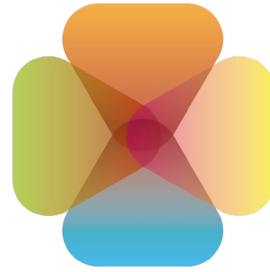




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ACCUREU
Assessing
Climate Change
Risk in Europe

D3.1 Conceptual and methodological framework for adaptation assessment

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Changes with respect to the DoA

Not all partners mentioned in the agreement directly contributed to the writing. Instead, their feedback was collected during meetings, and processed by Deltares/PWA.

Dissemination and uptake

This document is primarily aimed at participants of the ACCREU project, and structures their case study (D3.2), decision type (D3.3), and macroeconomic research (D3.4) on the economics of adaptation. It might give some inspiration to other EU projects, notably those under the mission-of-adaptation, as well.

Short Summary of results (<250 words)

This deliverable describes the protocol for the assessment of case studies (D3.2), the upscaling and synthesis into generic adaptation strategies and evaluation per adaptation decision types (D3.3) and the integration of costs and benefits in CGE/IA models (D3.4).

The case study and adaptation decision type analyses take a policy-first approach, implying that they depart from concrete policy questions. The case study analyses are oriented at the needs of individual stakeholders that participate in the ACCREU project. The adaptation decision type analyses focus on the needs of *all European regions and communities* that face more-or-less the same policy questions. The corresponding description of adaptation decision types draw from the ACCREU (and other) case studies, as well as information from sectoral modelling and literature.

The integration of costs and benefits in CGE/IA models takes a science-first approach, meaning that it departs from the needs of the macro-economic modelling teams in ACCREU. The outcome will be an inventory of the costs and benefits of different adaptation measures, that can be used in WP4.

In appendix A, a timeline and engagement plan for the work package management can be found.

Evidence of accomplishment

N.A.

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Glossary

Adaptation option	Specific action, measure or intervention that can be taken to address the impacts of climate change.
Adaptation decision type (ADT)	Archetypes of common adaptation decisions / policy questions that match the cross-cutting themes of the European Mission on Adaptation to climate change. Table 3 lists the seven adaptation decision types
Adaptation strategy	A clustering of similar adaptation options that outline how a region or sector intends to address climate change impacts over time.
Barrier to adaptation	“Factor or process that makes adaptation planning and implementation more difficult” (Klein et al., 2014)
Generic adaptation strategy	Broad overarching strategic directions designed to address the impacts of climate change. They are called “generic” as they are intended to be adaptable and applicable across various contexts and locations, offering generic strategic choices and solutions to different ADT policy questions.
Green adaptation	“[E]cosystem-based (or nature-based) approach and make use of the multiple services provided by natural ecosystems to improve resilience and adaptation capacity” (CLIMATE-ADAPT, n.d.)
Grey adaptation	“[T]echnological and engineering solutions to improve adaptation of territory, infrastructures and people” (CLIMATE-ADAPT, n.d.)
Incremental adaptation	Adaptation options or strategies that create small changes to the status quo. System relations remain unaltered.
Path-dependency	“A process that has the property of staying on a particular trajectory, so that past decisions and contingent (accidental, arbitrary) events pre-determine what further steps may be taken” (Seebauer et al., 2023)
Soft adaptation	“[P]olicy, legal, social, management and financial measures that can alter human behaviour and styles of governance, contributing to improve adaptation capacity and to increase awareness on climate change issues” (CLIMATE-ADAPT, n.d.)
Transformative adaptation	Drastic change to the system as a result of an adaptation option or strategy. The system relationships have changed.

1. Introduction

Work package (WP) 3 of the ACCREU project focuses on adaptation decisions from micro-level to macro-level. It has three objectives. The first objective is to **economically appraise the adaptation options** for a selection of stakeholders, that face practical adaptation decisions in a diverse set of case studies. This will be reported in deliverable D3.2: adaptation case study analysis.

The second objective is to **derive actionable insights and practical recommendations** for common adaptation decisions that many European communities and regions will be confronted with. Within the ACCREU project, we refer to such archetypical decisions as ‘Adaptation Decision Types’ (ADT). In total, 7 adaptation decision types (ADTs) have been formulated which are closely connected to Adaptation Missions of the EU (see Figure 1). For each ADT, generic adaptation strategies will be formulated that offer a broad range of generalized strategic directions for decision-makers across the EU that face comparable problems. The insights on these decision types are derived from a synthesis from the specific case studies, stakeholder consultations and draw from the sectoral and integrated WP2 and WP4 results. The protocol for this process will be reported in D3.3: adaptation decision types.

The third objective is to **gather data and studies on adaptation costs and effectiveness**, to inform the macroeconomic models (CGE and IAM) that will be used in the integrated macroeconomic analysis of WP4. This will be reported in D3.4: economics of adaptation. The present deliverable D3.1 lays the methodological groundwork for the three objectives mentioned above. It is both a conceptual and methodological framework, which pays attention to systematic reporting within each deliverable, to the relations between different deliverables in WP3, and to the relations with other work packages.

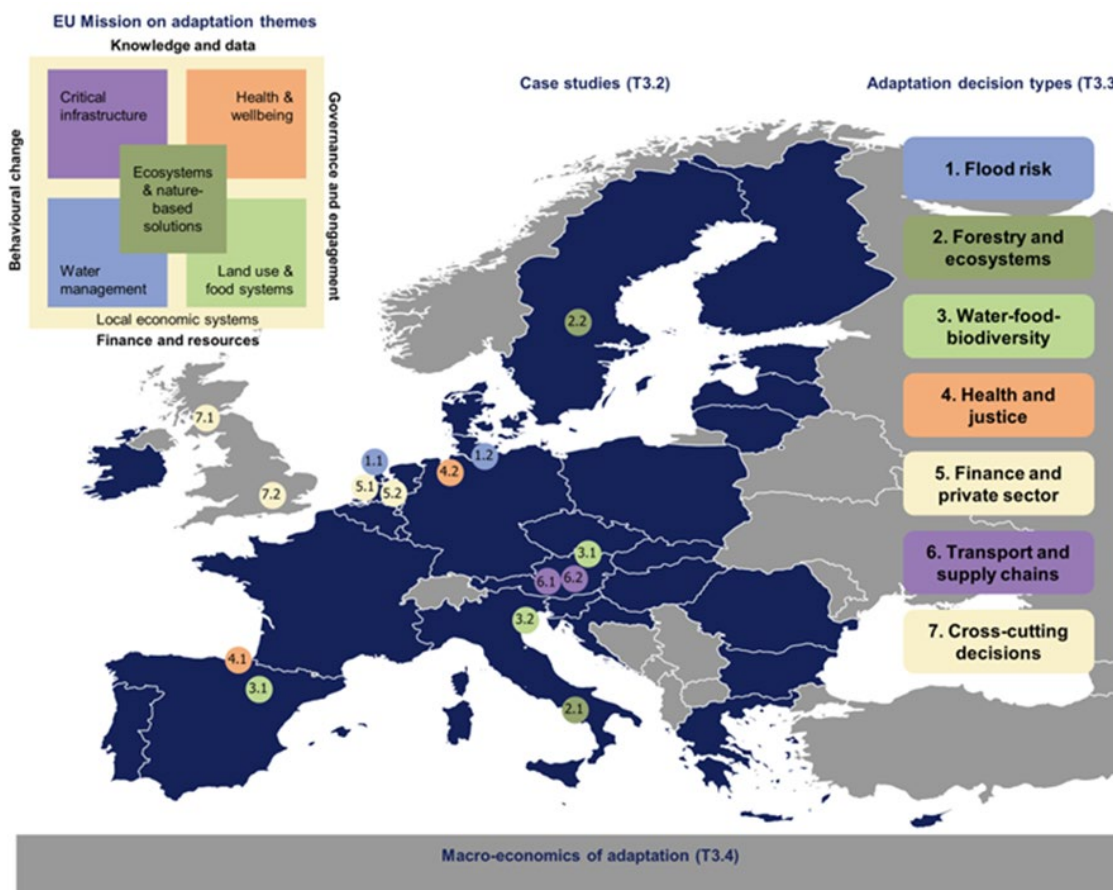


Figure 1. Relation between case studies, adaptation decision types and the European Mission on Adaptation.

This work package combines a ‘policy-first’ and ‘science-first’ approach to the economics of adaptation (Figure 2). The case studies and adaptation decision types represent policy-first approaches to the economic appraisal of adaptation. The questions of the stakeholders in the cases are leading and inform the specific policy **objectives**, how **the risks of not meeting these objectives** can be analysed and what strategy and actions can be followed to **mitigate the risks over time**. Where possible these two deliverables build on the science-first impact assessment of WP2. Deliverable 3.4 provides a more science-first perspective on adaptation, as input for WP4.

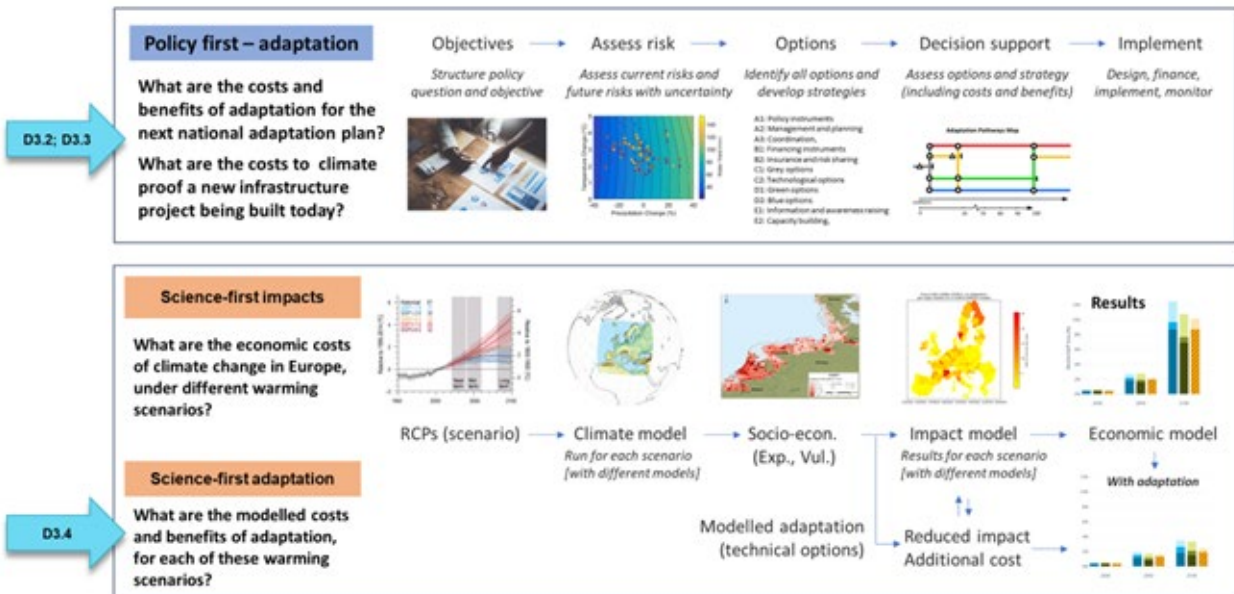


Figure 2. Science-first and policy-first approach to adaptation in work package 3.

An overarching element for this deliverable is concerned with the **economics of adaptation**. In the case studies, economics of adaptation come into play in different ways:

- In most cases they are implicitly **shaping the objective** via overarching macroeconomic objectives. E.g. certain growth of production of a certain sector, certain levels of flood protection to secure economic attractiveness.
- In many cases they are informing the evaluation and choices of which strategies and actions to choose, based on the valuation of risks and other outcomes. This mostly involves appraisal questions connected to **cost benefit analysis**. Through ACCREU additional focus will be put on distributional impacts and benefits (groups, space and time), valuation of nature-based solutions etc.
- In some cases, they also guide so called **decision rules**, such as the economically optimal, least regret, fit with annual budgets etc.
- Every decision context knows its **barriers** and offers particular **opportunities** for mainstreaming adaptation action. At a macro-economic level this also limits the potential for adaptation to reduce societal damage and costs. These **limits of adaptation** are an additional economic interest of ACCREU.

The outline of this document is as follows. We start by offering a case-study framework that describes how the case study analysis (D3.2) is to be carried out in a systematic way, enabling a consistent reporting of the results of the different case studies. The case-study framework and its building blocks are outlined in chapter 2. Second, we reflect on how case studies insights, stakeholder consultations and other sources can be used to synthesize insights into generic

adaptation strategies for each ADT in D3.3. This is described in the form of a synthesis protocol, which is outlined in chapter 3. Next, we address the third objective of WP3: collection of data on costs and benefits of adaptation to inform the integrated analysis with macroeconomic models (D3.4). We describe how insights from academic and grey literature will be processed into a comprehensive inventory on the costs, effectiveness, and benefits of adaptation strategies at EU level. This is done in chapter 4.

This introduction is concluded with a short note on the process through which this deliverable was constructed. Deltares presented a try-out version of the case study analysis framework during the first general assembly, in Venice in June 2023. During the meeting, the consortium partners filled out the framework, followed by a feedback session on the framework's merits and limitations. Using this feedback, Deltares wrote a draft of the present deliverable, which was finalized after a final round of feedback during the second general assembly in Vienna in February 2024.

2. Framework for case study analysis

This section outlines the framework that will be used for the economic evaluation of adaptation options and strategies in the case studies. Insights from the case studies are, among other sources, used to formulate generic adaptation strategies for each Adaptation Decision Type for D3.3. The results of this case study analysis will be published in D3.2 (M30), with two intermediate milestones in month 12 and month 20 of the ACCREU project. In the Engagement Plan (Appendix A), more information is provided on the expected outcomes for each deliverable and milestone that is part of this Work Package.

Our case-study framework follows the policy-first approach to adaptation economics (Figure 3) and consists of different ‘building blocks’. These building blocks are partly inspired by the robust decision making XLRM framework (Lempert et al., 2003), which is used to guide long-term policy analysis for decision problems that face large uncertainties, such as climate change (Lempert et al., 2003; Kwakkel, 2017; van Ginkel et al., 2022). The XLRM framework can be considered an “intellectual bookkeeping mechanism” (Lempert et al., 2003), which we use here to ensure uniform reporting of outcomes across the different case studies. We have adapted the XLRM framework to explicitly include information on the policy question of the stakeholders and to cluster the individual adaptation options into broader strategies, including barriers of implementation and possible path-dependencies of these strategies. In short, the robust decision making XLRM framework distinguishes itself from conventional scenario analysis characterizing uncertainty by reversing the order of the process and by starting from a selection of decision options and assessing their utility or value. It thus follows a more bottom-up, policy-first approach instead of a top-down science-first approach.

Figure 4 and 5 provide an overview of our case-study framework and its building blocks. For future reference, each building block is delineated with a letter. An explanation of each building block is provided in the subsequent sections in this chapter. A PowerPoint is included as attachment to this Deliverable, which case study holders can use to go through each building block of the framework with their stakeholders to fill out. Outline of this chapter is as follows: It starts with an explanation of the differences between options, strategies and generic adaptation strategies (section 2.1), followed by a description of the stakeholder’s policy question (section 0) and subsequently structuring of the decision problem (section 2.3). Finally, a reflection on the clustering of individual options into adaptation strategies is provided (section 2.4).

