Intended for
European Environment Agency

Document type
Report

Date
February 2022

COSTS OF ADAPTATION VS COSTS OF INACTION
FINAL REPORT

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Project name	**Costs of Adaptation vs Costs of Inaction**
Recipient	**European Environment Agency**
Document type	**Report**
Date	**24/02/2022**

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1. INTRODUCTION

1.1. Background

Immediate action is needed to meet the challenges posed by climate change to Europe and to the rest of the world. The recent series of dramatic events across Northern and Southern Europe, such as heatwaves, wildfires and floods, has drawn attention to the impacts climate change may cause. This awakening has been accompanied by the **Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report** (Masson-Delmotte et al. 2021) published in 2021, which indicates that the current extreme events being experienced around the world will be exacerbated in the future, even if efforts to limit warming to 1.5°C above pre-industrial levels are successful.

However, governments have responded to the challenges, and are prioritising public policies aimed at a more sustainable future. Likewise, scientific evidence indicates that countries should urgently move beyond discussions and begin to prepare to adapt to climate change at a larger scale, as vulnerability will continue to do increase for decades to come.

Given the urgency to adapt, the European Union (EU) has already taken key first steps. In February 2021, it formalized the **EU Adaptation Strategy** (European Commission 2021f), a clear message to the European and global community of the urgency for countries to strengthen their resilience to the effects of climate change.

The Communication from the European Commission on the new EU Adaptation Strategy, as well as the new Climate Law and the Government Regulation set out how the continent should adapt to the unavoidable impacts of climate change and achieve climate resilience by 2050. The EU Adaptation Strategy has several objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change (European Commission 2021f). By following what is outlined in these documents, specifically the Climate Law and the Government Regulation, governments will be able to ensure that their populations are at least prepared for an uncertain future.

However, this has not been the EU's first or only effort towards fostering the continent's resilience to climate change, given that the 2021 Strategy followed the previous 2013 EU Adaptation Strategy. The 2021 EU Adaptation Strategy forms an integral part of the framework of the **European Green Deal** (European Commission 2021h), announced in December 2019. The Deal applies a holistic approach, emphasising that to achieve a resilient, sustainable Europe, environmental, economic and societal goals must be integrated.

One of the most difficult aspects of structuring these adaptation strategies has been precisely the poor access to information and the lack of knowledge on key concepts surrounding adaptation financing. More specifically, the cost of adaptation and the cost of inaction are the two concepts that permeate all decisions made by policy makers, though their definitions are still vague.

Since 2007, when the **European Environment Agency** (EEA) published a first report on the costs of inaction and the costs of adaptation, more reports assessing the status of adaptation measures in Europe have been published. Many of them", highlight access to public budgets and adaptation expenditure information as a major barrier to mainstreaming public adaptation investments.

As regulations and strategies progress in the EU, efforts by countries should be focused on understanding the difference between key concepts that will subsequently enable their governments to take well-informed decisions for public investments, towards a more resilient planet. In addition, it is important to note the efforts done in parallel to this report by the EEA, such as the briefing on economic losses and fatalities due to climate events in the EU by type of hazard. Hence, in addition to the definitions and prioritization of the obstacles to be overcome, it is necessary to find a method to identify Key Type Measures (KTMs), so that countries can begin to make information-based decisions. These measures would improve the quality of reporting by including not only physical infrastructure, but also policies, economic instruments, behavioural changes, communication strategies, among others.

Moreover, it would aid in harmonizing 32 context-specific adaptation strategies in order to obtain a more accurate and comparable image of what is being done at the European level among member countries.

1.2. Objectives

The main objective of this report is to provide the EEA with scientific, theoretical and practical knowledge on two key concepts, namely adaptation costs and inaction costs, and how they influence adaptation finance in a domestic context. The report does not focus on methodologies at the project level, but rather looks at frameworks or programmes of measures, such as National Adaptation Plans (NAPs). This knowledge in the form of a background report also informs a briefing, to strengthen resilience to climate change and thus promote compliance with the 2021 EU Adaptation Strategy towards 2050. The EEA briefing focuses on domestic financing of adaptation, comparing the efficiency and effectiveness of adaptation measures versus the costs of inaction.

This report further elaborates on the types of risk, the ancillary impacts of adaptation, and how to integrate the knowledge in practical ways for European countries. This will help identify strategies for countries to operationalize the concepts of adaptation costs and inaction costs, and for readers to understand in a clear, concise and explanatory manner the different concepts surrounding adaptation finance. The study concludes by putting into perspective the costs of adaptation versus the costs of inaction, through describing the current state of knowledge, remaining gaps in method, and the implications for countries in their planning of adaptation finance.

1.2.1 Outline and reading guidance

Chapter 1 continues with concepts and definitions to create a common understanding about key terminology throughout the report.

Chapter 2 consists of a brief introduction to the framework of cost and benefit concepts and therefore emphasizes the importance of understanding the efficiency and effectiveness of adaptation measures. The chapter continues by explaining the use cases for understanding the efficiency of adaptation measures, touching on key issues such as the awareness proxy for knowledge on societal resilience, the timing of options and maladaptation. The chapter concludes with a link to policies at the European level, with a strong focus on the EU Adaptation Strategy, the Taxonomy Regulation and the Governance Regulation on the Energy Union and Climate Action.

Chapter 3 discusses the elements surrounding the costs of inaction. For this purpose, it will define what inaction is, what sources of information exist (modelling information about inaction costs and empirical data such as economic losses) and the minimum information needed to define this concept. Thus, the chapter will close by recommending next steps to improve knowledge around the concept of inaction and by building bridges with the recent work led by the EEA on economic losses due to climate change.

Chapter 4 addresses adaptation costs. For the purposes of assessing and estimating these costs, it describes the minimum amount of information required (ex-ante and ex-post) at the national level, it presents the different blocks of methods and sources of information typically used, including the use of proxies and indicators at various levels. The chapter proceeds with suggestions for public authorities (focussing on country level) willing to (further) develop a methodology and ends with recommendations on how to improve the planning of adaptation finance.

Chapter 5 will discuss the benefits of adaptation, including defining the scope of these benefits, describing how the selection of adaptation options determines the benefits (and the costs), and proceeds to analyse the importance of taking into account positive ancillary impacts or “co-benefits”. For the purposes of assessing the benefits of adaptation, the chapter also evaluates the different methodologies used to measure the benefits, including the assessment of both market and non-market impacts. It finalises with an analysis of the current gaps and opportunities for improvement in the context of the European Union.

Finally, chapter 6, will discuss the costs of adaptation versus the costs of inaction. After defining and specifying the methodologies, concepts, proxies and measures, the chapter will evaluate which ones can be strategically combined and make recommendations for the future. This implies looking at both sides of the decision-making equation at the national level with regards to comparing the costs of taking adaptation actions versus the costs of inaction. Furthermore, based on current policies, it will allow the drawing up of a roadmap for countries to strengthen their resilience towards 2050, both for countries that are well advanced in policymaking for resilience, as well as for those which have not yet put such policies in place.

1.3. Concepts and definitions

This subchapter, beyond defining concepts that are necessary on the topic of adaptation finance, seeks to introduce the reader to terms that will be presented throughout the report and that should be clear and transparent to avoid potential misunderstandings. Since the subject of inaction and adaptation costs involves investment decisions, some concepts will refer only to financial literacy, while others will refer to technical elements. The report aims to blend both sciences for better investment decision making.

As defined in the IPCC's Fifth Assessment Report, **adaptation to climate change** is the process of adjusting to the current or expected climate and its effects (Field et al. 2014). It is important to clarify that it is not a one-time response to an emergency, but a series of proactive measures to deal with the nexus of hazard, exposure and vulnerability. Complications and hazards are generated by tipping points in the environment (European Commission 2021f). Adaptation can take several forms, which are briefly outlined below (Table 1: Types of adaptation (Levina and Tirpak 2006).

Table 1: *Types of adaptation (Levina and Tirpak 2006)*

Type of adaptation	Definition
Anticipatory	Takes place before impacts of climate change are observed (proactive)
Autonomous	Triggered by ecological changes in natural systems and by market or welfare changes in human systems (spontaneous)
Planned	Deliberate policy decision based on awareness that conditions have changed or will change
Private	Initiated and implemented by individuals, households, or private companies
Public	Initiated and implemented by governments at all levels
Reactive	Takes place after impacts of climate change have been observed

Three fundamental concepts are found in the definition of adaptation. The first is **hazard**. In the framework of the EU Adaptation Strategy, it is described as a physical hazard related to climate, with examples such as droughts, floods, or sea level rise. The other two concepts are closely linked to the definition and determination of risk (see below): **exposure** and **vulnerability**. Defined according to the IPCC, exposure refers to the inventory of elements in an area where hazard events may occur (Cardona et al. 2012). Vulnerability to climate change, on the other hand, refers to the extent to which exposed elements such as human beings, their households or assets are likely to suffer the adverse effects when impacted by hazard events (Cardona et al. 2012).

According to the IPCC (Masson-Delmotte et al. 2018), **risk** refers to the potential for adverse consequences where something of value is at stake and the occurrence and degree of an outcome is uncertain. In the context of assessing climate impacts, risk refers to the potential for adverse consequences of a climate-related hazard (or of adaptation or mitigation responses to such hazards). Risk assessments are a qualitative or quantitative estimation of risks (Masson-Delmotte et al. 2018).

Governments around the world are encouraged to establish a **National Adaptation Plan (NAP)** as a means to identify medium- and long-term needs, and to develop and implement strategies and programs that address such needs. It is a continuous, progressive and iterative process that is country-dependent, gender-sensitive, participatory and transparent in its approach as set out in the Cancun Adaptation Framework (CAF) (UNFCCC 2021). NAPs articulate how **National Adaptation Strategies (NAS)** are implemented, defined as national documents that represent this national strategic vision for adaptation to prepare for current and future impacts of climate change in a country (EEA 2020). The NAS generally provides the framework for adaptation, from which other governance or policy documents could emerge, though the line between what it should cover when compared to the NAP remains blurry and underdeveloped, even at an international level (EEA 2020).

The **Nationally Determined Contributions (NDCs)** are those efforts deployed by the different COP21 signatory countries that demonstrate their efforts to reduce their emissions and adapt to the effects of climate change (Bekkers et al. 2020).

Even with a clear planning framework for what they want to achieve in terms of resilience to climate change hazards, governments still have to make decisions regarding their budgets. Most of these decisions must be **cost-effective**, meaning that they deliver good value for the amount invested. One of the most commonly used decision-making tools is an **opportunity cost** assessment between two or more investment options. Opportunity cost represents the potential gain that the investor will not accede to as a result of his decision to invest in one option rather than the other. Minimizing opportunity cost is closely linked to the ability to measure which policy option (or investment decision) is most cost-effective.

Following this line, to know if something is **effective**, it is necessary to analyse the difference between the maximum loss potential and the residual value once the event occurs. To know if it is **efficient**, the costs and benefits of the measures must be analysed. These terms on both sides of the equation will be explained and analysed throughout the report.

In order to understand the volume of financial resources that are being allocated to these types of investments, basic definitions such as **total investment needs** must be known. This concept refers to how many investments are required to meet their NAPs or any other programme of measures. **Actual spending** are those expenditures that have been mobilized towards adaptation measures and have been tracked and categorized in this way by governments, on an annual basis (over the last year and/or since the beginning of the planning period). Finally, **planned expenditures** are those that governments have already committed to mobilize for NAP compliance but have not yet disbursed.

Complementary to the amount of financial resources that governments invest and need is the concept of additionality. The **additionality** of an adaptation project is the portion of finance required in addition to, or separate from, the cost of development; the amount of finance needed to include the impacts of climate change (Church and Hammill 2019). This share of spending or additional investment that makes a project climate resilient, as defined by the European Commission, is codified within Article 4 of the Commission Implementing Regulation (2020/1208), pursuant to Article 19(1) of the Governance Regulation (2018/1999), as part of the reporting on national adaptation actions (European Commission 2020d). When calculating the amount of climate adaptation spending, it is important to differentiate between the costs that would have occurred in the absence of adaptation and the additional amount of adaptation expenditure required to adapt to climate change. For instance, given that adaptation is not the main aim of the project, if the government builds a new bridge, only the additional cost arising due to climate change adaptation should be considered adaptation expenditure.

According to the first Adaptation Gap Report by the UN Environment Programme, the **adaptation gap** is defined as the difference between the implemented adaptation and the societally predetermined adaptation goal, set by preferences relating to tolerated climate change impacts, while reflecting resource limitations and competing priorities (UNEP 2014)). It underscores three main adaptation gaps, related to funding, technology and knowledge. This report will focus on the first one, the finance gap, thus the adaptation gap will be understood as the difference between the costs of meeting a pre-defined adaptation target and the amount of finance available to do so (UNEP 2014). This gap has been studied over the years by the EU, and several mechanisms, funds and instruments have been structured to reduce this gap, though it remains significant. For instance, the European Commission has published a Staff Working Document titled Closing the Climate Protection Gap – Scoping policy and data gaps, defining the climate protection gap as the share of non-insured economic losses in total losses after a climate-related event, or the gap between potential climate-related impacts and existing resilience measures (European Commission 2021g). The document is part of an overall effort in ensuring the region strengthens its resilience vis-à-vis these increasing climate catastrophes and limits economic loss. Throughout the report, it will be explored whether the adaptation gap correlates with the understanding of key concepts such as inaction costs and adaptation costs.

Maladaptation occurs when an intervention in one location or sector increases the vulnerability of another location, sector, or target group to future climate change (Noble et al. 2014)). Increased vulnerability may occur due to the intervention's contribution to climate change, for example in the case of installing air conditioning systems to aid populations remain cool in warmer weather, but which directly increases carbon dioxide emissions. This is a cause of concern for governments. The definition of maladaptation used in the IPCC's AR5 has shifted to be able to recognize that it arises not only from inadvertent badly planned adaptation actions, but also from deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions (Noble et al. 2014).

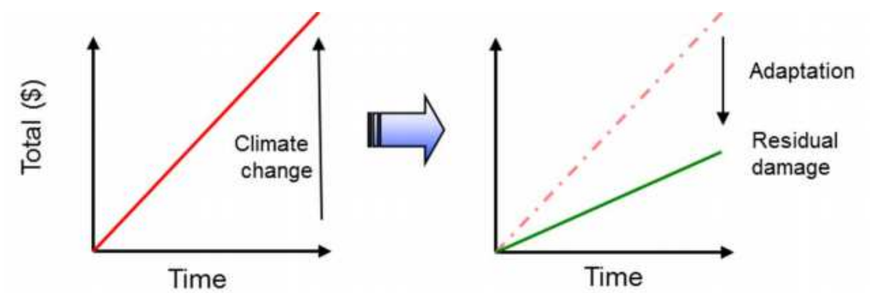
2. EFFICIENCY AND EFECTIVENESS OF ADAPTATION

2.1. Defining efficiency and effectiveness of adaptation measures

Like any investment decision in a competitive market, decisions to invest in climate change adaptation actions are based on cost-benefit or cost-effectiveness considerations. In an ideal efficient market, all public and social climate change adaptation investments that generate net benefits (i.e. benefits exceed costs) would be taken (Pauw et al. 2021). In the case of climate change adaptation, the cost refers to the cost of adaptation actions and the expected benefits are the expected avoided climate change-related damages due to the investment, including reduced risk, reduced damage to people and property, along with any ancillary benefits. This section defines the difference between efficiency and effectiveness concepts around adaptation measures.

The OECD (2021) defines effectiveness as the extent to which the objectives of an intervention were achieved or are expected to be achieved. In the case of adaptation investment, effectiveness measures how well the adaptation reduces expected climate change damages. That is, the effectiveness of an adaptation measure is the difference between the damages due to climate change and the residual damages after a climate change adaptation action is implemented. Figure 1 shows the basic economic methodology proposed by the UNFCCC in 2009 to calculate benefits.

Figure 1*: Stylised framework for assessing adaptation benefits. Source: (UNFCCC 2009)*



Efficiency occurs when an action’s benefits exceed the costs (including opportunity costs). Adaptation is considered efficient if the cost of implementing such actions is lower than the resulting benefits (Mendelsohn 2000).

The definition of both terms gives a good approximation of their relationship to climate change investments. In their decision-making, governments need investments to be effective but in the most cost-efficient way possible. Used in conjunction, both concepts provide a more complete assessment of investment decisions. Such an analysis has already been codified in climate finance institutions such as the Green Climate Fund; ‘efficiency and effectiveness’ is one of the key indicators of their investment framework criteria for both mitigation and adaptation projects.

It is important to emphasise that both efficiency and effectiveness are context-specific concepts, varying according to the needs of countries and sectors, as well as dependent on spatial and temporal scales (Neil Adger, Arnell, and Tompkins 2005). For example, the assessment of efficiency of adaptation measures is subject to each country's institutional framework and its level of risk acceptance, capital value and opportunity cost.

To find out the effectiveness of an adaptation action it is necessary to assess its (expected) benefits. To assess efficiency, it is necessary to know the costs and residual value of investments at the end of its lifetime, as well as expected benefits. This information is therefore essential for everyone who wants to invest in climate change adaptation.

Information on the costs and benefits (and thus on effectiveness and efficiency) of adaptation can be used to convey different messages and for different types of decision making, depending on the geographic scope and level of aggregation:

- At the global level: can be used to raise awareness and to discuss financing needs.
- At the national level: relevant for national adaptation plans, their investment plans and needs and the prioritisation of tailor-made policies
- At the local level: it helps in the design and prioritization of adaptation policies, programs and projects

This report focuses on decision-making at the **national level**. Depending on the necessary information, a cost-effectiveness or cost-benefit analysis can be carried out to support decision-making for investments. Cost-effectiveness analyses relates investment costs (in monetary terms) to results or benefits which do not have to be monetised. Cost-benefit analyses compare the investment costs with the quantified and monetised benefits of the adaptation measure. In short, cost-effectiveness analysis answers the question of how much it costs to reach a certain policy outcome, while cost-benefit analysis answers the question whether the benefits outweigh the costs (Stadelmann et al. 2015).

Some issues may arise when measuring effectiveness and efficiency of adaptation (Neil Adger, Arnell, and Tompkins 2005). Those include:

- Determining and measuring non-market costs and benefits, especially the benefits provided by adaptation measures which in many cases cannot be measured in economic terms alone, but also include social and environmental benefits;
- Establishing an appropriate division between the private and public costs and benefits of actions and assessing the regulatory system that defines which category do these elements belong to;
- The timing of adaptation actions (efficiency of long- vs. short-term strategies);
- Remaining uncertainties around the impact of a specific adaptation action, even if efforts are made to define most variables;
- Uncertainties around the future state of the world (i.e. climate, socioeconomic conditions, political context, among others);
- Selection between adaptation measures, which involves weighing different ethical and subjective considerations (Watkiss 2015).

In conclusion, adaptation measures taken by governments should be subject to an appropriate evaluation of efficiency and effectiveness. To calculate both, a cost-benefit and cost-effectiveness analysis can be performed. Much attention has been paid over the years to the effectiveness of adaptation in terms of reducing vulnerability to climate change and its potential impacts. However, a poorly executed adaptation measure can exacerbate the negative effects of climate change on those the measure is intended to aid, which is a subject that has not been as widely discussed. Thus, information plays a key role in such analysis.

2.2. Use cases for knowledge on efficiency and effectiveness

Why is it important to gather data on adaptation expenditure, efficiency and effectiveness? This subchapter describes use cases for knowledge on the efficiency and effectiveness of adaptation measures, which can provide further evidence on the importance of robust data on adaptation within European countries. Comprehensive and reliable data will result in successful adaptation planning, in the context of the EU Green Deal and its long-term vision of becoming a climate-resilient society by 2050 (European Commission 2021h).

The EU Adaptation Strategy underscores the importance of **informed citizens** and governments for mainstreaming adaptation strategies into national and local planning. Firstly, **improved knowledge** on efficient and effective adaptation measures within governments may result in more informed budgeting decisions with the goal of obtaining optimal results with lower costs. Thus, these types of assessments can serve as a way to **optimize spending and improve prioritization of adaptation actions** within government planning and budgeting in the long term. Secondly, disseminating knowledge on the efficiency and effectiveness of adaptation actions is critical to create more resilient societies, conscious of the negative consequences some behaviours may have on the environment and quality of life. Adaptation measures that demonstrate increased resilience in a specific community may be brought to the attention of other communities and national governments, highlighting the benefits of resilient infrastructure, food systems, public health, and economies. This, in turn, may contribute to the goal of increased ambition on adaptation put forth by the EU Adaptation Strategy.

Beyond awareness raising, the accumulation of knowledge on efficiency and effectiveness in the long term will improve the overall **education** of public authorities (national, regional and local), industry leaders, citizens and other relevant stakeholders. Improved data collection is one of the solutions to the persistent gap in adaptation knowledge, which hinders the estimation of risks and hazards in all sectors and prevents appropriate policy design. Further developing and improving climate knowledge platforms such as Climate-ADAPT will be key in ensuring data is accessible to all relevant parties for decision-making at all levels, and thus ensuring policy coherence across the continent.

Similarly, improved understanding of climate issues and the strategies to address them will inevitably bring a higher demand for **accountability and transparency in public spending by citizens to their governments.** As citizens become more aware of how adaptation measures directly impact their communities in a positive manner, they will demand from governments more actions and policies that result in successful resilient planning that, at the same time, makes efficient use of their taxes.

Efficiency and effectiveness can also serve as an **indicator of societal resilience**. By identifying which adaptation measures are successful through cost-benefit and cost-effectiveness analyses, we can determine to what extent communities are prepared for the impacts of a changing climate by evaluating whether they have implemented similar measures. Other analyses can also provide a **better understanding of the timing of adaptation options**; determining when it is appropriate to assume the cost of an adaptation measure or not is important to ensure budgets at all levels are deployed in an efficient manner, while delivering better results. This is especially important at EU level, when preparing to deploy the EU Green Deal, to ensure they maximise the positive effects of adaptation strategies and consequently increase the resilience of their communities.

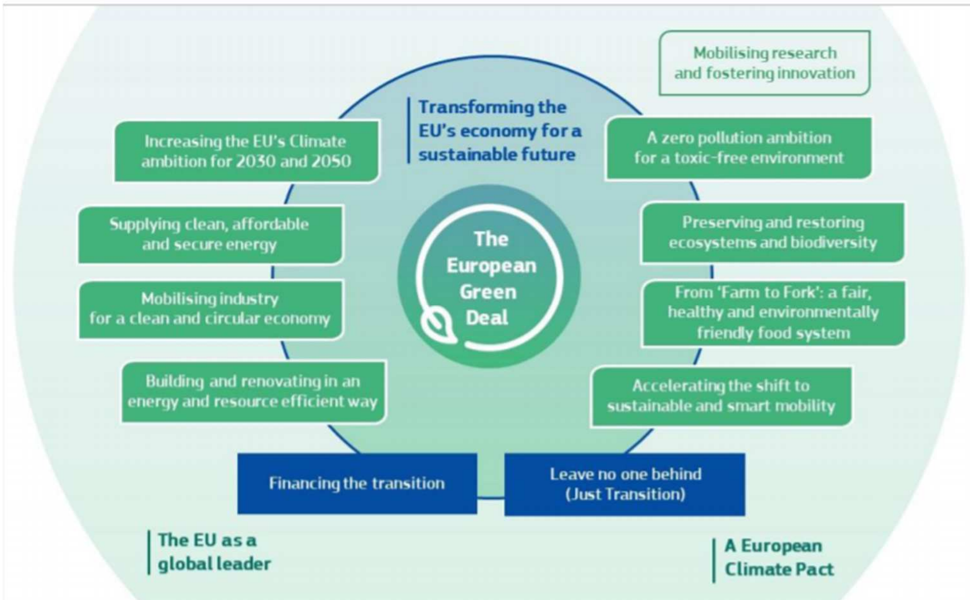
By combining all these use cases, determining the optimal timing of adaptation measures, collecting the necessary data, and integrating climate uncertainties into adaptation strategies, we will prevent actions that result in **maladaptation**. Nevertheless, measures that result in higher costs and lower benefits could be taken as lessons learned for future reference on which strategies work and which ones should be avoided, depending on the context of the communities involved. Overall, a more thorough understanding of the effectiveness and efficiency of adaptation will improve decision-making by officials at local, regional, national, and European/international levels.

