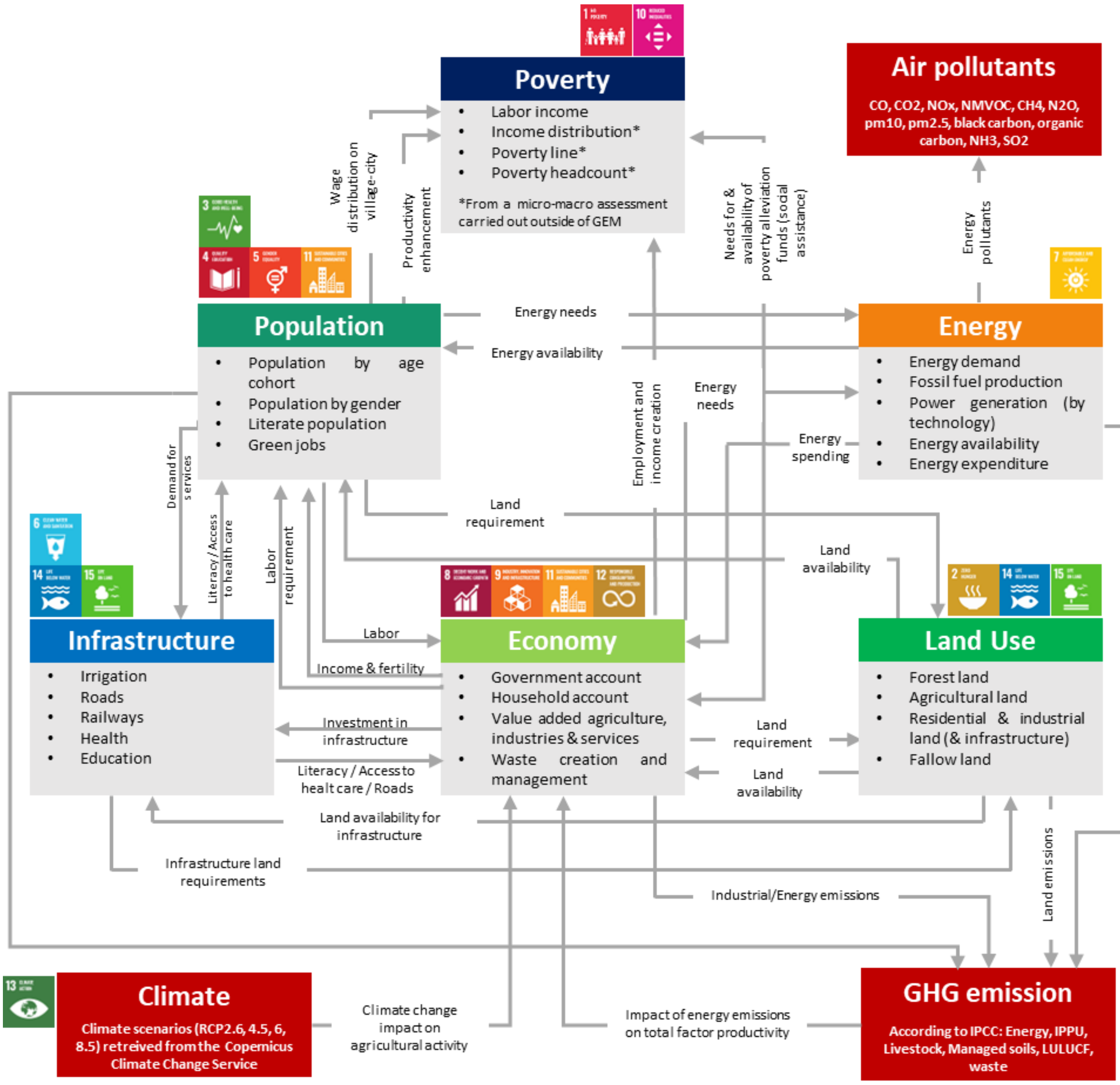


Figure 2: Sub-system diagram presenting the key sectoral components of GEM.

The current model consists of over 40 interconnected modules (Figure 2), each representing a distinct component of the national system analyzed, organized into specific categories. These categories include climate assumptions, population dynamics, macroeconomics, infrastructure, land use and agriculture production, energy demand and supply, emissions, and policy inputs and outputs (including required investment). The climate assumptions are based on representative SSPs, which capture different climate scenarios that influence long-term projections. The population and poverty module captures demographic trends, including births and deaths disaggregated by gender and labor income providing a detailed understanding of how human populations evolve and interact with economic and environmental systems.

The macroeconomic modules cover critical aspects such as gross domestic product (GDP), disaggregated by industry, services, agriculture, and also include employment by sector (also regarding green jobs), and the government and household accounts. These variables collectively depict the overall economic landscape of the country, supporting the analysis of the drivers of growth and development and how these change over time. Infrastructure and public services are also modeled through subcomponents including assets related to roads, agricultural infrastructure, productive capital for industry and services, buildings, power generation capacity and transmission lines, which play essential roles in determining both the capacity for economic productivity and the quality of life within a society.

The agriculture and land-use modules focus on land-use patterns and land cover change (e.g. considering forest, fallow, urban and agriculture land), crop production (considering land, land productivity and production), livestock numbers and related production, as well as production input and related infrastructure (e.g. irrigation). This offers a detailed understanding of how land is being used, and the extent to which it contributes to climate mitigation and adaptation, directly (e.g. based on the stock of land and ecosystem service provisioning, and indirectly via socio-economic activity).

Simultaneously, the energy module tracks energy demand by sector (residential, commercial, industrial and transport) and energy source (coal, petroleum products, natural gas, electricity, biomass and waste, and hydrogen), estimates the cost of energy consumption, and the needs for power generation (by technology). It further estimates employment for power generation (construction and operation and maintenance) and for investments in energy efficiency and fuel switching. Energy is critical, as it interacts with the economy in several ways: via energy spending and capital productivity, employment and income generation, air pollution and labor productivity. Further, all energy, land use, IPPU, waste and agriculture practices are connected with the emissions module, which captures greenhouse gas (GHG) emissions and air pollutants from various energy sources, economic activities and natural processes (e.g. carbon sequestration by forest land).

While Figure 2 provides a simplified visual representation of sub-components of GEM, it does not fully capture the complexity of the feedback loops present within the model. This is shown, at a high level, in Figure 1. On the other hand, the two diagrams highlight the most relevant interconnections existing in the model across sectors and indicators, such as the central role of the economy in driving growth, investment (from both government and private sectors), and production; the impact that the economy has on energy, and conversely the economic repercussions of energy spending, employment, and air pollution. The same applies to infrastructure more in general, driven by economic growth but also impacting economic activity. Infrastructure that is efficient and resilient to climate extremes contributes to economic growth. On the other hand, infrastructure that is vulnerable to climate change curbs economic growth, both directly (via reduced efficiency and availability of infrastructure services) as indirectly (by requiring resources for reconstruction that could be used for other purposes). These relationships are crucial in understanding the broader dynamics of sustainable development, as these are embedded in GEM, where economic growth must be balanced with environmental sustainability and social well-being.

1.3 Climate Pathways

Various climate impacts can be simulated in the model as each infrastructure asset and economic sector experience climate change impacts, albeit differently. Extreme weather events can damage infrastructure, reduce agricultural productivity, and reduce labor productivity. In the model, climate change impacts the various sectors, via the use of climate damage functions, as follows (Figure 3):

Power Generation & Load Factors: Climate change affects the efficiency and capacity of power generation, with impacts on load factors due to extreme weather events and increased variability in weather patterns.

Roads & Buildings: Infrastructure such as roads and buildings face increased damage from extreme weather, leading to higher repair and maintenance costs and reduced usability over time.

Industry & Service Capital: Climate impacts result in increased depreciation and loss of capital in the industry and service sectors, affecting overall productivity and economic stability.

Transmission Networks: The reliability and efficiency of transmission networks are compromised by climate impacts, with increased risk of damage and disruption due to extreme weather events.

Labor Productivity: Climate change affects labor productivity through health impacts, heat stress, and altered working conditions, reducing overall workforce efficiency and economic output.

Yield & Livestock: Agricultural yields and livestock productivity are directly impacted by changing climate conditions, such as shifts in precipitation patterns and temperature extremes, leading to variability in food production.

The damage thresholds in the model are based on established climate impact research, ensuring alignment with accepted standards, see model documentation for more detail (Bassi & Andreasson, 2024). However, these thresholds are adaptable to accommodate the specific environmental, economic, and social conditions of each local context. This flexibility allows for more precise assessments of climate impacts and the effectiveness of adaptation strategies, ensuring that the model's outcomes are relevant and tailored to the unique vulnerabilities and needs of the regions being studied. This type of customization would also be necessary for carrying out a sub-national assessment, e.g. by province.

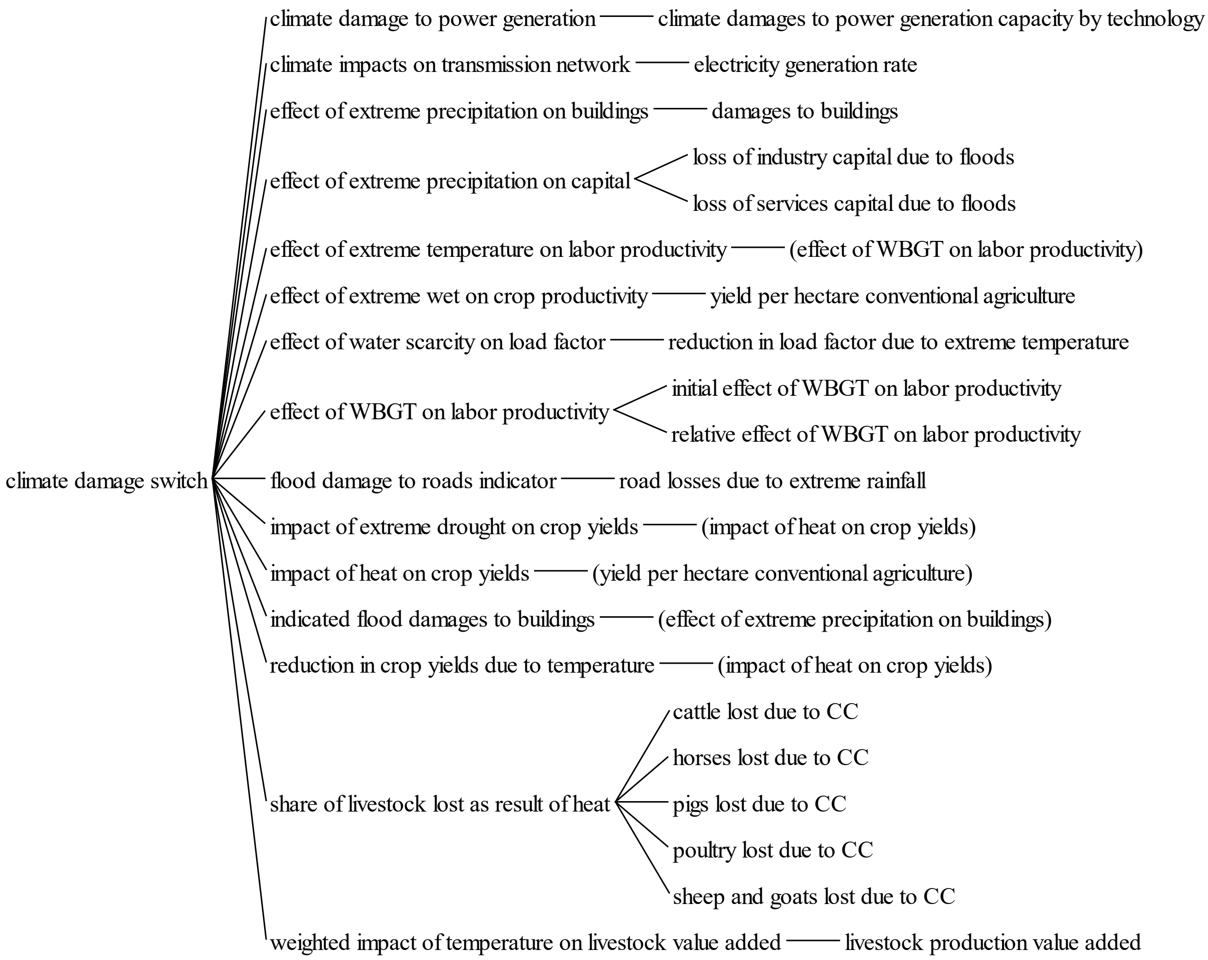


Figure 3: Impact pathways of climate change within GEM

1.4 Assets at Risk

GEM estimates adaptation needs based on the amount of assets at risk, defined as the absolute value or the share of either infrastructure (buildings, power generation capacity, roads, power transmission networks) or productive assets (productive capital for industry and services). The spatial maps provided by Zutari in the Climate Hazard Assessment play a crucial role in the GEM's estimation of adaptation needs by offering detailed, localized insights into the amount and geographical distribution of assets at risk. These maps, which overlay climate hazard data with existing infrastructure and productive assets, enable a more precise identification of areas and assets vulnerable to climate hazards. By integrating these spatial representations (e.g. via the percentage of assets at risk) the analysis carried out with GEM can better reflect the local context (Figure 4). GEM then adds the time dimension, forecasting model outputs with monthly time steps to fully account for climate variability during seasons and over time, up to 2050/2070. This allows to first estimate the total amount of assets at risk based on the climate hazard assessment, and then estimate -for any given point in time- the amount of assets that are actually damaged, based on climate forecasts and asset-specific climate damage functions. GEM then offers the opportunity to simulate different climate scenarios, along with different assumptions for climate action (proactive or reactive). This is required to assess impacts for socio-economic and environmental indicators, and finally estimate the economic viability of climate adaptation investments with an integrated Cost Benefit Analysis (CBA).

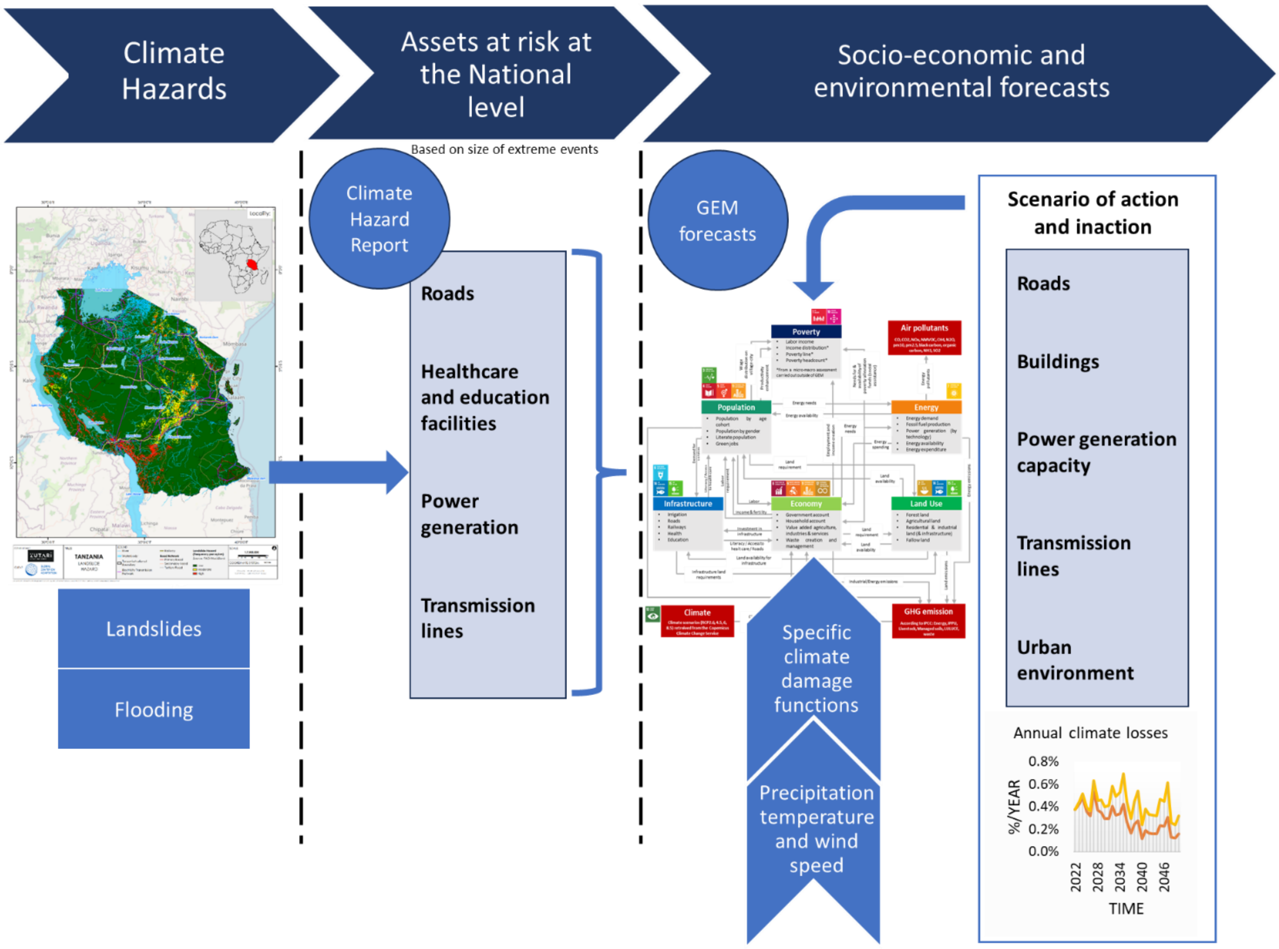


Figure 4: Process for Integration of the Climate Hazard Assessment into GEM

Specifically, the output of the Climate Hazard Assessment includes assets-at-risk maps[4] and tables, which categorize assets based on the probability of climate damage into four levels: High, Medium, Low, and Very Low. The "Very Low" category includes assets with a probability of damage occurring only once in over 1,000 years. The analysis carried out with GEM considers the "High" and "Medium" categories for a realistic representation of adaptation ambition and costs.

Table 2 presents the amount of assets at risk at the country level. It is important to note that liveable cities and buildings were not included in the climate hazard assessment and thus required separate estimations, which were conducted using Zutari's work. For liveable cities, the risk was set at 25%, reflecting the high ambition for nature-based solutions that aim to mitigate the impact of heat-related damages (i.e. 1 in 4 people in urban areas would benefit from nature-based solutions) (Zakka, Permana, Majid, & Danladi, 2017; UNICEF, 2024). Regarding. buildings, the percentage of assets at risk was estimated by using the median percentage at risk observed for educational centers and healthcare facilities.

This method operates on the premise that educational centers and healthcare facilities, being essential community structures, are generally situated in areas that reflect the broader urban or rural landscape. These buildings often exhibit similar construction standards, land use patterns, and exposure to

[4] The areas defined in the hazard exposure categories are based on globally available flood maps from UNEP and have a coarse resolution making them good for national level assessments but may need refinement if zooming into the regional level.

environmental risks as other nearby structures. By employing the median percentage of assets at risk for these facilities, an estimate was derived for the vulnerability of other buildings, thereby avoiding the need for individual assessments of each structure type. Since these types of buildings are typically situated within or near other settlements, their risk level is considered representative of broader building stock. For instance, if 8% of healthcare facilities are identified as being at risk, it is reasonable to use a similar percentage to estimate the risk for all buildings in similar areas. This approach ensures a consistent approach with the work done in the climate hazard assessment. For a methodological note, see the corresponding model documentation (Bassi & Andreasson, 2024).

Assets at Risk		
Asset	Unit	Tanzania
Roads (km)	%	8.0%
Buildings (Buildings)	%	11.0%
Power Generation Capacity (MW)	%	52%
Transmission Lines (km)	%	16%
Livable cities	%	25.0%

Table 2: Asset at risk per assets from the climate hazard assessment carried out by Zutari

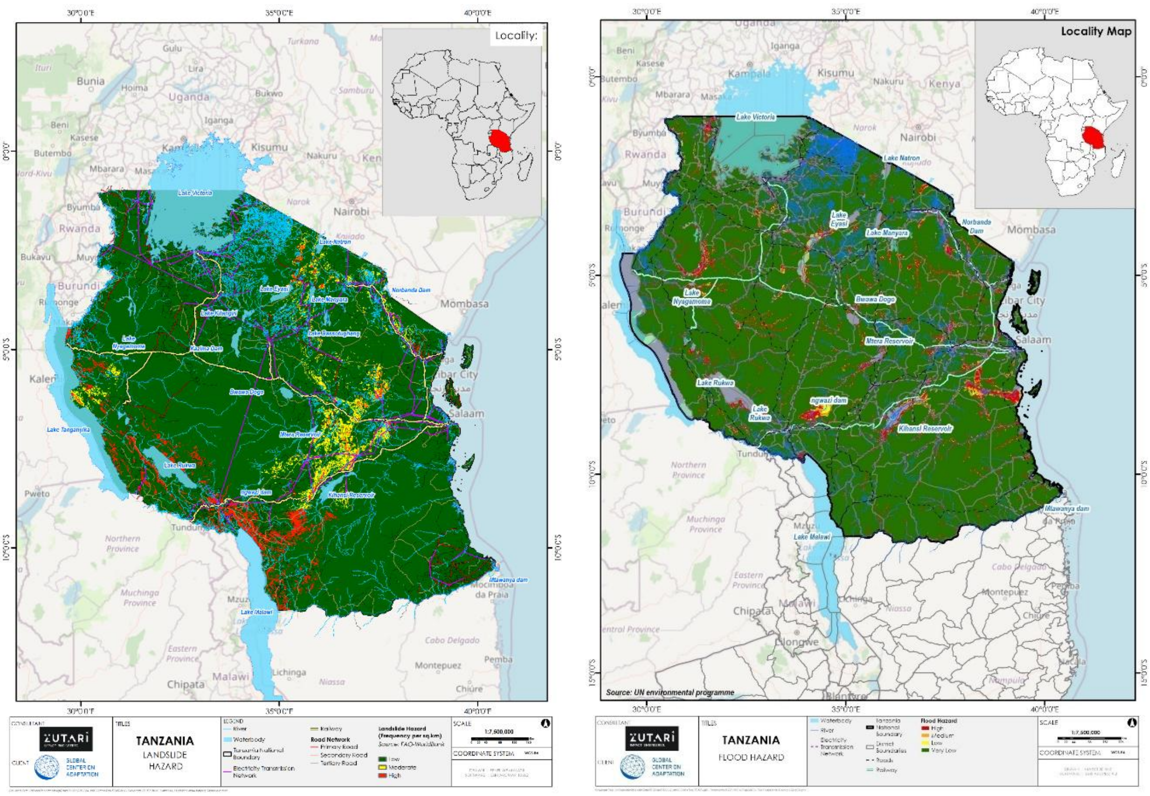


Figure 5: Hazard maps for Tanzania from the climate hazard assessment carried out by Zutari

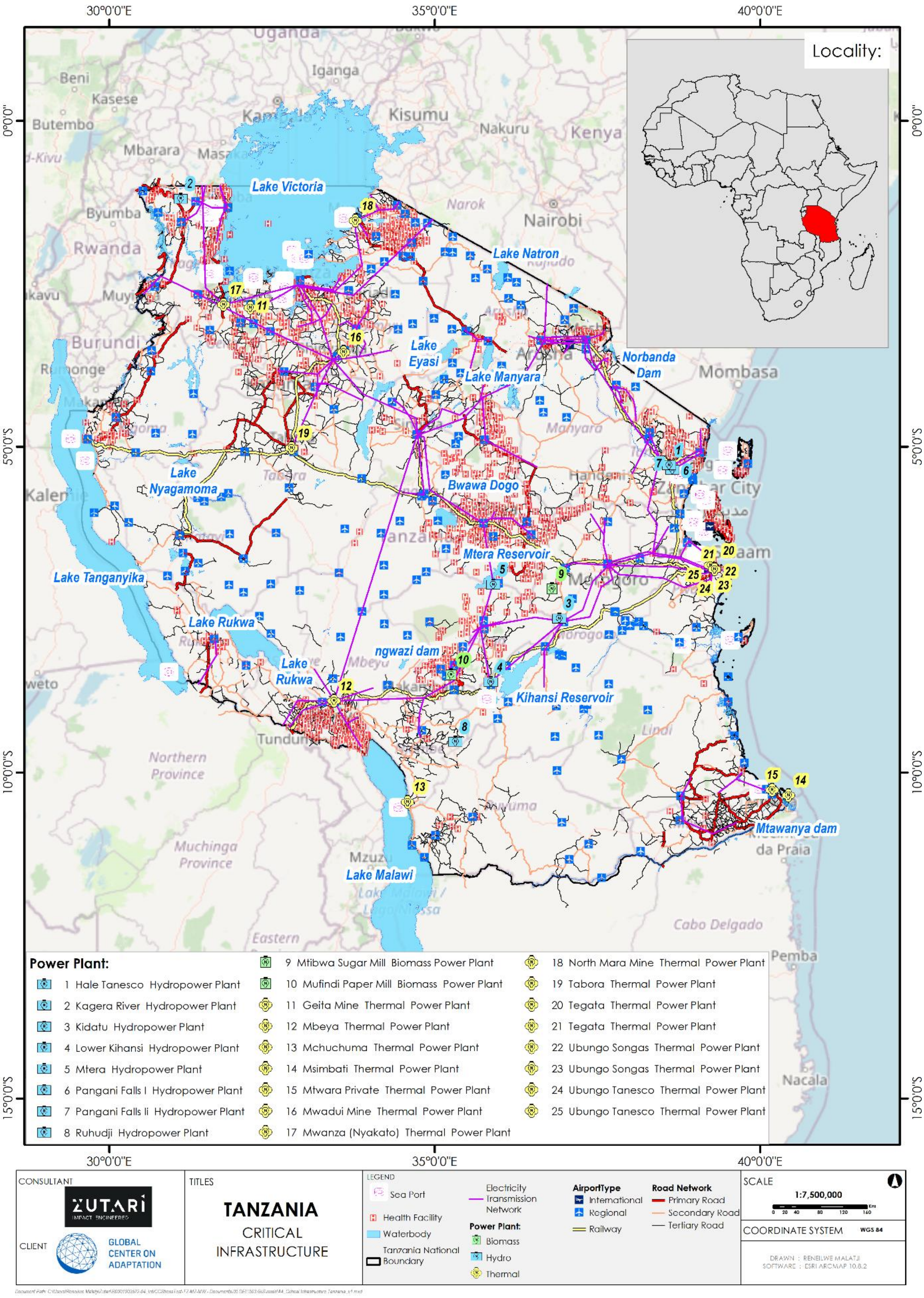


Figure 6: Critical infrastructure system for Tanzania from the climate hazard assessment carried out by Zutari

1.5 Scenario overview

Several scenarios have been produced with GEM, as presented in this report: (i) a Business as Usual (BAU) case without any climate impacts, (ii) three different BAUs that consider three SSP scenarios (SSP1, SSP3, and SSP5), (iii) two adaptation cases with one focused on resilience (proactive), and one rebuilding any damages without climate proofing (reactive). The ambitions for the adaptation scenarios are currently based on assumptions.