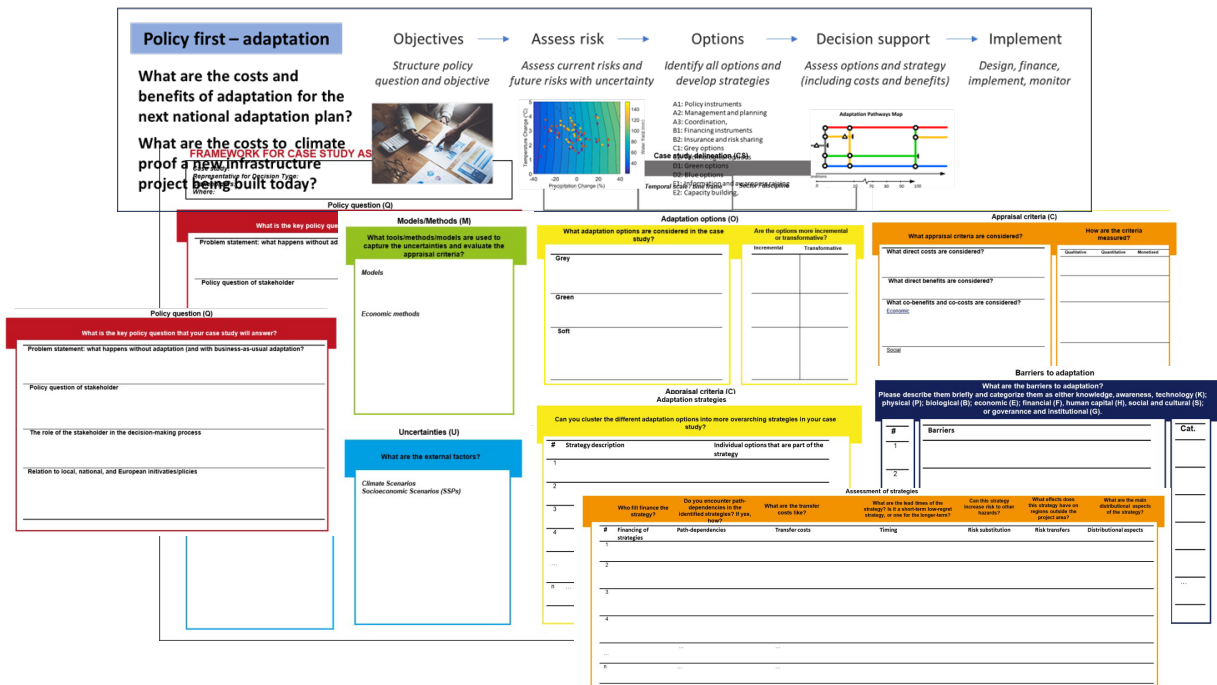


Figure 3. Policy-first framework for economic appraisal of case studies and how it is connected to the building blocks of the case-study framework.

FRAMEWORK FOR CASE STUDY ASSESSMENT ACCREU

Case study:
Representative for Decision Type:
Stakeholders:
Where:

Policy question (Q)

What is the key policy question that your case study will answer?

Problem statement: what happens without adaptation (and with business-as-usual adaptation?)

Policy question of stakeholder

The role of the stakeholder in the decision-making process

Relation to local, national, and European initiatives/policies

Uncertainties (U)

What are the external factors?

Climate Scenarios
Socioeconomic Scenarios (SSPs)

Models/Methods (M)

What tools/methods/models are used to capture the uncertainties and evaluate the appraisal criteria?

Models

Case study delineation (CS)

Spatial scale

Temporal scale / time frame

Sector / discipline

Adaptation options (O)

What adaptation options are considered in the case study?

Are the options more incremental or transformative?

Grey

Green

Soft

Incremental

Transformative

Appraisal criteria (C)

What appraisal criteria are considered?

How are the criteria measured?

What direct costs are considered?

What direct benefits are considered?

What co-benefits and co-costs are considered?

Economic

Social

Environmental

Are you considering general welfare effects? If so, how? YES/NO

Qualitative

Quantitative

Monetised

Distributive

Temporal

Spatial

Figure 4. Template for ACCREU case-study Framework Analysis – part 1: appraisal of adaptation options.

Adaptation strategies (S)

Can you cluster the different adaptation options into more overarching strategies in your case study?

#	Strategy description	Individual options that are part of the strategy	Is the strategy transformative or incremental?
1			
2			
3			
4			
...			
n			

Barriers to adaptation (B)

What are the barriers to adaptation for each strategy? Please describe them briefly and categorize them as either knowledge, awareness, technology (K); physical (P); biological (B); economic (E); financial (F), human capital (H), social and cultural (S); or governance and institutional (G).

#	Barriers	Cat
1		
2		
3		
4		
...		
n		

Assessment of strategies (SA)

	Do you encounter path-dependencies in the identified strategies? If yes, how?	What are the transfer costs like?	What are the lead times of the strategy? Is it a short-term low-regret strategy, or one for the longer-term?	Who will finance the strategy?	What are the main distributional effects of the strategy?	Will be you be able measure the direct costs and benefits qualitatively, quantitatively, or monetised?	For which co-costs and co-benefits could you provide an order of magnitude?
#	Path-dependencies	Transfer costs	Timing	Financing of strategies	Distributive effects	Direct costs & benefits	Co-costs & -benefits
1							
2							
3							
4							
...							
n							

Figure 5. Template for ACCREU case-study Framework Analysis– part 2: from options to strategies.

2.1. Defining options, strategies and generic adaptation strategies

Within WP3, we distinguish between options, strategies and generic adaptation strategies. To understand the differences in use in WP3, we will first start with an elaboration of these terms. In general, individual options and strategies are part of the case study analysis, while generic adaptation strategies refer to the strategic directions of the decision-makers within the different adaptation decision types.

For the case study analysis, we define **Adaptation options** as specific actions, measures or interventions that can be taken to address the impacts of climate change. **Adaptation strategies** can be seen as clusters of similar adaptation options, offering policy actions that outline how a region or sector intends to address climate change impacts over time. Strategies usually encompass a broad range of (more specific) adaptation options and activities that are more-or-less similar in the way they affect the region.

Within the original XLRM framework, policy strategies refer to the policy Levers. The ‘lever’ metaphor is envisioning the adaptation strategies as ‘handles’ that can be set to several different settings. For example, in agricultural adaptation, ‘crop choice’ could be a lever (a strategy), that can be set to several different values (options), such as ‘drought-tolerant fig trees’ or ‘drought-vulnerable wheat’. For this example, another lever (strategy) could be: ‘type of irrigation’, which can be set to the values (options): ‘no irrigation’, ‘sprinkler irrigation’ and ‘drip irrigation’.

A third term that we will use often are **generic adaptation strategies**. These refer to archetypical directions decision-makers can take to answer key policy questions of the ADT. Instead of focusing on specific strategies that answer specific needs of a regional decision-maker, the generic adaptation strategies are designed to offer generalized insights for decision-makers in different regions and contexts. A more elaborated explanation can be found in Chapter 3. Continuing with the example on agricultural adaptation, the combination of adaptation strategies of drought-tolerant crops and irrigation could be part of a broader choice or generic adaptation strategy to reduce the vulnerability of agricultural production. See also Figure 6 and Box 1 for a further explanation.

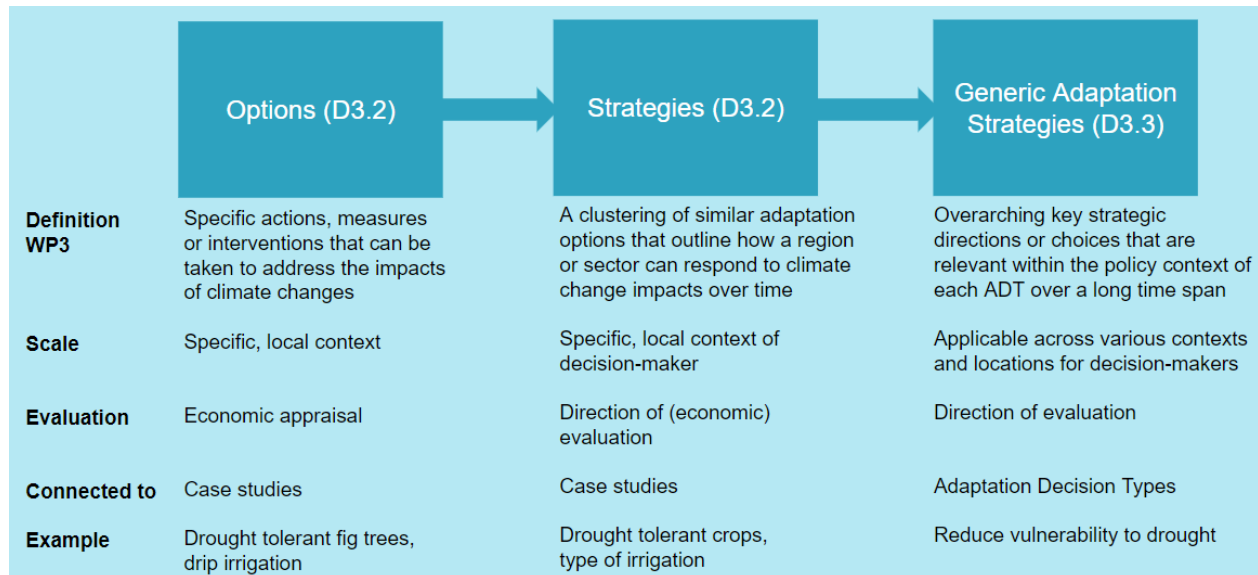


Figure 6. Overview of the differences (in use) of options, strategies and generic adaptation strategies for the ADTs.

Box 1: difference between adaptation options, strategies, and generic adaptation strategies

Example – Forest fire risk reduction

To reduce the forest fire risk in a local forest in region B, the following potential adaptation options were identified: two awareness campaigns among local residents during spring and summer; an awareness campaign targeting outside visitors (e.g., tourists) during summer time; closing the forest during spring; a new zoning policy that does not allow construction within three kilometers from the forest; more trashcans in the forest; annually burn small parts of the forest; and creating corridors in the forest. The first options can be considered part of a broader adaptation strategy to raise awareness among visitors, while the prescribed burning and corridors can be part of a strategy that aims at reducing fire spread. Insights on both strategies can be upscaled to be applicable for other regions and decision-makers, thus becoming more generic adaptation strategies.

The case-study framework starts with a focus on adaptation options, while adaptation strategies will be further addressed in section 2.4. Generic adaptation strategies in turn are addressed in Chapter 3.

2.2. Description of the case study and the stakeholder's policy question

The case-study framework analysis starts with the problem description. This entails a short description of the policy question that will be addressed and a delineation of the case study. This part consists of two building blocks in the case-study framework.

2.2.1. Case study delineation (CS)

To understand the scope of the problem, we start with a few short questions on the delineation of the case study.

Some scoping points that are to be addressed in this process are:

- The spatial and temporal delineation of the case study
- The sectoral/disciplinary delineation of the case study, including overlap with generic decision domains such as integrated land-use planning.

See Figure 7 for how these questions can be answered.



Figure 7. Example based on case study 1.1 on how the case study delineation information could be reported.

2.2.2. Policy question (Q)

The formulation of the policy question is primarily based on the outcome of the co-design process as described in ACCREU Deliverable 1.4.

Some scoping points that are to be addressed in this process are:

- The role of the stakeholder in the decision-making process.
- Primary topics that the stakeholder is interested in.
- Whether this policy question contributes to specific local/regional initiatives, national adaptation programs, and/or pan-European policies and/or Adaptation Decision Types.

In addition, the most important outcomes of this step are:

- Problem formulation: what would happen if the region/community would not adapt? In some cases, it can be useful to distinguish between ‘completely not adapting at all’ and ‘adaptation according to current business-as-usual (but no new) policies’. This can be based

on information provided by the stakeholders during bilateral exchanges, as well as by the sectoral models (WP2).

- A sketch of the economic considerations and decision-making context of the stakeholder, including broader cross-cutting land-use planning and socio-economic considerations (including a broader welfare perspective).

See Figure 8 for an example on how to address these questions in your case study.

Policy question (Q)

What is the key policy question that your case study will answer?

Problem statement: what happens without adaptation (and with business-as-usual adaptation)? No adaptation: Flood risk exceeds social- and economic acceptability (and legal) thresholds. Business-as-usual adaptation: reduction in the attractiveness and spatial quality of the area.
Policy question of stakeholder How to adapt to flood risk such that spatial attractiveness is increased, on the short and long term?
The role of the stakeholder in the decision-making process Water board: responsible for safeguarding flood risk Province: responsible for spatial planning
Relation to local, national, and European initiatives/policies National: HWBP flood directives/standards (specifies flood protection standards) National: WBS spatial planning directive / Delta programme / national adaptation strategy (emphasis on long-term) Provincial: adaptation strategy Municipal: adaptation strategy

Figure 8. Example based on case study 1.1 on how the answer to the policy questions could be reported.

2.3. Structuring the case study decision problem

Once the policy issue is clear, the next step is to identify the elements that are needed to analyse potential adaptation options that could address the problem. There are four elements that are relevant, which are presented as building blocks in the case-study framework:

- i) the adaptation options (O) that are considered in the case study (section 2.3.1);
- ii) the uncertainties (U) in the system (2.3.2);
- iii) the models and methods (M) used to evaluate the adaptation options (2.3.3); and
- iv) the appraisal criteria (C) on which the adaptation options will be assessed (2.3.4).

These four elements are derived from the traditional components of the XLRM framework on which our framework is based.

2.3.1. Adaptation options (O)

After the formulation of the policy issue (section 2.1) we start with an inventory of the adaptation options at hand. As per our definitions outlined in 2.1, options are considered specific measures or actions that can be taken to reduce the impacts of climate change. In WP3 we move from options to strategies to generic adaptation strategies per ADT. In order to do this in a structured way, it is useful to classify the specific options into different categories upfront.

First, we differentiate between grey, green and soft measures, following the definition of the European Climate Adaptation Platform Climate-ADAPT. “Grey measures refer to technological and engineering solutions to improve adaptation of territory, infrastructures and people. Green measures are based on the ecosystem-based (or nature-based) approach and make use of the multiple services provided by natural ecosystems to improve resilience and adaptation capacity. Soft options include policy, legal, social, management and financial measures that can alter human behaviour and styles of governance, contributing to improve adaptation capacity and to increase awareness on climate change issues.” (Climate-ADAPT)¹.

Second, we differentiate between more incremental and more transformative adaptation options. With ‘incremental’ we refer to changes that are relatively small compared to the status-quo. After an incremental change, the system works somewhat differently, but most relations between system components are still intact and the *form* or *shape* remains more-or-less the same. With ‘transformative’ we imply changes that bring the system across/over (*trans*) to another shape (*form*). In other words, it refers to changing the system substantially, including the relations between the components of the system. Fedele et al. (2019) explain transformative adaptation as a fundamental change in the social-ecological systems’ underlying functions. This can be done at different levels. Kates et al. (2012) distinguish between three types of transformative (transformational) adaptation; “those that are adopted at a much larger scale or intensity, those that

¹ European Climate Adaptation Platform Climate-ADAPT, no date. Adaptation Options. Retrieved from: <https://climate-adapt.eea.europa.eu/en/knowledge/adaptation-information/adaptation-options>. Latest accessed on 20 September 2023.

are truly new to a particular region or resource system, and those that transform places and shift locations.” They also mention that it is not always clear-cut to categorize adaptation in either incremental or transformational, as this depends on the context and scale. For example, a seawall could be both transformative or incremental, depending on whether the adaptation is substantially larger than traditionally built in an area, and whether or not it fundamentally changes coastal land uses. Although it can be difficult to distinguish in some cases, it helps in thinking along those two categories. In general, if the response is fundamentally different than before, it can be considered transformative. Thus, in flood risk management, heightening an existing dike is a typical example of an incremental adaptation option, whereas relocating people to safer grounds is a typical example of a transformative option. In forestry, clearing vegetation is an incremental adaptation option, while replanting with totally different tree species could be considered a transformative option, as it fundamentally changes the systems’ response from hazard-focused towards decreasing vulnerability.

Figure 9 provides an example of how these questions could be answered.