2.3. Linking to relevant policies

EU GREEN DEAL

The EU Green Deal is a set of policies with the goal of making Europe climate neutral by 2050, through transforming the continent into a modern, resource-efficient and competitive economy (European Commission 2021h). The European Green Deal aims to accelerate the shift from a high-emission to a sustainable economy, where economic growth and prosperity are decoupled from resource use. This strategy and the accompanying policies have set a clear sustainable vision for Europe’s future, illustrated by headline commitments to no net GHG emissions by 2050 and restored and protected nature and biodiversity. The deal has deployed key initiatives such as the EU Strategy on Sustainable Finance (including the Taxonomy) (European Commission 2021d), Fit for 55, the EU Adaptation Strategy (European Commission 2021f), the EU Climate Law (European Union 2021), or the EU Biodiversity Strategy (European Commission 2020a). Clearly, what happens around finance for adaptation will be relevant for the fulfilment of this deal by Member States. Within the various elements of the Deal, there are some that directly relate to defining and explaining the efficiency and effectiveness of adaptation measures (Figure 2).

***Figure 2**: European Green Deal (European Commission 2021h)*



Increasing EU's climate ambition (European Commission 2021h) seeks to strengthen all efforts to build resilience, preparation, and prevention. Precisely to achieve this, the goal is to strengthen public (and private) investments in adaptation. However, governments will not be able to decide or plan adequately which investments to make if they are not able to categorize them according to their level of efficiency and effectiveness. Naturally, depending on the urgency and objectives, sometimes efficiency will be more relevant than effectiveness and vice versa. It is also mentioned in this point that reliable, comparable, and verifiable information is required to allow "buyers" to make the right decisions, and as mentioned, when financial markets function properly, the concepts of efficiency and effectiveness will be the cornerstone of decision making.

Building and renovating energy and resources in an efficient manner (European Commission 2021h) will require investing in infrastructure that is resilient, considering the most cost-efficient and effective way of spending national budgets, and takes into account the future impacts of climate change.

ADAPTATION ASPECTS OF THE TAXONOMY REGULATION

The EU's Taxonomy Regulation is part of the European Commission's Sustainable Finance Action Plan which in turn is part of the European Green Deal. This EU law is a "framework to facilitate sustainable investment" (European Union 2020). It provides a common classification of economic activities significantly contributing to environmental objectives including to climate change adaptation. Activities include both adaptation solutions or enabling activities that contribute significantly to preventing or reducing the risk of the adverse impact of the current climate and the expected future climate. Adapted activities should answer the following requirements:

- They should not lead to increased climate risks for others or hamper adaptation elsewhere;
- They should not increase the risks of an adverse climate impact on other people, nature and assets;

- They should consider the viability of 'green' or 'nature-based' solutions (NbS) over 'grey' solutions to address adaptation;
- They must be consistent with sectoral, regional, and/or national adaptation efforts.

This framework is meant to promote prioritization of adaptation measures and enabling activities, the search for efficiency and effectiveness as well as harmonization between the different policy levels including both private and public domains. The specificity of these economic activities varies depending on what is outlined in the EU Taxonomy Climate Delegated Act (European Commission 2021a), and their prioritization depends on the availability of the 'do no significant harm' (DNSH) criteria.

EU ADAPTATION STRATEGY

The new EU Adaptation Strategy was adopted in February 2021. It has several objectives: i) to make adaptation smarter through improved data and decision-making tools, ii) to speed up adaptation and ensure that it is comprehensive, iii) to make adaptation systemic across all sectors and levels of society and the economy, and iv) to support the increased international climate resilience (European Commission 2021f).

Cost-efficiency is mentioned in the strategy to support implementation of adaptation activities in the EU. One main aspect is to provide information for prioritisation of efficient adaptation activities in EU funding and investment programmes, including nature-based solutions with a number of ancillary benefits. Furthermore, different (sectoral) legislative proposals could benefit from taking into account cost and benefit of adaptation to increase efficiency and effectiveness of integrative policies and strategies. The efficiency of national and regional adaptation plans and strategies, including cost and benefit information, can increase an uptake of adaptation actions on the ground. In addition, the Strategy emphasises the importance of increasing data on adaptation, as well as the importance of consolidating knowledge and developing tools to support better decision making.

It is also important to note the European Commission Staff Working Document on *Closing the Climate Protection Gap* as part of the knowledge base for the Adaptation Strategy. It also represents some of the measures to be taken under the Renewed Sustainable Finance Strategy to close the climate protection gap, and could be relevant for future, additional policy documents addressing adaptation issues at a national, regional and local level (European Commission 2021g).

JUST TRANSITION MECHANISM

The Just Transition Mechanism has the objective to address the unequal effects the transition into a climate-neutral economy will have throughout the EU by ensuring no one is left behind. Thus, it will target the social and economic effects through support to the most affected regions with the creation of i) a new Just Transition Fund, ii) an InvestEU "Just Transition" scheme, and iii) a new Public Sector Loan Facility (European Commission 2021e). These three pillars aim to mobilise investments, provide budgetary guarantees and open additional pathways for grants and loans to cover the costs of these new investments. It is for this reason that understanding the definition and concepts of the basics of efficiency and effectiveness of adaptation measures will allow us to build a comprehensive glossary around them.

EU CLIMATE LAW

The EU Climate Law will be the mechanism through which the EU's ambitions presented in the European Green Deal will be codified into law, for all Member States to adhere to, such as becoming climate-neutral and climate resilient by 2050. The Law will also ensure policy coherence by aligning all EU policies towards the achievement of these goals and ensuring the support of communities and all relevant economic and political actors (European Union 2021).

One of the Climate Law's objectives is to put in place a system that allows countries to monitor progress to these goals as well as correct their pathways, if needed. This underscores the argumentation of this report regarding the importance of setting up accurate and reliable data gathering, reporting, and monitoring processes, to ensure the efficiency and effectiveness of the measures taken by European governments. This is also related to another of the Law's objectives in providing predictability and decreasing uncertainty for economic actors, to facilitate investments in climate projects and programmes. De-risking climate projects would also ensure appropriate support to adaptation.

More specifically to adaptation, the EU Climate Law will commit Member States to adopt measures that will ensure and improve resiliency and reduce vulnerability of communities vis-à-vis climate change. To ensure adaptation measures are efficient and effective, it is important that governments, citizens, and industry leaders and other relevant stakeholders are informed about the benefits of taking the appropriate steps, regulations and investments to adapt to the effects of climate change as well as know the negative consequences and the costs if they do not. This is linked to the newly presented EU Adaptation Strategy, which will aid Member States adhere to this commitment.

EU REGULATION (2018/1999) AND IMPLEMENTING REGULATION (2020/1208)

The Regulation is comprised of several reporting mechanisms, and outlines the legislative base needed for "reliable, inclusive, cost-efficient, transparent and predictable governance of the Energy Union and Climate Action" (European Union 2018). With regards to adaptation to climate change, the Regulation aims to ensure Member States provide reporting, especially related information on national adaptation actions and support in the context of the integrated national energy and climate plans, and on support relevant to the external dimension on the Energy Union, codified under Article 19 "Integrated Reporting on national adaptation actions, financial and technology support provided to developing countries and auctioning revenues" (European Union 2018). In addition, Article 17 requires each Member State to report every two years on the status of implementation of their integrated national energy and climate plan regarding progress on the goals put forth in this plan, their financing and implementation of these policies (European Union 2018).

The Implementing Regulation (2020/1208) sets out the rules to implement the aforementioned Regulation, regarding reporting on national adaptation actions, use of auctioning revenues and financial and technology support provided to developing countries, national system for policies and measures and projections, among others (European Commission 2020d). It aims to translate the Regulation (2018/1999) into concrete reporting elements, although these are not yet strictly defined for Member States. In the context of adaptation reporting, Article 4 (Annex I) requires Member States to report information on their national adaptation actions, which includes reporting on spending earmarked for climate adaptation and the share of spending in each sector (European Commission 2020d). However, the information is requested without specifying any further details, therefore comparison among Member States is challenging.

In the context of adaptation measures, the harmonization of national energy and climate plans will ensure policy coherence across the continent and will facilitate accountability and comparison of adaptation measures across each of the Member States. By including the necessary elements to track progress of national long-term strategies, the assessment of the efficiency and effectiveness of adaptation measures will be streamlined. As it is a regional undertaking, it will serve as an opportunity to bridge knowledge gaps on adaptation, as all Member States will be able to provide more accurate and reliable data on adaptation programmes, given the Regulation's mandate on integrated reporting on national adaptation actions, financial and technology support (European Union 2018). Ultimately, this will result in improved policy and decision making, that will allow for the successful achievement of the goals of climate neutrality and resiliency by 2050.

More accurate reporting and monitoring will also allow governments to have a clearer picture of where budgets are being directed and which measures were more successful across time. The Implementing Regulation hopes to support this through a more streamlined reporting by Member States, with a clear structure, format, submission processes and review of information., Although sometimes its lack of clarity causes problems for reporting, this could also be an opportunity for further developing and refining a structure that is useful for all Member States to improve their understanding of the topic.

Consequently, increased awareness and education on what successful adaptation measures look like, as well as more detailed data, will contribute towards more robust efficiency and effectiveness assessments.

2.4. Conclusion

This report will aid member countries in the taking stock of where they are with regards to policymaking, budgeting, investing, knowledge creation and planning for adaptation. It will also aid them in adhering to these policies by providing concrete explanations on key concepts for understanding the value of adaptation measures versus the cost of inaction, as well as providing suggestions on how to improve policy-making processes and engaging relevant stakeholders to achieve these climate ambitions. The following chapters will also provide a more practical perspective on how to incorporate these concepts and policies into their own contexts.

3. ELEMENTS OF THE COST OF INACTION

In the following chapter, we look at the definition of inaction, explore what constitutes a baseline for inaction and which types of costs should be included, and assess some of the challenges in estimating inaction (Section 3.1). In section 3.2, we present various methodological approaches to calculating the costs of inaction, both for the whole economy and at sector level. Next, we move to the more practical "building blocks" of these approaches, looking at what elements are combined in order to estimate the cost of inaction (Section 3.3). Finally, in Section 3.4, we present opportunities to further improve knowledge on inaction.

3.1. Defining inaction

The cost of inaction can be defined as the total cost due to climate change in the absence of adaptation and mitigation measures (EEA 2007; Nicklin et al. 2019). Essentially, it is the "damages that will result from allowing climate change to continue unabated" (Ackerman and Stanton 2006). However, behind this simple definition lie some challenging philosophical and methodological issues. In this section, we explore different possible definitions of 'cost' and 'inaction' and identify challenges for practically calculating the cost of inaction.

The EEA Technical Report Climate Change: The Cost of Inaction vs. the Cost of Adaptation (2007) discussed methodological issues and uncertainties of cost estimation and reviewed existing information on economic costs of climate change at the European level. The report was useful for practitioners in identifying key conceptual issues associated with the cost of inaction. These include: diverse definitions of the 'cost of inaction' and 'adaptation'; an incomplete and uncertain understanding of the costs of inaction; different assumptions and choices in the methodology for cost assessment; and limits on quantification and valuation. The aim of the present report is to fill the previous gaps. Hence, the following section analyses and summarises theoretical development since the EEA report from 2007. Subsequent sections explore practical progress in developing and implementing a methodological framework for calculating cost of inaction, drawing on both the academic literature and practical examples.

3.1.1 Establishing a baseline to define inaction

To calculate the cost of inaction, we implicitly must compare two states. The first is an optimistic future where we implement policies to adapt to climate change, thus avoiding its impacts. The second is a baseline where no policies to adapt to climate change are implemented (i.e. no action on climate change). According to the OECD (2008), this second inaction baseline could take one of three forms:

- A *hypothetical no adaptation scenario*, where we assume that no policies to adapt to climate change have ever been implemented, including in the past;
- A *current policy baseline*, where we assume that current and past climate adaptation policy is maintained in its current form and level of stringency;
- A *credible future baseline*, which also assumes that current credible future adaptation policy commitments will be implemented (increasing future adaptation stringency).

The baseline selected depends on the objectives of the study and available data and information. In some cases, a credible future baseline may be theoretically most attractive (e.g. when considering the change in the costs of inaction due to a new climate adaptation plan, relative to previous plans), however, this requires relatively high levels of information on policies as well as assumptions about their future implementation and impact. Some studies have applied hypothetical no adaptation scenarios (e.g. Sanderson and O'Neill 2020), and may be useful for example for backwards-looking studies assessing previous policy decisions. Pragmatically, the current policy baseline may be the simplest and most certain to implement, as recommended by OECD (2008a).[1]

3.1.2 What costs should be included?

The cost of inaction should include all costs borne by society that arise due to failure to mitigate or adapt to climate change. Without adapting, society will bear numerous types of costs, including direct financial costs, indirect financial costs, a loss of adaptation options in the future, and non-use costs (see Table 2).

As the cost of inaction is a multidimensional and multiscale notion, its estimation should not be limited to direct and monetary assessments. The resulting cost of inaction value will depend on the scope considered; the calculation must be as comprehensive as possible, in order to avoid an underestimation of the benefits of the adaptation action. Direct and indirect effects should be defined in a systematic way, e.g. along developed climate impact chains, emphasising clear and transparent definition of boundaries for the included costs. Furthermore, non-monetary and qualitative information on cost of inaction should also be included to get a complete picture.

Table 2 describes each cost type, gives examples, assesses how simple it is to include such costs in cost of inaction analyses, and identifies potential data sources the types of costs and identifies challenges with their calculation.

[1] Whichever baseline approach is applied, the definition of "inaction" must also allow private individuals and companies to dynamically respond to the new information: this is because, even in the absence of policy interventions, private sector actors and individuals may respond to climate change or expectation of future climate change (for example by investing in water-efficient equipment). This would be important to allow within the inaction baseline, as this will impact the difference between the optimistic future with no climate impacts and the baseline scenario, which includes private responses, though these will likely be somewhat muted due to policy inaction.

Table 2: *Types of economic costs to consider in 'costs of inaction'*

Cost type	Description	Examples	Availability	Data sources
Direct costs – financial	All direct costs that society has to pay due to a failure to adapt	• Bridge replacement costs • Increased health-care costs	Relatively simple to identify and monetise	• National accounts • Bottom-up sectoral assessments of expected climate impacts
Direct costs – non-financial	All direct costs that society has to bear due to failure to adapt, including intangible impacts	• Direct environmental costs of damaged ecosystems (e.g. cost of loss of non-resilient forests) • Intangible costs, such as pain and suffering associated with increased early mortality	Relatively simple to identify but challenging to monetise	• Individual studies on physical climate impacts • Individual economic studies
Indirect costs	Costs associated with flow-on impacts of climate change due to a failure to adapt that have indirect market and societal impacts	• Impact on affected markets (e.g. real estate market impacts) • General equilibrium impacts (i.e. on GDP growth, etc.) • Indirect costs of environmental damage (e.g. lost ecosystem services from damaged ecosystems) • Political instability	Challenging to identify and to monetise	• Bottom-up sectoral assessments of expected climate impacts
Option costs	The cost of lost future options, due to inaction today	• The inability to take different adaptation decisions in the future, due to inaction today ("lock-in") • Missed learning or innovation opportunities (and associated cost)	Challenging to conceptualise, identify or quantify	• Little available data
Non-use costs	Cost of knowing that we are leaving a damaged world for future generations	• Individuals value the existence of a healthy planet, and the chance to pass this on to descendants; the loss of this is a cost	Challenging to quantify and define in detail	• Surveys and economic studies

These costs can be described in physical terms (e.g. number of buildings flooded, number of bridges requiring replacement) or in monetary terms, where these physical impacts are converted into monetary values. A further possibility is to assess costs in semi-qualitative or qualitative terms where other assessments are not possible, e.g. when considering social impacts or future innovation and learning potential. Monetising costs can be useful, as it allows the comparison of dissimilar items. For example, without presenting the cost of a flooded building or a replacement bridge in monetary terms, it is difficult to compare outcomes that result in such different types of impacts. There are different possibilities for monetisation of effects: market prices if a link to marketed goods exists (e.g. the agriculture sector); if market prices are not available: revealed or stated preferences are alternatives. **Revealed preferences** are estimated based on observed choices of individuals, e.g. how much travel money do individuals spend to reach a certain recreational area. **Stated preferences** are based on surveys where individuals indicate the maximum amount they would pay for a certain service or good. This approach is often used for estimating a change in quality of life linked to health or city planning measures. More information on the range of economic valuation methods and their application can be found here in (Abdullah, Markandya, and Nunes 2011).

3.1.3 Challenges with implementing the 'cost of inaction'

The literature identifies a number of challenges related to identifying and calculating the cost of inaction (OECD 2008a; Tröltzsch et al. 2011; OECD 2015b). These include:

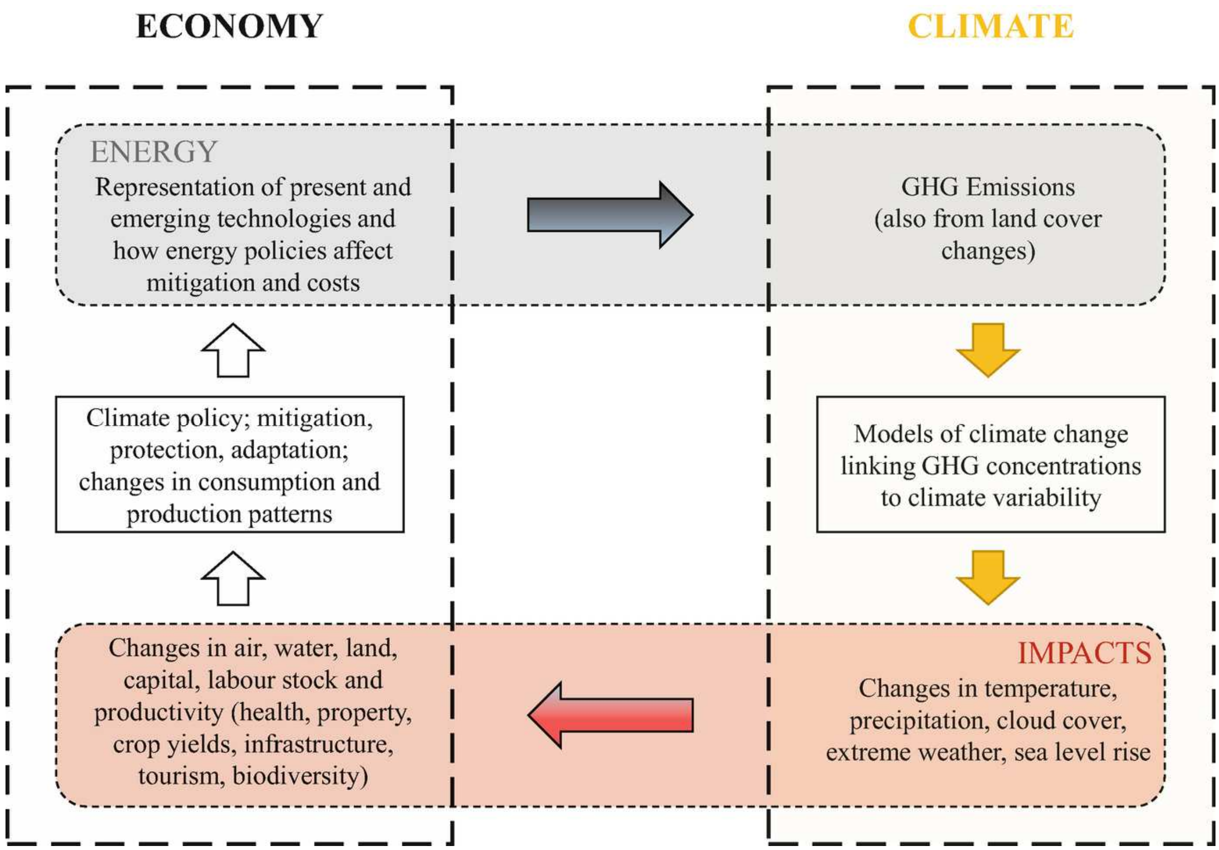
- Monetising costs – While some direct costs of inaction can be relatively easily monetized, as there are existing markets and prices available, other types of costs can be difficult to monetise. Non-financial direct costs can be more challenging, e.g. how do we quantify the value of leaving a healthy climate to later generations? Or truly capture the cost of failing to help adapt natural ecosystems climate change, with all of their complex indirect impacts on human society? While there are economic methodologies for attempting to estimate the value of non-market goods and services (including intangible benefits, option values, and non-use values) and for calculating indirect impacts, these are often complex or result in disputable cost estimates.
- Irreversibility of climate impacts and implications for costs – Related to the issue of monetising costs, some climate damages will be irreversible, such as the loss of species and habitats. There are ethical arguments against valuing the costs of such events, which may be considered to have socio-cultural or intrinsic value that cannot be compared with other costs.
- Discounting and equity considerations– To calculate the future cost of inaction, we need to consider to what extent we value future costs relative to current costs. It is common to consider current costs as more important than future costs, that is, we discount future costs. This can be problematic for long-term issue such as climate impacts, as it can imply that the costs borne by future generations are given very little weight relative to our own. A related issue is that cost of inaction can fail to adequately illustrate how these costs fall harder on some groups (e.g. the Global South) or sectors (e.g. agriculture).
- Uncertainty – Given these challenges, along with the inherent complexity or unknowability of predicting future climate impacts and societal responses, high levels of uncertainty are implicit in estimated costs of inaction.

3.2. Methodological approaches to costs of inaction

Estimating costs of inaction generally involves the use of climate-economy models, often referred to as integrated assessment models (IAMs). This is a broad categorisation, which encompasses a variety of more specific modelling approaches and frameworks. The literature on these modelling frameworks is exhaustive, and many efforts have been made to compare and contrast their applications, assumptions, and results. Nikas et al. (2019) provide a helpful and detailed overview and classification of these models. The fundamental framework of most IAMs draw a connection between the dynamics of the economy and climate, considering factors like greenhouse gas emissions, land use, labour productivity, among others. IAMs can also consider knock-on effects, co-benefits, as well as trade-offs[2] in policymaking. The figure below presents a representation of these dynamics.

[2] Knock-on effects are secondary, indirect or cumulative effects causing other events or impacting a broader system. Co-benefits (or ancillary benefits) are positive effects that a policy or measure aimed at one objective might have on other objectives, thereby increasing the total benefits for society or the environment. Trade-offs positively impact some aspects and negatively impact others. (Source: Allen et al. 2018).

Figure 3: Climate-economy dynamics (Source: Nikas, Doukas, and Papandreou 2019)



In their assessment, Nikas et al. (2019) identify six main types of IAMs: optimal growth (or welfare optimisation), computable general equilibrium (CGE), partial equilibrium (PE) and their subset energy system models, macro-econometric models, and other IAMs. For the purposes of this report, we will focus on the models most relevant to estimating the cost of inaction, which includes CGEs for economy-wide estimations and PEs for sector-level estimations. Econometric approaches, which – in contrast to CGEs and PEs – are based on historical empirical data rather than market equilibrium assumptions, will also be discussed. These are, however, more suitable to evaluate policy impacts rather than climate damages or the cost of inaction (Nikas, Doukas, and Papandreou 2019).

The table below presents an overview of the different methodologies, including the data sources, advantages and disadvantages.

Table 3: *Methodological approaches to assess costs of inaction*

Methodological approach	Description	Advantages	Disadvantages
Computable General Equilibrium (CGE) Model	Detailed, multi-sector representation of the economy	Highly detailed macroeconomic assessment Cross-country and cross-sector linkages	Economic growth is harder to model Complex structure
Partial Equilibrium (PE) Model	Detailed representation of the relationship between climate impacts and one sector of the economy	Detailed sectoral assessment	Unable to capture how sectoral changes will affect broader economy
Econometric assessment	Simulation of the economy (or sector) based on historical data	Can be used both for macroeconomic assessments and sectoral estimates Detailed consideration of geographic scope	Historical data may not be best suited to project future behaviour and trends, especially climate.

3.2.1 Estimating the cost of inaction at the economy-wide level

CGE models include very detailed representations of the overall economy, including multiple sectors, regional detail, and high resolution of energy technologies (Nikas, Doukas, and Papandreou 2019). By using inputs from sector-specific models (biophysical models, PE models, econometric approaches, etc.), CGE models can provide an overall picture off the macroeconomic effects of climate change. CGEs can consider how impacts in one sector or country will carry through to another (also known as cross-country and cross-sector linkages). Additionally, these models can factor in trade in goods and services. As an output, CGE models can estimate climate impacts on macroeconomic metrics like GDP (COACCH 2021a).