Business as Usual without Climate Change (No CC BAU)

The BAU without climate impact scenario represents the status quo and serves as an indicator to show a scenario of plausible growth without climate impacts. In this scenario, no additional measures for climate resilience or transition are implemented beyond what is already mandated by policy/law or currently in practice. It reflects a future where the nation's policies and actions remain largely unchanged, following historical patterns and conventional practices.

SSP scenarios

The SSP scenarios continues to assume inaction on any development-related strategy but add climate trends and the impact of extreme weather events estimated respectively in the SSP1, SSP3 and SSP5 climate scenarios.

Adaptation Scenarios, proactive and reactive

Two different alternative scenarios are considered, reflecting action to (a) climate-proof the economy through adaptation investments (proactive approach) or (b) rebuild infrastructure after damages occur (reactive approach). Specifically, the proactive scenario considers specific ambition for climate change resilience by sector and asset, to safeguard the nation against the adverse impacts of climate change (see Table 3 for proactive policy ambitions). The reactive scenario focuses instead on investments to rebuild infrastructure from climate damage, without focusing on climate proofing.

Proactive scenario - climate resilience: investments to reduce climate change damage by anticipation. Climate resilience measures within the proactive scenario are strategic investments aimed at minimizing the negative impacts of climate change. These interventions anticipate and prepare for the challenges posed by a changing climate, such as extreme weather events, sea-level rise, and changing precipitation patterns. The key principle is to build resilience within the nation's infrastructure, agriculture, and communities. This approach not only reduces the immediate damage caused by climate change but also minimizes long-term economic and social costs.

Reactive scenario - loss and damage: investments to recover from climate damage. Loss and damage interventions in the reactive scenario recognize that, despite transition and climate resilience efforts, some climate-related impacts may still occur. These interventions are focused on providing the necessary financial, logistical, and social support to recover from the adverse consequences of climate change. They encompass insurance mechanisms, disaster recovery plans, and assistance to affected communities. Differently from the proactive scenarios, the goal of the reactive scenario is quantifying the cost of reacting to climate impacts and estimating the economic upside resulting from reconstruction.

Climate change Adaptation				
Intervention	Unit	2030	2040	2050
Labor productivity				
Additional buildings with airco	%	0%	0%	0%
Buildings with retrofit insulation	%	0%	0%	0%
Livable cities (green spaces)	%	66%	100%	100%
Flood protection for infrastructure				
Share of buildings with flood protection	%	50%	100%	100%
Industry capital with flood protection	%	50%	100%	100%
Services capital with flood protection	%	50%	100%	100%
Roads with flood protection	%	66%	100%	100%
Power generation				
Wind protection				
Thermal generators	%	66%	100%	100%
Wind generators	%	66%	100%	100%
Solar generators	%	66%	100%	100%
Flood protection				
Thermal generators	%	66%	100%	100%
Hydropower	%	66%	100%	100%
Wind generators	%	0%	0%	0%
Solar generators	%	0%	0%	0%
Transmission Lines	%	66%	100%	100%

Table 3: Proactive adaptation ambition

2. SIMULATION OUTCOMES

Under the SSP 3 BAU scenario, climate damages are projected to escalate significantly, driven by the increasing frequency and intensity of extreme weather events. Without intervention, buildings, infrastructure, and economic activities face substantial risks, leading to constantly growing repair and replacement costs. This scenario highlights the urgency of addressing climate vulnerabilities to mitigate long-term financial and structural impacts.

Effective adaptation strategies can enhance resilience, reduce economic losses, and ensure sustainable development. This report provides an overview of the simulation outcomes, highlighting the projected impacts on infrastructure and evaluating the effectiveness of different adaptation measures. The results of the analysis show that the proactive scenario offers a strong synergy between investments, economic growth, social empowerment and environmental preservation, as follows:

In the SSP3 BAU scenario, damages from climate impacts total 135 billion USD by 2050, being 38% of GDP by 2050.

This figure reflects the extensive economic toll of climate-related damage on infrastructure and assets. This includes damage to roads, buildings, power generation and the transmission network, as well as productive capital for industry and services.

Under the SSP3 climate forecast, 0.4% of service and industry capital is lost annually, costing a cumulative sum of 65 billion USD by 2050. The damage to buildings totals 41 billion USD by 2050.

This persistent annual loss underscores the significant economic toll on key economic sectors. Addressing these vulnerabilities is crucial to prevent substantial long-term losses, both of capital and value addition for the economy.

In the SSP3 BAU scenario, total real GDP is reduced by 8% in 2050 compared to scenario without climate change. The annual reduction is 0.2%.

This substantial decline illustrates the severe economic impact of unmitigated climate change. GDP growth could be 0.2% higher every year, with a climate resilient economy.

A proactive approach to climate resilience is a competitive economic development strategy. It achieves a Benefit to Cost Ratio (BCR) of 7.91 by 2050 and realizes USD 12.6 billion of cumulative net benefits between 2023 and 2050. A reactive approach, one that focuses on reconstruction only, achieves instead a BCR of 0.54 by 2050.

The proactive scenario stands out as a competitive economic development strategy at the national level, it offers a unique approach to address the pressing issue of climate change. It recognizes that climate action and economic prosperity are not mutually exclusive but can, in fact, be mutually reinforcing. The investments outlined in the proactive scenario are not just ambitious but economically viable as well.

Investments into climate proofing under the proactive scenario reduce total climate damage by 26% compared to SSP3 BAU.

Investing into climate resilience effectively reduces the size of the impact on infrastructure and thus, is a cost-effective method of saving money in the long term. The climate proofing under the proactive scenario reduces the economic loss of capital by 36%, buildings by 26%, km of roads by 15%, and power generation infrastructure damage by 36% compared to SSP3 BAU. The investments total 1.2 billion USD by 2050.

The adaptation interventions implemented under the proactive scenario reduce the loss of buildings from on average 0.4% to 0.1% annually.

This reduction translates to saving approximately 83,500 buildings each year. Climate-proofing measures, which have the largest impact, are projected to save these 53,600 buildings annually by 2050. This emphasizes the substantial potential of proactive adaptation strategies in mitigating the adverse effects of climate change on infrastructure, highlighting the importance of investing in resilience to protect assets and ensure sustainable development.

Climate proofing power generation infrastructure under the proactive scenario saves 1371 MW generation capacity by 2050.

The proactive scenario protects power generation capacity from wind and flood climate impacts. While the reactive scenario has the same damage as the SSP 3 scenario as no climate resilience is included.

The proactive scenario stimulates economic growth (GDP 0.6 % higher than BAU by 2050) and job creation (0.2% higher than BAU by 2050) both by reducing costs of climate change (resilience) and by increasing productivity.

Proactive generates economic growth and job opportunities through a dual strategy. On one hand, it mitigates the economic burdens associated with adapting to climate change, reducing the costs incurred due to climate-related disasters.

The required investment is highest for the proactive scenario (close to 0.4% of GDP by 2030) while the reactive case has initially lower investments levels (0.01% of GDP by 2030). This higher ambition would save Tanzania USD 35 billion in avoided climate impacts in the future, and offers a positive return on investment.

The adaptation scenario envisions significant investments, making it a comprehensive and proactive strategy to address climate change. By earmarking substantial funds, the proactive scenario ensures that it has the financial resources to make a significant impact. While the proactive case has higher initial investments the reactive case becomes more expensive overtime.

2.1 Climate Trends

The climate trends section provides an overview of the projected impacts of climate change based on the SSP 1, 3, and 5 scenarios. The climate impacts discussed in later chapters are calculated using this climate data parsed into the model. Any impacts considered in the model are derived from these trends.

In the SSP3 scenario, temperature is forecasted to increase in Tanzania (Figure 7). The data for this forecast is obtained from the Copernicus Climate Data Store, with monthly time steps, and the model used is MPI-ESM1.2. The integration of climate data into GEM is covered in section 4 of the model documentation (Bassi & Andreasson, 2024).

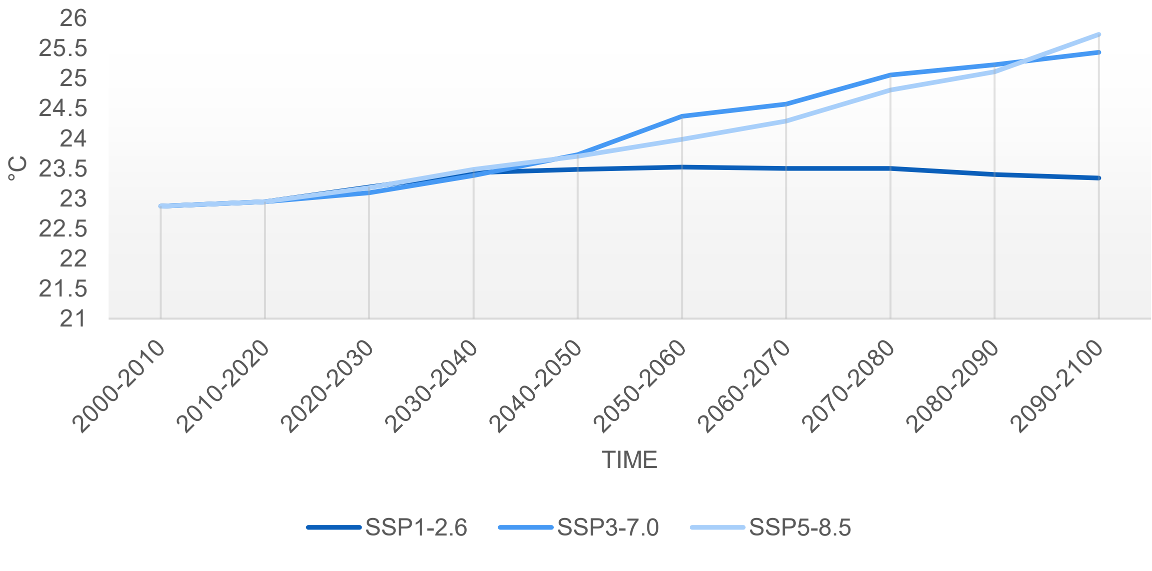


Figure 7: Average monthly temperature obtained from MPI-ESM1.2

The increasing trend continues for average monthly precipitation between 2090 and 2100 where, in SSP3 the monthly precipitation starts to increase towards 95 mm/month, otherwise it oscillates around 80 mm/month throughout the simulation (Figure 8). In SSP5, monthly average precipitation increases over 95mm per month in the 2090s.

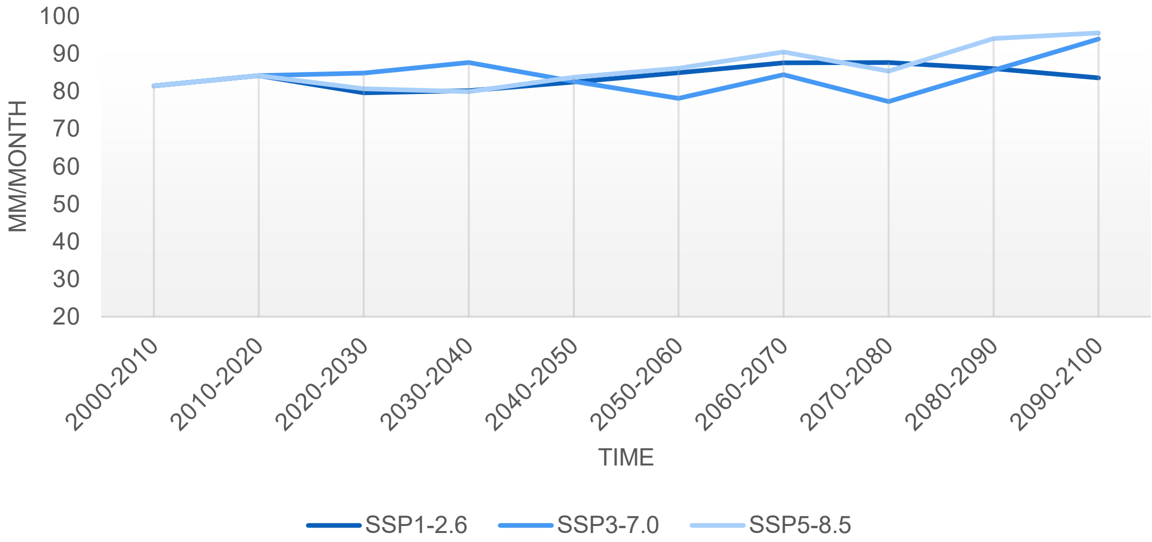
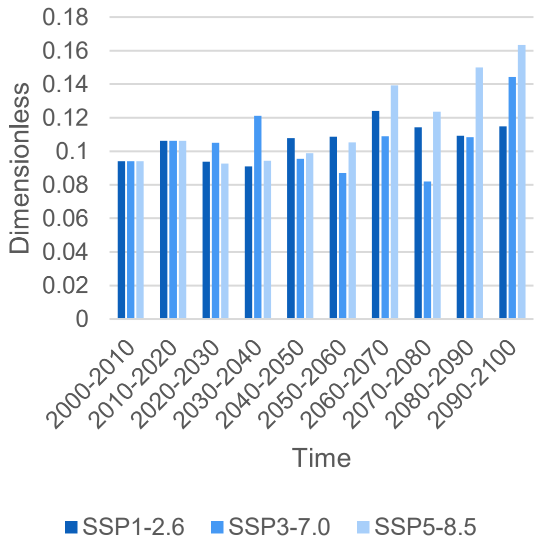


Figure 8: Average monthly precipitation obtained from MPI-ESM1.2

The growing volatility in climate, highlighted by average temperature and precipitation, leads to higher levels of incidence of abnormalities of extreme wet events under SSP3 and SSP5 (Figure 9). In the SSP 1 the extreme wet incidences decrease while in the SSP3 and SSP5 the rate increases substantially meaning more extreme floods will occur (Figure 10).



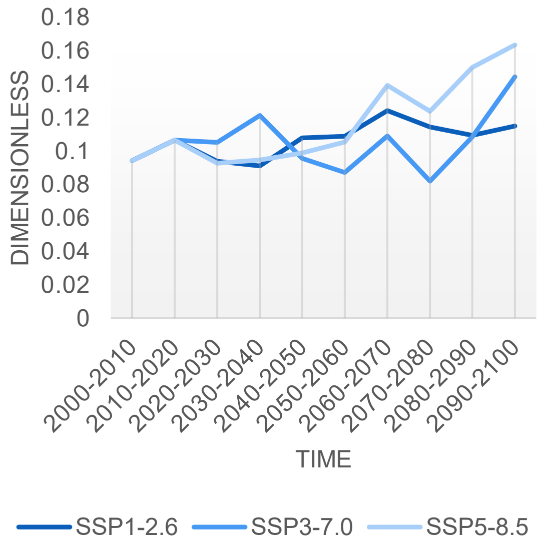


Figure 9: Incidence of abnormalities - extreme wet for Tanzania

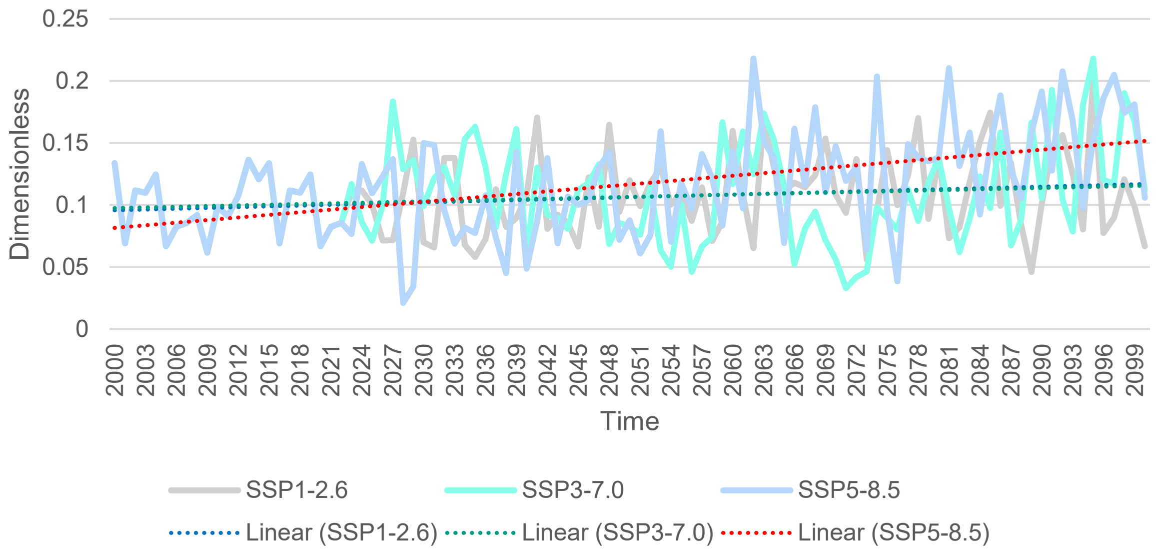


Figure 10: Extreme wet percentile for Tanzania

The same trend applies to extreme dry events. As the temperature and precipitation rise, extreme dry incidents become more frequent (Figure 11 and Figure 12). This results in more droughts and other heat related impacts. Generally, despite oscillations, SSP 3 and 5 have extreme dry events occur more frequently compared to SSP 1.

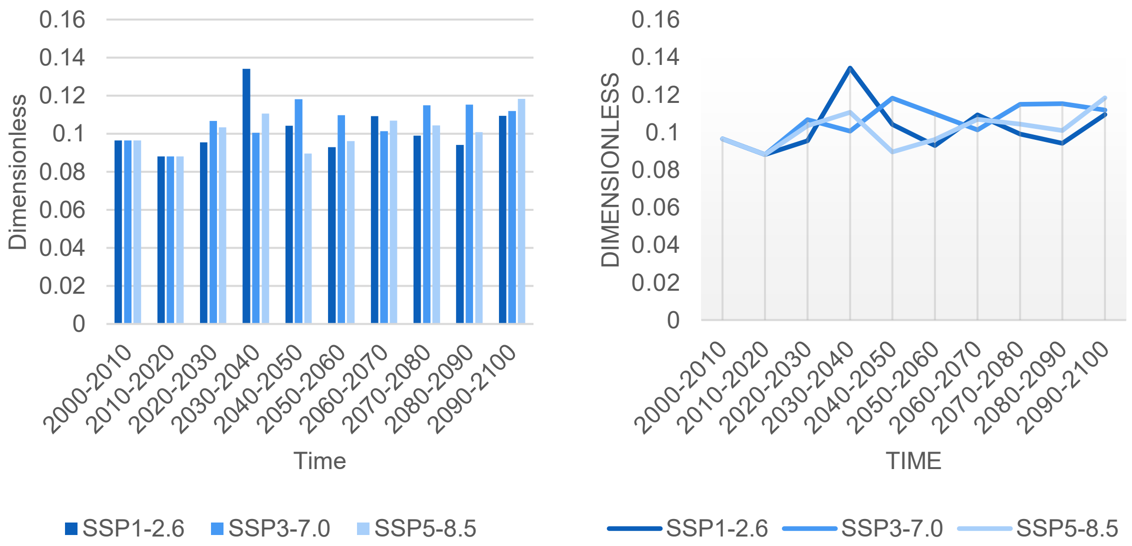


Figure 11: Incidence of abnormalities - extreme dry for Tanzania

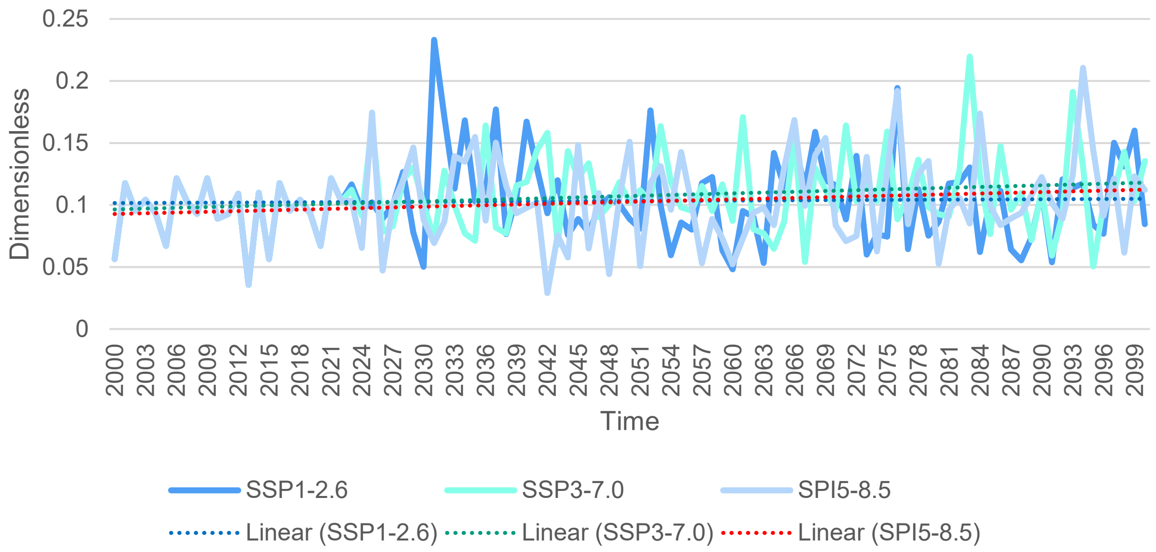


Figure 12: Extreme dry percentile for Tanzania

Climate trends indicate a significant increase in temperature and fluctuating precipitation patterns, particularly in the SSP3 and SSP5 scenarios. The data used as input into GEM shows that these changes will likely exacerbate the frequency and severity of extreme weather events. Such trends foreshadow substantial climate impacts, including increased incidence of floods and other climate-related abnormalities, highlighting the urgent need for adaptation measures.

