Malawi
Climate Stress Test
Cascading Socioeconomic Impacts and Adaptation Policies Pathways

Technical report

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GLOBAL CENTER ON ADAPTATION

IISD International Institute for Sustainable Development

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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.

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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 Malawi. 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 scenarios[1], and the implementation of reconstruction and climate adaptation investments. The analysis is systemic and takes into consideration 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 Malawi 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 Malawi.

The results of the analysis are summarized as follows:

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

The SSP3 BAU scenario is estimated to generate 34 billion USD of damage, cumulatively by 2050. This results in a cumulative negative GDP impact of 56.76 billion USD by 2050, or the equivalent of 4.70 years' worth of value addition (using the 2024 GDP value).

The largest costs are from productive capital and buildings, which combined equal 29 billion USD. These costs not only reduce public revenue and income generation but also hinder economic growth and development efforts. The extensive damage to infrastructure and assets could also reduce access to essential services, disrupt livelihoods, and exacerbate socio-economic inequalities.

[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.

Climate impacts cause annual losses across key sectors due to climate impacts. 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 0.6% of service and industry capital, totaling 13 billion USD by 2050. Similarly, buildings are expected to incur a cumulative loss of 15 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 Malawi is estimated to reach USD 30.21 billion by 2050 (the value would increase to 34 billion USD when considering agricultural losses), corresponding to 2.51 times GDP in 2024.

Concerning assets on specific impacts:

- Roads: annual losses are projected at 130.69 km (0.07% of the 2024 stock), with cumulative losses valued at USD 431 million by 2050, equating to 18.2% of the total road stock.
- Buildings: forecasted annual damage is expected to reach 34,529 units, resulting in cumulative damages of USD 15 billion by 2050, which accounts for 18.3% of the total building stock in 2024.
- Power Generation: projected annual damage of 32.5 MW of capacity would cumulatively result in 587 MW damaged by 2050, representing 90.6% of the 2024 power generation capacity. This emphasizes the need for careful setting of power plants away from areas vulnerable to climate impacts.
- Industry and Service Capital: cumulative damages are forecasted to reach USD 13 billion by 2050, equivalent to 74.2% 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 10% in 2050 compared to scenario without climate change. The annual reduction is 0.4%.

The projection of a 14% 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 0.4% higher every year, as a result of a more climate resilient economy. In this scenario, climate impacts on GDP could be reduced to 46 billion USD cumulatively by 2050, or a 19% reduction.

Adaptation is a competitive economic development strategy, with a Benefit to Cost Ratio (BCR) of 2.67, a payback time within 10 years, and net benefits of USD 1.8 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 2.67 by 2050. The reactive scenario achieves a BCR of 0.54 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 proactive scenario generates 1.8 billion USD in net benefits between 2023 and 2050.

The adaptation proactive scenario stimulates economic growth (GDP 3.6 % higher than BAU by 2050) and job creation (2.1% 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 0.8% 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 0.8% 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, Malawi faces substantial climate change costs, with the SSP3 BAU scenario forecasting cumulative damages of USD 34 billion by 2050. This translates to total economic losses of USD 56 billion, equivalent to 4.7 years of GDP. The overall impact on assets is estimated at USD 30.2 billion—2.51 times the 2024 GDP. A proactive adaptation scenario would reduce GDP losses by 19%, to USD 46 billion cumulative by 2050. These investments result in a Benefit to Cost Ratio (BCR) of 2.67 (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	Definitions
ABM	Adaptation Benefits Mechanism
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.
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.
BCR	Benefit to Cost Ratio
CBA	Cost-Benefit Analysis
EMA	Environmental Management Act
GCA	Global Centre on Adaptation
GDP	Gross Domestic Product
GEM	Green Economy Model
GIS	Geographical Information Systems
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
MW	Megawatt
MDBs	Multilateral Development Banks
MEL	Monitoring, Evaluation and Learning
NAPs	National Adaptation Plans
NAPA	National Adaptation Programme of Action
NCCAMS	National Climate Change Adaptation and Mitigation Strategy
NDCs	Nationally Determined Contributions
SD	System Dynamics
SLB	Sustainability-Linked Bonds
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.
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change

1. INTRODUCTION

1.1 Introduction

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 Malawi. 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. These 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 program.

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 Malawi'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.

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

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.

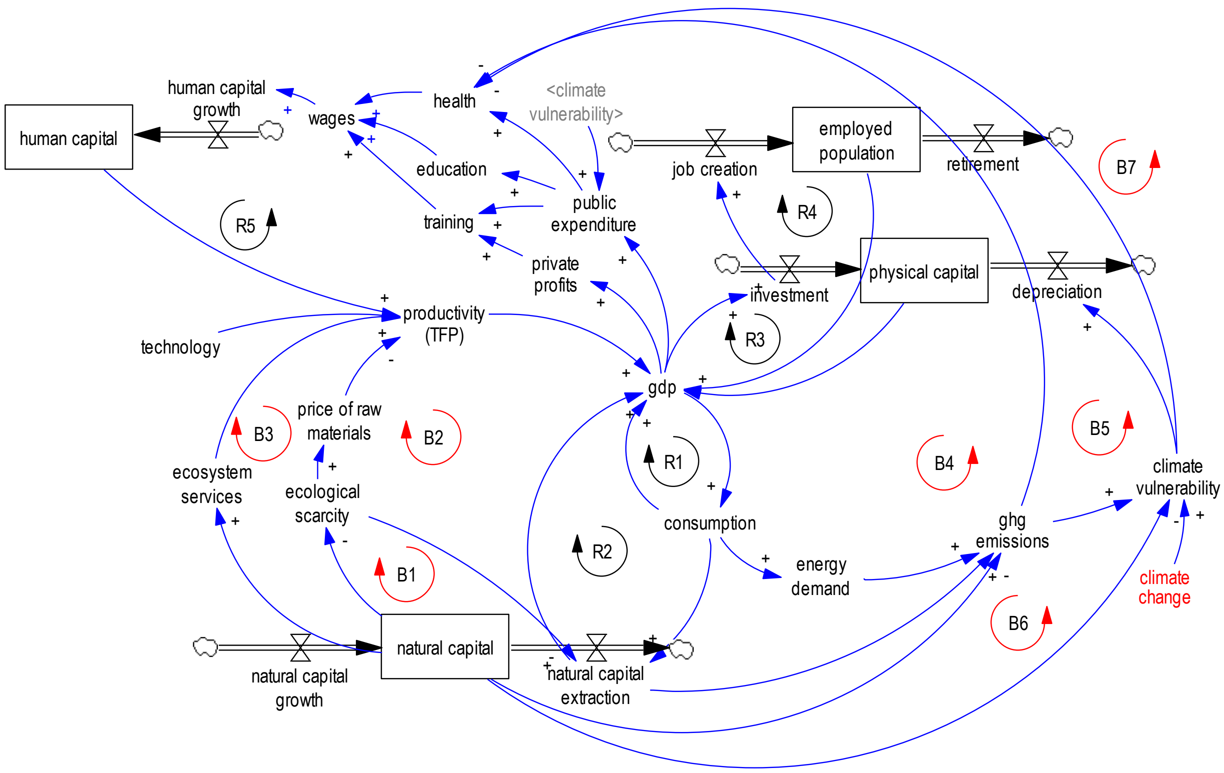


Figure 1: Overview of GEM, built on (Bassi A. , 2015).

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 200 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 model documentation for a full overview of data inputs, calibration, and functions.

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.
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: Overview of data inputs into 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)[2]. 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

[2] 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.

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.

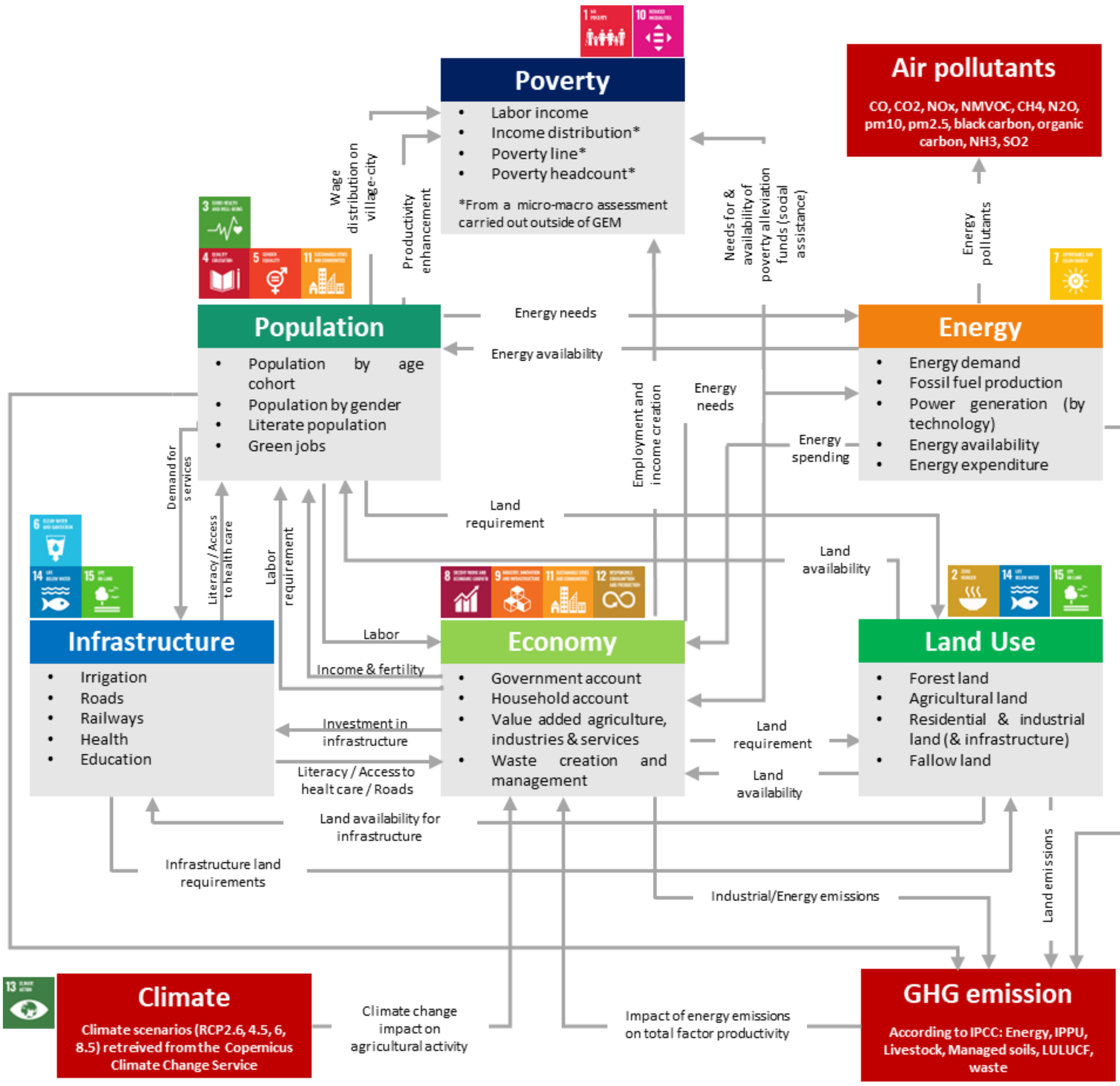


Figure 2: Sub-system diagram presenting the key sectoral components of GEM.

The current model consists of over 40 interconnected modules (Figure 2: Sub-system diagram presenting the key sectoral components of GEM.

), 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: Sub-system diagram presenting the key sectoral components of GEM.

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.

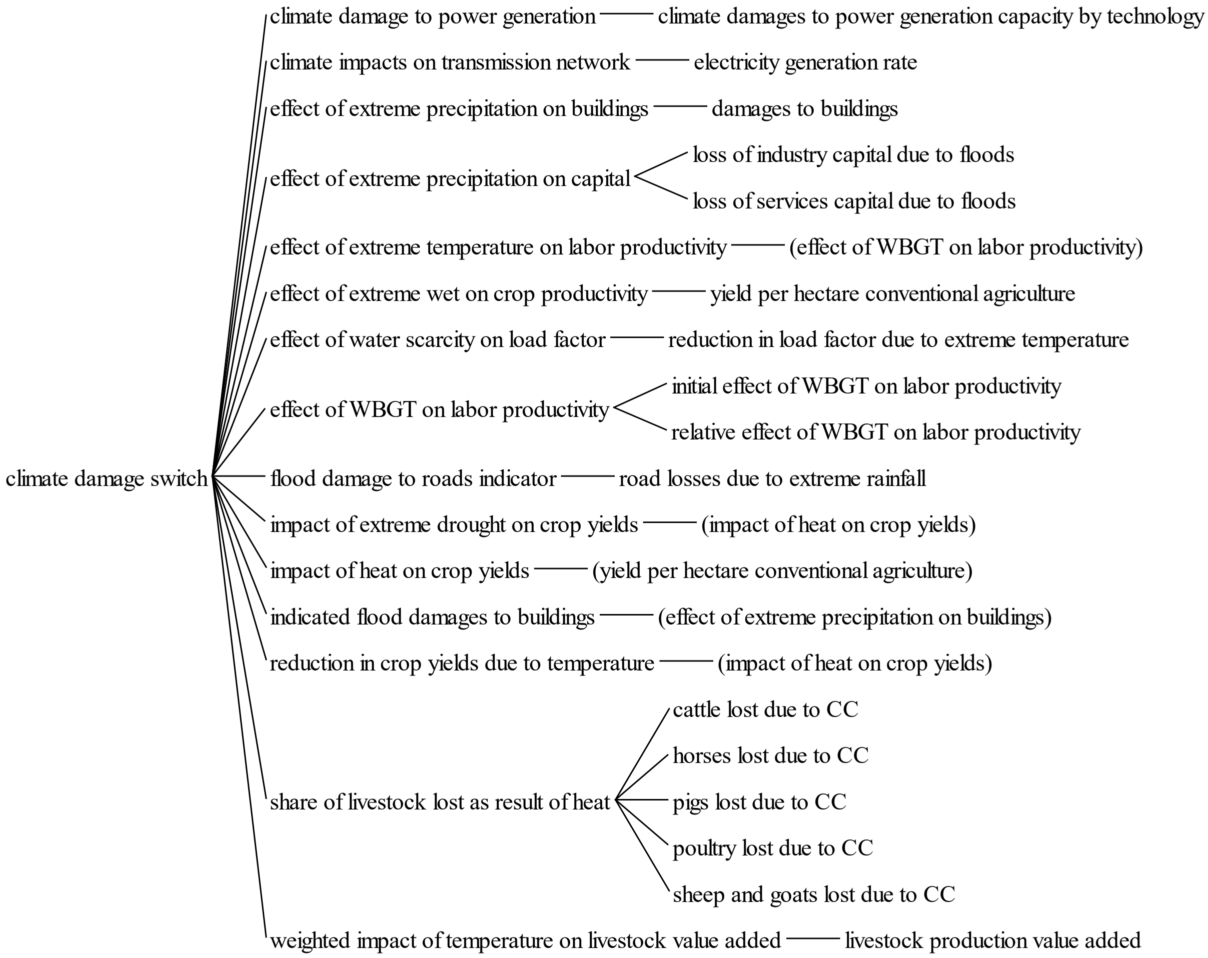


Figure 3: Impact pathways of climate change within GEM

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 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 (see 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).

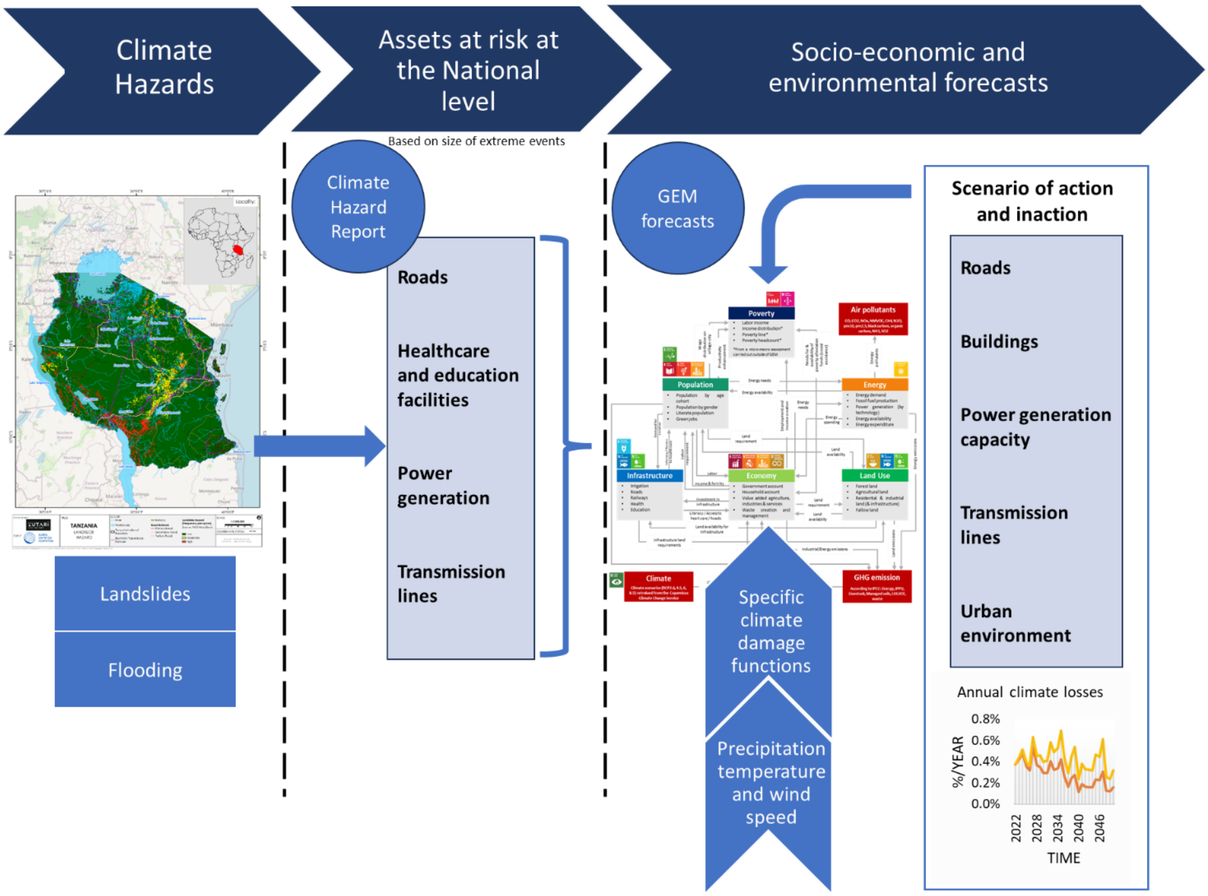


Figure 4: Process for Integration of the Climate Hazard Assessment into GEM

Specifically, the output of Climate Hazard Assessment includes assets-at-risk maps[3] 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 asset 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 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 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.