Another important feature of CGE models is their ability to estimate climate impacts on other factors of economic output such as capital, labour, and productivity. Consideration of the impacts of climate change on these factors can lead to further insights on changes to economic growth rates, which may have important cumulative effects over time that are more significant than changes to economic output alone (COACCH 2021a).

The table below presents a summary of recent studies estimating the cost of inaction at the economy-wide scale:

Table 4: *Studies estimating the cost of inaction at economy-wide scale*

Study	Method(s)	Sectors	Geographic Area
JRC PESETA IV (2020) "Climate change impacts and adaptation in Europe"	Process-based models Empirical models Multi-commodity market models Economic integration through CaGE model	Heat and cold waves, windstorms, water resources, droughts, river flooding, coastal flooding, wildfires, habitat loss, forest ecosystems, agriculture and energy supply	Europe
OECD (2015b) "The Economic Consequences of Climate Change"	Multi-sectoral, multi-regional dynamic general equilibrium model (ENV-Linkages)	Modelled: Agriculture, coastal zones, extreme events, health, energy, tourism Qualitatively considered: ecosystems, water stress, human security, tipping points	Global
COACCH (2021a)	Multi-sectoral, multi-country, computable general equilibrium model (ICES)	Agriculture, forestry, marine fisheries, sea-level rise, river floods, transport, energy, labour productivity	Europe
Sanderson & O'Neill (2020) Assessing the costs of historical inaction on climate change	Top down, optimal economic growth model (DICE 2013R)	Whole economy	Global

3.2.2 Estimating the cost of inaction at the sector level

At the sector level, PE models can estimate the cost of inaction by providing a detailed analysis of the interaction between climate impacts and specific economic sectors. To do so, PE models assume that conditions in other sectors of the economy do not change (Nikas, Doukas, and Papandreou 2019).

Another approach to estimating the cost of inaction at the sector level is econometric analysis. In contrast to CGE and PE models, econometric analysis uses historical data to establish past relationships between climate and the economy, which are then applied to future climate scenarios (COACCH 2018).

"The Economic Cost of Climate Change in Europe - Synthesis Report on State of Knowledge and Key Research Gaps" report (COACCH 2018) can be used to appraise the coverage of economic analysis and costs estimates of climate impacts and adaptation at the sectoral level. The report monetises impacts in terms of social welfare and provides information related to methods used to conduct economic costs analyses. Additionally, the report highlights some key gaps to effective cost assessment. Notably, the estimates collected in the report arise almost entirely from modelling studies, which project climate change impacts (and, in some instances, costs) based on possible future climate and socio-economic scenarios. There are few estimates based on empirical data from past events.

COACCH (2018) shows a diverse picture for the different sectors in Europe. A good coverage with assessments can be seen for coastal and river flooding as well as agriculture. The study notes that economic estimates of the cost of inaction are lacking in some other sectors, such as forestry and fisheries, water management, biodiversity and ecosystems services, business and industry, as well as climate and socio-economic tipping points.

The COACCH project also produced sector estimates of the economic costs of climate change, capturing the costs and benefits to society (i.e. market and non-market impacts). The estimation was based on a harmonised approach, e.g. using agreed climate, socio-economic scenarios and timelines. Taking selected examples for sea-level rise (using the DIVA integrated assessment model), the costs are estimated at EUR 135-145 billion/year with no discounting, rising rapidly to EUR 450-650 billion by 2080 (COACCH 2021b). These estimates include only direct costs, though further unquantified costs are expected as a result of ecosystem losses and knock-on effects in other sectors. Annual river flooding costs are estimated at EUR 11-18 billion by 2050 to EUR 18-42 billion by 2080 (using GLOFRIS model). The estimates include the combined effects of climate and socio-economic change. For transport, the baseline analysis identified EUR 200 million of annual direct costs, primarily from river flooding, with the highest risks identified in Germany, France and Italy (COACCH 2021b).

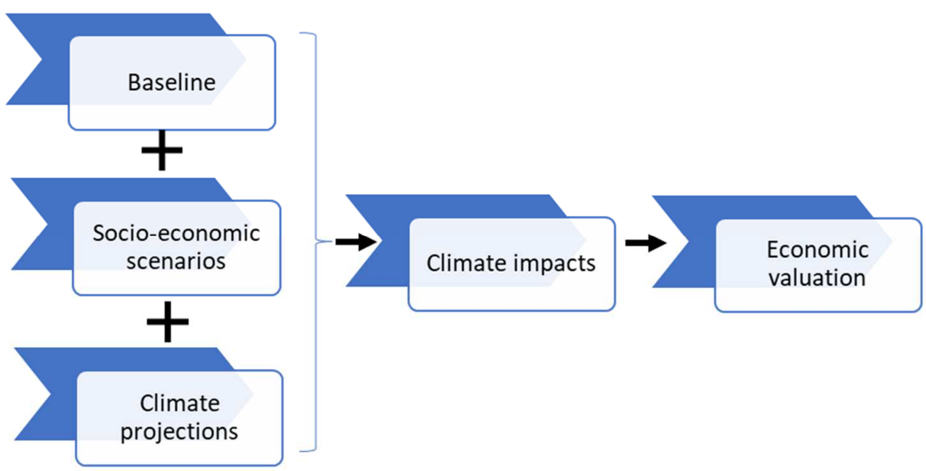
3.3. Minimum information required to estimate inaction

Chapter 3 has thus far presented what constitutes inaction and how different types of costs can be considered, as well as the various methodological approaches to estimating inaction both at the sector level and for a whole economy. We can now dig one level deeper to identify and develop the five "building blocks" that are required to estimate the cost of inaction in practice. The previous EEA technical report (2007) identifies the following elements that are integral to assessing the cost of climate change impacts. These are:

- Current baseline
- Change in socio-economics
- Change in climate
- Change in impact
- Monetary valuation

The graphic below is a visual representation of how these elements are combined to reach economic estimates of the cost of inaction:

Figure 4: *Building blocks to estimate the cost of inaction*



Building on this framework, below we will explore how these elements have developed in the last 10-15 years. We especially look at how knowledge, data availability, and methods have progressed, and what sort of results have emerged. We examine each of these building blocks individually, providing some examples of potential sources of data and information, and explore how they are considered in cost of inaction estimates.

Building block 1: Baseline

Description: The baseline defines the "business-as-usual" climate policy scenario that describes the inaction situation, i.e. it defines what policies would be in place if no additional adaptation actions would be taken. As explored in section 3.1, there are multiple theoretical baselines that can be justified when evaluating costs of inaction. Most commonly implemented, for practical reasons, is a baseline of current policy (OECD 2008a). That is, any climate policies already implemented are considered to continue. This baseline should describe adaptation- and mitigation-relevant policies from all sectors and at all relevant policy scales: local and regional policy commitments (such as build flooding protections), national policies (such as changes to building codes), and EU policies (such as Common Agricultural Policy support for adaptation) and other documents such as Nationally Determined Contributions (NDCs) or National Adaptation Plans (NAPs) will all affect the expected level of adaptation (and costs of inaction).

Building block 2: Socio-economic scenarios

Description: To calculate the cost of inaction, we have to understand how society and the economy will develop into the future. This builds on the definition of building block 1: baseline, which defines the business-as-usual policy settings. Socio-economic scenarios go beyond this, extrapolating from today to try to predict how individuals, companies, and other actor will respond to current policy and other information. These scenarios can be narrative (i.e. tell a story about how society will develop) but should also enable this to be translated into qualitative and quantitative description of the future (e.g. in terms of economic growth and population growth) and how society is likely to behave (e.g. level of education and technological development).

Developed for the sixth IPCC assessment report, the IPCC community of scientists have defined a set of five Shared Socio-economic Pathways (SSPs), informed by (and eventually replacing) the Representative Concentration Pathways (RCPs), discussed further below. The SSPs present narratives that are broadly similar to those from the Special Report on Emissions Scenarios (SRES) used in the third and fourth IPCC assessment reports. One difference, however, is that mitigation is considered separately from the socio-economic narrative, and thus the SSPs can be combined with different mitigation targets.

The SSPs are five different potential narratives for future global development, that include differing estimates for population growth, human and economic development, technology, lifestyles, environmental and natural resources, and policies and institutions. Importantly, the SSPs present potential pathways for future development *in the absence of climate policy*, meaning that commitments to enact new policies (e.g. commitments towards the goals of the Paris Agreement) are not considered. The SSPs are further framed according to the challenges faced by mitigation and adaptation efforts (Riahi et al 2017; COACCH 2018):

- SSP1: Sustainability – Taking the green road: Swift but gradual shift to sustainable development that respects planetary boundaries. There are few challenges to both adaptation and mitigation.
- SSP2: Middle of the road: This is the Business-as-usual scenario. The world continues to develop similarly to the past 100 years, with some countries quickly shifting to sustainable paths while others are slow, with population growth moderate and tapering and energy use declining over the century. Both adaptation and mitigation continue to face moderate challenges.
- SSP3: Regional rivalry – A rocky road: A world driven by national or regional competition, with little cooperation on environmental issues, high population growth, high global inequality in income and environmental outcomes. There are significant challenges for both adaptation and mitigation efforts.
- SSP4: Inequality – A road divided: Inequalities compound, with the developed world seeing swift technological and economic development, and the opposite in other states. In this scenario, adaptation faces high challenges, while mitigation faces lower challenges.
- SSP5: Fossil-fuelled development – Taking the highway: Rapid technological and well-functioning institutions support global social and economic development on the back of fossil fuel-based energy, resulting in high emissions. Challenges to adaptation are low; mitigation challenges are high.

Each scenario describes alternative pathways for the future, making it possible to envisage what society will look like, and thereby understanding the costs that society will have to bear under different climate scenarios. Further information on the development of the SSPs and additional details on each of the pathways is available here.

European-specific scenarios for the future have also been developed in relation with the European Green Deal (European Commission 2019). As part of the analysis supporting the development of the European Green Deal, the EU Commission considered three scenarios, each which would achieve the objectives of the European Green Deal, though in different ways. These scenarios include energy, transport and overall GHG emissions; non-CO2 emissions; land use, land use change and forestry changes; and air pollution impacts. The three considered scenarios propose the following paths (European Commission 2021c):

- REG: The REG scenario relies on very strong intensification of energy and transport policies in absence of carbon pricing in road transport and buildings, and inclusion of the maritime transport sector in the EU Emissions Trading System (ETS).
- MIX: The MIX scenario extends carbon price signals to road transport and buildings and intensifies energy and transport policies, effectively extending the EU ETS to all sectors.
- MIX-CP: Similar to MIX, except with different carbon prices for the new sectors (rather than one carbon price for all, as in the MIX scenario).

National level scenarios must not follow any of the IPCC or EU Green Deal scenarios, but they may find useful data and direction in these sources.

Recommendation: A constant economy evaluation

In the lack of a long-term socio-economic perspective **for the country**, it is possible to maintain the socio-economic situation (such as demography, technology or economic growth) **of the country** as it is currently (the scenario "constant economy" or "fixed economy").

This choice makes it possible to separately identify the impact of climate change from other evolutions. It does not add macroeconomic uncertainties to the climate ones and eliminates the issue of updating factors. The question of the update rate is, in fact, set aside. This corresponds to the following question: "What would the consequences be if we experienced today the climate, we expect tomorrow?” However, this remains problematic for some sectors where socio-economic change is already anticipated or where socio-economic change is a key determinant of vulnerability to climate change (e.g. health).

Data sources:
IIASA SSP Database (https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about): The International Institute for Applied Systems Analysis maintains a database that aims to document quantitative projections of SSPs and the associated integrated assessment scenarios.

Building block 3: Climate projections

Description: Climate models are numerical representations of the global climate system, generating projections of how the global climate will develop under different expectations. Climate models build on the socio-economic scenarios, which describe what society looks like – and what this implies for emissions, mitigation, and removals of greenhouse gases. Based on these, climate models can generate the likely climatic changes that we will see, in terms of global and more localized temperature change and other impacts such as precipitation, drought, extreme weather, heat waves, etc.

Modelling the global climate system is a complex exercise that demands some assumptions and simplifications to be computationally tractable. A key limitation of global climate models is that they operate at a coarse geographic scale; for example, recent global modelling projects have generated climate projections at resolution of 100-300km (COACCH 2018). These results are sufficient to support global and even national estimates of climate impacts but higher resolution impact mapping is important to identify expected local or regional impacts. To calculate these local impacts, the global results are fed into regional climate models, which can estimate impacts at a much finer geographic resolution, around 10km spatial scale.

Up until the development of the SSPs, climate models have been driven by assumed 'representative concentration pathways' (RCPs)[3]. These RCPs represent potential emissions concentrations in the future, which will generate total levels of radiative forcing (i.e. the excess heat from the sun that will be captured by the earth's climate as a result of emissions). A set of RCPs was defined by the IPCC for modelling climate impacts in the IPCC's fifth assessment. These RCPs are named after the amount of radiative forcing they generate, commonly referred to RCPs include RCP2.6 (a "very stringent" scenario with significant, fast emissions reductions and removals, which would have a high possibility of keeping global warming below 2 °C in 2100), RCP4.5 (an intermediate scenario, with significant emissions reductions and high removals, which would have a better than even chance of keeping global warming below 2 °C in 2100), and RCP8.5 (which assumes emissions continue to rise through the century, with temperatures rising by 3.7°C by 2100, commonly assumed a worst-case scenario).

It is worth noting that under high climate change scenarios (e.g. RCP8.5), estimation of non-financial, indirect, and option costs become especially difficult to calculate. Under such scenarios, climate impacts are especially high, making these non-market calculations particularly challenging. The European Green Deal scenarios offer some guidance, making it clear that within the EU, net emissions are expected to track to net zero (meaning that the emissions levels of RCP8.5 will not occur within the EU). However, the EU Green Deal scenarios do not determine how the rest of the world will act, meaning that there is still potential that the emissions levels envisioned in RCP8.5 could be reached. To adequately capture this risk, cost of inaction calculations should consider such high climate change scenarios as part of their analysis, to ensure that the risk of their occurrence is considered. However, the focus should be on climate projections that are more closely aligned with EU Green Deal scenarios.

Data sources:
EURO-CORDEX (https://www.euro-cordex.net/): EURO-CORDEX is the European arm of a global research project to downscale global climate impacts to improve regional climate change projections. It produces projections at a finer scale, either at approx. 50km or 12.5km granularity. Projection data, explanatory information and other publications are publicly available.
Copernicus Climate Data Store (https://cds.climate.copernicus.eu/#!/home): The Climate Data Store is implemented by the EU's Copernicus Earth observation programme, and contains extensive datasets, applications, and tools.

Building block 4: Impacts

Description: Once the changes in socio-economics and climate are established, the impacts can be quantified with process-based approaches (based on biophysical modelling) or empirical approaches (based on historical data). This is generally carried out within a particular sector or for a particular impact category. Process-based approaches simulate physical impact relationships to describe system responses to climate change. Empirical methods rely on historical data to examine and extrapolate correlated relationships between climate, socio-economics, and impacts. In practice, the line between process-based and empirical approaches is blurry, as many models include information from relationships identified from empirical data (Feyen et al. 2020).

Data sources:
There is a wide range of biophysical models for different impact categories (e.g. LISFLOOD for water and flooding, GLOBIOM for land use analysis, DIVA for sea-level rise). The EU's PESETA IV study employs

[3] For the IPCC's Sixth Assessment Report, the RCPs have been largely replaced by the Shared Socio-economic Pathways, which have been extrapolated from narrative descriptions to future emission and concentration scenarios that would arise under particular assumptions. Implicitly, these SSPs now contain both building block 2 (i.e. a scenario of the future economy and society) and building block 3 on climate projections (i.e. climate impacts).

a range of models in its assessment, including, inter alia, LISFLOOD for water resources, WOFOST for crop yields, and POLES for energy supply modeling.

Building block 5: Monetary valuation

Description: Finally, impacts arising from climate change need to be valued economically. A variety of approaches are possible for this step, depending on what is being considered. These have been outlined in section 3.2 Methodological approaches to costs of inaction. Generally, the outputs of impact models described above are combined with either socio-economic impact modelling, or econometric analysis is employed. The impact of future heat waves can be estimated by combining heat wave magnitude index modelling (biophysical modelling) with human exposure and mortality rates (socioeconomic impact modelling); the impact of droughts can be estimated through hydrological and water use modelling (biophysical) and empirical drought loss functions (socioeconomic) (Feyen et al. 2020). The economic impact of changing crop yields can be estimated using existing market data, which can feed into a partial equilibrium model for a more detailed analysis. In some instances, monetary valuation of climate impacts is challenging (e.g. health, biodiversity). To get around this challenge, other economic approaches are frequently employed (e.g. contingent valuation, hedonic pricing). Finally, computable general equilibrium models can be used to estimate multi-sector, multi-country costs in order to gain a broad, yet detailed estimate of the value of climate impact damages. The table below presents an overview of different methods for monetary valuation of impacts, outlining the basic approach, which types of costs and sectors it can be used for, as well as the data needs.

***Table 5**: Overview of monetary valuation methods*

Method	Approach	Used for: Cost type and sector	Data needs
Market approaches			
Market valuation	Calculate cost of inaction by calculating change in value of output produced	Direct and indirect values. **Sectors**: All with market prices (e.g. agriculture, fisheries, industries)	Current and future output data; prices.
Replacement cost method	Calculate value of a service based on how much it would cost to replace or restore it.	All direct, indirect, and non-use values. **Sectors**: Sectors reliant on natural processes e.g. agriculture, water, biodiversity	Data on service provision and cost of replacement
Stated preference techniques			
Contingent Valuation Method	Survey where respondents state how much they would be willing to pay (WTP) for different outcomes (e.g. different levels of adaptation action)	All direct, indirect, and non-use values. **Sectors**: especially biodiversity, health	Survey with scenario description and questions about WTP for specific services
Choice experiments	Survey where respondents select between hypothetical combinations of outcomes and costs	All direct, indirect, and non-use values. **Sectors**: especially biodiversity, health	Survey with scenario descriptions and questions about alternative options

Method	Approach	Used for: Cost type and sector	Data needs
Revealed preference techniques			
Travel cost method	Estimate the value of a recreation site or its attributes by based on respondents' travel expenditures	Direct and indirect values. **Sectors**: e.g. biodiversity, city planning & recreation	Survey on expenditures of time and money to travel to specific sites
Hedonic Pricing	Calculate cost of climate impacts by identifying the impact that it has on a marketed good (e.g. (e.g. property values)	Direct and indirect values. **Sectors**: especially buildings, city planning	Property values and characteristics including environmental quality
Derived demand measures	Calculate the value of climate impacts by observing change in climate-affected input (e.g. water availability) on output, and valuing that output	Direct and indirect values. **Sectors**: All sectors with production processes (e.g. Water, agriculture, fisheries)	Data relating climate impact to output; value of produced goods
Benefits Transfer	Use results from related existing studies to calculate values	Depends on the scope of the original study (i.e. can only transfer like-to-like) **Sectors**: All	Require a relevant original valuation study

Data sources:
As with biophysical models, a range of climate-economy models are in existence. For example, the ICES and ENV-Linkages models are both dynamic general equilibrium models that represent multiple sectors and cover the global scale, while the the PESETA IV study employs the CaGE general equilibrium model for its assessment of the economic impacts of climate change in Europe. At a smaller scale, the COIN model was developed to assess the costs of climate change specifically for Austria (details below).

Stepwise approach to calculate the cost of inaction at national level:

The following example for Austria shows how costs if inaction can be estimated at national level and refers to all five building blocks described in the chapter.

Estimating inaction in practice: an example from Austria (Source: Steininger et al. 2016)

The following is an example of how the costs of inaction can be estimated at the national level, referring specifically to the five building blocks presented above. The Austrian assessment presents a clear approach towards incorporating these five elements to produce estimates both at the sector level and for the economy as a whole.

For Austria, a harmonized cross-sectoral impact assessment has been developed and published in 2016. It is based on an assessment approach including climate and socio-economic scenario analysis, harmonized economic costing, and sector specific (bio)physical impact assessment models and a uniform multi-sectoral computable general equilibrium model.

The "inaction assumption" supposes that no adaptation or mitigation measures that are not already agreed upon will be taken up. The assessment covers 14 sectors or impact fields mentioned in the

Austrian Strategy for Adaptation to Climate Change, such as Agriculture, Forestry, Water, Transport, Tourism, Energy, Human Health and Biodiversity.

- The assessment starts with an identification of economically relevant impact chains potentially triggered by climate change. Furthermore, suitable assessment models for the quantification of the respective (bio)physical impacts (e.g. losses to harvest during a drought) are screened and selected.
- Second, each physical impact is translated into an economic impact by means of a consistent costing approach. Five types of economic impacts are covered: changes in productivity, in production cost, in investment requirement, in final demand or in public expenditures. Market data is used as much as possible and indirect approaches are used for health impacts and impacts on urban green (e.g. life years lost).
- As a third step, the economy-wide and cross-sectoral effects are assessed within a multi-sectoral computable general equilibrium (CGE) model, including sectoral economic impacts.
- To gain information on the spread of potential impacts, the team identified as a fourth step which climatic and socioeconomic parameters contribute to significantly higher (or lower) sectoral damages. The analyses started with a mid-range climate and a socio-economic scenario for all sectors. The selection of scenarios is based on RCP and SSP scenarios, e.g. using SSP2 as intermediate challenge-scenario. Uncertainties are discussed based on a range of scenario combinations.

An additional aspect of this study was a communication strategy that translated the modelling results into fact sheets and narratives to inform stakeholders.

The impacts for 2050 show that economic gains due to climate change are reflected in reduced heating demand or higher crop yields in agriculture, but these are estimated to be small relative to projected losses. Weather and climate-related economic damages are estimated to be at least four times higher than today in a mid-range climate scenario by 2050.

This interdisciplinary assessment was based on the availability of datasets, modelling resources and a collaboration of inter- and transdisciplinary experts such as climate scientists, economists and scientists related to the different impacts.

Considering the five building blocks outlined above and the example from the case of Austria, a set of general guidelines have been developed for calculating the cost of inaction at the national level. The approach to calculating inaction will vary in each country, and the below should considered as important considerations in preliminary stages, in order to ensure that the assessment is carried out effectively. Following these steps should help produce estimates that prove useful for policymakers, researchers, as well as civil society and other relevant stakeholders.

- Select an approach for economic assessment that is in line with capacities. This includes available time and personnel resources, as well as datasets and technical capabilities.
- Use a harmonized approach (e.g. baseline, scenario choice) for cost assessment, so that values are easier to interlink and are comparable.
- Define climate and socio-economic scenarios to be used. Use already nationally agreed/used RCP-SSP combinations or timelines, and ensure that these are consistent with EU Green Deal scenarios
- Begin impact assessments in prioritized sectors or impact fields in your country, e.g. according to national vulnerability and risk assessments or adaptation strategies and plans, and proceed to extend the assessment in a step-by-step approach.
- Analyse climate impact chains and indicate direct and indirect effects to be included in the assessment. Define clear boundaries for analysis.
- Identify key economic impacts you wish to estimate (e.g. change in productivity or investment requirement) and select appropriate methods and models accordingly.
- Discuss main sensitivities for assessments.

3.4. Gaps and further research perspectives

Studies highlight that the cost of inaction in many countries, and particularly in different sectors, is increasing. Indeed, as countries' exposure to the negative impacts of climate change and the frequency of these extreme weather events increase, vulnerable areas multiply, and the economic costs of resulting damages grow (Nicklin et al. 2019). Overcoming market imperfections, such as information asymmetry, is needed to increase awareness around climate change and motivate the required investments (Pauw et al. 2021).

Many studies estimate a measure of incremental damages, or the 'social cost of carbon'. Essentially, if carbon emissions can be reduced with a lower cost per ton than its social one, social welfare is increased: the arbitrage prioritizes greenhouse gas cut (Auffhammer 2018). Recent studies have identified further points of concern with current economic models estimating the cost of climate change. Notably, many models focus on short-term damages, with little consideration for long-term effects on economic growth (Kikstra et al. 2021). However, there remains significant uncertainty around exactly how economic growth will be impacted, thus making this field of investigation particularly challenging.