2.2 Climate impacts

The projected climate trends, characterized by rising temperatures and variable precipitation patterns, are expected to have profound impacts on various sectors. In the SSP3 scenario (used in the simulations), these changes will increase the frequency and intensity of extreme weather events, such as floods and heatwaves. These impacts will not only affect natural ecosystems but also cause significant damage to infrastructure, buildings, and capital. As a result, economies may experience substantial financial losses, and vulnerable populations could face heightened risks. For a full list and description of climate functions, both on their input and impacts, see complimentary model documentation (Bassi & Andreasson, 2024).

2.2.1 Climate impact on capital

In the SSP3 BAU scenario, the effect of extreme precipitation on capital is influenced by the SSP 3.6 climate forecast, resulting on average 0.4% capital losses due to floods. However, in the proactive adaptation scenario, climate resilience measures effectively reduce the average loss of total capital due to floods from 0.4% on average to 0.1% (Figure 13).

In economic terms, in the SSP 3 scenario, cumulative total capital losses start at 6.6 billion USD in 2022 and rise to 65 billion USD by 2050, the equivalent of 38% of the 2024 value of capital for industry and services. In the reactive scenario, the damages do not show a substantial reduction compared to SSP 3 BAU. However, in the proactive scenario, damages are significantly reduced by 36%, bringing the total down to 41 billion USD by 2050 (Figure 14). The key adaptation drivers include a reduction in climate change damages. The indicators used to measure these outcomes are nominal investments and a flood indicator, highlighting the effectiveness of proactive adaptation measures in mitigating financial losses from climate impacts.

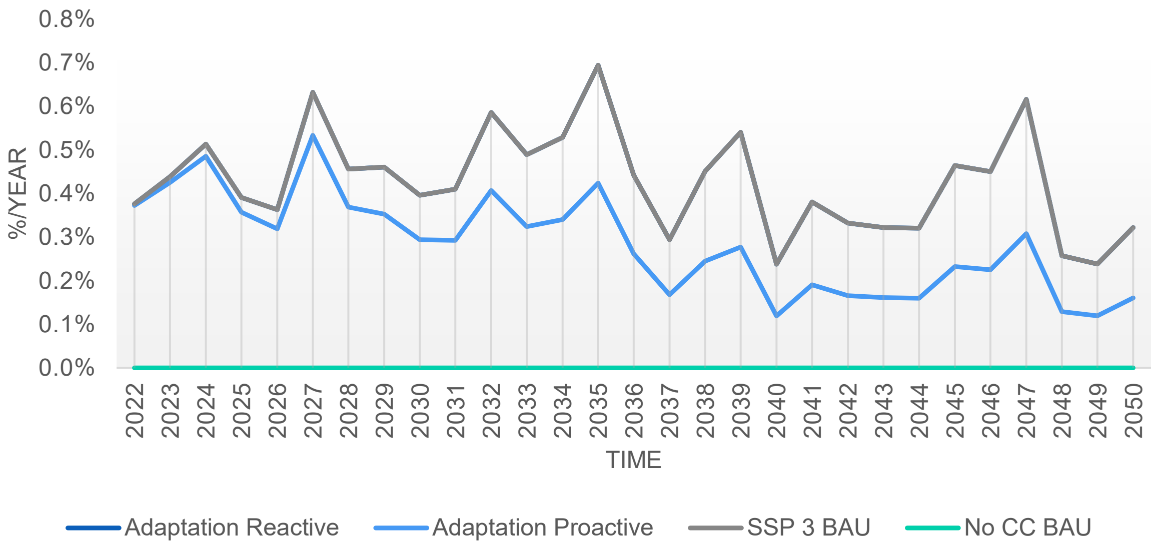


Figure 13: Annual percentage of losses of capital under SSP and Adaptation scenarios

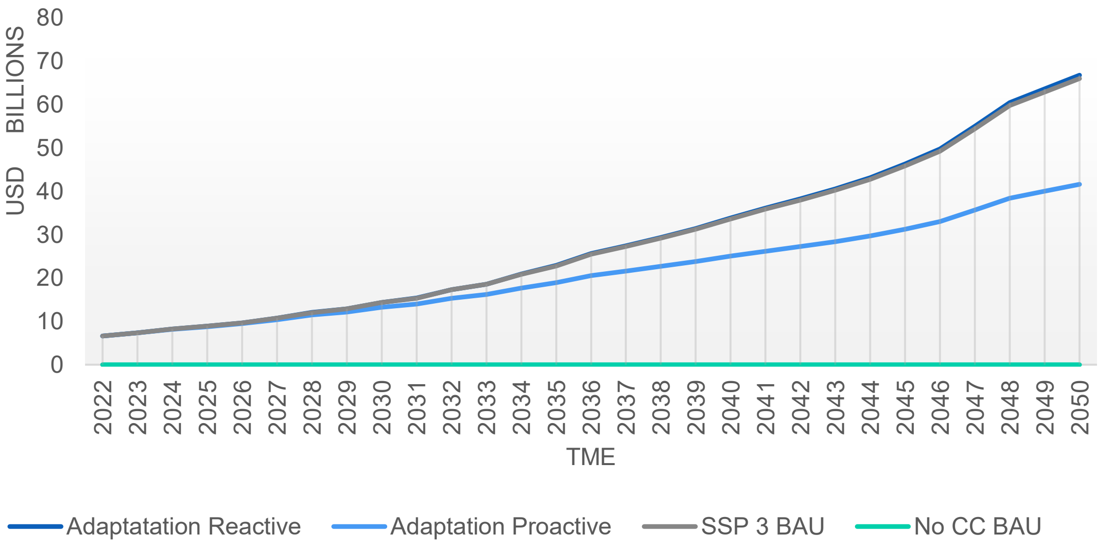


Figure 14: Cumulative total capital losses under BAU, SSP, and Adaptation scenarios

2.2.2 Climate impact on buildings

In the SSP3 scenario, extreme precipitation (such as flooding and landslides, and general water related damage) results in damage to an average of 83,500 buildings (0.4%/annually), In the reactive scenario, where no adaptation interventions are implemented, this level of damage remains unchanged. Conversely, in the proactive adaptation scenario, the impact of extreme precipitation on buildings decreases to an average of 53,600 dwellings (0.1%) due to enhanced flood protection measures. The annual losses result in significant economic losses. Namely, in the SSP 3 scenario, climate change damages to buildings are projected to reach 32 billion USD by 2050, corresponding to 28% of the total building stock in 2024. In the reactive scenario, cumulative damages increase past the SSP 3 level by 0.1% due to higher GDP growth but a lack of climate resilience measures. In contrast, the proactive scenario reduces cumulative damages to buildings by 26% compared to the BAU, lowering the total to 23 billion USD by 2050 (Figure 17). The key adaptation drivers include a reduction in climate change damages and enhanced flood protection. The indicator used is the stock ofbuildings, which reflects the effectiveness of these adaptation measures in protecting buildings from climate impacts.

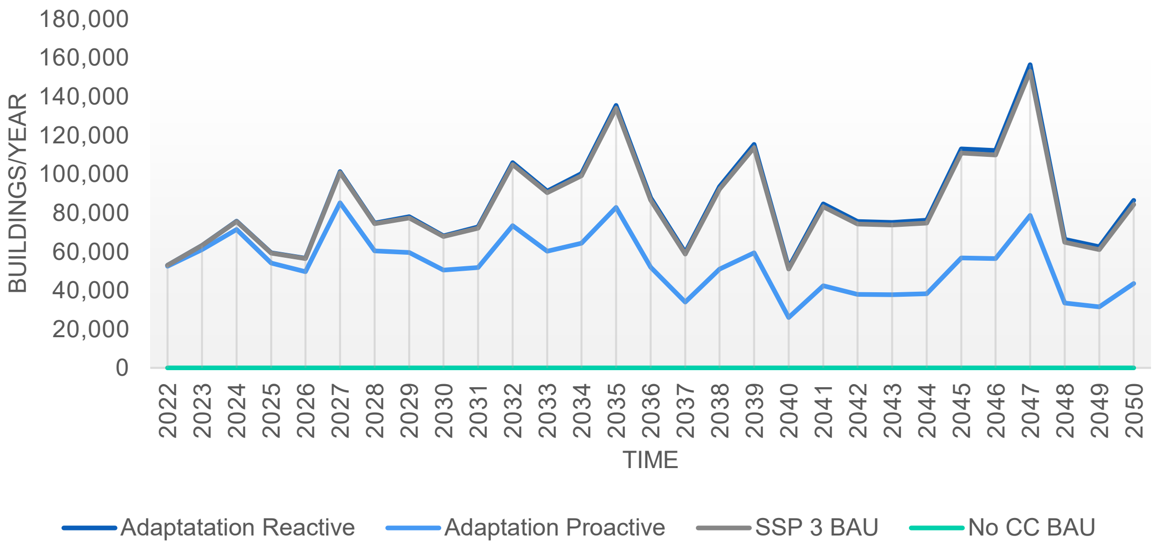


Figure 15: Annual loss of buildings due to extreme weather events in Tanzania

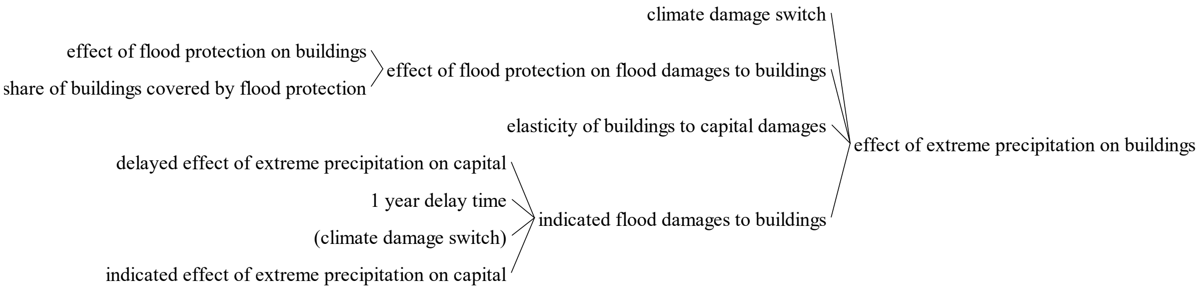


Figure 16: Tree diagram of GEM structure for building damages

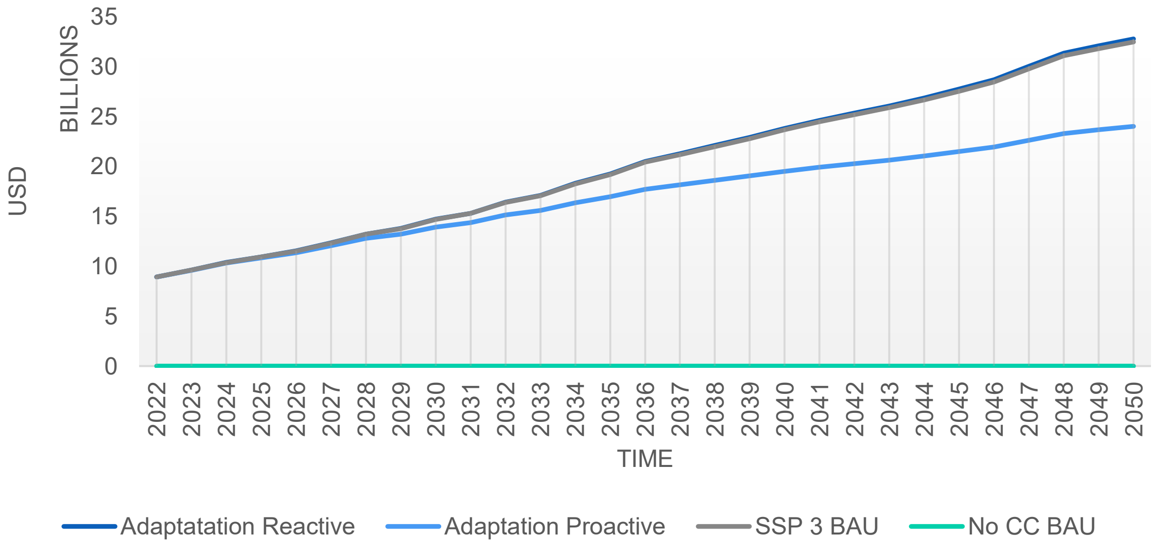


Figure 17: Cumulative Damage to Buildings under BAU, SSP, and Adaptation scenarios

2.2.3 Climate impact on roads

In the SSP3 scenario, approximately 0.4% of roads are damaged annually due to flooding, landslides, and erosion, leading to climate change damages totaling USD 865 million by 2050. Annual losses for roads are projected at 3,566 kilometers, which represents 4% of the total road stock in 2024. This significant physical loss would equate to 104% of the entire road network as it exists in 2024. It is important to clarify that this figure does not imply that every kilometer of road will be damaged; rather, it suggests that the same stretch of road could sustain damage multiple times over the next 25 years. In the reactive scenario, without specific adaptation interventions, cumulative climate change damages to roads reaches 872 million USD, driven by higher economic growth. In contrast, the proactive scenario, which includes flood protection measures, reduces the annual road damage to 0.05%, translating to 729 million USD in cumulative damages by 2050, 15% less than in the SSP3 scenario. Key adaptation drivers are the reduction in climate change damages and the implementation of flood protection measures. The indicator for assessing these outcomes is the stock of roads and cumulative climate change damage to roads, highlighting the effectiveness of proactive strategies in minimizing infrastructure damage.

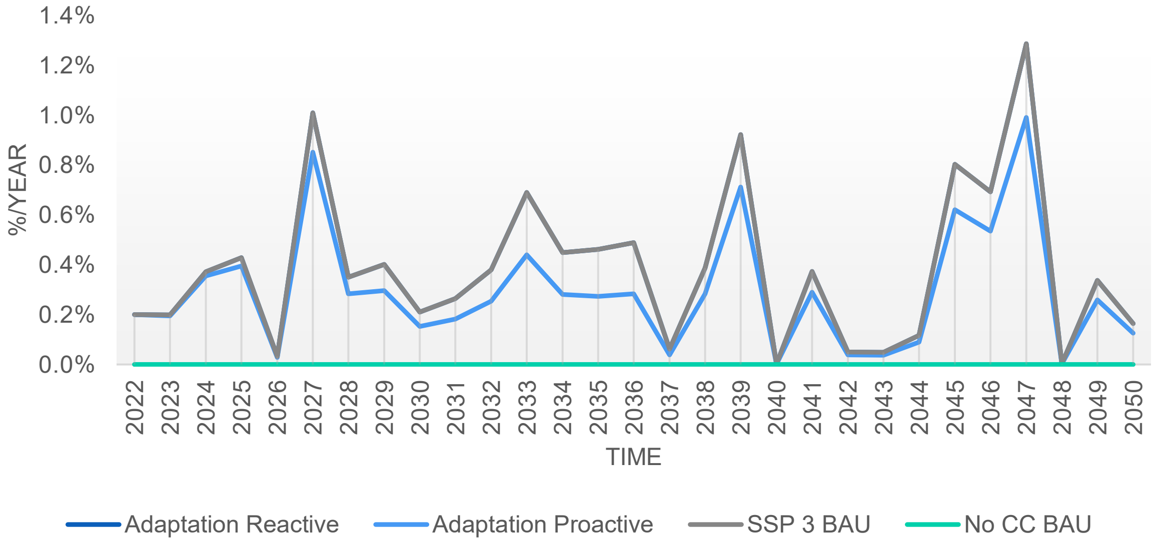


Figure 18: Annual percentage of roads damages due to climate change

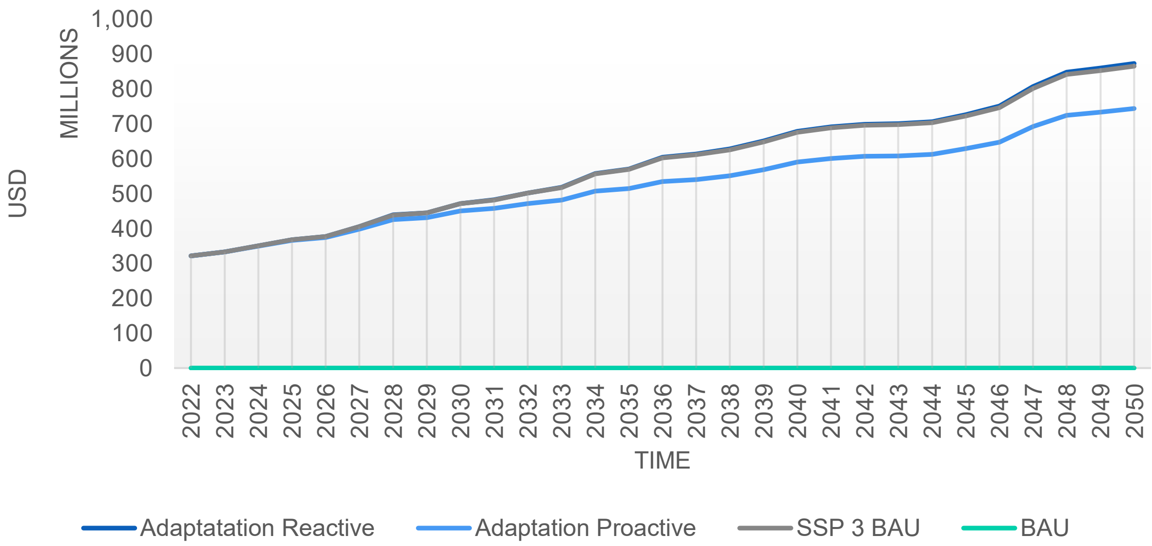


Figure 19: Cumulative economic damage to roads in USD under BAU, SSP, and Adaptation scenarios

2.2.4 Climate impact on power generation

Regarding power generation structures, GEM calculates the damages based on extreme wet and wind percentile derived from the SSP 3.6 climate forecast for Tanzania. Based on the elasticity, input, and effect table, specific percentage of losses is computed which in turn, reduces the stock of power generation capacity by said amount (Figure 20).

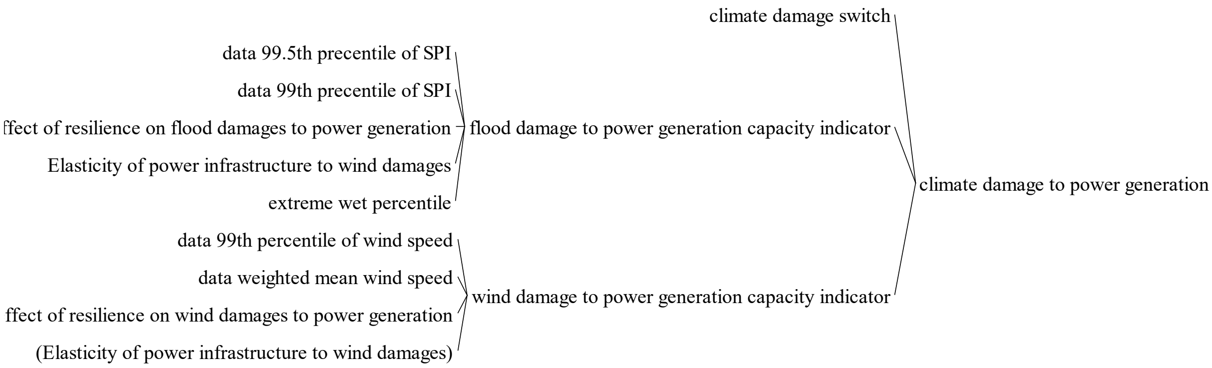


Figure 20: Tree diagram for climate damage to power generation

In the SSP3 scenario, total power generation capacity losses due to climate change are projected to reach 2,677 megawatts (MW) by 2050, translating to economic costs exceeding USD 5.8 billion. The projected annual damage of 205 MW of capacity would cumulatively result in this significant loss, representing 130% of the power generation capacity in 2024. In the reactive scenario, where no climate resilience measures are included and the focus is solely on reconstruction efforts, MW capacity losses remain the same as SSP3 BAU. Conversely, in the proactive scenario, where infrastructure is climate-proofed, cumulative MW capacity losses are reduced by 59%, resulting in a loss of 1094 MW and lowering economic damages to 3.7 billion USD by 2050. This represents a 36% reduction in cumulative damages compared to the BAU scenario. Key adaptation drivers include a reduction in climate change damages and increased resilience to weather variance.

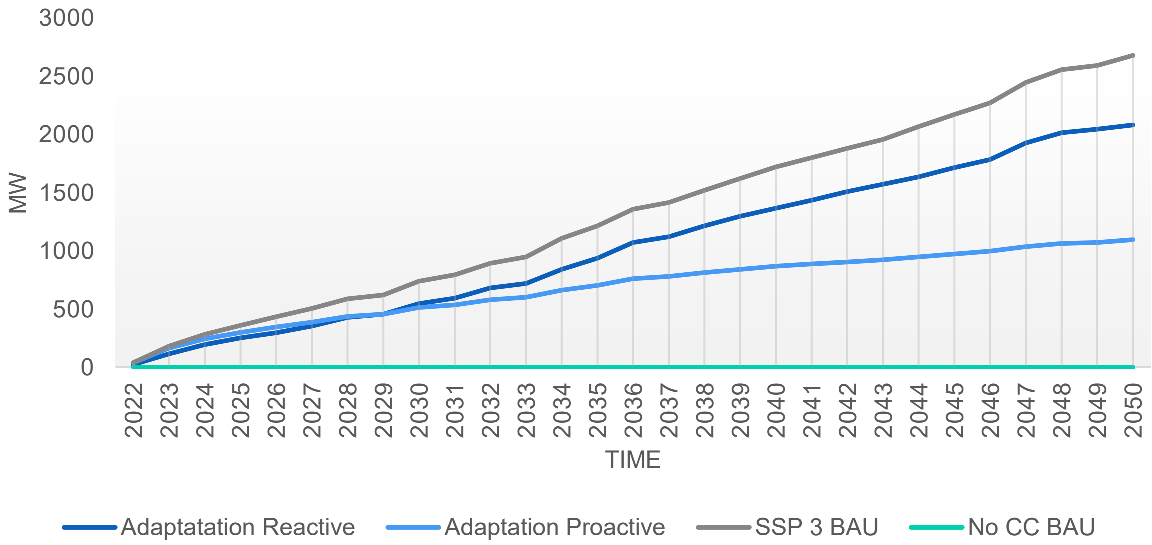


Figure 21: Cumulative MW Capacity losses for Tanzania

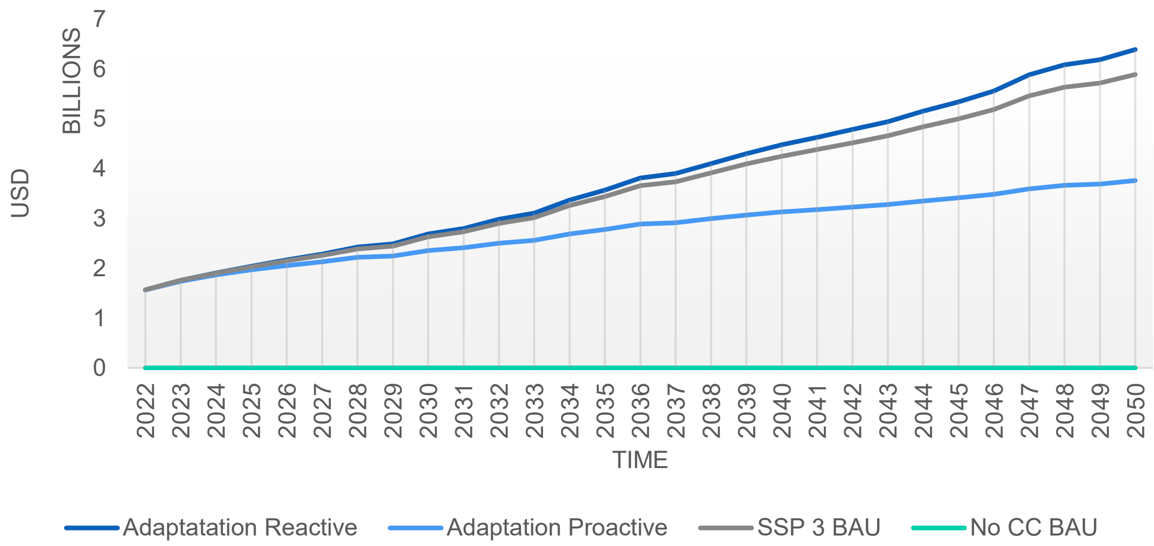


Figure 22: Cumulative economic losses of power generation capacity in Tanzania

Lastly, in the SSP3 scenario, the climate impacts on transmission networks remain at approximately 30% of the stock of transmission network that are at risk of climate impact (16% of total). On the other hand, this damage is estimated to have a short duration. In the adaptation scenario, where climate-proofing measures are implemented, these impacts are reduced by half, to 15% compared to SSP3 BAU.