[3] 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.

Assets at Risk		
Asset	Unit	Malawi
Roads (km)	%	23.45%
Buildings (Buildings)	%	15.34%
Power Generation Capacity (MW)	%	28.57%
Transmission Lines (km)	%	17.18%
Liveable cities	%	25%

Table 2: Asset at risk per assets by Zutari (see Annex on methodology)

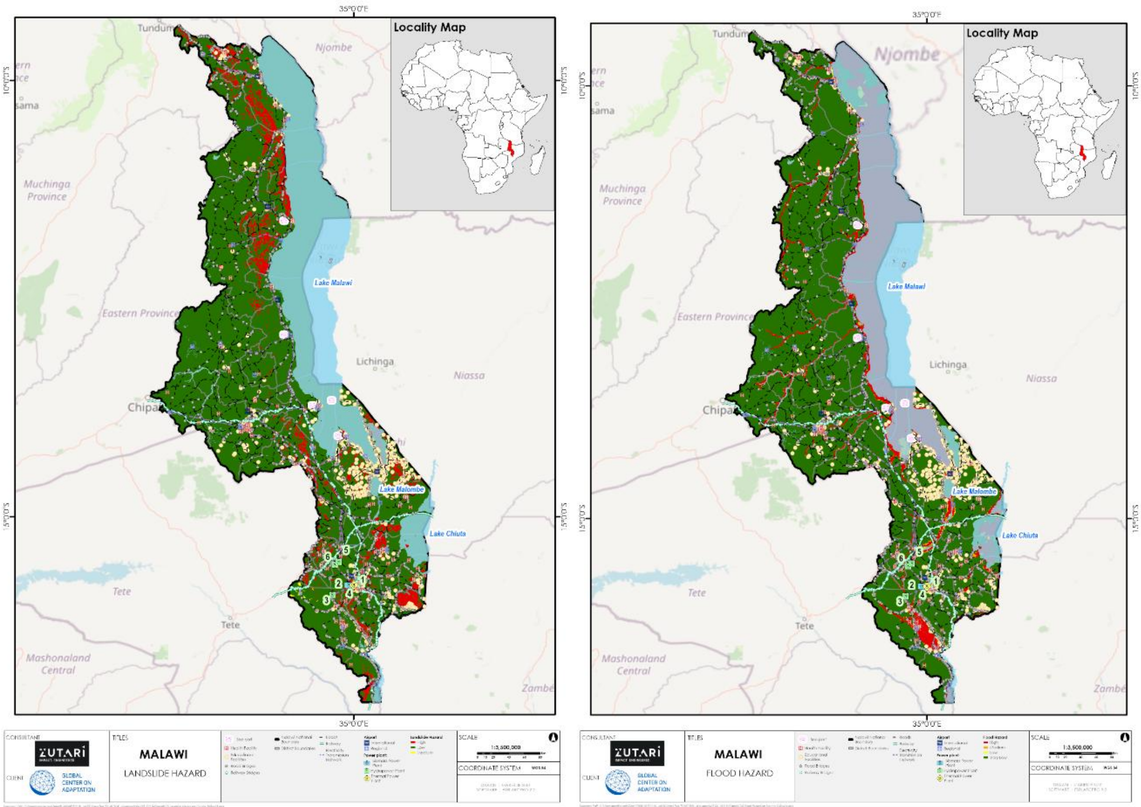


Figure 5: Hazard maps for Malawi from the Climate Hazard Assessment by Zutari (see Annex on methodology)

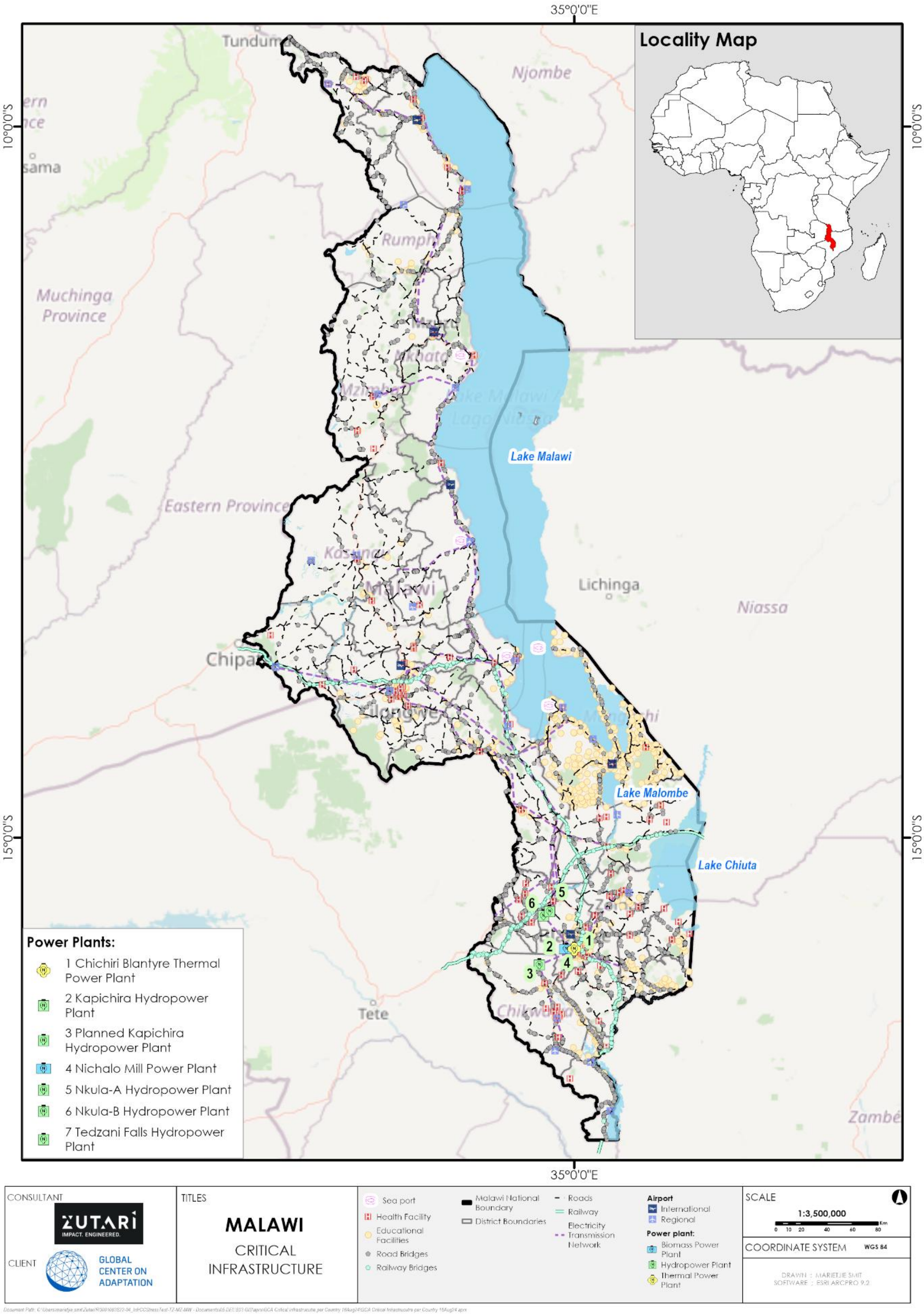


Figure 6: Critical infrastructure system for Malawi from Climate Hazard Assessment Report carried out by Zutari

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 34 billion USD by 2050, being 98% of GDP by 2050.

This figure reflects the extensive economic toll of climate-related damages 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, 0.6% of service and industry capital is lost annually, costing a cumulative sum of 13 billion USD by 2050. The damage to buildings totals 15 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 10% in 2050 compared to scenario without climate change. The annual reduction is 0.4%.

This substantial decline illustrates the severe economic impact of unmitigated climate change. GDP growth could be 0.4% 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 2.57 by 2050 and realizes USD 1.8 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 25% 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 62%, buildings by 23%, km of roads by 23%, and power generation infrastructure damage by 43% compared to SSP3 BAU. The investments total 511 million USD By 2050.

Adaptation interventions implemented under the proactive scenario reduce the loss of buildings from on average 0.6% to 0.2 annually.

This reduction translates to saving approximately 23,000 buildings each year. Climate-proofing measures, which have the largest impact, are projected to save these 23,000 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 260 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 3.6 % higher than BAU by 2050) and job creation (2.1% 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 0.8% of GDP by 2030) while the reactive case has initially lower investments levels (0.1% of GDP by 2030) but overtake the proactive scenario by 2045 due to higher reconstruction costs. This higher ambition would save Malawi USD 8 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 Malawi (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).

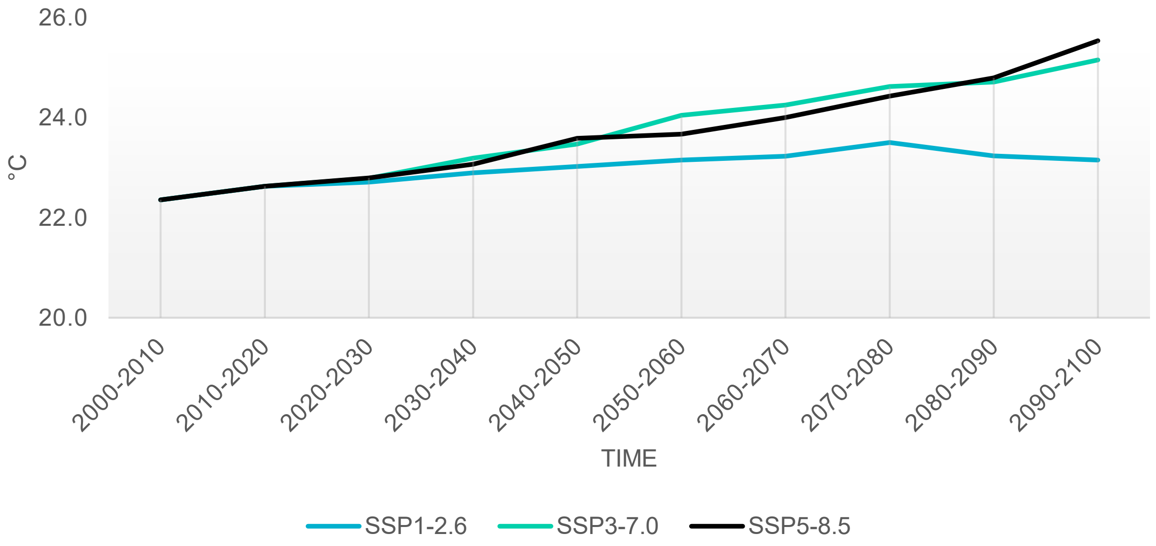


Figure 7: Average monthly temperature obtained from MPI-ESM1.2

The increasing trend continues for average monthly precipitation between 2090 and 2100 where, in SSP3 the monthly precipitation starts to increase towards 100 mm/month, otherwise it oscillates around 90 mm/month throughout the simulation (Figure 8). In SSP5, monthly average precipitation increases over 100mm per month in the 2060s.

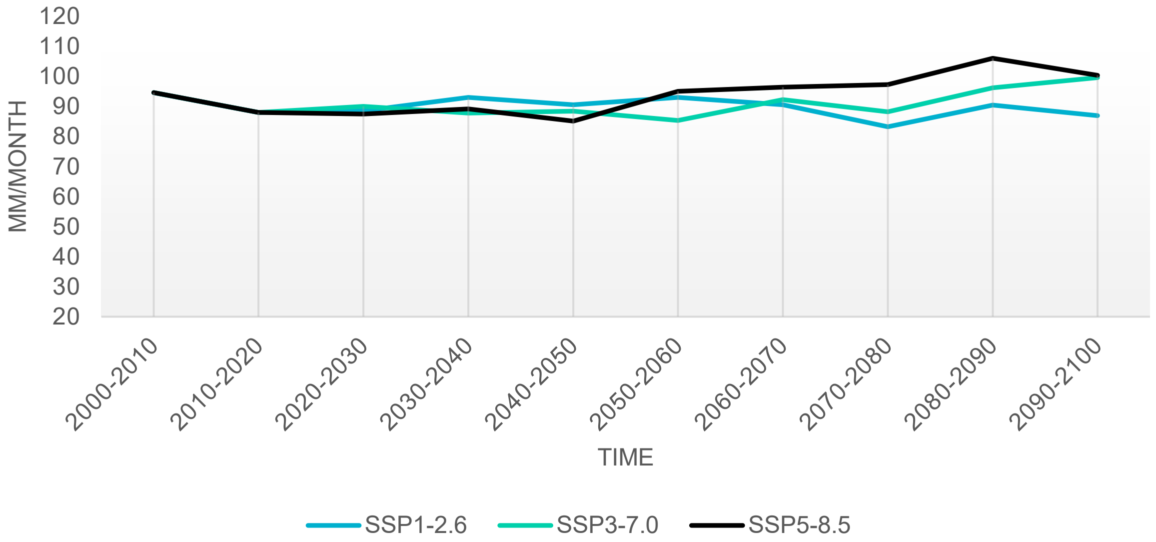


Figure 8: Average monthly precipitation obtained from MPI-ESM1.2

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).

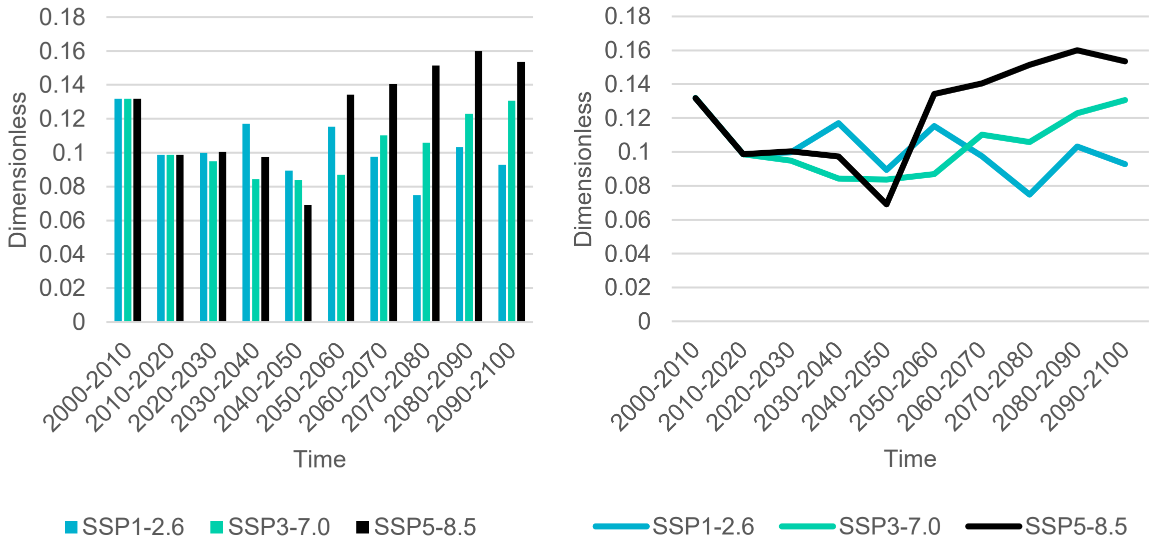


Figure 9: Incidence of abnormalities - extreme wet for Malawi

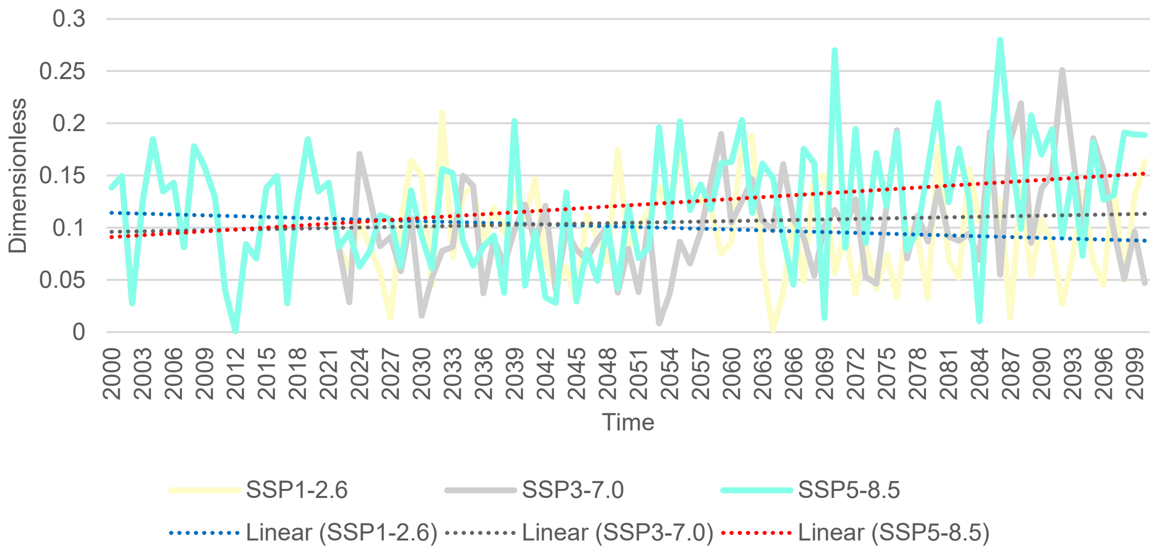


Figure 10: Extreme wet percentile for Malawi

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.