Recent studies have also highlighted important considerations for policymaking on climate change. The CASCADES research project points to the importance of considering both cascading (knock-on) climate impacts as well as possible cross-border risks in decision-making. Climate impacts like droughts, heatwaves, floods, and wildfires can have impacts that not only cascade, but also escalate, beyond the biophysical realm, into financial markets, security relations, and international trade. This is particularly relevant for policymakers in Europe, which is strongly linked to the rest of the global economy (Hildén et al. 2020). Similarly, the COVID-19 pandemic has demonstrated that compound events will lead to increasingly complex risks. Such related and overlapping stressors, be it for example pandemics or pre-existing financial and economic vulnerabilities, should be considered in climate and economic impact analysis in order to avoid underestimations (Dunz et al. 2021).

4. ELEMENTS ON THE COST OF ADAPTATION

4.1 Defining the costs of adaptation

In the context of increasing and widespread impacts of climate change, policymakers need to make informed decisions about the long-term costs and benefits of investing in adaptation. However, economic approaches to climate change risk were relatively scarce until recent years, inducing a lag in knowledge development pertaining to the costing of inaction and adaptation. Indeed, obtaining robust information on the value, effectiveness, and feasibility of adaptation projects and strategies rides on our ability to first quantify and monetize the impacts of climate change.

Assessing the cost of adaptation is widely regarded as a still-emerging field, with a slew of possible approaches, several overriding conceptual frameworks, and no clear perimeter for which elements fall under costs of adaptation. To date, there is no common definition at European level.

Other definitions of the cost of adaptation vary:

1. The IPCC defines adaptation costs as “the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs” in 2007 (Adger et al. 2007)
2. The UNFCCC defines the cost of adaptation as the cost of any additional investment needed to adapt to or exploit future climate change (UNFCCC 2007)
3. The newer IPCC report adopts the UNFCCC definition, adding on that ‘a full accounting needs to consider the resources spent to develop, implement, and maintain the adaptation actions along with accruing reduced damages or welfare increases involving monetary and non-monetary metrics’ (Chambwera et al. 2014a)
4. The costs of adaptation are also defined as “the value of the resources society uses to adapt to climate change” (Fankhauser 1997).

Following the IPCC definition, the cost of adaptation can be summed up as all the costs necessary to implement adaptation options, or measures. These costs are generally divided up into four types, beginning with direct costs comprised of:

- **Initial costs,** which represent the total costs of expenditures incurred from project design to completion and commissioning of the adaptation option, including land costs, study costs, construction costs and equipment costs.
- **Ongoing/recurring costs**, for instance, regarding maintenance, operations, etc.

Two additional types of costs are generally more difficult to measure and therefore often omitted from economic evaluations. These are:

- **Indirect costs** - involuntary side effects of adaptation activities: associated with the challenges, hazards, and unintended effects of adaptation activities. They are unintended and often unplanned effects of adaptation with a time lag. Usually are not directly valued in the marketplace; however, not including them in estimates of adaptation cost can lead to underestimates and misrepresentations of the total cost of adaptation. (see also section: What are the ancillary impacts of adaptation?)
- **Transition costs** - those consequential to the investment and which correspond to adjustments or additional expenses, triggered by adaptive responses (e.g., monitoring, maintenance, and management costs).

Other breakdowns of cost categories include transaction costs, information acquisition costs, and adjustment costs.

By contrast, in the other definitions above, the cost of adaptation does not apply to specific measures but is tied to the wider notion of ‘adapting to climate change’. This may be closer to the cost of adaptation for a national coordinating authority; however, adaptation itself is difficult to capture adequately. It can take place at various scales, involve segments of activity not directly linked to climate change, and does not have a common measure for success. Using this broader definition, several supplementary concepts are decisive to factoring in which adaptation costs should be accounted for, or not:

- **Additionality**

The additionality of an adaptation project is the portion of finance required in addition to, or separate from, the cost of development. It is the amount of finance required to include the impacts of climate change (Church and Hammill 2019). The implementing regulation 2020/1208 on reporting of climate and energy action by member states mentions additionality in a footnote: 'the additional investment that makes a project (that would have been realised anyway) climate resilient' (European Commission 2020b).

There are considerable overlaps, including geographical and sectoral, between development and climate change, and the integration of respective activities is important for effectiveness and efficiency (Knoke and Duwe 2012).Tracking and monitoring domestic adaptation finance must ensure that the geographical and sectoral allocation of finance considers traditional development objectives, where activities focus on vulnerability issues, with climate resilience and adaptation allocations additionally. For example, at city level, if an activity is planned that includes costs to climate proof the investment, that share would be accounted as additional adaptation.

- **Scale of adaptation**

Adaptation actions may be implemented at different levels: national, regional and local respectively. Existing work embraces two logics of scale:

  - A sectoral segmentation, generally covering infrastructure, coastal areas, water management, agriculture and food, health, and disaster risk/civil protection and emergency management[4] – a sectoral approach makes a practical and comprehensive representation of adaptation costs possible; and
  - A regional segmentation, with adaptation costs evaluated at scales ranging from local, to regional, to national, to global. The objectives and precision of cost estimates vary between the different scales. For instance, national and global scale figures are less precise but more relevant for country's decision-makers. Global level studies were initially developed to guide international negotiations on adaptation finance.

ECONADAPT (2015) state that adaptation costs are partially available, and coverage of economic estimations is unevenly distributed among sectors |i.e. good coverage for coastal zones, medium coverage for agriculture and water sectors, flood infrastructure and over-heating (energy, built environment) and limited sectoral data is available for energy, transport infrastructure, tourism, biodiversity, industry and public health sectors].

To put this into perspective, a questionnaire was sent to EU countries[5] including a question on the availability of adaptation finance data by sector. Of the twelve European countries that responded, most reported having some data on the agriculture and food sector, coastal zones, forestry, water management, buildings and infrastructure and tourism. However, gaps appear in the public health, transport and energy sectors.

[4] Adaptation finance reporting as required by the Implementing Regulation 2020/1208 covers sectors that are less frequently represented in literature. The full list comprises 'Agriculture and food, biodiversity (including ecosystem-based approaches), buildings, coastal areas, civil protection and emergency management, energy, finance and insurance, forestry, health, marine and fisheries, transport, urban, water management, ICT (information and communications technology), land use planning, business, industry, tourism, rural development, other'.

[5] As part of an EEA-funded project on climate adaptation finance, a questionnaire was developed to assess availability of adaptation finance data. The questionnaire was distributed to EEA national focal points and national reference centres on climate impacts and adaptation in the last semester of 2020. Responses were received for 19 out of the 32 countries.

Finally, switching over from the economic analysis sphere to the policymaking sphere, adaptation costs are viewed in terms of investments. Investment into adaptation actions be grouped into three broad categories:

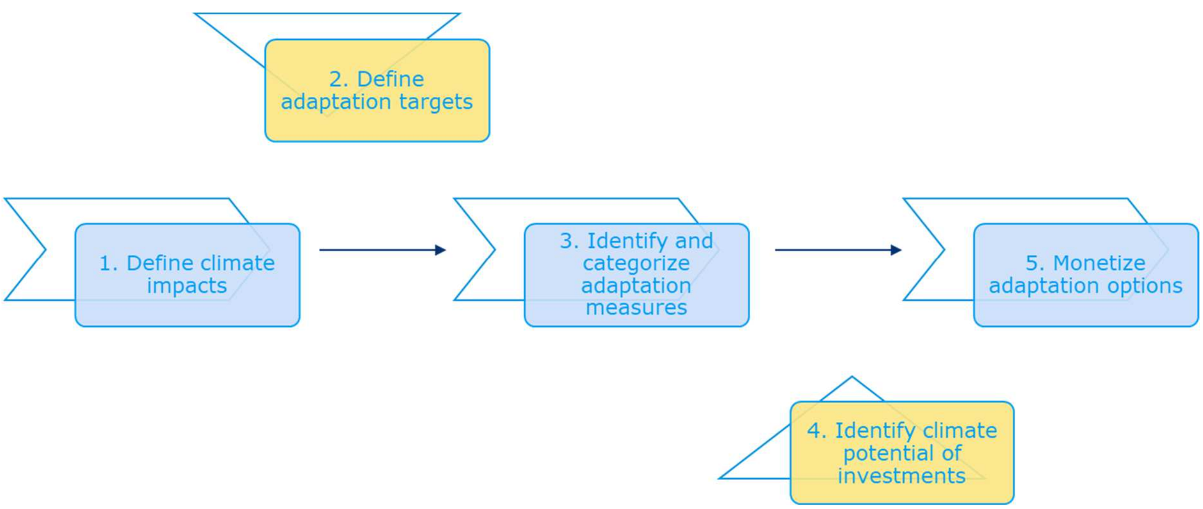
- **Total investment needs** -correspond to the definitive cost of adaptation but are very difficult and almost impossible to estimate as they depend on scientific elements, ethical and subjective decisions, and are related to the balance between adaptation costs/benefits and residual impacts (Watkiss et al. 2015).
- **Actual spending,** which involves up-front costs incurred today to build resilience to future climate risks over the lifetime of the investment (Christiansen, Martinez, and Naswa 2018a).
- **Planned expenditure**, corresponding to the costs envisaged for investments.

The "finance gap" is defined as the difference between the costs, i.e. the finance required, for meeting a given adaptation target and the amount of resources available to do so. Since the total investment needs are usually unknown, especially at the beginning of a project, the finance gap could be difficult to estimate. Therefore, one possible method to overcome the issue consists of defining intermediate goals and to proceed step by step such to determine the economic amount needed to reach the following objective.

4.2 Minimum information required to estimate costs of adaptation

The previous section shows that are multiple competing frameworks and no single approach to estimating the costs of adaptation. Following the approach laid out in Section 3, five steps to estimating costs of adaptation are suggested below. The initial steps are not specific to estimating adaptation costs; rather, they are usual stepping-stones for establishing adaptation strategies. Therefore, only the penultimate and final steps are explored in detail below, as the process for estimating costs of adaptation could be initiated starting from a list of adaptation measures. Steps 2 and 4 are conceptual inputs which run parallel to the process of estimating the cost of adaptation.

Figure 5: *Five steps to estimating costs of adaptation. Authors, based on concept in World Bank,* (2010)



It is worth noting that the methodological difficulties in estimating the cost of inaction (namely, uncertainty linked to scenarios and valuation of nature) are also applicable for the cost of adaptation. The latter also entails a new set of methodological issues linked to the categorization of adaptation types, the valuation of ancillary benefits, and the scale and timing considered (EEA 2007).

4.2.1 Building block 1: Defining economic, social, and environmental impacts of climate change

Description: Defining or rather predicting future climate impacts actually relies on several successive steps: setting a baseline, selecting socio-economic scenarios as drivers of change, selecting emissions scenarios and climate models (see this described in greater detail in Section 3). Finally, climate projections are injected into impact models in order to quantify future changes. Impacts can be quantified with process-based approaches (based on biophysical modelling) or empirical/statistical approaches (based on historical data). This is generally carried out within a particular sector or for a particular impact category. Process-based approaches simulate physical impact relationships to describe system responses to climate change. Empirical methods rely on historical data to examine and extrapolate correlated relationships between climate, socioeconomics, and impacts. In practice, the line between process-based and empirical approaches is blurry, as many models include information from relationships identified from empirical data.

Examples: In Europe, the PESETA project helped quantify the impacts of climate change in economic terms. More recently, the COACCH project provides a broad overview of economic cost of climate change for a set of major sectors (coastal flooding, agriculture, business and industry, energy, transport, ecosystem services, health, etc.), using different biophysical and economic models.

Data sources: This step requires multiple data sources[6]:

- Socio-economic data for baseline projections
- Climate projections
- Biophysical model outputs

See Section 3 for more detail.

4.2.2 Building block 2: Defining adaptation targets

Rationale: Some, but not all, climate change impacts can be minimised through adaptation. It is important to understand which impacts can be managed in order to define adaptation targets and then stake out measures for reaching those targets. As shown in Figure 6, adaptation targets are usually reduced in scope compared to the adaptation that would be required to prevent all negative impacts from climate change. This has implications for the cost of adaptation.

On one hand, technological and physical limits to adaptation usually mean that there will be residual impacts from climate change, no matter how much is invested into adaptation. Also, adaptation costs are expected to follow an exponential decay model (see Figure 7), so that investments become less efficient over time.

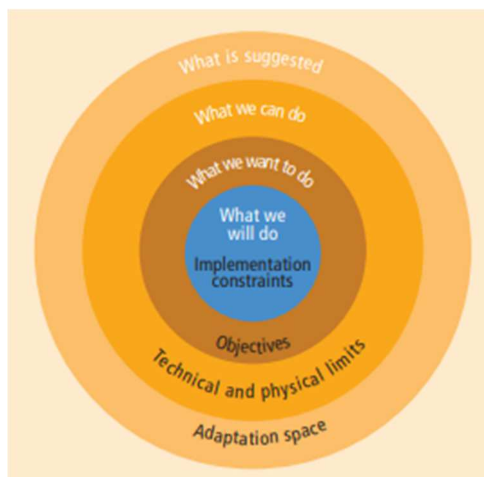


Figure 6: *The narrowing of adaptation from the space of all possible adaptations to what will be done. Forces causing the narrowing are listed in black. (Chambwera et al, 2014)*

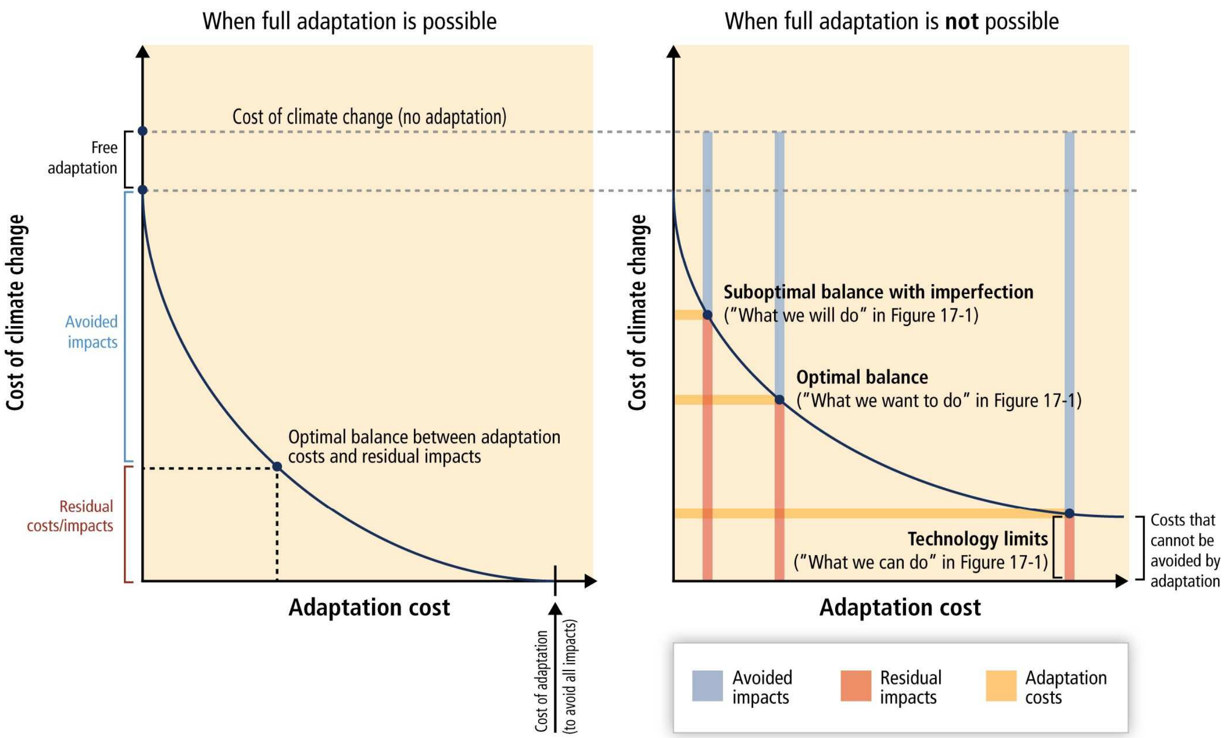
[6] That can be different from country to country (or even region), depending on what is available

Before calculating the cost of adaptation, it is necessary to determine the level of impact to which one wishes to adapt. Costs will vary depending on whether adaptation options aim to avoid:

- All impacts that may reduce human well-being
- Those to which it is rationally economical to adapt, i.e., impacts reaching the "optimal-balance", with a cost-benefit ratio<1
- All those to which it is possible to adapt given a budgetary constraint (e.g., national fund dedicated to adaptation)

This adaptation target is important for the interpretation of adaptation cost estimates.

Figure 7: *Graphical representation of link between the cost of adaptation (on the x-axis) and the residual cost of climate change (on the y-axis). The left panel represents a case where full adaptation is possible, while the right panel represents a case in which there are unavoidable residual costs. The figure referred to as 17-1 is* ***Figure 6*** *in this report (Chambwera et al, 2014).*



4.2.3 Building block 3: Identifying adaptation options

Description: Having gained a general understanding of the potential impacts of climate change on a given area, the next step involves identifying plausible adaptation options, or measures. Selecting and prioritizing adaptation measures is constrained by financial resources, capacity of public authorities, and pre-existing conditions, and as such is a context-specific exercise. Several systematic analysis methods are suggested in literature:

- Cost-benefit analysis
- Climate risk management approaches
- Multi-criteria analysis

The framing of the 'ideal' adaptation strategy evolved over the years from one that maintains the status quo, towards dynamic strategies inducing transformational changes (Chambwera et al. 2014a). Nowadays, the need for systemic adaptation is widely acknowledged, see for instance the new EU

Adaptation strategy. This is also reflected in the typology of Key Type Measures (KTMs) that has been developed based on the IPCC categorization and connected to existing reporting experiences. This typology aims to consider the diversity of adaptation options for different sectors and stakeholders.

Table 6 : *KTMS, Sub-KTMS and specifications (Source: Leitner et al. 2021)*

KTM	Sub KTM	Specifications
A: Governance and Institutional	A1: Policy instruments	Creation / revision of policies Creation / revision of (implementing regulations
	A2: Management and planning	Mainstreaming adaptation into other sectors Creation / revision of technical rules, codes and standards
	A3: Coordination cooperation and networks	Creation / revision of ministerial coordination formats Creation / revision of stakeholder networks
B: Economic and Finance	B1: Financing and incentive instruments	Creation / revision of incentive mechanisms Creation / revision of funding schemes
	B2: Insurance and risk sharing instruments	Creation / revision of insurance schemes and products Creation / revision of contingency funds for emergencies
C: Physical and Technological	C1: Grey options	New physical infrastructure(s) Rehabilitation, upgrade and / or replacement of physical infrastructure(s)
	C2: Technological options	Early warning systems Hazard / risk mapping Service / process applications
D: Nature Based Solutions and Ecosystem-based Approaches	D1: Green options	Creation of new / improvement of exiting green infrastructure Natural and/or semi-natural land-use management
	D2: Blue options	Creation of new / improvement of existing blue infrastructure Natural and / or semi-natural water and marine areas management
E: Knowledge and Behaviour	E1: Information and awareness raising	Research and innovation Communication and dissemination Decision support tools and databases
	E2: Capacity building, empowering and lifestyle practices	Identification and sharing of good practices Training and knowledge transfer Reporting on lifestyle practices and behaviours

Most current studies focus on the technical (engineering) costs of implementing adaptation, thus focusing mainly on physical and technological adaptation options, and overlook other costs of adaptation option. However, non-technological adaptation options can also offer significant co-benefits. For example, Nature-based Solutions and ecosystem-based approaches for adaptation are receiving growing attention for their potential to reduce people’s vulnerability to a range of climate change impacts and provide significant co-benefits for biodiversity and people.

4.2.4 Building block 4: Identifying climate adaptation potential of other investments

Description: Adaptation measures are rarely designed purely to address climate opportunities or risks. They are often led with the aim to fulfil other primary objectives, such as economic development or poverty reduction, while obtaining co-benefits linked to climate. The World Bank (2010) report concludes that economic development is indeed the 'most basic and cost-effective method of adaptation'. Increasing attention is paid to how climate change is integrated into government policy and private sector activities, linking in with the concept of additionality. This is relevant to estimating the cost of adaptation, as the full cost of such transversal measures should not be included in the adaptation finance budget. Methods for estimating the cost of measures that bring adaptation co-benefits usually involve either applying a premium to measures depending on their assessed contribution to adaptation, or classifying them into virtuous, neutral, or harmful categories relative to adaptation potential.

Examples: Examples of well-known methods or approaches include:

- **Rio Markers** – these markers were initially designed to facilitate reporting on National Communications or National Reports by parties to the Rio Conventions, by identifying activities that contributed to environmental objectives. Markers relative to climate change mitigation were introduced in 1998, and climate change adaptation in 2010. These markers are applied to funding flows to estimate how much funding supports climate objectives The markers function as follows: afunding envelope is scored with an RM value of 0, 1, or 2, using a decision tree which relies on eligibility criteria as defined by the OECD Development Assistance Committee (DAC). Guidance is provided by sectors/subsectors for scoring various activities in the DAC Handbook (OECD 2016)Then, to each RM value is affixed a which is recognized as climate relevant, though there is no universal standard for this percentage. The EU has elected to use the following budget accrual rates[7]:

IS NOT TARGETED	RM = 0	0% OF BUDGET RECOGNISED
IS A SIGNIFICANT OBJECTIVE	RM = 1	40% OF BUDGET RECOGNISED
IS A PRINCIPAL OBJECTIVE	RM = 2	100% OF BUDGET RECOGNISED

  In the Implementing Regulation's Annex IV reporting template on qualitative methodological aspects pursuant to Article 6, explicit mention of Rio markers is made (European Commission, 2020). The free-text field is named 'Application of Rio marker coefficients'. This means member states are expected to report on their use of Rio Markers.
- **TEG classification** for "substantial contribution to climate change"
  The European Taxonomy (European Parliament and Council 2020) defines a sustainable activity if it meets each of the following 4 conditions:
  1. Make a substantial contribution to at least one of the six EU environmental objectives[8] including climate change adaptation
  2. Do no significant harm to other environmental objectives[9]
  3. Comply with basic social criteria ("minimum social safeguards"), including respect for human rights
  4. Comply with the technical review criteria for assessing points 1 and 2

  The Taxonomy is therefore likely to advance adaptation to global warming in two ways:

    - By allowing companies to demonstrate a substantial contribution of their activities to adaptation, if indeed this contribution is real (point 1 above);
    - By ensuring that economic activities that meet other sustainability criteria are compatible with adaptation efforts (point 2 above). For example, a solution aligned with the "mitigation" criteria will not be sustainable in the sense of the Taxonomy if it runs counter to adaptation efforts, and vice versa

[7] https://europa.eu/capacity4dev/public-environment-climate/wiki/short-guide-use-rio-markers

[8] Climate change mitigation, climate change adaptation, sustainable use and protection of aquatic and marine resources, transition to a circular economy, prevention and reduction of pollution, protection and reforestation of biodiversity and ecosystems

[9] "DNSH" principle for "do no significant harm"

In this context, it is interesting to look at how development banks consider adaptation finance. We looked at EIB, "the climate bank", and a group of multilateral development Banks.

- **EIB's new climate adaptation plan** (EIB 2021)- At COP 26, the EIB launched its plan to support projects that adapt to the effects of climate change. It is committed to ensuring that all the operations it supports are adapted and build greater resilience to current weather variability and future climate change, in line with the adaptation goals of the Paris Agreement and the EU Taxonomy. One of the objectives of the new plan is to accelerate financing for adaptation, and in support of this goal EIB plans to measure the results of adaptation finance through dedicated indicators.
  EIB currently and will continue to track adaptation finance using the framework defined by the EU Taxonomy regulation described above. To evaluate impact of adaptation finance, EIB evaluates how investments reduce climate vulnerability and build resilience and are currently measured through metrics like residual physical climate risk of financed operations and number of people sheltered from risk. The EIB aims to enhance this approach by developing indicators to help monitor the 'degree to which EIB finance has contributed to reduce the exposure of people to flood, drought, wildfire and other climate-related hazards […] contributed to reduce or avoid losses that would have been incurred as a result of a changing climate'. Other metrics include the share of investment cost which directly targets an adaptation goal.
- **The 2020 Joint Report on Multilateral Development Banks' Climate Finance** (EBRD 2020) uses a specific methodology to track how much the major Multi-lateral Development Banks spend on adaptation finance. This involves a granular approach which looks at sub-project level elements to identify specific adaptation activities. This captures activities directly related to adaptation but might exclude activities that contribute significantly to resilience. It also might exclude activities without associated incremental costs, like contingency plans for business continuity, or locating assets outside potential storm surge flood zones. Thus, total contribution to adaptation may be underestimated using this method. The tracking method consists of vetting three criteria within project activities:
  1. Project sets out the climate change vulnerability context
  2. Project makes an explicit statement of intent to reduce climate change vulnerability
  3. There is a clear and direct link between specific project activities and the objective to reduce vulnerability to climate change.