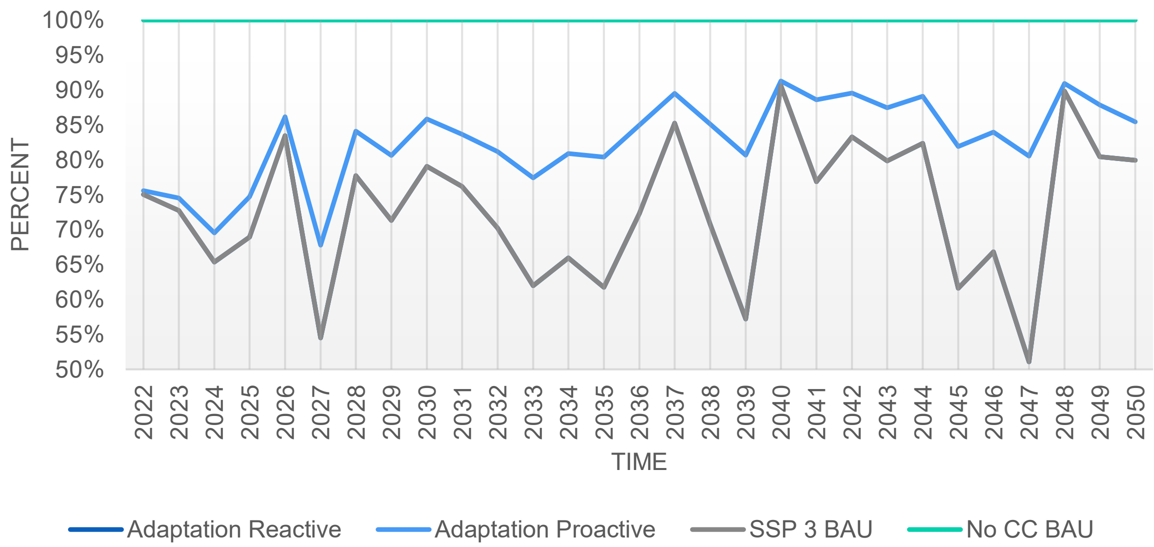


Figure 23: Annual reduction from the km of transmission network at risk due to climate change

2.2.5 Total climate impact

Altogether, the climate damages to assets total 135 billion USD by 2050 in the SSP 3 BAU scenario. The largest impacts can be seen in the building and capital sectors. In the reactive scenario, the damages remain close to 138 billion USD as no climate-proofing measures are included. However, in the proactive scenario, climate damages are reduced to 100 billion USD due to building climate resilience (Figure 24, Figure 25 and Figure 26). The primary drivers of these damages are extreme wet conditions, floods, and other extreme weather events. The indicator used to measure these impacts is the accumulation of annual climate damage.

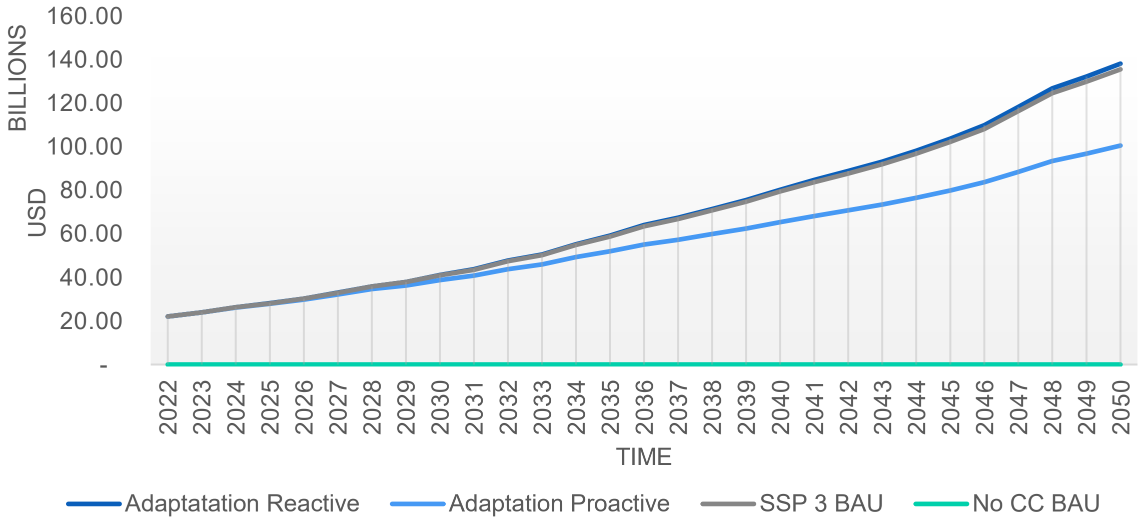


Figure 24: Cumulative climate damages under BAU, SSP, and Adaptation scenarios

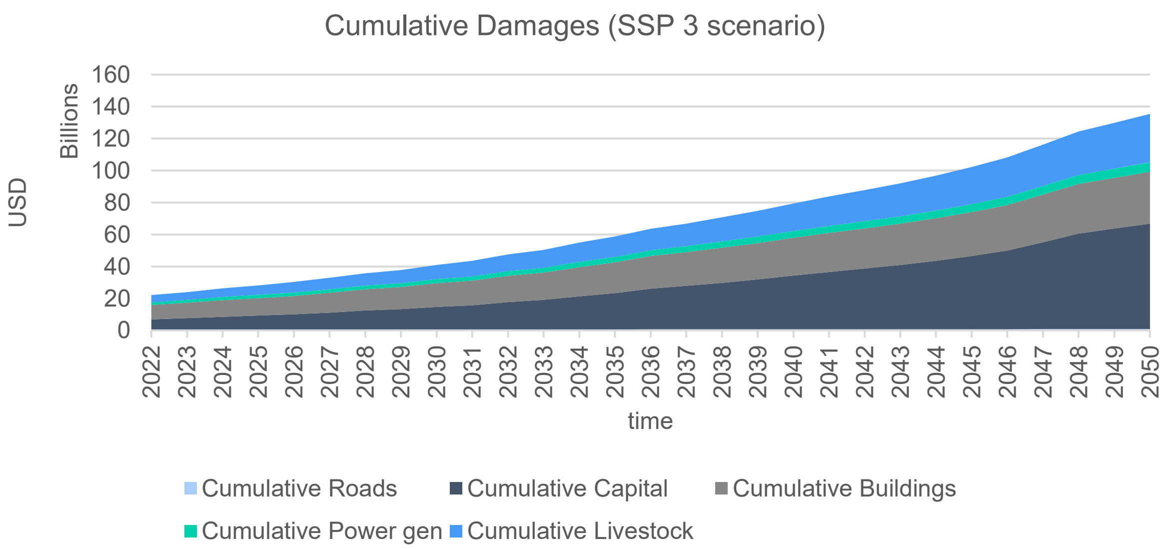


Figure 25: Stacked cumulative damages for Tanzania in SSP3 BAU scenario

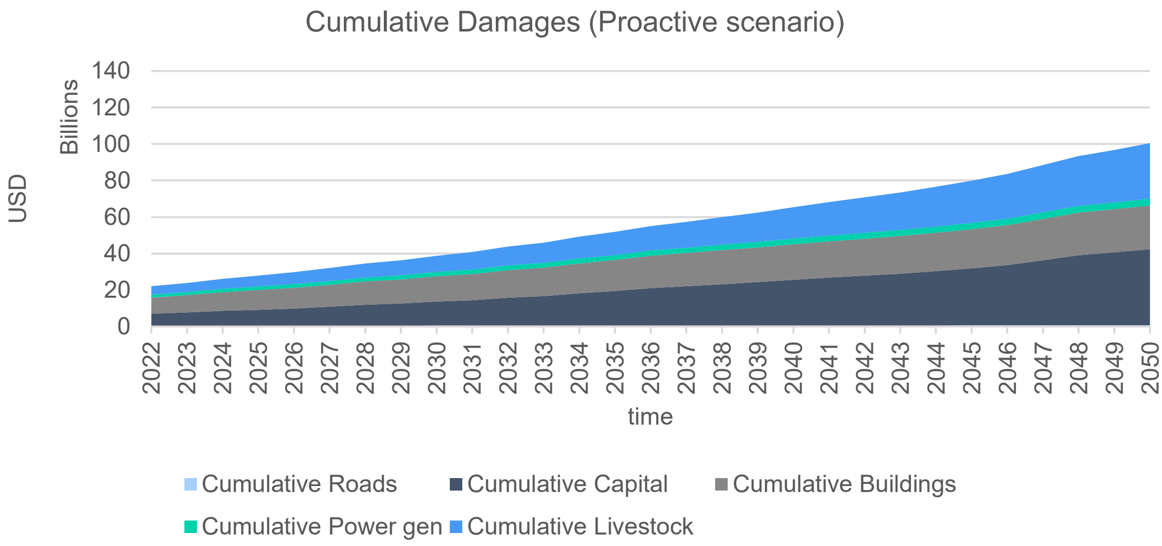


Figure 26: Stacked cumulative damages in the adaptation proactive scenario

The analysis highlights the significant climate impacts on assets, particularly within the building and capital sectors, with damages potentially reaching 135 billion USD by 2050 in the SSP 3 BAU scenario. While the reactive scenario does not reduce climate damage, it can still boost the impacts on the economy through reconstruction. On the other hand, proactive measures can significantly reduce these damages signifyingly. These findings underscore the importance of building climate resilience to mitigate extreme weather events. In the following section, we will explore how these climate impacts translate into broader economic effects, influencing GDP growth and other economic indicators.

2.3 Macro-Economic Impacts

Climate impacts on infrastructure have profound implications for economic growth. Extreme weather events, such as floods and severe storms, can cause extensive damage to buildings, roads, and other critical infrastructure, leading to significant repair and replacement costs. These disruptions not only strain public and private finances but also hinder economic activities by reducing productivity and increasing operational costs.

The impact of climate-related damages directly influences the projected growth trajectories depicted in the total real GDP graphs. If climate change impacts are not included total real GDP accumulates to 418 billion USD by 2050. However, In the SSP 3 BAU, total real GDP increases from USD 60.78 billion in 2022 to 385 billion in 2050. Given that the 2050 value represents a single point in time, it is more appropriate to examine the cumulative impacts occurring between 2024 and 2050. By 2050, cumulative GDP losses in Tanzania are projected to reach USD 395 billion, translating to an annual average loss of approximately USD 14.64 billion. This annualized loss represents 20% of Tanzania's GDP in 2024, which corresponds to around 5.39 years of GDP. Thus, between now and 2050, the workforce in Tanzania is expected to dedicate the equivalent of 5.39 years to offset the costs associated with climate impacts. This is aligned with previous research by the IMF (International Monetary Fund. African Dept., 2023).

This narrative continues in the reactive scenario as the focus is on reconstruction rather than adaptation. Therefore, in the reactive scenario, total real GDP grows by 1.3% compared to SSP 3 BAU, reaching 389 billion USD by 2050. However, In the proactive scenario, total real GDP grows to USD 393 billion by 2050, which is 1.9% higher compared to the SSP 3 scenario (Figure 27). Adaptation drivers include the reduction in climate change damages and higher levels of economic growth related to climate adaptation investments.

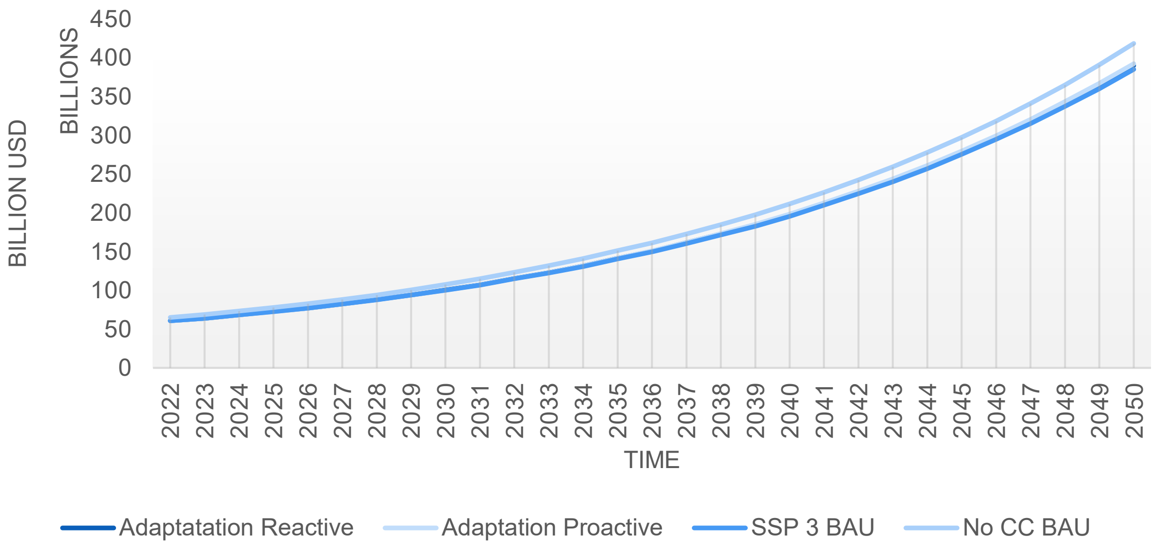


Figure 27: Total real GDP for Tanzania under BAU, SSP, and Adaptation scenarios

In the No CC BAU scenario, the average real GDP growth stands at 6.8 percent over the period from 2022 to 2050. In the SSP 3 scenario, the real GDP growth rate averages 6.72 percent over the same period. The lower growth comes from climate impacts. In the adaptation scenarios, the growth rate is generally larger as there is higher reconstruction rates or more emphasizes on climate resilient infrastructure. Thus, in the reactive scenario, the real GDP growth rate averages 6.77 percent over the same period, with 0.1 percent contributed by insurance. Conversely, in the proactive scenario, the real GDP growth rate also averages 6.79 percent over the same period (Figure 28). Both scenarios prioritize adaptation measures, including the reduction of climate change damages and increased capital accumulation, to sustain economic growth.

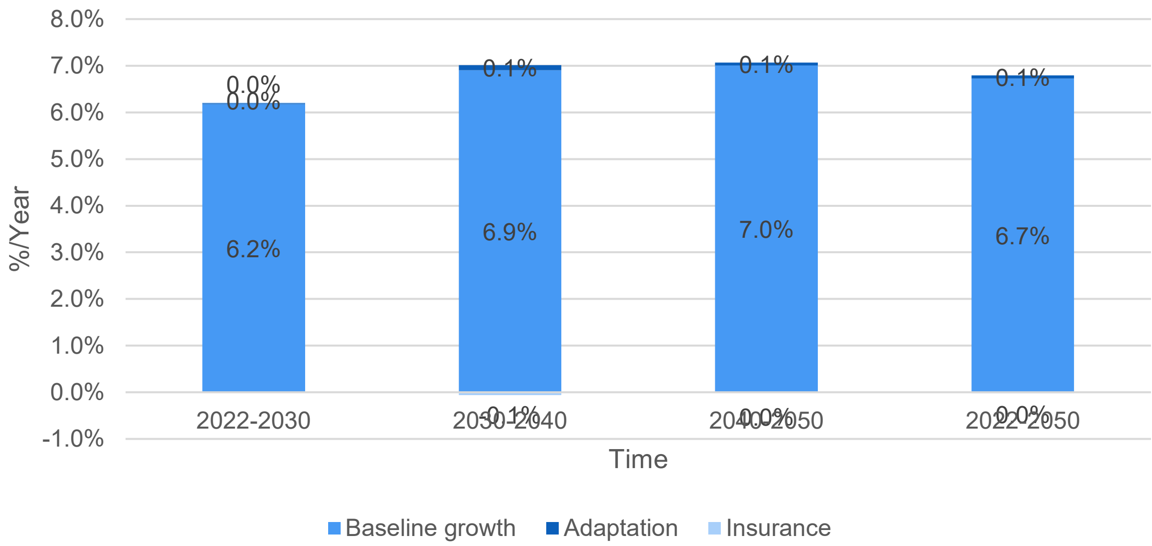


Figure 28: Real GDP growth rate over the decades, comparing growth under Adaptation and SSP scenarios

Average real GDP Growth	Unit	2022-2030	2030-2040	2040-2050	2022-2050
Adaptation Reactive	%/Year	6.2%	7.0%	7.1%	6.771%
Adaptation Proactive	%/Year	6.2%	7.0%	7.1%	6.792%
SSP 3 BAU	%/Year	6.2%	6.9%	7.0%	6.724%
Adaptation vs SSP 3 BAU	%/Year	0.6%	0.8%	0.7%	0.704%

Table 4: Average real GDP growth rate under simulated decades for Tanzania

According to climate forecasts, projections indicate that an extreme climate event is anticipated to occur around November 2045. In the SSP 3 scenario, the extreme climate event leads to a significant 1.5% decline in real GDP compared to a BAU scenario without climate change. This stark reduction underscores the vulnerability of economic systems to the adverse effects of climate change. It highlights the urgent need for proactive measures to mitigate the impact of extreme climate events and build resilience within our socioeconomic structures.

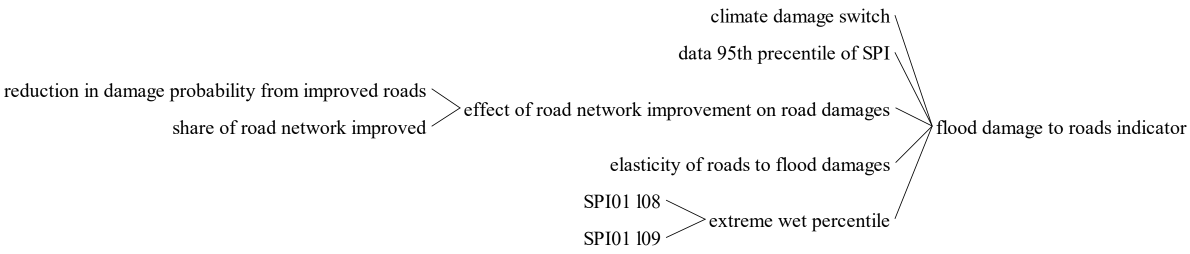


Figure 29: Tree Diagram for road losses calculations in GEM

In the reactive scenario, the impact of the extreme event is mitigated to some extent. Specifically, compared to the BAU scenario of SSP 3, the extreme event is projected to be improved by 7.8%. However, in the proactive scenario, which involves more comprehensive adaptation measures, the improvement is even more significant, with a projected enhancement of 1.4% compared to the BAU scenario (see monthly change in roads in Figure 30). These scenarios highlight the importance of proactive measures in climate adaptation.

In the SSP 3 scenario, it is projected that the occurrence of an extreme climate event would lead to a substantial 50% increase in road disruptions compared to a BAU scenario without climate change. This emphasizes the vulnerability of transportation infrastructure to the impacts of climate change, highlighting the urgent need for adaptation measures. In the reactive scenario, where no specific climate resilience strategies are implemented, road disruptions align closely with the projections of the SSP 3 BAU scenario. This underscores the potential exacerbation of climate-related impacts in the absence of proactive intervention. However, in the proactive scenario, with explicit climate resilience measures, the extreme event is projected to be improved by 2% compared to the SSP 3 BAU scenario.

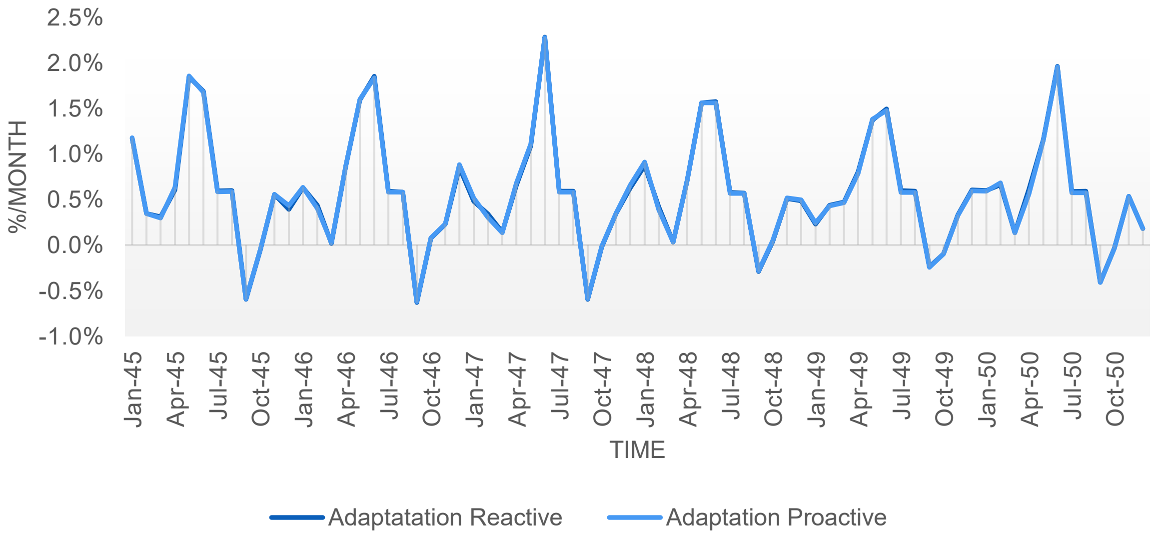


Figure 30: Monthly change in roads between 2045 and 2050, under BAU, SSP, and Adaptation scenarios

An example of reduced climate impacts between 2045 and 2050 is the stock of roads as in the reactive scenario, where no specific climate resilience measures are implemented, the trajectory of real GDP closely aligns with the projections of the SSP 3 BAU scenario. This suggests that without proactive intervention, economic performance follows a path largely determined by existing socioeconomic trends and climate impacts. Contrastingly, in the proactive scenario, where climate adaptation measures are implemented, the peak impacts of extreme climate events are mitigated (Figure 31). These measures, aimed at reducing climate change damages, play a crucial role in minimizing the adverse effects on various sectors, including the economy.