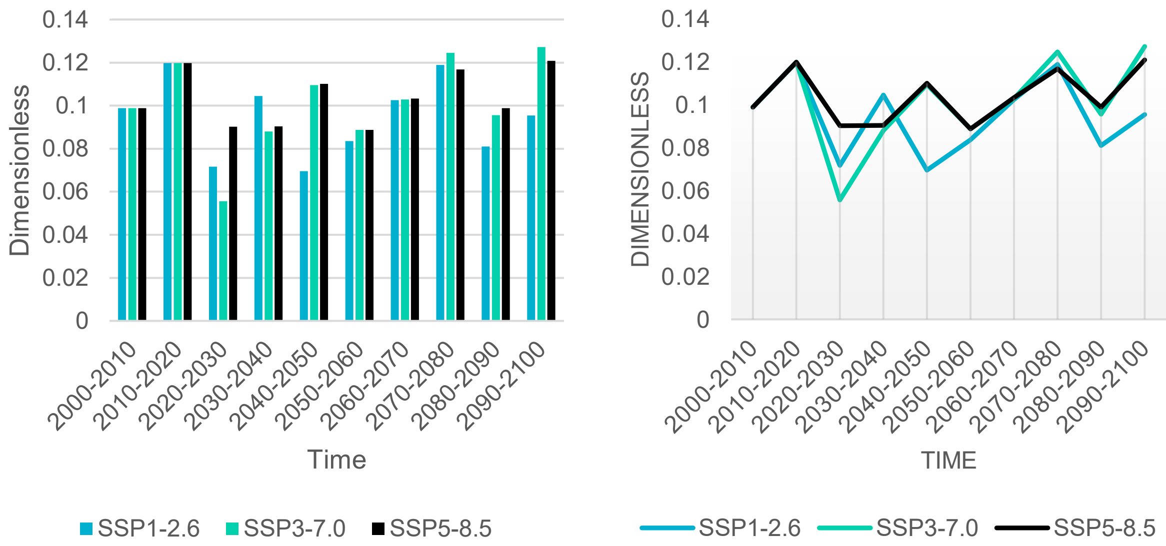


Figure 11: Incidence of abnormalities - extreme dry for Malawi

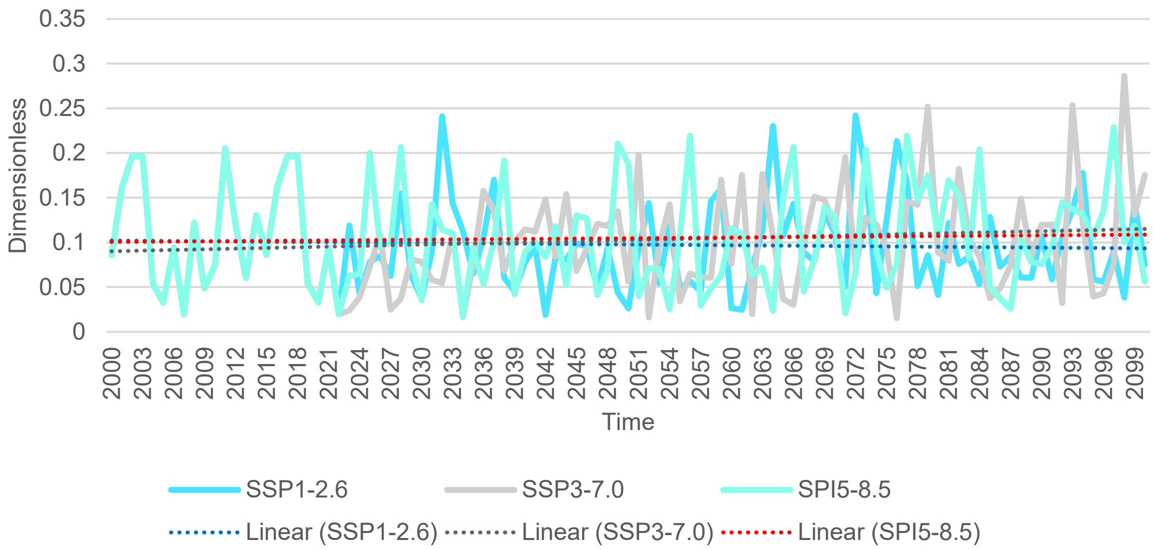


Figure 12: Extreme dry percentile for Malawi

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 0.6% 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 0.6% on average to 0.2% (Figure 13).

In economic terms, in the SSP 3 scenario, cumulative total capital losses start at 4 billion USD in 2022 and rise to 13 billion USD by 2050, the equivalent of 74.2% 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 62%, bringing the total down to 8.5 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.

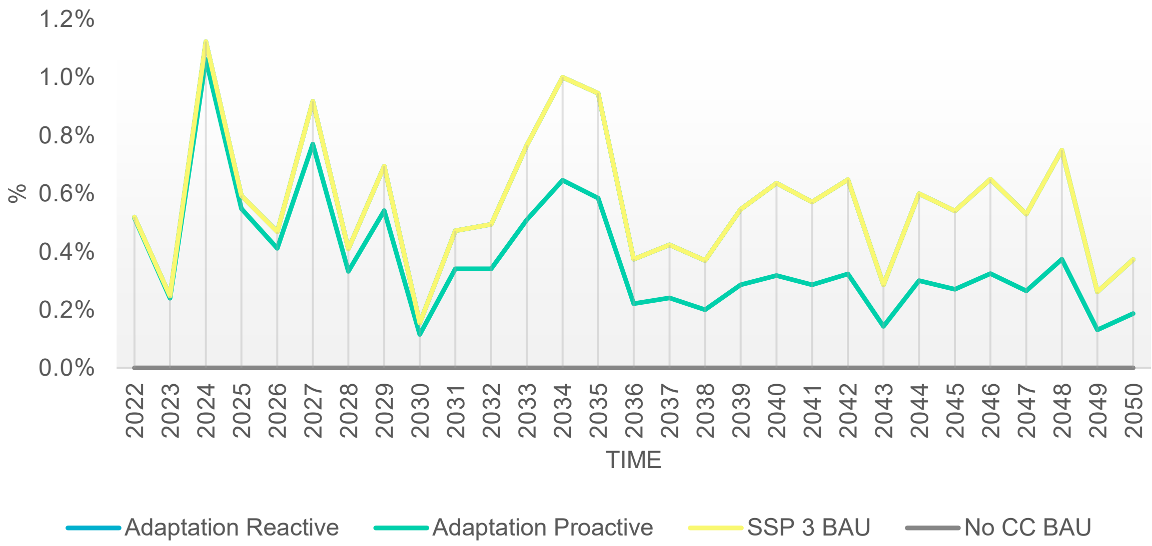


Figure 13: Annual percentage of losses of capital under SSP and Adaptation scenarios

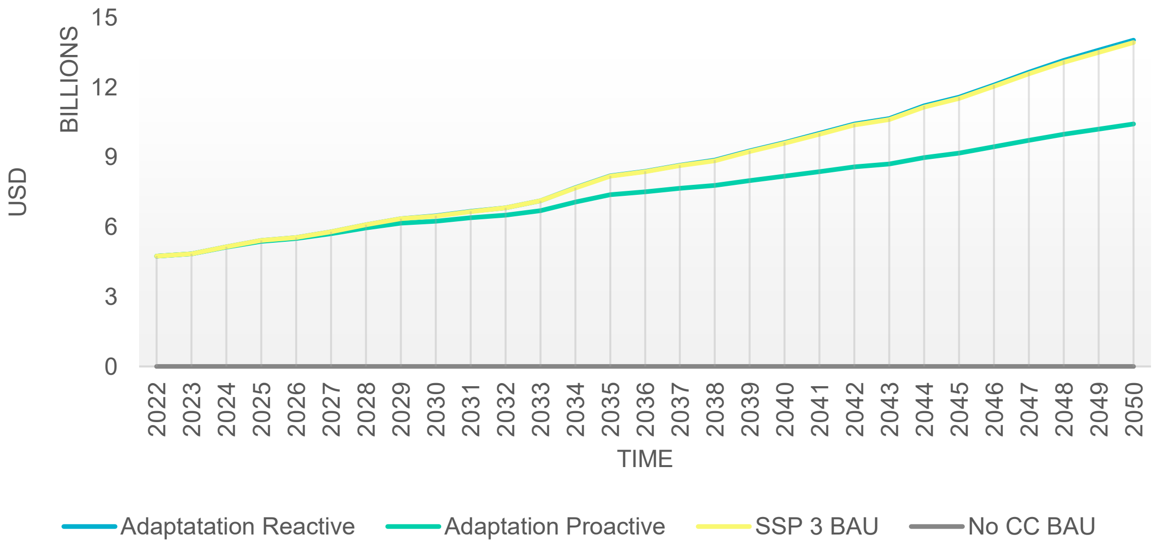


Figure 14: Cumulative total capital losses under BAU, SSP, and Adaptation scenarios

2.2.2 Climate impact on buildings

In the SSP3 scenario, extreme precipitation (such as flooding, and landslides, general water related damage) results in damage to an average of 40,000 buildings (0.6%/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 17,000 dwellings (0.2%) 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 15 billion USD by 2050, corresponding to 18.3% of the total building stock in 2024 In the reactive scenario, cumulative damages increase past the SSP 3 level by 1% due to higher GDP growth but a lack of climate resilience measures. In contrast, the proactive scenario reduces cumulative damages to buildings by 23% compared to the BAU, lowering the total to 11.6 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 of building, which reflects the effectiveness of these adaptation measures in protecting buildings from climate impacts.

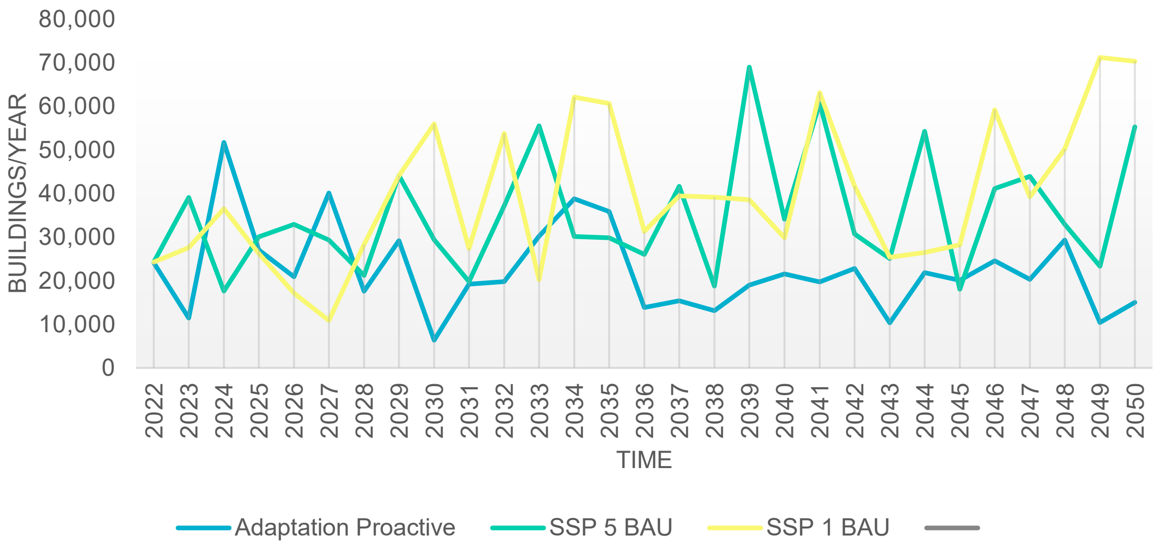


Figure 15: Annual loss of buildings due to extreme weather events in Malawi

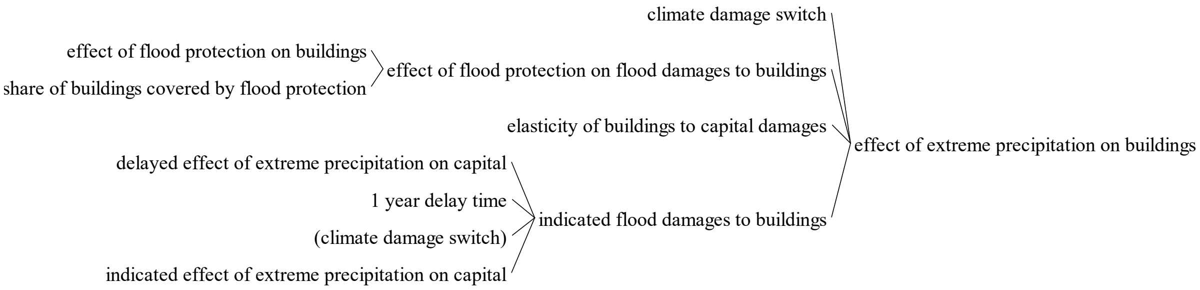


Figure 16: Tree diagram of GEM structure for building damages

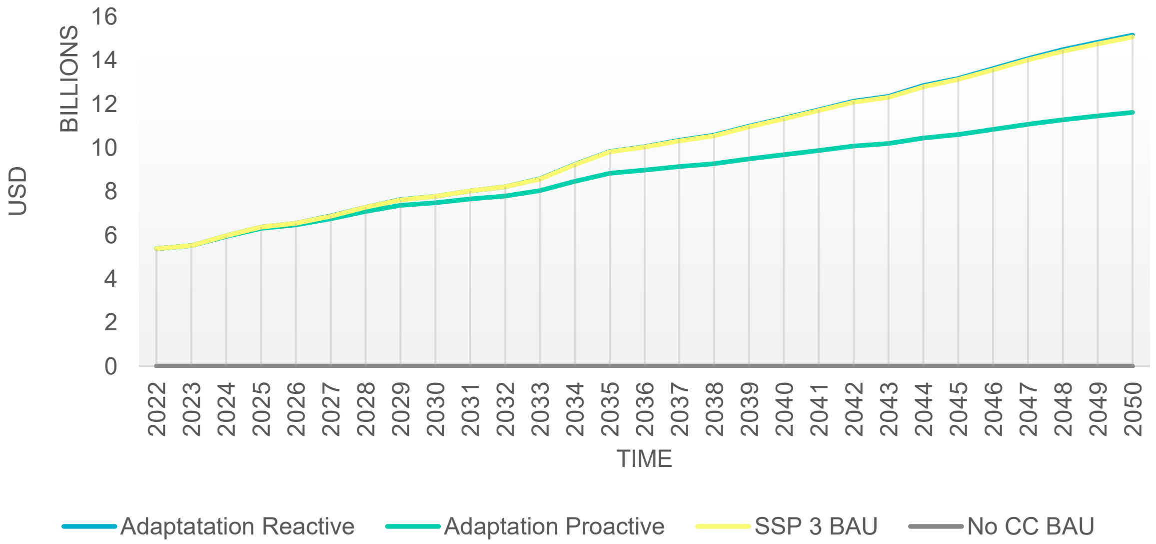


Figure 17: Cumulative Damage to Buildings under BAU, SSP, and Adaptation scenarios

2.2.3 Climate impact on roads

In the SSP3 scenario, approximately 0.7% of roads are damaged annually, due to flooding, landslides and erosion, leading to climate change damages totaling 431 million USD by 2050. Annual losses for roads are projected at 130.6 kilometers, which represents 0.7% of the total road stock in 2024. Cumulatively this results in the damage of 3398 km of roads by 2050.This significant physical loss would equate to 18.2% 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 433 million USD, driven by higher economic growth. In contrast, the proactive scenario, which includes flood protection measures, reduces the annual road damage to 0.4%, translating to 332 million USD in cumulative damages by 2050, 23% 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.

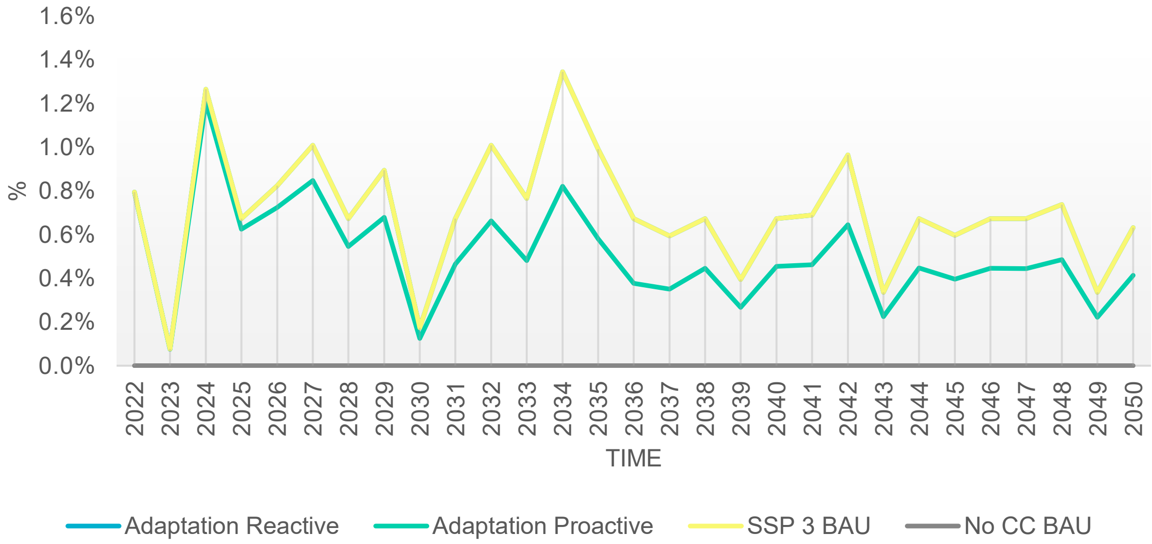


Figure 18: Annual percentage of roads damages due to climate change

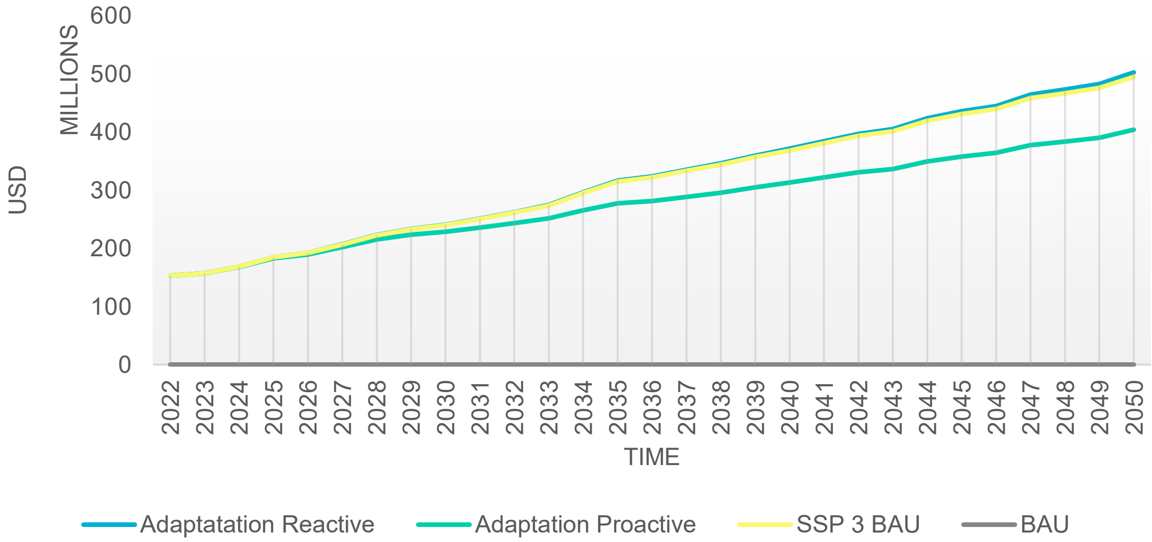


Figure 19: Cumulative economic damage to roads in USD under BAU, SSP, and Adaptation scenarios

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 Malawi. 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).