4.2.5 Building block 5: Monetizing adaptation

As highlighted throughout the report, it is a challenge to define, plan and identify adaption actions, which, in turn, is a crucial precondition to estimating the cost of adaptation.

Challenges in this regard include, inter alia, the identification of additionality and the related definition of the baseline (see above); the definition of the desired level of protection from the probabilistic impact from climate change; the different actors (public and private) and categories of adaptation (spontaneous/autonomous and planned adaptation) involved; and the breadth of possible adaptation actions, spanning from behavioural changes to infrastructure measures (see the categories of KTM mentioned above). These challenges are related to "quantifying" the adaptation.

The estimation of the costs related to those adaptation actions, or, in other words, putting a price tag on them (or "monetising" them), is a sequential challenge. The nature of this challenge depends on the main approach taken, which can be a micro and bottom-up approach (i.e. estimating the costs for a number of specific projects and then summing up those costs) or a macro top-down approach (i.e. modelling the expected costs at regional and/or sectorial level); and the timing of the estimation of the costs (i.e. ex-ante or ex-post).

The actual step of costing adaptation relies on several tools within the realm of economic assessment. We will consider two categories of approaches: top-down approaches, and bottom-up approaches.

Table 7: *Comparison between top-down and bottom-up methods for costing adaptation*

Method	Description	Critical points
Top-down method [as used in World Bank,(2006); the Stern Review (2007); Project Catalyst 2009; AFDB, (2011)]	Current financial flows, such as official development aid, foreign direct investment, and gross domestic investment, are estimated and a mark-up is applied which is based on their assumed climate sensitivity and costs of climate proofing those investments.	• Specific adaptation activities not represented • Tend to underestimate costs (Gov Fiji, 2020) • High sensitivity of results to 'marker' estimates • Lack of empirical grounding • Mostly applied to developing countries and aggregate scales
Bottom-up method [as used in World Bank, (2010); UNFCCC 2007**;** PESETA, 2009; Joint report on MDB climate finance, (2020); NAP Costing for Fiji, (2020); PACINAS study (2017), Green budget for France (2019)]	Relevant adaptation measures necessary to overcome the negative impacts of climate change (divergence from the baseline, as projected) are identified (ex-ante or, often, from review of NAP). The costs of implementation are estimated. Also called "engineering costs" approach.	• Comprehensive and heavy analysis • With ex-ante analysis, high uncertainty linked to climate and socio-economic projections • Challenge in taking additionality into account (i.e., measures not included in NAP but contributing to overall resilience) • Works best at local or national scale

- **Top-down approaches**

Description: Macro approaches can be used ex-ante for estimating the costs of adaptation across a region and/or sector without identifying, costing and summarising the costs of different adaptation actions. Available literature and estimates focus mostly on two levels of costing: global scale estimates, largely to assess the overall need for adaptation finance funds; and regional and local-scale estimates, often limited to a particular vulnerable economic sector, which may be applied to inform budgeting or to support adaptation decision making, or to allocate scarce resources (Chambwera et al. 2014a).

In terms of sector coverage there exist large differences in the available estimates for costs as summarised by OECD (2008b) and updated in ECONADAPT (2015), shown in the table below[10].

[10] The overview of sectors, drawn from existing analyses, is not comprehensive. Some sectors, like buildings, transport, and urban, are implicit in the "infrastructure" category, while knowledge-based sectors like the financial sector and DRR (insurance) are not apparent. Also missing from these estimates are biodiversity and ecosystem-based approaches.

Table 8: Coverage of adaptation costs. *Source: (OECD 2008b), and ECONADAPT (2015)*

Sector	Coverage of cost estimates	
	OECD - 2008	ECONADAPT - 2015
Coastal areas	Excellent	Comprehensive
Agriculture, Forestry	Very limited	Medium
Water management	Limited	Medium
Energy	Good	Low to Medium (for cooling)
Infrastructure – Buildings, urban, transport	Good	Low to Medium(for floods)
Health	Limited	Low to Medium (for overheating/cooling needs)
Tourism	Limited	Low or very low

It should be kept in mind that both the costs for but also the benefits from adaptation actions, is very much context specific depending on the respective local risk profile, economic conditions, and others. There is no single agreed methodological approach for estimating costs for adaptation at macro level and a wealth of different methods have been applied in the existing literature using a premium approach, extrapolation, modelling or others.

Examples:

In an approach using premiums, existing estimates for investment costs in a sector are multiplied by a factor which reflects additional costs for climate proofing those investments. This approach has been used e.g. in World Bank (2006) which estimated cost of adaptation by applying a premium to foreign direct investments.

Using extrapolation can be done either by extrapolating results from another local context or by extrapolating insights from selected assessments (e.g. at project level) to a larger geographical scope. It should be kept in mind again that for using such an approach it is crucial to acknowledge the local specifics of existing cost estimates.

Regarding models, different approaches can be used such as integrated assessment models (as e.g. done in De Bruin et al, (2009) which used the DICE[11] model and refined it, and Agrawala (2011) or simple general equilibrium models (as e.g. done in Margulis et al.,(2011), i.e. models using actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. Integrated Assessment Models (IAM) approaches can actually be considered a subset of the top-down method, consisting of using integrated assessment modelling to estimate first the impacts of global or regional climate change, then the costs and benefits of adaptations. These are usually based on economic development trajectories and are distinct from other top-down approaches in that they are directly tied to future climate change scenarios. They are optimization models and resolve equations to determine the most cost-effective path to adapt to a given emissions scenario. They allow for comparison of adaptation costs between different warming scenarios, but the following limitations apply:

- Only works at global or regional scale
- Assume that adaptation is a highly effective response to CC
- Provide extremely wide range of estimates depending on model parametrization

[11] Dynamic Integrated Climate-Economy model

- **Bottom-up approaches**

Description: In the bottom-up way of estimating costs of adaptation actions the costs from different adaptation actions are summed up. The approaches for estimating the costs per action (or per project) differ depending on whether the assessment is aimed at planning needs (ex-ante) or monitoring (ex-post). Ex-ante assessments are intended to estimate the financing needs for implementing adaptation. Ex-post evaluations, in other words, once the adaptation option has been implemented, allow for a more precise assessment of the costs.

Ex-post evaluation:

Ex-post evaluation, the assessment of the costs for adaptation actions is in general in line with normal principles of economic appraisal. In terms of minimum information needed, this includes that, instead of assumptions, actual values can and should be used (wherever available) since there is much more certainty and knowledge on what actually happened and is observed.

In general, the costs include the capital expenditure (CAPEX) and operating expenditures (OPEX) over the lifetime of the action. This includes direct costs and transition costs (see definitions in 4.1)[12].

It should be noted in this context that, in order to qualify as an actual ex-post assessment, the estimation of costs should be done after the lifetime of the project is over. In practice, in the vast majority of cases, assessments are conducted after the implementation of adaptation projects but within their lifetime (Hugenbusch and Neumann 2021) and thus are de facto interim assessments. This bears the risk of omitting future costs including operational costs, maintenance and repair/replacement costs and, where applicable, dismantling costs. For this reason, when performing a cost-benefit analysis in the middle of the project lifecycle, the social discount rate should be adopted so as to capitalise the cash flows of the past and discount those of the future.

Ex-ante

The approaches to estimating the direct costs to a large extent follow the same methods as economic appraisal of any public project.

First, direct costs can be estimated through existing literature review.

> This review could include, on the one hand, similar actions already carried out in the country and, on the other hand, examine how similar countries have possibly costed adaptation actions of this type.
>
> Where the cost of certain adaptation options has already been estimated in other countries, it can be used to give the cost of that same option in one of the EEA member countries. Examples of template projects include Fiji's costing of its national Adaptation Plan (Government of Fiji 2020), and GIZ work on costs and benefits of adaptation (GIZ 2013). Adaptation costing projects have mostly taken place in developing countries, so these may not be perfectly transposable to EEA members states but still provide some guidance.
>
> Even when comparing among countries with similar economic profiles, specific adaptation cost estimates are not easily transferable between countries, as they can vary depending on parameters such as purchasing power parity and the price of land. A study published by Oxfam International (Raworth 2007) extrapolates scales up estimates of adaptation costs provided for a handful of developing countries (sourced from submitted NAMAs) to all developing countries, using three factors: population, income and land. The resulting estimate of total adaptation

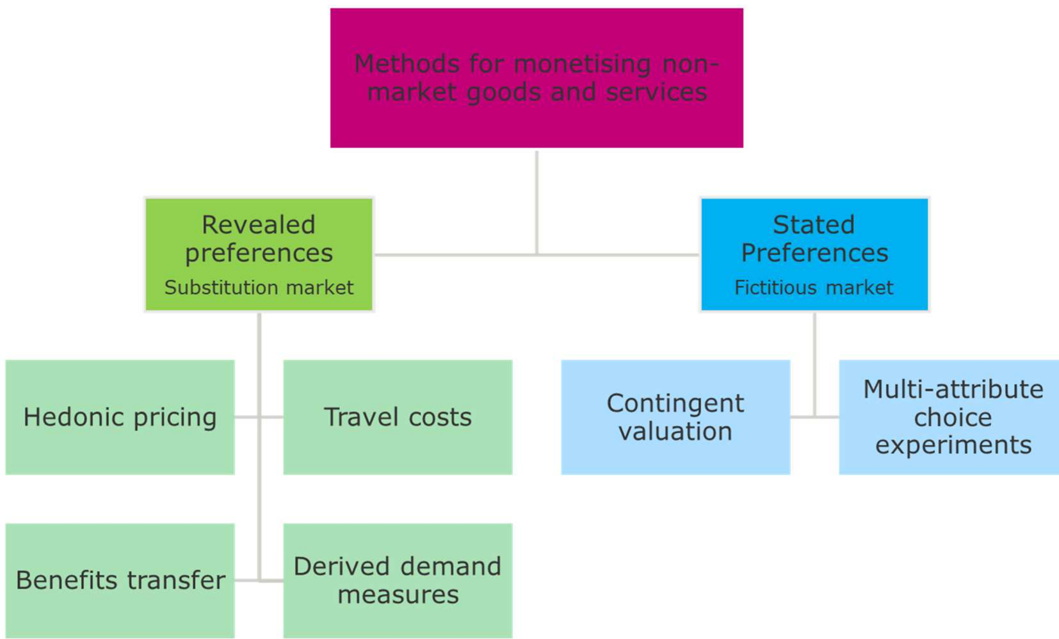
[12] Additionally, adaptation costs represent only one type of cost, i.e. those that reduce the impacts of climate change, while the overall response to climate change also includes the costs of mitigation, i.e. those to reduce the extent of climate change, and the costs of residual damages that cannot be mitigated nor adapted to

costs for all developing countries is lowest when population is used as the scaling parameter (US$8 billion) and highest when GDP is used (US$33 billion).

As a second step, it is strongly recommended to verify the estimates revealed by the literature review with relevant national experts and stakeholders.

Adaptation stakeholders should not overlook the **indirect costs** associated with the challenges, hazards, and unintended effects of adaptation activities. Although measurable, they are not directly valued in the marketplace and so are an additional challenge to estimating adaptation costs. There are two main categories of monetary valuation methods for non-market goods: revealed preference methods and stated preference methods. Refer to Table 5 for a complete description of each method and data needs, which are briefly summarized below.

***Figure 8** : methods of monetary valuation of non-market goods*



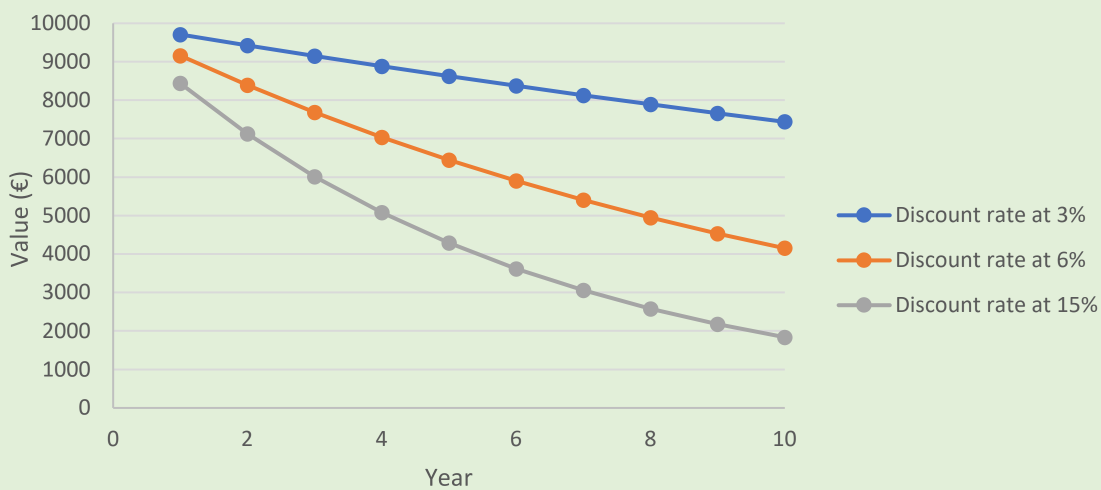
Revealed preferences methods are based on the actual market behaviour of users of ecosystem goods and services in a proxy market. However, their application is limited to a few ecosystem goods and services. These methods start from the observation of actual behaviour to determine value. Stated preference methods can be applied to all types of ecosystem goods and services. However, their main drawbacks are that they are based on hypothetical situations and are complex and resource-intensive to implement. They are survey-based methods. They consist of questioning rather than observation. In cases where it is difficult to monetize indirect costs, it is important to at least identify them and formulate a narrative on these costs so as not to underestimate them.

Box: Applying a discount rate to estimate cost in future

When comparing the costs of adaptation options with the costs of inaction (see Chapter 3), it is important to include the application of a discount rate. Discounting is the mathematical process of comparing economic values over time: it involves reducing the future value of an asset or expense to its present value. The discount rate is a substitution rate between the present and the future.

For example, paying 10,000 euros in ten years would be equivalent to paying only 7,441 euros today if the discount rate is 3%, 4,155 euros for a rate of 6% and 1,839 euros if the rate is 15%. The higher the discount rate, the more the value of the amount decreases over time.

***Figure 9** : Impact of a discount rate on present value estimates*



When choosing a discount rate, an important distinction must be made between private sector investments (which seek a profit above the prevailing market rate of interest) and investments in public goods such as coastal protection or emergency services. This is because public adaptation investments are generally intended to maximize not only economic but also social and environmental benefits and thus may not be comparable to for-profit investments. Therefore, a social discount rate may be appropriate for investments that address climate change adaptation. According to the definition provided by the European Commission (2014) "the social discount rate reflects the social view on how future benefits and costs should be valued against present ones and [...] is based on estimates of long-term growth potentials" of a given country.

Social discount rates are generally lower than financial discount rates because the objective of these investments is not to compete with stock market or other market-based rates of return. The choice of a discount rate from a climate change perspective is highly controversial in the literature; there is no consensus on whether and what level of discount rate should be applied for economic evaluations of climate change adaptation. Social discount rates for climate change have been suggested in the range of 1-6%. Some authoritative publications include:

- Economics of climate change – Stern Review (Stern 2007) – **1,4 %**
- Challenge of Global Warming: Economics Models and Environment Policy (Nordhaus 2007) – **4,5 %**
- Guide to Cost Benefit Analysis of Investment projects (European Commission 2015) - **3%** for Member States (**5%.** for Cohesion Countries), for the 2014 -2020 Programming period
- Lebègue Report, (2005) - **4%,** decreasing from 30 years onwards, 3% at 100 years and converging towards 2% for very distant horizons

However, as compared to other public actions and projects, especially for adaptation actions with a long lifetime there might be challenges linked to the uncertainty of the general development of climate change and its spatial/temporal manifestation (Chambwera et al. 2014a). For example, the eventual costs for a public adaption project that entails setting up (or public reinsurance) an insurance scheme against damages from flooding events will depend on the actual occurrence of floods. There exist several approaches for handling this uncertainty within the context of economic appraisal, including sensitivity analysis, risk premiums and others.[13] There are no general rules for the minimum information that needs to be available in order to be able to estimate costs ex-ante but in general in can be assumed that more available information and data leads to more accurate predictions on cost.

4.3 Methodological approaches to costs of adaptation

This section will focus on the application of adaptation costing methodologies at national scales (as opposed to sectoral). From a decision maker's standpoint, there are two components that have bearing on efficient adaptation finance:

- Planning costs of adaptation as a basis for budgeting these costs
- Tracking adaptation spending in a manner which integrates the concept of additionality

A synthesis of methods used for each in existing work are presented below.

4.3.1 Methodologies for estimating investment needs for adaptation

At the global and national level, different approaches have been used to assess the costs of investing into adaptation to counterbalance negative climate impacts. Most information on estimating the costs of adaptation at national level stems from a shortlist of multi-country studies, which mostly look at developing countries. These initiatives and studies are very heterogenous both in their method and their final estimates of adaptation costs and are considered as low-range estimates of adaptation needs. Initial estimates for adaptation costs per annum ranged from **US$40 billion to US$100 billion by 2050** (see World Bank (2006), World Bank (2010), UNFCCC 2007, UNDP 2007). They mostly relied on top-down approaches applying marker approaches to financial flows, or economic modelling (see Section 3.2 for a list of modelling approaches). Global adaptation cost estimates from more recent studies range from around US$ 25 billion a year to well over US$ 100 billion by 2015-2030, and **up to US$ 280-500 billion by 2050** (Pauw et al. 2021).

4.3.2 Methodologies for tracking adaptation costs at the national level

Data availability in EEA Member States

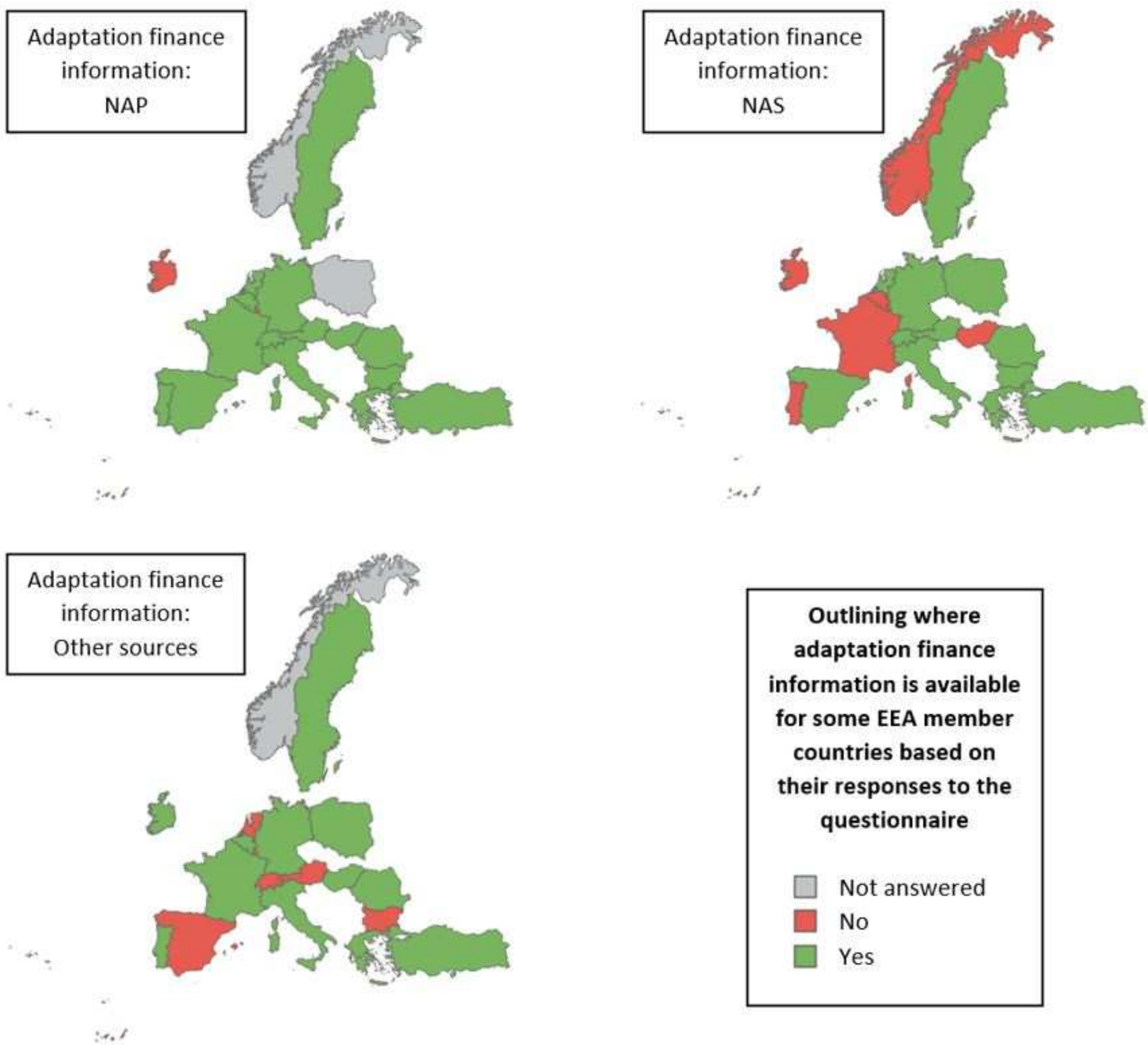
Results from a questionnaire in December 2020-January 2021 with EIONET national reference centres[14] on adaptation in the context of this project showed that in their adaptation accounting, many countries focus on specific adaptation actions or projects, rather than having a methodological framework in place to collect data on overall (national) adaptation finance spending. NAS and NAP are the main tools through which countries formalize adaptation finance planning and monitoring, but some cover different notions of adaptation costs. For instance, Poland's NAP includes information on the cost of inaction, while Spain tackles the budgetary aspects by identifying funding instruments. Only a minority carry out financial monitoring within the context of the NAS/NAP processes (7 out of 19); several countries do

[13] At the stage of planning the adaptation action (as compared to the assessment of costs attached to it as discussed here), uncertainty can also be mitigated by aiming at designing the actions in a way that also generates ancillary benefits, including those benefits arising also if no hazard events occur during the lifetime of the adaptation action.