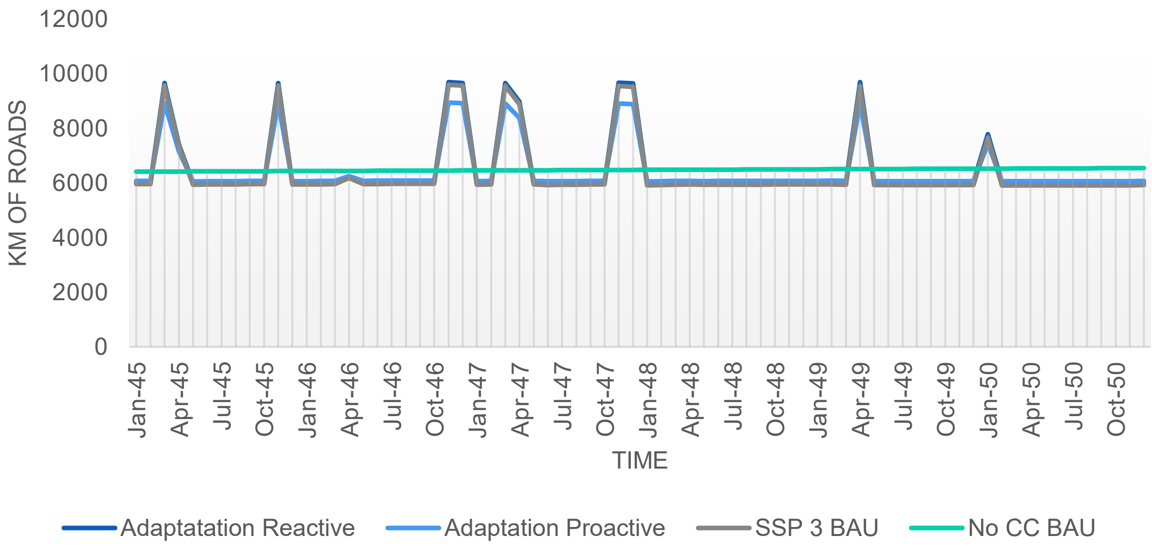


Figure 31: Monthly change in the stock of roads under BAU, SSP, and Adaptation scenarios

2.4 Social

Climate impacts on infrastructure can significantly influence employment. Damage to infrastructure from extreme weather events can cause immediate job losses in sectors like construction, transportation, and utilities due to damages work sites and capital.

In SSP3, total employment is projected to reach 57.58 million people by 2050. In the reactive scenario, employment increases slightly to 57.62 million, while the proactive scenario sees a more significant rise to 57.67 million, reflecting a 2% increase compared to the baseline (Figure 32). Ambitious adaptation interventions drive this growth, alongside higher GDP. Investments such as nature-based solutions, flood resilience for roads via the use of stormwater management infrastructure or permeable pavement, and flood walls for buildings reduce damage and allow for additional and more resilient economic activity, in addition to stimulating direct, indirect and induced jobs creation. Monitoring the ratio of total unemployed persons to the total population nationally provides insights into labor market conditions and the effectiveness of adaptation strategies in mitigating unemployment and fostering sustainable economic development. Additionally, in the SSP3 scenario, the unemployment rate averages 6.2 percent from 2022 to 2050. In the reactive scenario, it averages 5.9 percent over the same period, while in the proactive scenario, it averages slightly lower than 5.9 percent (Table 5).

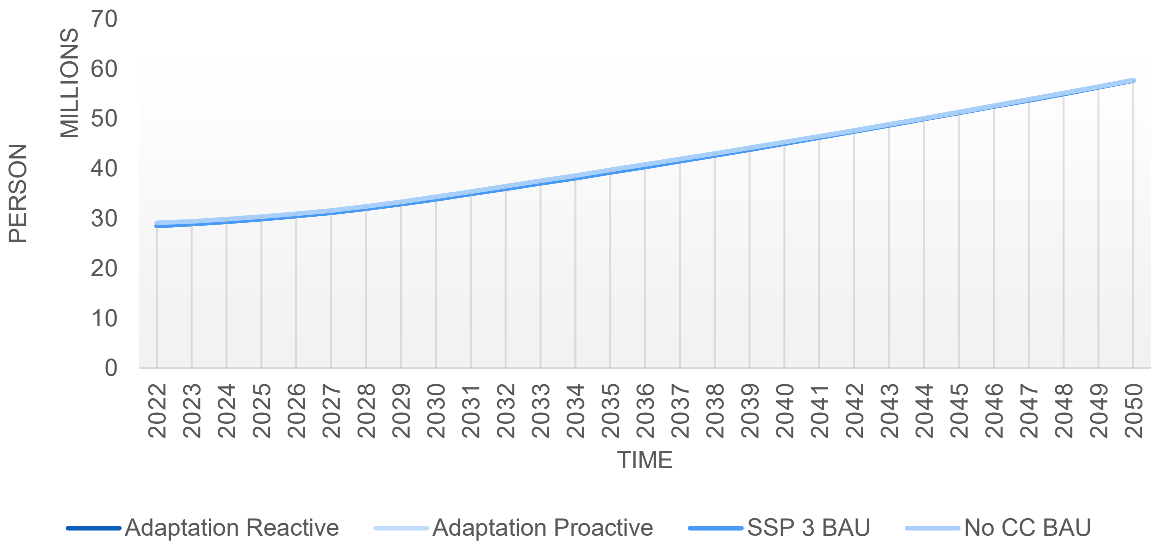


Figure 32: Total employment for Tanzania under BAU, SSP, and Adaptation scenarios

The higher employment under the proactive scenario comes from higher economic growth resulting in further employment. The adaptation measures aid in boosting the employment rate but less so than the increased growth in the economy.

Unemployment Rate	Unit	2022-2030	2030-2040	2040-2050	2022-2050
Adaptation Reactive	%/Year	5.8%	5.8%	6.2%	5.9%
Adaptation Proactive	%/Year	5.8%	5.7%	6.1%	5.9%
SSP 3	%/Year	5.8%	6.0%	6.4%	6.2%
Reactive vs BAU	%/Year	-1.5%	-3.9%	-3.0%	-4.3%
Proactive vs BAU	%/Year	-0.8%	-5.3%	-5.2%	-4.7%

Table 5: Average unemployment rate under each simulated decade in SSP and Adaptation scenarios

2.5 Investment and Financing

The costs and financing of climate adaptation are substantial yet essential for mitigating long-term economic impacts. Adaptation measures, such as upgrading infrastructure, and implementing flood defenses, require significant investment. Public and private financing must be mobilized to cover these costs, often through innovative funding mechanisms like green bonds, public-private partnerships, and international climate funds. Despite the high initial expenditure, these investments can lead to substantial savings by reducing future climate-related damages and associated costs, emphasizing the importance of proactive financial planning in climate adaptation strategies.

In the reactive scenario, investments are made but categorized as reconstruction efforts rather than adaptation measures. Conversely, in the proactive scenario, total additional real investment compared to SSP3 amounts to 249 USD million in 2030 and 225 USD million by 2050, indicating high upfront adaptation costs early on, with a reduction over time (Figure 33). Policy ambition across sectors drives adaptation efforts, with the transition and adaptation investment serving as a key indicator to monitor the allocation of resources towards climate resilience and sustainable development initiatives.

In the reactive scenario, the total additional real investment compared to SSP3 amounts to 0.01% of GDP in 2030 and decreases to 0.0009% by 2050. Conversely, in the proactive scenario, additional real investment peaks at 0.4% of GDP in 2030, gradually decreasing to 0.1% by 2050 as ambitions are realized by 2040 (Figure 34). GDP and policy ambition across sectors drive these adaptation efforts, with the transition and adaptation investment divided by GDP serving as a critical indicator to assess the scale and effectiveness of investment in climate resilience and sustainable development initiatives relative to economic output.

In the proactive scenario, the total additional real investment compared to SSP3 amounts to 246 USD million in 2030, reflecting ambitious policy measures for adaptation. However, by 2050, the additional real investment decreases to 120 USD million (Figure 34). This reduction highlights potential shifts in policy focus or evolving priorities over time. Policy ambition for adaptation measures drives these investment decisions, with adaptation investment serving as a key indicator to assess the allocation of resources towards climate resilience and adaptation initiatives.

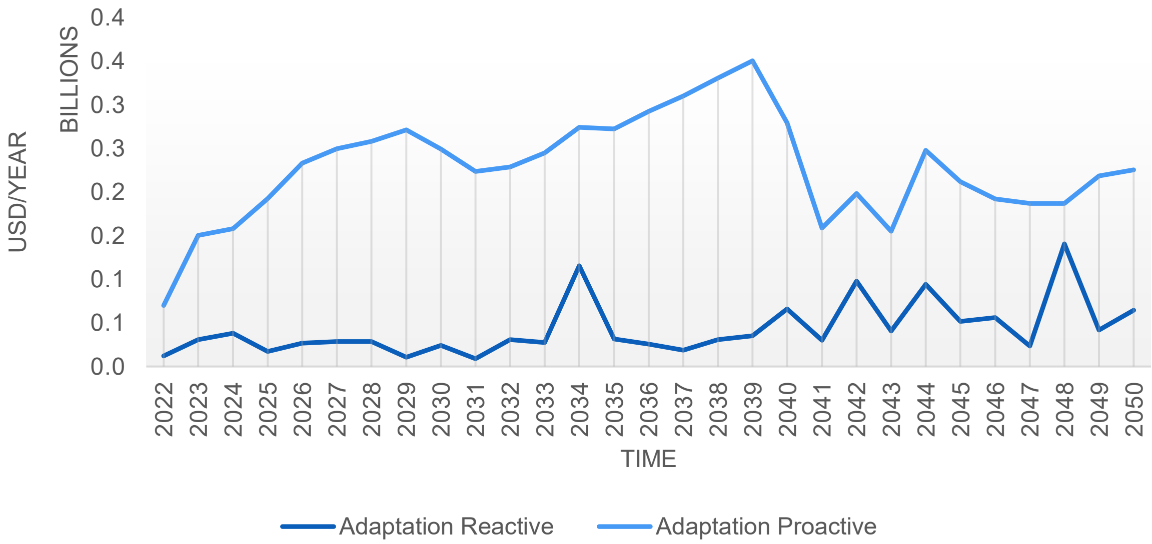


Figure 33: Additional Investments in Adaptation for Tanzania

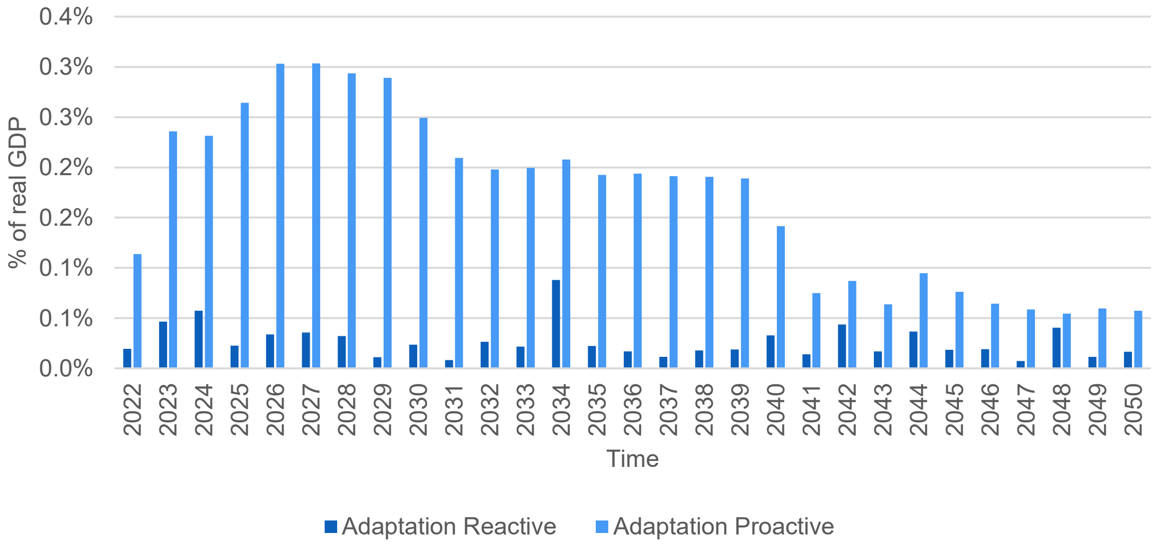


Figure 34: Additional Investments as a share of GDP under BAU, SSP3, and Adaptation scenarios

In the reactive scenario, contingency payments commence at approximately 500 million USD in 2022 and escalate to 5.07 billion USD by 2050, equivalent to 1% of GDP. These payments, influenced by policy ambition across sectors, represent a significant component of adaptation efforts, alongside adaptation investments. Conversely, in the proactive scenario, contingency payments begin at approximately 102 million USD in 2022, rising to 615 million USD by 2050, amounting to 0.2% of GDP. These figures underscore the proactive approach's effectiveness in reducing contingency payments relative to GDP compared to the reactive scenario

In the reactive scenario, the Benefit to Cost Ratio (BCR) stands at 0.14 by 2030 and increases to 0.54 by 2050. This ratio indicates that for every USD invested in the adaptation scenario, 0.17 and 0.54 USD in system-wide benefits are realized by 2030 and 2050 respectively (Table 6). As there is no investment into the climate resilience the BCR for the reactive scenario is lower as there is not mitigating the damage from climate change. However, the reconstruction efforts do bolster the economy over time.

CBA Indicator	Unit	**2022-2030**	**2022-2050**
Investments in mitigation	USD million	**159**	**336**
Investments in adaptation	USD million	**2**	**6**
Contingency payments	USD million	**3,813.99**	**9,455.98**
Total Investment required	USD million	**3,975**	**9,799**
Total avoided cost	USD million	**-193**	**-974**
Total added benefits	USD million	**736**	**6,243**
Net integrated benefits	USD million	**-3,432**	**-4,530**
Ratio avoided cost to investment	USD/USD invested	-0.05	-0.10
Ratio added benefits to investment	USD/USD invested	0.19	0.64
Ratio avoided cost and added benefits to investment	USD/USD invested	0.14	0.54
Net investment	USD million	**3,975**	**9,799**

Table 6: CBA (2022-2050) for the reactive scenario

Comparatively, by 2030, the proactive scenario yields a Benefit to Cost Ratio (BCR) of 1.47, which increases significantly to 7.91 by 2050 (Table 7). These ratios signify that for every USD invested in the adaptation scenario, 1.47 and 7.91 USD in system-wide benefits are realized by 2030 and 2050 respectively. This underscores the effectiveness of proactive mitigation investments in generating substantial returns and underscores the importance of strategic resource allocation to bolster resilience and sustainability in the face of climate change.

CBA Indicator	Unit	2022-2030	2022-2050
Investments in mitigation	USD million	**-101**	**-214**
Investments in adaptation	USD million	**1193**	**2052**
Contingency payments	USD million	**14.02**	**8.82**
Total Investment required	USD million	**1105**	**1828**
Total avoided cost	USD million	**1320**	**6243**
Total added benefits	USD million	**306**	**8227**
Net integrated benefits	USD million	**520**	**12,641**
Ratio avoided cost to investment	USD/USD invested	1.19	3.41
Ratio added benefits to investment	USD/USD invested	0.28	4.50
Ratio avoided cost and added benefits to investment	USD/USD invested	1.47	7.91
Net investment	USD million	**1,105.87**	**1,828.85**

Table 7: CBA (2022-2050) for the proactive scenario

In the proactive scenario, the benefits surpass investments as early as the year 2026. Cumulative investments amount to 1.2 billion USD by 2050, while cumulative benefits reach 14.4 billion USD by the same year (Figure 36). This shift underscores the effectiveness of proactive adaptation strategies, driven by policy ambition across sectors and mitigated climate damages. The indicator of cumulative investments compared to cumulative benefits demonstrates the substantial returns yielded by strategic investment in adaptation measures, highlighting the economic viability of proactive climate resilience initiatives.

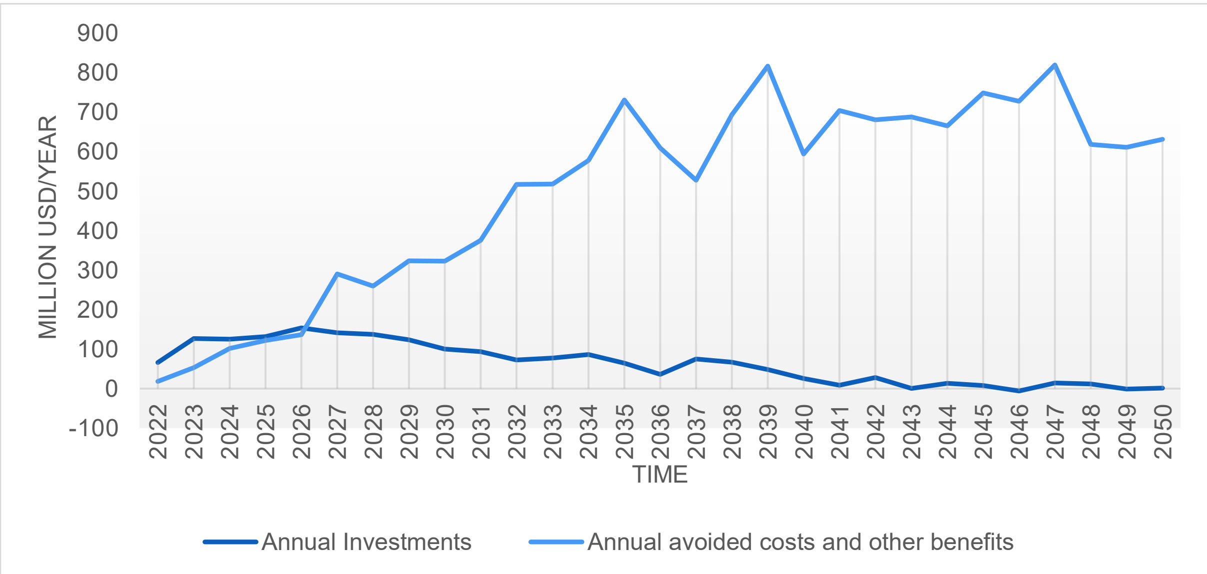


Figure 35: Investment required vs benefits generated in the proactive scenario

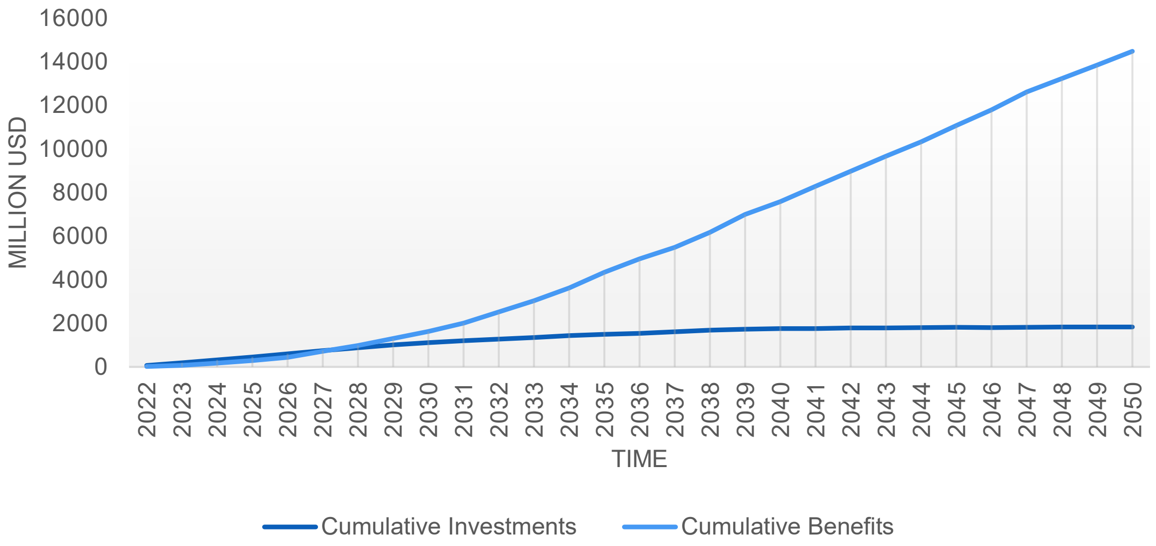


Figure 36: Cumulative investment required vs cumulative benefits generated in the proactive scenario

3. Key Findings and Illustrative Policy Insights

3.1 Results from the Analysis

Key insights emerging from the use of GEM reveal that, without climate change adaptation measures (according to the SSP3 scenario), climate impacts in Tanzania could result in USD 135 billion in cumulative damages by 2050. This results in a cumulative negative GDP impact of USD 395 billion by 2050, or the equivalent of 5.39 years' worth of value addition (using the 2024 GDP value).

The greatest costs will be to productive capital and buildings, accounting for USD 96 billion, with losses of USD 64 billion in service and industry capital and USD 32 billion in buildings by 2050. These annual losses in key sectors would significantly hinder economic growth, reducing total real GDP by 8% in 2050 compared to a scenario without climate change, with an annual reduction of 0.2%. This projection highlights the severe economic consequences of climate change. However, implementing climate resilience measures could boost annual GDP growth by 0.7%. In this scenario, climate impacts on GDP could be reduced to USD 334 billion cumulatively by 2050, or a 15% reduction.

The proactive climate change adaptation scenario stimulates GDP growth and job creation, that is 0.4 % and 0.2% higher respectively, by 2050, compared to a scenario without climate change. This approach reduces climate-related costs and boosts productivity, positioning it as a competitive economic development strategy at the national level. With a benefit-cost ratio (BCR) of 7.91 by 2050, the proactive climate change adaptation scenario significantly outperforms the reactive scenario, which has a BCR of only 0.59. By focusing on climate resilience, the proactive approach generates USD 12.7 billion in net benefits between 2023 and 2050, offering a sustainable and efficient approach to addressing the challenges of climate change.

Building climate resilience to address climate impacts like extreme weather events could increase total real GDP by 1.9%, reaching USD 393 billion by 2050 compared to a no-action scenario. Both proactive and reactive climate scenarios prioritize adaptation measures that aim at reducing climate change damages and increasing capital accumulation, to sustain economic growth. However, the proactive approach yields stronger results, with an average GDP growth rate of 6.79% from 2022 to 2050, compared to 6.77% in the reactive scenario over the same period.

Without climate change action, the occurrence of extreme climate events would increase road disruptions by 50%, underscoring the vulnerability of transportation infrastructure to climate impacts and the urgent need for adaptation measures. Proactive interventions that include climate resilience strategies such as flood protection measures, would reduce the impact of an extreme climate event by 2%, while the reactive approach offers no significant improvement over the no-action scenario. This highlights the importance of proactive measures to safeguard infrastructure and support economic growth.

A proactive climate change adaptation approach that includes flood protection measures for road infrastructure, including significantly reduces cumulative damage costs from USD 865 million under a no-action climate change scenario to USD 729 million. It also lowers the annual percentage of roads damaged by climate impacts to 0.05%, compared to 0.4% in the no-action scenario. In contrast, a reactive approach without specific adaptation measures results in cumulative road damages amounting to USD 872 million, driven by higher economic growth.

For energy infrastructure, proactive climate-proofing measures reduce cumulative losses in MW capacity by 59% and cut cumulative economic damages to USD 3.7 billion by 2050, compared to USD 5.8 billion in economic damages under scenarios focused only on reconstruction efforts. In addition, these proactive measures reduce climate impacts on transmission networks by half, demonstrating the effectiveness of proactive climate resilience interventions over reactive approaches.

Climate-proofing measures for buildings reduce cumulative damages from extreme precipitation and flooding from USD 32 billion to USD 23 billion by 2050, compared to the no-action and reactive climate change scenarios. These climate-proofing measures limit damage to an average of 53,600 dwellings (0.1%) annually, while the absence of such measures results in 83,500 dwellings (0.4%) being affected.

Investment levels are the highest for the proactive climate change adaptation scenario, reaching 0.4% of GDP by 2030, with upfront adaptation costs that decrease over time. In comparison, reconstruction efforts require USD 249 million in additional investment by 2030 and USD 225 million by 2050, while proactive adaptation measures require USD 246 million by 2030 but almost half the amount (USD 120 million) by 2050. The BCR for reconstruction efforts is 0.14 by 2030, rising to 0.54 by 2050. In contrast, the proactive approach yields a BCR of 1.47 by 2030, increasing to 7.91 by 2050. Net benefits from the proactive scenario exceed investments by 2032, with cumulative investments of USD 1.2 billion and cumulative benefits reaching USD 12.7 billion by 2050.

