# Handbook on Macroeconomic Modelling for Climate Resilience

A manual for designing technical assistance on macroeconomic modelling supporting climate resilient development

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| | |
|---|---|
| **AGR** | Adaptation Gap Report |
| **CBA** | Cost-benefit analysis |
| **CIEM** | Central Institute for Economic Management |
| **CRED** | Climate Resilient Economic Development |
| **DGE** | Dynamic General Equilibrium |
| **EWE** | Extreme Weather Event |
| **GDP** | Gross domestic product |
| **GHG** | Greenhouse gas emissions |
| **GIZ** | Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH |
| **GRMA** | Global Risk Modelling Alliance |
| **GWS** | Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung) |
| **IISD** | International Institute for Sustainable Development |
| **IKI** | International Climate Initiative |
| **IO** | Input-Output |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IWH** | Halle Institute for Economic Research |
| **LTS** | Long-term strategy |
| **MoESD** | Ministry of Economy and Sustainable Development of Georgia |
| **NAP** | National Adaptation Plan |
| **NDC** | Nationally Determined Contribution |
| **NGFS** | Network for Greening the Financial System |
| **RCP** | Representative Concentration Pathways |
| **SDG** | Sustainable Development Goals |
| **SSP** | Shared Socioeconomic Pathways |
| **ToR** | Terms of Reference |
| **UIB** | University of the Balearic Islands |

# GLOSSARY OF KEY TERMS

The entries in this glossary are primarily taken or modified from definitions provided by the Adaptation Gap Report 2022 (AGR 2022, p. VIII-IX) published by the United Nations Environment Programme.

| | |
|---|---|
| **Adaptation** | The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC 2022a). |
| **Adaptation costs** | Costs of planning, preparing for, facilitating and implementing adaptation measures, including transaction costs (IPCC 2007). |
| **Climate resilient devel-opment** | The process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all (IPCC 2022a). |
| **Climate resilient eco-nomic development** | Climate resilient economic development mitigates economic and social risks due to climate change, harnesses economic opportunities from adaptation action and thereby maintains the performance of economic development, which secures income and employment. |
| **Co-benefits** | A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment (IPCC 2022a). |
| **Cost-benefit analysis (CBA)** | Monetary assessment of negative and positive impacts associated with a given action. Cost-benefit analysis (CBA) enables the comparison of different interventions, investments or strategies and reveals how a given investment or policy effort pays off for a particular person, company or country. |
| **DGE model** | Dynamic general equilibrium models consider the interaction between demand and supply. Model equations are derived from first principles to make explicit assumptions about the behavior of the main economic agents in the economy, i.e., households, firms, and the government. |
| **e3 model** | An e3 model is a model covering the demand-and-supply-relationships of an economy and its main connections to the environment, i.e. the use of energy resources and the input of $CO_2$ emissions into the environment. This integrated modelling approach of the 3es in one model framework assures a consistent view of possible transition pathways. It enables to calculate macroeconomic and sector-specific impacts as well as conclusions to be drawn on social balance and ecological benefits. |
| **Exposure** | The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC 2022a). |
| **Hazard** | The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC 2022a). |
| **Impacts** | The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial (IPCC 2022a). |
| **Maladaptation** | Actions that may lead to increased risk of adverse climate-related outcomes, including via increased vulnerability to climate change, diminished welfare, or increased greenhouse gas emissions, now or in the future. Maladaptation is usually an unintended consequence (IPCC 2022a). |
| **Mitigation of climate change** | A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2022a). |

| | |
|---|---|
| **Resilience** | The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation (IPCC 2022a). |
| **Risk** | The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards (IPCC 2014; IPCC 2022a). |
| **Scenario** | A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions. |
| **Trade-offs** | A competition between different objectives within a decision situation, where pursuing one objective will diminish achievement of other objective(s). |
| **Vulnerability** | The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2022a). |

*Source: Based on IPCC (2018) for climate-related terms*

# EXECUTIVE SUMMARY

This Handbook on Macroeconomic Modelling for Climate Resilience provides **guidance for designing and implementing a technical assistance programme on macroeconomic modelling to support climate resilient development in partner countries**. It presents an approach and concrete steps to design interventions that build capacities for assessing the impacts of climate change on the national economy and evaluating sector-specific adaptation measures that contribute to climate resilience. It introduces **macroeconomic modelling as an instrument to assess the economy-wide impacts of climate hazards and adaptation measures**.
The results of such a climate-sensitive macroeconomic model may **inform key planning documents**, as for example, **national adaptation plans (NAPs) or (low emission) long-term strategies**. Key advantages, main steps required and respective estimations on how many expert days are needed to fulfill them are summarized here.

The handbook's recommendations reflect **experiences and learnings of the global programme on Policy Advice for Climate Resilient Economic Development (CRED)** implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) under the International Climate Initiative (IKI). The programme **piloted the approach of macroeconomic assessments for adaptation planning** (referred to as CRED approach) in Georgia, Kazakhstan and Vietnam between 2019 and 2023. This handbook is a manual to **support transfer of this innovative approach** to further international partner countries.

**The key advantages of the described capacity building approach are:**

- added-value for policymakers by unveiling the mid- to long-term economy-wide impacts of climate hazards and investments in adaptation action
- contribution to cross-sectoral and long-term adaptation planning
- facilitation of climate adaptation mainstreaming by engaging stakeholders from different ministries and government agencies
- assessment of interactions of adaptation and mitigation measures (key trade-offs and synergies) by quantifying the impact of adaptation measures on the national GHG emission trajectory allows for coherent climate policies
- support of access to finance

**To reap these benefits, we recommend the following 7 steps** (described throughout the handbook):



The handbook provides general estimates on a potential timeline and expert days required for implementation the CRED approach and its key steps in a different country or set of countries. For all the key steps the handbook proposes tasks that should be completed. It also provides estimations on the expert days (both national and international experts are required) realizing those tasks.

*Table 1* provides a first rough overview of the sequencing of the steps required. Each of the 7 steps involves several tasks, which are described in detail in the chapters 1 to 7. Therefore, a more detailed workplan is presented in *Table 2* in the *introductory chapter*, which also indicates specific sub-tasks of the different steps.

**Table 1: Generic workplan for developing and applying a macroeconomic model**

| **WORK PLAN** (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Step 1:** Project setup | ◑ 70-110<br>● 0-15 | | | | | | | |
| **Step 2:** Creating a macro-economic model | ◑ 20-40<br>● 0-10 | ◑ 55-95<br>● 40-65 | ◑ 45-75<br>● 50-75 | ◑ 5-20<br>● 55-80 | ◑ 0-10<br>● 35-50 | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | |
| **Step 3:** Identifying adaptation options | ◑ 5-10<br>● 0-5 | ◑ 25-40<br>● 15-25 | ◑ 30-40<br>● 10-15 | | | | | |
| **Step 4:** Assessing adaptation options | | | | ◑ 5-10<br>● 20-30 | ◑ 10-20<br>● 25-50 | ◑ 5-10<br>● 20-30 | | |
| **Step 5:** Selection of adaptation options | | | | | ◑ 20-30<br>● 5-10 | ◑ 30-45<br>● 20-30 | ◑ 20-30<br>● 15-20 | |
| **Step 6:** Supporting implementation | | | | | ◑ 20-30<br>● 10-15 | ◑ 40-60<br>● 20-30 | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 |
| **Step 7:** Towards independent model application | | | | | | | | ◑ 20-40<br>● 15-30 |
| **National expert days (total 470–785)** | **95-160** | **80-135** | **75-115** | **10-30** | **50-90** | **75-90** | **40-65** | **40-70** |
| **International expert days (total 435–695)** | **0-30** | **55-90** | **60-90** | **75-110** | **75-125** | **80-120** | **45-65** | **25-45** |

The workplan in *Table 1* outlines only the external support potentially needed. It does not list the personnel requirement for the project management unit implementing the project. In terms of permanent staff, there should be at least one full-time person in each country facilitating the activities. Additional support from the headquarter is also needed to arrange contracting, reporting and facilitating learning and exchange, in particular when more than one country is involved, as was the case in the CRED project. The suggested project duration of 30 months is also only indicative, additional time for project preparation and closing might be considered as well as for supporting the implementation of concrete adaptation measures. It is also possible to replicate parts of the steps suggested – for example, only the first 4 steps were implemented under the CRED programme. However, our experience leads us to suggest supporting partners also for the last 3 steps. We estimate that full implementation of the 7 steps would require the support of 470-785 national expert days and 435-695 international expert days, which in turn could require more time depending on the adaptation measures to be implemented (and the time frame of the respective policies).

**Throughout the project implementation there are some key success factors to keep in mind:**

- **Maintain political mandate:**
  Clear responsibilities among governmental actors for modelling and adaptation planning are key. If the two responsibilities lie in different institutions, it is important to facilitate exchange between the two to ensure that the institution in charge of adaptation planning understands and demands assessments with the climate-sensitive macroeconomic model for its policymaking.

- **Identify key modelers and keep them engaged:**
  Independent application and further development of a climate-sensitive macroeconomic model requires in-depth understanding of the model through participation in model builder trainings. To ensure that the model can be independently applied after the project end, it is necessary to identify and support key modelling experts who have the respective capacity and mandate/political backing.

- **Invest in communication geared to different target groups:**
  Macroeconomic assessments involve many technicalities – therefore it is important to clearly differentiate the communication about the model, its results and its validity depending on the target group (e.g. policymakers vs. modelling experts).

# INTRODUCTION: HOW TO USE THIS HANDBOOK?

This handbook provides guidance for development cooperation projects that support strengthening capacities for climate resilient economic development. It presents an approach and concrete steps to design interventions that build capacity for assessing the impacts of climate change on the national economy and evaluating sector-specific adaptation measures that contribute to climate resilience. It introduces **macroeconomic modelling as an instrument to assess the economy-wide impacts of climate hazards and adaptation measures**. The handbook builds on the experience and learnings gained by the International Climate Initiative's (IKI) global programme on Policy Advice for Climate Resilient Economic Development (CRED), which piloted the approach of macroeconomic assessments for adaptation planning in Georgia, Kazakhstan and Vietnam between 2019 and 2023.[1]

### Why do we need to strengthen capacities for climate resilience?

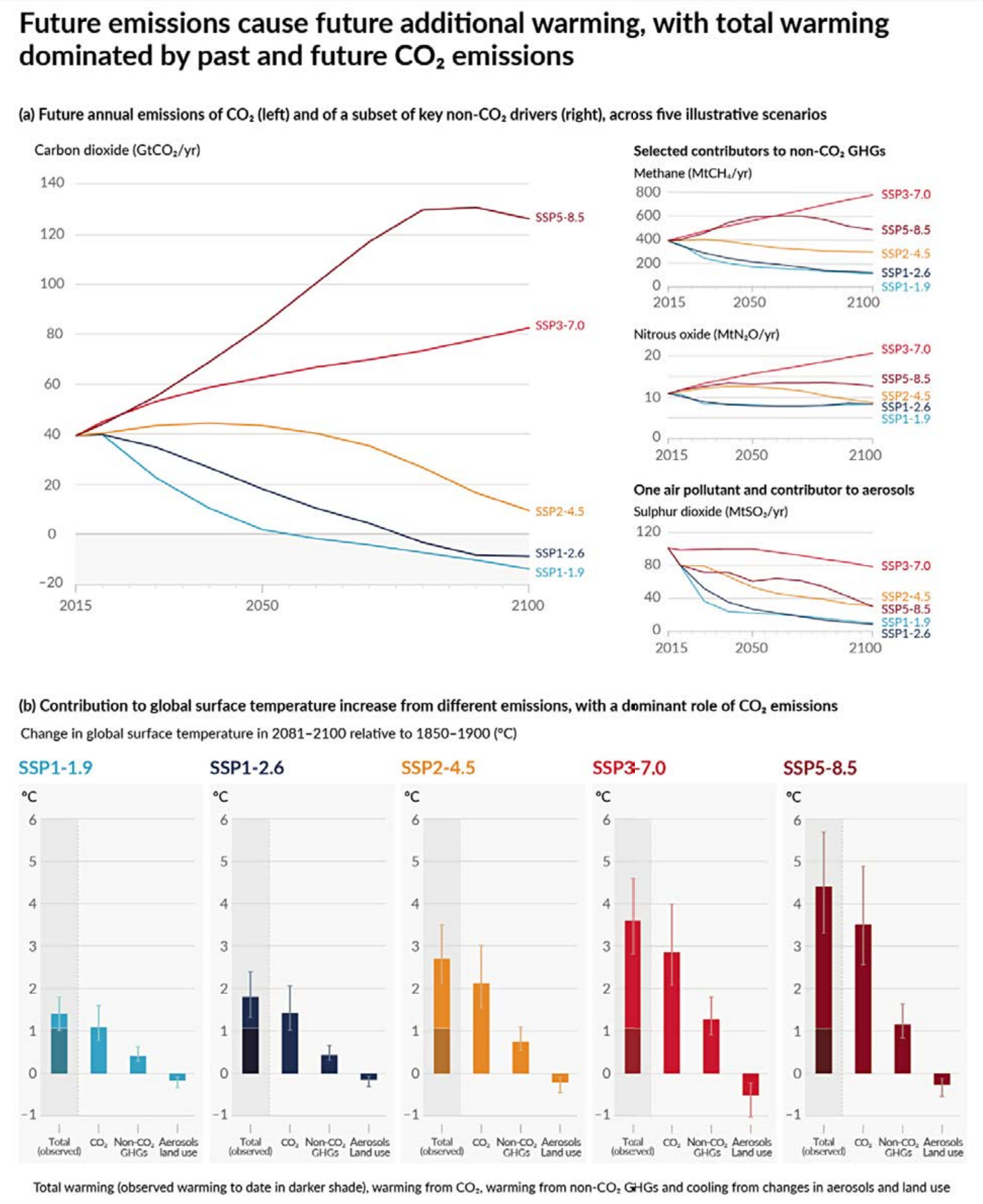
Climate resilience is gaining importance because climate risks are becoming more severe as a result from anthropogenic climate change. The 2022 IPCC AR6 report outlines in great detail how the risks of climate change could unfold over the course of the century. A key concept are emission scenarios, now described in the Shared Socioeconomic Pathways (SSPs), building on the older RCP scenarios (Representative Concentration Pathways – RCPs) that still can be found in the last two digits of the SSPs. In this handbook both concepts are used. A figure from the IPCC outlines the emission trajectories associated with the SSPs (*Figure 1*).

For economic assessments of climate change the full spectrum of risk should be considered involving at least one severe and one less severe climate scenario. Scenario analysis is an established tool for strategic planning and increasingly applied to climate risk management.[2] The translation of climate hazard scenarios into economic risks is outlined further in *chapter 2*.

1 *Find an overview on the project and knowledge products on the programme's website: https://www.giz.de/en/worldwide/79266.html*

2 *See for example: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities – TCFD Knowledge Hub (tcfdhub.org)*

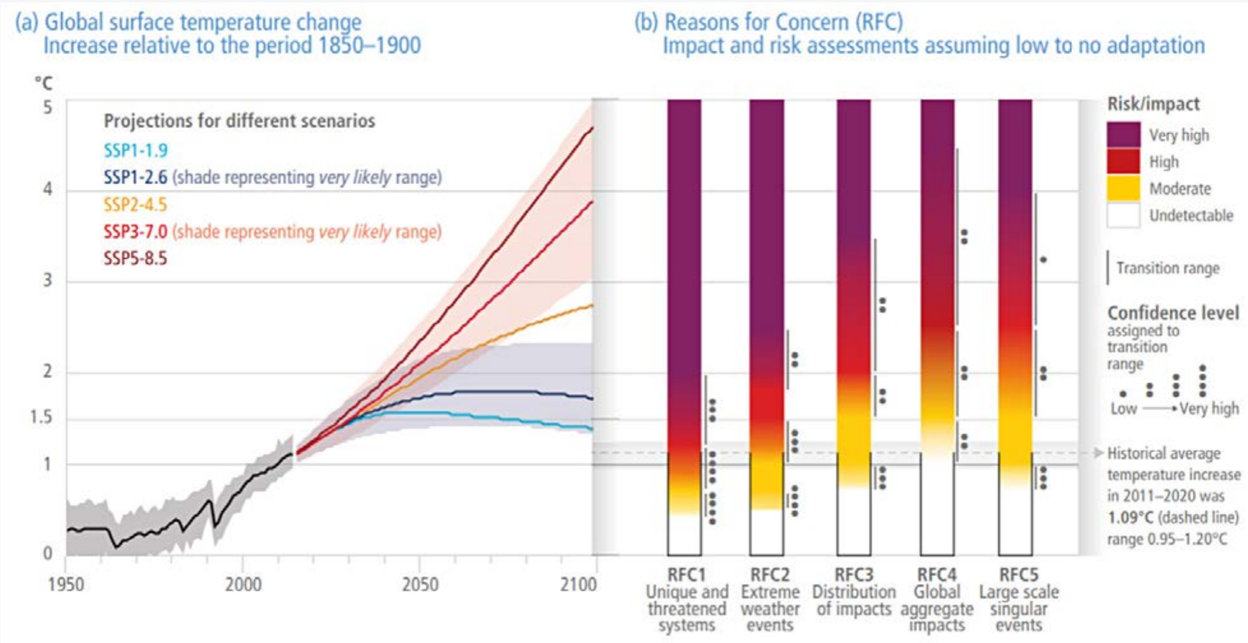
**Figure 1: Climate change scenarios according to IPCC**




*Source: IPCC 2021*

The impacts of climate change can be reduced with effective adaptation action. However, as the 2022 Adaptation Gap Report stresses that "[g]lobal efforts in adaptation planning, financing and implementation continue to make incremental progress but fail to keep pace with increasing climate risks" (AGR 2022, p. XIII) and presents key reasons for concern from IPCC's Sixth Assessment Report. As *Figure 2* outlines, all climate scenarios (i.e., shared socioeconomic scenarios (SSPs)) that do not involve rapid and large-scale greenhouse gas emission reductions result in high risks.

**Figure 2: Key risks and reasons for concern according to IPCC**




*Source: IPCC 2022a*

With the current (as of 2022) pace of GHG emission increase per year, many countries will face with rather high confidence large climate-induced impacts that scientists are only beginning to understand in terms of severity and timing, as risks are also cascading and compounding.[3]

Given these increasing risks, all countries must increase their capacities for climate resilient planning. But what is climate resilience? According to the IPCC, "Climate Resilient Development integrates adaptation measures and their enabling conditions with mitigation to advance sustainable development for all" (IPCC 2022b). Additionally, the IPCC describes resilience as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities." (IPCC 2022b).

3 *Cascading and compounding risks refer to amplification effects resulting from interdependencies between systems and sub-systems of coupled natural and socio-economic systems in response to changes and feedback loops. The combined effects of interacting stressors are important but complex, macroeconomic analysis can support the analysis by integrating non-climatic risks into the analysis (see e.g. Lawrence et al. (2020): Cascading climate change impacts and implications. Climate Risk Management, Volume 29)*

Climate resilience is thus a comprehensive emerging concept and development paradigm that not only involves climate adaptation but also mitigation. Because on a global scale, resilience can only be achieved if emissions are reduced rapidly.

With expected strong impacts of climate change on economic growth and development, it becomes imperative to include a long-term and economic perspective in adaptation planning and risk management. Planning and implementation of adaptation measures focussing only on short-term, incremental effects could result in maladaptation, which increases vulnerability in the long-term. In this context, climate-sensitive macroeconomic modelling provides important information to put the different sectoral adaptation actions into context. With adequate data input macroeconomic models can also assess interactions of adaptation and mitigation measures (key trade-offs and synergies) by quantifying the impact of adaptation measures on the national GHG emission trajectory.

The approach presented in this handbook aims to provide some practical recommendations how economic modelling can be a tool to support adaptation planning in partner countries. Finally, the success of such efforts depends on the effective integration within the broader adaptation agenda in partner countries. To summarize, the approach presented is compared to the set of key principles identified in the UN Adaptation Gap Report (see *Box 1*). If implemented successfully the macroeconomic modelling has the potential to contribute to several of these principles. Relevance is high for the integration with development strategies, integration of scientific knowledge into adaptation planning, avoiding maladaptation and a systematic reduction of the systematic drivers of vulnerabilities by tackling economic root causes of vulnerability, such as strong economic reliance on sectors with high vulnerability.

## Box 1: Best adaptation practice according to AGR 2022 and link to CRED approach

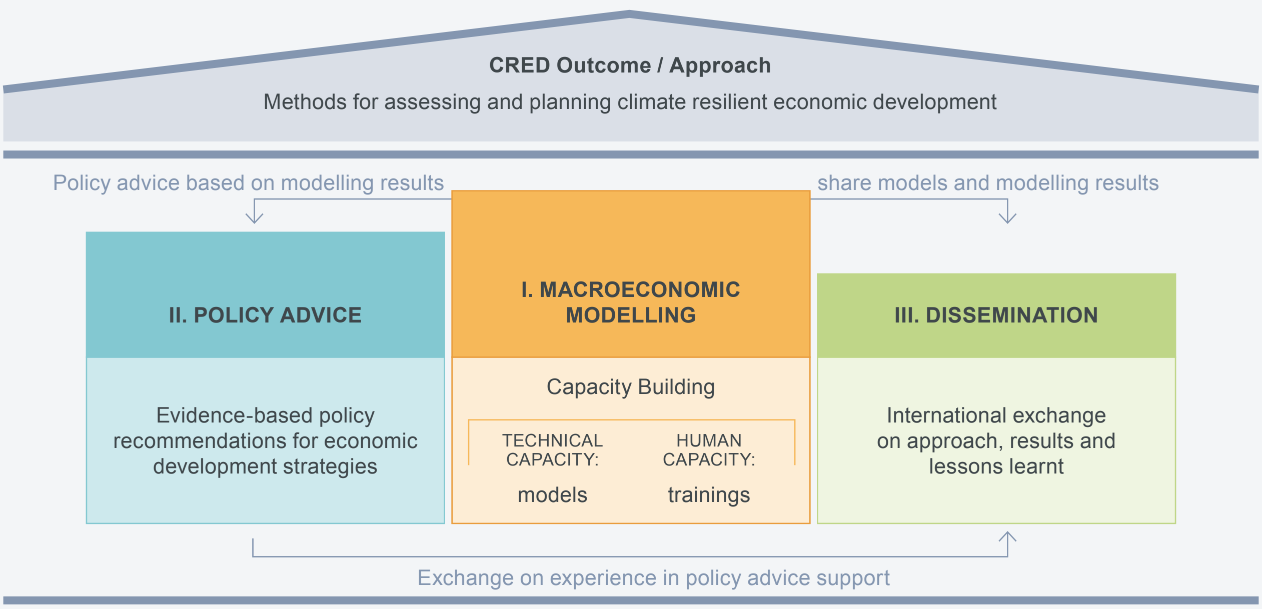
- **Genuine inclusion of stakeholders, local communities, women and marginalized groups** (e.g. indigenous peoples) into decision-making and co-development of adaptation planning and implementation to reflect differing values, perspectives and interests and produce equitable, fair and just adaptation outcomes.
  - *Limited: The CRED approach supports inclusion of economic, finance and private sector stakeholders. Its focus on linking adaptation with economic development should be utilized for inclusion of marginalized groups.*
- **Transparency, accountability and predictability** of support and integration of adaptation into national development priorities, strategies, and the SDGs
  - *Key: the CRED approach is instrumental for achieving this integration. Linkages to SDGs can be achieved with more comprehensive macroeconomic models that explicitly inform national SDG indicators (e.g. by expanding the socio-economic part of the model).*
- **Flexible programming and adaptative management** of implementation to consider feedback and learnings and to enhance efficiencies
  - *Limited, but CRED approach enables to engage stakeholders with sectoral adaptation actions and enhances efficiencies with regard to public benefits.*
- **Investment in local capabilities, capacity building and democratic governance structures** in support of climate risk management and empowerment for long-term sustainability.
  - *Key: The CRED approach is a systematic capacity building approach that improves adaptation governance structures by the necessary multi-stakeholder cooperation it entails.*
- **Consideration of future risks including climate trajectories and uncertainties** to minimize unintended consequences and maladaptation, while enhancing adaptation ambition.
  - *Key: The CRED approach provides evidence to scrutinize intersectoral dynamics and avoid maladaptation. Adaptation ambition is enhanced by exposing economic benefits.*
- **Integration of local, traditional, indigenous, and scientific knowledge** into design, implementation and monitoring and evaluation to enhance buy-in and ownership
  - *Limited: Mainly concerning scientific, economic and sectoral knowledge integration.*
- **Tackling inequalities and structural drivers of vulnerability** in addition to reducing exposure and/or vulnerabilities to climate hazards to embark on climate-resilient development pathways
  - *Key: The macroeconomic scenarios expose economic structures and identify transformations required to structurally reduce vulnerability and support resilience. The extent to which social inequalities are addressed depends on the scope of the model (in current version very limited). It is also a systematic approach for assessing the effects of structural transformation of the national economy on the vulnerability / climate risk pathways of a country. Such analysis can inform what is referred to as "transformative adaptation", that is intentionally growing / transforming an economy out of the most vulnerable economic sectors or regions.*

### LEARNING FROM A PILOT: THE CRED PROJECT

Responding to the increasing need for climate resilience, the Policy Advice on Climate Resilient Economic Development (CRED) programme supported evidence-based policymaking on adaptation to climate change at the national level. The programme was implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) from 2019 until the beginning 2023. Together with its partners in Georgia, Kazakhstan and Vietnam, the CRED project piloted economy-wide assessments of climate change impacts and respective adaptation measures. Country-specific macroeconomic models have been developed together with national partners. These models provide key information for policy makers: First, the modelling results show how different climate hazards impact the economy up to the year 2050. Second, economy-wide effects of investments in different adaptation options are assessed.
This allows to compare a set of adaptation measures and thereby to identify those measures (or a combination thereof) contributing the most to economic development. For example, the energy sector in Kazakhstan is affected by heat waves which increase the electricity demand for cooling and limit the electricity generation from hydropower and thermoelectric power plants. Therefore, it is beneficial to combine adaptation measures – in this case, energy efficiency measures and wind power expansion – to maintain energy security (GIZ, 2021a).