[14] https://www.eionet.europa.eu/

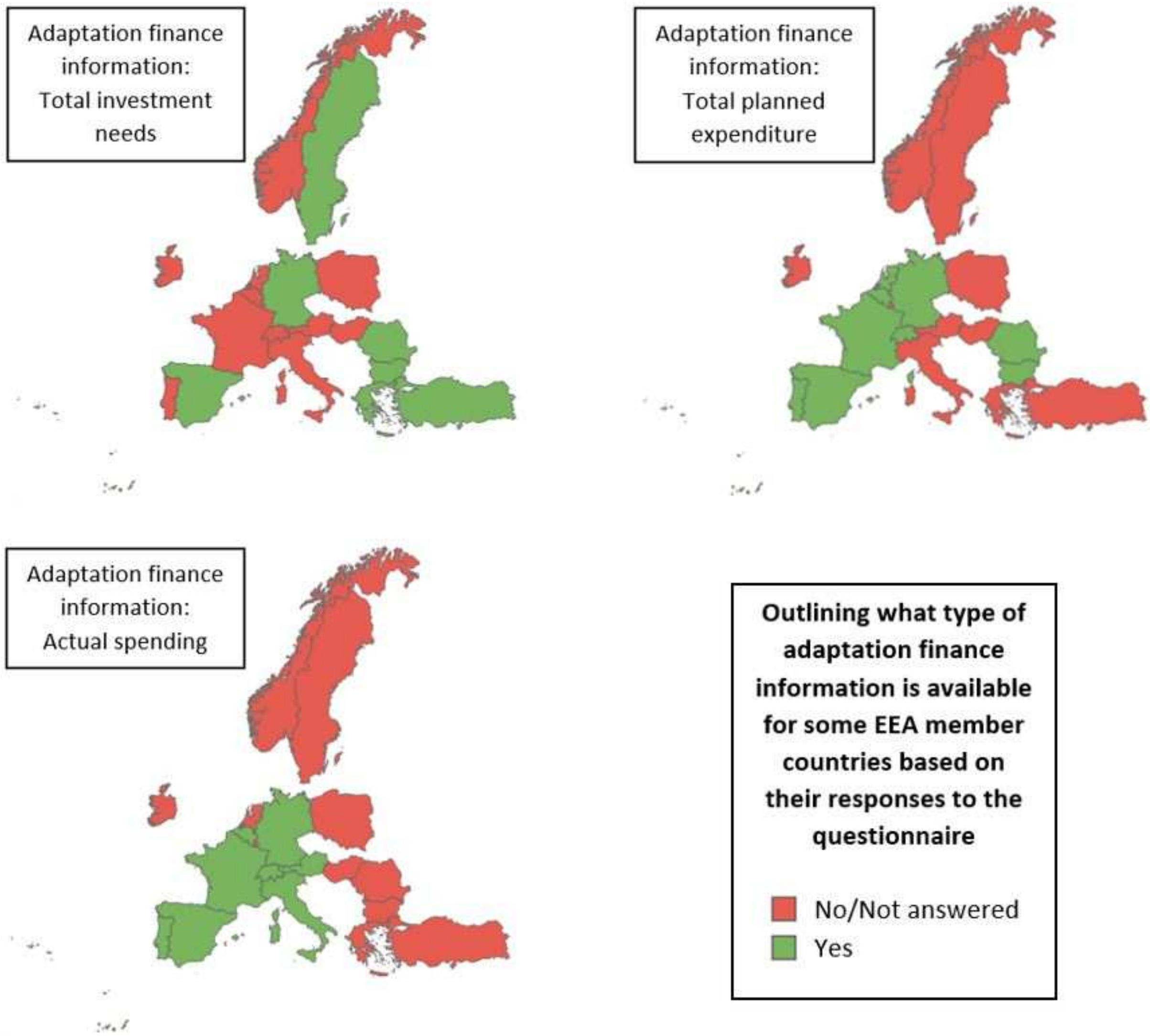
have other public sources of information on adaptation financing. The information from this questionnaire is summarized in the maps and tables below (Ramboll - Ecologic -Frankfurt School, 2020, not published).

Figure 10*: Availability of adaptation finance data from NAS/NAP or other documents in EEA member countries*



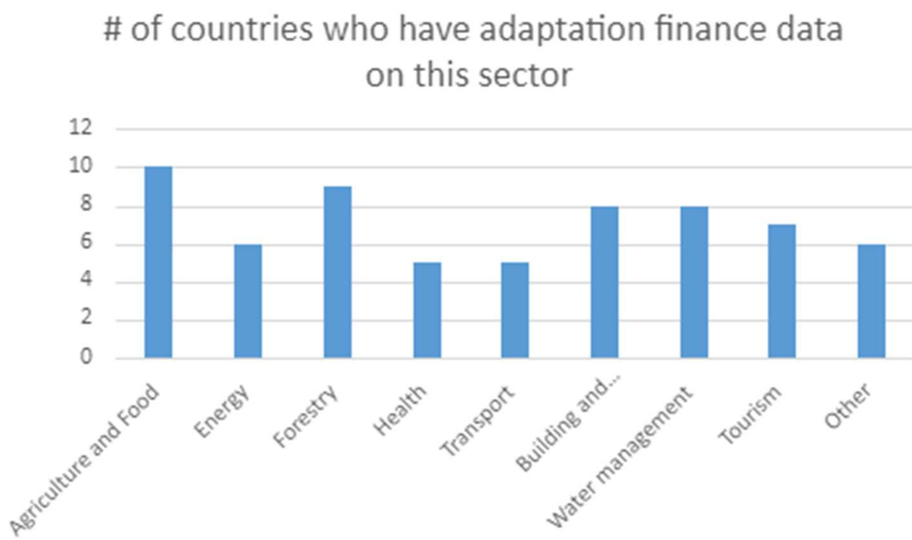
As shown in Figure 10, two countries did not include adaptation finance information in their national reports, namely Luxembourg and Norway. Ireland did not include adaptation finance information in its NAP and NAS, but in other documents. Poland included information in its NAS and other documents. Belgium, France, Hungary and Portugal included information in their NAP and other documents. Austria, Bulgaria, the Netherlands, Spain and Switzerland included it in their NAP and NAS, while only Germany, Greece, Italy, Romania, Sweden and Turkey included information in all above-mentioned documents.

Figure 11: *Type of data on adaptation finance that is available in the EEA member countries*



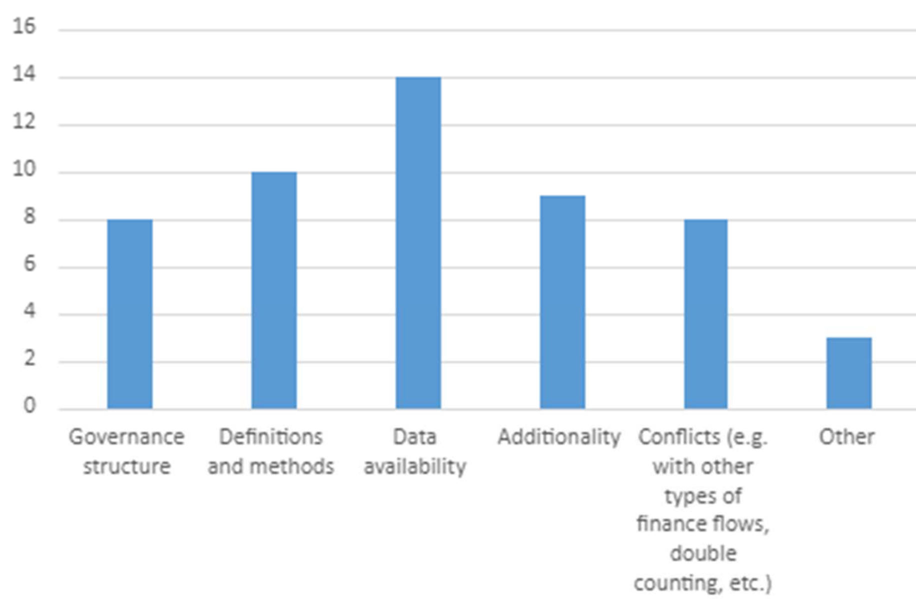
As shown in Figure 11, Hungary, Ireland, Luxembourg, Norway and Poland did not include any type of information in their national documents. Austria and Italy only included actual spending information in their national documents. The Netherlands included only total planned expenditure in its national documents. Belgium, France, Portugal and Switzerland included both total planned expenditure and actual spending information. Greece, Sweden and Turkey only included total investment needs data. Bulgaria and Romania included both total investment needs and total planned expenditure information, while only Germany and Spain included all above-mentioned adaptation finance information.

***Figure 12**: Availability of adaptation finance data according to the sectors*



Adaptation finance data is most readily available for Agriculture, Food, and Forestry, while fewer countries have data for the health, transport, and energy sectors.

***Figure 13**: Main difficulties faced in tracking adaptation finance data*



As shown in Figure 13, the biggest challenge is data availability; of the nineteen respondents, fourteen countries listed this as a challenge. Definitions and methods was second most commonly identified challenge (ten countries), followed by additionality (nine countries). Governance structure and the challenge of conflicts with other types of financing flows were both listed by eight countries.

Examples of adaptation costing methodologies

As mentioned, adaptation actions may be undertaken in two broad sectors including the public sector which is the main driver of adaptation action; and the private sector, where adaptation actions are mostly integrated into development interventions or business activities (UNEP 2016) and therefore are difficult to track because adaptation actions rarely stand-alone (e.g. payments for ecosystem services, product labelling and certification, bio-carbon markets or biodiversity compensation funds). Spontaneous adaptation in the private sector is not typically considered in the cost estimates of adaptation. However, this is different for costs borne by the private sector due to climate change legislation and regulation, such as building codes. EU Member States should consider if they aim to include those costs in their estimates or not and clearly state what is within the scope of their cost estimates and what is not.

The following section several examples where adaptation costs were calculated at national level, based on different methodologies. Because relatively few documented examples were found from within Europe, an international example is presented too.

- Fiji – NAP Costing methodology

A costing methodology tool was created to assess the costs of Fiji's National Adaptation Plan, measure-by-measure (bottom-up engineering costs methodology). The tool is designed to produce a quick cost estimate for each measure that is consistent with the estimates for other NAP measures. It employs a straightforward bottom-up approach to break down each adaptation measure into roughly two to four major activities embedded within it, and then find cost data for them. Default activity categories considered within a single measure include: 1) Conduct research and feasibility studies, 2) Enhance capacity building, 3) Conduct technology transfer, 4) Enhance policies & institutions, 5) Undertake infrastructure improvement.

The features of this methodology are:

- Users are asked to input only additional costs, that is, adaptation going beyond business as usual. This requires finding baseline costs for activities, for instance using past budget documents or relying on expert input.
- Costs are divided up between one-time (capex) and recurring (opex) costs
- Measures costed on a local/community scale can then be scaled up for national estimates
- Method is constructed to be able to account for all types of measures (green, grey, soft)
- Proposes framework for sharing costs across multiple activities measures (ie, revision of key legislation, or consultative workshops)
- Does not specifically consider transaction costs, opportunity costs
- The tool has two separate worksheets which can be used jointly in a hybrid approach:
    - calculated cost approach, inputting cost data for all components of an activity within a measure (down to cost of organizing workshops, acquiring equipment, labor costs, etc.)
    - aggregate approach: when data on the cost of an entire activity is already accessible in agency budgets, prior reports, etc.

The tools are available for download from the Costing Methodology document, which provides many practical recommendations for implementing adaptation costing[15].

[15] https://napglobalnetwork.org/wp-content/uploads/2020/09/napgn-en-2020-costing-methodology-for-Fiji-NAP.pdf

- **Austria – PACINAS project**

An Austrian project on Public Adaptation to Climate Change (Knittel et al. 2017) estimated federal spending on public climate change adaptation at the national level in Austria, that is, adaptation which is funded and/or implemented by the federal government. Two methods were applied in parallel:

1. **Top-down approach,** based on a review of the national government budget plan & expenditure reports. The top-down approach consists of screening government expenditure reports for adaptation relevant budget envelopes, progressing down from global to detailed budgets. The relevant sub-division budgets were selected according to their mission statements. Using the narrowed down set of detailed budgets, adaptation relevant expenditures were singled out. Finally, these were classified according to whether adaptation was a primary goal (100% of the expenditure counts as adaptation costs) or whether adaptation was a significant goal (default 40%, using the EU markers method- where possible expert evaluation was used to give a more precise % between 1-99%). Final results showed both the total expenditure for which adaptation was a primary or significant goal [€ 2.1 billion], and the total adaptation cost [€ 488 million] (applying 'markers' to the total expenditure).
2. **Bottom-up approach**, based on sum of the costs estimated as necessary to implement the strategy for adaptation to climate change. The bottom-up approach relied heavily on expert input, where each adaptation measure listed in the National Adaptation Plan was given an estimated cost and all of these costs were summed. The bottom-up method produced similar cost estimates of €385 million (compared to total adaptation cost of €488 million; compared to the top-down approach, the agriculture sector had higher adaptation costs (from 30 to 80 million €) while water resources/management and transportation infrastructure still retained the greatest share of costs (230 to 270 million €).

- **France - Green Budget methodology**

In 2019 France carried out an initial green budgeting exercise (Alexandre, Tordjman, and Roucher 2019). This was directed towards understanding how the state budget -including expenditures and tax revenue- impacts France's greenhouse gas emissions and other environmental aspects. The task force acknowledged that assessing expenditures was more complex than assessing budgets, and that there was no consensus around preferential methods. Among the obstacles cited include the fact that most accounting methods focus on investment and subsidy spending, and hardly consider operational costs.

Here, climate change adaptation is one of six environmental axes for which each of the measures included in expenditure accounts are rated as contributing to positively, negatively, or not at all. A baseline impact scenario is used to determine whether the measures provoke significantly different outcomes (positive or negative) to the reference situation, and thus to classify the measures from detrimental (-1) to very favorable (+3) for each axis.

This method was applied on the 2019 financial law for the sectors most closely tied to climate and environmental spheres. The results obtained show, for each of the sectoral areas analysed, the amount of spending considered favourable or detrimental to the various environmental scopes, including climate adaptation.

- **Comparison between the two methods**

Table 9: *Comparison between the two methods*

	PROS	CONS
PACINAS Top-down method	- Relatively simple method - Takes concept of additionality into account - Clear distinction between adaptation-relevant spending and adaptation costs using 'markers' method - - Accounts for actual rather than planned spending	- Method applied at federal (national government) level, and excludes regional or local spending on adaptation, so potential to underestimate total spending - Private sector costs are excluded - Not easily replicable to other MS (state accounts structured differently) - -Conducted as a once-off exercise
Green Budget method	- Considers a wider range of instruments, including tax measures - Includes some operators working at local and transnational level, not only State budget - - Method meant to be taken up and standardized to assess future spending bills on regular basis	- Double counting between adaptation and other objectives (esp. mitigation) - No final calculation of adaptation cost - Very complex method mobilizing internal revenue service - Uses budget bills rather than spending accounts - Only applied partially, i.e., to relevant sectors, so far

This overview shows that methods for calculating adaptation costs are promising but still immature. When implementing a rigorous method for adaptation cost accounting, the starting point is to investigate state expenditure accounts. This part of the method is not easily replicable between member states as each likely has different structuring and specific documents overseeing their budgetary balances and expenditures. The second methodological aspect consists of assigning 'markers', or premiums, to the measures identified as relevant to adaptation. A single method could devised to emulate the approach across European countries.

4.4 Gaps and recommendations for future research

Initial estimates on costs of adaptation were first presented 15 years ago with the Stern Report, followed by a series of UNFCCC and World Bank studies which are considered seminal works. Although a reference in setting the methodology, the estimates for total investments needs coming from the reports are disputed, with the AR5 noting low confidence in the estimates due to methodological challenges and data shortcomings. The more recent 2021 Adaptation Gap Report notes that new estimates of financial needs to cover adaptation costs in developing countries appear higher than previously reported, based on NDC and NAP analysis and compared to the 2016 Adaptation Gap report estimates (UNEP 2021; UNEP 2016). Additional studies have been produced since then, mostly based on sectoral level impact assessments, and mostly for developing countries. On a parallel note, focus is also turning towards considering and tracking adaptation in domestic budgets, likely a more powerful lever in the struggle to adapt to climate change as compared to deficient international finance.

In spite of ongoing efforts and interest in expanding knowledge on adaptation costs, several gaps persist and should be the priority focus for future research:

- **Improve sector coverage** – The number of studies and estimates for the cost of adaptation are growing, but sectoral knowledge is uneven. A robust body of work underpins the coastal and infrastructure sectors, while adaptation costs are still less known for sectors like ecosystems, industry, or services. This is a limiting factor for decision-makers.

- **Take the private sector contribution into account** – the necessity for state intervention in adaptation comes from the multiple market failures involved in adaptation (EIB 2021). Nonetheless, some private sector activities will likely proceed without public finance support and their cost will then reduce public cost. Private sector activities could also directly influence publicly-funded adaptation through **learning and innovation dynamics** – costs fall with learning and innovation, and private sector intervention could deliver adaptation in an effective and innovative way, thus reducing adaptation costs. This could be taken into account in both modelling and scenario-based ex-ante studies.
- **Include autonomous adaptation in estimates -**
- **Refine the methods for economic analysis** -
    - **Better representation of indirect costs and transition costs** - Most studies focus on the technical costs of implementing adaptation, overlooking costs that are not direct, like transition and opportunity costs. Not including these leads to underestimates and misrepresentations of the total cost of adaptation. (see also Section 5: What are the ancillary impacts of adaptation?). This is especially important for taking soft adaptation options into account, as alternative options like risk pooling mostly carry hard-to-monetize costs like institutional capacity and mechanisms. Whether in ex-ante or ex-post, a solid framework for taking into account indirect and transition costs would help adjust estimates of total cost of adaptation.
    - **Dealing with uncertainty** – this is considered a main factor in the discrepancies between climate adaptation estimates. Uncertainty is introduced through the emission scenarios, the climate models, and the socioeconomic projections. In the UNEP (2016), solutions for dealing with uncertainty in policy making include considering a range of future conditions and proposing flexible adaptation strategies that can shift over time. Studies that explicitly consider uncertainty result in higher cost estimate.
- **Accompany shifts in adaptation framing** -As mentioned above, a thought shift is underway in the adaptation sphere, with greater emphasis being given to low-regret options, "early" implementation of adaptation, and more flexible options that can be phased with a progressive roll-out. This implies a need for cost of adaptation studies to focus on soft, low-regret, high benefit-to-cost adaptation measures, creating a basis for decision makers to prioritize and implement such actions (UNEP 2021).

Beyond the research sphere, there are also notable gaps in application of cost methodologies at national level and subsequently, of the reporting of adaptation costs.

- **Improve and homogenize the markers approach** - current markers used by Europe for reporting to OECD use only three levels of contribution to climate adaptation (none, some, full), and the TEG adds the "Do No Significant Harm" criteria. A single, more elaborate set of markers could help countries prepare uniform reporting of their adaptation costs after examining state accounts.
- **Jointly tackle the topics of adaptation efficiency and adaptation costs, using a sectoral lens** – beyond the costing of adaptation, which when done from a bottom-up perspective can seem like a mostly budgetary exercise, countries are also concerned with assessing the effectiveness of adaptation policies. This means their effectiveness towards the resilience objective but also their economic efficiency. Although the objectives are different, similar methodological elements can be drawn upon to identify which elements in sectoral policy contribute effectively to adaptation, and extrapolating costs on this basis.
- **Make it possible to report on sub-national adaptation finance** - In the questionnaire responses registered in a previous segment of the project, national focal points, several countries reported that local or regional policies contained information on adaptation finance, but this was not then transferred to national level reporting.

5. BENEFITS OF ADAPTATION

5.1 Introduction

The IPCC defines adaptation benefits as "the reduction in damages plus any gains in climate-related welfare that occur following an adaptation action" (Chambwera et al. 2014b). Adaptation actions can also bring about a wide range of co-benefits.

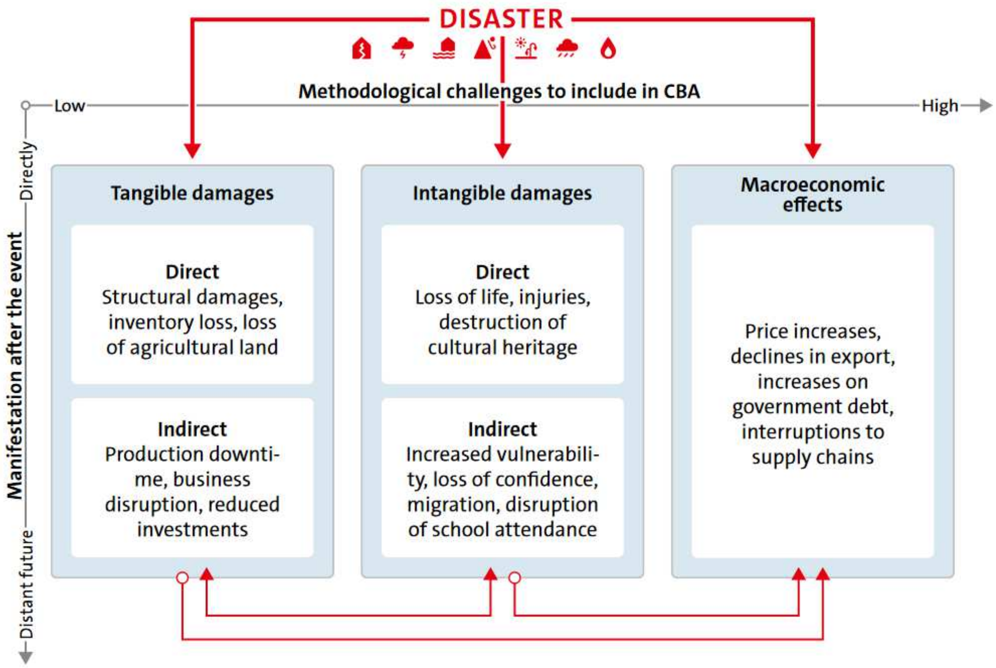
Measuring benefits generally involves assessing expected (or, in an ex-post perspective identifying) harm caused by climate events in monetary value and assessing how effective –or beneficial– the measures would have been (or were) at avoiding this damage (Hoffmann 2019).

Like for defining the costs of inaction and the costs of adaptation, defining the benefits of an adaptation measure contains context-specific, and methodological nuances that need to be considered to evaluate the local risk profiles, economic conditions and frameworks, among others, to ultimately measure avoided damage as well as the gains in welfare. For instance, when weighing adaptation strategies, the analysis should go beyond investment options and include evaluations of policy and institutional weaknesses or other constraints that prevent investments, which are unique depending on the place where the measures will be implemented (Bapna et al. 2019).

As introduced in the previous chapters on costs, when determining whether to implement an adaptation measure and selecting one among many, cost-benefit and cost-effectiveness analyses are common to assist decision-makers in determining the best strategy. The costs and benefits can either be assessed narrowly, taking into account only the financial costs and benefits of implementation, or in a more comprehensive manner, by including the costs and benefits in the context of the entire local economy, including social and environmental dimensions.

However, the difficulties in determining whether to pursue an adaptation measure increase when attempting to quantify the benefits, as they are harder to predict and often intangible (Climate-ADAPT 2021c). Market damages and benefits can be simpler to quantify, but nonmarket values present more difficulties; they are defined by their impact on nonmarket items such as ecosystems, health, water quality, poverty, employment, among others. The complexity involved in assessing damages and benefits can be seen, for instance, when assessing measures related to disaster risk reduction (DRR), in which tangible, intangible, direct and indirect damages factor into the assessment, as well as a macroeconomic overview (see Figure 14) (Hugenbusch and Neumann 2021).

Figure 14: *Challenges in DRR cost-benefit analysis (Hugenbusch and Neumann 2021)*



Consequently, those benefits are often not included in economic calculations. Thus, the IPCC (2014) states that it is insufficient to assess whether to implement an adaptation action through a standard economic approach measuring costs and revenues. It is then helpful to think about adaptation actions creating several types of benefits or "triple dividends", firstly described as part of the disaster risk management (DRM) theory (Tanner et al. 2015) and recently generalised for all adaptation measures (Bapna et al. 2019):

- **Avoiding losses:** considering direct and indirect damages to infrastructure and assets, but also considering saved lives. It is the most common incentive for investing in resilience, although if considered by itself it underestimates the true benefits of an adaptation action;
- **Additional economic benefits:** also described as "unlocking economic potential" (Tanner et al. 2015). These benefits include the reduction of future risks, improving the productivity of the affected resources and population, and boosting innovation through seeking solutions in the midst of new challenges;
- **Social and environmental benefits:** also categorised as nonmarket benefits or development co-benefits (Tanner et al. 2015), which are harder to quantify.

The last two types of benefits are categorised as positive ancillary impacts of adaptation actions, or "co-benefits", which are further explored in Section 5.3. The IPCC (2014) defines co-benefits as "the positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices, among other factors."

They are important because they contribute to a more comprehensive cost-benefit analysis when considering adaptation actions as they reflect the true net benefits if the decision-maker were to implement them.

These benefits can be categorised as economic, social and environmental (de Murieta 2020):

- **Economic co-benefits** can be derived from decreasing background risk generated by climate-related events by lowering the population's risk aversion. A perception that measures for resilience have been carried out can influence individuals' perceptions on the risks future events might pose to their livelihoods, affecting their economic decisions and the overall economic growth of their communities. In addition, imminent climate impacts and potential risks can serve as incentives for innovation and economic activities, e.g., regarding resilient infrastructure, climate-smart agriculture, and new financial products, among others.
- **Social co-benefits** are related to improving the social capital of the population through more robust networks between individuals when responding to climate change as well as better public health and support through resilient infrastructures and overall emergency preparedness (de Murieta 2020). Moreover, adaptation measures can influence urban planning and design that can have a beneficial impact, e.g., through increased green space, which could influence wellness and health practices.
- **Environmental co-benefits** are related to the secondary effects of measures related to ecosystem-based adaptation, for instance, increasing forest cover, salt marshes and mangroves (de Murieta 2020). These measures reduce climate vulnerability through improved livelihoods, prevention of erosion, improved water quality, prevention of mudslides and flooding, biodiversity conservation, among many others.