Adaptation options (O)							
What adaptation options are considered in the case study?	Are the options more incremental or transformative?						
Grey - Dike reinforcement following HWBP protection standards (around 2080/2100), and again in 22nd century - Large dike reinforcement (3.5m SLR) combined with housing development (small, medium, large)	<table> <tr> <th>Incremental</th><th>Transformative</th></tr> <tr> <td>X</td><td>X</td></tr> </table>	Incremental	Transformative	X	X		
Incremental	Transformative						
X	X						
Green Dike reinforcements following HWBP protection standards combined with extra attention for spatial quality around the dike	<table> <tr> <td>X</td><td></td></tr> </table>	X					
X							
Soft - Zoning (no new buildings within 1km from the coast) - New construction standards requiring flood proof housing - Flood proofing of existing buildings	<table> <tr> <td>X</td><td></td></tr> <tr> <td>X</td><td></td></tr> <tr> <td>X</td><td></td></tr> </table>	X		X		X	
X							
X							
X							

Figure 9. Example based on case study 1.1 on how to report the information on adaptation options in the case study.

2.3.2. Inventory of uncertainties (U)

In this building block, the most important uncertainties for the decision makers, and the system dynamics are described. This can include climatological factors such as temperature, precipitation, and sea level rise. It can also include other biophysical factors that are not reflected in the available climate scenarios, such as rate of species migration and consequences of such migrations. Relevant socio-economic uncertainties, that are outside the control of the decision maker can also be included. This includes those in the Shared Socioeconomic Pathways (SSP) space such as population growth and energy use (O'Neill et al., 2017), but can also address other uncertainties such as poverty or inequality. On a local scale, there can also be (very important) social-economic uncertainties that are not reflected in the SSP/RCP space. Other factors that are outside control of this decision maker (including decisions by other actors) can also be seen as uncertainties for the case study. Figure 10 gives an example on the uncertainties that could be considered, based on case study 1.1.

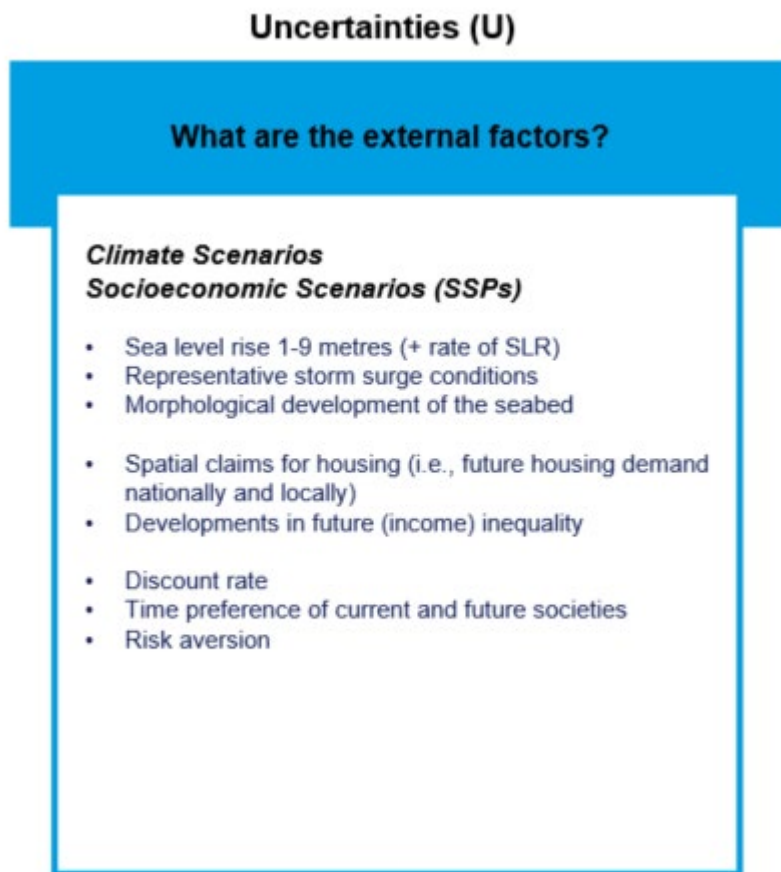


Figure 10. Example based on case study 1.1 on how to report the information on uncertainties relevant to the case study.

2.3.3. Models/Methods (M)

In this building block, we indicate with which tools, methods and/or models the adaptation options will be assessed economically. The model relationships translate the adaptation options (2.2.1) and uncertainties (2.2.2) into effects or metrics of interest (2.2.4). We are particularly interested in understanding which impact models will be used, and which economic method(s) are utilized to perform the economic evaluation of the adaptation options. Figure 11 gives an example on how this question can be answered.

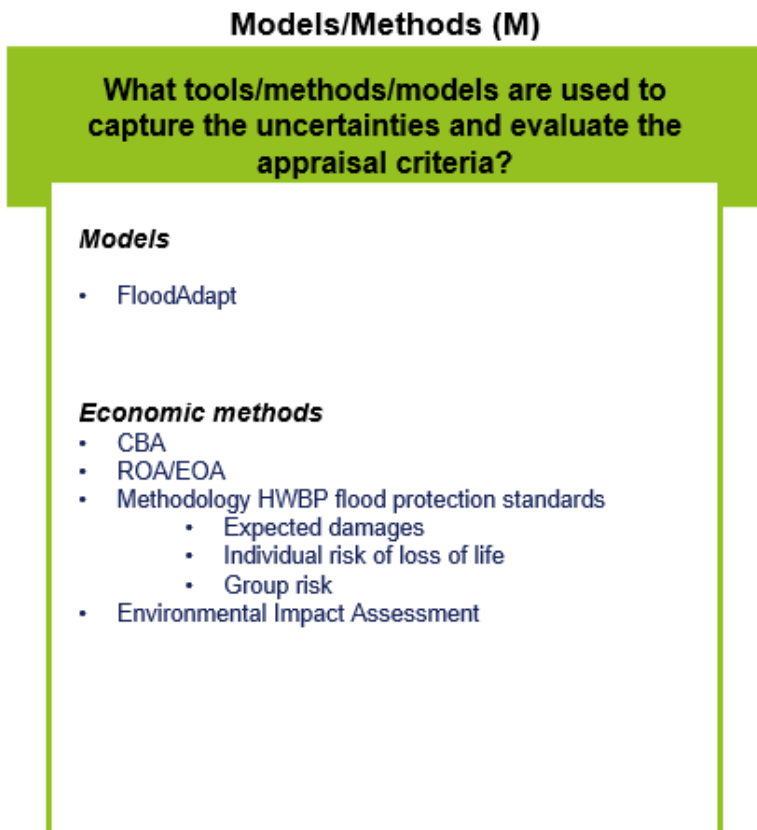


Figure 11. Example based on case study 1.1 on how to report the information on the models and methods used to analyse the case study.

There are different economic tools and methods possible for the evaluation of alternative adaptation measures. In appendix B a table is included that describes some of the main methods and applications, including its drawbacks, merits and data requirements. Some methods offer a detailed economic analysis but have higher data requirements while other methods only evaluate options qualitatively. A quantitative economic analysis is a required part of the case-study analysis, however taking into account broader welfare perspectives in addition is also highly recommended, even though quantification of this remains challenging.

2.3.4. Assessment of adaptation options (C)

This section outlines the assessment of adaptation options. An economic appraisal of the options is required for the case studies. An economic appraisal can encompass a very narrow cost-effectiveness analysis of a primary effect or a more comprehensive approach, including socioeconomic and environmental co-benefits and/or negative externalities. The appraisal can even extend to a general welfare approach, accounting for distributional effects, temporal and spatial trade-offs and synergies (Figure 12).

For the appraisal of the adaptation options in the case study, we ask you to include at minimum the direct effects in terms of costs and benefits (ideally monetized), and the indirect costs and benefits, hereafter referred to as the co-costs and co-benefits (e.g., Chambwera et al., 2014; Vorhies & Wilkinson, 2016). We classify the co-benefits and co-costs into the following categories: social, environmental, and economic. Co-benefits and co-costs can include any secondary effect of the adaptation measure related to wellbeing, health, economic stability, biodiversity etc. If this categorisation is not applicable for your case study, this can be discussed through bilateral meetings, and an alternative categorisation may be used. For each appraisal criterium we also want to know how it is evaluated, i.e., qualitative, quantitative, or monetized.

In the most comprehensive form of economic appraisal, a general welfare perspective is taken into account (Bos et al., 2022). This method extends the cost-benefit analysis with measuring wellbeing effects on three dimensions: (i) “who”; how the effects are distributed over different socioeconomic groups or stakeholders (ii) “when”; whether wellbeing is sustainable for future generations and (iii) “where”; how trade-offs are made spatially. We would like to understand if any, and if so which of these dimensions are covered in your case-study appraisal and how.

Examples of distributional effects are whether the costs of an adaptation option are borne mostly by farmers while the benefits are accrued by the wholesaler, or whether more green spaces and associated health improvements and house values are mainly benefiting richer neighbourhoods. With temporal effects we refer to the potential effects the adaptation option can have within the project region at a later point in time and on future generations, such as potential lock-in or path-dependencies that can arise from an adaptation option or strategy. With spatial effects, we refer to (unintended) effects outside of the project region, e.g., is risk transferred to other areas as a result of this adaptation option (Chi et al., 2021), for instance as a result of a relocation or zoning policy. The distributional and temporal components are part of the assessment of the adaptation strategies and are explained in more detail in Section 2.4.1. Where possible, it would be very relevant and helpful to include these dimensions into the economic appraisal of the adaptation options as well. This can be done quantitatively or qualitatively, for instance, for the distributional component, the results could be disaggregated and several distributive moral principles could be used (see for instance Jafino et al., 2022). See Figure 13 for an example of how these questions can be answered.

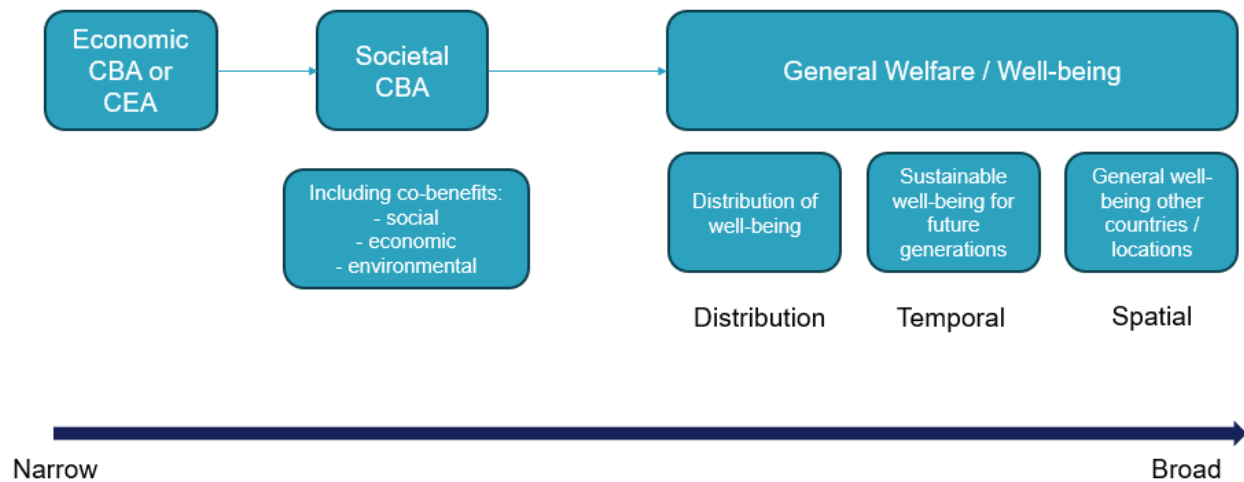


Figure 12. Comprehensiveness of economic appraisal.

Appraisal criteria (C)				
What appraisal criteria are considered?		How are the criteria measured?		
What direct costs are considered?		Qualitative	Quantitative	Monetised
Operational costs				X
Investment costs				X
What direct benefits are considered?				
Reduction in expected annual flood damages				X
Reduction in individual risk of loss of life			X	X
What co-benefits and co-costs are considered?				
<u>Economic</u>				
• Housing values				X
• Value of the land				X
• ...				
<u>Social</u>				
• Living comfort			X	X
• Social cohesion			X	X
<u>Environmental</u>				
• Biodiversity			X	
Are you considering general welfare effects? If so, how?		Distributive	Temporal	Spatial
YES/NO		X	X	
Quantitatively assess how the changes in (co-)benefits are distributed among different age classes, based on gender, educational attainment, income, migration background, and/or disability status. Take a lock-in perspective for the transformational dike approach (and monetise/quantify these lock-in/regret costs)				

Figure 13. Example based on case study 1.1 on how to report the information on performance metrics used for the case study.

2.4. From options to strategies (S)

Once all the required building blocks for the assessment of adaptation options have been filled out in the case-study framework, the next step is to formulate individual options into strategies. It is not required to economically appraise strategies at the same level of detail as adaptation options, but a certain level of evaluation is needed to synthesize results into more generic adaptation strategies for each ADT (see chapter 3). As explained earlier, a strategy refers to a bundle of specific options. For a more detailed description of the differences between adaptation options and strategies, see Figure 6 and Box 1 in section 2.1.

In this building block (S) several questions help in formulating adaptation strategies:

- Is the adaptation option a separate action (that can be seen in isolation) or part of a larger adaptation strategy (in which multiple options together make one coherent plan)?
- If so, could you cluster the options into more generic strategies?

Adaptation strategies (S)

Can you cluster the different adaptation options into more overarching strategies in your case study?			
#	Strategy description	Individual options that are part of the strategy	Is the strategy transformative or incremental?
1	Continuation of BAU – incrementally strengthening dikes and no new coastal development	Inner dike improvements around 2080/2100	Incremental
2	Transformative dike reinforcement with integrated spatial planning	3.5 and/or 5.0 m SLR proof dike + housing development	Transformative
3	Planned relocation from Den Helder	Zoning policies; compensation; ...	Transformative
4	Flood-proofing of existing and new buildings in Den Helder	Policies aimed at new housing development; policies aimed at old housing; wet and dry flood proofing measures. Zoning in risky areas.	Incremental
...	...	...	...
n	...	...	...

Figure 14 provides an example of how this categorization into adaptation strategies could be made. In chapter 3, table 7, examples of strategies are listed for all adaptation decision types, which can be used as inspiration.

Adaptation strategies (S)			
Can you cluster the different adaptation options into more overarching strategies in your case study?			
#	Strategy description	Individual options that are part of the strategy	Is the strategy transformative or incremental?
1	Continuation of BAU – incrementally strengthening dikes and no new coastal development	Inner dike improvements around 2080/2100	Incremental
2	Transformative dike reinforcement with integrated spatial planning	3.5 and/or 5.0 m SLR proof dike + housing development	Transformative
3	Planned relocation from Den Helder	Zoning policies; compensation; ...	Transformative
4	Flood-proofing of existing and new buildings in Den Helder	Policies aimed at new housing development; policies aimed at old housing; wet and dry flood proofing measures. Zoning in risky areas.	Incremental
...	...	...	...
n	...	...	...

Figure 14. Example based on case study 1.1 on how to report the information on adaptation strategies in the case study.

2.4.1 Assessment of adaptation strategies (SA)

After the identification of adaptation strategies, the next step is the provision of decision support as defined in the policy-first framework (Figure 2). While a complete economic appraisal of the adaptation strategies is not required, where possible an indication or order of magnitude of the cost and benefits should be given for each strategy, as well as the co-costs and co-benefits (Figure 15). Furthermore, the evaluation should include aspects of the temporal and distributional dimensions of the general welfare (broader wellbeing) approach (Figure 12) to support decision-making. This is further explained below.