The targeted outcome was to provide methods and instruments to analyse and plan climate resilient economic development. This also supports the implementation of the adaptation components of the nationally determined contributions (NDCs). The outcome was tied to three different outputs, which are capacity building, policy advice and the dissemination of the CRED results, illustrated in *Figure 3*.

**Figure 3: Outcome and outputs of the CRED programme**




*Source: GIZ (own illustration)*

The handbook summarizes the experience from the CRED programme in piloting the development and application of macroeconomic models in Georgia, Kazakhstan and Vietnam for supporting adaptation planning. The handbook presents general guidance on how to replicate the approach in similar projects in the future. Detailed modelling results are documented in the CRED project's national reports[4] and compared across in the three pilot countries in the *CRED Global Report* (GIZ, 2023b).

This handbook aims at providing policymakers and consultants with practical and structured guidelines on how to create a country-specific climate-sensitive macroeconomic model and build corresponding capacities to use and further develop the model. Resulting from this intervention, national policymakers and economists gain technical expertise on macroeconomic models, and strategic capabilities for long-term policy planning. Moreover, as a key feature, the capacity building approach specifically targets the ability of model builders to independently refine and adapt the national climate-sensitive macroeconomic models to include future exogenous shocks and other unforeseen circumstances. The most significant benefit of macroeconomic modelling is to identify the long-term direct, indirect, induced and overall socio-economic impacts resulting from the implementation of adaptation measures under conditions of the climate crisis. National policymakers in ministries may use these results to identify which adaptation measures hold high benefits for the whole economy in the mid- to long-term (across a set of adaptation options). In addition, chances of receiving climate finance for implementation might increase if policymakers back their funding applications up with robust and science-based modelling results.

The macroeconomic models supported by CRED were designed to inform policy decisions at the national level by improving the information basis with long-term estimations on key economic indicators. While the **principle of integrating climate risks and (economic) benefits of adaptation measures in macroeconomic models** is the same across all partner countries, the underlying models differ. In Kazakhstan and Georgia, e3-models (economy, energy, emissions; called e3.kz (Kazakhstan) and e3.ge (Georgia) model) were used, while partners in Vietnam opted for a dynamic general equilibrium model (DGE-CRED). The specific mechanisms and data requirements underlying the CRED models are elaborated in the *CRED Global Report* (GIZ, 2023b) that is a more technical summary of the models.

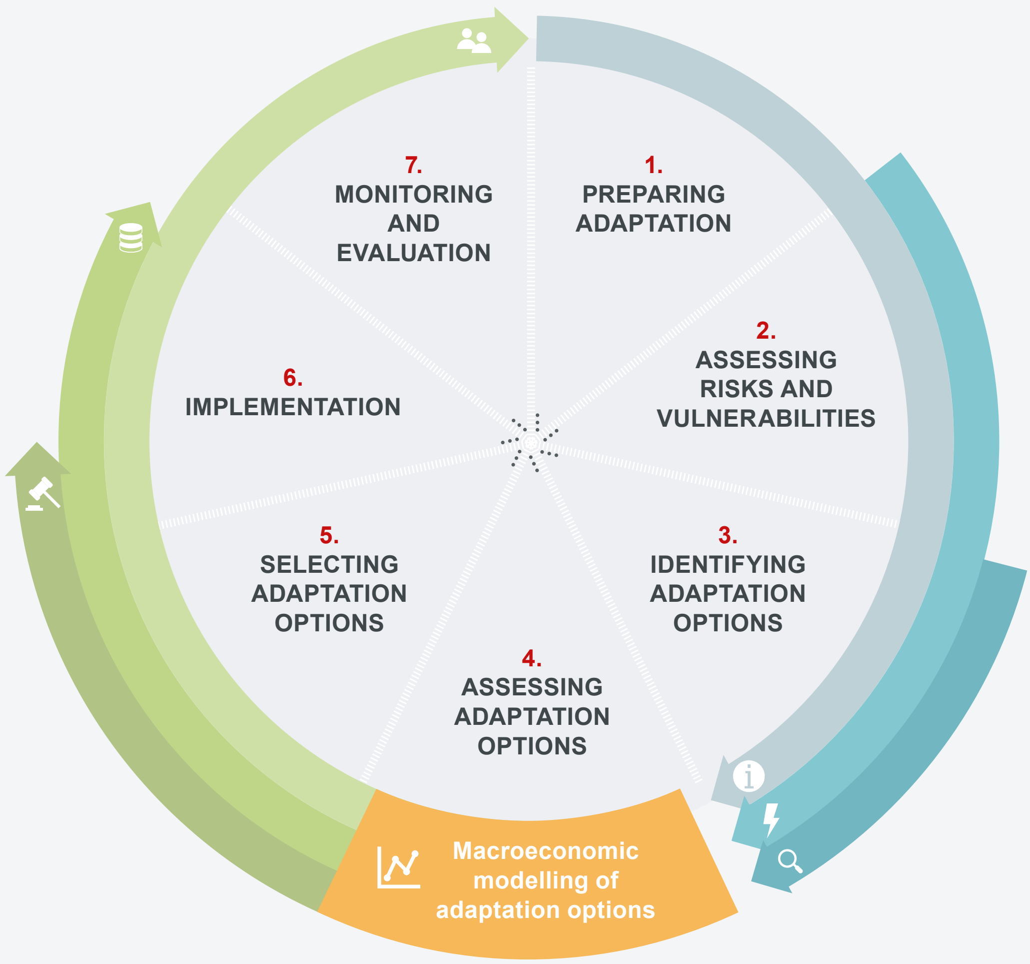
Instead of detailed model descriptions, the handbook focuses on how such technical assistance and international projects can be structured, what resources are required and which aspects are critical to achieve impact. Accordingly, the handbook outlines a pragmatic 7-step approach on the aspects on what is needed to support adaptation planning with macroeconomic models. Starting from the use case might help development practitioners to design their own projects on climate-sensitive macroeconomic modelling in the most efficient way. The handbook is a first step to structure practical insights from piloting the approach and feeding these into an emerging field. Each chapter of the handbook thus outlines the relevance of macroeconomic models for supporting adaptation planning and summarizes key steps for organizing capacity building to enable partner countries to use economic models independently. The implementation of the CRED project was limited to steps 1-4 so the experience is stronger in those steps, but relevant implications are provided in order to have a more comprehensive approach and handbook enabling adaptation action.

*4 Read the national reports:*
- *GIZ (2022a): National Report: Supporting Climate Resilient Economic Development in Georgia*
- *GIZ (2022b): National Report: Supporting Climate Resilient Economic Development in Kazakhstan*
- *GIZ (2023a): Technical Report of the Dynamic General Equilibrium Model for CRED in Vietnam*

**The 7-step approach for climate resilience is clustered around three distinct phases** (visualized in *Figure 4*):

- **Phase 1** **(blue, step 1-3)**: Establishing the basis for supporting country-specific adaptation action with macroeconomic models. A key step is identifying most affected economic sectors. This is based on a systematic review of sectoral and regional data on past and ongoing economic damages from climate change. The macroeconomic model is developed and validated to analyse how future climate change may impact the national economy. In addition, national priority adaptation measures are identified for subsequent in-depth assessments.
- **Phase 2** **(orange, step 4)**: Modelling economy-wide effects of climate hazards and systematic evaluation of investments in identified priority adaptation measures.
- **Phase 3** **(green, step 5-7)**: Modelling results of selected adaptation measures are combined with additional information for comprehensive guidance on climate resilience. Implementation is supported by using the systematic economic evaluation, including the improved understanding of investment and climate finance needs for adaptation. Monitoring and evaluation of adaptation action is improved by considering the economic effects of adaptation, supporting the identification of additional new measures to enable climate resilient economic development.

**Figure 4: Macroeconomic modelling in the adaptation policy cycle**




*Source: Cycle based on European Commission, Directorate-General for Climate Action, Ebrey, R., Ruiter, M., Botzen, W. (2021)*

### FOR EACH OF THESE KEY STEPS OF ADAPTATION PLANNING THE HANDBOOK WILL OUTLINE:

- the added value of a macroeconomic perspective
- possible capacity building needs and suitable approaches
- resources required to implement the approach in terms of international and national expert input (including estimation of expert days and time required for key steps)
- draft terms of reference (ToR) – as used by the CRED project, only accessible via GIZ intranet – for tendered work packages
- required engagement of key stakeholders to enable creation of macroeconomic models and use of results in adaptation planning processes

The approach presented in the handbook contributes to the broader effort of Climate Risk Management with a specific instrument (macroeconomic models) that is open to a broad range of interfaces and development objectives (disaster risk management, climate finance and insurance in particular). The approach presented thus aligns with efforts of the Global Risk Modelling Alliance (GRMA) and other initiatives. It is however unique in its focus on climate risks and adaptation perspectives for the real economy and the reliance on capacity building for enabling independent modelling by experts in the partner countries.

The handbook remains generic but stresses key areas where it is of importance to adapt content to the specific circumstances (i.e. conduct a baseline on economic models in the beginning). Future interventions using macroeconomic models will be different each time, depending on the countries' exposure to climate change impacts, economic structure, partner set up and funding available. It is encouraged to share experiences and contribute to an improved updated version. The adaptation community web portal provides a valuable space for exchange in that regard Climate Change Adaptation – *Adaptation Community*.

### OVERVIEW OF TIMELINE AND REQUIRED EXPERT DAYS

The handbook also provides general estimates on a potential timeline and expert days required for implementation the CRED approach in a different country or set of countries. For this a typical implementation time of 30 months is assumed.[5] For all the key steps the handbook indicates tasks that should be taken. It also provides estimations on the expert days (both national and international experts are required) realizing those tasks. Such tables are provided at the end of each chapter. *Table 2* provides a detailed overview of the sequencing of the steps and sub-tasks including the potential expert days required.

*5 It certainly could be more time (e.g. 48 months) to allow for more support in the application of macroeconomic models for decision making, so it might be considered the lower bound. It might also be possible to have a faster implementation with less focus on capacity building. But for the sake of simplicity the handbook presents an average case, which anyway needs to be tailored to specific requirements.*

## Table 2: Detailed workplan for developing and applying a macroeconomic model

| **WORK PLAN** (month of project implementation) | **1 – 6** | **7 – 9** | **10 – 12** | **13 – 15** | **16 – 18** | **19 – 21** | **22 – 24** | **25 – 30** |
|---|---|---|---|---|---|---|---|---|
| **STEP 1: PROJECT SETUP** | ◑ **70-110**<br>● **0-15** | | | | | | | |
| **Task 1.1:** Establish high-level political mandate | ◑ 10-20<br>● 0 | | | | | | | |
| **Task 1.2:** Build network with key national partners | ◑ 20-30<br>● 0- 5 | | | | | | | |
| **Task 1.3:** Conduct baseline study on existing models | ◑ 30-40<br>● 0- 5 | | | | | | | |
| **Task 1.4:** Workshop on model type and scope | ◑ 10-20<br>● 0-5 | | | | | | | |
| **Task 1.5:** Tendering international support | | | | | | | | |
| **STEP 2: CREATING A MACRO-ECONOMIC MODEL** | ◑ 125-250<br>● 220-340 | | | | | | | |
| **Task 2.1:** Identification of macroeconomic model | | ◑ 5-10<br>● 5-10 | | | | | | |
| **Task 2.2:** Economic data collection | | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 | | | | | |
| **Task 2.3:** Setup and calibration of macro-economic model | | | ◑ 5-10<br>● 20-30 | ◑ 5-10<br>● 20-30 | | | | |
| **Task 2.4:** Capacity building | | | | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | |
| **Task 2.5:** Review economic risks from climte change | ◑ 10-20<br>● 0-5 | | | | | | | |
| **Task 2.6:** Identification of key vulnerabilities and hazards | ◑ 10-20<br>● 0-5 | ◑ 10-20<br>● 5-10 | | | | | | |
| **Task 2.7:** Modelling climate hazard scenarios | | ◑ 0-5<br>● 15-20 | ◑ 0-5<br>● 15-20 | | | | | |
| **Task 2.8:** Assessment of economic damages | | ◑ 20-30<br>● 5-10 | ◑ 20-30<br>● 5-10 | | | | | |
| **Task 2.9:** Model integration with damage functions | | | | ◑ 0-5<br>● 15-20 | ◑ 0-5<br>● 15-20 | | | |
| **STEP 3: IDENTIFYING ADAPTATION OPTIONS** | ◑ 60-90<br>● 25-45 | | | | | | | |
| **Task 3.1:** Identification of priority adaptation action | ◑ 5-10<br>● 0-5 | ◑ 20-30<br>● 10-15 | | | | | | |
| **Task 3.2:** Compiling data on priority adaptation action | | ◑ 5-10<br>● 5-10 | ◑ 30-40<br>● 10-15 | | | | | |

<table>
<tr><th>WORK PLAN<br>(month of project implementation)</th><th>1 – 6</th><th>7 – 9</th><th>10 – 12</th><th>13 – 15</th><th>16 – 18</th><th>19 – 21</th><th>22 – 24</th><th>25 – 30</th></tr>
<tr><td>STEP 4:<br>ASSESSING ADAPTATION OPTIONS</td><td></td><td></td><td></td><td colspan="3">◑ 20-40<br>● 65-110</td><td></td><td></td></tr>
<tr><td>Task 4.1: Integration of adaptation options into model</td><td></td><td></td><td></td><td>◑ 5-10<br>● 20-30</td><td>◑ 5-10<br>● 5-10</td><td></td><td></td><td></td></tr>
<tr><td>Task 4.2: Modelling macroeconomic impacts</td><td></td><td></td><td></td><td></td><td>◑ 5-10<br>● 20-40</td><td>◑ 5-10<br>● 20-30</td><td></td><td></td></tr>
<tr><td>STEP 5:<br>SELECTION OF ADAPTATION OPTIONS</td><td></td><td></td><td></td><td></td><td colspan="3">◑ 70-105<br>● 40-60</td><td></td></tr>
<tr><td>Task 5.1: Translate results into recommendations</td><td></td><td></td><td></td><td></td><td>◑ 20-30<br>● 5-10</td><td>◑ 20-30<br>● 5-10</td><td></td><td></td></tr>
<tr><td>Task 5.2: Integration of modelling results into planning</td><td></td><td></td><td></td><td></td><td></td><td>◑ 10-15<br>● 15-20</td><td>◑ 20-30<br>● 15-20</td><td></td></tr>
<tr><td>STEP 6:<br>SUPPORTING IMPLEMENTATION</td><td></td><td></td><td></td><td></td><td colspan="4">◑ 100-150<br>● 50-75</td></tr>
<tr><td>Task 6.1: Establish stakeholder interfaces for results</td><td></td><td></td><td></td><td></td><td>◑ 20-30<br>● 10-15</td><td>◑ 20-30<br>● 10-15</td><td></td><td></td></tr>
<tr><td>Task 6.2: Build linkages with budget and climate finance</td><td></td><td></td><td></td><td></td><td></td><td>◑ 20-30<br>● 10-15</td><td>◑ 20-30<br>● 10-15</td><td>◑ 20-30<br>● 10-15</td></tr>
<tr><td>STEP 7:<br>TOWARDS INDE-PENDENT MODEL APPLICATION</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>◑ 20-40<br>● 15-30</td></tr>
<tr><td>Task 7.1: Expand adaptation indicators for monitoring resilience</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>◑ 10-20<br>● 5-10</td></tr>
<tr><td>Task 7.2: Preparing for updating the model</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>◑ 10-20<br>● 5-10</td></tr>
<tr><td>Task 7.3: Official model handover to partner institution</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>◑ 0<br>● 5-10</td></tr>
<tr><td>◑ National expert days<br>(total 470-785)</td><td>95-160</td><td>90-145</td><td>75-115</td><td>10-30</td><td>45-80</td><td>75-120</td><td>40-65</td><td>40-70</td></tr>
<tr><td>● International expert days<br>(total 435-695)</td><td>15-40</td><td>55-90</td><td>60-90</td><td>80-120</td><td>75-125</td><td>80-120</td><td>45-65</td><td>25-45</td></tr>
</table>

# 1 PROJECT SET-UP

**TIME / INPUT REQUIRED:**

- up to 6 months
- 70–110 National expert days
- 0–15 International expert days


**THIS CHAPTER EXPLAINS:**

→ What is climate resilience all about?

→ Which cooperation structures are needed for macroeconomics climate assessments?

→ Where to start?

## THIS CHAPTER PROVIDES AN OVERVIEW ON **5 TASKS**

When setting up a project to support adaptation planning with macroeconomic modelling, it is key to prepare the grounds for adaptation action. This includes:

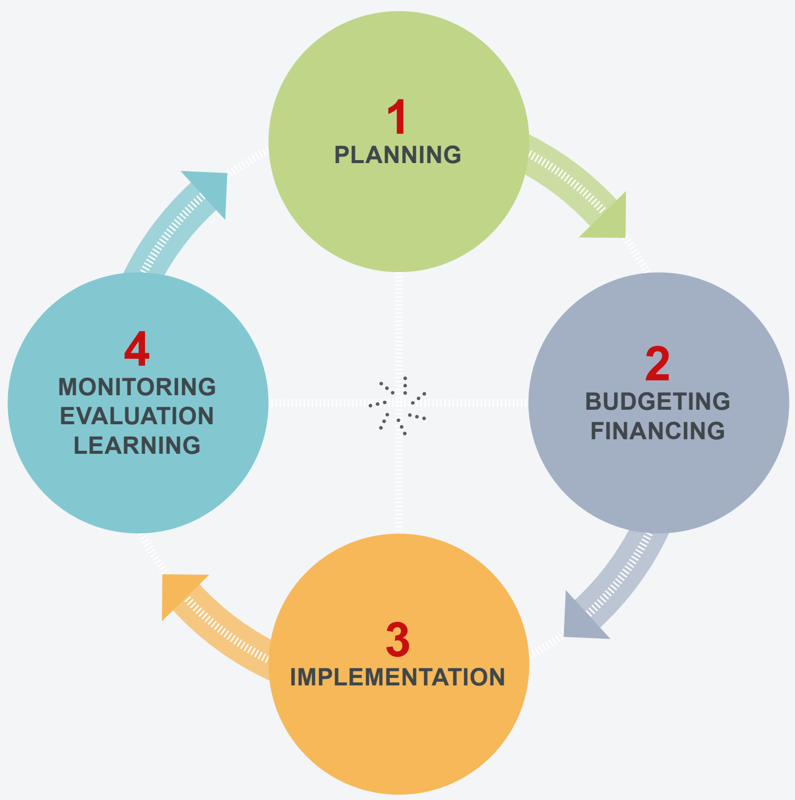
STEP 1 **TASK 1**

# ESTABLISH A HIGH-LEVEL POLITICAL MANDATE FROM GOVERNMENT

Macroeconomic models can play an important role to achieve climate resilient economic development because they allow partner countries to create their very own country-specific evidence base on the economic benefits of adaptation action. This potential of the macroeconomic approach to support national debates with better evidence needs to be understood by decision makers in partner countries to ensure full ownership and high-level backing. Therefore, it is key to initiate a stakeholder engagement process early to share this knowledge and clarify related questions.

The successful set-up of a stakeholder engagement process to guide and use macroeconomic modelling depends on establishing strong ownership to integrate adaptation into existing institutional frameworks and the national planning process. This has been discussed in detail in the practitioners' guide *"Using Climate Economic Modelling for Sustainable Economic Development"*. The report established key entry points for macroeconomic models to support adaptation planning.

**Figure 5: Entry points steps in policy cycle**




*Source: GIZ (2021b)*

## Box 2: Entry Point of Political Mandate

### ROLE OF A HIGH-LEVEL POLITICAL MANDATE

The political mandate for macroeconomic modelling supporting adaptation plays a key role for ensuring ownership an effective implementation of activities. The mandate should be established within a particular ministry, leading the economic assessment of climate impacts for the country. This will help to establish a clear vision for a national adaptation process, direct the mainstreaming agenda, foster leadership and ensure stakeholder participation. Many of the subsequent entry points depend on a country's vision and commitment to enhance its adaptative capacity as well as on a clearly assigned responsibility who leads the policymaking on adaptation.

To achieve a clear political mandate, the implementing organisation and its partner organisations should set up a joint steering structure in the beginning to enable the various partners needed for macroeconomic modelling to interact efficiently. Within the steering structure, it is recommended that experts work on a common strategy, which stipulates who the owner of the macroeconomic model is and which additional stakeholders use the model for policymaking (model users). The strategy should further clarify the contributions to the process of the different experts and institutions involved.