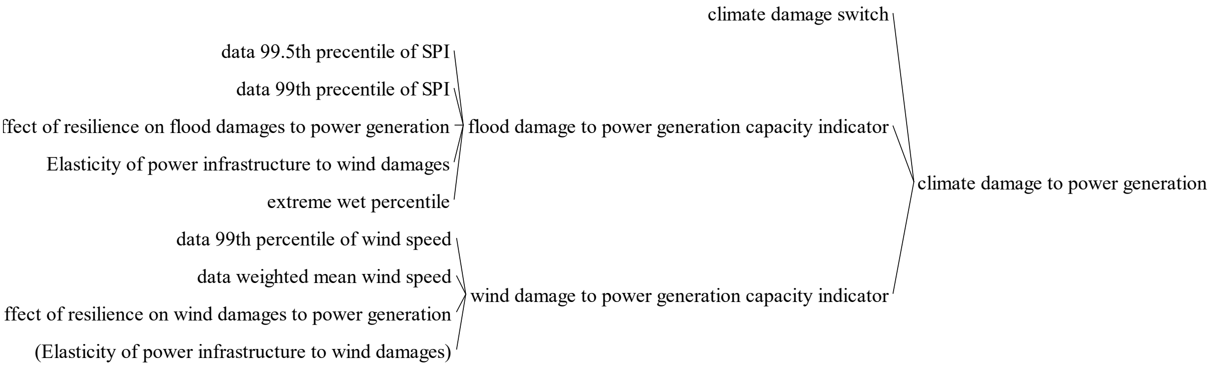


Figure 20: Tree diagram for climate damage to power generation

In the SSP3 scenario, total power generation capacity losses due to climate change are projected to increase to 587 MW by 2050, translating to economic costs of 1,780 million USD. The forecasted annual damage of 32.4 MW of capacity would cumulatively result in this significant loss, representing 90.6% 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 43%, resulting in a loss of 332 MW and lowering economic damages to 1,491 million USD by 2050. This represents a 16% 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.

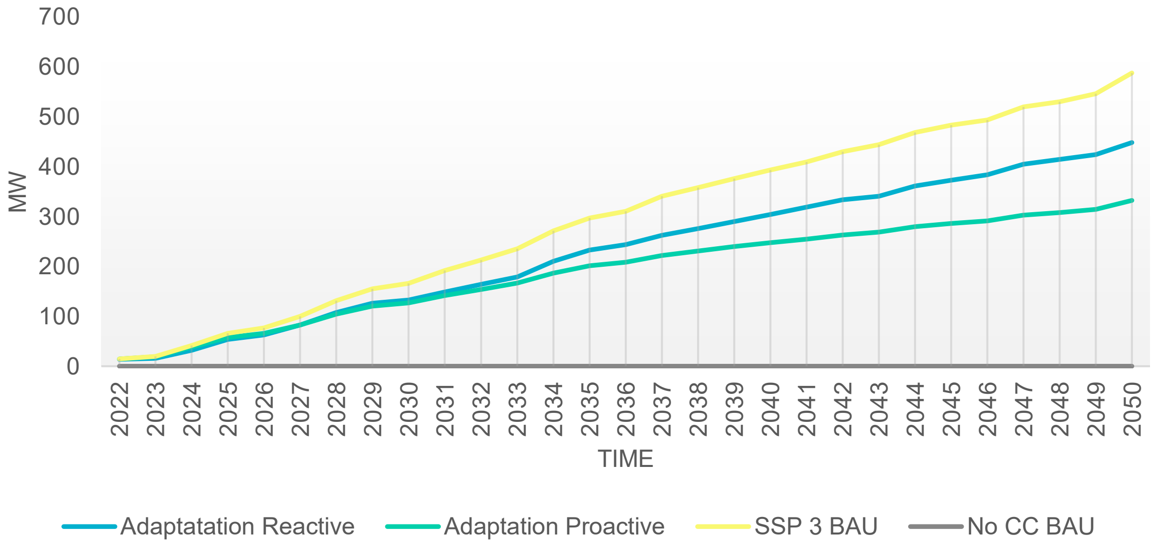


Figure 21: Cumulative MW Capacity losses for Malawi

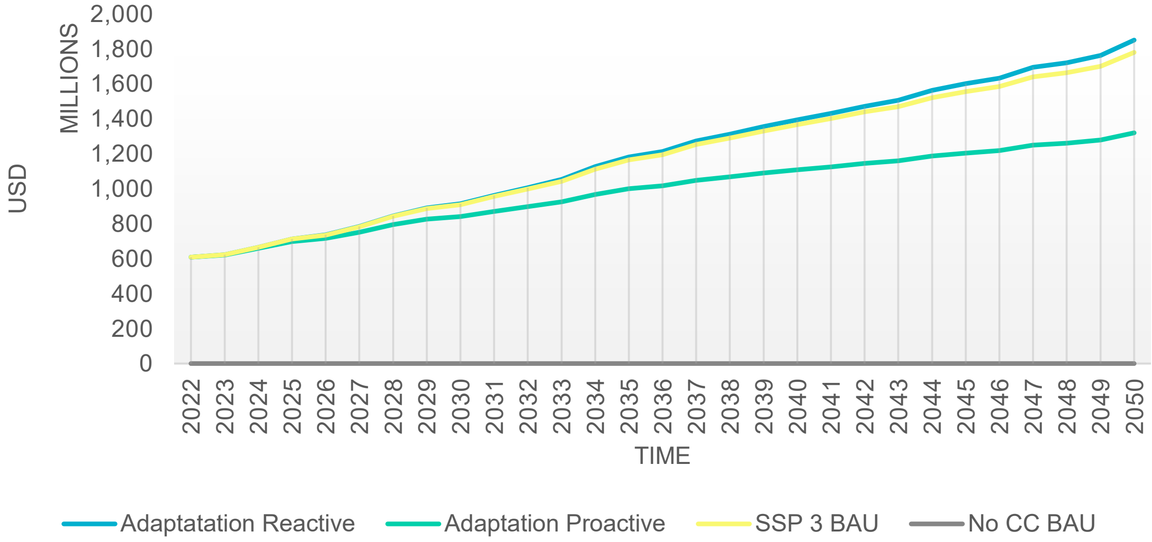


Figure 22: Cumulative economic losses of power generation capacity in Malawi

Lastly, in the SSP3 scenario, the climate impacts on transmission networks remain at approximately 10% of the stock of transmission network that are at risk of climate impact (17.18% 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 5% compared to SSP3 BAU.

However, in the adaptation scenario, where climate-proofing measures are implemented, these impacts are reduced by half to 5% compared to SSP3 BAU.

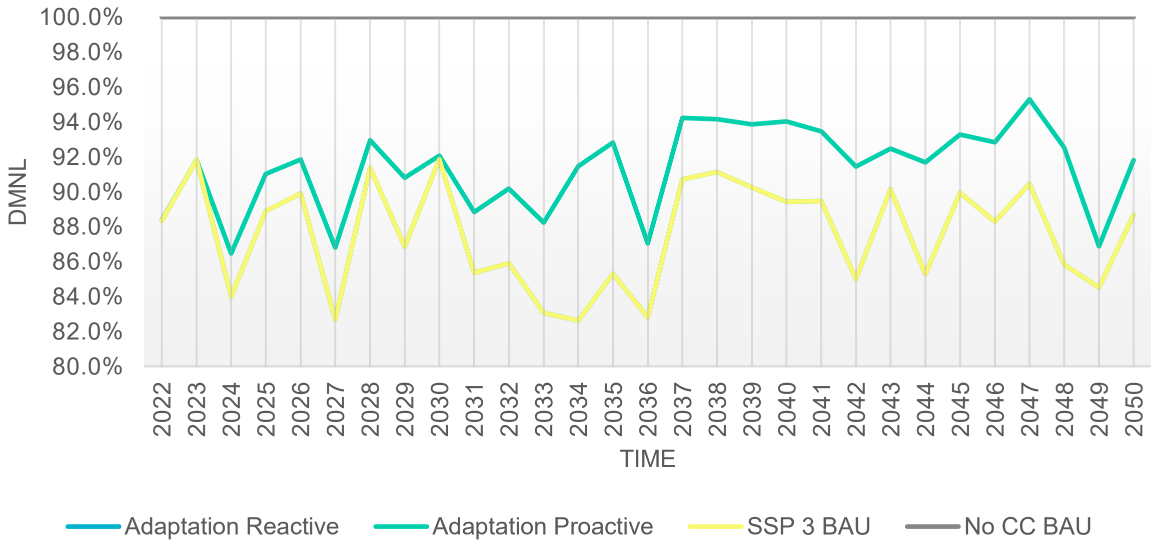


Figure 23: Annual reduction from the km of transmission network at risk due to climate change

2.2.5 Total climate impact

Altogether, the climate damages to assets total 34 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 34 billion USD as no climate-proofing measures are included. However, in the proactive scenario, climate damages are reduced to 27 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.

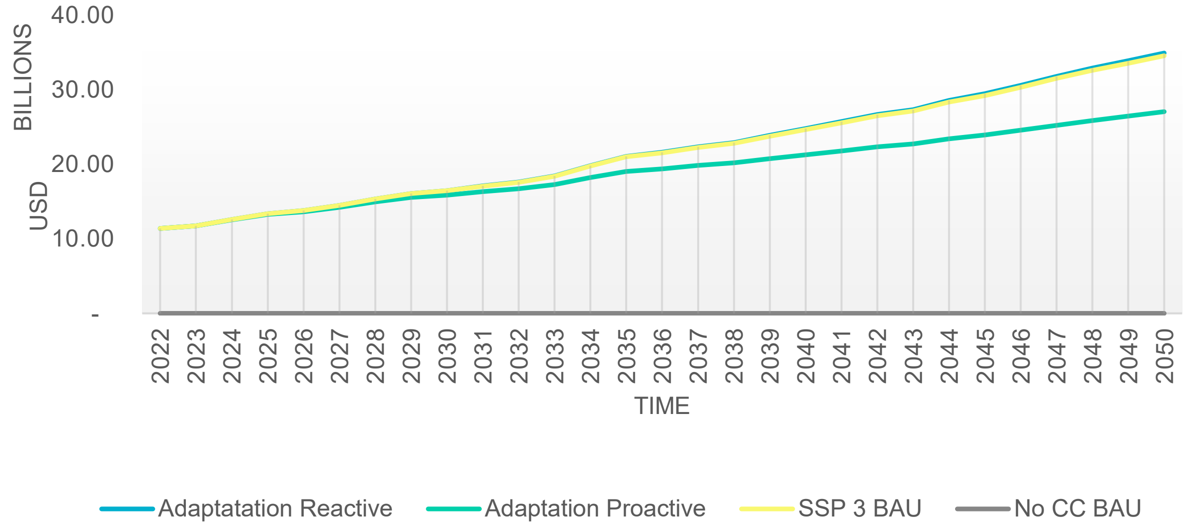


Figure 24: Cumulative climate damages under BAU, SSP, and Adaptation scenarios

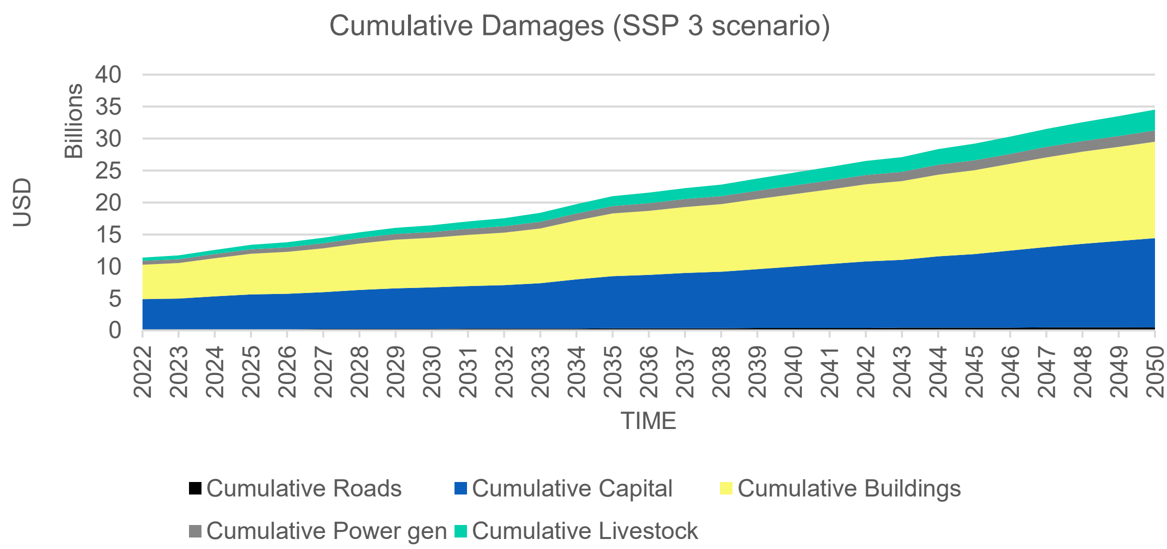


Figure 25: Stacked cumulative damages for Malawi in SSP3 BAU scenario

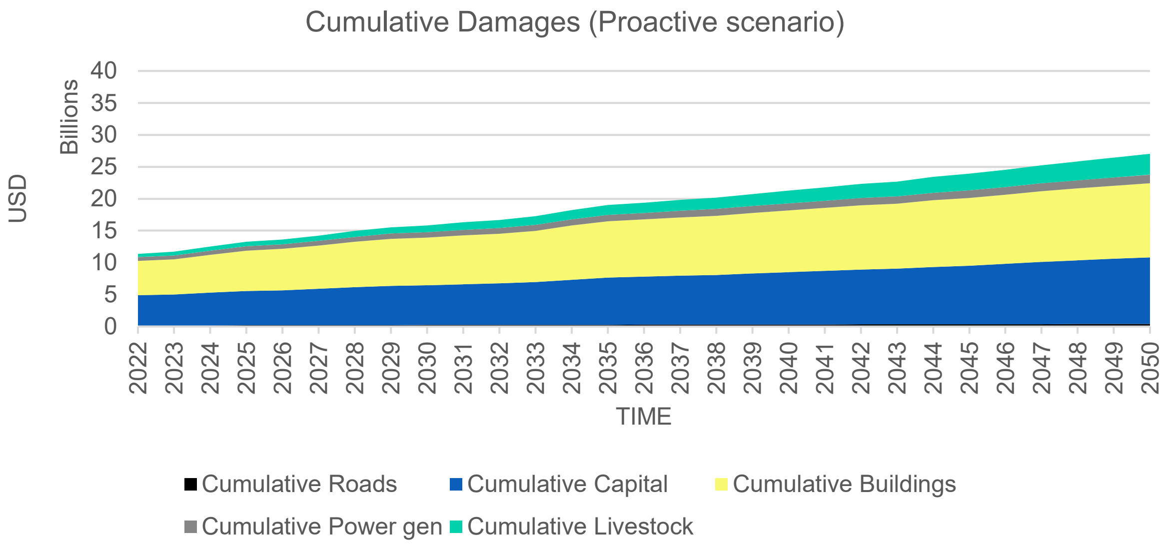


Figure 26: Stacked cumulative damages in the adaptation proactive scenario

The analysis highlights the significant climate impacts on assets, particularly within the building and capital sectors, with damages potentially reaching 34 billion USD by 2050 in the SSP 3 BAU scenario. While the reactive scenario does not reduce climate damages, 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 39.05 billion USD by 2050. However, In the SSP 3 BAU, total real GDP increases from USD 10.75 billion in 2022 to 34.63 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 Malawi are projected to reach USD 56.72 billion, translating to an annual average loss of approximately USD 2.1 billion. This annualized loss represents 17.4% of Malawi's GDP in 2024, which corresponds to around 4.7 years of GDP. Thus, between now and 2050, the workforce in Malawi is expected to dedicate the equivalent of 4.70 years to offset the costs associated with climate impacts. This is aligned with previous research by the IMF (International Monetary Fund. African Dept., 2023).

In the reactive scenario, total real GDP grows by 1.7% compared to SSP 3 BAU, reaching 35.2 billion USD by 2050. However, In the proactive scenario, total real GDP grows to USD 36.82 billion by 2050, which is 3.4% 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.

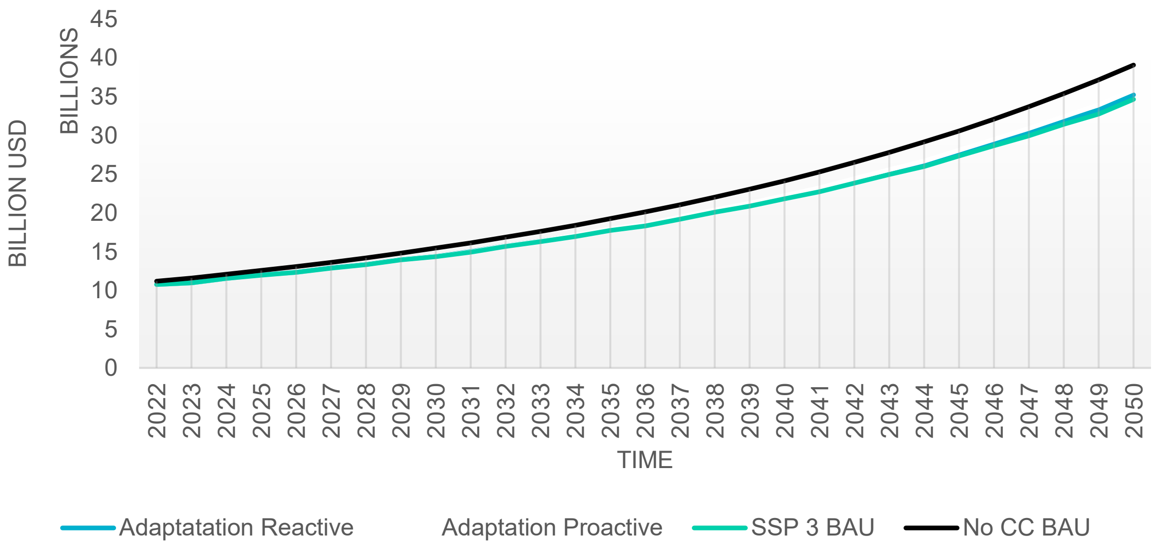


Figure 27: Total real GDP for Malawi under BAU, SSP, and Adaptation scenarios

In the No CC BAU scenario, the average real GDP growth stands at 4.5 percent over the period from 2022 to 2050. Contrastingly, in the SSP 3 scenario, the real GDP growth rate averages 4.2 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 4.27 percent over the same period, with 0.1 percent contributed by insurance. Conversely, in the proactive scenario, the real GDP growth rate also averages 4.33 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.