Will be you be able measure the direct costs and benefits qualitatively, quantitatively, or monetised?	For which co-costs and co-benefits could you provide an order of magnitude?
Direct costs & benefits	Co-costs & -benefits
Direct costs: monetised	Social cohesion
Direct benefits: monetised/quantitatively	
Direct costs: monetised	Housing values;
Direct benefits: monetised/quantitatively	social cohesion; gentrification
Perhaps a general order of magnitude	–
Direct costs: monetised; Direct benefits: (monetised) order of magnitude	TBD

Figure 15. Example based on case study 1.1 on how to report the information on direct and indirect costs and benefits of the adaptation strategies.

Temporal dimension

With the temporal dimension we refer to the effects of the adaptation strategies within the project region for future generations. More specifically, want to understand whether **Path-dependencies** could occur when choosing for a certain adaptation strategy. What is meant by ‘path-dependencies’ in the context of strategies? Path dependency is “a process that has the property of staying on a particular trajectory, so that past decisions and contingent (accidental, arbitrary) events pre-determine what further steps may be taken” (Seebauer et al., 2023). In other words, if one decides to implement adaptation option X, this choice also steers which further adaptation options may be taken. The canonical example from flood risk management is the so-called ‘levee-effect’. Adaptation to flood risk by raising levees increases the attractiveness of the (now protected) hazard zone. This may attract new developments in the hazard zone, which leads to an increased exposure, which justifies even further levee raising, etc. Building dikes therefore leads to path-dependency, making switching to another option less cost-effective, and thus continuing raising the dikes in the future more likely.

A closely related concept is a so-called ‘lock-in’. An adaptation strategy is **locked-in** when there is no reasonable (attractive) alternative strategy available. In other words, a lock-in is the lack of freedom to choose from several more-or-less comparably attractive strategies, because a continuation of the business-as-usual strategy outperforms the alternatives. A lock-in can result from a strategy that is strongly path-dependent. In the levee-effect example, the continuous investments in dike reinforcements caused a concentration of valuable assets in the hazard result. As a result, alternatives to levee raising, such as retreat from the area, have become less and less attractive, because it would require ever larger buyouts of property owners. The marginal costs of dike raising will therefore always outperform the integral costs of the transformational ‘retreat’ strategy (van Ginkel & Klijn, 2023).

Furthermore, in this context we also introduce the term ‘**transfer costs**’, referring to the costs of changing from one strategy to another. In the levee-effect example, we see that the costs of transferring from the ‘raising levees’ strategy to the ‘retreat’ alternative, is becoming higher-and-higher, each time that new property developments are done. Because the more property is developed in the hazard zone, the more costly the buyouts in case of retreat. In other words: a lock-in can be defined as a situation where the transfer costs to an alternative strategy have become unacceptably high (Haasnoot et al., 2020).

As part of the case study analysis, it is important to reflect whether path-dependencies could affect the identified adaptation strategies, and if this is the case, explain how the potential ways path-dependency and/or lock-in come into play. For all strategies, we request you to reflect whether transfer costs would be high, if switching is required. Here, we also ask you the potential lead time of the strategies, e.g., how long would it take to introduce a flood insurance policy or a prescribed burning policy in the context of your case study? In line with this, we would like an indication on whether the strategy is a low-regret option that can be implemented in the short-term, or if it is a strategy that is considered for the longer-term? This information can also be filled into the PowerPoint framework. Please consider different biophysical and socio-economic scenarios when thinking of path-dependencies. For instance, if only one SSP was included in the appraisal of the adaptation options, we would like you to reflect on what effects another SSP scenario could have on the outcomes and performance of the options and/or strategies (see also Table 2). See Figure 16 for an example on how to answer these questions.

Assessment of strategies (SA)			
	Do you encounter path-dependencies in the identified strategies? If yes, how?	What are the transfer costs like?	What are the lead times of the strategy? Is it a short-term low-regret strategy, or one for the longer-term?
#	Path-dependencies	Transfer costs	Timing
1	Path-dependency and lock-in of BAU (hard protection approach)	High when transferring to NBS; low when transferring to other types of strategies	~decade lead time; current situation
2	Lock-in if SLR is more or is less than expected (little flexibility in this strategy). It locks-out alternatives, by reducing the benefits of the alternative options	high – requires expropriation of home owners and relocation of renters – loss of place attachment	~a decade lead time; current or longer-term option.
3	Once this strategy is chosen, it is difficult to change to another option.	Very high – property rights lead to high societal costs when transferring out of this strategy	Long lead-time and longer-term strategy (for high SLR scenario)
4	Little lock-in / path-dependencies.	Low; this investment can become a sunk cost when other strategies are implemented	Shorter-term option – not sufficient in extreme SLR scenarios
...	...	...	...
n	...	...	...

Figure 16. Temporal dimension of general welfare assessment of adaptation strategies.

Distributional dimension

Besides considering the temporal dimension, ideally the strategies are also evaluated on the distributional dimension. This entails that case studies should reflect on which demographic groups and stakeholders (or sectors) would benefit the most from the strategies and who benefit the least (or bear the cost) as a result of the strategy. A qualitative description is sufficient. Questions that can help in answering this for your case study are:

- Does the strategy have a regressive or progressive effect?
- Are the most vulnerable communities benefiting most?
- Who will (most likely) finance each strategy (e.g., households, national government, local government etc.).

If a distributional analysis was included in the appraisal of the adaptation options (Section 2.3.4), that information could be scaled up here to the strategies level. See an example in Figure 17

Who will finance the strategy?	What are the main distributional effects of the strategy <i>within</i> the project area?
Financing of strategies	Distributional aspects
Public (national and water boards)	Equal protection of individuals;
Public (water boards and regional)	Possible gentrification; regressive effect. Low-income households pay for protection high-income households
Public (national)	Possibly unequal loss of social cohesion; compensation (e.g., for property rights);
Private (+ government subsidies?)	Low-income households might struggle with financing this; could exacerbate risk inequality

Figure 17. Distributional dimension of general welfare assessment of adaptation strategies.

2.4.2 Barriers and limits to implementation (B)

Part of our assessment of the strategies is concerned with the conditions and potential barriers for implementation. In this building block, the key aim is to identify potential adaptation barriers and limits to adaptation that could complicate the implementation of the strategies.

An **adaptation barrier** is a “factor or process that makes adaptation planning and implementation more difficult” (Klein et al., 2014). Barriers could arise during all stages of the decision-making process from problem definition and planning to execution of the plans (Moser & Ekstrom, 2010; Ekstrom & Moser, 2014). Most barriers are not specific to climate change (Biesbroek et al., 2013), but refer to lack of resources, institutional barriers, technical barriers, lack of motivation of actors and/or competing planning objectives, socio-cultural barriers etc. (Adger et al., 2007; Biesbroek et al., 2011; McClure & Baker, 2018). There are also sector-specific studies on adaptation barriers, such as for coastal flooding (Hinkel et al., 2018), agriculture (Masud et al., 2017), or urban adaptation finance (Richmond et al., 2021). Specific adaptation barriers could be the appointment of climate adaptation responsibility to the environmental departments in public authorities instead of the (spatial) planning departments (Measham et al., 2011; McClure & Baker, 2018), more

pressing demands for basic needs that authorities are responsible for (Bulkeley et al., 2011), lack of leadership, or legal barriers (Moser & Ekstrom, 2010; see also Table 1).

Besides barriers to adaptation, the literature on this topic also identifies **limits to adaptation**. Limits are generally seen as nearly impossible to overcome, whereas barriers can generally be overcome with effort (Barnett et al., 2015). However, clearly distinguishing between the two is often difficult in practice, as some ‘softer’ limits, could potentially become barriers due to socio-cultural change or institutional change, whereas some barriers could become limits, due to path-dependencies (Barnett et al., 2015).

To gain insight into potential barriers and limits to adaptation, case studies, briefly reflect on the foreseen barriers and limits for the identified strategies, and classifying them in either of these categories: 1) knowledge, awareness, and technology; 2) physical; 3) biological; 4) economic; 5) financial; 6) human capital; 7) social and cultural; or 8) governance and institutional (Klein et al., 2014). See Table 1 for examples per category and Figure 18 for an example on how to answer this question in the framework.

Table 1. Examples of barriers to adaptation (Klein et al., 2014).

Type of barrier	Example
Knowledge, Awareness, and Technology	• Role of traditional knowledge • Availability of and access to technology • Effectiveness of technology
Physical	• Mountains that form a barrier to migration • Water availability • Soil quality
Biological	• Rate of migration of species • Environmental quality • Invasive species
Economic	• Poverty • Financial crisis • Economic growth
Financial	• Access to funding • High insurance costs • Access to insurance
Human capital	• Tight labour market • Lack of leadership • Greying population
Social and cultural	• Place attachment • Gender norms • Religious beliefs
Governance and institutional	• Urgency ascribed to adaptation • Land rights • Backwards rather than forwards looking legal framework • Corruption • Coordination across governance levels

Barriers to adaptation (B)

What are the barriers to adaptation for each strategy? Please describe them briefly and categorize them as either knowledge, awareness, technology (K); physical (P); biological (B); economic (E); financial (F), human capital (H), social and cultural (S); or governance and institutional (G).

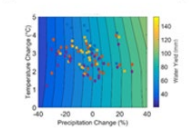
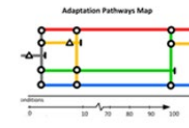
#	Barriers	Cat.
1	1A – Competing local planning objectives 1B – Availability of future resources 1C – Availability of land for future reinforcements	G F F
2	2A – unsuitable financing institutions (not nationally funded) 2B – Acceptability of expropriating home owners ...	F S
3	3A – Place attachment 3B – socio-economic development priorities 3C – Land availability	S G P
4	4A – institutional framework (voluntary or forced activity) 4B – Lack of workers able to do the renovations	G H
...		
n	...	...

Figure 18. Example based on case study 1.1 on how to report the information on adaptation barriers in the case study.

2.5. Reporting of results

The case-study framework provides guidance on what information is to be gathered and analysed for the case study. In the final deliverable (D3.2), the economic appraisal of options and evaluation of strategies will need to be reported in a document. Table 2 provides a template for the reporting of the final results per case study. For each case study, we aim for around 2–3 pages of the description on the key results, and an appendix with explanation of the methodology and a detailing of the results. Through bilateral meetings with the case study owners, more tailored information on this process will be provided. See Appendix A for an overview of what work is expected to be completed for the intermittent milestones.

Table 2. Outline deliverable 3.2

Outline deliverable 3.2 – appraisal of adaptation options in case studies			Key sources of information
1. Decision context			
Objectives → Structure policy question and objective 	The first part of the document should contain a general introduction of the problem statement and policy question of the deep engagement stakeholder and the role of the stakeholder in the decision-making context. This includes a description of broader cross-cutting land use planning and socio-economic considerations the stakeholders face.	Block CS, block Q (from framework)	
2. Current and future risks			
Assess risk → Assess current risks and future risks with uncertainty 	This part should elaborate on the key climate risks that the stakeholders face in this area. This should include both current and future risks. Key uncertainties should also be stated, as well as what would happen without adaptation and with business-as-usual adaptation.	Block Q, block U. Results sectoral models (WP2)	
3. Identifying adaptation options and strategies			
	Adaptation options	Adaptation strategies	
Options → Identify all options and develop strategies A1: Policy instruments A2: Management and planning A3: Coordination, B1: Financing instruments B2: Insurance and risk sharing C1: Grey options C2: Technological options D1: Green options D2: Blue options E1: Information and awareness raising E2: Capacity building.	This part should include a reflection on the typology of adaptation options (is there a balance of grey, green and soft options; is there a mix of incremental and transformational options). In the text, please also include a reflection on how these options were selected.	This part should include a description on the type of strategies that could be identified for the case study and which options this entails.	Options: block O Strategies: block S
4. Assessment adaptation options and strategies			
	Adaptation options	Adaptation strategies	
Decision support → Assess options and strategy (including costs and benefits) 	Describe the main results from the economic appraisal of the adaptation options, including a description of the effects of the options under different biophysical and socio-economic scenarios. This should also include a brief overview of the methodology that was used and uncertainties that were	This part includes a reflection on the primary cost and benefits of each strategy, including co-effects – based on the analysis of the options. This includes a description of important trade-offs and synergies of the strategies. Furthermore, an indication of the temporal and distributional effects at	Options: block U, M, and C Strategies: block SA

	included in the assessment. If only one SSP was used as input for the assessment, also include a reflection on the performance of the options under different socio-economic scenarios.	strategy level should be described.	
5. Barriers & conditions for implementation			
→ Implement <i>Design, finance, implement, monitor</i>	This part includes a description of the main barriers for the adaptation strategies (and options, where applicable). Key here is also to provide some recommendations for the successful implementation of the strategies in light of the barriers identified here, as well as the appraisal results of 4A and 4B.		Framework: block B

3. Protocol for synthesizing case studies into generic adaptation strategies for Adaptation Decision Types

The second objective of WP3 is to derive actionable insights and practical recommendations for common adaptation decisions that many European communities and regions will be confronted with. Within the ACCREU project, we refer to such archetypical decisions as ‘Adaptation Decision Types’ (ADT). In total, seven adaptation decision types (ADTs) have been formulated which are closely connected to Adaptation Missions of the EU (see Table 3).

For each ADT, **generic adaptation strategies** will be formulated that offer a broad range of strategic directions that many European communities and regions could follow. The difference between the case study and the ADT analysis is that in the case study analysis the focus lies on the specific needs of one regional decision maker, while the ADT analysis is addressing more generic needs of other decision makers that face comparable problems. The insights on these decision types are derived from a synthesis from the specific case studies, stakeholder consultations and draw from the sectoral and integrated WP2 and WP4 results (Table 4). It will summarize findings across the case studies and enrich this with outcomes of the sectoral model analysis and literature. Where possible findings from similar other past or ongoing projects and cases will be integrated.

Table 3. Link Adaptation Decision Types and EU Mission on Adaptation.

Adaptation decision type	EU Missions on Adaptation
Flood risk	Water management
Forestry and ecosystems	Ecosystems & nature-based solutions
Water-food-biodiversity	Land use & food systems
Health & justice	Health & wellbeing
Finance & private sector	Local economic systems
Transport & supply chains	Critical infrastructure
Cross-cutting	Local economic systems

Table 4. Links between adaptation decision type work and the sectoral modelling in Work Package 2.

Adaptation decision type	Relevant task in WP2
1 (Flood risk)	2.1
2 (Forestry and ecosystems)	2.5
3 (Water-food-biodiversity)	2.2; 2.4
4 (Health and justice)	2.3
5 (Finance and private sector)	2.1; 2.5
6 (Transport and supply chains)	2.1
7 (Cross-cutting decisions)	–

This section describes the protocol that will be used for synthesizing case study insights into generic adaptation strategies for the seven adaptation decision types. The results of this synthesis will be reported in D3.3, with two intermediate milestones in month 20 and 30 of the ACCREU project. For each Adaptation Decision Type, an ADT owner is assigned that will coordinate the team to work on the final deliverable in a stepwise approach (Table 5).

This protocol describes the different elements to draw up general insights from the case studies and other sources to identify and assess these generic **adaptation strategies** for each **Adaptation Decision Type**. Similar to the case study analysis (D3.2), we take a ‘policy-first approach’ in the analysis of the decision types (D3.3). In the next chapter both the ‘science-first approach’ and the policy-first approach’ will be further elaborated on (including the merits and drawbacks), which are used to address the economics of adaptation.

For each ADT, at least two case studies are evaluated (Table 5). For each case study, the considered adaptation options have been translated into more generic strategies. These insights are used to formulate distinctive and MECE (mutually exclusive, collectively exhaustive) generic adaptation strategies for each ADT.

Table 5. Case study and adaptation decision-type owners.