**Steps to be considered for ensuring partner ownership:**

- Setting up a joint steering structure
- Developing a joint strategy for implementation
- Develop a capacity development strategy
- Discuss and fix ownership of the model in an MoU

Aspects of these steps are further discussed in the technical chapters (i.e. *task 2.2* on how to set up the model). Setting up a clear cooperation and ownership strategy ensures the independent refinement and use of the models after the intervention, and smooth interoperability with existing structures. Accordingly, an agreement (e.g., a Memorandum of Understanding) should specify that the work on and use of models will be carried out jointly with the partner and that all results of the collaboration will remain in the possession of the partner.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS:

*Support by national experts is advised and estimated to be around 10-20 days, related to identification relevant decision makers and policy processes, process guidance from international experts is also advisable.*

STEP 1 **TASK 2**

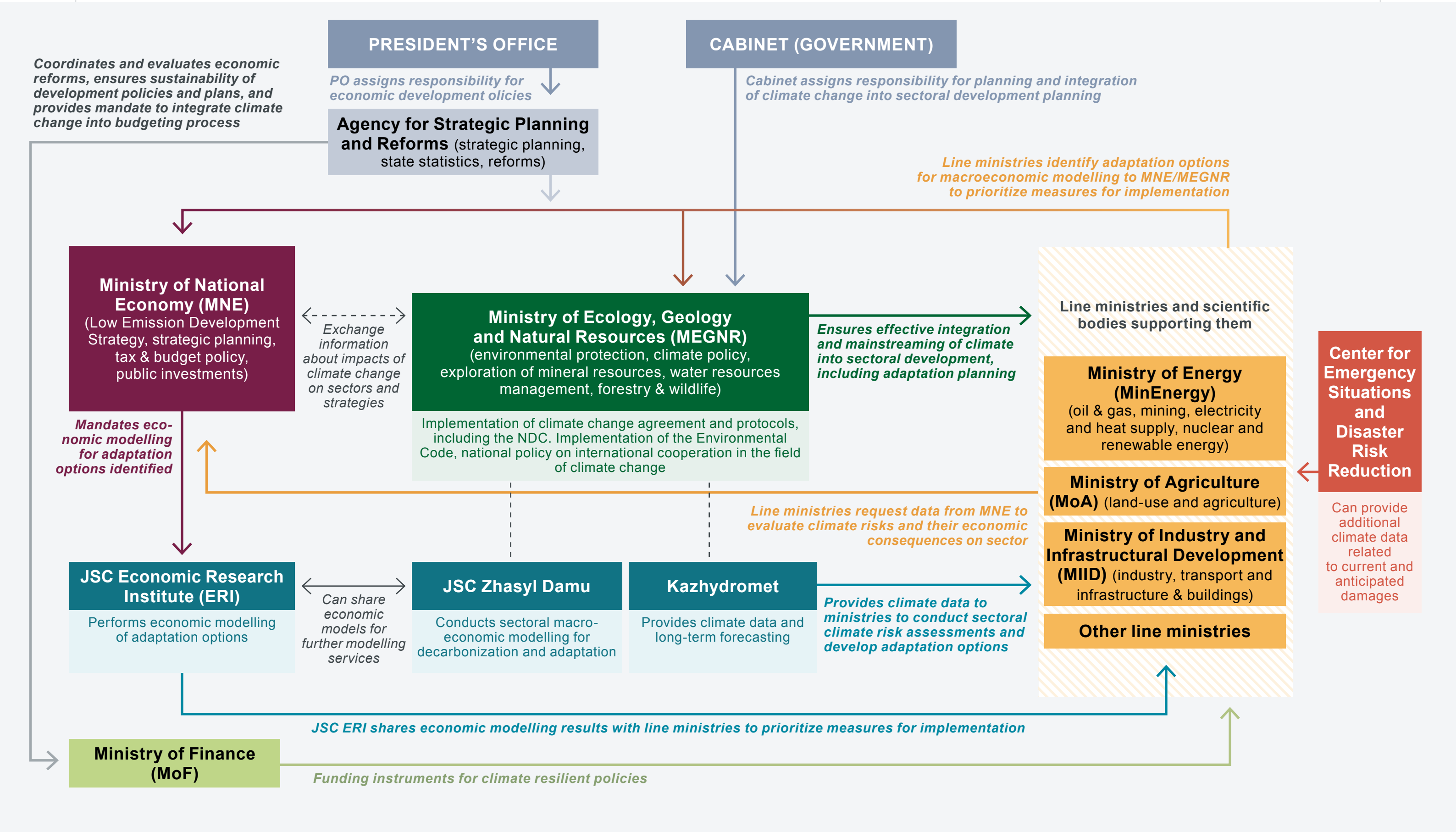
# BUILD NETWORK WITH KEY NATIONAL ACTORS

Ensuring that results from the macroeconomic modelling are included in adaptation decision-making processes requires to coordinate and align efforts across different actors, sectors, and scales of governance. These various steps represent a challenge for successful implementation, both individually and in combination. This is because the process requires various networks and exchanges among national experts and the willingness and ability to cooperate and to progress on a common ground of understanding. This includes:

- The common understanding of climate and socio-economic data and results from the modelling.
- The ability to frame adaptation action with political long-term planning
- Detailed knowledge of the entry points to use model results to inform policy process related to long-term strategies (LTS) including NDCs and National Adaptation Plans (NAPs).

*Figure 6* illustrates how national institutional arrangements on climate change (adaptation) could be set up. Taking from CRED project the example of Kazakhstan illustrates an overview of possible roles and responsibilities as it relates to the possible use of the macroeconomic modelling results to support adaptation action.[6]

**Figure 6: Managing stakeholder interfaces – example from Kazakhstan**




*Source: GIZ (2022c)*

6 *This proposal for a possible institutional set up in Kazakhstan was developed for the publication "Toward Climate Resilient Economic Development in Kazakhstan" under the work of the CRED programme.*

The institutional arrangement shown above aims at strengthening and mainstreaming adaptation macroeconomic modelling into Kazakhstan's existing development-planning process. A complete outline on policy mainstreaming of CRED results in Kazakhstan is available *here*. It showcases how to create an enabling environment for adaptation through clearly defining the interfaces between different actors. Key action points are:

- Raising awareness of current and future climate change impacts on strategic economic sectors
- Overcoming existing silos among government ministries and actors in different sectors, including economic planning, budgeting, and environmental policymaking
- Utilizing platforms for cross-sectoral coordination on adaptation
- Producing and sharing relevant climate data and information
- Strengthening financing to plan, design, and implement adaptation measures.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

*To effectively set up networks, it is important to have a solid overview of the existing stakeholders and understand the potential contributions of macroeconomic modelling in this context. A study by national experts (for example 20-30 expert days) on the existing network and policy entry points is advised. A method for understanding entry points was developed by the International Institute for Sustainable Development (IISD) under the CRED project and is available here.*

STEP 1 **TASK 3**

## CONDUCT A BASELINE STUDY ON EXISTING ECONOMIC MODELLING APPROACHES

At or before project start a baseline study is recommended in order to identify which economic models are already used by potential partner organisations and review their relevance for macroeconomic analyses on adaptation. In addition, stakeholder dialogues should complement this process to determine the policy and/or research questions the model should be able to answer once established. The following provides a brief overview of the main components of the baseline study to establish existing modelling capacities.

The capacity building begins with a baseline study, which will form the base to draw conclusions for formulating the capacity building strategy. Thus, the baseline study supports the implementation of an effective and targeted capacity building. The baseline study comprises information gathered through quantitative and qualitative assessment methods (survey and interviews) among decision makers. The baseline study provides a detailed overview on existing methods and instruments currently used for analyses and planning, the competencies existing to do these analyses, data availability and requirements. It identifies gaps and needs for capacity development and other support measures.

For the drafting of the model baseline study, the following tasks need to be executed (supported by national experts):

- **Identify key stakeholders and entry points/ national policy processes** (climate policy including NDC implementation, other initiatives related to building climate resilience and/ or increasing modelling capacities).
- **Draft a questionnaire and an interview guide** (partly adapted to the key stakeholders identified) to capture:
  - **Existing methods and instruments** (e.g., biophysical and macroeconomic models) used for macroeconomic forecasts as well as upgrading potential.
  - **Modelling capacities**, including the number of people working on economic modelling, full-time or part-time etc. in concerned departments.
  - **Inventory of available data for macroeconomic modelling** (climate data, socio-economic data, and biophysical data) as well as data processing capacities.
  - **Entry points** for modelling results to inform adaptation action in key sectors.

This assessment should also cover **data sets concerning the impacts of climate change** in the country, including for example data on:

- value addition per sector and region, existing climate impact projections, Social Accounting Matrix, relevant data on social vulnerability, other forecasting data.
- water resources and land use data.
- economic value of specific land uses, and impact channels for extreme weather events like droughts, flooding.
- past weather and climate data, projections.

The assessment should also cover relevant institutions with their role and mandate in data collection, processing and provision as well as their current capacities, such as e.g. the ministries of Economy, Finance and or Planning, Ministry of Natural Resources, Ministry of Agriculture, Department of Meteorology or the Statistics Office.

- **Inventory of relevant institutions** (Ministry of Economy and Planning as well as national research institutes) and their existing capacities to apply and process integrated models as well as their needs for upgrading. This should also reflect on the mandate and responsibilities of the institutions to conduct modelling activities according to relevant regulations and current cooperation mechanisms (inter-ministerial working groups etc.).
- **Overview of communication of modelling results.** This should detail how (by whom and when) results of national economic modelling activities could be communicated to decision makers and other relevant stakeholders.

All findings should be summarised in a baseline report and made available to the implementing organisation to inform the decision on the concrete modelling approach and capacity building requirements, see also next step.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

*Conducting the baseline is a crucial step to have a common understanding of a suitable model, policy entry points for adaptation action and involved stakeholders. At least 30-40 expert days for national expert days should be allocated. The involvement of international experts for informing the design of the baseline study and discussing results could take 0-5 days.*

*Draft ToR for conducting a baseline assessment and exemplary baseline studies from the CRED project are provided in the DMS folder for Chapter 1 (GIZ access only).*

STEP 1 **TASK 4**

## WORKSHOP ON MODEL TYPE AND SCOPE

Based on the results of the baseline study a first "model focus workshop" should be convened with partners to achieve a common understanding of what expectations exist regarding a macroeconomic model and what type of model is suitable to set up for the country. This can be used as input for designing the following steps, in particular the final decision on which model to setup (see *chapter 2*).

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

*This step complements the efforts to ensure ownership and relevance of the macroeconomic modelling efforts. Support from national experts for technical preparation and networking might be around 10-15 days. If possible, already some international expert input is advisable to support identification on the model type and scope.*

STEP 1 **TASK 5**

## TENDERING INTERNATIONAL SUPPORT FOR PROJECT IMPLEMENTATION

The implementation of a capacity building programme on macroeconomic modelling for climate resilience is not part of the standard portfolio of most international organizations in development cooperation. It is thus advised to start tendering out the international support required for the subsequent steps early on. Most of the subsequent steps of the handbook involve active involvement of "international experts", who can be included in the project based on an international tender. Example ToR as they have been developed for the past CRED project are provided *here* *(GIZ access only)*. However, given the lessons learnt from CRED implementation, restructuring of the work packages is suggested as explained in this handbook.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

*No external support necessary.*

*Table 3* summarizes the key steps suggested for getting started in the project set up. It already involves some international expert days, prior to the large tendering of international support (*task 5*) for creating the model and translating results into adaptation action. The support in the months 1-6 should have a different modality, being more short-term and explorative in scope.

The tables at the end of each chapter do not list the staff requirement for the project management unit but just the additional external support needed. As suggested, there should be at least one full-time person in the/each country facilitating the activities. Additional support from the headquarter is also needed to arrange contracting, reporting and facilitating learning and exchange, in particular if more than one country is involved, as was the case in the CRED project.

## Table 3: Key steps for project set up / getting started

| **WORK PLAN** (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Establish high-level political mandate | ◑ 10-20<br>● 0 | | | | | | | |
| **Task 2:** Build network with key national partners | ◑ 20-30<br>● 0-5 | | | | | | | |
| **Task 3:** Conduct baseline study on existing models | ◑ 30-40<br>● 0-5 | | | | | | | |
| **Task 4:** Workshop on model type and scope | ◑ 10-20<br>● 0-5 | | | | | | | |
| **Task 5:** Tendering international support | | | | | | | | |
| ◑ **National expert days** (total) | **70-110** | | | | | | | |
| ● **International expert days** (total) | **0-15** | | | | | | | |

*Note: Numbers refer to a systematic application of CRED approach in one country. Required time frames and expert days strongly on national circumstances, number are rough estimations only. For several countries scale effects do apply (implementing in x countries implies multiplication by less than x). Additional project management costs and overheads are not included.*

# 2 CREATING A MACROECONOMIC MODEL

**TIME / INPUT REQUIRED:**

- up to 18 months
- 125–250 National expert days
- 220–340 International expert days


**THIS CHAPTER EXPLAINS:**

- What are economic risks from climate change?
- How to build a macroeconomic model?
- How to assess climate hazards?
- How to integrate climate hazards into an economic model?

## THIS CHAPTER PROVIDES AN OVERVIEW ON **3 TASKS**

Once the grounds for adaptation planning have been prepared and international support has successfully been tendered a country specific macroeconomic model can be developed. Key steps include:

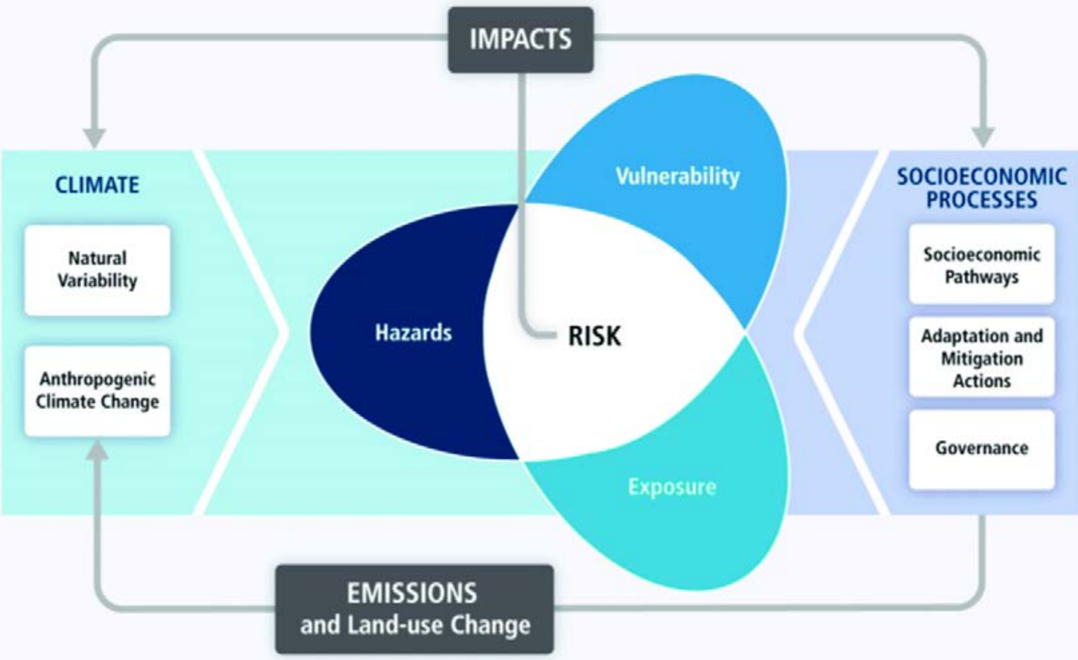
| | |
|---|---|
| **TASK 1:** setting up a country-specific macroeconomic model | *p. 33* |
| **TASK 2:** conducting capacity building for applying and using the macroeconomic model | *p. 34* |
| **TASK 3:** modelling climate hazard scenarios | *p. 46* |

STEP 2 **TASK 1**

# BACKGROUND ON ASSESSING CLIMATE RISKS

For any economic assessment of climate change two strands of information are critical: first economic vulnerability and exposure (that is the population and workforce, economic sectors, assets and infrastructure actually exposed) and second the climate hazards (increase of extreme weather events and slow onset events like sea-level increase) driving the climate risks. Only the combination of these factors provide a systematic understanding of the risks posed by climate change.
This is the key approach underlying also the risk assessment followed by the IPCC:

**Figure 7: Comprehensive climate risk framework**




*Source: IPCC (2014)*

Understanding economic resilience requires a systematic assessment of what constitutes a climate hazard for a given national economy. A key added value of the CRED approach is to provide an analytical framework for the systematic integration of both economic vulnerability and relevant climate hazards. Instead of assessing climate change as a general shift in climatic and ecological parameters, the approach is to focus on climatic changes that are most relevant, i.e. pose the most significant risk from the perspective of the national economy. This does not replace the need for comprehensive climate change assessment from a more ecological perspective, focusing on interactions of natural systems. But the hazard analysis from an economic perspective builds on studies on climate and ecological change and provides a focused analysis on what this means from the perspective of the economy. It thereby complements existing climate impact studies with a perspective that aims to translate the climate induced changes into potential effects for the economic system and the people depending on it for their economic welfare.

A systematic understanding of climate risks is needed because the estimations for adaptation costs are rapidly increasing. *Table 4* outlines current estimations on adaptation costs for developing countries. It compares numbers from the AGR and the IPCC WGII AR6. The *Table 4* highlights the high uncertainty about annual costs that could occur and the corresponding need to have country-specific assessments.

**Table 4: Annual cost of adaptation for developing countries**

| | 2030 | 2050 |
|---|---|---|
| **AGR** | $160 billion – $340 billion/year | $315 billion – $565 billion/year |
| **IPCC WG II AR6** | $15 billion – $411 billion/year (Median $127 billion/year) | $47 billion – $1.088 billion/year (Median $295 billion/year) |

*Source: United Nations Environment Programme (2022)*

STEP 2 **TASK 2**

## SETTING UP A COUNTRY-SPECIFIC MACROECONOMIC MODEL

This section provides a background on macroeconomic models and related capacity building. This includes guidelines on how to best conduct trainings and coaching on model-building (i.e., the process of constructing the model) and model-using (i.e., the process of applying the model). This section provides practitioners with the key information to consider for setting up a country-specific macroeconomic model and enables them to initiate the data collection processes that is the basis for robust, country specific climate risk assessment. The process of integrating climate risks into the macroeconomic models is described in *task 2.3*, this section presents the process to setup a model.

## IDENTIFICATION OF SUITABLE MACROECONOMIC MODEL FOR PARTNER COUNTRY

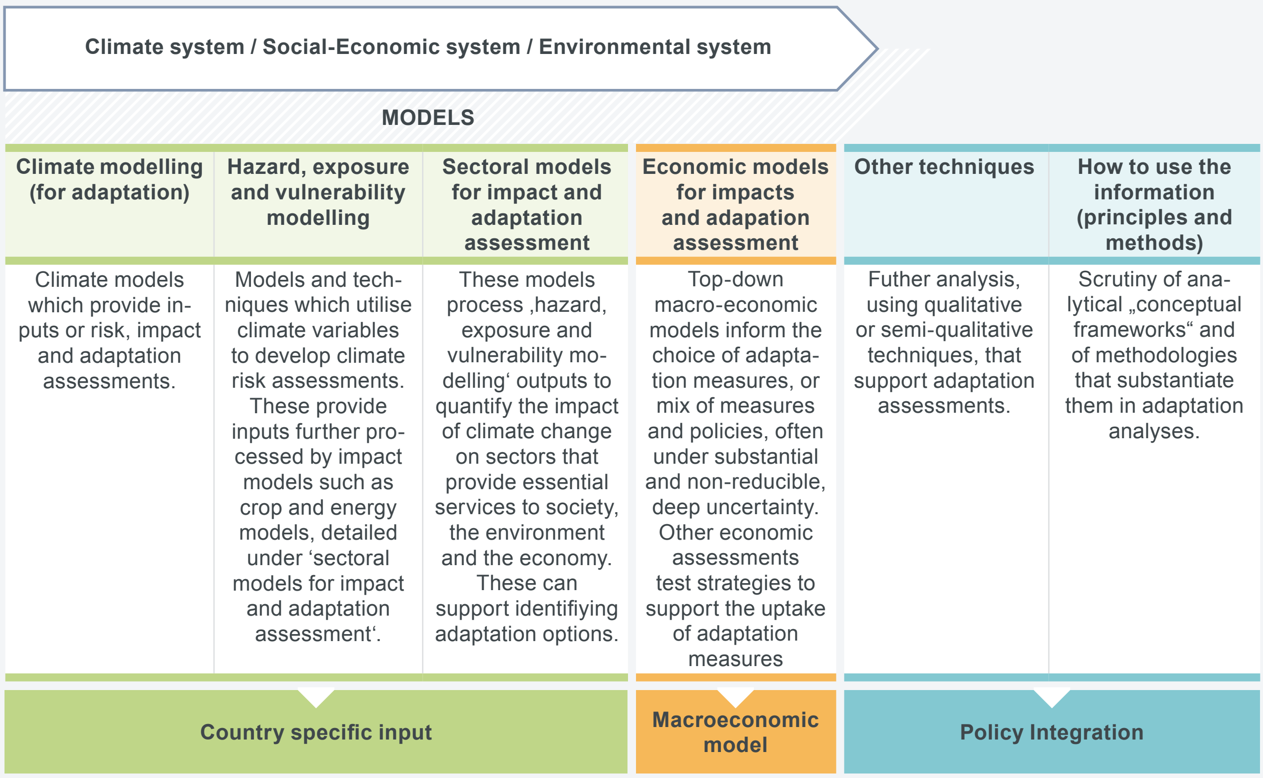
A first task in the setup of a suitable macroeconomic model is a joint understanding of the type and scope of the model. Following the model focus workshop suggested in *chapter 1* (*task 1.4*) a final decision should be made jointly with involved stakeholders. The following provides selected background on macroeconomic models.

Macroeconomic models are well-established instruments of economic planning ministries and have a large potential to inform actionable, evidence-based policymaking for enhancing economic resilience. Macroeconomic models replicate in simplified terms the structure of a national economy, demonstrating inter- and intra-sectoral dynamics and relations. This allows macroeconomic models to deliver (simplified) analyses on the development of key economic indicators like employment, GDP, consumption and productivity.

Policymakers need reliable economic models to anticipate climate impacts and adaptation options. Deciding upon effective direct economic policies and fiscal policy instruments to enhance climate resilience then becomes a lot easier. Informed decision-making can increase adaptation capacities and decrease vulnerabilities of the economy and population.

A recent comprehensive desk review for the EU Commission developed an adaptation modelling typology, which ranges from climate system modelling, over hazard, exposure and vulnerability modelling, sectoral models for impact and adaptation assessment to economic models (see *Figure 8*). Results from sector models and analyses are used as inputs into the macroeconomic models that are focused on in this report. The model and its results will be complemented by other techniques and information available in the countries. A deeper technical discussion is found in the *CRED Global Report*.