The concept of triple dividends is utilised in practice by institutions such as the World Bank, delivering impacts in areas such as ecosystem-based approaches, transport systems and agricultural projects (Tanner et al. 2015). Programmes such as the World Bank's flood management project in Colombo, Sri Lanka evidence these ancillary benefits as the programme reduces not only flood risks, but also ensures the economic security of the population by making activities such as fishing and rice cultivation, tourism more resilient (Tanner et al. 2015). In collaboration with the European Commission, the triple dividends concept was also used by the World Bank to produce a report titled *Economics for Disaster Prevention and Preparedness*, where economic analysis of investments include the study of ancillary benefits, such as the study of protective measures against avalanches, mudflows and floods in Austria, and flood protection and water governance in the Netherlands (World Bank 2021).

In a European context, the goals and foundations of the EU Adaptation Strategy reinforce the importance of comprehensively assessing adaptation benefits and co-benefits. The Strategy builds on the knowledge and capacities developed so far and acknowledges the ideas of triple dividend and the conception of adaptation solutions as "no regret" (i.e. worth pursuing regardless of the climate impacts). It also advocates for increased ambition and the inclusion of new areas and priorities. These new areas include NbS as "no regret" options that provide environmental, social and economic benefits while helping build climate resilience. Quantifying their benefits and communicating them can improve the take-up by decision-makers s (European Commission 2021f).

5.2 The selection of adaptation options determines the benefits

When considering the benefits of adaptation, it is important to differentiate among various adaptation options because they come with different costs and benefits.

The Adaptation Support Tool (AST) outlines several steps in order to develop, implement, monitor and evaluate climate adaptation strategies and plans (Climate-ADAPT 2021b). Step four of the AST focuses on the assessment and selection of adaptation options, considering the local context, effectiveness in reducing vulnerability or enhancing resilience, and the overall impact on sustainability, in order to avoid actions that will lead to maladaptation (Climate-ADAPT 2021a). Assessments generally focus on:

- Urgency of the climate hazard or risk
- Feasibility
- Governance implications
- Social and environmental considerations

- Stakeholders
- Costs and benefits, among others.

More specifically, climate risk management follows a risk-layered approach, differentiating adaptation options, such as risk reduction, risk retention, and risk transfer. The selection of adaptation options is partly dependent on the frequency and impact of (expected) climate-related risks and extreme events. Applying the risk layering approach can help to estimate which option will provide long-term cost savings (and benefits).

Table 10: *Exemplary options to manage and adapt to climate change risks and their potential benefits (Lu and Abrigo 2017) (Adapted from UNFCCC 2012)*

Climate risk management options		**Potential benefits**
Risk reduction Reduce existing climate risks, avoid/prevent damage	Comprises measures implemented before an event occurs (e.g., in response to sea level rise or extreme weather events, incl. storms and flash floods) and aims for the reduction of loss and damage, incl.: - Adjusting building codes to increase the resilience of new infrastructure - Retrofitting or maintaining existing infrastructure - Building new flood defences - Exploiting new opportunities, e.g. engaging in a new activity, or changing practices to take advantage of changing climatic conditions Considering high costs, particularly in the context of infrastructure, the benefits should justify the costs. Reducing risks should be done to the point where it is no longer cost efficient to reduce further (→residual risks).	- Decreasing number of mortality and injuries - Reducing the destruction of private and public infrastructure - Lowering the interruption of business activities - Increased awareness of hazards and of their potential impacts - Improved ability to respond to climate change and recover in case of acute events
Risk retention Accept the impacts, and bear the losses that result from risks	An approach by which stakeholders accept a degree of risk of loss and damage (e.g. caused by extreme weather events, etc.); incl.: - Planned risk retention measures, such as setting aside funds earmarked for the response to emergency requirements - Unplanned risk retention measure, such as drawing from a general budget, e.g., for the reconstruction of infrastructure following an unforeseen event	- An option for targeting certain stakeholder groups to build up their resilience to the impacts of extreme weather events
Risk transfer Off-setting losses by sharing or transferring risks	An option that relies on a shifting of risk of loss and damage from one organisation to another and helps limit the financial liability of recovering from loss and damage, incl.: - Insurance products (e.g. microinsurance) - Catastrophe bonds The cost of risk transfer may be lower than the cost of risk retention. However, some residual risks remain after risk transfer (since not all risk can be transferred). The Commission Staff Working Document on Closing the climate protection gap underscores the importance of increasing the availability of insurance solutions, improving risk awareness and risk-transfer creating the proper incentives in order to close the protection gap (European Commission 2021g).	- Reducing the volatility of losses - Increasing the willingness to invest

5.3 Beyond direct costs and benefits: co-benefits

Ancillary impacts are indirect or secondary effects of an adaptation action, which can be positive externalities (co-benefits); however, they can also include negative and unintended externalities. They are generally challenging to identify due to the difficulty in disentangling them from the overall main impacts of adaptation. Thus, the primary impacts of a climate adaptation action depend on the objectives of the adaptation action, and any unintentional impacts are ancillary. When identifying the ancillary impacts, the decision-maker's objective is important, as the same action can have different primary and ancillary benefits: e.g. if a city planner implements larger green spaces with the main objective to reduce urban heat island effects, then the accompanying reduced urban flood risk would be ancillary.

Furthermore, despite the challenges in identifying them, ancillary impacts are important to include in adaptation action decisions for the following reasons:

- **Understand the relative efficiency of different adaptation actions and prioritization**: this is also important at a more general fiscal level in order for decision-makers to know the full net-benefit of adaptation expenditure and decide how much to invest in adaptation, relative to other policy priorities.
- **Improve the benefit-cost ratio of climate adaptation**: generally, adaptation co-benefits outweigh negative externalities (de Murieta 2020); including positive ancillary impacts in calculations can strengthen the case for increasing adaptation action.
- **Build coalitions and increase incentives for action**: ancillary impacts are often diverse, affecting multiple stakeholders in a local area. Thus, focusing on ancillary impact can help build coalitions to adapt by strengthening local incentives for action (Pittel and Rübbelke 2008).
- **Integrative approach is suitable**: considering ancillary impacts in an integrative manner is needed to address the multiple environmental crises (e.g. climate change and biodiversity loss), and social and economic challenges (e.g. COVID-19, economic recession, etc.) Europe faces. Such integrative approaches are central to recent EU policy proposals such as the European Green Deal (European Commission 2021h) or the COVID recovery plan 'NextGenerationEU' (European Commission 2020c), which recognize that these challenges cannot be solved in isolation but rather can be most effectively and efficiently approached together.

Experts suggest that when co-benefits are considered, the willingness to invest in climate policy increases, which underscores their importance in addressing scepticism and triggering climate action (de Murieta 2020). Nevertheless, despite their value for government policy, they have often been disregarded (de Murieta 2020).

In addition, the EU Adaptation Strategy makes note of the increasing importance of adaptation actions and the role of co-benefits, as they are the main reason why often adaptation measures are characterised as 'no regret' or justifiable to adopt independent of the ultimate climate path (European Commission 2021f). This is the case in particular for nature-based solutions (NbS), *actions inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic* [co-]*benefits and help build resilienc*e (European Commission 2021b). Nature-based solutions include ecosystem-based adaptation (EbA), sustainable management, sustainable forest management, green and blue-green infrastructure, natural water retention measures, among (EEA 2021).

Assessing the benefits and co-benefits of soft and hard adaptation measures is essential to complement the analysis of the costs of inaction, which might neglect the ancillary advantages of adaptation.

5.4 Methodologies

In general, the economic valuation of benefits and costs facilitates the comparison between different adaptation measures, or between action and inaction, by expressing all values in monetary terms. Nevertheless, it poses significant methodological challenges due to assumptions and omissions around nonmarket values typically linked to co-benefits, i.e. the way and extent to which the triple dividends are considered (Tanner et al. 2015). Additionally, each methodology builds upon particular definitions around adaptation (e.g. which measures, which actions, which timeframe, relationship with mitigation) and oftentimes integrates the estimation of costs, limiting the comparability of results. Moreover, it is important to distinguish the (potential) benefits of a project and those of a programme (group of related project or initiatives), as well as the costs, where the assessments will need to be done at an aggregate level. Although not exhaustive, this section introduces a selection of more comprehensive methodologies in terms of the array of benefits they analyse. The underlying goal is to show how the existing approaches can serve different objectives and needs depending on the objectives and priorities of specific programmes of measures within each country.

5.4.1 Recent methodologies

The following methodologies are more recent and represent some of the existing approaches to assess benefits.

1. **CLIMADA/ECA**

The premise of this methodology is that assessing benefits relies on solid climate risk assessments. However, this can be challenging e.g., due to uncertainties about future developments and general availability of quantitative and qualitative data, but also due to the process of scenario analysis and stress testing.

Different providers and standardised tools are available to better understand climate risks and benefits. One of them is CLIMADA, a probabilistic modelling tool used to conduct risk assessments. CLIMADA enables the analysis of the cost and benefits of adaptation measures. It operates as an open-source and open-access global platform that uses state-of-the-art risk modelling and options appraisal. It has been developed by the insurance sector to provide globally consistent multi-hazard risk assessments on scales from national to local levels. The probabilistic modelling approach leads to the estimation of the expected economic damage as a measure of risk today, the incremental increase from economic growth and the further incremental increase due to climate change (KfW 2021).

One step further, the Economics of Climate Adaptation (ECA) methodology combines the probabilistic risk modelling techniques of CLIMADA with in-depth, inter-sectoral stakeholder discussions. The framework provides decision-makers with information about potential climate-related damage to the environment, economies and societies. By quantifying future climate risks, measures can be prioritised for different sectors. Hence, it can also be used to formulate National Adaptation Plans (NAPs) and other related strategies (KfW 2021).

CLIMADA/ECA helps answer the following questions:

- What are the climate risks today and in the coming decade?
- How can we address these risks? Which adaptation measures are appropriate?
- Which investments are necessary?
- Do the benefits outweigh the costs?

2. **Assessment approaches focused on the treatment of uncertainty**

Despite advances in climate projections and modelling, many aspects of climate change – including current climate variability, but especially future change over different time horizons and scenarios – remain surrounded in uncertainty. The effective treatment of this uncertainty is critical to effective adaptation decision making. Most traditional assessment approaches, such as cost-benefit analysis and cost-effectiveness analysis, do not incorporate uncertainty in their methodologies (however, sensitivity analysis and modelling can be added in order to include some treatment of uncertainty).

More recently, a variety of other assessment methodologies have emerged which have as a key feature their treatment of uncertainty (Tröltzsch et al. 2016). These include:

- **Robust decision making** (RDM): centered on the concept of "robustness," RDM attempts to identify actions which perform well across a range of possible future scenarios, rather than optimizing for a single scenario. RDM is especially useful for effective identification of short-term options which may have long term implications, e.g. large infrastructure investments. The full application of RDM can be data and resource-intensive, relying on a modelling approach, however "light-touch" approaches have also been developed.

- **Real options analysis** (ROA): traditionally used in financial markets, ROA can be applied to adaptation decision making to gain insight into the risks associated with investing in physical assets, providing an economic assessment of the value of flexibility. Like RDM, it is well suited to large-scale and long-term infrastructure investments, such as dykes or dams. ROA can be helpful to understand the potential value in modifying (or even stopping) an adaptation action during its lifecycle. Unfortunately, like RDM, it is a very data and resource intensive approach.
- **Portfolio analysis** (PA): considers the value of developing a diverse set of adaptation options into a strategy, rather than relying on a single action. It is a helpful approach in comparing different portfolios of actions against future uncertainties, especially where different actions are likely to be complementary in reducing risk. When developing an adaptation policy, this can be especially helpful as a means of considering the trade-offs that can be expected between the risks and benefits of different actions or strategies.

3. Computable General Equilibrium

Computable General Equilibrium (CGE) models have already been presented as tools for computing costs of inaction and costs of adaptation; these can also serve to quantify adaptation benefits. Determining market damages of climate change impacts such as extreme weather events is a relatively easy task, e.g., estimating the impacts on the GDP. Nevertheless, the first dividend includes avoided fatalities, which pose ethical challenges to translate into monetary units.

The GCE model requires a skilful group of experts and sound sources of information. If the quality of the inputs and the expertise are available, this type of approach allows for the inclusion of impacts such as mortalities beyond the usual headcount (Hoffmann 2019). This rationality can be applied to other items of the dividends, for example, what are the sectoral impacts of polluted water after a natural hazard? And conversely, what are the economic benefits of preventing water pollution due to natural hazards?

CGE models builds on generally neoclassical assumptions (i.e. rational agents react to price changes) and build simulations under equations and general equilibrium theory (Hoffmann 2019). A general criticism relates to the accuracy of models based on neoclassical assumptions, such as optimization and rationality, which may not account for the full impact of climate extreme events on the economy (Hoffmann 2019).

Hoffmann (2019) manages to overcome this and applies this approach to evaluate nonmarket damages that affect human welfare due to heatwaves in Switzerland. In her approach, nonmarket damage includes the increase in human mortality due to heatwaves. By applying the CGE model, the number of fatalities can be translated into reduced welfare and GDP under all the corresponding assumptions.

According to the author, the existing reports revolve around fatalities or rates of excess mortality, which is considered as misleading since "(1) the benefits (in terms of prevented damage) are not evaluated in monetary units and therefore are not comparable to the costs of the adaptation measures; and (2) extreme events can induce excess death and affect the total labour supply, as well as consumption and leisure demand" (Hoffmann 2019). This means the broad impact of fatalities on societies should be acknowledged and, to the extent possible, described in terms that allow for comparison, i.e. monetary terms.

Another study in Hamburg analysed the costs and benefits of adapting to floods. The results for different scenarios showed that interventions to increase the critical water level improve welfare. Hence, these options could be considered as no-regret measures, meaning that they produce benefits (i.e. welfare) even in the absence of any increase in flood risk (Jahn 2014).

4. Assessment of the co-benefits of nature-based solutions

As mentioned in Section 5.3, the inclusion of ancillary benefits when assessing adaptation measures and deciding whether to implement them is critical. However, they are not always easy to quantify, though efforts in drafting methodologies have been made.

For instance, in 2017, a group of European researchers (Raymond et al. 2017) proposed a framework to assess and implement the co-benefits of nature-based solutions (NbS) focusing on different sectors such as water management or coastal resilience. Their findings can be extrapolated to different ecosystems as the same logic adapts to varying contexts via corresponding indicators. However, they study proposes a framework for assessing and implementing NbS co-benefits on urban areas only; a wider study would need to be undertaken in order to determine whether the results could be extrapolated in order areas.

Since the problems to be addressed by NbS are multi-dimensional and complex, the methodology proposed is not linear and requires the participation of many stakeholders, multi-disciplinary teams and policy and decision-makers working together in different loops of interaction (Raymond et al. 2017). The assessment is composed of the following seven stages:

1) identify problem or opportunity;
2) select NbS and related actions;
3) design NbS implementation processes;
4) implement NbS;
5) frequently engage stakeholders and communicate co-benefits;
6) transfer and upscale NbS, and the transversal stage of
7) monitor and evaluate co-benefits.

Multiple types of engagement and communication are required to reach stakeholders of different power, expertise and interest at each stage (Raymond et al. 2017). According to the framework, the evaluation of the co-benefits cannot ultimately occur before the interventions start as actual impacts should be monitored over time, which, if adequately recorded, will facilitate future analysis (i.e. NbS are highly context-dependent). Monitoring can take place, for example, via earth observation (satellite imaging). Earth observations combined with data from complementary sources may provide an evidence-based approach to NBS adaptive management specific to a location(Chrysoulakis et al. 2021).

The various methodologies in this section will present different types of results. For instance, the CLIMADA tool would produce useful estimations on risk and potential benefits of adaptation actions, which are suited for devising national strategies or plans that need to consider long term risks and uncertainties. Likewise, assessment approaches that deepen on the uncertainty of adaptation and future climate threats are good for estimating outcomes for different types of adaptation options, which is beneficial when choosing from a menu of different policy decisions, but perhaps not suited for analysing impacts on one specific scenario. However, these types of assessments are data intensive. Countries who do not yet have a robust data bank on finance for adaptation, climate impacts and risks may want to adopt other methodologies (e.g. RDM, ROA).

Countries looking for results that reflect impacts on ecosystems, socio-economic and socio-cultural systems and strive for heavy stakeholder engagement would benefit from assessing the co-benefits of nature-based solutions. This approach could also aid countries that struggle to identify and analyze non-market impacts, as this methodology aims to move beyond general costs and seeks to include all externalities involved. Likewise, results from the GCE analysis also include non-market impacts, which could aid in producing more holistic sectoral policies.

5.4.2 Most common methodologies

In 2011, the UNFCCC published a report on different approaches to estimate adaptation costs and benefits, which are considered key techniques (UNFCCC 2011); these three main methodologies are also used in a European context. The methodologies are presented along with relevant case studies in Table 2.

To determining which one to apply, decision trees with specific criteria could be used to determine this, reflecting how each technique might or might not incorporate different sorts of impacts and their characteristics. It is worth mentioning that applying more than one methodology can enhance the results by providing more information to make decisions.

As already mentioned in this chapter, including co-benefits as part of the analysis is essential. This is why multi-criteria analysis (MCA) offers the possibility to integrate a more comprehensive approach. Under the application of MCA, quantitative as well as qualitative information feeds the analysis and helps communicate what each adaptation might entail in terms of economic, social and environmental costs and benefits (Noleppa 2013). In addition, MCA relies on direct stakeholder engagement, which facilitates the creation of ownership of the adaptation measures.

Despite the advantages of the MCA methodology, there are some difficulties associated with assigning weights when there are many criteria and the need to standardise scores, which leads to potentially losing valuable information (UNFCCC 2011). Adding to this, the researchers that analysed the application of MCA in the Netherlands concluded that the estimation of costs and benefits of the adaptation options is deemed as accurate for only some of the alternatives. Generally, there are knowledge gaps and missing data for the majority of the options. Currently, access to new data has improved due to the advancement of information technologies, which makes approaches such as MCA more robust, although not perfect. The relevant stakeholders should consistently collect and disclose data by following clear, responsive standards (K. de Bruin et al. 2009).

***Table 11**: Methodologies (Adapted from UNFCCC, 2011) and relevant case studies*

Methodology	Description	Steps	Application example
Cost-Benefit Analysis (CBA)	CBA involves calculating and comparing all of the costs and benefits, which are expressed in monetary terms. It is challenging to include co-benefits as part of this analysis as often nonmarket costs and values are excluded.	1. Agree on the adaptation objective and identify adaptation options. 2. Establish a baseline. 3. Quantify and aggregate the various costs. 4. Determine the monetary benefits. 5. Compare the costs vs the benefits of options.	<u>Czechia: Appraisal of adaptation options to river flood at the Vltava River, Prague</u> (de Murieta et al. 2016) The goal of the study was to assess ex-post the implementation of the Prague flood protection measures for the period 1999-2014, consisting of fixed anti-flood earth dikes, reinforced concrete walls, mobile barriers and back-flow control. By comparing the costs (provided by the Citi Hall of Prague) and quantifying the benefits (estimated as avoided Expected Annual Damage, representing the differences between the status-quo situation and the adaptation investment situation), it was determined that the flood protection measures provided a positive expected net present value (ENPV) and thus efficient across scenarios of a changing climate. Nevertheless, the study posits a caveat that the selection of discounting approach and discount rate is critical and will influence the CBA results.
Cost-effectiveness analysis (CEA)	CEA is used to find the least costly adaptation option for meeting selected physical targets (e.g. clean water provision). CEA is applied in assessing adaptation options in areas where adaptation benefits are difficult to express in monetary terms, including human health, freshwater systems, extreme weather events, and biodiversity and ecosystem services, but where costs can be quantified.	1. Agree on the adaptation objective and identify adaptation options. 2. Establish a baseline. 3. Quantify and aggregate the various costs. 4. Determine the effectiveness. 5. Compare the cost-effectiveness of the options.	<u>Germany: Adaptation measures at Wupperverband research site</u> (Strehl et al. 2019) The water level of the Große Dhünn reservoir in the Wupper basin is at risk of faling below a critical threshold for future supply. The report explores the cost-effectiveness of adaptation measures to reduce the risk, measured by a non-monetary indicator (technical performance), defined as the additional amount of available water per year (van Alphen et al. 2021). From the measures evaluated (1. Reduction of low water elevation, 2. Transfer pipeline from the Kerspe reservoir to the Große Dhünn reservoir, 3. Horizontal well, 4. Water-saving and emergency schemes), the study concluded that the reduction of low water elevation (non-infrastructural) was the most cost-effective solution, though they note that if a risk averse strategy is preferred, additional infrastructural measures are needed, in case the impacts of climate change are stronger than expected.
Multi-Criteria Analysis (MCA)	MCA allows the assessment of different adaptation options against a number of criteria. MCA is useful for when only partial data is available, "**when cultural and ecological considerations are difficult to quantify and when the monetary benefit or effectiveness are only two of many criteria**." MCA essentially involves defining a framework to integrate different decision criteria in a quantitative analysis without assigning monetary values to all factors.	1. Agree on the adaptation objective and identify adaptation options. 2. Agree on the decision criteria. 3. Score the performance of each adaptation option against each of the criteria. 4. Assign a weight to criteria to reflect priorities 5. Rank the options.	<u>The Netherlands: Inventory of adaptation options for spatial planning</u> (K. de Bruin et al. 2009) The project team constructed a database of adaptation options and their effects for various sectors through a literature review and stakeholder consultations. Some of the criteria were (1) The importance - level of necessity; (2) The urgency;(3) No-regret options (non-climate related benefits, e.g. improved air quality, exceed the costs of implementation); and (4) Co-benefit options. Moreover, in order to properly inform policymakers, the feasibility of the different options was assessed using three different criteria: (a) Technical complexity; (b) Social complexity (e.g. diversity of values which are at stake, the changes which are necessary in the perceptions of stakeholders, the necessity of their cooperation); and (c) Institutional complexity (i.e. the more institutions involved the higher the bureaucracy).

5.5 Current gaps and opportunities of improvement in Europe

This chapter has shown how policy approaches that consider co-benefits have an additional number of advantages from different perspectives. Identifying co-benefits provides policymakers with a more comprehensive picture of what is at stake and adds a near-term positive policy framing since many co-benefits are relatively close in time and space. This in turn, improves the opportunities for science-based decisions and socio-economically better policies, which can help counteract the 'wicked' nature of the climate change problem. Despite these different advantages, co-benefits are commonly not considered in policymaking. One reason may be that decision-making still often takes place in silos, where single ministries or committees focus on their core issues and often overlook other critical dimensions, including co-benefits in other areas (Karlsson, Alfredsson, and Westling 2020). In the case that countries aim to mainstream decisions regarding adaptation, for instance through NAPs, the difficulty lies in harmonizing synergies, diverse agendas, policy frameworks and governance arrangements, so baselines to calculate co-benefits could be difficult to determine. This is also the case at a regional level, though policies such as the EU Adaptation Strategy aim to tackle this to ensure coherence (EEA 2021).

In order to use the same scale to compare all possible options, the calculation of costs and benefits should include market and nonmarket values, as well as quantitative and qualitative data that equip decision-makers with useful information to select the best alternatives and avoid inaction. Some of the methodologies introduced in this chapter allow for the inclusion of co-benefits. Still, complimentary use of them will likely cover up some of their deficiencies, leading towards better results.

It is important to note that determining whether to adopt an adaptation measure or programme remains a somewhat daring process, entailing decision-making under uncertainty, difficulties regarding availability of data, and challenges regarding monitoring and evaluation of programmes to determine benefits in the long term. This will inevitably increase the difficulty in measuring overall adaptive capacity and increased resilience.

To achieve the goals of the Strategy, and associated policies, new capacities should be built among relevant stakeholders and especially policymakers to select and utilise the appropriate tool or set of tools to assess benefits. A good alternative to close knowledge gaps in the short term is to promote the exchange of good practices among countries in and outside of the region (OECD 2015a). Nevertheless, for the required actions to be climate-resilient and unfold ecological, social and economic co-benefits demand, there is a demand for solid institutions (able to enforce and monitor over long periods), robust and transparent information systems, scientific and technical know-how and financial resources. In addition, institutional reforms must foster cooperation among economic sectors and public entities and eliminate harmful incentives hindering climate action (Bapna et al. 2019).