Adaptation-decision type	ADT owner	Case studies	Case study owners
1 (Flood risk)	Deltares	1.1 Sub-national adaptation investments for coastal/riverine floods 1.2 Large scale adaptation options for European coastal policy	1.1 <i>Deltares</i> 1.2 <i>GCF</i>
2 (Forestry and ecosystems)	DTU	2.1 Multi-sectoral adaptation to wildfire risk 2.2 Adaptation options forest fire risk reduction	2.1 <i>DTU</i> 2.2 <i>DTU</i>
3 (Water-food-biodiversity)	IIASA	3.1 Integrated adaptation decisions water-food nexus 3.2 Conservation and mitigation preservations	3.1 <i>IIASA</i> 3.2 <i>CMCC/IIASA</i>
4 (Health and justice)	Ecologic	4.1 Adaptation policy assessment, health and distributional aspects 4.2 Social justice dimensions of climate policy	4.1 <i>BC3/Ecologic</i> 4.2 <i>Ecologic/BC3</i>
5 (Finance and private sector)	Deltares/VU	5.1 Adaptation options for enhancing financial stability 5.2 Stimulation of private sector adaptation through insurance arrangements	5.1 <i>Deltares</i> 5.2 <i>VU</i>
6 (Transport and supply chains)	UniGraz	6.1 Adaptation to minimize the risk of disruptions of trade corridors 6.2 Reduction supply chain risk PV industry regarding critical raw materials	6.1 <i>Deltares</i> 6.2 <i>UniGraz</i>
7 (Cross-cutting decisions)	PWA	7.1 Cross-sectoral economic analysis for adaptation of region/community 7.2 Economic analysis for national and EU partner	7.1 <i>PWA</i> 7.2 <i>PWA</i>

3.1. From case studies to Adaptation Decision Type

The objective of Task 3.3 is to generalise the case study insights and to demonstrate practical adaptation solutions to support and empower all European communities, beyond the deep engagement and generic stakeholders. This enables a larger number of regions to take concrete action. Additionally, we seek to demonstrate how all European territories may benefit from the physical and sectoral results of WP2 as well as integrated analysis of WP4 and complement these with local case study deep-dives as inspirational examples.

Why is a synthesis needed? Because the case study analysis is *stakeholder need oriented*, whereas the decision types are oriented at the *needs of all European territories*. The case studies give insight in the practical economic adaptation considerations of local (subnational) stakeholders. The decision types are focused on the generic economic adaptation considerations that many regional decision-makers in Europe face. See Table 6 for a preliminary description of the decision problems that each ADT addresses and the decision-makers that are tasked with making decisions on these problems.

In this context, how would we define the term ‘decision type’? A decision type is archetypical adaptation decision that many European regions and communities will need to make. The difference between adaptation decision types and case studies is best illustrated with an example. For example, let’s consider case study 6.2: reduction of supply chain risks for the photovoltaics industry regarding critical raw materials. This is a specific case study for the photovoltaics industry in Austria. It is representative for a decision type that many European regions and communities have to make: how can we configure transport networks and supply chains in such a way that we facilitate (and not work against) the climate mitigation process?

This approach is in line with the *Mission on Adaptation* of the European Commission. The objective of this mission is “to support at least 150 European regions and communities in becoming climate resilient by 2030”. By focusing on a *selection* of regions and communities, the mission seeks to build momentum for *all* regions and communities that need to become more climate resilient. Likewise, our case studies focus on a *selection* of regional adaptation decisions, while our decision type analysis seeks to learn from these for *all* regions and communities.

Table 6. Decision context and decision-makers within each adaptation decision type.

ADT	Decision Context	Case study stakeholders	Generic stakeholders (decision-makers)
1 (Flood risk)	Regional authorities must decide on how to cope with increasing flood risks, under limited budgets and while also pursuing other spatial planning goals.	1.1: Water board HHNK & Province North-Holland (NL) 1.2: WWF Germany; States Schleswig-Holstein & Mecklenburg-Vorpommern; European agencies	Local water boards; Regional governments (provinces/states); National governments; Nature conservation agencies; European Agencies
2 (Forestry and ecosystems)	Regional and municipal authorities must decide on the creation of new wildfire management plans, for which they need to coordinate with partners beyond the regional and municipal level, such as private forest owners and forest managers.	2.1: STRESS S.c.a.r.l.; municipality of Sorrento; Campania region 2.2: private sector (Miljö och Skog i Leksand Aktiebolag)	Forest managers; Regional governments (provinces/states); Local governments; Private land owners; Private companies
3 (Water-food-biodiversity)	River basin managers must decide on the allocation of scarce water resources, while also optimizing towards food and biodiversity objectives, i.e. trying to find a delicate balance between diverse water users including drinking water, large-scale irrigation, and nature. Protected area managers need to maintain and protect the areas from extreme events and anthropogenic pressures.	3.1: Ebro River Basin Authority; Ministry of Agriculture (Czech Republic) 3.2: WWF Italia	River basin managers; National governments; Regional governments Nature conservation agencies; local and regional governments
4 (Health and justice)	Municipalities and regions must adapt to heat-related impacts through specific plans and take other adaptation measures to ensure public health, while making sure that such adaptation decisions do not exacerbate social injustice through distributional impacts e.g. harm vulnerable groups	4.1: Ministry of Environment (Basque Country) 4.2: Federal State of Bremen	Local governments; Regional governments; National governments
5 (Finance and private sector)	Private and commercial financial institutions, such as banks and insurers, must decide what (new) role they are going to fulfil in support of the urgent societal need to adapt to climate change, while being pushed by several new EU regulations.	5.1: Dutch Central Bank 5.2: Dutch Association of Insurers	Banks; National Central Banks; European Central Bank; Insurance companies

6 (Transport and supply chains)	The transport sector needs to decide on how it can meet mitigation challenges, while at the same time ensuring that these efforts are not maladaptation in terms of enhanced climate risk.	6.1: Ministry of Finance (Austria); Österreichische Bundesbahnen 6.2: Fronius; AT&S	National governments; European-scale governments; Transport companies; Sustainable energy companies
7 (Cross-cutting decisions)	National governments must decide on how much financial resources they need to reserve for funding the adaptation needs for a myriad of sectors and hazards.	7.1: national UK level stakeholder 7.2: UK Treasury; OBR	National governments

3.2. Generic Adaptation Strategies

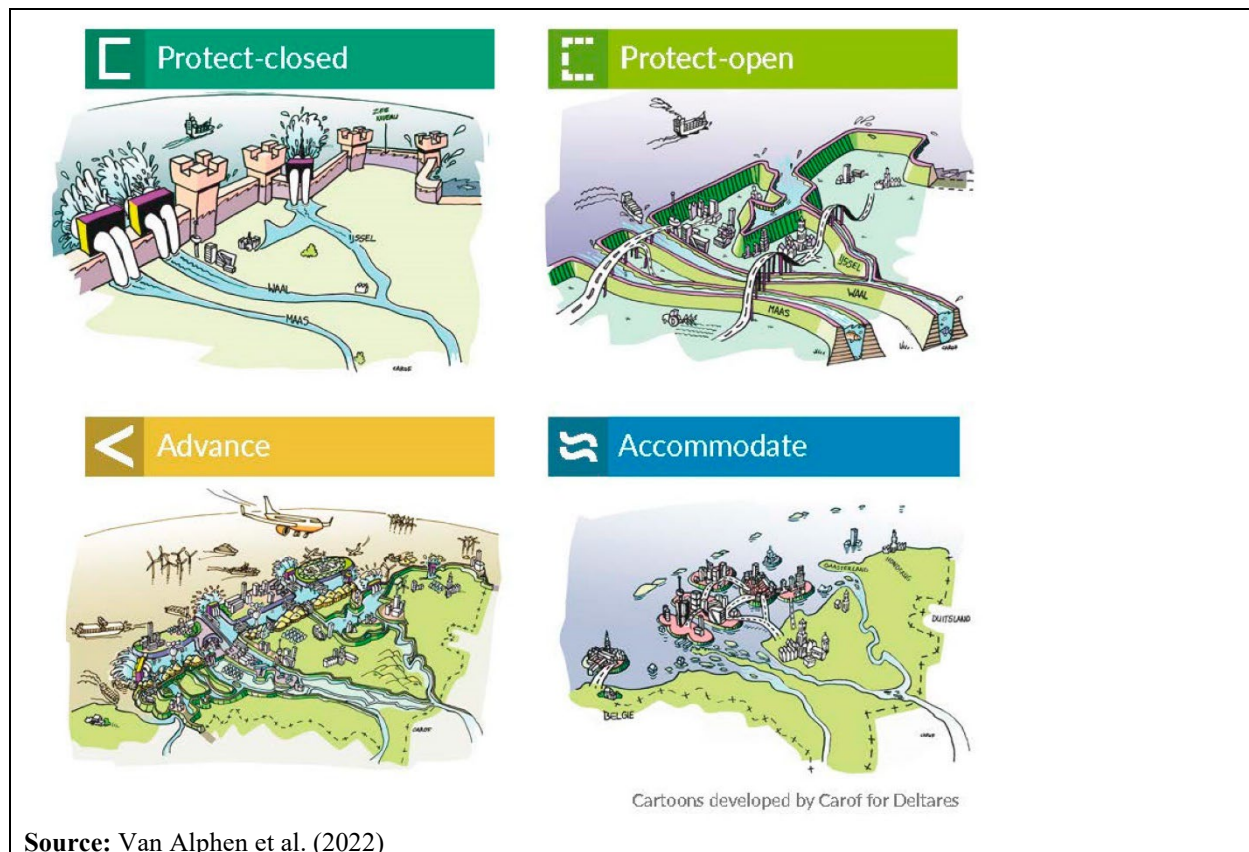
A key ingredient of the ADT consists of formulating archetypical adaptation strategies or directions, further referred to as ‘generic adaptation strategies’. These **generic adaptation strategies** can be considered overarching key strategic choices that are relevant within the policy context of each adaptation decision type. These are used to generalize insights and shape the landscape of policy directions of each ADT. As such, they are more high-level than the strategies as defined in Chapter 2, as they cover the wide spectrum of adaptation directions that can be taken with regards to an adaptation decision type. The generic adaptation strategies will guide the different directions that decision-makers can take when faced with similar policy questions as addressed in the ADTs.

A key example of these type of generic adaptation strategies is from the IPCC, that introduced three archetypical directions for coastal areas to deal with climate risks such as sea level rise: **protect, accommodate, advance, and retreat** (Glavovic et al., 2022). **Protect** is related to minimising further damage to people, property or infrastructure, often by means of hard or ‘grey’ infrastructure (e.g. seawalls, storm surge barriers, dikes) or soft strategies (e.g. beach nourishment or mangroves). **Accommodate** allows environmental changes (such as salinity intrusion or erosion) and is focused on systems to be able to cope with the change. Finally, **retreat** removes the assets or people at risk of the hazard, decreasing the impacts of damages (Suckall et al., 2019). These strategic decisions can also be framed under the three categories of risk; hazard, exposure and vulnerability, whereby protect is focused mainly on reducing the impacts of the **hazard**, accommodate is related to decreasing the **vulnerability**, whereas retreat reduces the **exposure**.

These generic adaptation strategies are closely linked to Adaptation Decision type one, specifically for the policy question related to *How can coastal areas deal with the impacts of sea level rise*. Each strategic direction can encompass several different types of *strategies*. For instance, within the ‘accommodate’ / ‘vulnerability’ strategic direction, strategies such as flood-proof buildings, disaster preparedness or flood insurance are possible.

Box 2: Generic adaptation strategies for the Dutch Delta Program

Another, related example is based on the Dutch Deltaprogram. Within the Dutch Deltaprogram, a key policy question is related to how the Dutch coast is able to deal with the impacts of sea level rise. Four different directions are outlined: protect (Open), Protect (Close), Inward Accommodate and Seaward Advance, which are visualised in different ways.



Source: Van Alphen et al. (2022)

Table 7 outlines a non-exhaustive list of potential adaptation strategies for each Adaptation Decision Type. These ADT have been connected to the Key Adaptation Missions of the EU. We have summarised the generic adaptation strategies into five categories: hazard reduction, exposure reduction, vulnerability reduction, adaptive capacity, and synergy with mitigation. This categorization of generic strategies can serve as a starting point for each ADT. However, each ADT is also allowed to make an alternative categorisation if that suits the context of the ADT better.

Table 7. Provisional Generic Adaptation Strategies per ACCREU decision type and key community system of the mission-on-adaptation.

EU Adaptation Mission Key Community Systems (Adaptation decision type)						
Generic Adaptation Strategy	Water management (1. Flood risk)	Ecosystems and nature-based solutions (2. Forestry)	Agriculture and food security (3. Water, food, biodiversity)	Health and wellbeing (4. Health & justice)	Infrastructure (6. Transport & supply chains)	Crosscutting (5. finance & private sector; 7. crosscutting)
Hazard reduction	Retention, infiltration, room for the rivers, surge and wave reduction, wetlands, SuDS	Make corridors; prescribed burning	Large scale upstream water retention	Greening the cities	Clearing obstacles	
Exposure reduction	Flood zoning, planned relocation, spatial planning	Restrict human activity in/near forest	Shading nets, drip irrigation, eflow enforcement	Cool spots, white surfaces, increase shading	Drainage systems, risk-based planning	Zoning, differentiated premiums
Vulnerability reduction	Flood proof buildings, disaster preparedness, flood insurance	Increase heterogeneity, promote new climate resilient species	Drought resistant crops, diversification of rural economy	Heat alert system, public drinking water taps	Larger buffers	Reinsurance, mixed systems
Adaptive capacity / enabling environment	Improve integrated flood risk governance, increase awareness of citizens	Capacity building among practitioners, fire response planning	New business models for farmers, nature-inclusive landscape management, IWRM, watershed management	Include adaptation against heat, vector-borne diseases and floods into urban development	Response planning	Increase awareness among banks on mortgage risks related to climate change
Synergy with mitigation	Reforestation, mangroves, hydropower	Reforestation	Precision agriculture, intercropping	Cooler cities require less energy for cooling; greening		

3.3. Envisioned synthesis: generic adaptation strategies for ADTs

The synthesis of the case-study insights into generic adaptation strategies and recommendations (D3.3) is to be reported in a separate document per ADT. Ideally, each ADT also delivers a review paper of the results. For the outline of the deliverable, we follow the same structure as for the case-study template (Table 2 in paragraph 2.5), based on the policy-first framework. This template provides guidance for the reporting of the final deliverable per ADT. Similar for the case-study analysis, for each ADT we expect a document of around 2–3 pages with the description on the key results, and an appendix with explanation of the methodology and a detailing of the results. Through bilateral meetings with the ADT owners, more tailored information on this process will be provided. See Appendix A for an overview of what work is expected to be completed for the intermittent milestones. The different steps for this deliverable are outlined in Table 8 and further elaborated below.

Decision context and future and current risks

This should include the key policy questions and the decision context in which key strategies will need to be chosen that will help policy makers across the EU regions to overcome their current and future climate risks. Guiding for this will be the policy questions that have been provided during the stakeholder workshop and that are formulated within the different case-studies. Furthermore, to understand the broad spectrum of the decision context and current and future climate and socioeconomic risks, input will need to be gathered through a literature/desk review (including learnings from other cases).

Formulation of generic adaptation strategies

To formulate the different generic adaptation strategies per ADT, a first step will be to use the generalization of insights from the case study analysis, in particular a synthesis of the adaptation strategies within the case studies. However, this will (most likely) not cover the broad spectrum of policy questions that require direction in the ADT, as the collection of cases is still rather small. In order to provide a more complete overview in the generalization of directions per decision type, additional sources of information will have to be used, such as:

- Grey and academic literature.
- Other existing cases and their outcomes from parallel or past projects.
- Modelling exercises within ACCREU in WP2 (see also next paragraph)
- Input from ACCREU stakeholders

Main objective is to formulate overarching and distinctive strategic directions within the ADT, such as the example explained in Box 2. Important here will also be to indicate whether the strategy is part of an incremental adaptation response, or whether it would entail a transformative system change. See paragraph 2.3.1 for an explanation of these terms and some examples.