**Figure 8: Adaptation modelling typology**




*Source: GIZ (own illustration)*

The macroeconomic models developed under the CRED programme were constructed in a way that integrates various country-specific inputs (e.g. hazard assessments and sectoral analyses) to provide coherent evaluation for policymaking.
The CRED approach is depicted in *Figure 9*:

**Figure 9: Key steps of the CRED approach**

| DATA | MODEL | SCENARIO ANALYSIS | RESULTS | RECOMMEN-DATIONS |
|---|---|---|---|---|
| • Collect economic data<br>• Collect climate data | • Set up country-specific macro-economic models<br>• Dynamic General Equilibrium model (DGE-CRED model)<br>• Dynamic Input-Output model E3 (Economic model, Energy and Emission modules) | • Select sectors<br>• Select climate hazards<br>• Make assumptions on frequency and intensity weather events<br>• Estimate damage costs<br>• Model adaptation | • GDP effects<br>• Employment effects<br>• Individual effects<br>• Direct and indirect effects | • Feed results into policy process and stakeholder discussions<br>• Further analyse and rank adaptation options<br>• Discuss financing options |

*Source: GIZ (own illustration)*

Under the CRED project, two different kinds of macroeconomic models have been developed:

→ *Macro-econometric (dynamic) Input-Output (IO) models (called e3 models)*

→ *a Dynamic General Equilibrium (DGE) model*

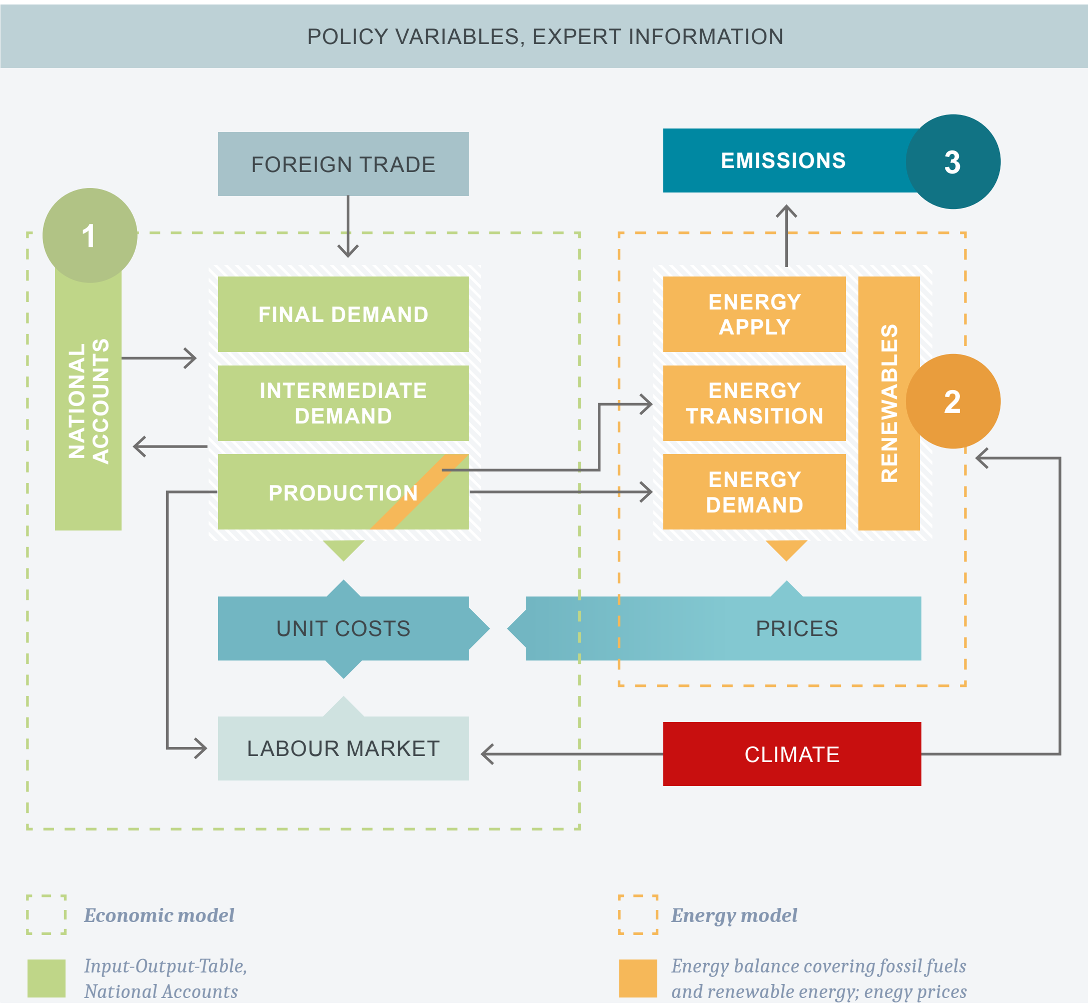
The setup and calibration of the respective model depends on which model type is chosen based on existing modelling capacities and available data. A comparison of the two approaches can be found in the *CRED Global Report*. Please find below a summary of key points.

## MACRO-ECONOMETRIC E3 MODELS

In Kazakhstan and Georgia, the CRED project supported macro-econometric e3 models built in Microsoft Excel. The CRED project also developed a prototype model that can be presented in teaser trainings to provide potentially interested countries with an introduction on what such models are (see *here* for details on the e3 model-prototype developed in cooperation with partners from Mongolia). The prototype is built on international available economic data for many national economies and can provide a first impression on the potential of the model to assess climate risks.

In the case of Georgia, the macroeconomic model e3.ge has been developed in cooperation between the Ministry of Economy and Sustainable Development (MoESD) of Georgia supported by the Institute of Economic Structures Research (GWS). The e3.ge model contains three interlinked model parts: the (1) economic model, the (2) energy module and the (3) emissions module. The abbreviation ge denotes the respective country (Georgia). The economic part of the e3.ge model is a macro-econometric (dynamic) Input-Output (IO) model. This model structure allows the determination of climate change effects on macroeconomic indicators like GDP and employment. Furthermore, the model is capable to quantify the economy-wide effects of different adaptation measures to elaborate adaptation strategies that ensure a sustainable development of the economy. The structure of the e3.kz model developed for Kazakhstan is very similar.

**Figure 10: The e3.ge modelling approach**

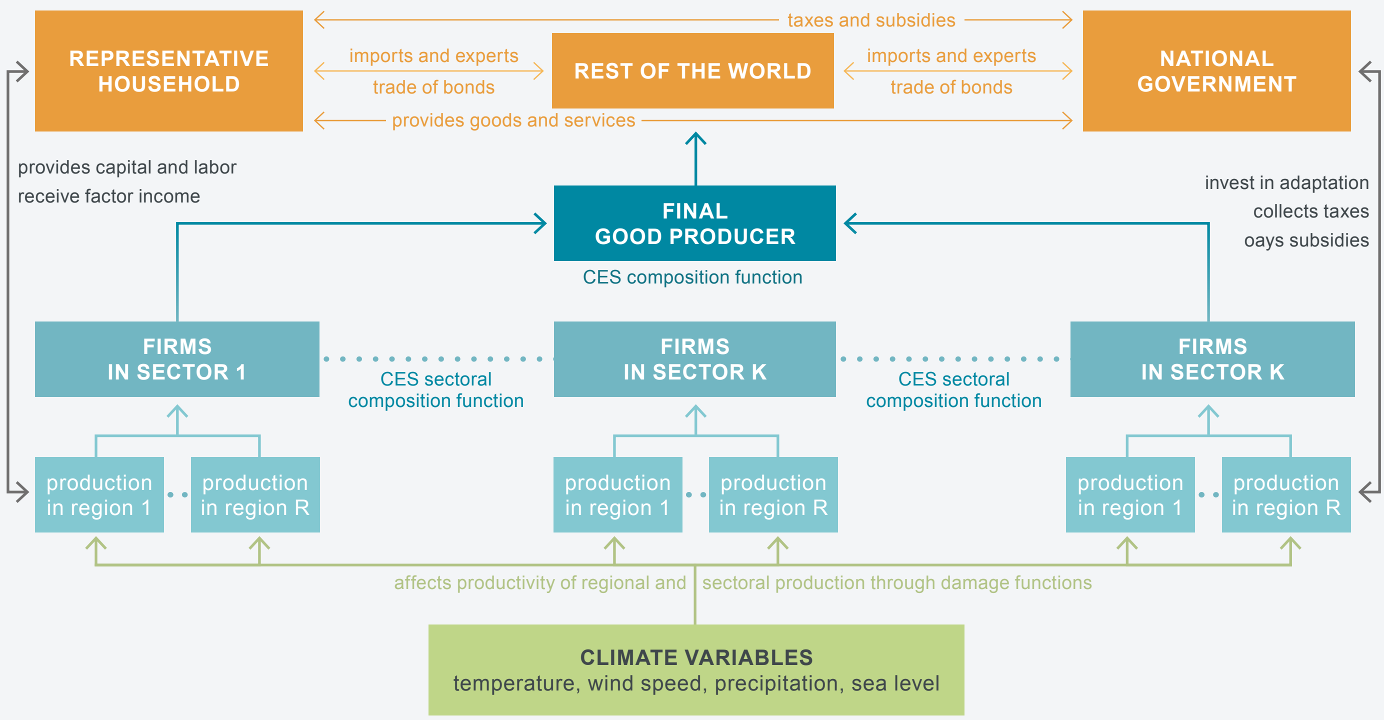



*Source: Own figure based on GWS (2022)*

# DYNAMIC GENERAL EQUILIBRIUM (DGE) MODEL

In Vietnam, a Dynamic General Equilibrium (DGE) model has been implemented. GIZ in cooperation with the Halle Institute for Economic Research (IWH) had been supporting the Central Institute for Economic Management (CIEM) to develop the DGE-CRED model to predict sectoral and regional economic effects of climate change on the Vietnamese economy. A full technical description and an overview paper are available on the CRED project website. The model differentiates between different regions and sectors to replicate the different climatic conditions experienced in various areas of Vietnam. Moreover, accounting for different productivities across sectors allows to understand how each of them evolves in the presence of varying climate circumstances. To consider the impact of climate change, the model uses sector and region-specific damage functions that affect labor and capital productivity. In this sense, climate variables and weather extremes impact production at the regional and sectoral levels. For instance, cyclones can destroy the capital stock used in the construction sector, which can either substitute capital using more labor or lay off workers as they become unproductive without machines.

**Figure 11: DGE-CRED modelling approach in Vietnam**




*Source: GIZ (own illustration)*

The CRED models provided a country-specific modelling platform to integrate all relevant national data concerning climate risks. Once the models are calibrated, they can be used to conduct scenario analysis on climate risks and adaptation options (see *Chapter 4* for details). In summary there are two key steps: First, model how different climate hazards impact the economy in the long-term, e.g. up to the year 2050. Second, evaluate the economy-wide effects of investments in different adaptation options. This allows to compare a set of adaptation measures and thereby identify measures (or a combination thereof) that are especially beneficial for the economic development. Potential trade-offs also become evident through macroeconomic models, thus granting policymakers the opportunity to make an informed choice on policies. What is more, climate-sensitive macroeconomic models become increasingly important to evaluate climate change policies. Such models provide a single framework to integrate climate change related issues in order to analyse not only the direct impacts but also the indirect, induced and total socio-economic impacts of both climate hazards and adaptation.

When taking the decision regarding which type of model should be developed, stakeholders should consider the type of policy questions the models should answer.
In the context of the CRED project the macroeconomic models had been designed to answers in particular two types of questions:

**Questions on the economic vulnerability to climate change:**

- Looking at the next 30 years, **how does a specific climate hazard** (e.g., increasingly severe droughts) **impact the national economy** (including jobs and GDP), economic sectors and which intersectoral dynamics[7] does it trigger?
- Which climate hazards will likely harm the national economy the most in the long-term?

**Questions on benefits/rentability of investments in adaptation measures:**

- Looking at the next 30 years, **how do investments in a specific adaptation measure** (e.g., irrigation systems) **reduce the economic risks of said climate hazard** and **potentially unlock economic opportunities**?
- What are the macroeconomic implications of this adaptation measure compared to a scenario without investment in adaptation, what is the effect on $CO_2$ emissions?
- Which investments lead to the highest economy-wide benefits?

Based on this capacity the models enable partner countries to **integrate climate risks in macroeconomic models** and thereby **improving adaptation planning**. However, what should be kept in mind regarding macroeconomic models: just like any other model, they represent a simplification of reality. This means that macroeconomic models rest upon a set of assumptions about future developments. In this regard, the quality of the modelling results hinges upon the quality of data, and the robustness of the assumptions.

It should also be noted that other macroeconomic models could be used beyond those applied in the CRED project. This is an emerging field and it will be important to systematically screen for current best solutions applied in the field. Another interesting model is for example the *GEMMES model*.

7 *Example for an intersectoral effect caused by a climate hazard: Increasing droughts result in lower agricultural production (direct effect), which then leads to production losses in sectors like food production or chemical industry as they rely on the agricultural sector.*

For the design of the stakeholder set-up and ownership structure existing international guidelines and criteria should be considered. For example the "*Key principles for improving the support to strategic energy planning in developing and emerging economies*" provide a useful framework. Another platform discussing criteria for modelling in the context of public policy support is the *U4RIA forum*. The focus of the U4RIA principles is on mitigation but they also apply to modelling adaptation.
For macroeconomic models on adaptation, the following criteria might be considered:

## Box 3: Modelling principles

- The model should be open-source, country-specific and the development of the enhanced model should start from existing and already in-use models by the partner institution
- The model enables the estimation of the sectoral impact from climate change effects (including value addition) and the effects of plausible adaptation measures to reduce climate change related impacts.
- The model should use available data or data which may be collected within the scope of the project considering recent and past extreme weather events and slow-onset changes
- The model enables the development of sector specific policy implications for policymakers (including but not limited to the NDC implementation and NAP process).
- The model should be designed in a way that ensures ongoing utilization after project end, taking into account capacity of the partner institution and guaranteeing full ownership of the software license by the partner institutions.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

*The decision on which model to develop builds on the previous studies on existing models and the policy entry points. The model developers from the key institution acting as the model owner should take the final decision. The process can be supported by national experts discussing findings from the baseline study (around 5-10 days). International experts can support the the discussion by contributing international lessons learnt and presenting the key aspects to be considered (around 5-10 days).*

# COLLECTING DATA FOR A ROBUST MACROECONOMIC MODEL

Already in parallel to the model setup the data collection can start. Climate-sensitive macro-economic models are based on the following data:

- **historical macroeconomic data:** GDP, imports/exports, price information of goods and services, consumption, employment, gross fixed capital formation, labour market annual national input-output tables providing sectoral data
- **economic growth forecasts** (growth rates and population forecasts)
- **energy and GHG emission data** (energy balances, energy-related $CO_2$ emissions, energy prices)
- **historical climate change effects** (occurrence, (economic) damage data)
- **projected climate hazard occurrence and intensity** based on SSP scenarios
- **cost-benefit analyses (CBAs) of adaptation measures**

For the data collection process, cooperation with national partner institutions is essential. They provide the necessary economic data as far as possible. If national data is not available, international data represents an alternative.

As already noted, the quality of modelling results depends on the quality of input data. In case of missing data, assumptions on economic damages as well as costs and benefits of adaptations measures need to be discussed and agreed upon with national experts.

The independent refinement of the models by partners is a central outcome of the capacity building intervention.
Involved stakeholders should actively support the process of data collection in two key steps:

a) data collection to set up the model;
b) continuous update of the model data after completion.

Furthermore, discussions on assumptions on climate risks are needed for credible integration of climate scenarios into the models. Ownership of the model data can be supported by data sharing agreements, see example in the following *link* for a draft *(GIZ access only)* further details on required data for different model types can be found in the CRED Global Report.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS:

*The collection of robust and validated data is a crucial and challenging step. The partner institutions are in the lead, based also on their networks with national statistic authorities etc. However national experts need to support (about 40 – 60 days) and international experts should involve to ensure compatibility of data with the macroeconomic model (about 20 – 30 days).*

## SETUP AND CALIBRATION OF MACROECONOMIC MODEL

The setup and calibration of the model should be done in cooperation between the international experts and selected model developers from the partner institutions. Calibration is based on the national data, so this might be an iterative process where data gaps are identified during model setup resulting in new data collection, data verification etc.

### IMPLEMENTATION REQUIREMENT AND ESTIMATED EXPERT DAYS

> *A flexible cooperation is needed between national experts supplying data and the international experts setting up the macroeconomic model. About 40 – 60 international expert days might be calculated. National experts should also support with data verification (about 20 – 30 days). The additional efforts to integrate climate risks and adaptation options is not included in this step, the calibration of the macroeconomic model to the national economic structure and dynamics is in itself a challenge, in particular if also regional disaggregation is implemented (as has been done with the DGE-CRED model in Vietnam).*

## CAPACITY BUILDING ON THE MACROECONOMIC MODEL

The CRED approach requires a country-specific capacity building concept. Given that familiarity with economic modelling or availability of data are usually still emergent in partner countries, the concrete support needs to be tailored to the national context. Getting capacity building right is essential, as it lays the foundation for later ownership of the model in partner institutions. Only if the capacity building concept ensures later independent use of the model, lasting impact on national policymaking towards climate resilient economic development can materialise. The capacity building targets the technical experts involved as model developers but should also involve responsible authorities by introducing a long-term planning perspective.

For effective capacity building, involving a set of experts from different institutions is advisable. This ensures that the potential of the model to inform long-term planning is known beyond the model owning institution and increases the chances of a wider model application. Moreover, offering capacity building across different institutions contributes to both mainstreaming adaptation action and strengthening interinstitutional ties. Usually, the group of experts comprises the national economics/planning ministries and their subordinate institutions as well as ministries of environment who are commonly in charge of adaptation planning. It should also cooperate closely with various local data providers, such as statistics offices, climate information providers, such as meteorological institutes, and possibly academic institutions. The private sector plays a role in preparing actionable recommendations. Its representatives (e.g., industry associations) could be involved in making recommendations for action via various participation mechanisms (e.g., online commentaries, information material on climate risks in different sectors, meetings with actors from the organised business community).

### TARGET GROUPS OF THE CAPACITY BUILDING

While the intervention supports the development of human and technical capacities, the focus lies here on the human capacity building. A crucial part of the capacity building is to enable experts from economics, planning and line ministries as well as subordinate authorities to assess the macroeconomic impacts of climate change and respective investments in adaptation measures. The main aim of the capacity building is to train and establish an expert group of professionals who receive in-depth knowledge as macroeconomic model developers and/or users of the climate-sensitive macroeconomic models jointly developed by the intervention. The capacity building will involve multiple training sessions and coachings, accompanied by workshops and policy dialogues on model refinement. The capacity building should be conducted by an economic consultancy, which also extensively supports the model development. This way, model development and model training go hand-in-hand.

The capacity building approach needs to be tailored to the capabilities of the participants and correspond to their needs. To this end, the CRED approach suggests distinguishing between two broad groups of participants: “model builders” and “model users” when designing capacity building activities.

## Box 4: Key components of the required capacity building

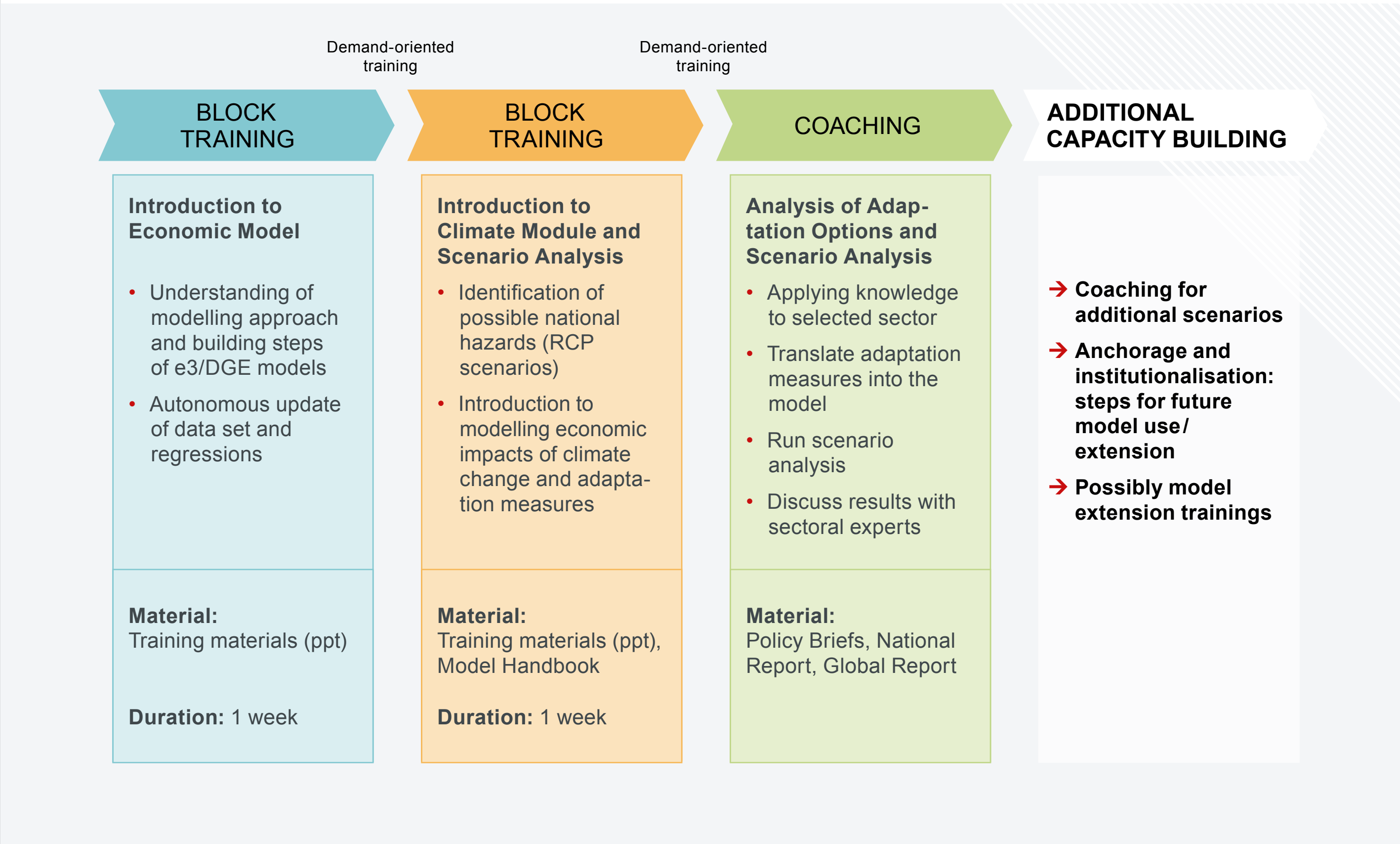
- Technical capacities: Development of a climate-sensitive macroeconomic model
- Human capacities of
  - *model builders (i.e., experts who are capable of further developing the model)*
  - *model users (i.e., experts who are capable of understanding how the model works and, importantly, know how to make use of the modelling results to inform policymaking).*

**“Model builders”** comprise the group of experts that will later be able to independently adjust the model contents and further refine the model with up-to-date data. As a point of departure, model builders should already bring advanced economic-modelling skills to the table, allowing the CRED trainings to build on the existent knowledge, enabling these experts to independently use and adapt climate-sensitive macroeconomic models. A careful selection process should ensure that participants represent relevant partner organisations, including key sectoral experts (e.g., agriculture). It is also recommended to include experts from universities. They might function as knowledge carriers supporting sustainability of the capacity building. All participants should have a mandate from their respective institution to deeply engage with the modelling training and support the model building process. In this regard, it is recommended to specifically target the modelling departments of partner institutes and ministries, as a basic understanding of economic modelling is required but more important is an interest in expanding capacities.