In summary, without adaptation measures, Tanzania faces substantial climate change costs, with the SSP3 BAU scenario forecasting cumulative damages of USD 135 billion by 2050. This translates to total economic losses of USD 395 billion, equivalent to 5.39 years of GDP. The overall impact on assets is estimated at USD 103 billion—1.41 times the 2024 GDP. A proactive adaptation scenario would reduce GDP losses by 15%, to USD 334 billion cumulative by 2050. These investments result in a Benefit to Cost Ratio (BCR) of 7.91 (discounted at 10%), highlighting the economic viability of investing in climate resilience.

3.2 Discussing policy implications

This section aims to illustrate how analytical results can be translated into potential policy implications for climate change adaptation in Tanzania. Rather than presenting definitive recommendations, it showcases examples of policy actions that are aligned with the findings of the climate stress-testing and systems analysis, particularly under the SSP3 scenario and across key socio-economic parameters and infrastructure systems.

These examples are intended as an initial step toward policy formulation. Further work is required to support stakeholder consultation, validate policy and institutional frameworks, and assess available options through multi-criteria analysis to identify priority interventions. As such, this section should be read as an illustration of possible policy directions, grounded in the analytical results and contextualized within Tanzania's national development priorities and exposure to regional climate risks.

The analysis illustrate that, without climate change adaptation measures, climate impacts will impose substantial costs to Tanzania, particularly on critical infrastructure assets such as service and industry capital, buildings and roads. By 2050, these assets are projected to suffer significant damage, leading to reduced public revenue and diminished income generation, which will hinder economic growth and development efforts. Extensive infrastructure damage could also limit access to essential services, disrupt livelihoods, and exacerbate socio-economic inequalities across the country.

Climate change is expected to have severe economic consequences in Tanzania. This national climate stress-test projects reductions to total real GDP by 8% by 2050. However, building a climate-resilient economy could enable an annual GDP growth of 0.7%. Climate resilience and adaptation present a competitive economic development strategy, with a BCR of 7.91, a payback period of just 18 years, and net benefits of USD 5.8 billion. In contrast, a focus only on reconstruction efforts yield a BCR of just 0.59. These findings demonstrate that proactive climate adaptation not only addresses environmental challenges effectively but also promotes long-term economic growth, therefore climate action and economic prosperity are not mutually exclusive but can, in fact, be mutually reinforcing.

Adopting a proactive climate change adaptation strategy in Tanzania will significantly reduce future economic, social and environmental impacts, particularly from extreme weather events, extreme wet conditions and flooding. Damage to infrastructure from extreme weather events can lead to immediate job losses in key sectors including construction, transportation, and utilities. A proactive approach promotes economic growth and job creation through a dual strategy: mitigating the economic burdens of climate adaptation while reducing the costs associated with climate-related disasters.

Transportation infrastructure in Tanzania is especially vulnerable to climate impacts and extreme weather events. Without climate change adaptation measures, an extreme weather event would lead to 50% increase in road disruptions compared to a scenario without climate change. However, adopting a proactive climate change adaptation strategy that includes flood protection measures for road infrastructure can reduce cumulative costs related to road damages by 15% by 2050 and can significantly lower the percentage of damaged roads by climate impacts from 0.4% to 0.05%.

Proactive interventions to climate-proof energy infrastructure in Tanzania result in a 59% reduction in cumulative MW capacity losses and a 36% decrease in cumulative economic damages by 2050. In addition, climate-proofing measures reduce climate impacts on transmission networks by half, compared to scenarios without such climate-proofing interventions. For buildings, these measures reduce cumulative damages from extreme precipitation and flooding by 26% by 2050, compared to the no action or reactive scenarios.

A proactive climate change adaptation approach anticipates substantial investments, amounting to nearly 0.4% of GDP by 2030. Nevertheless, the long-term benefits of this approach accumulate over time, outweighing the initial costs, as climate-related damages decline over time.

The Table 8 below presents illustrative examples of climate change adaptation measures across key infrastructure sectors in Tanzania, drawing on the analytical results of this assessment under the SSP3 scenario. It maps these measures against the relevant public authorities involved in their implementation and highlights regions most exposed to the climate risks identified.

Consistent with the approach outlined above, this table is not intended as a definitive or prioritized action plan, but rather as an initial framework to support the translation of analytical findings into potential policy directions. It highlights entry points for coordinated public action across sectors and governance levels, with a view to strengthening resilience in high-risk areas and safeguarding critical infrastructure. Further refinement will require additional scenario analysis, stakeholder consultation at national and subnational levels, and multi-criteria assessment to identify priority interventions.

Table 8. Illustrative Climate change adaptation measures across infrastructure sectors and regions in Tanzania (according to the SSP3 climate scenario).

Illustrative climate change adaptation measures / actions, alignment with national frameworks, and range of identified stakeholders responsible or to be associated. This is a preliminary analysis for refinement through stakeholders consultation and validation.			
Sector	Illustrative climate adaptation measures / actions and urgency	Screening associated national frameworks, strategies and plans	Identified associated government departments
Transport (roads and railway)	• Invest in and design road and rail transport infrastructure that is resilient to extreme climate events such as flooding and landslides (all regions). -MEDIUM to LONG term • Prioritize national roads and restore existing disrupted transport infrastructure that is vulnerable to extreme temperatures and flooding (all regions). -MEDIUM term • Employ flood protection measures for road infrastructure that have the potential to reduce road disruptions, saving USD 135 million in cumulative damages by 2050 (Tanga, Tabora and Iringa). -SHORT to MEDIUM term	-NCCRS addresses the need for resilient transport infrastructure due to climate vulnerabilities, including roads and railways affected by floods and landslides. The strategy notes that flooding and landslides heavily impact transport, with the need for prioritizing high-usage roads for retrofitting and restoration (NCCRS, p56). -NDC highlights the importance of climate-proofing transport systems to enhance resilience across key infrastructure sectors. Emphasis is on maintaining critical infrastructure to minimize disruption risks in high-use regions (NDC, p11)	Ministry of Transport, Tanzania Roads Agency (TANROADS), Tanzania Railways Corporation (TRC), Local government authorities

Illustrative climate change adaptation measures / actions, alignment with national frameworks, and range of identified stakeholders responsible or to be associated. This is a preliminary analysis for refinement through stakeholders consultation and validation.			
Sector	Illustrative climate adaptation measures / actions and urgency	Screening associated national frameworks, strategies and plans	Identified associated government departments
	• Employ landslide protection measures for road infrastructure (Iringa, Ruvuma, Mbeya and Morongoro) -SHORT to MEDIUM term • Employ flood protection measures for railways that are exposed to flooding and landslides (Morongoro, Tanga, Dodoma and Mbeya). -SHORT to MEDIUM term • Direct transport-related investment in regions where the risk of transport infrastructure exposure to flooding and landslides is the highest (Tabora, Iringa, Ruvuma, Mbeya, Morogoro). -SHORT to MEDIUM term • Explore the potential of nature-based infrastructure solutions as a way of reducing climate impacts such as flooding, landslides and extreme temperatures to transport infrastructure (can lead to increased water retention, temperature mitigation etc) (all regions). -SHORT to MEDIUM term	-NCCRS provides specific recommendations that target vulnerable regions, including Tabora, Iringa, Ruvuma, Mbeya, and Morogoro, for prioritized investments (NCCRS, p42).	
Energy/ telecommunications	• Promote, expand, and improve climate-proof energy infrastructure and distribution facilities in Tanzania's rural regions, especially electricity, beyond the current 16%-18% population rate (all regions). -MEDIUM to LONG term • Protect existing energy infrastructure by employing flood protection measures for power plants and transmission lines that have the potential to reduce cumulative energy losses by 59% and lower economic damages by USD 2.1 billion cumulatively by 2050 (Tanga, Iringa, Kagera and Morongoro). -SHORT to MEDIUM term	-NCCRS discusses Tanzania's targets to expand rural electrification and improve infrastructure to mitigate climate risks, emphasizing its enormous and diversified potential energy resources such as hydropower or biogas (NCCRS,p48). -SE4ALL prioritizes investments for on-grid and off-grid urban and rural electrification (SE4ALL,p30). -NCCRS mentions the vulnerability of energy infrastructure, highlighting the need for resilient systems against floods, landslides, and temperature extremes (NCCRS, p48).	Ministry of Energy (ME), The Energy and Water Utilities Regulatory Authority (EWURA), Tanzania Electric Supply Company (TANESCO), And the Rural Energy Agency (REA)

Illustrative climate change adaptation measures / actions, alignment with national frameworks, and range of identified stakeholders responsible or to be associated. This is a preliminary analysis for refinement through stakeholders consultation and validation.			
Sector	Illustrative climate adaptation measures / actions and urgency	Screening associated national frameworks, strategies and plans	Identified associated government departments
	• Invest in renewable energy infrastructure, considering potential future changes to energy output due to climate change impacts (e.g. hydropower and water shortages) (all regions). -MEDIUM to LONG term	- NAPA stresses challenges to energy infrastructure due to increased flooding and extreme weather, particularly affecting hydropower plants (NAPA, p10/11). -NCCRS mentions the government's plan to enhance the use of renewable energy sources, particularly in the national grid (NCCRS,p50). -SE4ALL, encourages investment in renewable infrastructure, focusing on low-carbon, resilient energy sources (SE4ALL, p 59/60).	
Water	• Invest and expand climate change resilient water infrastructure that is vital for hydropower generation and agricultural processes (all regions). -MEDIUM to LONG term • Upgrade and restore ageing water and sanitation infrastructure, especially in key urban areas (all regions). -MEDIUM to LONG term • Screen water infrastructure projects for climate risks and integrate cost-effective actions to build resilience. MEDIUM to LONG term	-WSDP addresses the need for resilient water management to support sectors like hydropower and agriculture, considering Tanzania's vulnerability to climate impacts like droughts and floods, necessitating significant investments in climate-adaptive water storage and distribution infrastructure (WSDP, p7-3) -NCCRS emphasizes the adverse impacts of climate change on water availability, highlighting the need for resilient water infrastructure (NCCRS, p46). -WSDP underscores the importance of upgrading water infrastructure, particularly in urban areas, to improve resilience and ensure consistent service. Specific projects for urban areas, including sanitation system upgrades, are also outlined in this section (WSDP,p 4-31,p-4-34). -NCCRS calls for investment in urban water infrastructure upgrades to handle increased pressure from climate events, highlighting that urban centers are especially vulnerable to infrastructure disruptions due to extreme weather (NCCRS, p61)	Ministry of Water, Supply and Sanitation Authorities (WSSAs), Rural Water Supply and Sanitation Agency (RUWASA), National Water Fund (NWF), Community Based Water Supply Organisations (CBWSOs), Urban Water Supply and Sanitation Authorities (UWSSAAs).

Illustrative climate change adaptation measures / actions, alignment with national frameworks, and range of identified stakeholders responsible or to be associated. This is a preliminary analysis for refinement through stakeholders consultation and validation.			
Sector	Illustrative climate adaptation measures / actions and urgency	Screening associated national frameworks, strategies and plans	Identified associated government departments
Health and education	• Protect existing education building infrastructure (e.g. social facilities, schools, universities) from extreme weather events such as floods and landslides, that threaten 978 and 325 education facilities respectively (Mbeya, Morogoro, Kagera, Tanga, Iringa and Ruvuma). -SHORT to MEDIUM term • Protect existing healthcare infrastructure such as hospitals from climate impacts, especially flooding and landslides which threaten 102 and 20 healthcare facilities respectively (Mbeya and Dodoma). -SHORT to MEDIUM term • Develop standards and regulations that incorporate climate resilience for new facilities -SHORT to MEDIUM term	-NCCRS Highlights the vulnerability of health facilities in high-risk areas to extreme weather events (NCCRS, p51-53)	Ministry of Heath, Community Development, Gender and Children (MoHCDGC), Ministry of Education, Science and Technology (MoEST), Tanzanian Institute of Education (TIE)

The regions of Mbeya, Morogoro, Iringa and Tanga face the highest climate risk across key infrastructure sectors, including transport, energy, telecommunications, healthcare and education, due to exposure to flooding and landslides. These regions should be prioritized in government investment plans aimed at building, restoring and climate-proofing cross-sectoral infrastructure assets. In addition, strengthening natural disaster management mechanisms in vulnerable areas, particularly urban and coastal areas, is crucial to mitigate the impact of climate-induced events.

Lastly, it is important to avoid poor land use practices such as the removal of trees on slopes, and inadequate sustainable catchment management that can lead to increased soil erosion and sedimentation, both of which can exacerbate flood and landslide risks and increase the risk of damage to critical infrastructure.

3.3 Financing Climate Change Adaptation

Financing climate change adaptation is essential for achieving the goals of the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC). Current funding needs for climate change adaptation and mitigation far exceed availability. For developing countries, implementing adaptation plans requires around USD 378 billion per year until 2030.[5] In addition, achieving net-zero

5 UNEP (2023), Adaptation Gap Report 2023: Underfinanced. Underprepared. Inadequate investment and planning climate adaptation leaves world exposed., Available a : https://www.unep.org/adaptation-gap-report-2023

emissions by 2050 will demand an estimated USD 6.2 trillion annually.[6] Unfortunately, the finance flows directed toward adaptation efforts in developing countries face a significant shortfall.[7] Moreover, private sector contributions currently remain insufficient to bridge this gap in climate finance.[8] In response, this section explores innovative financial instruments and mechanisms for implementing the recommended climate change adaptation actions in Tanzania.

Table 9. Financial instruments for implementing climate change adaptation measures[9]

Financial instrument	Category	Overview
Concessional loans	Debt instrument	Concessional loans are financial instruments provided at below-market interest rates or with favorable terms, such as extended repayment periods and grace periods. These loans are primarily used to finance climate adaptation projects that face challenges in accessing commercial funding due to high risks, uncertain revenue potential, or the public-good nature of their benefits. Examples of such projects include flood adaptation management infrastructure, nature-based solutions (e.g., wetland restoration for flood control), and sustainable agriculture practices that enhance resilience to climate change. Concessional loans are often blended with grants and guarantees to reduce financial risks and attract private sector participation. [10] **Strengths:** Concessional loans enable governments in developing countries to implement critical adaptation measures that enhance national resilience without incurring an excessive debt burden. These loans provide affordable financing, making it possible to fund large-scale projects that would otherwise be non-financially viable. Additionally, concessional loans can play a pivotal role in de-risking, which encourages private sector participation by reducing financial uncertainties and improving the overall attractiveness of adaptation projects.[11] **Limitations:** While concessional terms reduce the cost of financing adaptation projects, they still contribute to national debt levels, which can be problematic for countries already facing high debt burdens. This can exacerbate fiscal vulnerabilities, particularly in nations with limited capacity to manage additional debt. Furthermore, accessing concessional loans often involves complex application processes and compliance with stringent eligibility criteria, which can pose challenges for some developing countries.[12]

6 Solomon, M., Meattle, C., and Naran, B. (2023), How big is the net zero finance gap?, Available at: https://www.climatepolicyinitiative.org/publication/how-big-is-the-net-zero-finance-gap/

7 Butler, C. (2024), Simplicity is the key to closing the finance gap, Available at: https://www.chathamhouse.org/2024/04/simplicity-key-closing-climate-finance-gap

8 Buchner, B., Naran, B., Padmanabhi, R., Stout, S., Strinati, C., Wignarajah, D., Maio, G., Connolly, J., and Marini, N. (2023), Global Landscape of Climate Finance 2023, Available at: https://www.climatepolicyinitiative.org/wp-content/uploads/2023/11/Global-Landscape-of-Climate-Finance-2023.pdf

9 International Institute for Sustainable Development (IISD). (December, 2024). Innovative Financial Instruments for the Mobilization of Private Sector Investments in Climate Change Mitigation and Adaptation in Developing Countries. Unpublished report.

10 World Bank (2021) What You Need to Know About Concessional Finance for Climate Action, available at: https://www.worldbank.org/en/news/feature/2021/09/16/what-you-need-to-know-about-concessional-finance-for-climate-action

11 Ibid.

12 Runde, D., F., Romeu, R., Hardman, A., (2024) Reintroducing Concessional Loans into the Development Toolbox, Center for Strategies and International Studies (CSIS), available at: https://www.csis.org/analysis/reintroducing-concessional-loans-development-toolbox

Financial instrument	Category	Overview
Grants	Non-repayable funding	Grants are non-repayable financial instruments provided by governments, multilateral development banks (MDBs), or private donors to support climate adaptation projects. They are often smaller in size and play a critical role in the early stages of infrastructure projects and adaptation projects, particularly during the predevelopment phase. Grants are designed to "boost catalytic change" by addressing high-risk or innovative areas where other funding sources may not be readily available. These instruments are especially valuable for enabling pilot projects, feasibility studies, or capacity-building efforts that lay the groundwork for larger-scale adaptation initiative.[13] Strengths: Grants, due to their non-repayable nature, are highly accessible for low-income countries and communities with limited financial resources. They are particularly suited for financing projects with high societal value but low or zero revenue streams. By reducing financial risks, grants enable the implementation of critical adaptation projects. Limitations: Grants, as a funding source for adaptation projects, are limited in scale. The funding provided by international organizations and public sector entities is insufficient to meet the growing adaptation demands, particularly in developing countries where vulnerabilities are high.
Green bonds / Sustainability -linked bonds (SLB)	Debt instruments	Debt instruments are agreements between a lender and a borrower, where the lender receives fixed payments, usually with interest. Green bonds, issued by governments, corporations, and Multilateral Development Banks (MDBs), are a well-established option. The issuance of sovereign green bonds—those issued by governments—is relatively recent. These bonds are "use-of-proceeds," meaning funds are allocated to specific projects, often related to climate mitigation and adaptation. Countries like Brazil, Argentina, Chile, Colombia, and Egypt have incorporated these components into their green bond frameworks, supporting targeted environmental projects and sustainability goals. Proceeds from sovereign Sustainability-Linked Bonds (SLBs) can be used for general government operations with explicit sustainability targets tracked by key performance indicators (KPIs), including mitigation and adaptation goals. To date, only Chile and Uruguay have issued sovereign SLBs, both in 2022. Strengths: Issuing green bonds and SLBs signals a country's commitment to climate action and can attract investors focused on environmental, social, and governance (ESG) goals. Governments often uphold rigorous standards for impact reporting and verification, setting a benchmark for corporate issuers and reducing the risk of greenwashing.

13 Puzyreva, M., Carlucci, E., Uzsoki, D., & Méthot, J. (2024). Financing for natural infrastructure projects: Viable pathways to scale up natural infrastructure investments on the Canadian Prairies. International Institute for Sustainable Development (IISD). Available at https://www.iisd.org/system/files/2024-05/financing-natural-infrastructure-projects.pdfhttps://www.iisd.org/system/files/2024-05/financing-natural-infrastructure-projects.pdf

Financial instrument	Category	Overview
		Limitations: Issuing green bonds and SLBs can be more expensive than standard bonds and requires a strong pipeline of eligible projects. Sovereign green bonds may not suit all nations, especially those with high debt burdens or lacking the expertise to issue complex bonds. Assessing suitable developing countries involves examining the macroeconomic context, institutional capacity, and the government's ability to take on additional debt.[14]
Debt-for-nature/climate swaps	Financial risk management instruments	Debt-for-Nature swaps are financial arrangements where a portion of a country's debt is restructured or forgiven in exchange for commitments to environmental conservation. This enables debtor nations to reallocate resources from debt servicing to biodiversity protection or climate resilience. Typically organized as bilateral agreements between debtor nations and creditor governments or multilateral agencies, these swaps can also involve NGOs and vary by creditor type (public or commercial) and the number of actors (bilateral or trilateral). Funds from these swaps are often placed in dedicated conservation trusts, ensuring transparency and long-term environmental support.[15][16] Designed to address both conservation and debt relief, debt-for-nature swaps provide crucial financing for conservation projects in highly indebted countries. **Strengths**: Debt-for-nature swaps in developing countries "offer dual benefits of fiscal relief and environmental conservation" enabling nations to combat biodiversity loss while improving fiscal stability. These swaps are flexible and can be tailored to countries with high biodiversity or climate vulnerability. Examples in Ecuador, Belize, and Gabon highlight their capacity to attract both private and public investment, promoting collaborative conservation efforts with meaningful ecological outcomes.[17] **Limitations:** Debt-for-nature swaps often entail high transaction costs and may raise sovereignty concerns in developing countries, particularly around foreign influence on domestic conservation priorities. Furthermore, the small scale of many swaps limits their overall impact on debt relief. These challenges underscore the need for robust governance structures and strong multilateral partnerships to execute these swaps effectively.[18]

14 OECD (2024), Sustainability-linked bonds: How to make them work in developing countries and how donors can help, Available at: https://www.oecd-ilibrary.org/development/how-to-make-them-work-in-developing-countries-and-how-donors-can-help_7ca58c00-en

15 Essers, D., Cassimon, D. and Prowse, M. (2021) Debt-for-climate swaps: Killing two birds with one stone. Available at: https://ueaeprints.uea.ac.uk/id/eprint/81984/1/Accepted_Manuscript.pdf

16 Fedosova, O. and Turner, M. (2023) Debt-for-nature swaps: A viable alternative for vulnerable economies amid global challenges. Available at: https://www.whitecase.com/insight-our-thinking/africa-focus-winter-2023-debt-for-nature

17 Whiting, K. (2024) Climate finance: What are debt-for-nature swaps and how can they help countries?, Available at: https://www.weforum.org/agenda/2024/04/climate-finance-debt-nature-swap/#:~:text=It's%20now%20scoping%20out%20new,and%20help%20climate%20change%20adaptation.

18 Buenaventura, M., (2023) as cited in Chandrasekhar and Quiro (2023), Q&A: Can debt-for-nature 'swaps' help tackle biodiversity loss and climate change?, Available at: https://www.carbonbrief.org/qa-can-debt-for-nature-swaps-help-tackle-biodiversity-loss-and-climate-change/

Financial instrument	Category	Overview
Credit Guarantees	Financial risk management instruments	"**Credit Guarantees** are "promises to pay" where a guarantor assures lenders that they will cover repayments if the borrower defaults". In developing countries, credit guarantees often involve MDBs, development finance institutions, or bilateral donors, providing partial or full guarantees for loans to project developers, or covering principal or interest payments for bondholders up to a specified amount. These guarantees prevent defaults during short-term liquidity issues and leverage the guarantor's credit rating to improve loan and bond creditworthiness.[19] Primarily used for domestic financing, they facilitate lending in specific sectors, making credit accessible and affordable for groups like microenterprises, SMEs, and farmers who may lack sufficient collateral. Although traditionally not focused on climate change adaptation and mitigation projects, credit guarantees are increasingly being directed toward these areas. **Strengths**: In developing countries, credit guarantees leverage public funds to attract private sector investments by reducing investment risk and lowering capital costs for investors. "Preferred by private investors as a blended finance tool", guarantees have been the most effective aid intervention in mobilizing private capital, accounting for 25% of all mobilized private finance from 2018 to 2020.[20] These schemes enhance transaction bankability in cases of insufficient collateral, build capacity within local financial institutions, and encourage financing for target groups focused on adaptation and mitigation. **Limitations**: Many developing countries face challenges in providing guarantees, particularly those with high debt levels and limited fiscal capacity. Financial institutions in these regions often lack experience and expertise in climate-related markets, reducing the uptake of credit guarantee schemes aimed at adaptation and mitigation. These schemes also depend on broader macroeconomic conditions, and economic downturns can increase defaults, resulting in losses for guaranteed providers.
Pooled investment funds	Financial risk management instruments	Pooled Investment Funds combine finance from multiple sources into varied risk-return tranches for climate change adaptation and mitigation projects. By blending public and private capital, these funds lower risks or boost returns for private investors, attracting capital that might otherwise be absent. They reduce financing costs, while grant-based technical assistance can enhance project viability. In developing countries, climate-focused pooled funds often include partnerships between public entities (such as MDBs, and donors) and private players (banks, institutional investors, asset managers, private firms, and philanthropies), contributing grants, equity, loans, and guarantees. While mainly used for mitigation, adaptation-focused funds are also emerging.