Assessment of generic adaptation strategies

Although it will be a mere impossible task to assign numbers to the generic strategies in terms of cost and benefits, based on the insights from the different sources, it is potentially possible to

outline the cost and benefits relative to each other. Thus, for each direction (strategy) an evaluation should be made how the strategy performs compared to the other strategies formulated in terms of the primary effects and additional cost and benefits. In addition to the primary and secondary effects, the strategies are also to be (relatively) evaluated on the distributional and temporal dimensions, as outlined in paragraph 2.4.1. On the temporal dimension, we are mainly interested in how the pathway is receptive for possible lock-ins, and how feasible switching is when needed in terms of cost and social acceptance.

A helpful tool in this assessment could be through the formulation of adaptation pathways. In literature adaptation pathways are often understood as sequences of separate options that can be implemented over time, depending on future dynamics. They are specifically designed to deal with uncertainty and to reveal path-dependencies and potential lock-ins. Pathways help identify low-regret short-term decisions while keeping options open to adapt when necessary (Haasnoot et al., 2019). Once the strategic directions are formulated, it can be helpful to consider the connectivity between the strategies. Some strategies might follow a straight path into the future or can deviate and switch into another path if future dynamics require this (e.g. when a *tipping point* has been reached). At the same time, a choice for one strategy today can have consequences (e.g. create lock-ins), making it harder, or more costly to deviate into another strategy. Placing the different strategies in pathways can guide the evaluation on the temporal aspect, related to path-dependencies and lock-ins. This is by no means required within the ADT but can be used to guide the evaluation. An example of adaptation pathways is given in Figure 19.

Solution space for coastal cities and settlements by the sea

(a) Generic adaptation pathways for coastal cities and settlements to sea level rise

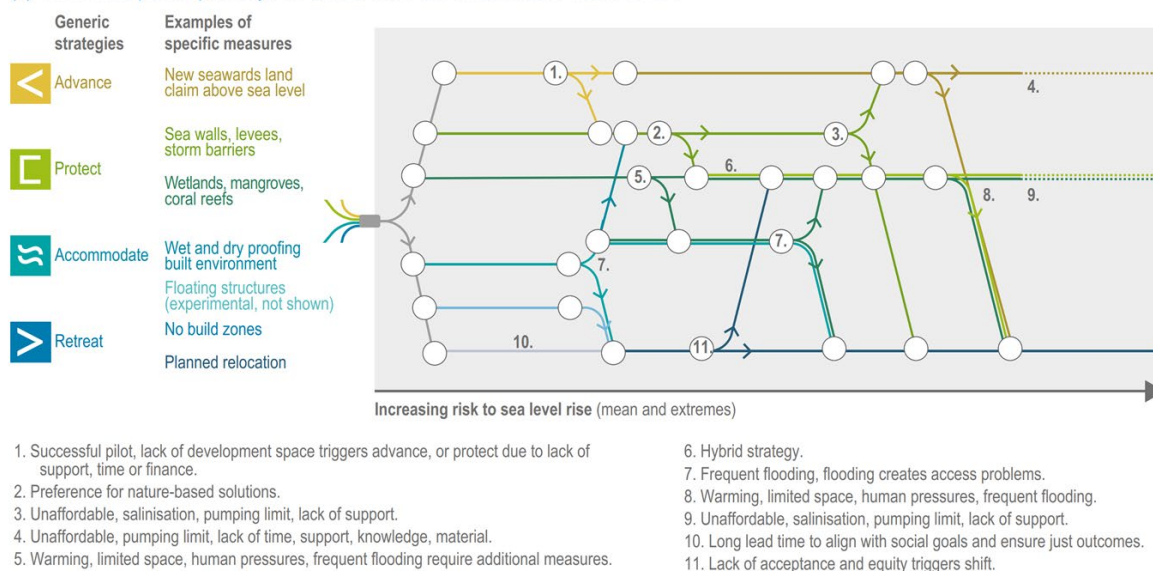


Figure 19: Example of adaptation pathways existing of generic and specific strategies to overcome the impacts of sea level rise (Van Alphen et al. (2022))

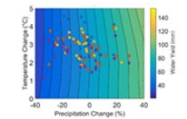
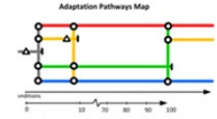
Barriers & Conditions for implementation

As a final step, a list of the key barriers and limitations should be provided for each strategic direction, in line with the analysis done at case-study level (paragraph 2.4.2). Again, this information should not solely depend on the case-study synthesis, but also on other sources of information, such as literature, other case studies, stakeholder input and potentially from the sectoral models.

Final Document

The **final document** for D3.3 will synthesise the generic adaptation strategies that are relevant within each ADT and will offer key insights on the evaluation of these strategies to inform policy makers in a practical way on the broad spectrum of policy questions and issues that exist within their adaptation decision type domain. As such, the generic strategy synthesis will guide the different directions that decision-makers can take when faced with similar policy questions as addressed in the ADTs. This includes providing recommendations on these directions and sketch the potential effects for each direction or strategy, including a rough evaluation of the costs and benefits (relative towards each other or order of magnitude). Furthermore, an indication of additional temporal and distributional effects are to be outlined to have a generic comparison of the different strategic choices. This also means that the final document should contain guidance on the methodology of assessment at the generic strategic level and a list of key **research questions** on how to tackle this. For each ADT owner, online workshops will be organized to provide further guidance on the process.

Table 8. Outline deliverable 3.3.

Outline deliverable 3.3 - Generic adaptation pathways of Adaptation Decision Types		Key sources of information
1. Decision context		
Objectives → Structure policy question and objective 	The first part of the document should contain a general introduction of the decision type and its key policy question(s). The following elements should be included: - Description of the adaptation decision type - Key policy objectives within the ADT - Key policymakers and stakeholders involved.	Literature review. Framework case studies (block Q). Input stakeholders (Brussels workshop) Input from other cases
2. Current and future risks		
Assess risk → Assess current risks and future risks with uncertainty 	This part should elaborate on the decision context of the ADT, specifically addressing key climate risks that are associated with the ADT. This should include both current and future risks. Key uncertainties should also be stated.	Literature review. Framework case studies (block Q and U). Stakeholders
3. Formulating Generic Adaptation Strategies		
Options → Identify all options and develop strategies A1: Policy instruments A2: Management and planning A3: Coordination, B1: Financing instruments B2: Insurance and risk sharing C1: Grey options C2: Technological options D1: Green options D2: Blue options E1: Information and awareness raising E2: Capacity building.	For each adaptation decision type, a number of generic adaptation strategies (strategic directions) should be drafted (ideally with a minimum of 2 and a maximum of 6). They should consist of fundamentally different strategic choices, which together ideally cover the complete spectrum of the decision context (MECE).	Literature review. Framework case studies (block O, S); Stakeholders Input from other cases
4. Assessment Strategic Adaptation Pathways		
Decision support → Assess options and strategy (including costs and benefits) 	To provide generic insights and policy recommendations at the ADT level, it is important to outline insights on the cost and benefits of the generic strategies. The assessment should consist of a relative comparison of the cost and benefits, and temporal and distribution of effects of the different strategies, including a description of the methodology of the assessment (what is possible/needed)	Literature review. Framework case studies (block C, SA). Stakeholders

5. Barriers & conditions for implementation		
→ Implement <i>Design, finance, implement, monitor</i>	To achieve actual implementation, numerous barriers and conditions will need to be addressed. What are the specific barriers for implementation within your ADT? What key conditions will need to be fulfilled?	Literature review. Framework case studies (block B). Stakeholders

3.4. To what extent could regions use the outputs of WP2 sectoral models?

There is an ongoing debate (e.g. Blankespoor et al., 2023) about the usefulness of large-scale models for local planning and adaptation needs. This debate is partly fuelled by optimistic claims that are made in the scientific studies in which sectoral models are presented, and partly by the rapid increase in publicly available datasets that they produce, notably in the field of ‘climate services’. This sometimes leads to disappointments for regional decision makers. After all, sectoral models typically cannot represent the many complexities of local geographic and socio-economic dynamics that are important to local decision makers. At the same time, this does not mean that sectoral models are completely useless for regional decisions. Therefore, it is important that the usefulness of sectoral models is explicitly discussed (Blankespoor et al., 2023).

To link the sectoral models as much as possible to the case-study and ADT analysis, ACCREU will carry out the following exercise to map out the usefulness of sectoral model outputs for the selected decision types. For each decision type, ADT-owners are asked to answer the following questions as per example for ADT 1 in Table 9 (roughly 1 A4 per decision type).

Table 9. Questions to connect sectoral models with case study and ADT analysis.

Decision type 1: adaptation decisions in flood risk management			
Sectoral model name and description	Can typically be used for...	Can sometimes be used for...	Can typically not be used for...
DIVA Global coastal impact and adaptation model with NUTS2 or smaller coastal unit resolution for the EU; modelling of direct damages to physical assets and infrastructure, loss of agricultural dry-land, loss and change of coastal ecosystems (wetlands); PM model for RA CBA; time horizon, 2030, 2050, 2100.	Rapid assessment of vulnerability to coastal flooding, including rapid assessment of expected economic and ecologic damages		Locally specific assessments and decision making <i>assessment of alternative options for NBS (?)</i>
JRC-Lisflood combined with RA2CE-OSdaMage for impacts to road network	- rapid assessment of aggregate flood damage to (road) transport infrastructure - giving insight in the distribution of damage over different road types - identification of critical network links that are exposed to large-scale river floods	- finding individual road segments within a region that are potential high-risk flood hotspots for large-scale river floods (estimated accuracy in COACCH: 50% True positives)* - rapid assessment of which road segments need further detailed inspection by road authorities	- precise forecasting of required repair activities, damage and adaptation needs at the level of individual road segment - forecasting of damage to bridges - forecasting damage from pluvial (rainfall) flooding, and small rivers/creeks with an upstream catchment < 500 km - forecasting damage resulting from landslides triggered by floods
GLOFRIS Global flood risk assessment model (river and coastal floods), 1x1km2 or EU- NUTS3 resolution. Climate change impacts and adaptation policy assessment in 2030, 2050, 2100. Assessments of direct damage across sectors (Rural, Urban, Agriculture, Industry, Infrastructure, Nature). Indirect economic damage via scaling factor			Locally specific assessments and decision making

4. Integrating costs and benefits in CGE/IA models

Task 3.4 is concerned with gathering data and studies on adaptation costs and benefits, to inform the macro-economic models (CGE and IAM) that will be used in the integrated macroeconomic analysis of WP4. In simple terms (UNEP, 2015), the costs and benefits of adaptation² can be assessed by estimating the future impacts of climate change, then assessing the reduction in these impacts (the benefit of adaptation) and the associated cost to deliver this reduction. However, there is a trade-off over how much adaptation to undertake, and the residual damage costs after adaptation (see figure 20). This reflects the fact that adaptation is rarely completely effective and that it usually becomes more costly (and less cost-effective) to reduce impacts towards zero, thus it is more efficient to have a residual level of damage after adaptation.

Increasing the quantity of adaptation implemented will lead to a greater reduction in climate impacts, and thus greater adaptation benefits, as well as lower residual damage. However, it will lead to higher adaptation costs. In theory, it is possible to identify the economic optimal level of adaptation, but as discussed below, this is extremely challenging, and also in many cases this will lead to high residual damages that may be unacceptable.

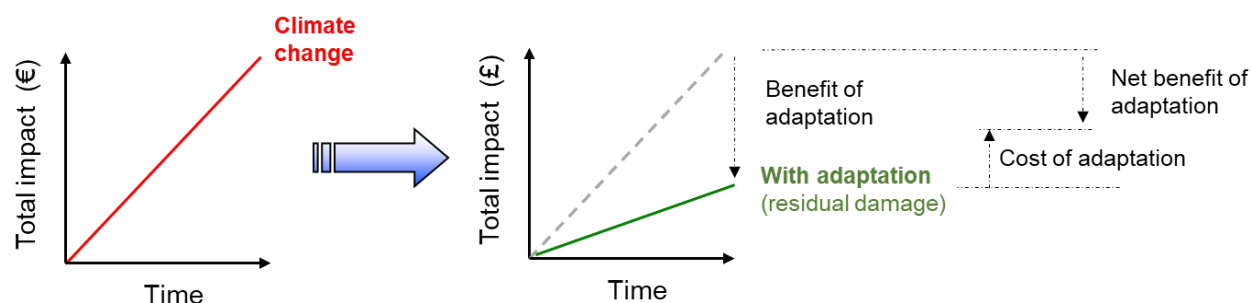


Figure 20. Schematic of the Costs of Climate Change, and the Costs and Benefits of Adaptation. Adapted from Boyd & Hunt (2004).

In practice, estimating the costs and benefits of adaptation is extremely complex (Watkiss, 2023). There is no single definitive estimate, i.e. the costs (and benefits) depend on the objectives chosen, the method used, and the assumptions made. These issues are important in developing new functions for the CGE and IAMs in this task.

² The costs of adaptation can be defined as the costs of planning, preparing for, facilitating and implementing adaptation measures to moderate harm or exploit beneficial opportunities arising from climate change (Intergovernmental Panel on Climate Change [IPCC] 2007; UNFCCC Adaptation Committee 2022).

4.1. Framing of adaptation

The economic costs of climate change can be assessed using scenarios and models. This is often called a 'science-first approach' because it starts with the climate models, and then undertakes a step- by-step analysis, where the output of one step is used as the input for the next (Brown et al., 2018; Watkiss & Betts, 2021). The climate model outputs are used as inputs in impact assessment models, for example to assess physical impacts of agriculture yield loss or flood damages. The outputs of these models can then be quantified in monetary terms and put into a macro-economic model. This approach is typically used for medium and long- term assessment of the costs of climate change.

This framework can be extended to model adaptation (see Figure 21). In this case, the impact analysis can assess the costs of adaptation (e.g., irrigation or dyke costs) and assess the benefits these have in reducing future climate change, as well as residual damage, but this is normally based on a prescriptive decision set in the modelling analysis, e.g., the model will assess flood protection to meet an acceptable level of risk such as protection to a 1 in 100 year return period, or the agriculture model will seek to optimize yields. Most importantly, the approach involves running the analysis repeatedly, for example, for each different scenario and climate model, or for different decision framing.

However, while the science first approach provides key results, it often does not provide the information needed for real-world adaptation decisions that have to be taken now (and not in 2050). This is because of two key reasons. First, the impacts of climate change, and thus the benefits of adaptation, primarily arise in the future, and this makes it difficult to justify up-front costs (today) in economic terms. Second, there is high uncertainty about future climate change, which makes it difficult to make decisions now, because of the risk of under- or overinvesting in adaptation.

To address this, an alternative approach is often used for adaptation, the 'policy-first approach' (Brown et al., 2018; Watkiss & Betts, 2021). This frames the analysis from the policy question and supports early decisions that are made under uncertainty. Most importantly, the policy first approach is focused explicitly on informing adaptation and thus adaptation objectives and framing come at the start of the analytical process (unlike the science first approach where adaptation comes at the end).