**"Model users"** are a broader group of (economic and other sectoral) experts interested in economic modelling of climate change impacts. Model users will be further supported to understand and use the climate-sensitive macroeconomic model to apply results to their specific sectoral requirements. To achieve this, they are not required to master programming of the model, but need to understand its main features, modelling approach, and interface to their specific sector (e.g., the logic behind damage functions and adaptation measures). Model users will only participate in general trainings, supported by simplified, selected training material. Online/presence workshops and particular sessions on the application of the model to specific sectors of interest complement the capacity building.

During the CRED trainings, both model builders and model users were targeted. The former were involved in implementing the national models, given their (macroeconomic) modeling experience and their role in the respective partner institutions. Model users were involved in the trainings on interpretation of results and scenario analysis. They do not need detailed macro-economic modeling knowledge, but can contribute specific knowledge about sectors, actors or policy processes. In general, the trainings in all countries included theoretical background and practical sessions for the model application. The following *Figure 12* gives an overview of the training and coaching process: First, the basics of the macroeconomic models were taught. Then the procedure of how to integrate the impacts of climate change using scenario analysis were presented. Subsequently, the analysis of adaptation measures was conducted in the form of virtual coaching sessions. At the end, there was a need for additional capacity building for the interpretation of results or wider use of the models. All these steps have been adapted in the countries according to demand and circumstances.

**Figure 12: Training programme for capacity building**




*Source: GIZ (own illustration)*

Draft Terms of Reference for building a macroeconomic model, exemplary training materials including the model handbooks developed for both types of CRED supported models (E3 and DGE-CRED) can be found here:

→ *Folder Chapter 2 – Building an economic model – OpenText Content Server (giz.de)*

*Participants of training on MATLAB software in Vietnam 2021.*

*Selected participants after completion of e3.kz model training in Kazakhstan 2022.*

## IMPLEMENTATION REQUIREMENTS AND ESTIMATED EXPERT DAYS:

*The capacity building is key to prepare independent use of the models after project termination. Different formats have been applied as part of the CRED project. In the beginning so called 1-week block-trainings have been implemented to train the functioning and of the macroeconomic model including the integration of climate impacts (damage functions) as well as adaptation scenarios. Presence trainings proofed to be more effective than virtual formats, causing a big challenge for CRED project implementation during COVID-19 travelling restrictions. A follow-up format in the context of CRED project have been coaching session, where experts in the countries could discuss specific questions or modeling problems with international experts. For the capacity building a total of 80-120 international expert days can be calculated. Some additional support from national experts can be also calculated (0-20). For example in Vietnam, some additional MATLAB (an economic analysis software) trainings had been organized with national experts as this was a required for the model developers to run the DGE-CRED model in the full version.*

Some examples of the capacity building material can be accessed *here* *(GIZ access only)*.

*Table 5* presents an overview of the time and estimated expert day requirements for the specific tasks involved to develop a country specific model and enable partners for its future independent use. Note that in parallel the assessment of climate risks and adaptation options should start to integrate both into the macro-economic model.

**Table 5: Timeline for the development of country-specific macroeconomic model**

| **WORK PLAN** (month of project implementation) | **1 – 6** | **7 – 9** | **10 – 12** | **13 – 15** | **16 – 18** | **19 – 21** | **22 – 24** | **25 – 30** |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Identification of macroeconomic model | | ◑ 5-10<br>● 5-10 | | | | | | |
| **Task 2:** Economic data collection | | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 | | | | | |
| **Task 3:** Setup and calibration of macro-economic model | | | ◑ 5-10<br>● 20-30 | ◑ 5-10<br>● 20-30 | | | | |
| **Task 4:** Capacity building | | | | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | ◑ 0-5<br>● 20-30 | |
| ◑ **National expert days** (total) | | **25-40** | **25-40** | **5-15** | **0-5** | **0-5** | **0-5** | |
| ● **International expert days** (total) | | **15-25** | **30-45** | **40-60** | **20-30** | **20-30** | **20-30** | |

*Note: Numbers refer to an application of CRED approach in one country. Required time frames and expert days strongly on national circumstances, number are rough estimations only. For several countries scale effects do apply (implementing in x countries implies multiplication by less than x). Additional project management costs and overheads are not included.*

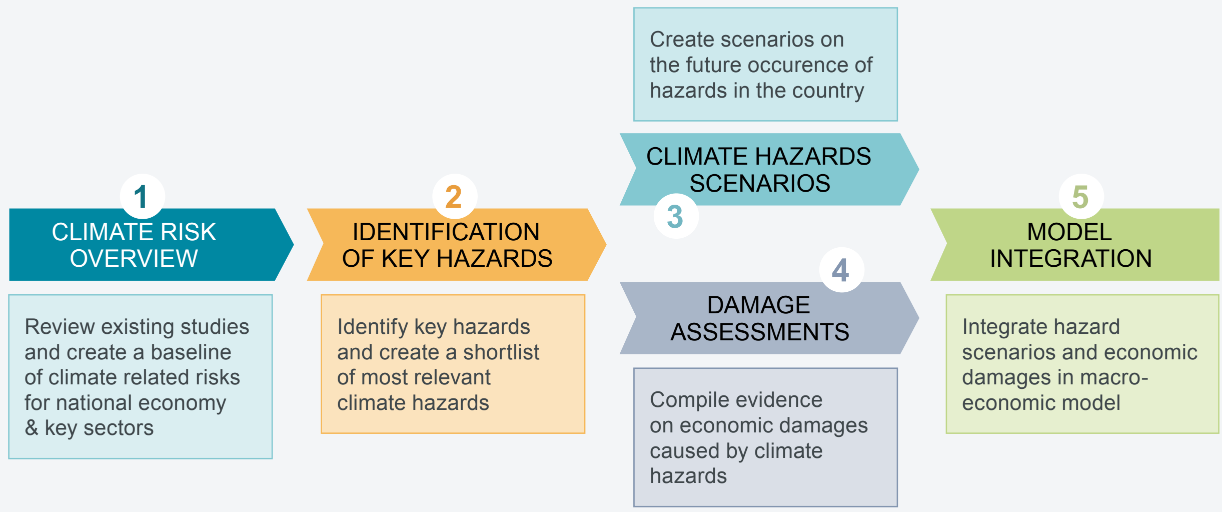
STEP 2 **TASK 3**

## CREATING CLIMATE DAMAGE FUNCTIONS

Climate damage functions refer to the translation and necessary simplification/aggregation of climate change impacts into economic effects and representations in an economic model. Economic effects are referred to as “damages”, assuming that effects considered are mainly negative for the economic indicators. Damage functions refer to the economic quantification of the broader climate impacts into specific impact chains that are represented in the model using “functions”. It is important to consider that the macroeconomic models add an extra level of analysis beyond simple damage functions. When sectoral economic effects (or damages) are integrated into the macro-framework the models also identify inter-sectoral dynamics effects that are not available from a sectoral economic climate risk analysis alone. But the starting point is to systematically map climate risks. And not just top-down, but using a bottom-up, country specific approach to generate and validate country specific damage functions. This grounding of the macroeconomic models and risk assessments in actual climate hazards had been an important innovation of the CRED project in its partner countries.
As indicated in *Figure 13* the creation of damage functions can be structured along 5 distinct steps/ tasks. Step 1 is to get an overview about key climate risks for the national economy. In a second step key hazards or climatic drivers expected to intensify these risks are analysed and prioritized. Step 3 is to develop climate hazard scenarios which inform about the future occurrence of these key hazards under different climate change scenarios in the country supported.

At the same time in a fourth step, data needs to be collected on past economic damages resulting from the respective prioritized hazards to understand the economic implications of the hazard intensifying in the future. In a last step, the information on climate hazard projections and hazard-related economic effects are integrated into the macroeconomic model, allowing to assess the macroeconomic impacts of specific or combined climate hazards. The different steps are described in more detail in the following sub-chapters.

**Figure 13: Integration of climate hazards into the modelling frameworks**

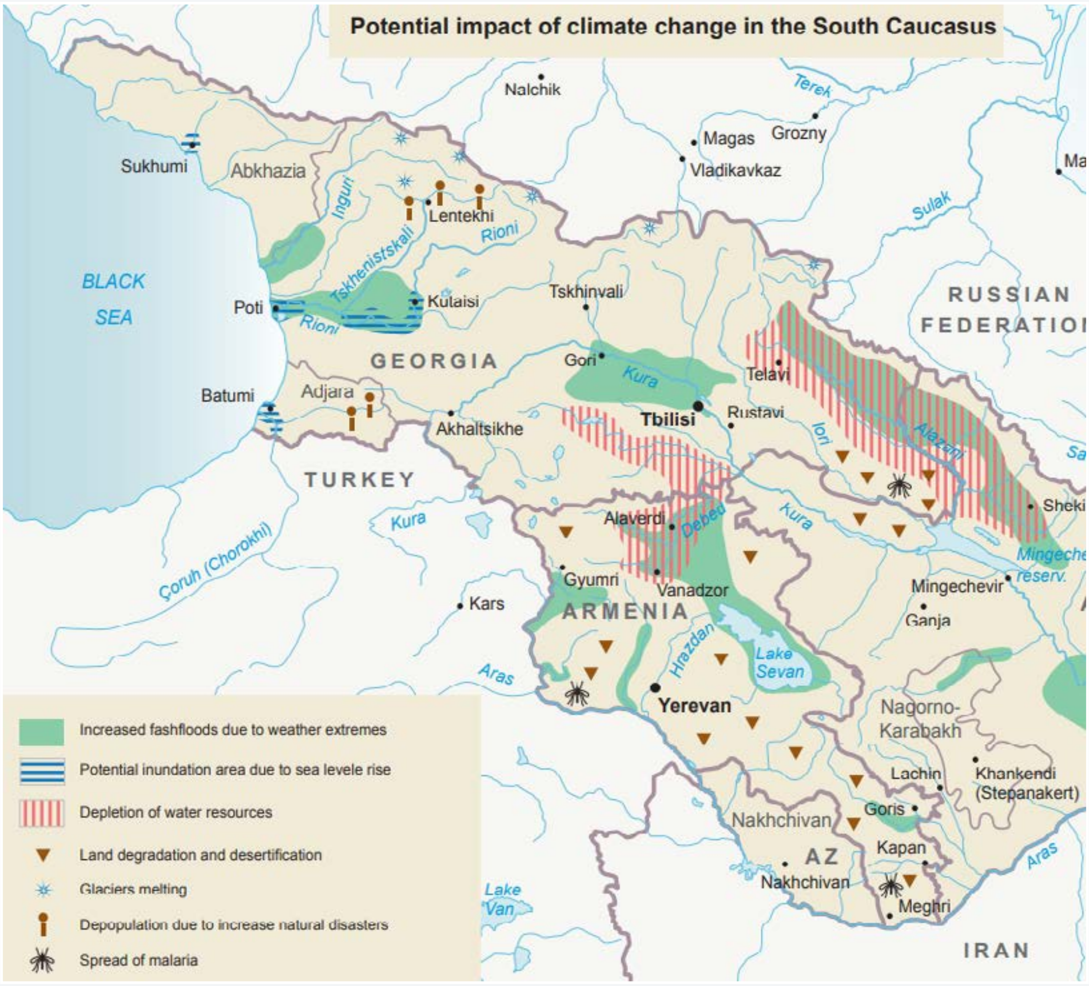



*Source: GIZ (own illustration)*

## REVIEW OF ECONOMIC RISKS FROM CLIMATE CHANGE

The starting point is an overview of the existing and emerges risks caused by climate change to the national economy. According to the IPCC, risk is the broader concept involving both the vulnerability and exposure of the economy as well as the hazards/ climatic drivers that drive those risks (IPCC AR5 risk concept, see also *Figure 7*). A systemic guide on assessing vulnerability is provided by *The Vulnerability Sourcebook* published by GIZ and the 2017 risk supplement. Conceptually it is important to distinguish between the material climatic hazards and the socioeconomic process that make regions or economic sectors vulnerable. Economic vulnerability to climate change refers to the sensitivity of an economy to be negatively impacted by extreme weather events and slow on-set events resulting from increasing climate change. Consider for example the climate risks depicted in *Figure 14*. The depletion of water resources is a risk to the economy only to the extent that agriculture or industry is exposed and actually relies on water and a decrease in availability. Adaptation is thus the process to reduce vulnerability and reduce the risks. The efficient allocation of adaptation financing is based on an understanding of what are the most severe risks and what is the possible change in climate hazards potentially intensifying those risks.

**Figure 14: Example of climate risks in South Caucasus Region**




*Source: Environment and Security Initiative (2011)*

The overview of national climate risks starts from existing reports (such as depicted above) but then takes an economic perspective on climate risks and asks what are the key economic sectors and impact channels. What are the climatic drivers/ hazards at the beginning of the impact channels? It might also be interesting to present to stakeholders the *climate risk assessment updated in 2021 for Germany*. A comprehensive risk assessment is the starting point for the next step, to identify and prioritize the key hazards driving the key national economic risks from climate change.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

*The risk overview / review should be created jointly with key stakeholders and based on existing national reports and analysis. It should already start in the first 6 months and about 10-20 days for national experts can be calculated. International experts might also provide input, such as international experiences and frameworks (0-5 days).*

# IDENTIFICATION OF KEY CLIMATIC HAZARDS

Based on the overview of the country-specific climate risks, an understanding should emerge on what are the critical climate hazards driving those risks. These could be increasing  occurence and intensity of extreme weather events, such as longer lasting heat waves, or more severe storms and floods, as well as proceeding of slow onset events such as sea level rise and desertification. To have a better understanding of the future it is advised to consider the past damages from key climatic hazards. In the context of the CRED project, the most relevant climatic hazards in terms of economic impact had been identified using historical time series of hazard reports. This can only be achieved in close collaboration with local experts and competent authorities (i.e. a national Disaster Management Authority).  The output of this step is a list of climate hazards that should be considered in *step 3*, the projection of how these hazards develop in future under different climate change scenarios.

### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

> *What can also start directly is the collection of data concerning the key climatic hazards. Data refers to the past damages available from international and national sources. While the main output of this step is the identification of a shortlist of climate hazards to considered further, already this should be based ideally on existing damage data. Therefore 20-40 national expert days might be calculated, deepening the analysis of the review. The final decision on the most relevant hazards should also involve the international experts supporting the model development. About 5-15 international expert days might be calculated.*

# CREATION OF HAZARD SCENARIOS

Once the most relevant hazards are identified, a set of indicators is to be defined to characterize those hazards. It is recommended to carry out in a way that keeps the definition of indicators as simple as possible while accurately representing the evolution of the hazards. The objective of step 3 is the estimation of the expected increase/ future occurrence of relevant climatic and meteorological hazards in the focus country. The hazard scenarios are country specific descriptions of the relevant hazards that can be expected under different climate scenarios, Representative Concentration Pathways (RCPs) or Shared Socioeconomic Pathways (SSP).

Such country specific hazard scenarios need to be derived from downscaling global or regional climate models. This expertise is likely not available among the economic consultancies supporting the economic modelling but could be acquired through the cooperation within a consortium. In case of the CRED project the creation of hazard scenarios was conducted by a climate data consultancy. The CRED project cooperated with a team from the University of the Balearic Islands (UIB) associated with *CORDEX* to create the data sets.

The following requirements were given.

- The contractor develops and adapts medium and long term (5-30y) climate hazard scenarios (selected SSP or RCP scenarios) for the partner countries.
- The contractor provides data sets on the future occurrence (change in intensity and/or probability) of the relevant weather/ climatic events (identified in step 2).
- The contractor models change in the distribution of standard climate parameters (temperature, precipitation etc.) for the scenarios.
- The contractor indicates the range of the model internal uncertainty.

The output of this step are suitable data sets (i.e. excel tables) that are handed over to the project / modelling team for further use. This includes the analysis of the hazards characteristics in the present climate and their projection for different time horizons along the 21st century. The results could also be summarized in maps, showing the spatial variability of the evolution of the hazards for different time horizons, and time series of the hazards yearly evolution at specific locations to be used in the economic models.

The evolution of hazards can be indicated by for example the expected change in the number of days or events per year. The following hazards have been covered as part of the CRED project:

- droughts,
- heat waves,
- extreme precipitation,
- extreme temperature,
- wildfires and
- extreme wind.

A detailed description of the definition and estimation of climate hazard indicators is given in the *Report on the climate hazard analysis for Georgia* (GIZ, 2021c).

**Optional: Creation of national climate risk profiles**

Based on the simulation of future hazards, it can be helpful to create climate risk profiles for partner countries. These risk profiles should contain key maps and visualizations of the main hazards for each country.

### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

*The modelling and provision of climate hazard scenarios involves as suggested additional international (climate modelling) experts. About 30-40 international expert days can be calculated, but it could also be more if further support in sub-models (for example changes in water cycle, other ecological feedbacks) should be considered. Additional support from national experts (0-10 days) is advised to support involvement of national meteorological or climate research departments.*

# ASSESSMENT OF ECONOMIC DAMAGES

Economic damages from current and past impacts of climate hazards provide the only available evidence and give some guidance on what to expect from future climate change. They thus play a critical role when modelling possible future economic damages and impacts from climate change. There can be different approaches to integrate economic damages into economic models, depending on the modelling approach. Both models considered in the CRED project (e3 and DGE model) work with some type of damage functions that is integrated in the economic model. The economic models are bottom-up, that is the damages from climate change are integrated from specified sectoral assessment of damages. The approach taken is to understand the current and past economic damages from extreme weather events (like flooding or drought) to extrapolate these damages in the future based on the increase in the severity of the climate hazards (see *step 3* of the hazard assessment). This approach has limitations in terms of capturing emerging new risks that are difficult to anticipate. The scenarios based on past climate damages certainly are not a complete guide to the future and provide only a limited proportion of the impacts to be expected. Such limitations should also be clearly communicated.

How to conduct an assessment of economic damages? The basic approach is to proceed with the shortlist of the climate hazards created in *step 2* of the hazard analysis and collect data on past economic effects from climate hazards. In the context of the CRED supported E3 models this involved creating an excel sheet to collect (supported by national experts) all available information on the key extreme weather events/ climatic hazards and reported damages. See for example below the columns of the excel sheet used to collect data on past climate hazards in Kazakhstan (thus damages are indicated in Kazakh Tenge):

| EWE | Region | Year | Month | Affected sector | Physical damage | Number of buildings damaged | Hectar affected | Economic damage (Mio. KZT) | Economic losses (Mio. KZT) | Recovery costs (Mio. KZT) | Persons affected | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

The data collection should be accompanied by additional stakeholder consultations and expert discussions. An example ToR for the task of collecting damage information is available *here* *(GIZ access only)*.

A different approach was taken for the development of sector-specific damage functions that can be integrated into DGE-models. Such damage functions can be created in cooperation with sectoral experts from the country that provide estimations of damages for a specific sector based on the requirements of the DGE-model. A comprehensive summary of the data requirements for the DGE-CRED model is available in the model overview on the open source platfrom github (see *GitHub – schultkr/DGE-CRED*).

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

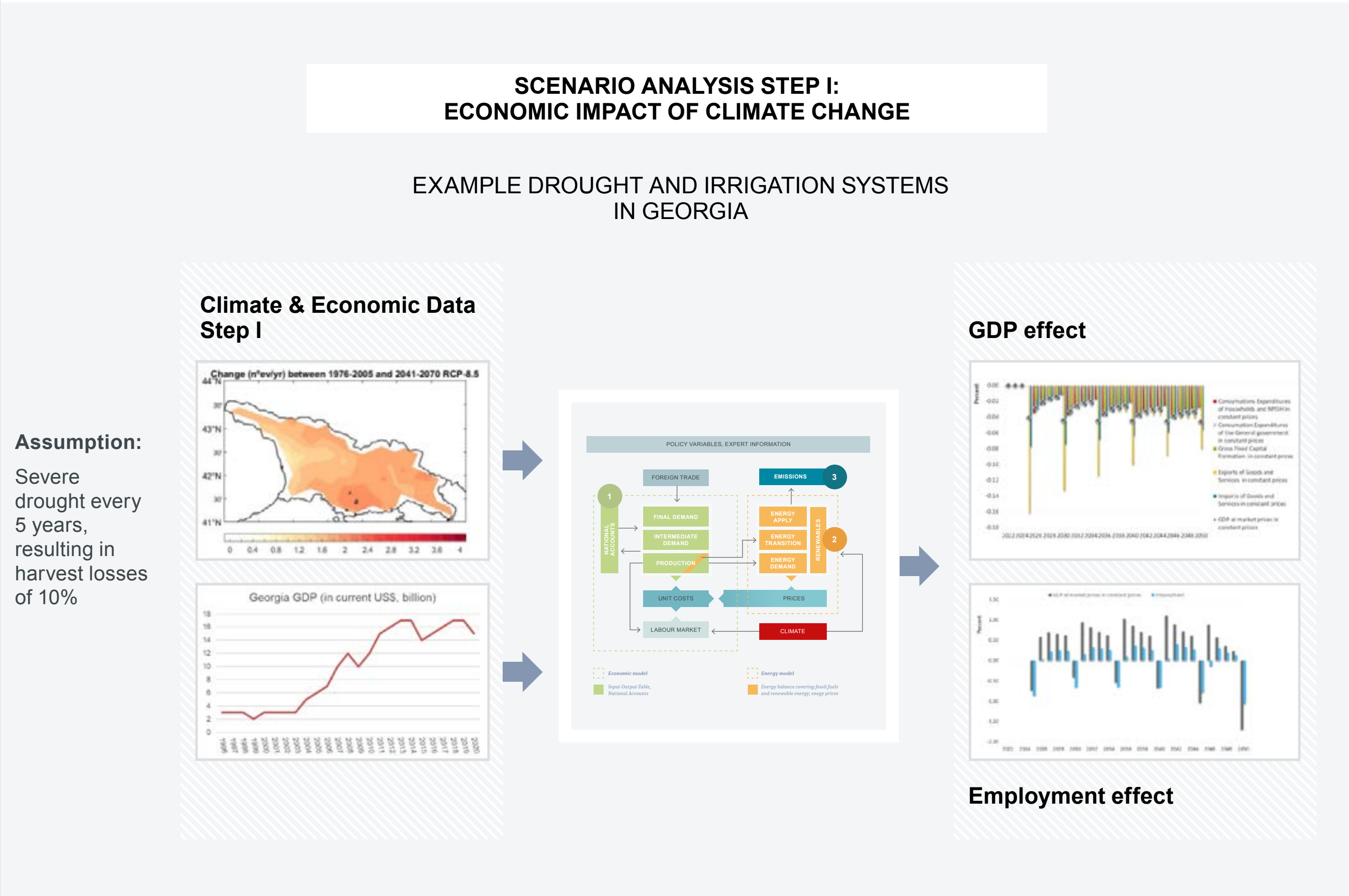
*Efforts to collect data on economic damages should already start in task 2.3.2 for a robust identification of the key hazards. This work should be deepened, and results need to formatted according to the technical demands from the macroeconomic model. This is not trivial, as the national experts providing data on economic damages need to understand the format requirements and provide data sheets accordingly. About 40-60 national expert days can be calculated, international expert days (10-20) are needed to ensure coherence of data sets and prepare for model integration.*

## INTEGRATION OF CLIMATE HAZARDS INTO THE ECONOMIC MODEL

The final step is the integration of damages into the economic model. This is achieved by combining the likelihood of a certain climate hazard to occur under a specific climate change scenario (e.g. RCP 4.5) with the damage estimates based on the review of past damages. The economic model includes and represents the economic vulnerability and exposure, in terms of the broader climate risk assessment framework (see *Figure 15*). It describes in detail the structure of the economy and its particular economic sectors, its productivity and employment patterns. The descriptions of the economic vulnerability and exposure are thus more fine grained and dynamic when compared to other existing climate risk assessment, for example the Economics of Climate Adaptation (ECA) framework (see *ECA-Framework*) which focuses mainly on economic assets.