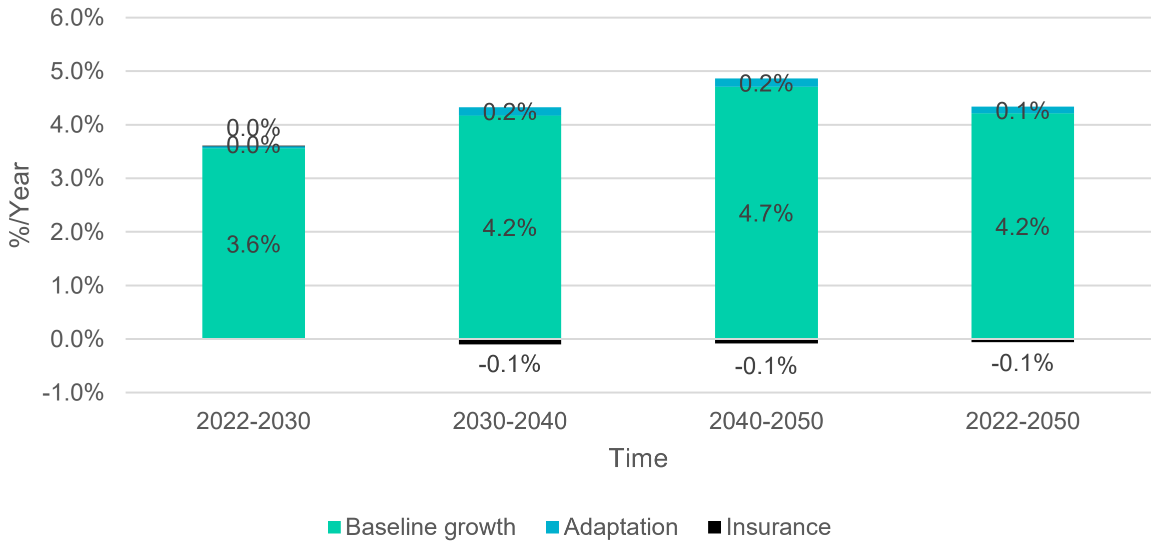


Figure 28: Real GDP growth rate over the decades, comparing growth under Adaptation and SSP scenarios

Average real GDP Growth	Unit	2022-2030	2030-2040	2040-2050	2022-2050
Adaptation Reactive	%/Year	3.6%	4.2%	4.8%	4.274%
Adaptation Proactive	%/Year	3.6%	4.3%	4.9%	4.336%
SSP 3 BAU	%/Year	3.6%	4.2%	4.7%	4.214%
Adaptation vs SSP 3 BAU	%/Year	1.3%	1.4%	1.6%	1.416%

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

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 13% decline in real GDP compared to a business-as-usual 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.

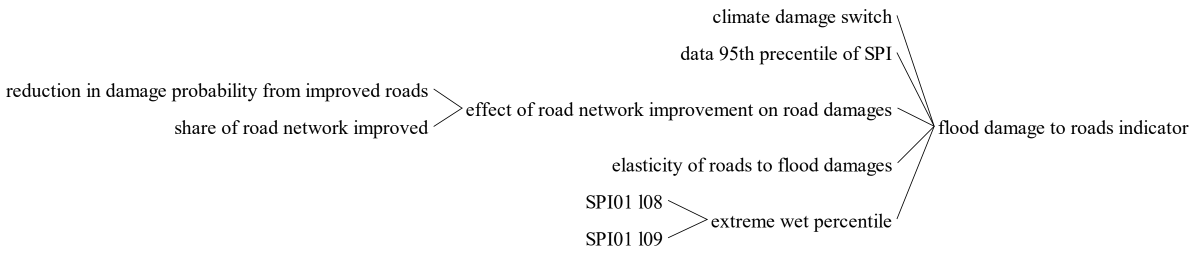


Figure 29: Tree Diagram for road losses calculations in GEM

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 1.3%. However, in the proactive scenario, which involves more comprehensive adaptation measures, the improvement is even more significant, with a projected enhancement of 2.9% compared to the BAU scenario (see monthly change in GDP 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 39.1% increase in road disruptions compared to a business-as-usual (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 8% compared to the SSP 3 BAU scenario.

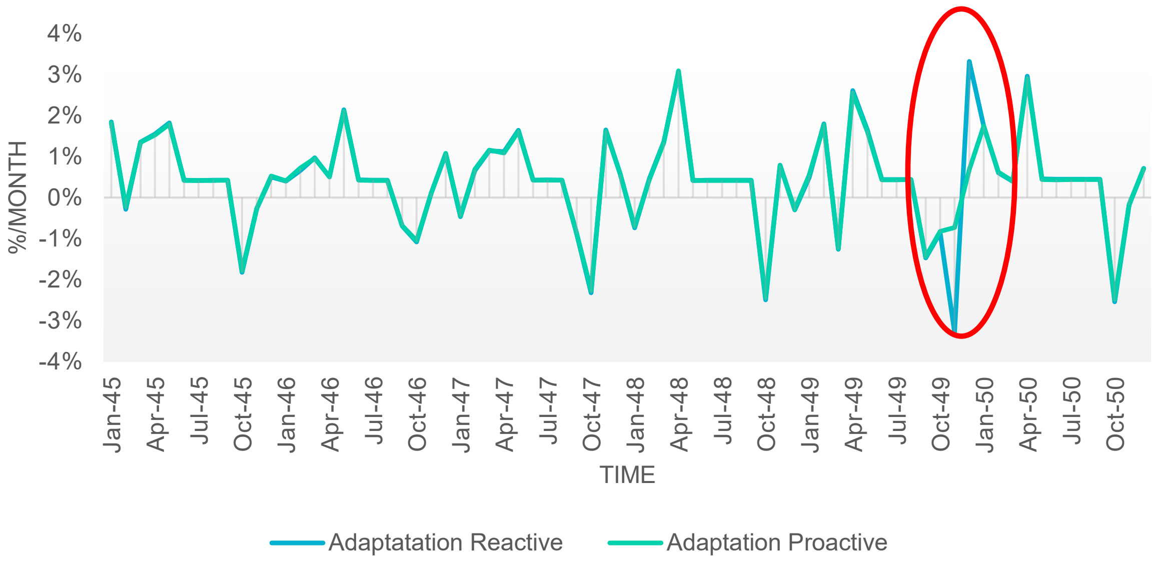


Figure 30: Monthly change in GDP between 2045 and 2050, under BAU, SSP, and Adaptation scenarios

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.

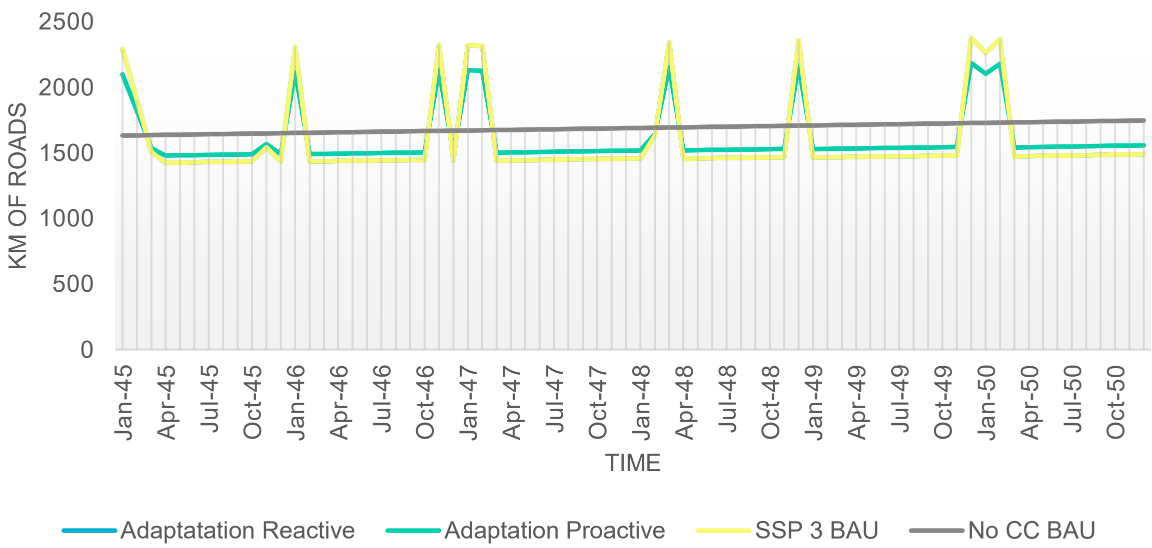


Figure 31: Monthly change in the stock of roads under BAU, SSP, and Adaptation scenarios

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 11.85 million people by 2050. In the reactive scenario, employment increases slightly to 11.96 million, while the proactive scenario sees a more significant rise to 12.1 million, reflecting a 2.1% 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 23.4 percent from 2022 to 2050. In the reactive scenario, it averages 23 percent over the same period, while in the proactive scenario, it averages slightly lower at 22.7 percent (Table 5).

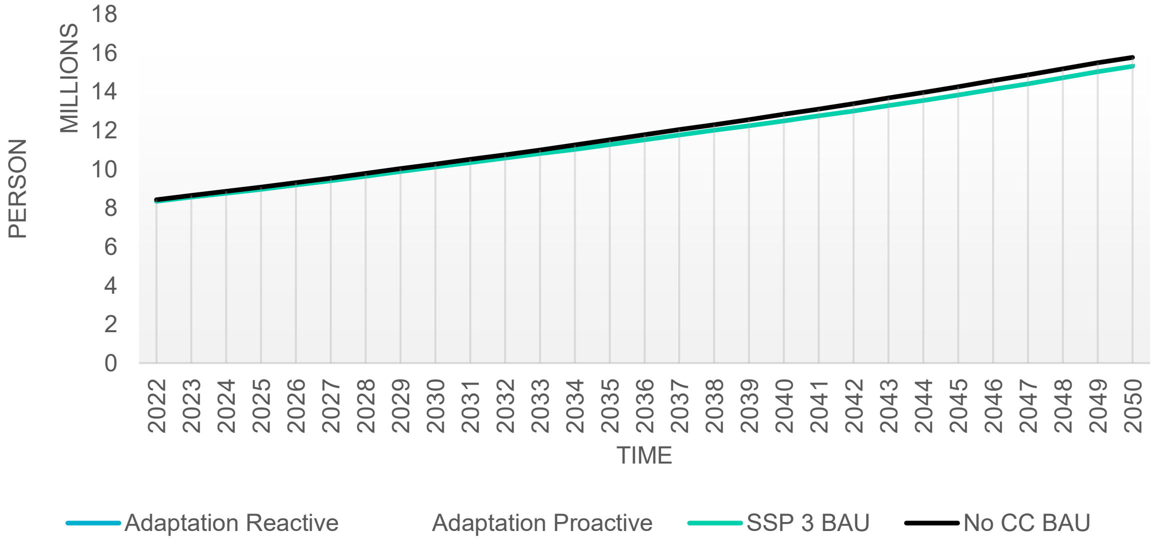


Figure 32: Total employment for Malawi under BAU, SSP, and Adaptation scenarios

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	7.5%	8.4%	7.7%	7.5%
Adaptation Proactive	%/Year	7.5%	8.3%	7.2%	7.2%
SSP 3	%/Year	7.6%	8.6%	8.2%	7.9%
Reactive vs BAU	%/Year	-0.8%	-2.3%	-5.5%	-4.9%
Proactive vs BAU	%/Year	-0.6%	-4.3%	-12.6%	-8.4%

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 148 USD million in 2030 and 61 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 0.03% of GDP in 2030 and decreases to 0.02% by 2050. Conversely, in the proactive scenario, additional real investment peaks at 0.8% 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 to147 USD million in 2030, reflecting ambitious policy measures for adaptation. However, by 2050, the additional real investment decreases to 53 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.

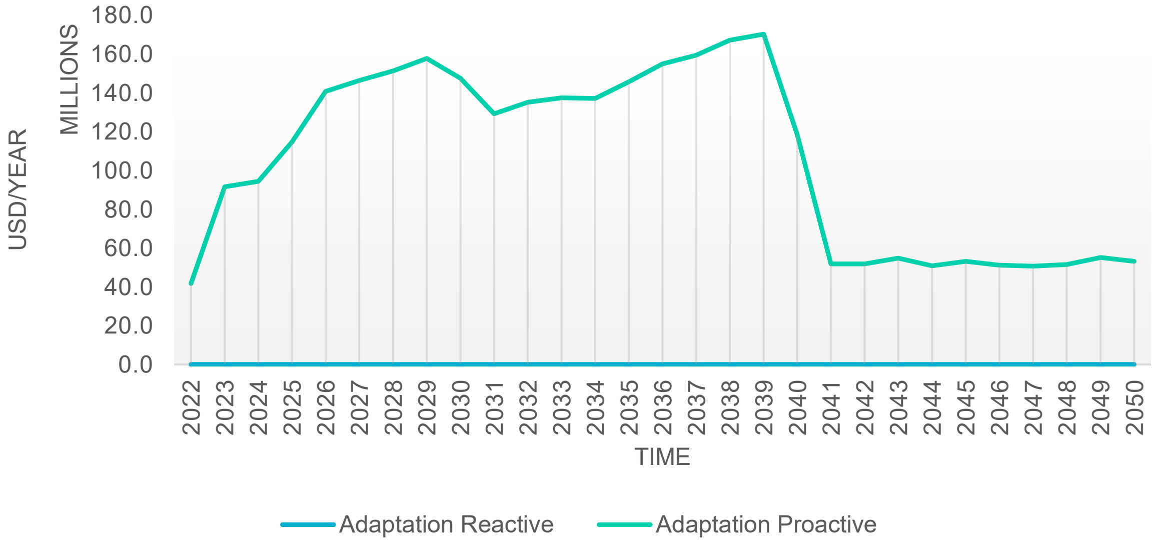


Figure 33: Additional Investments in Adaptation for Malawi

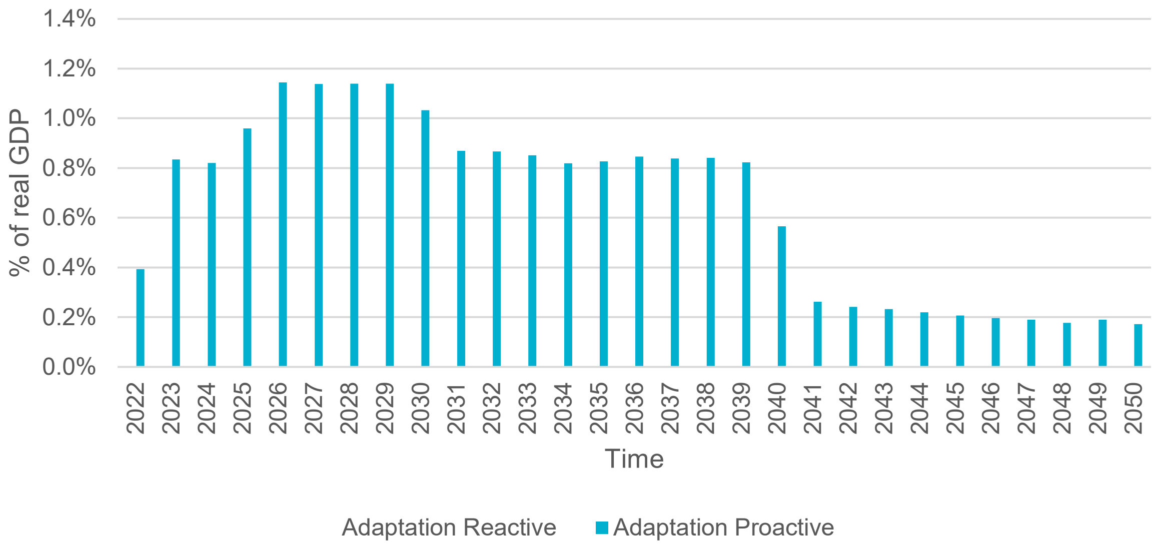


Figure 34: Additional Investments as a share of GDP under BAU, SSP3, and Adaptation scenarios

In the reactive scenario, contingency payments commence at approximately 107 million USD in 2022 and escalate to 351 million 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 20 million USD in 2022, rising to 62 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 0.16 by 2030 and increases to 0.54 by 2050. This ratio indicates that for every USD invested in the adaptation scenario, 0.16 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 no 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	**32**	**72**
Investments in adaptation	USD million	**0**	**1**
Contingency payments	USD million	**612**	**1,260**
Total Investment required	USD million	**644**	**1,333**
Total avoided cost	USD million	-27	**-146**
Total added benefits	USD million	**128**	**862**
Net integrated benefits	USD million	**-543**	**-617**
Ratio avoided cost to investment	USD/USD invested	-0.04	-0.11
Ratio added benefits to investment	USD/USD invested	0.20	0.65
Ratio avoided cost and added benefits to investment	USD/USD invested	0.16	0.54
Net investment	USD million	**644**	**1,333**

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

Comparatively, by 2030, the proactive scenario yields a Benefit to Cost Ratio (BCR) of 0.64, which increases significantly to 2.57 by 2050 (Table 7). These ratios signify that for every USD invested in the adaptation scenario, 0.64 and 2.57 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	**-7.7**	**-16.7**
Investments in adaptation	USD million	711	**1183**
Contingency payments	USD million	**-2.01**	**1.75**
Total Investment required	USD million	**701**	**1164**
Total avoided cost	USD million	**370**	**1532**
Total added benefits	USD million	**77**	**1,454**
Net integrated benefits	USD million	**-255**	**1,822**
Ratio avoided cost to investment	USD/USD invested	0.53	1.32
Ratio added benefits to investment	USD/USD invested	0.11	1.25
Ratio avoided cost and added benefits to investment	USD/USD invested	0.64	2.57
Net investment	USD million	**701.71**	**1,164.31**

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

In the proactive scenario, the benefits surpass investments as early as the year 2031. Cumulative investments amount to 1164 million USD by 2050, while cumulative benefits reach 2986 million 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 cumulative benefits are initially negative as early on there are largely costs as it takes time for the avoided costs to accumulate. 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.