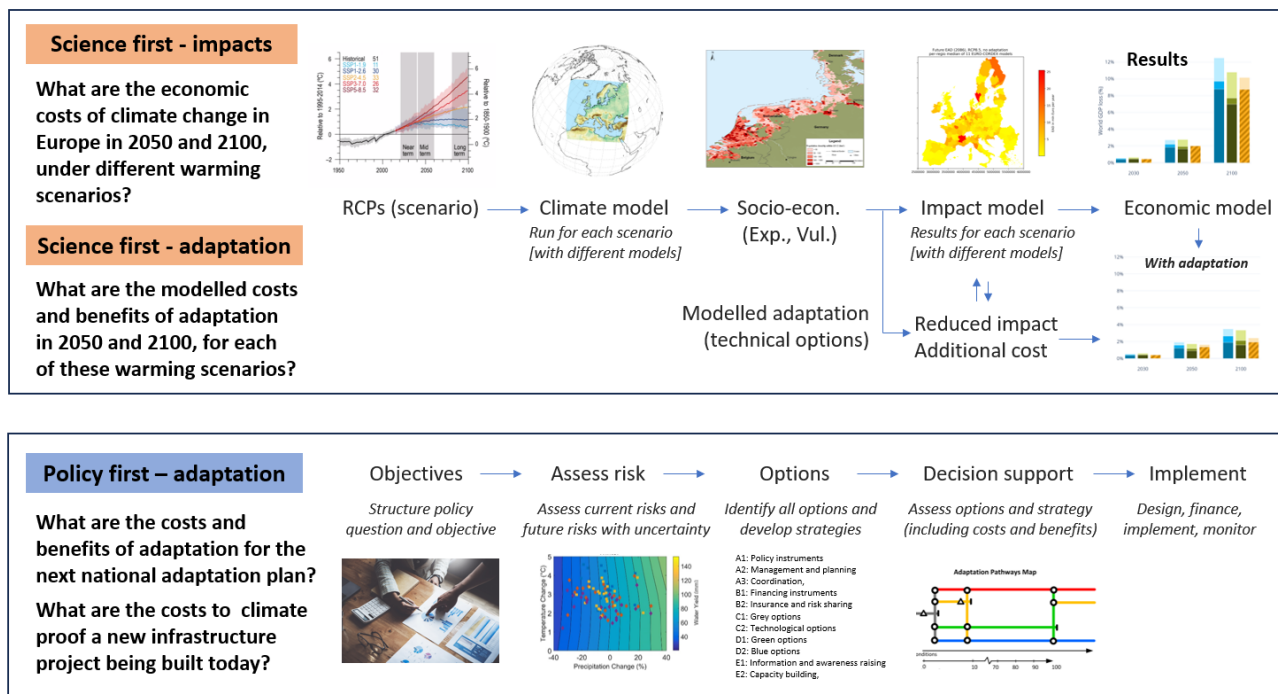


Figure 21. The Science-First and Policy First Approaches for Adaptation Analysis.

The analysis of adaptation costs and benefits will depend on the type of framework, and user needs. For this task, the CGE and IAM work in a science first framework. This therefore is the focus on the analytical work in this task, including review and potential functions.

4.2. Challenges of Estimating Adaptation Costs and Benefits

Even within a science-first approach, it is extremely difficult to estimate the costs of adaptation. The reasons for this were summarized in the ACCREU input to the UNEP 2023 adaptation gap report (UNEP, 2023).

Box 3: Why do the estimated costs of adaptation vary?

Framing issues

- Objectives. There is no single agreed quantitative goal for adaptation. The costs of adaptation vary with the objective and whether this is based on economic efficiency, acceptable risk levels or reducing impacts to current levels. This also determines residual damages, which are relevant for losses and damages.
- Uncertainty. There is high uncertainty around the future risks of climate change and thus the amount and cost of adaptation needed. This arises from alternative future emission and socioeconomic scenarios, alternative climate models as well as from uncertainty around the level of (physical) climate impacts.
- Coverage and boundaries. Adaptation costs vary with the coverage of sectors and the risks as well as the boundaries e.g. whether to include costs to address existing natural climate variability and extremes, and whether general development is included (e.g. activities to increase household incomes).

Methodological issues and assumptions

- Estimating adaptation costs is challenging because of the site- and context-specific nature of risks (hazard, vulnerability and exposure), which change over time non-linearly and have high uncertainty (as above).
- Adaptation costs vary with the method used, the assumptions within the modelling or analysis framework, and with the assumed effectiveness of adaptation (in reducing climate risks).
- The incremental level of climate impacts and the level of adaptation and costs both depend on the historical reference period chosen. More recent baselines reduce the level of impact and thus adaptation costs.
- Adaptation costs vary depending on whether autonomous adaptation is included in the analysis of impacts (e.g. from natural acclimatization to heat or from changes in prices in markets).
- Adaptation costs are higher if real world implementation is considered, and if associated opportunity and transaction costs as well as design, management, implementation and monitoring costs are considered.
- Adaptation costs are lower if learning and innovation are included, and if soft options are considered (e.g. early warning), as these can have lower costs than engineered options.
- Adaptation costs expressed in EUR can vary. Different studies have different price years and some estimates are presented as purchasing power parity values.

- Adaptation is often described as a process. An adaptive management approach frames risks iteratively over time, then uses decision-making under uncertainty, and so identifies different adaptation options and costs, compared with a linear static analysis.

Additional factors and key gaps. While there has been significant progress in estimating adaptation costs, there remain areas that are still not well captured in the literature.

- Most adaptation costing has focused on incremental adaptation, but the need for transformative and transformational adaptation will involve very different costs (and is a priority for further analysis).
- Adaptation costs will vary with soft and hard limits to adaptation, which also determine residual damages, but these limits have rarely been considered in analysis.
- Most studies have focused on direct climate change impacts, but there is increasing awareness of the need to adapt to cascading and compounding risks and address interdependencies.
- Adaptation that considers gender equity and social inclusion, or distributional analysis, will give different weight to different groups, which can affect costs.
- Mitigation and adaptation can involve positive synergies and potential trade-offs. Considering these can change adaptation options and costs.
- Adaptation is often delivered by integrating in existing policies and programmes, rather than as a stand-alone policy, and there can be synergies (or trade-offs) with other policy objectives, which affect costs.

Source: ACCREU project, written for the UNEP Adaptation Gap Report, Published in UNEP, 2023. References for material in box is published in Watkiss, 2023.

Because of these issues, it is not possible to produce a database of adaptation costs and benefits, hence the focus in previous projects has been on providing useful information. Previous EC research projects have produced inventories of case studies (as in the BASE project) and inventories of adaptation costs and relevant economic studies (as in the ECONADAPT project).

For ACCREU, work package 3.4 is focused on gathering relevant information for the CGE and IAMS. This is reflected in the task deliverable (D3.4 Economics of adaptation inventory (month 26)).

4.3. Objectives

The ideal information (the objective) produced from this task would be to produce a set of cost and benefit functions that can be used to assess adaptation in the ACCREU modelling suite.

However, while more studies have been published on the economic costs of climate change (see O'Neill et al., 2022), much less progress has been made in producing new estimates of global adaptation costs and benefits functions. Indeed, adaptation remains poorly represented in current global modelling frameworks and integrated assessment models (van Maanen et al., 2023).

This task aims to address this gap. An example of what is needed is shown below from the COACCH project (van der Wijst et al., 2021). This developed a set of functions for modelling the economic costs for climate change (for the CGE model and also new IAM functions) and produced one set of functions for sea-level rise adaptation, using information from the DIVA model. This converts the available information into a temperature function, that has rising sectoral damage costs, with and without adaptation, and an associated cost function, that changes with temperature. This can be input directly into the IAM and CGE framework.

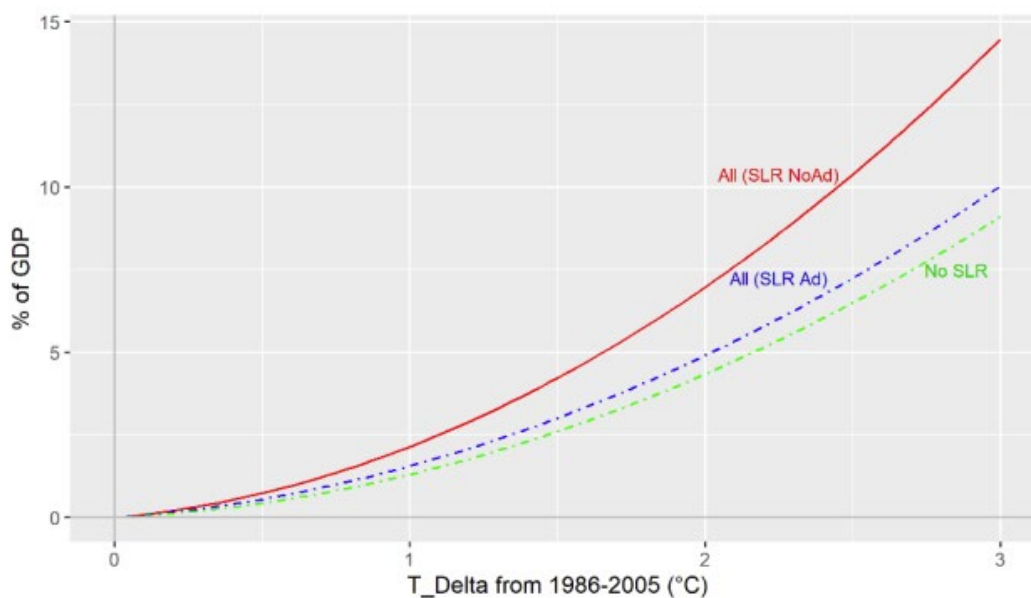


Figure 22. Aggregated CCDFs world: Including SLR without adaptation (red line), SLR with adaptation (blue dashed line) and all climate change impacts, but SLR (green dashed line). Source: van der Wijst et al. (2021).

However, COACCH only considered SLR because this was the only sector for which adaptation costs were available. The focus of ACCREU is to try and understand the costs and benefits of adaptation for all sectors. As highlighted in D1.1, this is difficult because the state-of evidence is very variable across different areas, shown in the Table below (Table 10).

Table 10. Coverage of Economics of adaptation. Source ACCREU D1.1.

Risk / Sector	Adaptation economics coverage
Coastal zones and coastal storms	✓✓✓✓
Floods	✓✓
Agriculture	✓✓
Forest and fisheries	✓
Infrastrucure including Transport	✓✓
Energy	✓✓
Water manage-ment	✓✓
Business, services and industry	✓
Tourism	✓
Finance	x
Health	✓
Biodiversity / ecosystem services	✓
Macro-economic analysis	x
Other	x

✓✓✓ = Very high coverage ✓✓✓ = High coverage. ✓✓ = Medium coverage. ✓ = Low coverage. x = Evidence gap.

Nonetheless, it is considered possible to advance a first set of functions, that move the literature beyond current state of the art. To do this an approach is proposed based on several evidence lines.

4.4. Proposed approach

To advance this task, four evidence lines are proposed.

- A detailed review and estimate of the costs of adaptation based on sectoral models (European and Global).
- A detailed review of the adaptation finance needs (costs) reported in NDCs and NAPs.
- A review of the WP2 models (see below) and adaptation functionality and outputs.
- A detailed review of other literature on the costs and benefits of adaptation.

4.4.1. Modelled costs and benefits of adaptation

This sub-task will review adaptation cost and benefit estimates from established sector models and recently published studies, and where relevant, it will follow up with these modelling teams to explore adaptation cost information. This will draw on the work funded by ACCREU for the Adaptation Gap report (UNEP, 2023), which investigated potential global impacts and adaptation costs for a number of sectors, see table 11. The analysis will derive functions for these sectors, and where possible convert these to a temperature function.

Table 11. Review of modelled costs and benefits per sector.

Sector or theme	Approach
Coastal zones	DIVA model (Hinkel <i>et al.</i> 2013; Hinkel <i>et al.</i> 2014) and model runs (Lincke <i>et al.</i> 2018)
River floods	GLOFRIS model (Ward <i>et al.</i> 2017) and model runs (Lincke <i>et al.</i> 2018)
Infrastructure	World Bank (Hallegatte, Rentschler and Rozenberg 2019; Hallegatte <i>et al.</i> 2019), extended to 2050 ([AFG] Update 2023)
Agriculture	IFPRI modelling suite and model runs (Sulser <i>et al.</i> 2021)
Fisheries, aquaculture and marine ecosystems	AFG Update 2023 using fisheries impact data from the Food and Agriculture Organization of the United Nations (2018)
Health	AFG Update 2023 using health impact data from the World Health Organization (2014)
Early warning and social protection	AFG Update 2023
Terrestrial biodiversity and ecosystem services	AFG Update 2023 based on data and approach of Protected Planet (2023), Waldron <i>et al.</i> (2020) and UNEP (2022). Noted as underestimate
Cooling demand and labour productivity	Qualitative review
Business and industry	Qualitative review
Capacity-building and governance	Qualitative review
Socially contingent effects	Qualitative review

Source: Watkiss *et al.* (2023b).

4.4.2. National Determined Contributions and National Adaptation Plans

An analysis of adaptation finance needs that have been submitted to UNFCCC in National Determined Contributions (NDCs) and National Adaptation Plans (NAPs) by countries will be made. Among 155 non-Annex I countries, all except Libya and Yemen, have submitted at least one NDC, and 46 countries have also submitted their NAPs as at 31 July 2023 (UNFCCC 2023a, 2023b). Of these submitted NDCs and NAPs, 85 countries have specified their adaptation finance needs for the period 2021–2030 in at least one of their submissions, and this is reported as a cost of adaptation (US\$) (UNEP, 2023). This information provides a useful set of alternative adaptation costs to the modelled costs above, though it should be noted much of this is closer to a policy-first framing than a science first analysis and focuses on costs of adaptation up to 2030. While the Annex I countries have also submitted NDCs, or have national adaptation programmes, most of these do not have costed adaptation estimates (World Bank, forthcoming) though a few estimates exist.

4.4.3. ACCREU impact models

As highlighted above, the previous project (COACCH) used the outputs of the DIVA model to build coastal adaptation. A review has been undertaken (WP2-WP4) of the adaptation functionality in other impact models in the WP2 modelling suite. This has identified some additional adaptation potential, in GLOFRIS (and also in LISFLOOD) for river floods, irrigation for agriculture in GLOBIOM, and some other elements that could be useful (for example on land use change or biodiversity).

4.4.4. Literature review

The final evidence line will be to undertake a wider review of the literature on adaptation costs and benefits, including more detailed national estimates as well as sector studies. This will build on the previous literature review undertaken by the ECONADAPT project and published (OCED, 2015) and recent reviews (EEA, 2023). This will include a deeper dive for Europe.

The information from these tasks will be summarized in an inventory of relevant adaptation economic studies. It is highlighted that this will include a list of studies, but will not include functionality to produce cost or benefit estimates.

4.5. Developing functions

ACCREU has a set of risk or sector models that include sector impact models, computable general equilibrium models (CGE) and integrated assessment models. The framework is shown below.

The final step of this task will be to use the information from the evidence review above to produce a set of adaptation cost and benefit functions for CGE and IAMs (see top of figure 23) for WP4, which are temperature related (as well as scenario related).