A simplified integration of climate hazard scenarios and damage estimations into the economic model is depicted in *Figure 15*. Impacts in terms of GDP and employment can be provided for each considered hazard independently or for all hazards depending on the specific climate change scenario considered. This allows to construct different risk scenarios to create a differentiated overview of potential economic impacts.

**Figure 15: Integration climate hazards and damage estimates into an economic model**




*Source: GIZ (own illustration)*

Detailed description on the results is provided in the sectoral policy briefs, for example the case of agriculture in Georgia (GIZ, 2021d), the energy sector in Kazakhstan (GIZ, 2021a) and the national reports (GIZ 2022a, 2022b) all available at the *CRED project website*.

The precise way of integrating climate hazards into the economic model depends on the structure of the economic model. An overview of the differences between e3 and DGE-models can be found in the *CRED Global Report* (GIZ, 2023b). For further information on the exact integration in the DGE model, please refer to the Technical Report (GIZ, 2023a), an example of results is provided in *Box 5*. For the e3 model, please refer to national report developed for Kazakhstan (GIZ, 2022b).

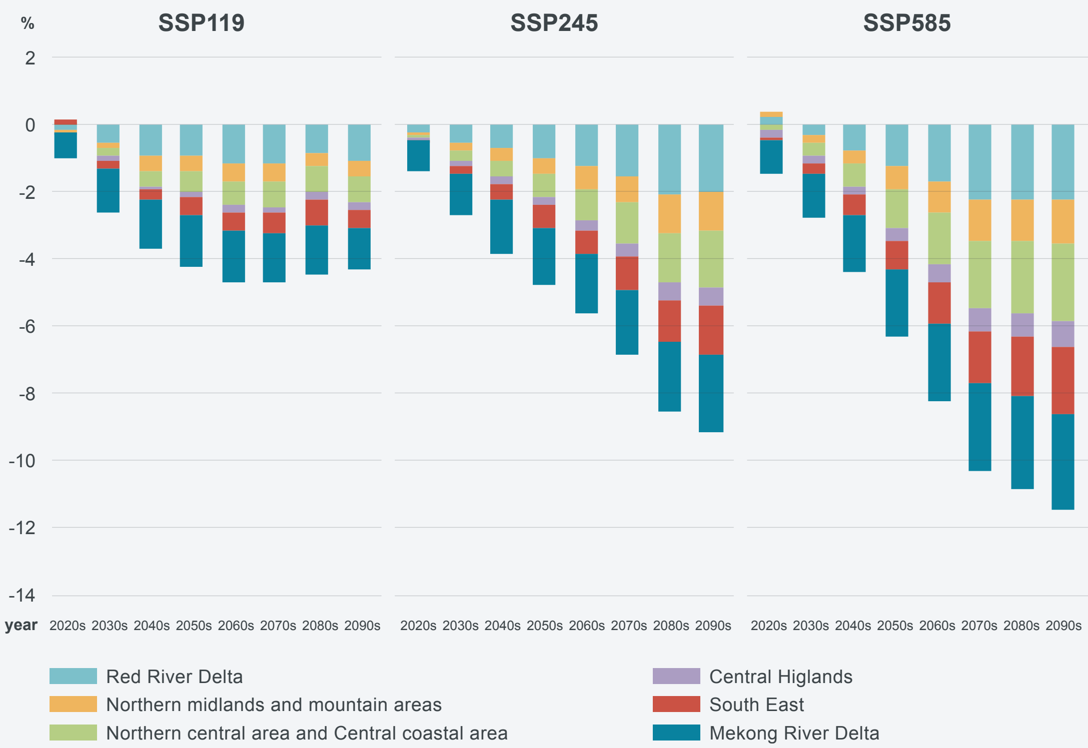
### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

*Once sufficient data is collected the macroeconomic model can be calibrated around the data. Additional international data might be considered to cross-check validity and fill data gaps. For the international experts 30-40 days might be allocated. Some additional days (0-10) for national experts can be expected as new requirements and data gaps emerge.*

## Box 5: Exemplary results calculated with the DGE-CRED model (I)

Due to the increasing impact of climate change on Vietnam's long-term economic growth and its consequences, the DGE-CRED model was applied to assess the effects of climate risks and potential adaptation strategies on Vietnam's economy. The model is constructed as a multi-region model, which allows to differentiate across regions to account for various regional climate developments. The paths of climate variables are defined with the help of meteorological models based on IPCC's SSP119, 245 and 585, i.e. scenarios with low, medium and high mitigation challenges. The DGE-CRED model compares the effects of the different climate change scenarios (SSP 119, 245 and 585) to a baseline scenario which assumes that climate change has no economic impacts. *Figure 16* visualizes the respective GDP losses expected under the different climate change scenarios without adaptation action. The simulation results indicate that climate change can reduce Vietnam's annual GDP on average by 5 percent in the 2050s. They also clearly show that the Mekong and Red River Delta are particularly affected by the economic losses, even in the most optimistic scenario (SSP 119), while mountainous areas are less vulnerable due to higher altitudes. Furthermore, the GDP losses only peak in the optimistic SSP 119 scenario during the second half of the 21st century, whereas in more severe climate change scenarios respective GDP losses continuously increase decade by decade until the end of the century if no adequate adaptation actions are taken.

### Figure 16: GDP losses in 6 regions form climate change impacts (in percent)




*Source: GIZ (own illustration)*

*Table 6* presents an overview of the time and estimated expert day requirements for the specific tasks involved to understand the key national risks posed by climate change and enable the integration of key drivers into the macroeconomic model.

## Table 6: Timeline for creating climate damage functions

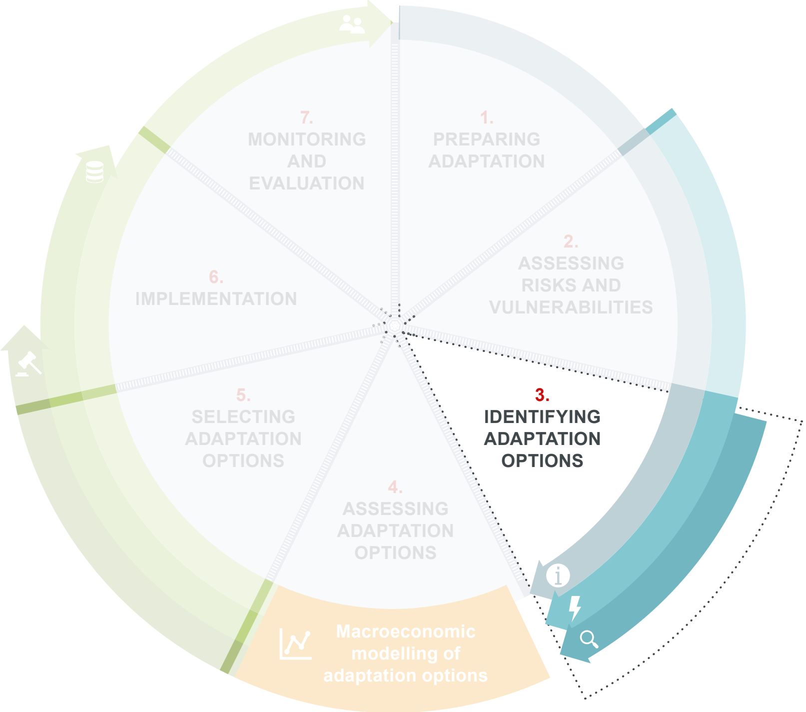
| WORK PLAN (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Review economic risks from climate change | ◑ 10-20<br>● 0-5 | | | | | | | |
| **Task 2:** Identification of key risks and climate hazards | ◑ 10-20<br>● 0-5 | ◑ 10-20<br>● 5-10 | | | | | | |
| **Task 3:** Modelling climate hazard scenarios | | ◑ 0-5<br>● 15-20 | ◑ 0-5<br>● 15-20 | | | | | |
| **Task 4:** Assessment of economic damages | | ◑ 20-30<br>● 5-10 | ◑ 20-30<br>● 5-10 | | | | | |
| **Task 5:** Model integration with damage functions | | | | ◑ 0-5<br>● 15-20 | ◑ 0-5<br>● 15-20 | | | |
| ◑ **National expert days** (total) | **20-40** | **30-55** | **20-35** | **0-5** | **0-5** | | | |
| ● **International expert days** (total) | **0-10** | **25-40** | **20-30** | **15-20** | **15-20** | | | |

*Note: Numbers refer to a systematic application of CRED approach in one country. Required time frames and expert days strongly on national circumstances, number are rough estimations only. For several countries scale effects do apply (implementing in x countries implies multiplication by less than x). Additional project management costs and overheads are not included.*

# 3 IDENTIFYING ADAPTATION OPTIONS

## TIME / INPUT REQUIRED:

- up to 12 months
- 60–90 National expert days
- 25–45 International expert days




## THIS CHAPTER EXPLAINS:

→ How to support sectoral adaptation?
→ How to pre-select adaptation options for macro-analysis?
→ How to prepare the data for model integration?

## THIS CHAPTER PROVIDES IN-DEPTH INFORMATION ON **2 TASKS**

Following the setup of the macroeconomic model and identification of climate risks, the task is to identify relevant adaptation measures by:

STEP 3 **TASK 1**

# CREATION OF A PRIORITY LIST OF ADAPTATION MEASURES

Since macroeconomic assessments are rather resource intensive it is not appropriate to conduct them all possible adaptation measures. One of the reasons is that macroeconomic assessments of adaptation measures rely on data that is not always readily available (more in *task 3.2*). As such, it is recommended to prioritize measures first to keep the need for additional data collection to an efficient level.

There should be clear criteria for selecting those adaptation measures to be analysed with a macroeconomic model. The following criteria provide a starting point for filtering the adaptation measures for model application. Thus, it should be noted that if an adaptation measure has not been chosen to be implemented in the model, it still can be important for the comprehensive adaptation strategy and provide positive impacts.

1. **Relevance in policy processes and need for action.** A first important aspect is the relevance of the adaptation measure for policy processes. If the need for action due to the climate risk or in an economic sector is particularly high, then adaptation measures that address these risks should rather be considered. As it has been shown above, for example, the agriculture and tourism are very relevant for the economy in Georgia. Accordingly, adaptation measures that have an impact on these two sectors may be particularly relevant for a detailed analysis.

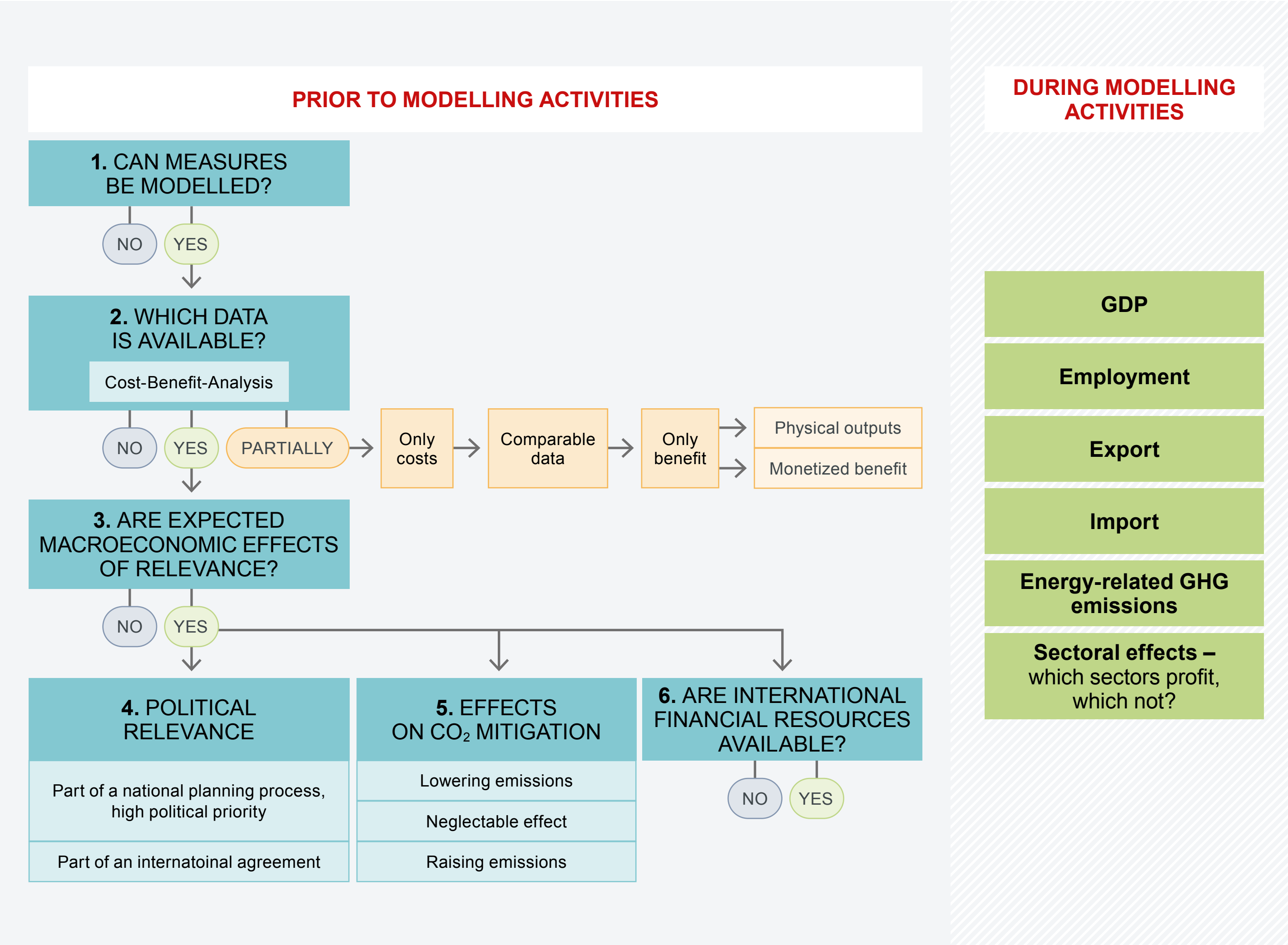
2. **The measures must be appropriate to the climate impacts.** Only those adaptation measures should be analysed with regard to the macroeconomic effects that are appropriate to reduce the impacts of a particular climate hazard under investigation. Thus, an adaptation measure for agriculture should have a positive impact on crop yields, for example in respect to increasing drought risks.

3. **The (expected) macroeconomic effects are relevant.** A third important aspect is the expectation about the macroeconomic effects. The use of the macroeconomic model only makes sense if the expected macroeconomic effects are relevant and if interactions between different economic sectors are expected. The macroeconomic relevance may result from both the costs and the benefits of the adaptation measure. It is especially useful to apply the model for assessments of high-cost adaptation measures, such as large infrastructures, and use to the results to justify respective investments.

4. **Ability to translate it into the macroeconomic model.** Only if the sectoral adaptation measures can be described in a from compatible with the macroeconomic model can they be integrated at the next step of assessment.

The following *Figure 17* gives an overview the criteria and a possible selection process:

**Figure 17: Criteria for the selection of adaptation measures**




*Source: GIZ (own illustration)*

For the selection of adaptation options stakeholders should also consider the different types of adaptation measures that can be assessed using macroeconomic models. This differs from the more engineering focus of technical adaptation as the adaptation of economic agents can be supported with a broad set of economic policy instruments. *Table 7* provides an overview of the different types of adaptation policy instruments that can be considered and highlights options how such measures can be translated or mapped into the economic model.

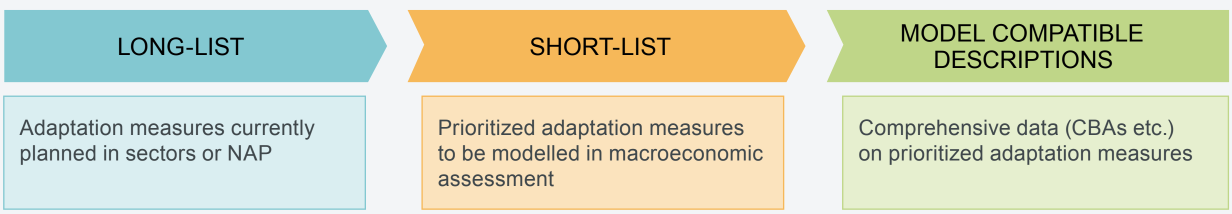
## Table 7: Overview of the different types of adaptation policy instruments

| TYPE OF INSTRUMENT | MAP INTO ECONOMIC MODEL |
|---|---|
| Command and control | The regulation is treated as binding. |
| Planning | If this results in a physical/monetary change, it is mapped. |
| Price instrument | Prices are implemented. |
| Direct subsidy | Subsidy is regarded as successful. |
| Volontary agreement | The agreement is considered to have been fulfilled. |
| Management of information and knowledge | If this results in a physical/monetary change, it is mapped. |
| Provision of basic data | If this results in a physical/monetary change, it is mapped. |
| Inspection | If this results in a physical/monetary change, it is mapped. |

The instruments are a possibility of the government to prescribe, regulate, initiate, or create incentives for adaptation measures. Not all types of instruments can easily be translated into model parameters. While the economic adaptation instruments (price instrument, direct subsidy) can be directly implemented to the macroeconomic model, other instruments need more clarification or assumptions. For example, with regard to a command-and-control instrument, the assumption entered into the model would be to treat the regulation as binding, i.e., all people comply to the regulation.
It is recommended to conduct stakeholder dialogues around relevant adaptation measures and raise awareness among the stakeholders for the factors to be considered as described above.

The identification process can be structured around the following steps: first establishing a long list (e.g. based on an existing NAP), second having a short list of priority measures and finally having adaptation measures described in a the required economic form such as cost-benefit analyses (CBA) compatible with the macroeconomic model, see *Figure 18*:

## Figure 18: Steps for identifying adaptation options for macroeconomic assessments:




*Source: GIZ, own illustration*

### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

*The identification of relevant adaptation options to be considered builds on the policy-entry point studies conducted with stakeholders. The identification of a short-list of measures operationalizes the adaptation planning into concrete policy options and should formulate concrete request to the technical experts running the macroeconomic model. Selected reports and templates for organizing this process are available here. Notably parts from the "Draft ToR on Policy Advice Support for CRED" could be used to organize support. In total national experts might provide 25-40 days to discuss key planned adaptation measures, organize workshops and report on most suitable measures, building on the criteria outlined above. International experts can facilitate these processes, contributing to around 10-20 days.*

STEP 3 **TASK 2**

## COMPILING DATA ON PRIORITY ADAPTATION MEASURES FOR MODEL INTEGRATION

Building on the shortlist of priority measures the subsequent model integration and assessment of the prioritized adaptation measures requires a robust sectoral pre-assessment and quantification of all measures.

In particular sectoral cost-benefit analyses (CBA) of the sectoral impacts of the different adaptation measures are needed for assessing further macroeconomic effects. If national data is not obtainable searching for international data is possible with assumptions on adequate cost and benefits to be made (for example taking heat stress effects on labour productivity from the ILO). Since the quality of the model conclusions is strongly reliant on the quality of the data, it is essential to have enough validation including stakeholder discussions verifying the assumptions to ensure the robustness of the model results.

It should be assumed that the ministries of economy themselves cannot provide this data, additional support and interaction with sectoral line ministries is needed to enable relevant institutes and experts are involved to deliver such data. If not existant they can be created by national experts building on similar CBAs created building on international reference cases and adapt them to local/national context. This might also involve additional interviews with stakeholder groups to have validated estimations on required investments (the adaptation costs), reduction in the climate damages they address and other associated economic co-benefits (the benefit of adaptation).

The cost component of the CBAs includes assumptions on the necessary investments and related interest payments. Different financing options (public, private international climate finance) should be taken into account, including different interest rates that would apply. These CBAs are then fed into macroeconomic models to assess the economy-wide impacts of these measures. Different financing options could be considered by different assumptions. For the macroeconomic analysis, it is primarily important whether financial resources are additional (international) or whether they crowd out other investments at home.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

The CRED project relied on national experts to collect and validate the CBAs on adaptation measures. Templates for collecting data on adaptation measures and CBAs and examples of CBAs for both e3 and DGE model used by the CRED project are available below. Certainly all such ToR and templates need to be strongly adapted to specific application contexts.

Selected reports and templates for data collection are available *here*.
Documents provided there include:

- "Template for e3 adaptation measure data collection (.xsxl)"
- "Template for DGE-CRED adaptation measures (.xsx)l"
- "Example report on dyke management in Vietnam – input for DGE-CRED model"
- "Draft ToR for Agricultural CBAs"
- "Draft ToR for Risk Assessment and Adaptation Overview"

The estimated expert days required for national experts are 35-50 but could be even more. The challenge is to describe planned adaptation measures in a quantitative way and format specific to the macroeconomic model (yearly investment needs for example), including its effect in reducing the impact from a specific hazard. Such estimations are not readily available and also need to be discussed with relevant stakeholders. For the facilitation of these and ensuring international best practices are taken into account the support from international experts is estimated to be 5-25 days just for ensuring that data sets are valid and compatible with the model requirement.

*Table 8* presents an overview of the time and estimated expert day requirements for the specific tasks involved to identify priority adaptation measures and compile relevant data needed to assess them with the macroeconomic model.

### Table 8: Timeline for identification of priority adaptation action

| **WORK PLAN** (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Identification of priority adaptation action | ◑ 5-10<br>● 0-5 | ◑ 20-30<br>● 10-15 | | | | | | |
| **Task 2:** Compiling data on priority adaptation action | | ◑ 5-10<br>● 5-10 | ◑ 30-40<br>● 10-15 | | | | | |
| ◑ **National expert days** (total) | **5-10** | **25-40** | **30-40** | | | | | |
| ● **International expert days** (total) | **0-5** | **15-25** | **10-15** | | | | | |

*Note: Numbers refer to a systematic application of CRED approach in one country. Required time frames and expert days strongly on national circumstances, number are rough estimations only. For several countries scale effects do apply (implementing in x countries implies multiplication by less than x). Additional project management costs and overheads are not included.*

# 4 ASSESSING ADAPTATION OPTIONS

**TIME / INPUT REQUIRED:**

- up to 9 months
- 20–40 National expert days
- 65–110 International expert days


**THIS CHAPTER EXPLAINS:**

→ How is the benefit of adaptation defined?
→ How to integrate adaptation options into the macroeconomic model?