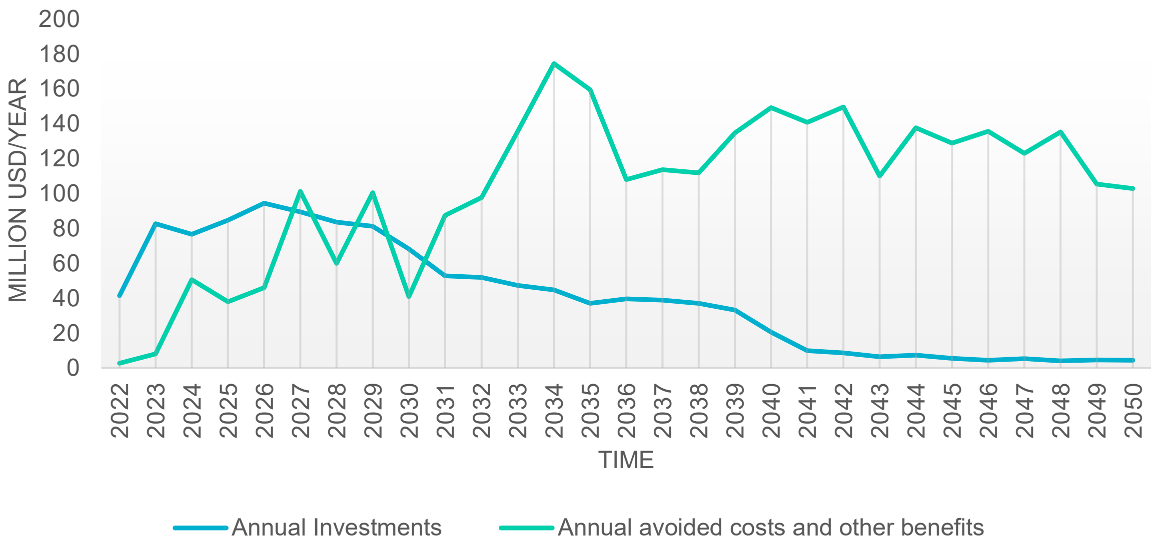


Figure 35: Investment required vs benefits generated in the proactive scenario

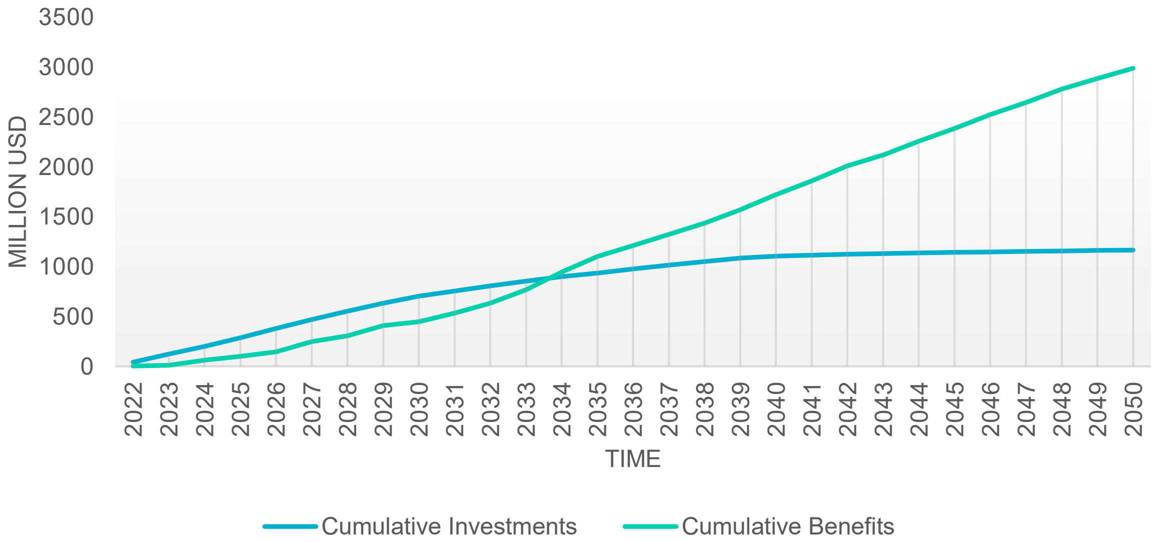


Figure 36: Cumulative investment required vs cumulative benefits generated in the proactive scenario

3. KEY FINDINGS AND ILLUSTRATIVE POLICY INSIGHTS

3.1 Results from the Analysis

Key findings from the national infrastructure assessment indicate that, without climate change adaptation measures (according to the SSP3 scenario), Malawi could face USD 34 billion in cumulative damages by 2050 due to climate impacts. This results in a cumulative negative GDP impact of USD 56.76 billion by 2050, or the equivalent of 4.70 years' worth of value addition (using the 2024 GDP value).

The largest losses will be in productive capital and buildings, totaling USD 28 billion—USD 13 billion in service and industry capital and USD 15 billion in buildings. These annual losses in key sectors will hinder economic growth, reducing real GDP by 10% by 2050, with an annual GDP growth reduction of 0.4%. Nevertheless, implementing climate resilience measures, the proactive scenario could increase annual GDP growth by 0.4%, mitigating these severe economic consequences. In this scenario, climate impacts on GDP could be reduced to USD 46 billion cumulatively by 2050, or a 19% reduction.

With a benefit-cost ratio (BCR) of 2.67 by 2050, the proactive climate change adaptation approach significantly outperforms the reactive scenario where only reconstruction efforts take place, which has a BCR of just 0.54. By prioritizing climate resilience, the proactive strategy generates USD 1.8 billion in net benefits from 2023 to 2050, providing a sustainable and efficient response to the challenges posed by climate change.

The proactive climate change adaptation scenario is also projected to stimulate 3.6% increase in GDP growth and 2.1% increase in job creation by 2050, compared to a scenario without climate change. This strategy reduces climate-related costs, enhances productivity, and strengthens national economic competitiveness.

Without climate change action, extreme climate events are projected to increase road disruptions by 39%, highlighting the vulnerability of transportation infrastructure and the urgent need for adaptation measures. Proactive interventions incorporating climate resilience strategies such as employing flood protection measures could reduce the impact of extreme climate events by 8%, whereas the reactive approach shows no significant improvement over the no-action scenario. Such climate resilience strategies for road infrastructure could significantly reduce cumulative damage costs from USD 431 million under a no-action climate change scenario to USD 332 million, by 2050. It also lowers the annual percentage of roads damaged by climate impacts to 0.4%, compared to 0.7% in the no-action scenario. This emphasizes the critical importance of proactive measures to protect infrastructure and promote economic growth.

Proactive climate-proofing measures for energy infrastructure can reduce cumulative losses in MW capacity by 43% compared to a no-action scenario. These strategies also lower cumulative economic damages to USD 1.5 billion by 2050, compared to USD 1.8 billion under scenarios focused solely on reconstruction or no efforts at all. Moreover, proactive measures cut climate impacts on transmission networks by half, from 10% to 5%, 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 15 billion to USD 11.6 billion by 2050, compared to no-action or reactive scenarios. These measures limit damage to an average of 23,000 dwellings (0.2%) annually, whereas the absence of such measures would result in 40,000 dwellings (0.6%) being affected each year.

The proactive climate change adaptation scenario requires the highest investment levels, reaching 0.8% of GDP by 2030, with upfront adaptation costs decreasing over time to 0.1% of GDP by 2050. In comparison, reconstruction efforts demand USD 148 million in additional investment by 2030 and USD 61 million by 2050, while proactive adaptation measures require USD 147 million by 2030 and USD 53 million by 2050. The BCR for reconstruction is 0.16 by 2030, rising to 0.54 by 2050. In contrast, the proactive approach delivers a BCR of 0.64 by 2030, increasing to 2.57 by 2050. Net benefits from the proactive scenario exceed investment by 2031, with cumulative investments of USD 1.16 billion and cumulative benefits reaching USD 1.86 billion by 2050.

In summary, without adaptation measures, Malawi faces substantial climate change costs, with the SSP3 BAU scenario forecasting cumulative damages of USD 34 billion by 2050. This translates to total economic losses of USD 56 billion, equivalent to 4.7 years of GDP. The overall impact on assets is estimated at USD 30.2 billion—2.51 times the 2024 GDP. A proactive adaptation scenario would reduce GDP losses by 19%, to USD 46 billion cumulative by 2050. These investments result in a Benefit to Cost Ratio (BCR) of 2.67 (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 Malawi. 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 Mozambique's national development priorities and exposure to regional climate risks. Such effort could further assist with the implementation of the Malawi 2063 First 10 Year Implementation Plan (MIP-1) 2021-2030, and to achieve the commitments set out in its Nationally Determined Contribution (NDC), 2021.

Malawi ranks 167 out of 187 assessed countries in the ND-GAIN Country Index for vulnerability to climate change in 2022.[4] Malawi also ranks as the 26th most vulnerable country and 158th 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 severe droughts, flash floods, and riverine conditions, with occurrences becoming more frequent the past few decades, undermining economic performance, reducing water availability and agricultural productivity and causing extensive damage to infrastructure[5].

Cross-sectoral action to address climate change impacts in Malawi 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. While efforts have been made to build climate resilience in the infrastructure sector in Malawi, it is important to clearly assess risks and infrastructure vulnerabilities in order to provide targeted recommendations on policy interventions and actions that proactively contribute to climate change adaptation in Malawi.

This national infrastructure assessment demonstrates that, without climate change adaptation measures, Malawi faces substantial costs from climate impacts, especially to critical infrastructure assets like service and industry capital, buildings, and roads. By 2050, these assets are expected to incur significant damage, leading to reduced public revenue and decreased income generation, hindering economic growth and development efforts. Extensive infrastructure damage may also restrict access to essential services, disrupt livelihoods, and deepen socio-economic inequalities across the country. According to this national infrastructure assessment, climate change is projected to reduce total real GDP in the country by 10% by 2050. However, building a climate-resilient economy could enable an annual GDP growth increase of 0.4%.

4 ND-GAIN (2022), Malawi, Available at https://gain-new.crc.nd.edu/country/malawi

5 USAID. (2017). *Climate Change Risk Profile: Malawi.*

The proactive climate change adaptation scenario reduces damages from climate change impacts by 25%, compared to a no-action scenario. In addition, climate proofing under the proactive scenario reduces the economic loss of capital by 62%, buildings by 23%, kilometers of roads by 23%, and power generation infrastructure damage by 43%, compared to the no-action scenario.

Climate change resilience and adaptation represent a competitive economic development strategy, with a benefit-cost ratio (BCR) of 2.67, a 10-year payback period, and net benefits of USD 1.8 billion. In contrast, a focus solely on reconstruction yields a BCR of just 0.54. These findings show that proactive climate change adaptation not only addresses environmental challenges but also supports long-term economic growth, demonstrating that climate action and economic prosperity are mutually reinforcing.

Adopting a proactive climate adaptation strategy in Malawi will greatly reduce future economic, social, and environmental impacts, especially from extreme weather events, heavy rainfall, and flooding. Infrastructure damage from these events can lead to immediate job losses in critical sectors such as construction, transportation, and utilities. A proactive approach supports economic growth and job creation by simultaneously reducing the economic burdens of climate change adaptation and lowering the costs associated with climate-related disasters.

Malawi's transportation infrastructure is particularly susceptible to climate impacts and extreme weather events. Without adaptation measures, extreme weather could increase road disruptions by 39% compared to a no-climate-change scenario. However, a proactive climate change adaptation strategy that includes flood protection measures for road infrastructure, could reduce cumulative road damage costs by 23% by 2050 and decrease the percentage of roads impacted by climate events from 0.7% to 0.4%.

Proactive interventions to climate-proof Malawi's energy infrastructure are projected to reduce cumulative MW capacity losses by 43% and cumulative economic damages by 16% by 2050. In addition, these climate-proofing measures cut climate impacts on transmission networks by half compared to scenarios without such interventions. For buildings, climate-proofing reduces cumulative damages from extreme precipitation and flooding by 23% by 2050 compared to no-action or reactive scenarios.

A proactive climate change adaptation approach requires significant investments, reaching approximately 0.8% of GDP by 2030 but tapering to 0.1% by 2050. Over time, the benefits of this approach accumulate, as reduced climate-related damages offset initial costs.

The Table 8 below presents illustrative examples of climate change adaptation measures across key infrastructure sectors in Malawi, drawing on the analytical results of this assessment. 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.

This is a preliminary analysis for refinement through stakeholders consultation and validation.

Table 8. Illustrative Climate change adaptation measures across infrastructure sectors and districts in Malawi (according to the SSP3 climate scenario) based on the climate stress-testing analysis

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	Recommendations/actions and urgency	Alignment with national frameworks, strategies and plans	Associated government departments
Transport (roads and railway)	• Invest in and design road, rail and bridge transport infrastructure that is resilient to extreme climate events such as flooding and landslides (all districts). -MEDIUM to LONG term • Restore existing disrupted transport infrastructure that is vulnerable to extreme temperatures and flooding (all districts). -MEDIUM term • Employ flood protection measures to road infrastructure that have the potential to reduce road disruptions from extreme climate events by 8% and save USD 99 million cumulatively until 2050 (Rumphi, Nhkata Bay, Mangochi, Nkhotakota and Nsanje). -SHORT to MEDIUM term • Employ landslide protection measures for road infrastructure (Rumphi, Nhkata Bay, Mangochi and Chitipa). -SHORT to MEDIUM term • Employ flood protection measures for rail infrastructure that is exposed to flooding (Tyolo, Balaka, Nsanje). -SHORT to MEDIUM term • Explore the potential of nature-based infrastructure solutions as a way of reducing climate impacts such as flooding, landslides and high temperatures to transport infrastructure (can lead to increased water retention and temperature mitigation) (all districts). -SHORT to MEDIUM term	-MGDS III emphasizes the development of resilient infrastructure to support economic activities while reducing vulnerability to climate impacts (MGDS III, pp. 52). -NCCMP notes that existing transport infrastructure is susceptible to damage from extreme temperatures and floods (NCCMP, p. 10). -NAPA document highlights the need to address the frequent flooding and temperature extremes that disrupt key transport routes. For these high-risk areas (NAPA, p. 12). -NDC highlights cyclones and winds as major climate drivers as a threat to Malawi's infrastructure (NDC, p. 51). -Malawi Vision 2063 includes exploring environmentally sustainable ways to enhance its natural infrastructure (Malawi Vision 2063, p. 44/45)	Ministry of Transport and Public Works (MoTPW) including departments in roads, railway services etc., Roads Authority
Energy/ telecommunications	• Employ flood protection measures for existing energy infrastructure such as hydropower plants which supply 95% of Malawi's electricity (Blantyre). -SHORT to MEDIUM term	-NDC highlights the vulnerability of Malawi's energy infrastructure, specifically hydropower plants, to flooding (NDC, p. 51).	Ministry of Energy, Environmental Affairs Department,

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	Recommendations/actions and urgency	Alignment with national frameworks, strategies and plans	Associated government departments
	• Promote, expand, and improve climate-proof energy infrastructure that has the potential to reduce cumulative energy losses by 43% and lower economic damage by USD 300 million cumulatively by 2050 (all districts). -MEDIUM to LONG term • Expand and climate proof energy distribution facilities in Malawi's rural regions, especially electricity, beyond the current 14% rate (all districts). -MEDIUM to LONG term • Invest in renewable energy infrastructure, taking into account potential future changes to energy output due to climate change impacts (e.g. hydropower and water shortages) (all districts). -MEDIUM to LONG term	-MGDS III addresses the need for safeguarding existing power plants against increasing rainfalls (MGDS III, p. 49). -The Malawi Vision 2063 sets ambitious goals to expand electricity access beyond the current rural coverage rate of (Malawi Vision 2063, p.2, p. 14, p. 19/20). -NCCMP suggesting the expansion of renewable energy sources (NCCMP, 16). -NAPA further emphasizes the importance of renewable energy investment and improving energy access in rural areas (NAPA, p. 9/10).	Electricity Generation Company of Malawi Limited (EGENCO), Electricity Supply Corporation of Malawi Limited (ESCOM), Malawi Energy Regulatory Authority (MERA).
Water	• Employ flood and landslide protection measures to water infrastructure, such as dams (Nsanje, Blantyre and Rumphi). -MEDIUM to LONG term • Protect and sustain Malawi's important water resources such as lake Malawi and riverine systems that are vital for hydropower generation and agricultural processes (all districts). -MEDIUM to LONG term • Screen water infrastructure projects for climate risks and integrate cost-effective actions to build resilience. MEDIUM to LONG term	-NDC highlights the need to protect water infrastructure from climate change (NDC, p. 50/51, p. 5). -MGDS III also calls for protective measures for existing water infrastructure, advocating for the inclusion of climate adaptation features to maintain water supply stability in affected regions (MGDS III, p. XVII, p. 42/43). -NCCMP underscores the importance of safeguarding Malawi's essential water resources, especially in light of climate change (NCCMP, p. 1, p.3). -Malawi Vision 2063 echoes this, focusing on sustainable management practices for water resources critical to hydropower and agriculture	National Water Resource Authority (NWRA), Ministry of Water and Sanitation, Ministry of Agriculture, Regional water boards

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	Recommendations/actions and urgency	Alignment with national frameworks, strategies and plans	Associated government departments
		(Malawi Vision 2063, p. 2, p. 15). -NAPA identifies the need for sustainable water resource management to combat water scarcity exacerbated by climate change (NAPA, p. 9).	
Health and education	• Protect existing healthcare infrastructure (e.g. hospitals, clinics, dentists and pharmacies) from climate impacts, especially flooding which threatens 24 healthcare facilities (17% of the total), (Lilongwe, Karonga and Chikwawa). -SHORT to MEDIUM term • Protect existing education infrastructure (e.g., kindergartens, schools, and colleges and universities) from climate impacts such as flooding which threatens 95 educational facilities (13% of the total) and landslides, which threaten 46 education facilities (6% of the total) (Mangochi and Lilongwe). -SHORT to MEDIUM term • Develop standards and regulations that incorporate climate resilience for new facilities -SHORT to MEDIUM term	-NCCMP highlights that Malawi's healthcare infrastructure is vulnerable to extreme weather (NCCMP, p. 1, p. 9). -NDC acknowledges that disruptions in healthcare due to climate impacts can severely affect the well-being of communities (NDC, p. 51). -MGDS III identifies education infrastructure as a critical area for climate adaptation, given that frequent floods and landslides threaten educational facilities (MGDS III, p. 44-48).	Ministry of Health, Ministry of Education

The districts of Rumphi, Mangochi, Karonga, Nsanje and Lilongwe face the highest climate risk across key infrastructure sectors, including transport, energy, water, healthcare and education, due to exposure to flooding and landslides. These districts 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 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.[6] In addition, achieving net-zero emissions by 2050 will demand an estimated USD 6.2 trillion annually.[7] Unfortunately, the finance flows directed toward adaptation efforts in developing countries face a significant shortfall.[8] Moreover, private sector contributions currently remain insufficient to bridge this gap in climate finance.[9] In response, this section explores innovative financial instruments and mechanisms for implementing the recommended climate change adaptation actions in Malawi.