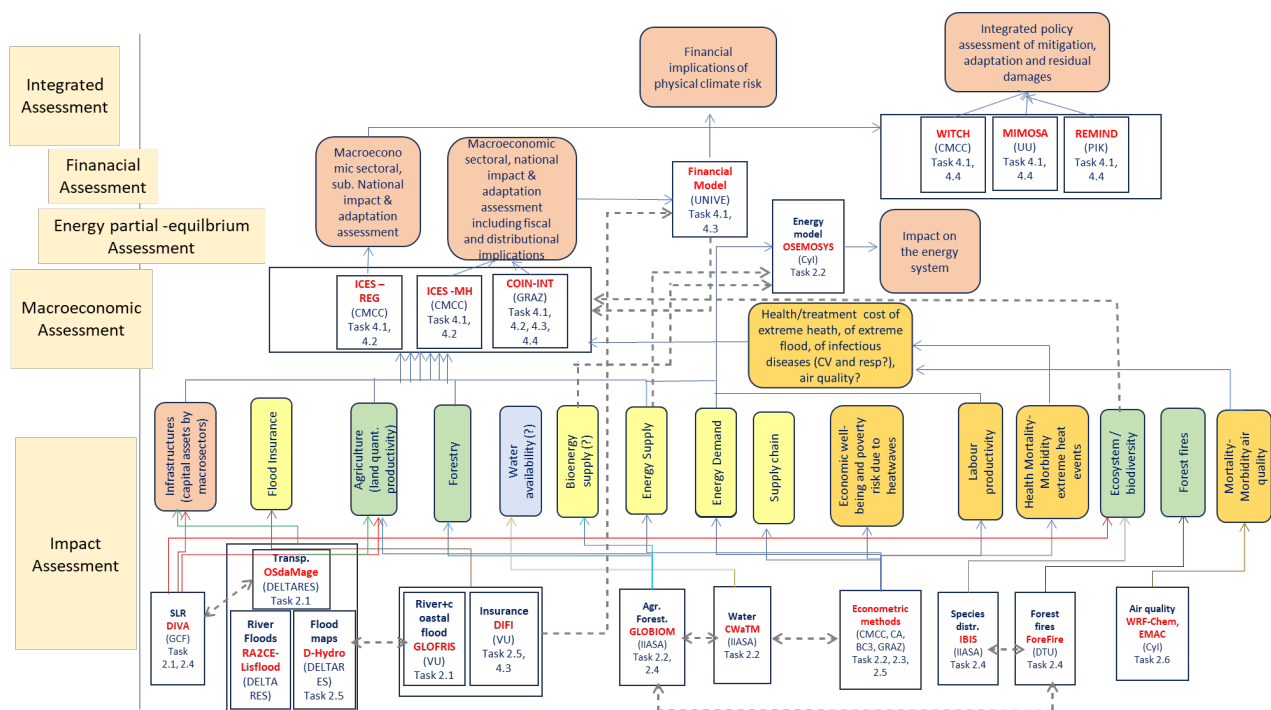


Figure 23. ACCREU modelling framework. Source ACCREU.

It is noted that each CGE and IAM has a different structure, with different representations of risks or sectors, and different geographical aggregation levels (e.g., overall world, aggregate IAM regional areas). They also have a different structural composition in each model. This means that the information from the sectoral analysis needs to be compiled specifically for each IAM and CGE, so this means a set of functions rather than one individual function. This will require a discussion with each WP4 team to understand the modelling structure and relevant aggregation. To address this the data will be compiled at the highest level of resolution (individual country, with as much resolution on public and private, capital and operating cost, etc.).

Discussion with WP4 has identified some needs for the IAMs. The ideal output would be aggregated temperature related damage functions (on model-regional level) without adaptation plus adaptation cost-effectiveness function - ideally built in a way that different sectors could be

separated out to accommodate different sectoral details that the different models can represent. There are also some specific sectoral requests, for example with greater detail for the energy sector from the WITCH model, and the potential for min-max approaches in MIMOSA.

There is also a need to link the adaptation functionality to the models, in terms of their consideration of different flows or agents (e.g., public or private, or in relation to capital stock, or productivity).

Early discussion has also identified a number of areas that would be useful to consider in the functions. These include feedback from policy stakeholders at the co-creation workshop (WP1). They include:

- Uncertainty. There will be a need to include as a minimum the three ACCREU scenarios.
- Objectives. It would be useful to consider different levels of adaptation (low, medium or high), and/or different objectives, for example with objectives that reduce residual damage down more, as compared to an economic optimal level.
- Timing. There is interest in looking at the phasing of adaptation, and what early planned adaptation buys, as compared to later and more reactive adaptation. This could also include mini-max frameworks or other approaches.
- Soft versus hard, adaptive capacity. There are policy questions about the costs and benefits of different types of adaptation, especially between non-technical (soft) and more engineered (hard) options. There are also important issues around the cost and benefits of building capacity and institutional and governance issues, including adaptive capacity.
- Grey versus green. There can also include comparison potentially of grey versus green adaptation.
- Autonomous, incremental, transformational. To date, most of the adaptation functions are based around incremental adaptation. However, there are important issues on what effect will happen autonomously (i.e., from changes in prices) and also the costs of more transformational adaptation.
- Limits of adaptation. Related to above, most functions to date have been fairly linear, but there are important non-linearities around the limits of adaptation, both soft and hard, and the residual damages. This is especially important when looking at functions for IAMs for comparing mitigation and adaptation.
- Interaction of mitigation and adaptation, with respect to costs or timing.

Other factors are likely to emerge, such as the trade-off between mitigation and adaptation, or adaptation co-benefits, as the study progresses, and these will be considered as part of the iterative approach used.

A more detailed analysis will be undertaken for the European analysis, working with the WP2 teams to provide adaptation functions for the impact assessment (for those models which do not include adaptation) which can be used in the regional CGE model (CMCC). This will be based on a similar approach but with higher resolution to reflect the greater level of analysis needed for Europe, and a greater disaggregation of sector risks and adaptation options, as well as sub-national analysis, though this will be determined by the evidence available.

5. Conclusion

This deliverable describes the protocol for the assessment of case studies (D3.2), the upscaling and synthesis into generic adaptation strategies and evaluation per adaptation decision types (D3.3) and the integration of costs and benefits in CGE/IA models (D3.4).

The case study and adaptation decision type analyses take a policy-first approach, implying that they depart from concrete policy questions. The case study analyses are oriented at the needs of individual stakeholders that participate in the ACCREU project. Their cases will be assessed following the framework as described in chapter 2, and the results will be reported in D3.2. The adaptation decision type analyses focus on the needs of *all European regions and communities* that face more-or-less the same policy questions. The corresponding description of adaptation decision types draw from the ACCREU (and other) case studies, as well as information from sectoral modelling and literature. The protocol of the assessment of generic strategies for each adaptation decision type is described in chapter 3, and the results will be reported in D3.3

The integration of costs and benefits in CGE/IA models takes a science-first approach, meaning that it departs from the needs of the macro-economic modelling teams in ACCREU. The outcome will be an inventory of the costs and benefits of different adaptation measures, that can be used in WP4. Chapter 4 describes how this inventory can be made. The results will be reported in D3.4.

In appendix A, a timeline and engagement plan for the work package management can be found.

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7. Appendix

7.1. Appendix A

Timeline & Engagement Plan Work Package 3 ACCREU

WP TASK	ACTIVITY	WHO	WHEN
3.1	Protocol finalization - Written feedback / exchange Deltares-CS owners with any feedback on the template	CS owners / Deltares	M8 (Jan 2024)
3.1	Informative meeting - Introduce engagement plan - Introduce protocol for adaptation decision types	WP3 partners	M9 (Feb 2024)
3.1	Deliverable 3.1	Deltares	M9 (Feb 2024)
3.2	Bilateral exchanges Deltares-CS owners (14x) - Discussion on key themes the case study will refer to (e.g. transformational/incremental adaptation, distributional impacts, transfer costs, time- and path-dependencies, lock-in) - Discussion on potential entry points for connection with models - Feedback based on preliminary framework (PowerPoint Template) filled out in November - Discussion on expected results for milestone 3.1.A	CS owners / Deltares	M10 (Mar 2024)
3.2	Milestone 3.1.A - Case study template: o Complete overview of adaptation options that will be evaluated (block O) – final version o Complete policy context and case study delineation (block CS and Q) – final version o Overview of uncertainties, methods and appraisal criteria (block U, M, C) – second-to-last version o First overview adaptation strategies (block S, B, SA) – first iteration - First sneak peek results of appraisal of adaptation options (costs, benefits, pros, and cons)	CS owners	M11 (April 2024)
3.2	Milestone 3.1.A - Description of potential entry points for connections with sectoral models (WP2)	Sectoral modelling teams & Deltares	M11 (April 2024)
3.2	Informative meeting (online) - Summary of bilateral exchanges in plenary session	WP3 partners	M11 (April 2024)
3.2	Milestone 3.1.A	Deltares	M12 (May 2024)

3.2/3.3	Small group exchange Deltares-CS owners [grouped by Adaptation Decision Type, 7x] - Introduction to ADT concept - Discussion on relationship case study $\leftrightarrow$ ADT - Discussion on potential relationship with sectoral & macro models (based on Milestone 4.1)	CS owners / ADT owners / Deltares	M14 (July 2024)
3.2/3.3	Informative meeting (online) - Summary of group exchanges in plenary session	WP3 partners	M16 (Sep 2024)
3.2	Bilateral exchanges Deltares-CS owners (14x) – optional - Discussion on case study progress - Feedback based on Milestone 3.1.A results - Discussion on expected results for milestone 3.1.B.	CS owners / Deltares	M16 (Sep 2024)
3.2/3.3	Informative meeting (online) Update towards M3.1.B & M3.2.A & M3.3	WP3 partners	M18 (Nov 2024)
3.2	Milestone 3.1.B - Update on appraisal results - Case study template: - o Overview of uncertainties, methods and appraisal criteria (block U, M, C) – final version - o Overview adaptation strategies (block S, B, SA) – second-to-last version - Textual description on the policy objectives and risk assessment (part 1 and 2 of table 2)	CS owners	M19 (Dec 2024)
3.3	Milestone 3.2.A - First conceptualization Adaptation Decision Types (ADTs) – description of decision context and current and future risks (part 1 and 2 of table 8) - First review of additional case studies that are relevant to ADT, but not part of the 14 case studies of D3.2 – at least a list of case studies that will be included in the synthesis. - Fill-out template questions on connection with sectoral models in WP2 per ADT (table 9)	ADT owners	M19 (Dec 2024)
3.4	Milestone 3.3 - Economics of adaptation inventory	PWA (lead); CMCC, IIASA, UNIGRAZ, VU, Ecologic, PIK, UU, GCF (participants)	M20 (Jan 2025)
3.2	Milestone 3.1.B	Deltares	M20 (Jan 2025)
3.3	Milestone 3.2.A - First textual elaboration on the relationship between case studies, WP2 (and possibly WP4 models)	Deltares	M20 (Jan 2025)
3.3	Exchange workshops per adaptation decision type (7x) - Based on co-creation protocol developed in T1.4	ADT owners / Deltares	M22 (Mar 2025)

	- Organized by adaptation-decision type owners - Involvement of deep engagement stakeholders and general stakeholders -		
3.4	Deliverable 3.4 - Comprehensive inventory on the costs, effectiveness, and benefits of adaptation strategies across all sectors for all world's countries by combining model-based estimates from WP2 with insights from a systematic literature review.	PWA (lead); CMCC, IIASA, UNIGRAZ, VU, Ecologic, PIK, UU, GCF (participants)	M26 (July 2025)
3.2	Deliverable 3.2 - 2-3 pages written summary of the decision context, risks, adaptation options and strategies, appraisal results, and barriers to implementation (See Table 2); details of the analysis in an appendix.	CS owners	M28 (Sep 2025)
3.3	Milestone 3.2.B - Description of generic adaptation pathways and assessment of the pathways as well as the barriers to implementation (part 3, 4 and 5 of table 8) - This includes a review of at least 2 case studies that are not part of the 14 case studies of D3.2, as well as a review on the generic parts of the ACCREU case studies per ADT.	ADT owners	M29 (Oct 2025)
3.2	Deliverable 3.2 - Review of all case study summaries	Deltares	M30 (Nov 2025)
df	Milestone 3.2.B - Elaboration on research questions of stakeholders for ADT	Deltares	M30 (Nov 2025)
3.3	Deliverable 3.3 - 2-3 pages written summary on the appraisal of generic adaptation pathways within an ADT, other relevant information in an appendix.	ADT owners	M38 (Jul 2026)
3.3	Deliverable 3.3	Deltares	M40 (Sep 2026)

7.2. Appendix B

Economic appraisal methods

Method	What and Why?	Advantages and disadvantages	Data requirements
Scorecard	In water management a scorecard is often used to compare the impacts of alternative strategies with respect to a given criterion or goal. Scoring can be quantitative (e.g. % people access to safe drinking water) or qualitative (e.g. more people access to safe drinking water than in the reference scenario expressed by a +-sign, a colour scale or a number)	A scorecard is especially suitable for initial screening of investment options. In the strategy analysis stage it is an easy to use tool to get an overview of the performance of strategies. A disadvantage is that the method mainly analyses the performance in relation to the objectives, other positive or negative benefits (for different stakeholders) are not included and therefore easily overlooked. Additionally it may be difficult to draw conclusions based on the multiple scores on the criteria for the different investment options in different scenarios.	Data requirements are relatively low in comparison with the other methods. It depends on the way of scoring but should ideally include data on the reference cases and quantitative information on the performance of strategies. However, the method can be also applied based on expert knowledge on the performance of strategies or a combination of both.
Multi-Criteria Analysis	MCA tools support comparison of e.g. different investment options or strategies on the basis of a set of multidimensional criteria (Greco et al, 2005). There are different types of MCA approaches, yet all approaches make strategies and their contributions to different criteria explicit and all require a certain level of judgement. The judgement aspect makes a MCA distinctive from a scorecard analysis. Depending on the objective, MCA can be used to identify a single most preferred strategy, rank strategies, short-list a number of strategies or distinguish acceptable from unacceptable strategies. The method can be used in different stages of the planning cycle, including initial screening of strategies or investment options and for the actual	The most important advantages of MCA are (1) the open and explicit process, which may very well be used in a stakeholder setting and (2) the possibility to take monetary values as well as qualitative or quantitative (non-monetary) values into account, which means that all available data can be used. This is related to one of the largest disadvantage of a MCA, it cannot show that an action adds more to welfare than it detracts (benefits doesn't need to exceed costs)	Required data includes either quantitative or qualitative data on the set criteria. Scoring may be done qualitatively by (local) experts or quantitatively by a model analysis.

	decision to take a certain strategy or investment option.		
Cost-effectiveness Analysis	Cost-effectiveness analysis (CEA) assesses the least-cost way of achieving an objective. CEA is mostly used when the objective itself is difficult to (economically) value. For example, in health care CEA is widely applied due to (ethical) difficulties in valuing a human life (WHO, 2003). The analysis is only applicable to compare options with the same goal. It can give answers to questions such as: 'What is the best way of achieving the set goal' and 'What is the best way of spending a given budget?' The result is a ratio of the costs divided by the effectiveness.	The analysis is useful when you have limited resources and data, one objective and trying to make the most strategic choice. It can be used in all stages in the planning cycle, but it is in particular helpful for the first screening of investment options. The biggest disadvantage is that it cannot be used if there are multiple important objectives or more than one kind of beneficial effect, which is frequently the case in climate adaptation plans.	The effectiveness should be expressed quantitatively. As such, a (physical) model is required to estimate the effectiveness. The data requirements differ between objectives. For example, if the objective is meeting the water demand different data and models are needed than if the objective is welfare growth.
Cost benefit analysis	Within a cost-benefit analysis all major benefits and all costs associated with an investment option or strategy are monetized, so that they can be directly compared with each other. After conducting a CBA the following question can be answered: Are the benefits for society (in money terms) of an investment option or strategy likely to outweigh costs for society? The result supports decision-making on proposed options so that policy decisions can be as objective as possible (Romijn & Renes, 2013).	The main advantages of a CBA are the easy to understand results, the inclusion of all benefits of an investment option, the option to use monte-carlo analysis and scenario discovery and the applicability to all sorts of investment options and strategies in all policy fields. To gain simplicity, money is used as a common measure, which is together with the need for a comprehensive analysis also the biggest disadvantage of CBA. Still there is no method found, which can express -without an extensive analysis- all benefits in monetary terms. Based on the advantages and disadvantages it is recommended to use CBAs especially during later stages in the process of choosing investment options or strategies. As such, CBA is the more extensive analysis that could be conducted after an initial MCA or scorecard analysis.	A cost-benefit analysis is generally seen as the most comprehensive economic analysis, which also means that there are serious data requirements (World Bank, 2013). A CBA begins with an assessment of the effects of an investment option or strategy, which is essential to determine the benefits. The effect analysis may be done with impact assessment models. However, a CBA in which all the effects can be calculated accurately and given a monetary value is an ideal situation that is challenging to achieve in practice. Even though a CBA can be conducted with limited data available, the minimum requirement is the availability of some quantitative information on the most important effects of the investment options.