19 World Bank Group (2024), Guarantees/MIGA: World Bank Group guarantees deliver efficiency and boost impact, Available at: . https://www.miga.org/

20 OECD (2022) as cited in Climate Policy Initiative. (2024). Landscape of Guarantees for Climate Finance in EMDEs, Available at: https://www.climatepolicyinitiative.org/wp-content/uploads/2024/02/Guarantee-Report-Final-2024_FINAL.pdf

Financial instrument	Category	Overview
		Strengths: Pooled investment funds use patient, risk-tolerant public capital to attract diverse private investors, including institutional investors, global partners, pension funds, and corporations. **Limitations**: "Establishing pooled investment funds can be time-consuming and complex due to the diverse range of investors, often requiring intricate governance and investment processes".[21] Effective pooling also demands a coordinated, programmatic approach.
Biodiversity credits	Market-based instruments	Biodiversity credits are certificates that verify measurable improvements in biodiversity achieved through project interventions.[22] These credits can be classified by their outcomes, including adaptation objectives that address climate impacts on biodiversity. For example, a project may implement strategies to enhance coral reef resilience against rising water temperatures. Adaptation-focused credits aim to strengthen vulnerable ecosystems, supporting both biodiversity preservation and climate resilience.[23] **Strengths**: This instrument can generate financial incentives by creating revenue streams for projects that may struggle to monetize their efforts, such as conservation and restoration initiatives. By enabling financial returns through credit sales, it promotes investment in activities that protect natural ecosystems and boost biodiversity. **Limitations**: A key challenge with biodiversity credits is the lack of standardized units, unlike carbon credits, which are clearly defined by one ton of carbon dioxide. This complexity arises from the diverse nature of biodiversity—what constitutes biodiversity in Indonesia differs from that in Brazil—making it hard to establish a universal metric. The use of varied methodologies and metrics could add further complexity without a global standard. Implementing biodiversity credits in Least Developed Countries (LDCs) also presents obstacles. Many LDCs lack the regulatory frameworks and market infrastructure necessary for biodiversity credits.[24] Additionally, companies in developed countries often show limited interest in funding biodiversity projects in regions like Africa, preferring conservation closer to their operations or supply chains, which can constrain demand and further hinder market development in LDCs. Finally, biodiversity projects should account for social considerations and minimize inequitable social impacts such as

21 Network for Greening the Financial System. (2023). Scaling up blended finance for climate mitigation and adaptation in emerging market and development economic (EMDEs, Available at: https://www.ngfs.net/sites/default/files/medias/documents/scaling-up-blended- https://cfm-impact.webflow.io/finance-for-climate-mitigation-and-adaptation-in-emdes.pdf

22 Nature Conservancy (2024), The Role of Biodiversity Credits in Promising Conservation Outcomes: How can we ensure that biodiversity credits truly contribute to meaningful and sustainable conservation outcomes?, Available at: https://www.nature.org/en-us/what-we-do/our-insights/biodiversity/biodiversity-credits/

23 Pollination (2023), State of Voluntary Biodiversity Credit Markets, Global Revies of Biodiversity Credit Schemes, Available at: https://pollinationgroup.com/wp-content/uploads/2023/10/Global-Review-of-Biodiversity-Credit-Schemes-Pollination-October-2023.pdf

24 Nature Finance (2024), Investing in Africa: Investing in Nature Channeling Finance into Conservation and Restoration at Scale and the Emerging African Biodiversity Credit Landscape, Available at: https://www.naturefinance.net/wp-content/uploads/2024/10/101424_Africa-Landscapes_FINAL_10.pdf

Financial instrument	Category	Overview
		the risk of indigenous and local communities losing access over their traditional lands in areas monetized for biodiversity credits.[25]
Adaptation Benefits Mechanism (ABM)	Results-based financing instruments	Results-based financing instruments, such as the Adaptation Benefits Mechanism (ABM) piloted by the African Development Bank, are emerging tools to mobilize private funds for climate adaptation. The ABM allows project developers to secure payments from public, private, and nonprofit entities for verified adaptation benefits. These payments can serve as collateral for additional funding, creating a revenue stream that makes adaptation projects more attractive to private investors. By monetizing adaptation outcomes, the ABM incentivizes climate-resilient development and aims to close the gap between adaptation finance needs and available resources. **Strengths:** A key challenge for nature-based projects is the lack of direct revenue generation, making it difficult to attract private investment despite their societal benefits. The Adaptation Benefits Mechanism (ABM) addresses this by issuing certificates for verified adaptation benefits, creating a revenue opportunity through certificate sales to make these projects more financially viable.[26] **Limitations:** ABM's main limitation is caused by its resource-intensive requirements. It relies on sustained demand and continuous engagement with donors, project developers, the private sector, financial institutions, and governments to ensure long-term scalability and effectiveness.[27] Additionally, as an early-stage mechanism, its impact remains challenging to assess accurately.

Using innovative financial instruments to boost private investment in adaptation requires insight into Tanzania's specific needs, adaptation priorities, and areas where public-private investment can best mitigate climate risks. Capacity building is often necessary for governments, financial institutions, and the private sector to understand adaptation needs and the role of financial instruments. Ensuring that mitigation projects also support adaptation, such as making energy infrastructure climate-resilient, can further attract private investment to adaptation initiatives. Lastly, the use of innovative financial instruments needs to consider social issues and recognise local communities by ensuring there are strong governance, regulatory, and accountability mechanisms as well as inclusive participation and decision-making, by strengthening and securing land rights and avoiding land grabs, and by ensuring communities receive fair and equitable benefits.

25 Carbon Pulse (2024), Interview: poor demand from global north hampers biodiversity credits uptake in Africa, Available at: https://carbon-pulse.com/284911/

26 African Development Bank (n.d.), ABM – Giving resilience a value – Pilot phase information note, Available at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/ABM_-_Giving_resilience_a_value_-_Pilot_phase_information_note.pdf

27 Naydenova, L., (2023), Update on the Adaptation Benefits Mechanism, best practices and lessons learned so far, Available at: https://unfccc.int/sites/default/files/resource/SB58_Art.6.8_AfDB_0.pdf

4. ANNEXES

4.1 Summary of Climate hazard assessment in Tanzania

This section presents the methodology and summarizes the results of the climate hazard assessment report for critical infrastructure in Tanzania. The assessment evaluated the potential impacts of climate change on Tanzania's infrastructure, focusing on the severity of changes and spatial variability to inform national development strategies and interventions. Finally, the analysis considers the condition, location and sensitivity of key infrastructure systems to socio-economic indicators.

4.1.1 Methodology

The assessment of the climate-related hazards to critical infrastructure systems was two-fold.

- The standard climate variables of temperature (minimum, mean and maximum), rainfall, aridity, and humidity have been assessed on both an annual and monthly basis to establish the potential new normal for Tanzania.
- The analysis of extreme climate parameters that may impact infrastructure. These include changes in the 95th percentile rainfall, peak single day, 5-day rainfall events, and peak prolonged monthly rainfall changes as well as the number of days over 20 mm; For temperature changes, these may include warm spell duration, changes in +35°C days and changes in the historical 99th percentile temperature days. Additional factors considered include sea level rise, extreme storm surge potential, drought conditions (SPEI) and aridity.

The climate hazard assessment report examines the climate vulnerability of key infrastructure sectors, including transport, energy, telecommunications, water, healthcare and education. It also considers critical assets at the sub-national level such as roads (paved and unpaved), railways, power plants, transmission lines, health and education facilities and airports, bridges and dams. The assessment applies the Intergovernmental Panel on Climate Change (IPCC) risk framework to determine climate risks to Tanzania's infrastructure by identifying specific climate-related hazards that may threaten infrastructure, assessing the extent to which the infrastructure is likely to be exposed to the hazards, and evaluating the vulnerability of infrastructure to the identified hazards.

RISK = HAZARD x EXPOSURE x VULNERABILITY

It is important to note that the climate hazard assessment focuses specifically on the potential damage or deterioration of the infrastructure asset rather than the broader risks of climate change to communities or the national economy. The assessment of those broader impacts is addressed through the socioeconomic modelling and analysis, which is presented in the Cascading Socioeconomic Impact report.

Overall Climate Risk for Critical Infrastructure

The overall climate risk to critical infrastructure, such as roads, is calculated by combining the standardized hazard indexes with the road condition index, resulting in a risk score from 1 (very low risk) to 5 (very high risk). Risks from hazards including extreme temperatures, heavy rainfall, flooding, drought, tropical cyclones, sea level rise, and landslides are assessed individually for targeted intervention at the road level. For infrastructure assets without a condition index, risk is based solely on climate hazards at the infrastructure's spatial location. Cumulative risk is determined by combining all hazard types, allowing for aggregation of road risk at district, regional and national level, and if necessary distinguished by road-type, to inform climate resilience planning.

Hazard

The assessment focuses on climate hazards that could significantly impact infrastructure resilience and functionality. Key hazards that are considered include heat, which may cause softening of asphalt or warping of surfaces, heavy rainfall and flooding that may cause physical damage to infrastructure, droughts that compromise soil stability, tropical cyclones and strong winds that damage exposed infrastructure, sea-level rise and coastal erosion affecting coastal areas, and rainfall-triggered landslides. These hazards are assessed using a standardized scoring system from 1 (very low hazard) to 5 (very high hazard), allowing for cross-country comparisons. In addition, the assessment evaluates risks in two future timeframes: near-term (2020-2039) and mid-term (2040-2059).

Exposure – River Flooding and Landslide Risk

The assessment also evaluates the exposure of critical infrastructure to climate hazards such as increased river flooding and landslide risks due to climate change. Exposure of critical infrastructure is determined using global flood hazard and landslide susceptibility maps from the United Nations Environmental Program (UNEP) global risk assessment portal[28]. The flood hazard assessment employs a probabilistic approach, utilizing global stream-flow data from over 8,000 stations across the globe to model riverine floods and produce hazard maps for various return periods (starting from 25 and ending at 1,000 years). These maps are validated against satellite data and provide a resolution of 1kmx1km. Based on recurrence intervals, the assessment then classifies flood exposure as high, medium, low, or very low. Moreover, the landslide risk assessment considers factors such as slope, geological conditions, vegetation, soil moisture, as well as precipitation and seismic conditions, to estimate the annual frequency of landslides.

Vulnerability – Road Condition Index

The vulnerability analysis assesses which parts of the infrastructure are most prone to damage or disruption from climate change, with a focus on the current condition of the road network in Tanzania[29]. The vulnerability analysis uses the road condition index which is derived from Geographical Information Systems (GIS) data, and covers 9,939 km of major roads with varying surface and condition characteristics. Roads are rated from 1 (very good) to 5 (very poor or unknown), with unknown conditions assumed to be poor as a conservative risk measure. This data is obtained from the World Bank database[30], and covers only major national roads. Local asset management systems could provide more detailed and updated information for prioritization at the local and national level.

Infrastructure Criticality

To assist in prioritizing investments for climate-proofing critical infrastructure, a first-order metric of infrastructure criticality is applied at the regional or district level. This metric considers the total population and the number or length of critical infrastructure assets within each district, (e.g.,the length of road per 1,000 people or the number of people served by each power plant in a district). The availability of additional local data on asset value or dependency could provide further prioritization in the future, particularly for critical infrastructure on a national or regional level such as major road corridors.

4.1.2 Analysis

As noted above, the climate hazard assessment examines the climate vulnerability of critical infrastructure sectors, including transport, energy, telecommunications, water, healthcare and education. The results of the climate hazard assessment indicate significant variability across the country and for the individual climate parameters. While there is general constancy in increasing temperatures there is greater variability in terms of the potential impact on both mean annual precipitation and extreme rainfall.

In terms of overall climate risk, critical infrastructure currently exposed to potential high level of river flooding (i.e. within the current 1:25 year flood hazard category) has the highest level of risk, particularly

28 Home (unepgrid.ch)

29 World Bank Group, Data catalog. Accessed 2024/07/05. https://datacatalog.worldbank.org/search/dataset/0041099/Tanzania-Roads

30 Tanzania Roads | Data Catalog (worldbank.org)

if combined with infrastructure in poor conditions. Overall, there is still a relatively small percentage of critical infrastructure exposed to high levels of river flooding or land slide risk, but these areas still have a significant potential impact on the overall climate risk for critical infrastructure.

The results of the climate hazard and infrastructure risk assessment are used to determine the overall potential economic impact of climate change using the Green Economy Model (GEM) at national scale. The analysis carried out with GEM considers the "High" and "Medium" categories for a realistic representation of climate change adaptation ambition and costs. This is also justified by the fact that the "Medium" category of risk is defined as the assets subject to a 1:100-year RI design flood estimate which is used in most country as an engineering design standard for infrastructure. The buildings value is the average of the hazard classification results for health and education facilities.

Table 10. Assets at risk considered in the Green economy Model (GEM)

Assets at Risk		
Asset	**Unit**	**Tanzania**
Roads (km)	%	8.0%
Buildings (Buildings)	%	11.0%
Power Generation Capacity (MW)	%	52%
Transmission Lines (km)	%	16%

The following section summarizes the results of the climate hazard assessment by infrastructure sector.

Transport

Tanzania's transport sector, particularly its road infrastructure, is highly vulnerable to climate impacts. Roads in poor condition are especially susceptible to extreme temperatures, which can cause surface softening and buckling. A significant proportion of roads are at risk from flooding, while smaller percentages are exposed to rising sea levels, storm surges, and landslides.

The assessment reveals that 5% of national roads in Tanzania are at risk of river flooding (within the 1-in-25-year flood line), and 4% of national roads face potential landslide risks. At the regional level, Tanga has the greatest road exposure to river flooding (22% of roads at risk), followed by Tabora and Iringa, while Iringa, Ruvuma, Mbeya, and Morogoro face the greatest landslide risks due to their topography and soil conditions.

Furthermore, 9% of Tanzania's railways are in areas prone to river flooding, and 2% are exposed to landslides. Railways in the regions of Morogoro, Tanga, and Dodoma are particularly vulnerable to river flooding, while those in Morogoro and to a lesser extent Mbeya, face the highest risks from landslides. This underscores the need for targeted climate resilience measures to safeguard transport infrastructure.

Energy

Approximately 37% of Tanzania's electricity production is dependent on hydropower, making it highly vulnerable to changes in precipitation patterns. Climate variability has already reduced hydropower output, causing significant economic disruptions. Although future projects may increase water flow within critical basins like Pangani and Rufiji, essential for hydropower, rising evaporation rates and increased silt accumulation from intensified rainfall and land degradation are expected to hinder electricity generation. This exacerbates the challenges facing Tanzania's already limited electricity supply, which currently reaches only 16-18% of the population.

Tanga region has the highest number of hydropower plants exposed to potential flooding, with three plants at risk, followed by Iringa (two plants), Kagera (one plant), and Morogoro (one plant). Morogoro is particularly vulnerable, with both its hydropower and biomass plants located in areas at high risk of landslides. Addressing these vulnerabilities is critical for ensuring a stable electricity supply for Tanzania's future development.

Telecommunications

Tanzania's telecommunications infrastructure is increasingly vulnerable to extreme weather events and climate variability. Frequent flooding, especially in coastal and low-lying areas, can damage underground cables, disrupt signal transmission, and cause extended service outages. Heavy rains and storms often lead to power outages, further compromising network reliability and accessibility, while recurrent droughts exacerbate power shortages, affecting the operation of telecom networks due to the country's dependence on hydroelectric power.

Rising temperatures and humidity also accelerate equipment wear and corrosion, increasing maintenance and replacement needs. The assessment highlights that extreme temperatures pose risks to transmission infrastructure, particularly in Morogoro and Mtwara regions, while Iringa faces significant current and future landslide risks to transmission lines. These vulnerabilities underline the need for climate-resilient telecommunications strategies to ensure network stability.

Water

Water plays a central role in Tanzania's economy, as it supports hydropower generation, agriculture, and domestic use. However, rising temperatures and droughts have diminished water levels in the country's major lakes, while sea level rise has further compromised water supply in coastal areas and districts such as Maziwi in Pangani and Fungu la Nyani in Rufiji.

In addition, increased flooding and landslides are causing significant damage to Tanzania's aging water and sanitation infrastructure, leading to high restoration costs. In urban areas such as Dar es Salaam, these risks are exacerbated by poorly planned sewage systems, inadequate drainage, and insufficient access to clean and potable water, which contribute to water contamination and flooding issues. Addressing these challenges is essential for safeguarding Tanzania's water resources and infrastructure.

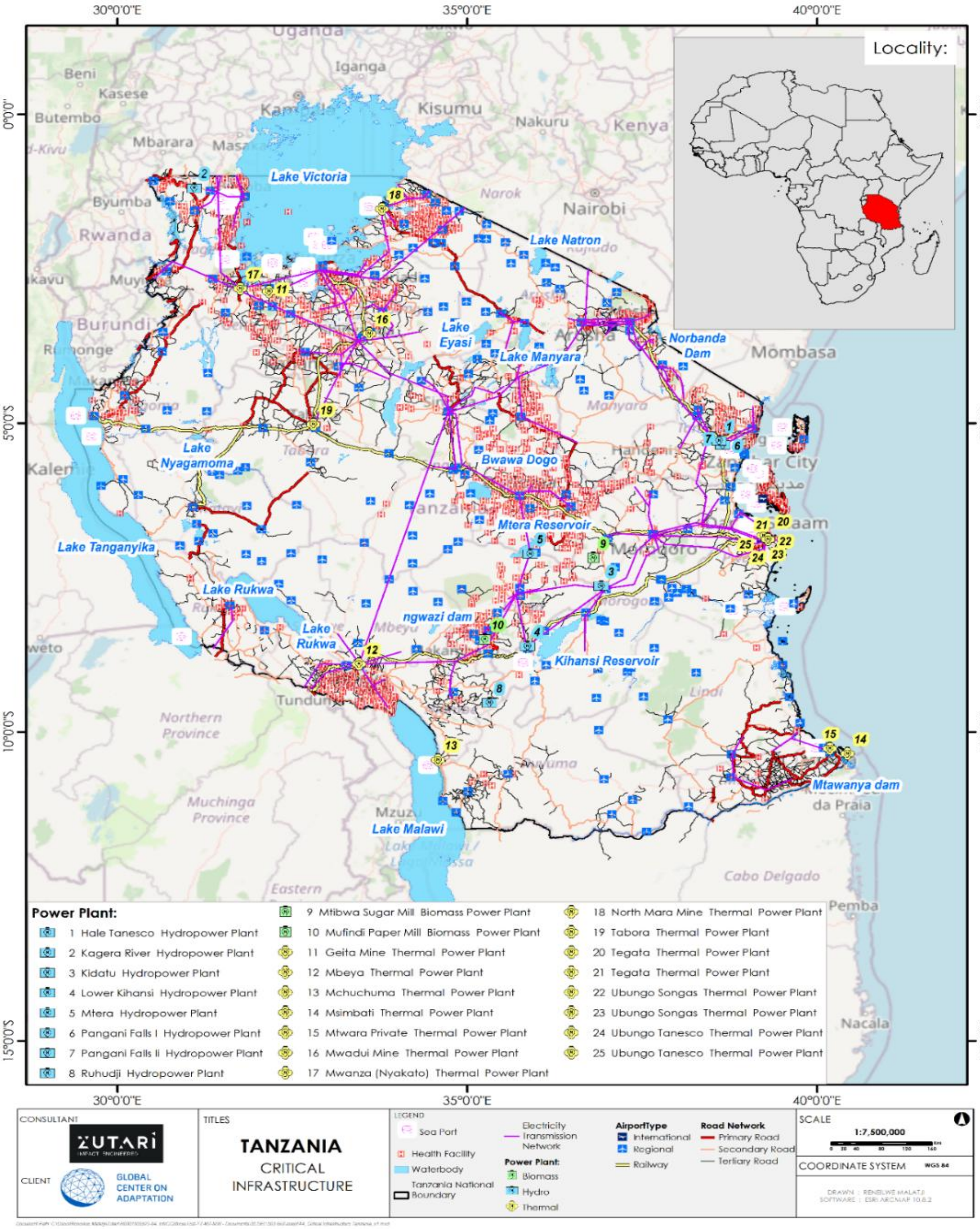
Health and Education

Extreme weather events such as heatwaves, floods, and droughts present significant risks to Tanzania's health and education infrastructure. These events contribute to increased heat-related fatalities and higher incidences of diarrheal diseases, malaria, and waterborne disease outbreaks. They also damage critical health and sanitation infrastructure, disrupt water supply and sanitation, and hinder healthcare access, particularly in rural areas. In addition, droughts and reduced agricultural productivity from water shortages exacerbate health issues and malnutrition, further straining healthcare systems. The assessment indicates that 102 healthcare facilities (3% of the total) are in high flood hazard zones, with 20 facilities located in high -risk areas for landslides. Regions such as Mbeya (44 healthcare facilities), and to a lesser extent Dodoma (12 healthcare facilities), have the highest number of healthcare facilities exposed to river flooding, with Mbeya also facing significant landslide risks.

Climate change is also threatening Tanzania's education system. The assessment reveals that 978 educational facilities (5% of the total) are situated in areas of high-risk from river flooding, particularly in the Mbeya (127 education facilities), Morogoro (122 education facilities), Kagera (91 education facilities), and Tanga(73education facilities), regions. Moreover, 325 educational facilities (2%) are in high-risk areas for landslides, with significant exposure in Mbeya (94 education facilities), Tanga (56 education facilities), Iringa(45 education facilities), and Ruvuma (42 education facilities), regions.

Figure 1 illustrates the current critical infrastructure in Tanzania, including primary, secondary, and tertiary roads, railways, airports, ports, power stations, and transmission lines. It is noteworthy that local infrastructure, such as rural roads, and critical ecological infrastructure, including wetlands and forests, are also vital but not depicted here.

Figure 37. Map of critical infrastructure systems for Tanzania



4.2 Stakeholders screening for climate change adaptation in infrastructure

Tanzania ranks 145 out of 182 assessed countries in the ND-GAIN Country Index for vulnerability to climate change.[31] Tanzania also ranks 151st in terms of readiness, emphasizing the urgent need for proactive climate change adaptation measures and substantial investment. The country is vulnerable to extreme weather events such as high temperatures, floods and droughts, with occurrences becoming more frequent and severe in the past few decades, negatively affecting infrastructure, agricultural production, food security, water resources, energy supply and demand, biodiversity, public health and ecosystem services[32].

Cross-sectoral action to address climate change impacts in Tanzania is both feasible and economically viable. The implementation of early adaptation strategies and actions in key sectors such as water, transport, energy, agriculture and health can mitigate harmful economic, social and environmental impacts, reduce damages to infrastructure and increase economic growth.

However, current climate change adaptation policies, plans and strategies provide only anecdotal evidence of the costs of adaptation measures over time. A Literature review reveals gaps in the recognition of risks, infrastructure vulnerabilities and tangible climate change adaptation efforts and actions. This may stem from limited knowledge of policy interventions that can enhance adaptive capacity and reduce climate impacts leading to a mismatch between planned efforts and the actual needs across regions, sectors and populations.

The implementation of proactive climate change adaptation measures and investment at scale in Tanzania requires better communication on climate impacts and effective collaboration and coordination among various stakeholders at local, regional and national levels. This includes national and regional government agencies and ministries and local communities. The promotion of strategic partnerships and coordinated efforts can enhance alignment and complementarity among different actors, improving the efficiency and effectiveness of climate investments to increase the climate resilience of Tanzania's infrastructure. Stakeholders must work together to develop an integrated and comprehensive framework that clearly defines their roles, responsibilities and relationships. Identifying and engaging these key stakeholders is therefore necessary for successful implementation.