Table 9. Financial instruments for implementing climate change adaptation measures[10]

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. [11] 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.[12] 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

6 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

7 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/

8 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

9 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

10 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.

11 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

12 Ibid.

Financial instrument	Category	Overview
		stringent eligibility criteria, which can pose challenges for some developing countries.[13]
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.[14] **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. **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,

13 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

14 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
		institutional capacity, and the government's ability to take on additional debt.[15]
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.[16][17] 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.[18] **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.[19]
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.[20] 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.

15 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

16 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

17 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

18 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.

19 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/

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

Financial instrument	Category	Overview
		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.[21] 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 guarantee 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. **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".[22] 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.[23] 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.[24]

21 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

22 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

23 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/

24 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

Financial instrument	Category	Overview
		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.[25] 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 the risk of indigenous and local communities losing access over their traditional lands in areas monetized for biodiversity credits.[26]
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.[27] **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.[28] Additionally, as an early-stage mechanism, its impact remains challenging to assess accurately.

25 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

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

27 African Develompent 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

28 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

Using innovative financial instruments to boost private investment in adaptation requires insight into Malawi'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.

4. ANNEXES

4.1 Summary of Climate hazard assessment in Malawi

This section presents the methodology and summarizes the results of this climate hazard assessment report for critical infrastructure in Malawi. The assessment evaluated the potential impacts of climate change on Malawi'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 Malawi.
- 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, electricity 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 Malawi'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 Section 3 of this policy brief.

<u>Overall Climate Risk for Critical Infrastructure</u>

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, provincial and national level, and if necessary distinguished by road-type, to inform climate resilience planning.

<u>Hazard</u>

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, 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[29]. 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 1km x 1km. 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 Malawi. The vulnerability analysis uses the road condition index which is derived from Geographical Information Systems (GIS) data and covers a total of 15,451 km of roads consisting of 4,312 of paved roads and 11,139 km of unpaved 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]. 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 provincial 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 for 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 consistency 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 if combined with infrastructure in poor conditions. Overall, there is still a relatively small percentage of

29 Home (unepgrid.ch)

30 World Bank Group. (2022b). Malawi Roads | Data Catalog.World Bank Group - International Development, Poverty, & Sustainability, Available at https://datacatalog.worldbank.org/search/dataset/0040789/Malawi-Roads

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. These results are shown in Error! Reference source not found.. 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**	**Malawi**
Roads (km)	%	23.45%
Buildings (Buildings)	%	15.34%
Power Generation Capacity (MW)	%	28.57%
Transmission Lines (km)	%	17.18%

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

Transport

Climate change impacts including increased frequency and severity of extreme events such as flooding are projected to cause significant damage to Malawi's road and rail infrastructure. In addition, roads in poor condition are especially susceptible to extreme temperatures, which can cause surface softening and buckling.

The assessment shows that 8% of the road network in Malawi is at high risk of flooding (within the 1-in-25-year flood line). At the district level, Rumphi has the greatest length of road exposure to flooding, followed by Nhkata Bay, Mangochi, Nkhotakota, and Nsanje. In addition, 6% of roads are located in areas at high risk of landslides, especially in the districts of Rumphi, Nhkata Bay, Chitipa and Mangochi.

Also, 11% of railways in Malawi are located in high-risk areas of river flooding, mainly in the districts of Thyolo, Balaka and to a lesser extent Nsanje. The risk of landslides for rail infrastructure is relatively low compared to the risk of flooding.

The assessment also considered bridges crossing rivers, canals or drainage lines that are exposed to river flooding and landslide risks. Approximately 16% of bridges are located in areas with high risk of river flooding, especially in the districts of Nsanje (47 bridges), Karonga (33 bridges), Rumphi (21 bridges) and Mangochi (20 bridges). Bridges located in high-risk areas for landslides make up 9% of the total and are predominantly located in the districts of Rumphi (29 bridges), Karonga (26 bridges) and Chitipa (23 bridges)

Energy

Approximately 95% of Malawi's electricity is provided by hydropower production based on lake Malawi and the Shire River. The country's energy infrastructure is vulnerable to climate impacts and variations in water flow that are caused by extreme weather events such as droughts. Additionally, only 14% of Malawi's population has access to electricity, mainly concentrated in urban areas.

This assessment reveals that 29% of power plants are in areas with a high risk of flooding. More specifically, two hydropower plants in the district of Blantyre are exposed to river flooding. Landslide risks to energy infrastructure are significantly lower. Addressing these vulnerabilities is critical for ensuring a stable electricity supply for Malawi's future development.

Telecommunications

Malawi's telecommunications sector is relatively new compared to other African countries and it is marked by high costs and low penetration rates, although it is expanding rapidly. Financial constraints have slowed network upgrades, although recent infrastructure improvements show promise. Despite having a strong national backbone, limited access to electricity makes broader usage and penetration challenging. Moreover, the telecommunications sector faces climate-related risks, such as frequent flooding, which threatens telecom infrastructure, particularly in regions such as the southern part of Lake Malawi such as Mangochi.

Water

Malawi's water resources are mainly provided from inland lakes like Lake Malawi and rivers[31]. These resources are under strain due to erratic rainfall, prolonged dry spells, and increasing evaporation rates, alongside population growth and rising demand. Flooding frequently damages water infrastructure and contaminates surface and groundwater supplies. Future water levels are expected to decline due to rising temperatures and unpredictable rainfall, further reducing water supply. This increases the risk of waterborne diseases, decreases water availability and quality, and reduces hydropower output. Water infrastructure is generally highly vulnerable to climate change impacts. Despite the above, the water sector was found to be one of the least vulnerable sectors to climate change in Malawi[32].

In terms of water infrastructure, the assessment reveals that 24% of dams are located in areas at high risk of flooding. Two dams at high risk of flooding were identified in the district of Nsanje and one dam at high risk of flooding was identified in each of the districts of Blantyre and Rumphi. In addition, one dam in the district of Zomba and one dam in the district of Rumphi are at high risk of landslides.

Health and Education

Malawi's limited healthcare infrastructure is projected to worsen as a result of climate change. Seasonal fluctuations, such as the rise in malaria, cholera, and diarrheal diseases before and during the monsoon season, increase the burden on healthcare services. The health system, already under-resourced, risks becoming overwhelmed as climate impacts such as flash floods can damage infrastructure and exacerbate the spread of vector- and water-borne diseases, further compromising essential health and sanitation services[33]. Moreover, floods, cyclones and droughts can weaken and reduce the integrity of education infrastructure in the country.

The assessment shows 24 healthcare facilities, or 17% of the total, which includes hospitals, clinics, dentists and pharmacies, are located in areas of high risk from flooding, and 3 healthcare facilities, or 2% of the total, are located in high-risk areas for landslides. Districts that have healthcare facilities at high risk of flooding include Lilongwe (8 healthcare facilities), Karonga and Chikwawa (both with 4 healthcare facilities).

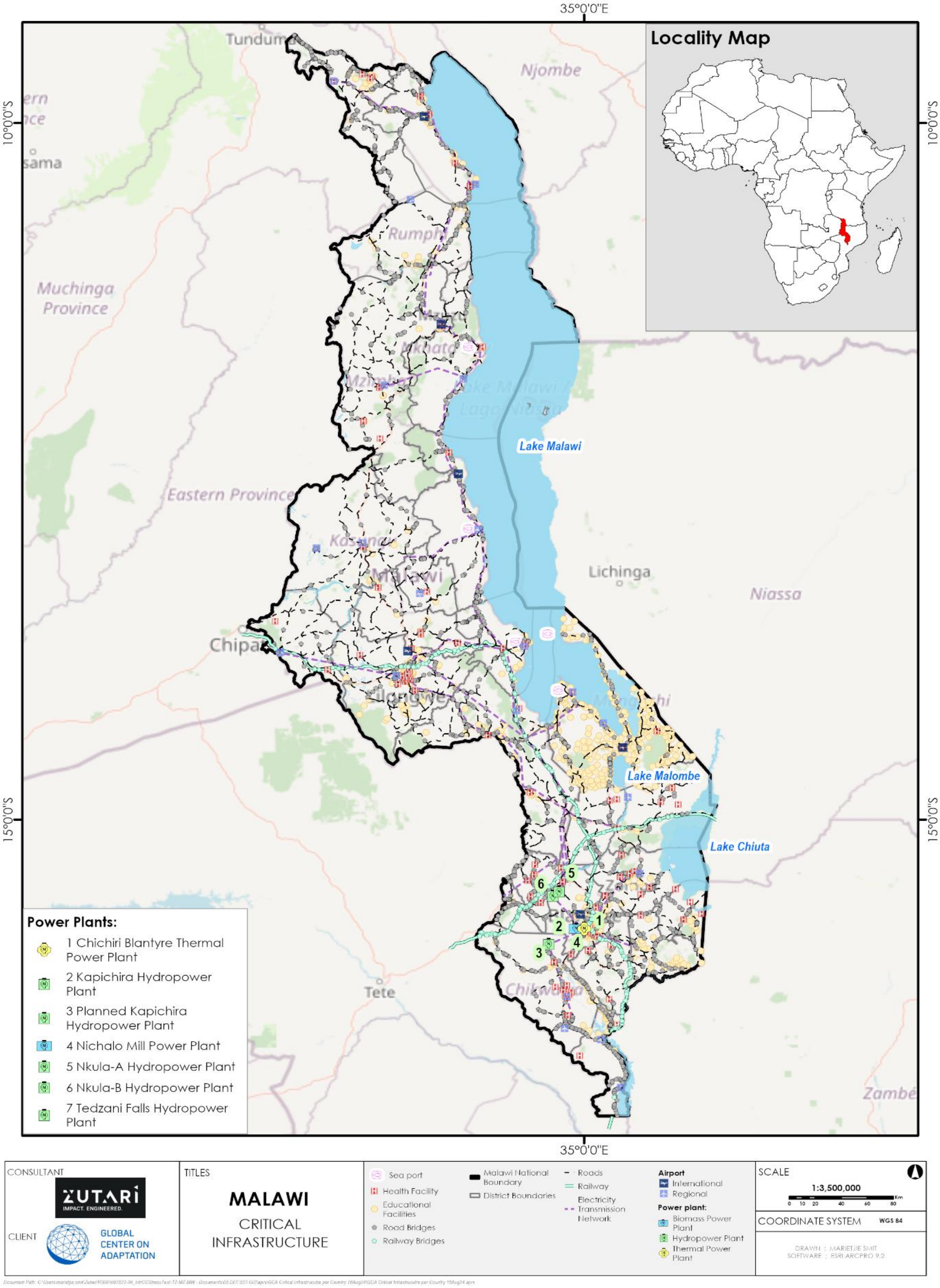
Furthermore, from a total of 714 education facilities identified in Malawi, including kindergartens, schools, and colleges and universities, 95. or 13%. are located in areas of high hazard to river flooding and 46, or 6%, in areas with high risk of landslides. The districts of Mangochi (49 educational facilities) and Lilongwe (15 education facilities) have the most educational facilities at high risk of flooding, and Mangochi is the only district with a high number of education facilities (26) that are at high risk of landslides.

31 USAID. (2017). Climate Change Risk Profile: Malawi.

32 ACF & IFPRI. (2023a). From Climate Risk to resilience: unpacking the economic impacts of climate change in Malawi. African Climate Foundation (ACF) and the International Food Policy Research Institute (IFPRI).

33 IFRC. (2021). Climate Change Impacts on Health: Malawi Assessment. Malawi Red Cross Society and IFRC Africa.

Figure 37. Map of critical infrastructure systems for Malawi



4.2 Stakeholders screening for climate change adaptation in infrastructure

The implementation of proactive climate change adaptation measures and investment at scale requires well-functioning 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 Malawi's infrastructure. The table below provides a first screening, which could support developing an integrated and comprehensive framework, which can help all stakeholders clearly defines their roles, responsibilities and relationships.

Table 11. Key stakeholders and potential roles and responsibilities for climate change adaptation measures in the infrastructure sector

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 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 Malawi, including its Nationally Determined Contribution (NDC), National Adaptation Plan Framework, National Adaptation Programme of Action (NAPA), National Climate Change Management Policy (NCCMP) and sectoral plans.

4.3.1 National Frameworks, Strategies, and Plan

The government of Malawi 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.

Malawi's National Adaptation Plan Framework(NAP)[34]

The NAP Framework aims to guide Malawi in reducing vulnerability to climate change impacts and building adaptive capacity and resilience while integrating climate change adaptation into development policies and programs at national level. The guiding principles of the NAP process emphasize sustainable development, uplifting the poor and vulnerable, promoting gender equality, fostering participation and ownership, incorporating traditional and indigenous knowledge, and ensuring financial accountability and integrity. These principles serve as the foundation for the NAP's comprehensive approach to addressing climate change challenges.

The process also builds upon key thematic areas, including improving access to energy sources, enhancing the resilience of food production systems, advancing weather and climate forecasting, refining agricultural practices and water resource management, and facilitating infrastructure development. It is designed to be inclusive to the needs of women, persons with disabilities, and other socially excluded or vulnerable groups.

As part of the NAP process, updated mandates focus on strengthening community resilience to climate change impacts through enhanced agricultural production, infrastructure development, and disaster risk management. Additional priorities include the sustainable utilization of natural resources, improving environmental management practices such as soil and land restoration, conserving and restoring biodiversity and ecosystems, and advocating for climate change adaptation among policymakers. By integrating these principles and mandates, the NAP process ensures a robust and inclusive response to the multifaceted challenges posed by climate change.

National Adaptation Programme of Action (NAPA) (2006) [35] - revised in 2015

Malawi's NAPA was developed to evaluate the impacts of adverse climatic impacts in eight important economic sectors, especially in response to rural communities' vulnerability to extreme weather events and an immediate need for climate adaptation. These sectors include agriculture, water, human health, energy, fisheries, wildlife, forestry and gender. Given Malawi's extremely low economic capacity to cope with climate change, the NAPA aims to plan and implement urgent interventions immediately, so future adverse effects of climate change can be minimized.

The NAPA identified thirty-one adaptation options across the key priority sectors, with emphasis to vulnerable rural communities in Malawi. From those options, a shorter list of fifteen priority adaptation options was developed based on further ranking and prioritisation for urgency and organised across five project profiles. These profiles include improving community resilience to climate change through the development of sustainable rural livelihoods, restoring forests catchments to reduce siltation and water flow challenges, improving agricultural production under changing climatic conditions, improving the Malawi's preparedness to cope with droughts and floods and improving climate monitoring to enhance

34 Ministry of Natural Resources, Energy and Mining Environmental Affairs Department (2020), Malawi's National Adaptation Plan Framework, Available at napgn-en-2020-malawis-national-adaptation-plan-framework.pdf

35 Ministry of Mines, Natural Resources and Environment (2006), Malawi's National Adaptation Programme of Action, Available at https://sarpn.org/documents/d0003013/NAPA_UNFCCC_Malawi_Mar2006.pdf

the country's early warning capability and decision making as well as the sustainable utilization of Lake Malawi and lakeshore are resources.

Nationally Determined Contribution (NDC) (2021)[36]

Malawi's updated NDC aims to develop a detailed and robust assessment of climate mitigation and adaptation actions for the period 2015-2040 and builds upon the country's existing NDC, new policies and national plans. Malawi is vulnerable to climate change impacts and extreme weather events, particularly floods, droughts and strong winds associated with tropical cyclones that threaten long term economic growth in the country. Malawi's agriculture sector faces the most significant losses due to climate change, particularly affecting resource-poor smallholder farmers that have limited capacity to cope with these impacts. The country's land and natural resources are heavily utilized and vulnerable to degradation, exacerbated by population pressures and expanding agriculture into marginal areas. In addition, dependence on traditional biomass for energy depletes forest resources, weakening carbon sinks and further threatening the climate. Like many developing nations, Malawi's economic growth is at risk due to the escalating challenges posed by climate change

Although Malawi is a least developed country (LDC) with one of the lowest per capita emissions globally, it is committed to contributing to the goals of the UNFCCC and the Paris Agreement. Malawi's updated NDC is based on its national climate strategies and outlines an ambitious and comprehensive set of measures that demonstrate the country's commitment to taking urgent action to mitigate and adapt to the effects of climate change and reduce the country's greenhouse gas emissions. Ten adaptation options were identified and prioritised, across three main pillars, namely, institutional framework, knowledge, technology and financing and resilience of the most vulnerable and includes objectives such as promoting an enabling environment to facilitate climate change adaptation (CCA) mainstreaming, improving capacity for data and information management and sharing to access technology and finance adaptation and planning and implementing adaptation actions towards an increased resilience of the most vulnerable Malawians.

Malawi's Strategy on Climate Change Learning (2021)[37]

The mission of the updated strategy is to build resilience against the negative impacts of climate change and achieve low carbon development pathways through high quality human and institutional capacity in Malawi. The strategy aims to strengthen human resources and skills development for the advancement of green, low emission and climate resilient development.