## THIS CHAPTER PROVIDES IN-DEPTH INFORMATION ON **2 TASKS**

Following the setup of the macroeconomic model and identification of climate risks, the task is to identify relevant adaptation measures by:

| | |
|---|---|
| **TASK 1:** integrating the adaptation options into the macroeconomic model | *p. 63* |
| **TASK 2:** compiling data on priority adaptation measures for model integration | *p. 65* |

STEP 4 **TASK 1**

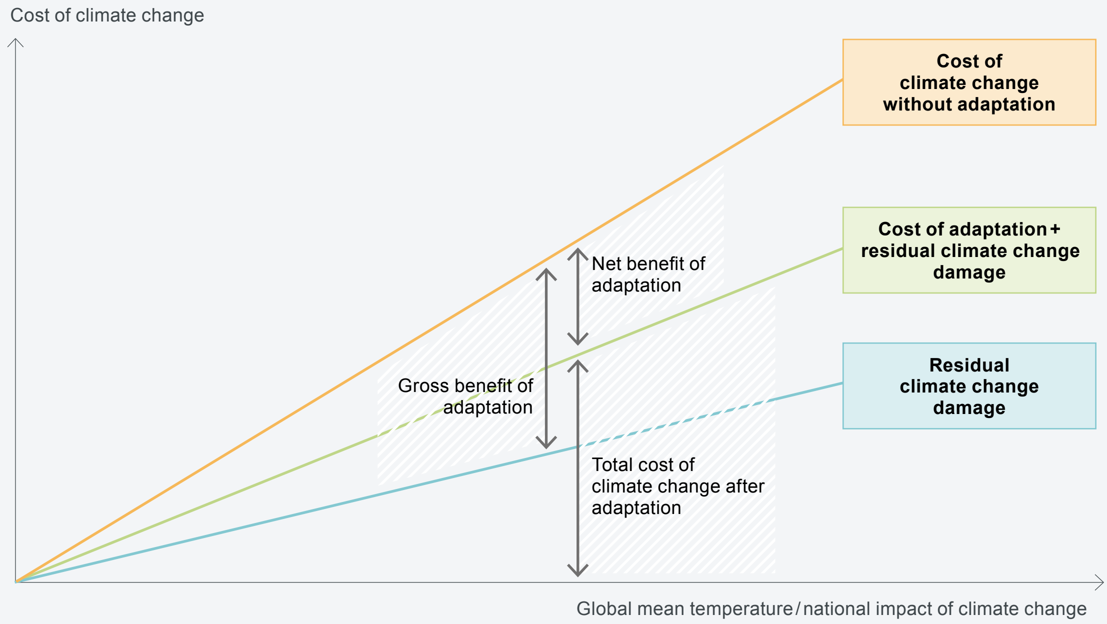
## INTEGRATION OF ADAPTATION OPTIONS INTO THE MACROECONOMIC MODEL

Step 4, the assessment of priority adaptation measures, is the key value proposition of the capacity development for climate-sensitive macroeconomic modelling. It is important to integrate this step systematically in ongoing adaptation action of the country by engagement of political stakeholder involved in adaptation planning, as outlined in *chapter 1*. The macroeconomic assessment is a highly technical process so good communication and stakeholder engagement is needed. The 2023 published *Climate Risk Communication Guideline* supported by the adaptation community provides useful advice in that regard.

The priority adaptation measures can now be integrated in the model as adaptation scenarios using the adaptation option-specific data. This provides insights into the broader economic effects of investments in specific adaptation measures compared to a situation with climate change impacts and no adaptation action. Such assessments allow to identify those measures (or a combination thereof) that are especially beneficial for the whole economy in the mid- to long-term and thereby contribute to resilience building.

One key challenge in the economics of climate change adaptation is the fact that the costs and benefits of different adaptation measures often occur at different times and in different places. For example, the costs of implementing adaptation measures, such as building sea walls or improving irrigation systems, are often borne by governments or individuals in the present, while the benefits of these measures, such as reduced damage from natural disasters, may only be realized in the future. Putting such costs (investments) and benefits into perspective is the key value added. A central approach is the comparison of scenarios with and without adaptation action. It is usually assumed that even with adaptation some residual damage persists.
This allows to compare a hypothetical scenario without investments in adaptation to a scenario with investments in adaptation (including the cost of adaptation and some residual damage). This difference can be described as the net adaptation benefit as depicted in *Figure 19*.

## Figure 19: The Economics of Adaptation




*Source: Own illustration based on Stern Review (2007)*

Another challenge in the economics of climate change adaptation is the fact that many adaptation measures have uncertain or "difficult-to-quantify" benefits. For example, it may be difficult to estimate the exact economic benefits of building a sea wall to protect against sea level rise, as it is difficult to predict exactly how much damage the sea wall will prevent.

Overall, the economics of climate change adaptation is a complex and challenging field, but it provides an important additional perspective for understanding how to reduce the negative impacts of climate change and support sustainable development. This aspect is taken up further in *chapters 5* and *chapter 6* on how to use results of macroeconomic modelling.

### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

*The two tasks of integration into model and actual modelling are closely related and overlap to some extent. The integration into the model refers more to adapting and translating the sectoral CBAs prepared in step 3 into the model. The final modelling refers more directly to the actual modeling and generation of outputs. For the integration of CBAs into the model international experts can allocate around 25-40 expert days. This focus on "model integration" is necessary as not all data sets might be directly fully compatible with the macroeconomic model and creating the corresponding scenarios and equations takes some time. National experts should also be involved in this task to respond to emerging data gaps when integrating adaptation measures in the model (about 10-20 expert days). Further demands on data can be expected on top of the support to compile the data (see task 3.2).*

STEP 4 **TASK 2**

# MODELLING MACROECONOMIC IMPACTS OF ADAPTATION MEASURES

Once the adaptation measures are integrated into the model, the actual assessment of potential macroeconomic effects can take place. For this step, scenario analysis can be used to assess the different adaptation options and compare their effects. Specifically, three different types of situations are compared with the macroeconomic model:

1. climate change is not occurring (hypothetical reference/ baseline scenario) based on historical economic data, which up to date does not show significant impacts of climate change.
2. a specific climate hazard (e.g., droughts) intensifies up to 2050 (climate change scenario) based on climate hazards analysis linked to IPCC's current Representative Concentration Pathway (RCP) or Shared Socioeconomic Pathways scenarios (SSP).
3. investments in a measure adapting to the climate hazard (e.g., irrigation systems) are made (adaptation scenario) based on cost-benefit analyses (CBA). The model compares impacts of one or a bundle of adaptation measures.

When comparing scenario (1) and (2) it becomes clear how the climate hazard impacts the national economy in the long run. For example, a CRED analysis showed that Kazakhstan's GDP is up to 2.4% lower with intensifying droughts compared to a situation without droughts. Amongst others, this is caused by the need to import more wheat and electricity.

Comparing scenario (2) and (3) allows to evaluate how investments in an adaptation measure can influence the long-term economic development under climate change. Following the previous example from Kazakhstan, the analysis showed that the GDP is annually up to 1.2% higher with adaptation investments compared to a drought scenario without adaptation action. This results from intensified construction activity and higher crop yields due to additional irrigation facilities. See the *policy brief on agriculture* for details. The modelling results should also be translated into adequate outputs to be discussed with relevant stakeholders.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

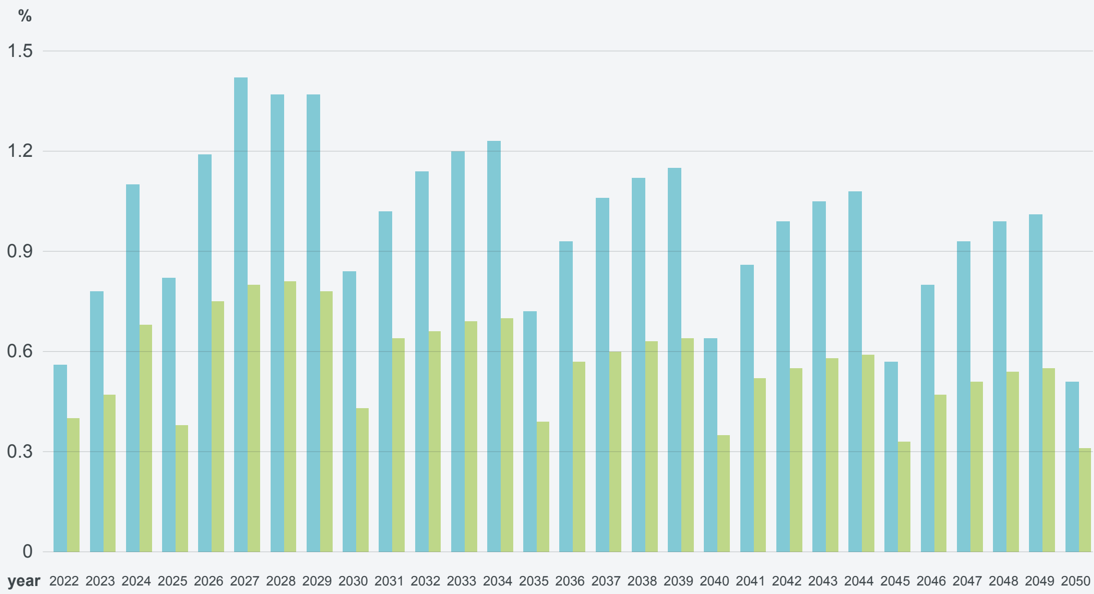
*A more extensive description of how the actual modelling works and how model developers take part in this step is available in the capacity building material discussed in* chapter 2*. In general, the final modelling of prioritized adaptation measures requires substantial engagement from international experts, 40-70 days might be calculated. National experts should also be involved in this task to respond to emerging data gaps and support preparation of results (about 10-20 expert days).*

Below are additional illustrations of results achieved by the CRED modelling.

## Box 6: Exemplary results calculated with the e3.ge model

With mounting impacts of climate change, Georgia's agriculture sector is expected to be increasingly affected by heavy winds and resulting wind erosion especially in dry land areas. In order to evaluate the usefulness of different adaptation options, Georgia's macroeconomic model e3.ge was used to assess the economy-wide effects of investments in windbreaks amongst other adaptation measures. *Figure 20* shows how investments in windbreaks could affect Georgia's GDP and level of employment.

### Figure 20: Economy-wide effects of windbreak investments




*Source: own figure based on GIZ (2022a)*

Compared to a situation without adaptation, investments in windbreaks result in a yearly increase of up to 1.4% of GDP and up to 0.8% higher employment rates corresponding to up to 13,000 additional jobs. Such investments have positive sectoral linkages leading to increased wage levels and higher consumption expenditure of up to 1.2% per year compared to a scenario where no adaptation action is taken. From a sectoral perspective, the agricultural sector experiences an increase in production due to increased yields as a result of the windbreaks, but also because the plants required for the windbreaks (seedlings) are grown domestically.

## Box 7: Exemplary results calculated with the DGE-CRED model

Evaluating several adaptation measures under different climate change scenarios, the DGE-CRED model depicts the effects on relevant components in comparison to climate change scenarios without adaptation action. *Figure 21* compares the impacts on consumption, investments, government expenditure, net exports, housing expenditures and GDP when dikes are being built as an adaptation measure under the SSP 245 scenario in comparison to no adaptation investments. Importantly, the adaptation measure has a positive impact on societal welfare as illustrated by the consistently higher consumption and less housing expenditures for the population in comparison to no adaptation. However, it should be noted here that the construction of dikes is associated with lower GDP and investments in the short, medium and long run under the SSP 245 scenario, as the dikes prevent damages of the capital stock by e.g. floods, which in turn leads to fewer investments in reconstruction. This shows that looking beyond the sole effect on GDP is important for a more holistic understanding of the economic impacts of climate change and respective adaptation investments.

### Figure 21: Economy-wide effects of windbreak investments


*Source: own figure based on GIZ (2022a)*

*Table 9* presents an overview of the time and estimated expert day requirements for the tasks involved to assess adaptation measures with the macroeconomic model.

## Table 9: Timeline for assessing adaptation options

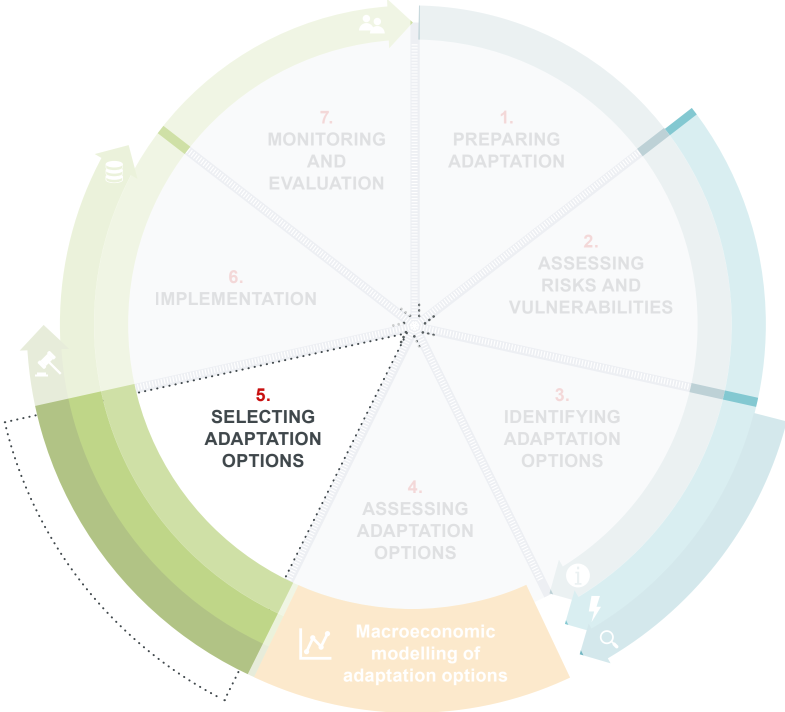
| WORK PLAN (month of project implementation) | 1–6 | 7–9 | 10–12 | 13–15 | 16–18 | 19–21 | 22–24 | 25–30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Integration of adaptation options into model | | | | ◑ 5-10<br>● 20-30 | ◑ 5-10<br>● 5-10 | | | |
| **Task 2:** Modelling macroeconomic impacts | | | | | ◑ 5-10<br>● 20-40 | ◑ 5-10<br>● 20-30 | | |
| ◑ **National expert days** (total) | | | | **5-10** | **10-20** | **5-10** | | |
| ● **International expert days** (total) | | | | **20-30** | **25-50** | **20-30** | | |

*Note: Numbers refer to a systematic application of CRED approach in one country. Required time frames and expert days strongly on national circumstances, number are rough estimations only. For several countries scale effects do apply (implementing in x countries implies multiplication by less than x). Additional project management costs and overheads are not included.*

# 5 SELECTION OF ADAPTATION OPTIONS

**TIME / INPUT REQUIRED:**

- up to 9 months
- 70–105 National expert days
- 40–60 International expert days




**THIS CHAPTER EXPLAINS:**

→ How the modelling results create added value for adaptation planning?
→ How to establish effective inter-ministerial coordination mechanisms?
→ How to establish interfaces for the integration of results?

**How can results from the macroeconomic models be used to inform adaption planning?**
Macroeconomic assessments of particular measures can inform adaptation planning in two distinct ways: first, it can **support adaptation planning in particular sectors of the economy** and second, it provides a **national overview concerning the distribution of climate impacts and adaptation benefits** on the economy thereby informing adaptation planning on a more general, aggregate level.

## THIS CHAPTER PROVIDES IN-DEPTH INFORMATION ON **2 TASKS**

In this chapter we suggest the following steps to select adaptation options for policies:

STEP 5 **TASK 1**

# TRANSLATE RESULTS INTO RECOMMENDATIONS

To support adaptation planning in particular sectors it is required that sectoral experts and decision-makers can access and understand the results generated by the macroeconomic models to improve their adaptation planning. Results of the modelling should therefore be translated into suitable policy briefs that provide specific recommendations. They should be discussed in stakeholder dialogues to raise awareness about the results and discuss implications for sectoral adaptation action.

For this the "model users" play an important, unlike model developers involved in the technical setup and modelling of models they are sectoral experts understanding the policy entry points for the modelling results. They should be included in stakeholder workshops and discussions as model users from the beginning, in particular when identifying the priority adaptation options to be modelled. This will enable them to use the results for improving their selection and ultimately implementation of adaptation measures.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

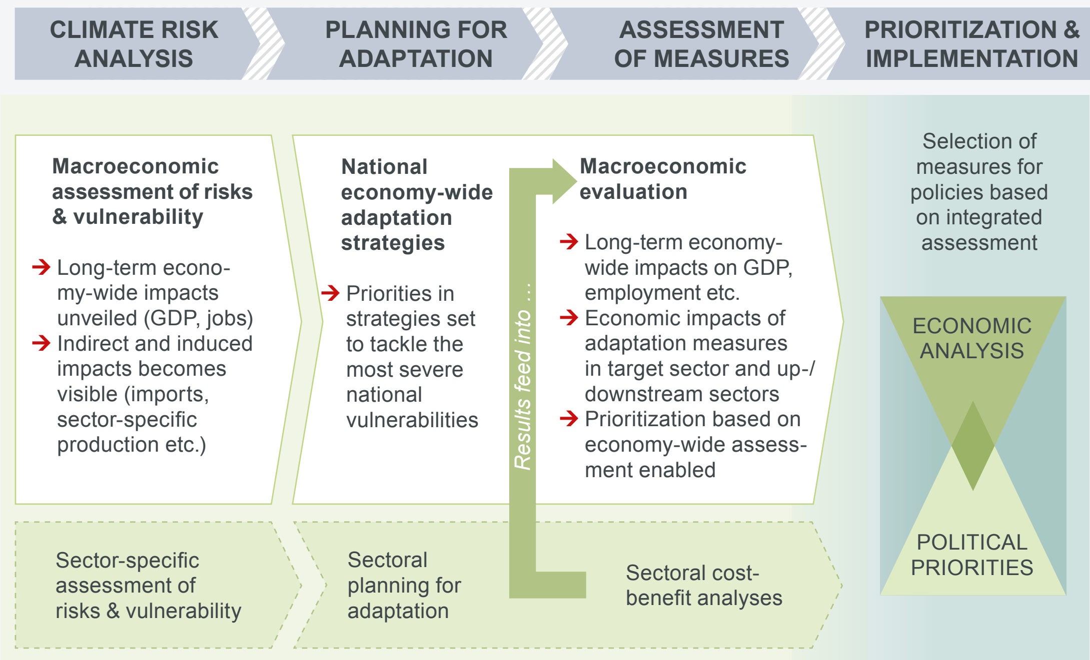
*It is recommended to commission national experts to support the development of recommendations based on the modelling results. This implies revisiting the priority adaptation measures identified and providing targeted additional information in the form of policy briefs and workshop input to present and discuss the model findings with relevant stakeholders. About 40-60 expert days can be calculated. International experts (modelling experts) are needed to extract further relevant numbers from the models or adjust the model as needed, adaptation policy experts are needed to facilitate stakeholder dialogues and ensure user centered communication of results. A total of 10-20 days can be calculated for international experts.*

STEP 5 **TASK 2**

# INTEGRATION OF MODELLING RESULTS INTO PLANNING

The final decision on spending public funds for an adaptation measure requires more than the modelling results. But the modelling results provide an additional valuable information to be considered in the decision-making process. For an actual investment decision, the macroeconomic modelling results need to be complemented with non-economic criteria. This is illustrated in *Figure 22*. In the upper part, the added value of the macroeconomic evaluation is highlighted, whereas the lower part shows the traditional sector-specific evaluation of adaptation measures.

**Figure 22: Added value of macroeconomic modelling for assessing adaptation options**




*Source: GIZ (own illustration)*

Macroeconomic analyses further support the prioritization of measures. They provide additional information on the broader public benefits (national GDP, employment effects etc.) of investments in adaptation of the targeted sector (e.g. agriculture) and in up- and downstream sectors (e.g. construction, food industry). Thereby, they unveil a more complete picture on economic implications allowing to embed adaptation investments in the broader framework of the national economy. However, the information needs to be targeted and linked to actual decision making processes. Sufficient support from national experts should be considered, as also indicated in *Table 10*.

Typical activities that facilitate the integration of results into policy planning include:

- Establishing appropriate working relation with the relevant ministries and departments in the partner countries to facilitate the development of policy recommendations.
- Ensuring participation of the private sector in the process, organizing and financing the production of technical reports and best practice examples by local experts from partner institutions.
- Facilitating requests for ad-hoc advice from other stakeholders to support policy relevance of the documents.
- Provision of technical input to high-level workshops with policy makers and their technical staff on the modelling results and derived recommendations for action.
- Targeted translation of technical modelling results into relevant policy advice and presentation at the workshop. This should include provision of feedback and other backstopping services on briefing notes etc. according to the specific demands that may arise.
- Enabling the participating institutions to timely and specifically provide the modelling results needed for policy advice and support the translation of technical modelling results into relevant policy advice.

## ESTABLISH EFFECTIVE INTER-MINISTERIAL COORDINATION MECHANISMS

As it has become clear throughout the handbook, it is important to consider that the establishment of a macroeconomic model does not work as a standalone workstream within one ministry, for example the ministry of economy. Rather it is necessary to establish a functioning network of stakeholders around the technical experts that will function as model developers. The setup of effective effective inter-ministerial coordination mechanisms is a key step to enable integration of modelling results into planning processes.

An example from Kazakhstan has already been shown in *Figure 6* in *chapter 1*. Such a network of interministerial institutions is required for effective use of the models. This becomes clearer when considering a typical process of key steps required. *Table 10* outlines key steps to embed the economic modelling into adaptation planning and which institution could be in the lead.

### Table 10: Key steps required for using a macroeconomic model for adaptation planning

| STEPS | LEAD | PURPOSE |
|---|---|---|
| **Requesting modelling support** | Public institution requesting modelling support (i.e. NAP coordinating unit, Ministry for Agriculture or Environment) | To submit an official request for modelling support to Ministry of Economy (here assumed as model owner) |
| **Reviewing and prioritizing requests** | Ministry of Economy (in collabora-tion with Ministry of Environment as needed, which is assumed here to lead national adaptation planning) | To review requests and identify which requests to prioritize if multiple requests are received at once |
| **Agreeing on a workplan** | Public institution requesting modelling support | To clarify roles and responsibilities, timeline, and the type and format of the model results |
| **Collecting data and information** | Public institution requesting modelling support | To collect data and information needed for running the model (through literature review, key expert consultations, and/or primary data collection) |
| **Updating the reference scenario (optional)** | Ministry of Economy | To recalculate the reference scenario to reflect the country most recent economic development and forecasts |
| **Running the model** | Ministry of Economy | To establish scenario(s) with climate change impacts and scenario(s) with investment in adaptation measure(s) |
| **Analysing and communicating the results** | Public institution requesting modelling support (with Ministry of Economy support as needed) | To compare the scenario(s) with climate change impacts and the scenario(s) with investment in adaptation measure(s) |

As the steps outlined in *Table 13* above indicate: different institutions consider adaptation from distinct political mandates and perspectives. Supporting adaptation action requires close coordination between policy makers involved in the adaptation planning process. The results of the modelling can support the dialogues and coordination by providing a common platform to integrate expectations regarding adaptation action and discuss possible cost and benefits in line with national development objectives. The following formats can facilitate interinstitutional cooperation on adaptation planning:

- Joint meetings with experts from other institutions to discuss adaptation options from different points of view. This is primarily to gather knowledge that can then be used for model-based scenario analysis.
- Capacity building on model application, i.e. scenario analysis for key experts and "model developers". This is a time-consuming activity and usually limited to selected modeling experts. It is a prerequisite for independent future use and ownership of the model.
- Joint commenting by experts from different institutions of policy briefs on modelling results to ensure ownership of modelling results across different ministries

Access to the model and/or model results. While the access to the macroeconomic model might be restricted by the model owner (e.g. Ministry of Economy), model results can be widely disseminated and discussed.

### IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

*The outlined activities to facilitate integration of results into policy planning require close cooperation with national stakeholder. A user-centered approach is advised to understand for each specific sector or national policy process what the requirements and potential added-value from the macroeconomic assessment are. Support from national experts can be calculated to be around at least 30-45 days for organizing stakeholder specific interfaces for using modelling results. International (adaptation policy) experts can facilitate dialogue processes, contribute best practices etc. The international modelling experts may need to support the translation of technical model results into recommendations, support the creation of additional data or develop specific model extensions that might arise. A total of 30-40 international expert days can be calculated for this.*

*Table 11* presents an overview of the time and estimated expert day requirements for the tasks involved in the selection of adaptation measures and the broader objective of integration modelling results into planning processes.

**Table 11: Timeline for selection of adaptation options**

| **WORK PLAN** (month of project implementation) | **1 – 6** | **7 – 9** | **10 – 12** | **13 – 15** | **16 – 18** | **19 – 21** | **22 – 24** | **25 – 30** |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Translate results into re-commendations | | | | | ◑ 20-30<br>● 5-10 | ◑ 20-30<br>● 5-10 | | |
| **Task 2:** Integration of modelling results into planning | | | | | | ◑ 10-15<br>● 15-20 | ◑ 20-30<br>● 15-20 | |
| ◑ **National expert days** (total) | | | | | **20-30** | **30-45** | **20-30** | |
| ● **International expert days** (total) | | | | | **5-10** | **20-30** | **15-20** | |

# 6 IMPLEMENTATION

## TIME / INPUT REQUIRED:

- up to 15 months
- 100–150 National expert days
- 50–75 International expert days


## THIS CHAPTER EXPLAINS:

→ How to support implementation by macroeconomic modelling results?
→ How to support budget and climate finance allocation?

The implementation of adaptation action was not supported by the CRED project due to time and other constraints. The step is nevertheless included as it emerged as an important learning that more emphasis should be placed on the translation of modelling results into adaptation action. Recommendations for this step are thus more speculative.
The macroeconomic modelling results can inform in particular larger public adaptation schemes. Implementation is enabled by providing expected returns on public investment in regard to impacts on the national economy for different adaptation measures and climate scenarios. Macroeconomic assessments provide an enhanced evidence base for the selection of measures (*chapter 5*) but also support follow up negotiations on budget allocation for prioritized adaptation. The chapter will also elaborate on the potential of modelling results for climate finance, finance risk management, and disaster risk reduction.

## THIS CHAPTER PROVIDES IN-DEPTH INFORMATION ON **2 TASKS**

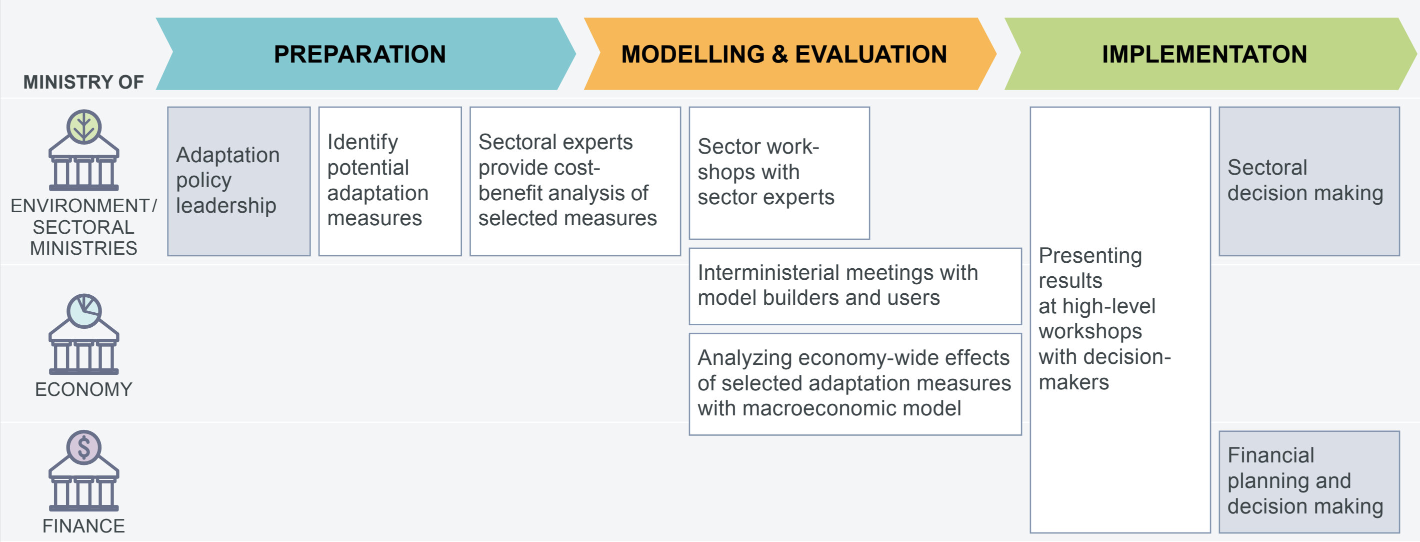
We suggest the following steps for the implementation of adaptation action:

STEP 6 **TASK 1**

# ESTABLISH STAKEHOLDER INTERFACES FOR ADAPTATION ACTION

Well established stakeholder interfaces are key for using the results achieved by macro-economic modelling. Working with and expanding existing networks and interfaces is thus key for moving into implementation. Recommendations focusing on selected key measures (*chapter 5*) can be used to facilitate adaptation action. This should build on the entry points identified in *chapter 1*. A generic process is depicted in *Figure 23*:

**Figure 23: Actor involvement in adaptation policy process**



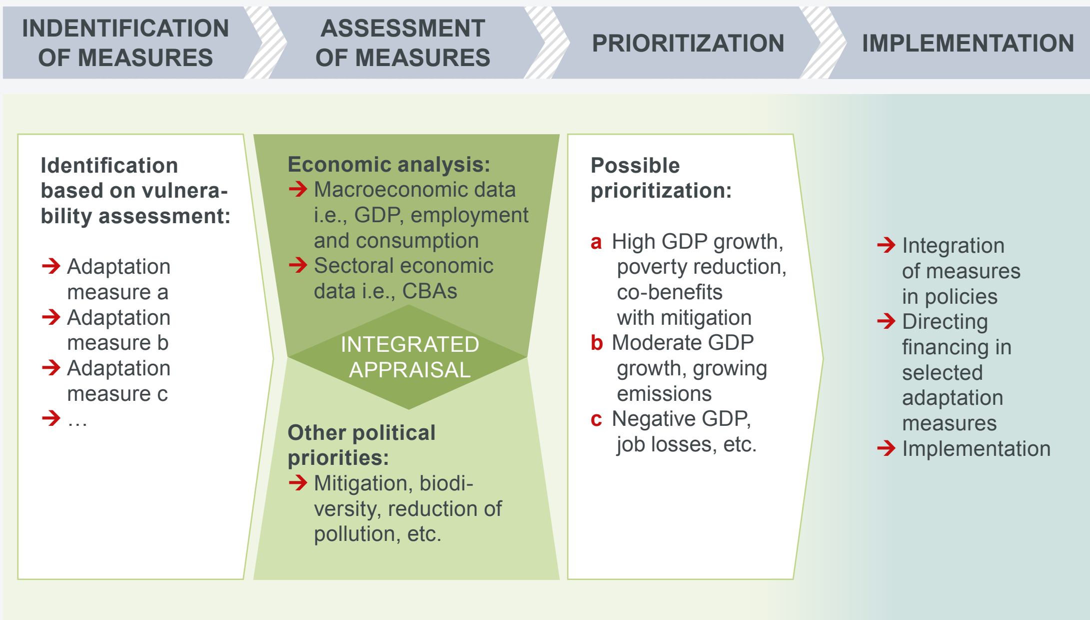

*Source: own illustration*

Economic modelling results can facilitate adaptation action, but it requires a deliberate approach for managing stakeholder interfaces. This is an imminent challenge because adaptation action happens in sectoral (e.g. agricultural) planning and budgeting, but the macroeconomic assessments are conducted by economic experts associated with e.g. the ministry of economy or similar depending on the country context. The flow of adaptation measures from preparation, to modelling and evaluation and implementation therefore involves different stakeholders. *Figure 23* highlights the broad range of interfaces that emerge between different stakeholders involved in adaptation planning, economic evaluation and actual implementation. Implementing adaptation action requires effective interfaces between the involved stakeholders and it is thus important to support these interfaces through effective coordination between the different authorities involved in the adaptation planning process. This involves the support of targeted communication channels, coordination mechanisms and clarification of responsibilities, as was also outlined in *chapter 5* concerning the selection of priority measures. To summarize, economic modelling contributes to implementation of adaptation action when the interfaces between different actors work effectively.

# INTEGRATING ECONOMIC ASSESSMENTS WITH DEVELOPMENT AGENDAS

National adaptation action can be improved by the economic evidence from the macroeconomic assessment of the prioritized adaptation measures. However, politically feasible action needs to be based on both qualitative and quantitative (i.e. supported by modelling) assessments. Economic assessments are crucial for political decision-making but need to be situated with other aspects that influence the decision for or against an implementation decision. As *Figure 24* illustrates, when selecting adaptation measures for implementation, other criteria resulting from political priorities are also taken into account. Political priorities, which cannot solely be analysed with the abovementioned economic instruments (i.e., biodiversity considerations, reduction of pollution, mitigation) complement the economic assessments. Although the financial and economic impacts are relevant for policymakers to prioritise adaptation measures, other criteria must be considered as well such as health aspects and ecosystem services (biodiversity, regulation of the water balance) to get a more comprehensive evaluation of a measure, and to formulate an appropriate adaptation strategy. The economic effects should only be one possible basis for decisions on the selection of adaptation measures. The combination of both macroeconomic analyses and socio-ecological considerations lead to an integrated appraisal of adaptation measures and support climate resilient economic development.

**Figure 24: From identification to implementation of different adaptation measures**




*Source: GIZ (own illustration)*

Ultimately, effective adaptation actions need to be mainstreamed in the decision-making of different ministries such as environment, economy, finance, energy, and other institutions.

## IMPLEMENTATION REQUIREMENTS:

*Projects can support stakeholder interfaces for adaptation action only by deeply engaging with national processes. Beyond an "entry point" study for policy integration it is suggested to cooperate closely with national and international experts to better integrate modelling results with actual requirements from national stakeholders. National experts and the local project implementation unit play a key role, a total of 40-60 expert days might be considered over a time span of 4-6 month allowing for sufficient engagement and developing of inter-stakeholder agreements. International experts also play a role by presenting lessons learnt from other countries and providing facilitative support for key steps. 20-30 expert days might be allocated (per country).*
*The CRED project engaged with the International Institute for Sustainable Development (IISD); exemplary ToR can be found here.*

STEP 6 **TASK 2**

# LINKAGES WITH BUDGET AND CLIMATE FINANCE ALLOCATION

Financing the necessary adaptation will be a huge challenge for many highly exposed economies. The Adaptation Gap Report 2022 summarized the potential finance needs for different regions where annual adaptation finance needs for some regions are in high scenarios up to 6% of GDP (see *Table 12*). The effective allocation of climate finance requires a solid evidence base.

**Table 12: Potential developing countries adaptation finance needs for 2021–2030**

| REGION | ANNUAL ADAPTATION FINANCE NEEDS IN US$ BILLION (2020 value) | | ANNUAL ADAPTATION FINANCE NEEDS AS A PERCENTAGE OF GDP | |
|---|---|---|---|---|
| | MEDIAN | MIN–MAX | MEDIAN | MIN–MAX |
| East Asia & Pacific | 69 | 27-208 | 0.35 | 0.14–1.05 |
| South Asia | 59 | 23–177 | 1.69 | 0.66–5.10 |
| Sub-Saharan Africa | 36 | 14–109 | 2.10 | 0.82–6.34 |
| Latin America & Caribbean | 21 | 8–62 | 0.41 | 0.16–1.25 |
| Middle East & North Africa | 15 | 6–44 | 0.47 | 0.19–1.43 |
| Europe & Central Asia | 4 | 1–11 | 0.69 | 0.27–2.08 |
| **Global** | **202** | **79–612** | **0.60** | **0.24–1.80** |

*Source: Own illustration based on United Nations Environment Programme (2022)*

The macroeconomic models can put the different investment needs for adaptation measures into context and contribute towards a systematic overview on the investment demand and finance needs for adaption. Aggregated estimation of investment demand is based on validated sectoral data on investments required for adaptation action. Macroeconomic models support the aggregation of sectoral investment needs and support prioritization and clustering and systematic reporting.

Such comprehensive assessment of investment needs also helps to make financing opportunities visible and can inform international partner organizations and investors by providing a solid economic evidence base. Cooperation should be established to link domestic adaption action with increasing international climate finance support.

Results can be discussed in that regard with relevant international partners for example Adaptation Fund, World Bank, Green Climate Fund, and regional climate finance organizations to leverage results and support finance allocation.

# USING MACROECONOMIC RESULTS TO INFORM FINANCIAL SECTOR EXPOSURE TO CLIMATE CHANGE

Central banks, private banks and other financial institutes are increasingly considering climate change and the effects of increasing physical risks on the financial sector. This concerns the credit portfolios of individual banks as well as the financial sector as a whole. Many central banks are thus developing their own models for this purpose, which increasingly recognize the importance of a differentiated sectoral representation for the issue. This is supported among others by the *Network for Greening the Financial System* (NGFS). A useful summary is provided on the *NGFS Scenarios Portal*. In the context of the CRED project for example, the Georgian central bank was interested in close cooperation and the (sectoral) modelling conducted by the Ministry of Economy and Sustainable Development (MoESD) of Georgia. The results from the CRED model focus on climate risks for the real economy and the specific sectors, this makes the result highly relevant for central and development banks that are interested to support the stability of the financial market of a particular country.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

*In the context of the CRED project this step was only partially achieved. The National Bank of Georgia was closely involved and continues to engage with the macroeconomic model developed in Georgia. CRED project did not result into funding allocation. However, it is recommended to put more emphasis on this and allocate national and international expert days on this task to support transfer of modelling results into adaptation action which requires funding. National experts could prepare integration into national public budgeting processes and support the drafting of climate finance proposals to international climate finance institutions. For both, specific technical support from international experts is advisable to facilitate linkages with relevant institutions and support compliance with international standards on adaptation finance. A rough estimation is around 60-90 days for national experts and 30-45 for international experts.*

*Table 13* presents an overview of the time and estimated expert day requirements for the tasks involved in supporting implementation of adaptation action.

**Table 13: Timeline for supporting implementation of adaptation action**

| **WORK PLAN** (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Establish stakeholder interfaces for results | | | | | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 | | |
| **Task 2:** Build linkages with budget and climate finance | | | | | | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 | ◑ 20-30<br>● 10-15 |
| ◑ **National expert days** (total) | | | | | **20-30** | **40-60** | **20-30** | **20-30** |
| ● **International expert days** (total) | | | | | **10-15** | **20-30** | **10-15** | **10-15** |

# 7 INDEPENDENT MODEL APPLICATION

**TIME / INPUT REQUIRED:**

- up to 5 months
- 20–40 National expert days
- 15–30 International expert days


**THIS CHAPTER EXPLAINS:**

→ How to expand indicators for monitoring adaptation sucess?
→ How to keep the model up-to-date?
→ How to enable independent use?

## THIS CHAPTER PROVIDES IN-DEPTH INFORMATION ON **3 TASKS**

Ultimately, the goal of the capacity building programme is to facilitate independent application of the model by national partners for their policy planning.
To ensure this, we recommend for the final phase of the project the following tasks:

STEP 7 **TASK 1**

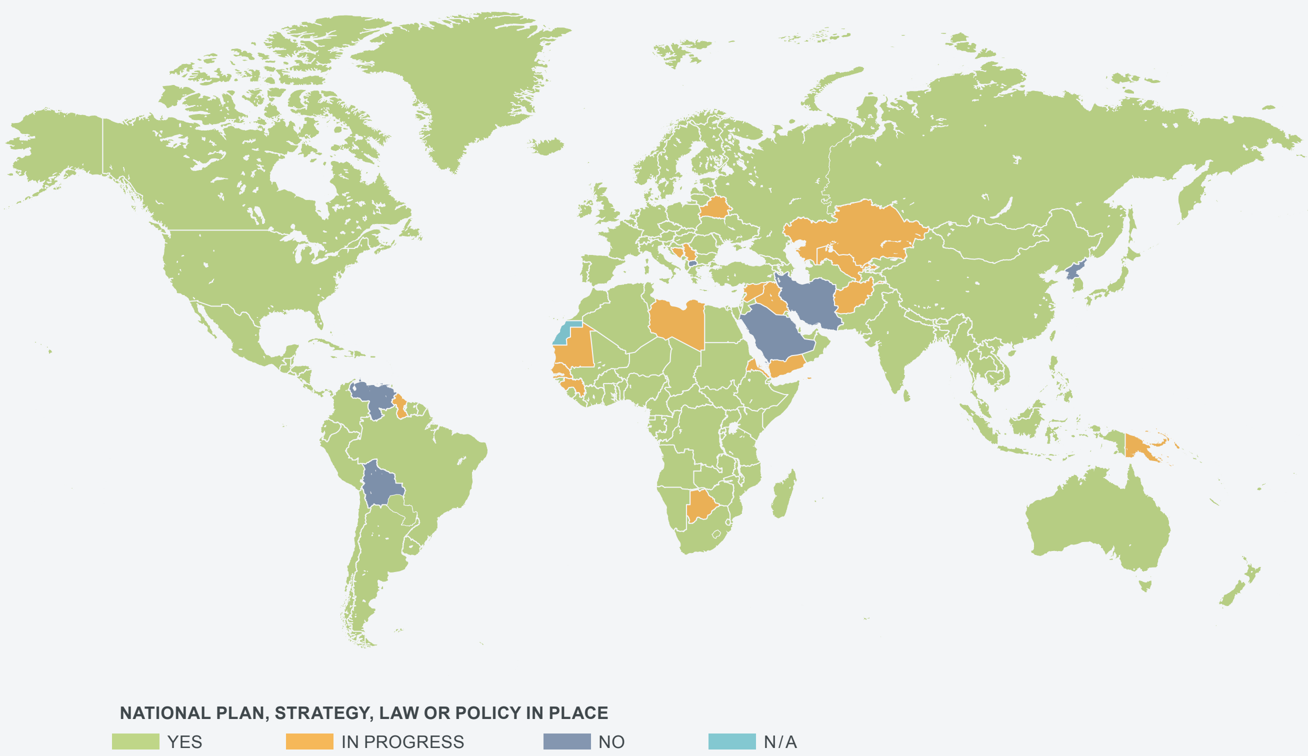
# EXPAND ADAPTATION INDICATORS FOR MONITORING RESILIENCE

The linkages between adaptation and its broader development co-benefits is an emerging field. A better monitoring of the contribution of adaptation to economic development indicators is a crucial part of progress in that area. In this sense, the macroeconomic perspective can also support monitoring and evaluation (M&E) activities. The economic perspective could be used to improve and expand national indicator systems to cover the economic co-benefits of adaptation action. In that regard macroeconomic models strengthen the capacities to monitor the effectiveness of adaptation action because they establish indicators against which the success of adaptation measures can be monitored and evaluated. Changes in investment, consumption, GDP and employment could be important indicators to monitor and evaluate adaptation action. This field could thus be used to support countries in improving their capacities for measuring their progress towards economic resilience and ultimately improve the basis for planning in that regard.

Results of such assessments would also contribute towards a better data base regarding the adaptation measures to be considered in macroeconomic modelling. In the closing phase of the project the integration of economic indicators into national monitoring and evaluation systems can be an important activity to support sustainability of the intervention.

Currently most countries are engaging in some form of adaptation planning, as can be seen from *Figure 25*. However, data on the effectiveness of adaptation in terms of reducing economic vulnerability is limited. A macroeconomic perspective on monitoring and evaluation of adaptation would be an important additional aspect to support partner countries achieve climate resilient development.

**Figure 25: Status of adaptation planning worldwide (as of 31 August 2022)**




*Source: Own illustration based on United Nations Environment Programme (2022)*

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS:

*Existing monitoring and evaluation systems should be reviewed and analysed in terms of potential additions with macroeconomic indicators on climate resilience. Also, the economic co-benefits of adaptation action might be more systematically assessed. A rough estimation on activities in that regard is around 10-20 days for national experts and 5-10 for international experts.*

STEP 7 **TASK 2**

# PREPARE FOR UPDATING THE MODEL

As the national economies develop and climate risk escalates it will be necessary to continuously adapt the model to ongoing changing circumstances. The design of the model should from the beginning take this into consideration. All input data (economic and climate related) should be in formats suitable for future updates. Ideally publicly available data (from national statistic offices) is used so updates can be realized conveniently.

In order to ensure future validity of the model, it should be regularly updated regarding the following key aspects:

- **Macroeconomic model:**
- update economic baseline development trajectories (e.g. Covid-19 massively affected the growth expectations, and partners of the CRED project adapted baseline scenarios accordingly)

- **Climate hazard scenarios:**
  - GHG emission scenarios will change
  - progress in climate models will result in new translations of these emission scenarios or SSPs into actual climate hazards
  - new regionalized and/or national climate hazard scenarios should be used to have the best science-based understanding of climate hazards

- **Damage functions:**
  - the translation of hazards into damages is an emerging field with damages potentially underestimated due to lack of understanding, uncertainty and ignorance regarding compounding or cascading risks. The estimation of future damages based on past damage events (as done in CRED project) is plausible but needs to be continuously updated and validated as new damage data is available.

- **Adaptation measures:**
  - new technologies and economic baseline scenarios require that the CBAs for adaptation measures should be updated based on improved understanding on their effectiveness.

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

*Preparing for future model updates and independent use by partner countries are integral to all steps of the handbook, as the independent use is the key objective of the capacity building. However, in the closing phase of the project it is advised to put additional emphasis on this. This might refer to the procedures for updating the different parts of the model as well as adjusting the policy processes and coordination mechanisms designed to support use of the model for adaptation action. A rough estimation is around 10-20 days for national experts and 5-10 for international experts.*

STEP 7 **TASK 3**

# OFFICIAL MODEL HANDOVER TO PARTNER INSTITUTIONS

A final step is an official handover of the macroeconomic model and dataset.
During a workshop key results can be presented and the developed arrangements for using and updating the model presented to partners.

*e3.kz model handover in Kazakhstan 2023*

## IMPLEMENTATION REQUIREMENTS AND ESTIMATION OF EXPERT DAYS

*Some final tweaks to data sharing agreements, questions relating to updating the model and its different data sources might occur. For this, 5-10 international expert days are calculated for the handover. This might also include arranging for extended cooperation between the national stakeholders and international partners of the project to continue scientific exchange and collaboration in future research or exchange programs, for example with national universities working on the topic.*

*Table 14* presents an overview of the time and estimated expert days involved in supporting post project independent model application.

**Table 14: Timeline for supporting independent model application**

| **WORK PLAN** (month of project implementation) | 1 – 6 | 7 – 9 | 10 – 12 | 13 – 15 | 16 – 18 | 19 – 21 | 22 – 24 | 25 – 30 |
|---|---|---|---|---|---|---|---|---|
| **Task 1:** Expand adaptation indicators for monitoring resilience | | | | | | | | ◑ 10-20<br>● 5-10 |
| **Task 2:** Preparing for updating the model | | | | | | | | ◑ 10-20<br>● 5-10 |
| **Task 3:** Official model handover to partner institutions | | | | | | | | ◑ 0<br>● 5-10 |
| ◑ **National expert days** (total) | | | | | | | | **20-40** |
| ● **International expert days** (total) | | | | | | | | **15-30** |

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