Table 11. Key stakeholders and potential roles and responsibilities for climate change adaptation measures in the infrastructure sector, to be refined through stakeholders consultation

Actors	Roles and responsibilities
Local communities	• Communicate to government officials the climate change impacts and the potential damage to infrastructure that occur in the community • Take action to minimize potential threats and damages
Local government authorities (i.e. provinces, districts, administrative divisions)	• Provide local knowledge and expertise to identify specific locations that should be prioritized for interventions to address the most pressing challenges • Improve the capacity of local communities and invest in local plans and programs to build climate resilience for critical infrastructure • Incorporate climate-resilient infrastructure in local adaptation plans • Facilitate efficient organization of local communities • Collaborate with local environmental groups and NGOs on prioritization of adaptation actions
National government ministries, departments and agencies (i.e. transport, health, education, energy, environment, water etc.)	• Empower and provide resources to local and regional governments that are exposed to climate change impacts • Instruct and engage the local governments and population to reduce possible climate related damages and loss of resources • Mainstream climate resilience in sectoral infrastructure policies and plans

31 ND-GAIN (2021), Tanzania, Available at https://gain-new.crc.nd.edu/country/tanzania

32 United Republic of Tanzania (URT) (2021). National Climate Change Response Strategy (2021-2026). Vice President's Office, Division of Environment, Government Printer, Dodoma. Tanzania, Available at https://faolex.fao.org/docs/pdf/tan214815.pdf

Actors	Roles and responsibilities
	• Take part in the design and implementation of programs to increase climate change resilience of infrastructure. Including the development of standards and regulations • Screen infrastructure projects for climate risks and implement cost-effective actions to reduce the impacts of climate change
Development partners (e.g. multilateral development banks, bilateral donors and organization, UN agencies)	• Provide international coordination, standardization and support on climate change adaptation measures • Facilitate the exchange of knowledge and data between individual regions and countries on climate change related issues and solutions, encouraging the application of best practices from international case studies • Where necessary, provide capacity development and technical assistance
Non-governmental organizations, community-based organizations, civil society	• Raise awareness on climate change issues and damage responses among communities and organizations • Assist in implementing early climate change adaptation measures and prepare local communities for natural disasters • Increase advocacy on climate change issues and solutions to influence policymaking • Ensure climate change adaptation measures consider the needs of women and vulnerable groups

4.3 Climate ambition and national frameworks screening

This annex provides an overview of national documents, policies and strategies related to climate adaptation and infrastructure development in Tanzania, including its Nationally Determined Contribution (NDC), National Adaptation Programme of Action (NAPA), National Climate Change Response Strategy (NCCRS) and sectoral plans.

4.3.1 National Frameworks, Strategies, and Plans

The Tanzanian government has developed several frameworks, strategies, and plans that focus on climate adaptation, resilience, and infrastructure. These documents aim to help the government address the adverse effects of climate change while supporting national development objectives. In addition to the documents outlined below, Tanzania has an ongoing National Adaptation Plan process led by the Tanzanian Vice President's Office, Division of the Environment, which aims to improve cross-sectoral coordination, integrate adaptation into development planning, and facilitate access to climate finance[33].

National Adaptation Programme of Action (NAPA) (2007) [34]

Tanzania's NAPA is one of the first documents to outline the country's vulnerability to climate change. It aims to identify urgent and immediate climate change adaptation actions that support long-term sustainable development. Its key objectives include adapting to climate variability, protecting lives, infrastructure, and biodiversity, and integrating adaptation strategies into national and sectoral development plans. The NAPA also seeks to raise public awareness, to assist communities to improve and sustain human and technological capacity for sustainable resource use, and support community development efforts affected by climate change, ensuring long-term sustainable livelihoods at both the local and national levels.

The NAPA identifies key priority sectors, adaptation options and strategies to best address vulnerabilities. Subsequently project activities were proposed for each sector, narrowed down based on their effectiveness in coping with and benefiting from climate change impacts and further ranked in accordance with their importance regarding impacts on poverty reduction and health, reliability, replicability and sustainability. A final list of 14 project activities were identified, including water efficiency in crop production irrigation, water harvesting and storage, investment in renewable energy sources, construction of artificial structures for flood protection, encouragement of afforestation in degraded lands and facilitation of sustainable human settlements.

Nationally Determined Contribution (NDC) (2021)[35]

Tanzania's NDC provides a set of climate change adaptation and mitigation interventions which are expected to build the country's resilience and contribute to reducing greenhouse gas emissions. The NDC states however that climate change adaptation is the priority. Tanzania is already affected by climate change and variabilities, with extreme events such as droughts and floods causing major economic costs, reducing long-term growth, and disrupting livelihoods of both rural and urban communities.

Climate change impacts in Tanzania affect almost all economic sectors in the country, including agricultural production, water resources, marine and coastal zones, public health, human settlement, land use planning, energy supply and demand, infrastructure, biodiversity and ecosystem services. Current climate variability and future climate change impacts are projected to be significant enough to curtail Tanzania from achieving key economic growth, sustainable development, and poverty reduction targets. The implementation of Tanzania's NDC is guided by UNFCCC principles, particularly the principle of equity

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33 UNDP, National Adaptation Plans in focus: Lessons from Tanzania (https://www.adaptation-undp.org/sites/default/files/resources/tanzania_country_brief_final_.pdf); See also, IISD, NAP Global Network, Tanzania National Adaptation Plan Approach (https://napglobalnetwork.org/wp-content/uploads/2018/02/napgn-en-2019-tanzania-nap-process-poster-3-1.pdf)

34 Vice President's Office, Division of Environment (2007), United Republic of Tanzania National Adaptation Programme of Action, Available at Microsoft Word - Tanzania NAPA Final Report.doc (unfccc.int)

35 The Republic of Tanzania (2021), Nationally Determined Contribution, Available at https://unfccc.int/sites/default/files/NDC/2022-06/TANZANIA_NDC_SUBMISSION_30%20JULY%202021.pdf

and that of common but differentiated responsibilities and respective capabilities. Furthermore, the implementation is guided by the Paris Agreement Work Programme adopted at the 24th Session of the Conference of the Parties (COP24) focusing on the actions such as: contributing to reductions in climate vulnerability and greenhouse gas emissions, enhancing long term climate resilience, achieving sustainable development consistent with the national development agenda and priorities and implementing the NDC in a transparent and participatory manner, as Tanzania's incremental contribution beyond the current efforts and upon availability of adequate and predictable financial and technological support from the international community.

Second National Communication (SNC) to the UNFCCC[36]

The United Republic of Tanzania followed in its initial National Communication (INC) that was submitted to the UNFCCC in 2003, with this SNC, that updates on the vulnerability, adaptation and GHG mitigation studies and actions.

Key adaptation strategies to enhance resilience in agriculture include using improved manure and fertilizers, advanced crop varieties, integrated pest and disease control, and biotechnology. Proposed measures for livestock include intensive stocking practices, advanced breeding technologies, and waste treatment solutions. Land management recommendations highlight the establishment of protected areas, habitat restoration, erosion control, and implementing structural controls.

For forest and land use, adaptation strategies include sustainable forest management, afforestation, the use of alternative materials, forest seed banks, and developing resilient plant varieties. These approaches should support both private and community forestry initiatives. Mitigation measures focus on forest conservation, establishment of managed plantations, and sustainable harvesting practices for timber and bioenergy production.

Further mitigation in transportation and waste management includes advancements in vehicle and fuel technologies, transport infrastructure improvements, and shifts toward fuel alternatives. Energy efficiency and cleaner technologies, such as co-generation, recycling, composting, and engineered landfills, are recommended to reduce emissions and promote sustainability.

National Climate Change Response Strategy (2021)[37]

The National Climate Change Response Strategy (NCCRS) aims to give guidance to stakeholders in an effort to enhance adaptive capacity to climate change in order to support long-term climate resilience of social systems and ecosystems, and to enhance participation in climate change mitigation activities to contribute to international efforts while ensuring sustainable development.

The Strategy covers adaptation, mitigation and crosscutting strategies that will enable Tanzania to benefit from the opportunities available to developing countries in their efforts to tackle climate change. The specific objectives of the NCCRS are to:

The plan aims to integrate climate change considerations into national and local development strategies and align with Tanzania's industrial development goals and global climate agreements. It includes the implementation and monitoring of the country's Nationally Determined Contribution (NDC), alongside strategic adaptation and mitigation measures. The plan also aims to enhance research, public awareness, and institutional capacity while promoting climate services. Additionally, it seeks to mobilize sustainable financing, advance climate-smart technology transfer, ensure gender-responsive approaches, and foster inclusive stakeholder engagement, including community and private sector involvement in climate change adaptation and mitigation efforts.

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[36] United Republic of Tanzania, Vice President's office (2014), SECOND NATIONAL COMMUNICATION TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, Available at https://unfccc.int/sites/default/files/resource/tzanc2.pdf

[37] United Republic of Tanzania (URT) (2021). National Climate Change Response Strategy (2021-2026). Vice President's Office, Division of Environment, Government Printer, Dodoma. Tanzania, Available at https://faolex.fao.org/docs/pdf/tan214815.pdf

Tanzania Development Vision 2025 (1999)[38]

Tanzania's Development Vision 2025 represents Tanzania's overall development framework and aims at attaining high quality livelihood for its people and developing a strong and competitive economy. Some of the strategies outlined toward attaining these objectives are ensuring food security and self-sufficiency; universal access to safe water; absence of abject poverty; reduction in infant and maternal mortality rates; economic growth rate of 8% per annum or more; attainment of macroeconomic stability; and an adequate level of physical infrastructure. The vision notes that investment in infrastructure is a high priority and that the development of the road network is essential for promoting rural development, while investments in energy, water, and telecommunications are critical for creating wealth and employment opportunities.

The vision has been implemented through The Long-Term Perspective Plan 2011/12 – 2025/26, which led to the development of three strategic Five-Year Development Plans (FYDP). The First FYDP 2011/12 – 2015/16, focused on unleashing growth potential in the country by removing constraints to growth. The Second FYDP 2016/17 – 2020/21 aimed at nurturing industrialization to promote economic and human development. The Third FYDP 2021/22 – 2025/26 is focused on attaining export growth and competitiveness and represents the final plan in the implementation of the Tanzania Development Vision 2025.

Integrated Industrial Development Strategy 2025[39]

Tanzania's Integrated Industrial Development Strategy (IIDS) 2025 responds to the need for a dynamic plan to guide the process of resource-based industrialization. The Strategy identifies that Tanzania's power supply has not been able to cope with demand for stable and reliable energy for industrial development and highlights that access to clean and reliable power supply for climate resilient industrial development needs to be sustained and supported.

Tanzania Sustainable Energy for All (SE4All) Action Agenda (2015)[40]

The goal of Tanzania's SE4All Action Agenda is to ensure access to modern energy, preferably clean energy; to improve energy efficiency; and to increase share of renewable energy in the national energy mix. The Government of Tanzania fully embraces the SE4ALL objectives including the fact that access to modern energy services is a necessary precondition for achieving development goals that extend far beyond the energy sector, such as poverty eradication, access to clean water, improved public health and education, women's empowerment and increased food production.

Power System Master Plan (PSMP), (2020)[41]

The Power System Master Plan (PSMP) of 2020 has a primary goal of increasing access to modern energy; and enhancing power supply availability, reliability and affordability in Tanzania. The plan has been prepared using data on electricity demand gathered during industrial surveys across the country and provides forecasts for the anticipated energy needs of the population and economy of Tanzania for the period up to 2044.

Water Sector Development Programme (WSDP) (2006 – 2025)[42]

The objective of the WSDP is to alleviate poverty through improvements in the governance of water resources management and the sustainable delivery of water supply and sanitation services in Tanzania. It is designed to address shortfalls in urban and rural water supply infrastructure, to improve water

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38 Planning Commission (1995), Tanzania Development Vision 2025, Available at https://www.healthdatacollaborative.org/fileadmin/uploads/hdc/Documents/Country_documents/tanzania_development_vision_2025.pdf

39 Ministry of Industry and Trade, The United Republic of Tanzania (2011), Integrated Industrial Development Strategy, Available at https://www.viwanda.go.tz/uploads/documents/sw-1620119076-IIDS%20Main%20Report%20signed.pdf.

40 Ministry of energy and Minerals, The United Republic of Tanzania (2015), Tanzania's SE4ALL Action Agenda, Available at https://www.seforall.org/sites/default/files/TANZANIA_AA-Final.pdf

41 Ministry of Energy, The United Republic of Tanzania (2020), Power System Master Plan 2020 update, Available at https://www.nishati.go.tz/uploads/documents/en-1638532283-PSMP%202020%20UPDATE%20FINAL%20signed.pdf

42 Ministry of Water, The United Republic of Tanzania (2006), Water Sector Development Programme (2006-2025), Available at https://faolex.fao.org/docs/pdf/tan178947.pdf

resource management primarily through upgrading the country's nine Basin Water Offices (BWOs), and to strengthen the sector institutions and their capacities. The WSDP comprises of three main components: (i) water resources management; (ii) rural water supply and sanitation; and (iii) urban water supply and sewerage.

The Water Sector Development Programme (2006 – 2025) emphasizes registration and licensing of water use activities and polluting enterprises, as well as monitoring of pollution, development and implementation of comprehensive water quality monitoring and pollution control programmes, adoption of permanent water quality standards, and protection of important water sources as ways of enhancing water and environmental conservation.

4.4 Sectoral Institutional, legal and regulatory frameworks screening

This annex provides an overview of the relevant institutional, legal and regulatory framework in Tanzania, relevant to climate adaptation, including key government actors and bodies across priority infrastructure sectors.

Responsibility for addressing climate change adaptation in Tanzania is distributed across various levels of government, with the Vice President's Office within the Division of Environment (DoE) leading the NAP process and developing environmental guidelines and regulations. In consultation with relevant sector ministries, the Vice President's Office takes measures to address climate change impacts, issues climate change adaptation guidelines, enforces strategies and action plans, and reviews and approves adaptation measures. The Office also serves as the National Climate Change Focal Point (NCCFP) for the UNFCCC.

In addition to the Vice President's Office, Tanzania's National Environment Management Council (NEMC) oversees environmental enforcement, compliance, reviewing and monitoring environmental impact statements, research and awareness raising. The National Environmental Advisory Committee (NEAC) advises senior government officials and sector ministries on matters relating to environmental protection and management.

The National Environmental Policy (NEP), first adopted in 1997 and updated in 2021, provides the overall policy framework for environmental management in Tanzania. The Environmental Management Act (2004) supports NEP implementation by establishing the legal and institutional framework for sustainable environmental management. Although the NEP identifies climate change as a priority, it highlights ongoing challenges within the country, including limited adaptive capacity, inadequate funding, low public awareness, inadequate institutional coordination, and limited investment by the private sector in adaptation. The NEP also requires sectoral ministries to ensure their policies comply with the NEP and integrate environmental management into their sectoral strategies, plans, programs, and projects. The following provides a brief overview of the institutional, legal and regulatory framework for key infrastructure sectors.

4.4.1 Transport

Tanzania's transport system is divided into five categories: roads, rail, water, air, and pipelines. Most of the country's infrastructure is not modernized and requires funding. The Ministries responsible for the planning and management of the transport sector are Transport, Works, Home affairs, Regional Administration and Local Government and Finance.[43] The National Transport Policy (NTP) considers other national guidelines including the National Poverty Reduction Strategy Paper (PRSP) and Rural Development Strategy (RDS) through which rural road transport, telecommunications and postal services are areas to fight poverty effectively.

To increase efficiency in the transport sector in Tanzania, the central government has decentralized its roles in road construction and maintenance. Rural roads construction and maintenance are implemented by the Local Government Authorities and the construction and maintenance of major roads in the country is supervised by the semi-autonomous Tanzania Roads Agency (TANROADS). In addition, according to the Surface and Maritime Transport Regulatory Authority (SUMATRA) Act (2001) and in order to address challenges related to traffic congestion, especially in the Tanzania's biggest urban areas, the government has established the Dar es Salaam Rapid Transport Agency, responsible for the design and operations of rapid transport networks. Private operators are also encouraged to create medium-size commercial fleet operations for the establishment of commuter city urban bus transport companies and for the creation of transport infrastructure such as parking, shelters etc.

Regarding Tanzania's railway transport system, the 2002 Railway Act aimed to restructure the Tanzania Railways Corporation (TRC) and separate the functions of running the railway business from ownership

[43] Ministry of Communications and Transport (2003), National Transport Policy, Available at https://www.mow.go.tz/uploads/documents/sw-1631778532-NATIONAL%20TRANSPORT%20POLICY%20%202003.pdf

of the infrastructure assets and its regulations. Railway services are concessioned to private sector while economic and safety regulation remains under SUMATRA.[44]

4.4.2 Energy

In terms of energy infrastructure, the Tanzanian Ministry of Energy (ME) is tasked with developing energy and managing the energy sector. Specifically, it is responsible for the formulation/articulation of policies that aim to create an enabling environment for different stakeholders in the energy sector, therefore the ME plays an important guidance role. Other major players include the Energy and Water Utilities Regulatory Authority (EWURA), an autonomous, independent regulatory authority, responsible for technical and economic regulation of Tanzania's electricity, petroleum, natural gas and water sectors, the Tanzania Electric Supply Company (TANESCO), a government owned utility company that is Tanzania's principal electricity generator, transmitter and distributor, providing the vast majority of generating capacity to the national grid and the Tanzania Petroleum Development Corporation (TPDC), a state-owned corporation that implements petroleum exploration and associated development policies.

Additionally, the Rural Energy Agency (REA) is an autonomous body responsible for (i) promoting, stimulating, facilitating, and improving modern energy access in rural areas to support economic and social development; (ii) promoting rational and efficient production and use of energy and facilitating the identification and development of improved energy projects and activities in rural areas; (iii) financing eligible rural energy projects through the Renewable Energy Fund (REF); (iv) preparing and reviewing application procedures, guidelines, selection criteria, standards, and terms and conditions for the allocation of grants; (v) building capacity and providing technical assistance to project developers and rural communities; and (vi) facilitating the preparation of bid documents for rural energy projects.[45]

Moreover, the Tanzanian Energy Development Access Programme (TEDAP) (2008) is a cooperation between the Tanzanian Ministry of Energy and the World Bank to improve electricity service provision in urban centers, as well as to establish a basis for sustainable energy access in rural areas. It is managed by the Rural Electrification agency through funding from the Rural Electrification Fund (REF) established through the 2005 Rural Energy Act.[46] The Act established the Rural Electrification Agency, and Fund and mandates the Rural Electricity Board through which the REF is used for subsidies and grants to develop rural energy projects. Further, the Scaling up Renewable Energy Programme for Tanzania (SREP Tanzania) in 2013 aimed to involve the private sector to overcome the higher-risk phases of development in the renewable energy sector. This was proceeded by the Small Power Producers (SPP) framework which was created to enable private project developments through standardized power purchase agreements. The SPP not only covers renewable energy but supports conventional energy systems as well.[47]

4.4.3 Water

Regarding the water sector in Tanzania, the Water Resources Management Act (WRMA) No. 11 (2009) was enacted to provide institutional legal framework for sustainable management and development of water resources, highlight principles for the management of water resources management; prevent and control water pollution. The WRMA established Integrated Water Resources Management (IWRM) institutions including the National Water Board, Basin Water Boards, Catchment Water Sector Status Committees and Water User Associations; and supports joint IWRM bodies on shared waters with other countries. On the other hand, the Water Supply and Sanitation Act No.5 (2019) was enacted to provide for sustainable management and adequate operation and regulation of water supply and sanitation services, outlined the key role of Urban Water Supply and Sanitation Authorities (UWSSAAs) and established Water

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44 Sustainable development, United Nations (NA), Transport Sector, Available at https://sustainabledevelopment.un.org/content/documents/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/tanzania/transport.pdf

45 International Trade Administration (2022), Tanzania – Country Commercial Guide, Available at https://www.trade.gov/country-commercial-guides/tanzania-energy

46 International Energy Agency (2016), Rural Energy Act 2005, Available at https://www.iea.org/policies/6003-rural-energy-act-2005

47 International Energy Agency (2016), Small Power Producers (SPP) Framework, Available at https://www.iea.org/policies/6005-small-power-producers-spp-framework

Supply and Sanitation Authorities (WSSAs), Rural Water Supply and Sanitation Agency (RUWASA), National Water Fund (NWF) and Community Based Water Supply Organisations (CBWSOs).[48]

4.4.4 Health and Education

The Ministry of Health, Community Development, Gender, and Children (MoHCDGC) and the Ministry of Education, Science, and Technology (MoEST) [49] are responsible for developing policies related to education and healthcare in Tanzania.[50] In 2023, the MoHCDGC reformed the National Health Insurance Fund (NHIF) in its third iteration since 1999.[51] The reform introduces the Universal Health Coverage (UHC) which introduced mandatory health insurance for all citizens and residents, thus increasing the insurance coverage in Tanzania. This was achieved by raising funds through mandatory contributions and expanding coverage to the informal sector through the Community Health Insurance Fund (CHIF) within the NHIF. Thereby, the Tanzania Insurance Regulatory Authority (TIRA), a regulatory body, is mandated to regulate the insurance sector in Tanzania. The Districts and Health Facilities are responsible for planning and management of district health care and health services respectively. The main actors include the Central Ministry of Health, President's Office Regional Administration and Local Government, NGOs and Faith Based Organizations, Development Partners in health both bilateral and multilateral. New initiatives are introduced in Tanzania towards investors to establish factories in the health sector to decrease spending [52]. In addition, the MoHCDGC has published a Health National Adaptation Plan (HNAP) 2018-2023 that includes objectives related to increasing climate resilience of health infrastructure from extreme weather events such as flooding[53]

The education sector in Tanzania is in reform and transformation as of 2022. During the transformation period, the MoEST reviews the education and training policy of 2014 and the curriculum of basic education. The reforms are targeted to ensure alignment with global developments in technology and innovation, as well as providing job-relevant skills. The key bodies for the education reform are the Tanzanian Institute of Education (TIE), as well as the school quality control offices, which were established in all 26 regions of mainland Tanzania. The MoEST and MoHCDGC collaborate to enhance early childhood development (ECD) through the National Multisectoral ECD programme for the financial year 2021/22 to 2025/26. The MoHCDGC is responsible to ensure the goal of gender equality in and through education is reached in Tanzania. This goal is enabled through the National Accelerated Action and Investment Agenda for Adolescent Health and Wellbeing 2021/22-2024/25 to assess the gendered implications in the education sector[54].

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48 Ministry of Water, The United Republic of Tanzania (2024), Water Sector Development Programme Phase III, Annual Water Sector Status Report 2023, Available at https://www.maji.go.tz/uploads/publications/sw1715165711-Water%20Sector%20Development%20Phase%20III%20Annual%20Water%20Sector%20Status%20Report%20%202023.pdf

49 International Institute for Capacity Building in Africa (2024), United Republic of Tanzania (Mainland and Zanzibar): Education Country Brief, Available at https://www.iicba.unesco.org/en/node/111#:~:text=Tanzania%20uses%20a%201%2D7,years%20of%20post%2Dsecondary%20education

50 Geneva foundation for Medical education and Research(2024) Medical schools, governments, ministries and medical associations, Tanzania, Available at https://www.gfmer.ch/Medical_search/Countries/Tanzania.htm

51 Osoro, O., Mbuthia, B., Nyawira, L., Githinji, J., and Gikonyo, S. (2024), Tanzania's Universal Health Insurance Act, 2023: Implications on Health Financing, Available at https://sparc.africa/wp-content/uploads/2024/02/Tanzania-UHI-Act-2023-Policy-brief.pdf

52 International Trade Administration (2022), Healthcare, Available at https://www.trade.gov/country-commercial-guides/tanzania-healthcare

53 The ministry of Community Development, Gender, Elderly and Children (2019), Health – National Adaptation Plan to Climate Change in Tanzania 2018-2023, Available at HNAP-FINAL-CLEAN-1-1.pdfhttps://climahealth.info/wp-content/uploads/2022/02/HNAP-FINAL-CLEAN-1-1.pdf

54 International Institute for Capacity Building in Africa (2024), United Republic of Tanzania (Mainland and Zanzibar): Education Country Brief, Available at https://www.iicba.unesco.org/en/node/111#:~:text=Tanzania%20uses%20a%201%2D7,years%20of%20post%2Dsecondary%20education

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GLOBAL
CENTER ON
ADAPTATION

ANTOINE PLATEKADE 1006
3072 ME ROTTERDAM
THE NETHERLANDS
+31(0)88-088-6800
WWW.GCA.ORG