In terms of individual learning and skills development in Malawi, further action is needed to increase public awareness and to expand the range of skills necessary to address both current and emerging climate challenges. Learning needs span from basic to advanced levels and priority actions include developing innovative national climate awareness programs, training lead trainers from key groups, such as youth, women, and faith-based organizations, in climate science, adaptation, and policy, implementing training programs on climate-smart agriculture and providing basic climate science training to government officials, policymakers, and parliamentarians to support climate change governance, financing, and negotiation.

For institutional capacity building and despite various institutions addressing climate change in Malawi, there is no institution fully dedicated to climate change training, research, and awareness. Priority actions have been identified to strengthen institutional capacity and enhance Malawi's capacity to address climate change challenges through education. These actions include reviewing and updating climate change curricula in primary and secondary schools, mainstreaming climate change education in tertiary institutions and strengthening infrastructure for climate change learning, including classrooms, e-learning facilities, libraries, and climate centres.

Finally, due to critical need for adequate financial resources to effectively implement these activities. financing—was introduced to ensure sustainable funding for climate change initiatives, particularly for

36 The Republic of Malawi (2021), Updated Nationally Determined Contributions, Available at https://unfccc.int/sites/default/files/NDC/2022-06/Malawi%20Updated%20NDC%20July%202021%20submitted.pdf

37 Government of Malawi (2021). Malawi's Strategy on Climate Change Learning, Available at https://www.uncclearn.org/wp-content/uploads/2021/02/Updated-Malawis-Strategy-on-Climate-Change-Learning-2021.pdf

learning activities. Key priorities include developing human resource capacity with skills to create fundable project proposals for both local and international funding sources and mobilizing local and international resources for climate change learning.

Malawi's National Climate Change Management Policy (NCCMP) (2016)[38]

The NCCMP aims to promote climate change adaptation, mitigation, technology transfer and capacity building for sustainable livelihoods through Green Economy measures for Malawi. It aims to achieve that by improving community resilience to climate change through the development of sustainable livelihoods and reduced emissions of GHGs in the medium turn and by reducing the socioeconomic impacts of adverse effects of climatic change in the long term.

Policy objectives include the effective management of the impacts of climate change through interventions that build and sustain the social and ecological resilience of all Malawians; the contribution towards the stabilization of greenhouse gas concentrations in the atmosphere; the integration of climate change into planning, development, coordination and monitoring of key relevant sectors in a gender sensitive manner in the country ; and the integration of cross-cutting issues into climate change management through an appropriate institutional framework.

The Malawi Growth and Development Strategy (MGDS) III (2017-2022) [39]

The objective of the strategy is to move Malawi to a productive, competitive and resilient nation through sustainable agriculture and economic growth, energy, industrial and infrastructure development while addressing water, climate change, environmental management and population challenges

The strategy identifies five key priority areas: (i) agriculture, water development and climate change management; (ii) education and skills development; (iii) transport and ICT infrastructure; (iv) energy, industry and tourism development and (v) health and population. In terms of climate change management, the Strategy highlights key desired outcomes such as improved weather and climate monitoring for early warning and preparedness, strengthened policy operating environment for climate change and meteorological services, enhanced community resilience to climate change impacts and enhanced climate change research and technology development.

Malawi Vision 2063[40]

The Malawi 2063 First 10 Year Implementation Plan (MIP-1) 2021-2030 replaces the Malawi Growth and Development Strategy (MGDS) III as the country's medium term development strategy. The Vision aims to transform Malawi into an industrialised upper 'middle-income country' by the year 2063 and is anchored in three pillars: agricultural productivity and commercialisation, industrialisation and urbanization. The Vision encourages Malawi's transformation by shifting the national development mindset from poverty reduction to wealth creation and by restructuring the economy from a predominantly importing system to an industrialized, exporting model. This transformative process will be driven and owned by Malawians, emphasizing nation-building, self-reliance, and sustainable development financing. Key focus areas include fostering industrial growth, commercializing agriculture, and ensuring a good quality of life for all citizens.

Achieving this vision entails guaranteeing year-round access to adequate and nutritious food, well-equipped and adequately staffed health facilities, and education systems that provide formal education for every child. It also includes access to reliable electricity, clean piped water, tarmac roads, technical and vocational training centers, internet connectivity, and decent housing. These foundational goals, benchmarked against international standards, form the pathway toward an inclusively wealthy and self-reliant Malawi by the year 2063.

38 Government of Malawi (2016), National Climate Change Management Policy, Available at https://faolex.fao.org/docs/pdf/mlw201716.pdf

39 Malawi Government (2017), The Malawi Growth and Development Strategy (MGDS) III, Available at https://npc.mw/wp-content/uploads/2020/07/MGDS_III.pdf

40 Malawi National Planning Commission (2020), Malawi 2063, Available at https://malawi.un.org/sites/default/files/2021-01/MW2063-%20Malawi%20Vision%202063%20Document.pdf

4.4 Sectoral Institutional, legal and regulatory frameworks screening

The following section provides an overview of the relevant institutional, legal and regulatory frameworks in Malawi relevant to climate adaptation, including key government actors and bodies across priority infrastructure sectors.

In 2004, the Ministry of Natural Resources and Environmental Affairs established the National Environmental Policy (NEP) (2004), which builds the basis for the institutional, legal, and regulatory framework in Malawi.[41] It aims to ensure a healthy environment for current and future generations through sustainable resource management and ecosystem restoration. It emphasizes public education, decentralized governance, and community participation, while promoting cooperation with international bodies and regular updates to environmental information systems. Key principles include securing tenure for smallholder farmers, empowering community-based organizations, recognizing customary land rights, and comprehensive land use planning. The policy integrates cross-sectoral efforts, involving local governments, NGOs, and the private sector in environmental management, which all is guided and led by the Ministry of Natural Resources and Environmental Affairs.

The National Climate Change Management Policy (NCCMP) of Malawi (2016) established a comprehensive framework aimed at addressing climate change challenges through adaptation, mitigation, and capacity building.[42] It recognizes the critical role of natural resources in Malawi's social and economic development and identifies key issues requiring urgent attention, such as climate variability and inadequate institutional capacity. The overarching goal of NCCMP is to promote climate change adaptation, mitigation, technology transfer, and capacity building for sustainable livelihoods through green economy measures. The guiding principle for the policy is the Malawi Constitution, UNFCCC, and Kyoto Protocol. Situated in a web of global, national, and regional policies, the NCCMP promotes actions to reduce vulnerability, decrease greenhouse gas emissions, increase awareness, enhance research and technology transfer, build capacity, and mainstream climate change considerations across various sectors. The policy is the result of extensive consultation with multiple stakeholders and is designed to be implemented in conjunction with other national strategies and international commitments. Further, this is underpinned by the National Adaptation Programmes of Action (NAPA) to address sector specific effects of climate change. The Malawi Vision 2063 is the country's overarching long-term strategy that aspires for technologically driven middle-income economy while providing an enabling framework for addressing climate change and other environmental challenges holistically.

The Implementation, Monitoring, and Evaluation Strategy (IMES) for the NCCMP emphasizes the importance of integrating climate change into national policies, promoting renewable energy, and enhancing waste management. The strategy also focuses on health, water management, and transport to reduce emissions. It encourages collaboration among sectors, supporting technology transfer, and seeking financial resources for climate initiatives. The strategy highlights the importance of engaging vulnerable groups and fostering public-private partnerships for sustainable development.[43]

In 2021, Malawi submitted its updated nationally determined contribution (NDC) to the UNFCCC, enhancing its climate change ambitions with broader sectoral scopes for mitigation and adaptation aligned with SDGs.[44] The updated NDC addresses challenges like poverty and overexploitation of resources, incorporating new sectors such as transport and biodiversity. It sets unconditional and conditional carbon emission reduction targets of 5% and 50% by 2040, respectively, with the latter depending on external support.

41 Ministry of Natural Resources and Environmental Affairs (2004), National Environnemental Policy (NEP), Available at https://faolex.fao.org/docs/pdf/mlw169499.pdf

42 Ministry of Natural Resources, Energy and Mining Environmental Affairs Department (2016), National Climate Change Management Policy (NCCMP), Available at https://faolex.fao.org/docs/pdf/mlw201716.pdf

43 Ministry of Natural Resources, Energy and Mining Environmental Affairs Department (2016), Implementation, Monitoring and Evaluation Strategy for National Climate Change Policy, Available at http://www.ead.gov.mw/storage/app/media/Resources/Miscellaneous/Climate change implementation Plan.pdf

44 NDC Partnership (2021), Malawi's Updated NDC: Advancing Ambition Towards a Green Economy, Available at https://ndcpartnership.org/news/malawis-updated-ndc-advancing-ambition-towards-green-economy

4.4.1 Transport

In 2015, the Ministry of Transport and Public Works (MoTPW) established the National Transport Policy which names the MoTPW as the principal steward of the multi-modal transport system, its policies, and regulations.[45] Along with the MoTPW's agencies and departments, other external agencies are involved in the planning and operation of the transport sector in Malawi including development partners, district and city councils as well as the private sector. Additionally, the National Road Safety Steering Group, which is a key part of the Directorate of Road Traffic and Safety Services (DRTSS) expanded remit, has yet to be established in order to lead the multi-agency action to tackle Malawi's acute road casualty record.

The MoTPW is the overall custodian of transport sector policy development. The following key departments, ministries, and authorities are also involved:[46]

- Ministry responsible for Local Government and Rural Development: responsible for the development and maintenance of district, urban, and community roads
- Ministry responsible for Finance: responsible for resource mobilization, budget allocations, and overall financial regulations
- Department of Roads: responsible for policy direction on construction and maintenance of roads
- Railways Regulatory Uni: responsible for regulation of the rail sector and oversight and monitoring of operations and infrastructure management which are under concession
- Department of Transport Planning: responsible for long- and medium-term planning, policy direction, and sector performance monitoring
- Roads Authority: responsible for construction, rehabilitation, and maintenance of public roads

The Malawi National Transport Master Plan (NTMP) focuses on developing a sustainable and integrated multi-modal transport sector across Malawi, covering roads, railways, water transport, aviation, and urban mobility.[47] Key goals include reducing transport costs, enhancing safety, supporting economic sectors like mining, oil, and tourism, and improving rural access. It promotes a shift from road to rail and water transport, with infrastructure improvements in ports, airports, and roads. The NTMP also addresses challenges like climate resilience, safety and regulatory reforms.

The MoTPW's Strategic Plan (2024) lays the foundation for the Ministry's future planning framework, guiding the operations for all of its functional areas.[48] The plan identifies performance measures aligned to the goals and objectives set out in the NTMP, the Comprehensive Medium Term Implementation Framework (CMTIF) and the National Building Policy.

4.4.2 Energy

The National Energy Policy of Malawi (2018) aims to provide affordable, reliable, and sustainable energy access to all citizens.[49] It aligns with national and international goals like the Malawi Growth and Development Strategy and the SDGs as well as aims to reduce climate change impacts in the energy sector. Key objectives include enhancing the electricity supply, ensuring affordable petroleum and biofuels, promoting efficient coal technologies, and fostering a robust renewable energy sector. The legal frameworks underpinning the National Energy Policy are:

- Rural Electrification Act (2004) – providing promotion, funding, management, and regulation of rural electrification;
- Liquid Fuels and Gas Act (2004) – providing for production, blending, extraction, conversion, importation, transformation, transportation, storage, distribution and selling of liquid fuels and gas in a liberalized market and for matters connected therewith or incidental thereto,

45 Ministry of Transport and Public Works (2015), National Transport Policy, Available at https://npc.mw/wp-content/uploads/2020/07/National-Transport-Master-Plan1.pdf

46 Ministry of Transport and Public Works (2015), National Transport Policy, Available at https://npc.mw/wp-content/uploads/2020/07/National-Transport-Master-Plan1.pdf

47 Ministry of Transport and Public Works (2020), Malawi National Transport Master Plan, Available at https://npc.mw/wp-content/uploads/2020/07/National-Transport-Master-Plan1.pdf

48 Ministry of Transport and Public Works (2024), Strategic Plan 2023-2030, Availabe at https://transport.gov.mw/index.php/resource-centre/downloads/strategic-plan/category/11-motpw-strategic-plan-book-final

49 Ministry of Energy (2018), National Energy Policy, Available at https://www.energy.gov.mw/energy-sector/

- Energy Regulation Act (2004) – establishing an Energy Regulatory Authority to regulate the energy sector, to define the function and powers of the Energy Regulatory Authority, to provide for licensing of energy undertakings, and for matters connected therewith or incidental thereto,
- Electricity Act (2004) – regulating the generation, transmission, wheeling, distribution, sale, importation and exportation, use and safety of electricity.

The Electricity (Amendment) Act 2016 facilitated the restructuring of the power market in Malawi. Under this amendment, the Electricity Supply Corporation of Malawi (ESCOM) was unbundled into two state owned power utilities: Electricity Generation Company of Malawi Limited (EGENCO) and ESCOM. This amendment marked the liberalization of the electricity generation sector, opening the electricity industry to new entrants and participants in electricity generation.[50]

4.4.3 Water

The Revised National Water Policy (2022) outlines strategies for sustainable water management and emphasizes the need to improve water supply, sanitation, and hygiene services across the country.[51] It addresses challenges such as climate resilience against extreme weather events, water scarcity, and ensuring access to safe drinking water for all Malawians by 2030, aligned with the SDGs. Additionally, Malawi launched the National Framework for Water and Climate Services (2024-2029), which seeks to strengthen the country's capacity to adapt to climate change impacts on water resources.[52] This framework focuses on mitigating risks like floods and droughts and improving response strategies for water-related crises.

4.4.4 Health and Education

Malawi's Health Sector Strategic Plan III (HSSP III) (2023-2030) focuses on achieving Universal Health Coverage (UHC) by 2030. This plan aligns with Malawi's Vision 2063, which focuses on human capital development and improving healthcare services. The HSSP III aims to improve the capacity to manage the effects of climate change at all levels of service, including impacts on health infrastructure and sets priorities such as improving service delivery, governance, health financing and infrastructure, with a unified plan and budget involving all stakeholders, including international partners.

The 2023/24 Education Budget focuses on the need for sustainable financing to support human capital development, despite fiscal constraints[53] .Education continues to receive the largest share of the national budget among social sectors in Malawi. However, its share has been declining over recent years. The budget supports efforts to improve access to quality education, particularly in response to the challenges posed by inflation and limited resources.

50 Ministry of Energy (2018), National Energy Policy, Available at https://www.energy.gov.mw/energy-sector/

51 Ministry of Water and Sanitation (2022), Revised National Water Policy, Available at https://water.gov.mw/index.php/en/downloads/policy-documents

52 Ministry for Natural Resources and Climate Change and Ministry of Water and Sanitation (2024), National Framework for Water and Climate Services, Available at https://www.metmalawi.gov.mw/documents/194/NFWCS_for_Malawi_FINAL.pdf

53 UNICEF Malawi (2023), Education Budget Brief 2023/24, Available at https://www.unicef.org/malawi/media/10106/file/Education%20Budget%20Brief%202023-24.pdf

5. BIBLIOGRAPHY

BAPPENAS. (2021). *A GREEN ECONOMY FOR A NET-ZERO FUTURE: How Indonesia can build back better after COVID-19 with the Low Carbon Development Initiative (LCDI).* Jakarta: Indonesian Ministry of National Development Planning.

Bassi, A. (2015). Moving towards integrated policy formulation and evaluation: The green economy model. *Rigas Tehniskas Universitates Zinatniskie Raksti, 16*, 5.

Bassi, A., & Andreasson, E. (2024). *GEM Model Documentation.* Knowledge SRL.

Eurostat. (2022). *Energy Balances*. Retrieved from Eurostat: https://ec.europa.eu/eurostat/cache/infographs/energy_balances/enbal.html?geo=IT&unit=GWH&language=EN&year=2022&fuel=fuelMainFuel&siec=TOTAL&details=0&chartOptions=0&stacking=normal&chartBal=FC_IND_TL_E&chart=barCart&full=1&chartBalText=&order=DESC&siecs=

Forrester, J. (2002). *Road Maps: A guide to learning System Dynamics.* Camebridge: Systen Dynamics Group, Sloan School of Management, MIT.

HMIT. (2021). *National Clean Development Strategy 2020-2050* . Hungarian Ministry for Innovation and Technology.

IEA. (2021). *World Energy Model Documentation.* International Energy Agency.

IEA. (2023). *World Energy Model Documentation.* International Energy Agency.

IMF. (2022a). *World Economic Outlook Database*. Retrieved from IMF: https://www.imf.org/en/Publications/SPROLLS/world-economic-outlook-databases#sort=%40imfdate%20descending

IMF. (2022b). *IMF commodity prices*. Retrieved from IMF: https://www.imf.org/en/Research/commodity-prices

Meadows, D. (1980). The unavoidable A Priori. In J. Randers, *Elements of the system dynamics method* (pp. 23-57). Camebridge: MIT Press.

Pallaske, G., Bassi, A. M., Garrido, L., & Guzzetti, M. (2023). Exploring the virtuous interdependencies existing between climate action and sustainability in the context of low-carbon development. In F. J. López, M. Mazzanti, & R. Zoboli, *Handbook on Innovation, Society and the Environment* (pp. 281 - 308). Edward Elgar.

Probst, G., & Bassi, A. (2014). *Tackling Complexity: A systematic approach for decision makers.* Sheffield, UK: Greenleaf Publishing.

Randers, J. (1980). *Elements of the System Dynamics method.* Camebridge: MA: MIT Press.

Richardson, G., & Pugh, A. (1981). *Introduction to System Dynamics with Dynamo.* Portland: OR: Productivity Press.

Roberts, N., Andersen, D., Deal, R., Garet, M., & Shaffer, W. (1983). *Introduction to Computer Simulation. The System Dynamics Approach.* MA: Addison-Wesley.

UN Population Division. (2022). *World Population Prospects: The 2022 Revision.* UN.

UNEP. (2020). *The Energy transition as a key driver of the COVID-19 economic recovery in Panama.* United Nations Environment Programme.

UNFCCC. (2024, September 27). *GHG data from UNFCCC*. Retrieved from United Nations Climate Change: https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc

UNICEF. (2024, July 25). *Secretary-General's press conference - on Extreme Heat* . Retrieved from United nations: https://www.un.org/sg/en/content/sg/press-encounter/2024-07-25/secretary-generals-press-conference-extreme-heat

Zakka, S., Permana, A., Majid, R., & Danladi, A. (2017). Urban Greenery a pathway to Environmental Sustainability in Sub Saharan Africa: A Case of Northern Nigeria Cities. *International Journal of Built Enviroment and Sustainability*.

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