6. COSTS OF INACTION VS. COSTS OF ADAPTATION

6.1 Introduction

Based on the concepts analysed throughout the previous chapters, this chapter discusses the costs of adaptation and the costs of inaction, with the goal of putting into perspective the current state of knowledge, remaining gaps in method, and implications for member states in their planning of adaptation finance. Similarly, this chapter examines the difference between the "costs of adaptation vs. costs of inaction" analysis", and the "costs of adaptation vs. benefits of adaptation" analysis. Both perspectives are needed in order to obtain an accurate picture of what the implications of investment in adaptation are at national level, as well as to provide an adequate baseline to which impacts from climate change can be compared to. The chapter will conclude with some important points to take into consideration when interpreting results.

6.1 Best available knowledge on costs of adaptation vs. costs of inaction

In general, estimating the costs of adaptation versus the costs of inaction in Europe could prove challenging, as aggregating data at a regional level could result in inconsistencies depending on data availability within countries and what types of indicators and baselines are used when determining these estimations. The best available knowledge at European scale, taken from existing studies, is summarized here. Studies such as PESETA IV (2020) and COACCH (2018) have attempted to estimate the costs of inaction for the European Union, covering sectors such as coastal and river floods, agriculture, windstorms, drought, energy demand and supply, heat and cold waves, forestry, sea level rise, fisheries, among others, according to different temperature increase scenarios (see Table 12). On the other hand, de Bruin et al (2009 in EC et al. 2017), using IAMs, and the BASE study (2016 in EC et al. 2017)) attempted to estimate the costs of adaptation within the European Union, covering floods, agriculture and health.

Table 12: *Estimations for the costs of adaptation and the costs of inaction in the European Union*

Source	Coverage	Type of costs	Estimated annual investment needs range per scenario (in billion €)
		Costs of inaction	
PESETA IV (2020)	Coastal floods, agriculture, windstorms, drought, energy supply, river floods, heat and cold waves	Direct costs (annual welfare loss)	175 (1.38% of GDP) (3°C path) 83 (0.65% of GDP) (2°C path) 42 (0.33% of GDP) (1,5°C path)
COACCH (2019)	Agriculture, energy demand, energy supply, forestry, sea level rise, fisheries, labour productivity, river floods and transport	Direct and some indirect costs	100-120 (2°C path, 2050s) ~200 (4°C path, 2050s)
		Costs of adaptation	
BASE study (2016) in (EC 2017)	Floods, agriculture and health	-	35-56 Time horizon 2050

De Bruin et al. (2009) in (EC 2017)	Agriculture, other vulnerable markets, coastal, health, nonmarket time use, catastrophic events and settlements	158 to 518 (Western Europe only) Time horizon 2185
Author, based on PACINAS (2014)[16]	Extrapolation of national adaptation costs based on EU member state population	19 to 25 (not annual)
	Extrapolation of national adaptation costs based on **GDP**	12 to 17 (not annual)
	Extrapolation of national adaptation costs based on **land area**	17 to 24 (not annual)

From Table 12, initial discussions could be triggered by the significant difference between the costs of inaction and adaptation, with significant caveats; for instance, the costs of inaction have a wider coverage than the estimates for the costs of adaptation. Moreover, it would be important to assess whether there are significant changes in the estimates when member countries are taken into account, instead of Member States. We used a very rough metric to calculate potential adaptation costs when using a bottom-up methodology, taking the national estimate from Austria, indexing it to population and summing across EU member states. Although very much a ballpark estimate – population is not the best parameter for indexing cost of adaptation -, this figure is far lower than what is suggested by the other, top-down methodology studies. This underlines how crucial it is to understand and harmonize methods for evaluating and reporting such costs.

Another point to bear in mind is that more information seems to be available for estimating the cost of inaction – or the economic cost of climate impacts without adaptation – as opposed to estimating the cost of adaptation. It seems important to maintain a balance between the knowledge available for cost of inaction vs cost of adaptation, because such information is the basis for decision making and a gap in knowledge will translate to less robust estimations and potentially skew decision making.

6.2 "Costs of adaptation vs costs of inaction" and the "costs of adaptation vs benefits of adaptation"

The analysis "costs of adaptation vs costs of inaction" aims to provide a clear idea of what is at stake in terms of costs for (national) policymakers in general if adaptation actions to address climate change are not taken. As discussed in previous chapters, the cost of adaptation focuses on the costs of planning, implementing and monitoring adaptation measures to reduce climate impacts and the vulnerability of communities, both in monetary and non-monetary terms (see Section 4). The cost of inaction will encompass damages and potential risks of climate phenomena in the absence of adaptation measures (see Section 3). Comparing these estimates will ultimately aid decision-makers to determine whether to undertake adaptation actions and mobilise additional investments quickly. Higher costs of inaction relative to the costs of adaptation measures and investments would tilt the balance towards adaptation planning. Finally, the analysis puts an emphasis on **potential losses** as an anchor to motivate action.

[16] Note : this was a ballpark calculation, using Austria's adaptation cost estimations as a basis and indexing yearly adaptation costs to population. This is not a peer reviewed nor official figure, it is meant to be illustrative and for comparison with figures from top-down studies – given lack of country-by—country adaptation cost estimates.

On the other hand, the analysis "cost of adaptation vs benefits of adaptation" is a useful assessment for evaluating and prioritising adaptation options or policies, as it puts into perspective the positive impacts that adaptation measures could have on European countries. Beyond quantifying what economies and countries will lose if no action is taken to make societies more resilient, as in the case of assessing the costs of inaction, the estimation of benefits and co-benefits offers a view of how livelihoods could be improved, and economies strengthened not directly foreseen in a cost analysis. More specifically, this type of assessment puts an emphasis not only on avoiding damages, but also on **potential opportunities and co-benefits,** motivating adaptation action from decision-makers.

Of note are the interrelations of these analyses: the cost of inaction calculation includes a baseline for impact assessment and climate change impacts calculation, which are the basis for benefit estimation. All three factors, cost of adaptation, cost of inaction and benefits of adaptation, are important to determine the efficiency and effectiveness of adaptation actions.

An analysis that focuses on the cost of inaction could potentially carry a much stronger impact, due to the fact that potential losses resonate more strongly than potential gains, according to Kahneman and Tversky's prospect theory (Kahneman and Tversky 1979). The theory posits that an important aspect of attitudes towards changes in welfare is that losses appear to have a larger effect than gains, subject to a specific reference point. This can have significant impacts in the framing of the adaptation gap issue, with regards to mobilising action and, thus, financing and investment, which is why it is crucial to underscore the cost of inaction for countries and decision-makers. Nevertheless, deciding between the cheapest options could also lead to an erroneous decision: a more expensive adaptation measure could still be more desirable if its future benefits and co-benefits are higher.

Thus, both analyses are essential; together, they provide a holistic approach to determining whether to implement an adaptation measure. These evaluations could be included as part of a general assessment framework to compare and select different adaptation measures to carry out a decision-making process that results in efficient and effective action, independent of the methodologies used (see Figure 16) In addition, evaluating the costs of inaction and the benefits of adaptation could motivate action further; results from these analyses showing the missed benefits adaptation actions could have brought to countries and societies could transform into incentives for adopting adaptation measures. Finally, as described in Section 2, any investment decision related to climate change adaptation actions by governments are based cost-benefit or cost-effectiveness assessments, which include an evaluation of the costs of inaction, and the costs and benefits of adaptation measures. In the case of efficiency, benefits need to exceed the costs, while effectiveness refers to the extent to which the objectives of a specific adaptation measure were achieved, regarding reduced damages.

Figure 15: *Costs and benefits of adaptation. Source: (Boyd and Hunt 2004)*

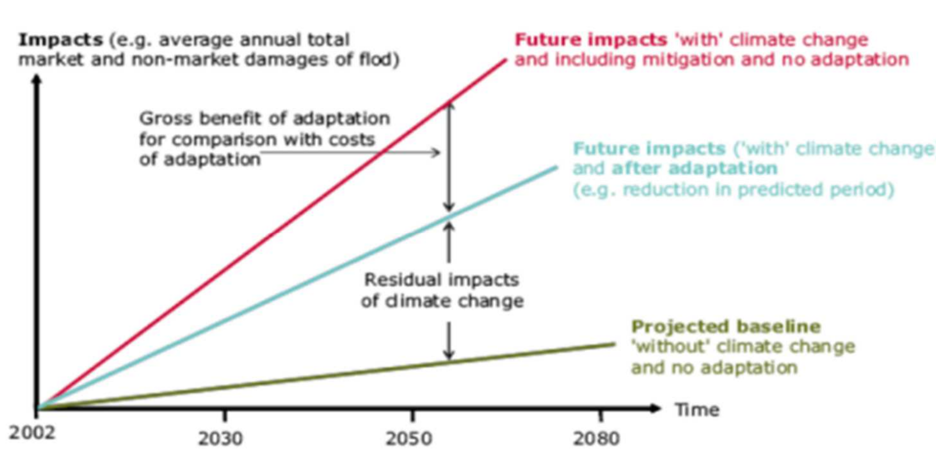
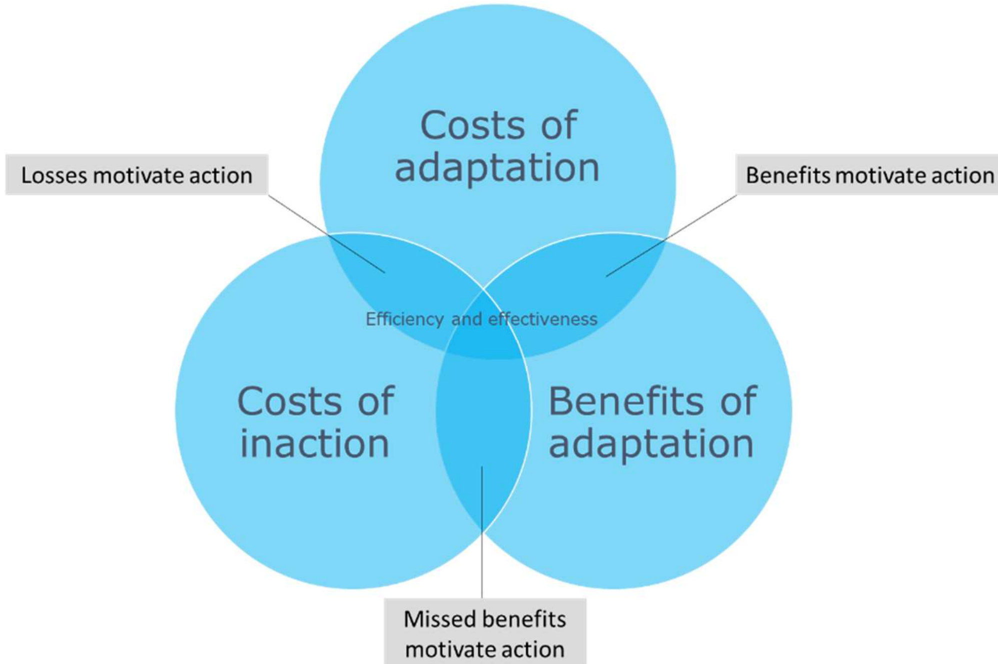


Figure 16: Inter-relation between costs and benefits when assessing adaptation measures (Source: FS)



6.3 Important points for interpreting results

When determining whether to implement a specific adaptation measure or selecting which action to adopt from a pool of options, there are some aspects that need to be taken into consideration. For instance, as previously mentioned, **adaptation costs will generally be easier to calculate than benefits or costs of inaction**. Thus, **costs of adaptation might be overestimated when compared to the benefits or costs of inaction**, which could lead to inefficient or ineffective decisions by policymakers.

One way to manage the methodological challenges is by putting the results in a wider context, **embedding the quantitative results into a qualitative narrative**, while also clearly outlining the limitations of the quantitative results. In addition, combining methodologies or approaches could prove advantageous: **the triple dividend of resilience approach** (saving lives and avoiding loss, unlocking economic potential, and generating development co-benefits), provides a good framework in which disaster risk management and the achievement of climate policy objectives are linked together, and form part of an overarching strategic risk management framework towards overall development progress (Tanner et al. 2015).

One example of this approach is presented in the report *Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results* (Christiansen, Martinez, and Naswa 2018b). The report posits that any universal metric for adaptation should include the approaches of vulnerability, cost-benefit and cost-effectiveness, which ensures both monetary and non-monetary indicators are included. In fact, they propose two different indicators for monetary and human life or health-related benefits: Saved Wealth (SW) and Saved Health (SH); the former considers productive assets and property that would be destroyed by climate change impacts, while the latter considers health benefits operationalised through the concept of Disability Adjusted Life Years Saved (DALYs), key to address non-monetary benefits of adaptation measures. Approaches such as this one provide more complete analyses of the costs of adaptation versus the costs of inaction and the benefits of adaptation (Christiansen, Martinez, and Naswa 2018b). However, the authors posit that **more could be done to account for the environmental and cultural benefits**, though they were not able to find any simple aggregate indicators for these indicators.

In general, addressing uncertainty and preparing several scenarios strengthens the credibility of the assessment, as well as its relevance, by incorporating context-specific characteristics into the evaluation. This could be done, for instance, by including the following:

- Highlighting sources of uncertainty;
- Stating reasons for all assumptions made;
- Expressing all types of benefits (or cost of inaction) which have not been included in the analysis and the reasons for the exclusion;
- Including a sensitivity analysis.

In conclusion, one standardised approach for all countries is probably out of reach, not only because of the different methodological choices made in each of these countries already working on determining the costs and the benefits of adaptation, and the costs of inaction, but also because of the specific context that needs to be considered to better select cost-effective and cost-efficient measures and avoid maladaptation. The only way to make useful statements derived from results is when the points above are described to the maximum level possible.

REFERENCES

Abdullah, Sabah, Anil Markandya, and Paulo A.L.D. Nunes. 2011. “Introduction to Economic Valuation Methods.” In *Research Tools in Natural Resource and Environmental Economics*, by Amitrajeet A Batabyal and Peter Nijkamp, 143–87. WORLD SCIENTIFIC. https://doi.org/10.1142/9789814289238_0005.

Ackerman, Frank, and Elizabeth Stanton. 2006. “Climate Change – the Costs of Inaction, Report to Friends of the Earth England, Wales and Northern Ireland.” Global Development and Environment Institute, Tufts University. https://static1.squarespace.com/static/5936d98f6a4963bcd1ed94d3/t/5968f188c534a5eeee400ea1/1500049801510/GDAE-CC-costs+of+inaction+%282006%29.pdf.

Adger, W Neil, Shardul Agrawala, M Monirul Qader Mirza, Cecilia Conde, Karen O’Brien, Juan Pulhin, Roger Pulwarty, et al. 2007. “Assessment of Adaptation Practices, Options, Constraints and Capacity.” In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 28. Cambridge, UK: Cambridge Univ. Press.

AFDB. 2011. “The Cost of Adaptation to Climate Change in Africa.” https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Cost%20of%20Adaptation%20in%20Africa.pdf.

Agrawala, Shardul, Francesco Bosello, Carlo Carraro, Kelly De Bruin, Enrica De Cian, Rob Dellink, and Elisa Lanzi. 2011. “Plan or React ? Analysis of Adaptation Costs and Benefits Using Integrated Assessment Models.” *Climate Change Economics* 02 (03): 175–208. https://doi.org/10.1142/S2010007811000267.

Alexandre, Sylvie, Florence Tordjman, and Dorian Roucher. 2019. “Green Budgeting: Proposition de Méthode Pour Une Budgétisation Environnementale.” Ministère de l’économie et des finances. https://www.igf.finances.gouv.fr/files/live/sites/igf/files/contributed/IGF%20internet/2.RapportsPublics/2019/2019-M-015-03_Green%20Budgeting.pdf.

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, et al. 2018. “Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (Eds.)].” In .

Alphen, Henk-Jan van, Clemens Strehl, Fabian Vollmer, Eduard Interwies, Anasha Petersen, Stefan Görlitz, Luca Locatelli, et al. 2021. “Selecting and Analysing Climate Change Adaptation Measures at Six Research Sites across Europe.” *Natural Hazards and Earth System Sciences* 21 (7): 2145–61. https://doi.org/10.5194/nhess-21-2145-2021.

Auffhammer, Maximilian. 2018. “Quantifying Economic Damages from Climate Change.” *Journal of Economic Perspectives* 32 (4): 33–52. https://doi.org/10.1257/jep.32.4.33.

Bapna, Manish, Carter Brandon, Anand Patwardhan, and Barney Dickson. 2019. “Adapt Now: A Global Call for Leadership on Climate Resilience.” Washington, DC and Rotterdam, The Netherlands: Global Commission on Adaptation. https://doi.org/10.1596/32362.

Bekkers, Ralien, Ariege Besson, Talia Chorover, Sam Morton, and Ivana Valdez. 2020. “Insight Brief: Adaptation and the NDCs.” NDC Partnership. https://ndcpartnership.org/sites/default/files/Insight_Brief-Adaptation_in_NDCs_October-2020.pdf.

Boyd, R., and A. Hunt. 2004. “Costing the Impacts of Climate Change in the UK: Overview Guidelines. (Metroeconomica).” *UK Climate Impacts Programme Technical Report*. http://www.ukcip.org.uk/images/stories/Pub_pdfs/Costings%20overview.pdf.

Bruin, K. de, R. B. Dellink, A. Ruijs, L. Bolwidt, A. van Buuren, J. Graveland, R. S. de Groot, et al. 2009. “Adapting to Climate Change in The Netherlands: An Inventory of Climate Adaptation Options and Ranking of Alternatives.” *Climatic Change* 95 (1): 23–45. https://doi.org/10.1007/s10584-009-9576-4.

Bruin, Kelly C. de, Rob B. Dellink, and Richard S. J. Tol. 2009. “AD-DICE: An Implementation of Adaptation in the DICE Model.” *Climatic Change* 95 (1–2): 63–81. https://doi.org/10.1007/s10584-008-9535-5.

Cardona, Omar-Dario, Maarten K. van Aalst, Jörn Birkmann, Maureen Fordham, Glenn McGregor, Rosa Perez, Roger S. Pulwarty, E. Lisa F. Schipper, and Bach Tan Sinh. 2012. “Determinants of Risk: Exposure and Vulnerability.” In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 65–108. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.005.

Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B. A. McCarl, R. Mechler, and J. E. Neumann. 2014a. “Chapter 17 - Economics of Adaptation.” In . Cambridge University Press. http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap17_FINAL.pdf.

Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B.A. McCarl, R. Mechler, and J.E. Neumann. 2014b. “Economics of Adaptation.” In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Interngovernmental Panel on Climate Change*, 945–77. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Christiansen, Lars, Gerardo Martinez, and Prakriti Naswa. 2018a. *Adaptation Metrics - Perspectives on Measuring, Aggregating and Comparing Adaptation Results*. Copenhagen: UNEP DTU Partnership.

———. 2018b. *Adaptation Metrics - Perspectives on Measuring, Aggregating and Comparing Adaptation Results*. Copenhagen: UNEP DTU Partnership.

Chrysoulakis, Nektarios, Giorgos Somarakis, Stavros Stagakis, Zina Mitraka, Man-Sing Wong, and Hung-Chak Ho. 2021. “Monitoring and Evaluating Nature-Based Solutions Implementation in Urban Areas by Means of Earth Observation.” *Remote Sensing* 13 (8): 1503. https://doi.org/10.3390/rs13081503.

Church, Clare, and Anne Hammill. 2019. “Defining Adaptation – and Distinguishing It From Other Development Investments.” IISD.

Climate-ADAPT. 2021a. "4. Assessing and Selecting Adaptation Options." European Climate Adaptation Platform, European Environment Agency. 2021. https://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast/step-4-0.

———. 2021b. "AST Step 0." European Climate Adaptation Platform, European Environment Agency. 2021. https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool.

———. 2021c. "Urban Adaptation Support Tool: Assessing and Selecting Adaptation Options." European Climate Adaptation Platform, European Environment Agency. 2021. https://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast/step-4-2.

COACCH. 2018. "The Economic Cost of Climate Change in Europe - Synthesis Report on State of Knowledge and Key Research Gaps." Policy brief by the COACCH project. https://www.coacch.eu/wp-content/uploads/2018/03/COACCH_Policy-Brief-1_Synthesis-Report-State-of-KnowledgeWEB.pdf.

———. 2021a. "The Economic Cost of Climate Change in Europe: Report on The Macro-Economic Cost of Climate Change in Europe." Policy brief by the COACCH project. https://www.coacch.eu/wp-content/uploads/2018/03/COACCH_Policy-Brief-4_Macroeconomic-results-EuropeWEB.pdf.

———. 2021b. "The Economic Cost of Climate Change in Europe: Synthesis Report on Interim Results." Policy brief by the COACCH project. https://www.coacch.eu/wp-content/uploads/2018/03/COACCH-policy-brief-2-Sector-results.pdf.

Dunz, Nepomuk, Andrea Mazzocchetti, Irene Monasterolo, Arthur Hrast Essenfelder, and Marco Raberto. 2021. "Macroeconomic and Financial Impacts of Compounding Pandemics and Climate Risks." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3827853.

EBRD. 2020. "Joint Report on Multilateral Development Banks' Climate Finance." https://thedocs.worldbank.org/en/doc/9234bfc633439d0172f6a6eb8df1b881-0020012021/original/2020-Joint-MDB-report-on-climate-finance-Report-final-web.pdf.

EEA. 2007. *Climate Change: The Cost of Inaction and the Cost of Adaptation.* Luxembourg: Publications Office. http://bookshop.europa.eu/uri?target=EUB:NOTICE:THAK07018:EN:HTML.

———. 2020. "Monitoring and Evaluation of National Adaptation Policies throughout the Policy Cycle." European Environment Agency. https://www.eea.europa.eu/publications/national-adaptation-policies.

———. 2021. "Nature-Based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction." Publication. Luxembourg: European Environment Agency. https://www.eea.europa.eu/publications/nature-based-solutions-in-europe.

EIB. 2021. "The EIB Climate Adaptation Plan: Supporting the EU Adaptation Strategy to Build Resilience to Climate Change." Luxembourg: EIB. https://www.eib.org/attachments/publications/the_eib_cllimate_adaptation_plan_en.pdf.

European Commission, ed. 2015. *Guide to Cost-Benefit Analysis of Investment Projects: Economic Appraisal Tool for Cohesion Policy 2014-2020*. Luxembourg: European Union.

———. 2019. *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE*

COMMITTEE OF THE REGIONS The European Green Deal. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640.

———. 2020a. “Biodiversity Strategy for 2030.” 2020. https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en.

———. 2020b. *Commission Implementing Regulation (EU) 2020/1208 of 7 August 2020 on Structure, Format, Submission Processes and Review of Information Reported by Member States Pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council and Repealing Commission Implementing Regulation (EU) No 749/2014*.

———. 2020c. “Recovery Plan for Europe.” Text. European Commission - European Commission. 2020. https://ec.europa.eu/info/strategy/recovery-plan-europe_en.

———. 2020d. “Commission Implementing Regulation (EU) 2020/1208 of 7 August 2020 on Structure, Format, Submission Processes and Review of Information Reported by Member States Pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council and Repealing Commission Implementing Regulation (EU) No 749/2014.” *Official Journal of the European Union* I. (278): 132.

———. 2021a. *COMMISSION DELEGATED REGULATION (EU) …/... of 4.6.2021*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2021)2800.

———. 2021b. “Nature-Based Solutions.” Text. European Commission. 2021. https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en.

———. 2021c. “Policy Scenarios for Delivering the European Green Deal.” 2021. https://energy.ec.europa.eu/data-and-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en.

———. 2021d. “Strategy for Financing the Transition to a Sustainable Economy.” Text. European Commission - European Commission. 2021. https://ec.europa.eu/info/publications/210706-sustainable-finance-strategy_en.

———. 2021e. “The Just Transition Mechanism: Making Sure No One Is Left Behind.” Text. European Commission - European Commission. 2021. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en.

———. 2021f. “EU Strategy on Adaptation to Climate Change.” European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A82%3AFIN.

———. 2021g. “Closing the Climate Protection Gap - Scoping Policy and Data Gaps.” European Commission. https://ec.europa.eu/clima/system/files/2021-06/swd_2021_123_en.pdf.

———. 2021h. “The European Green Deal.” European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN.

European Commission, Directorate-General for Climate Action (European Commission), Daniel Forster, Jeroen van der Laan, Robert Tippmann, Andrea Illes, Lisa Eichler, et al. 2017. *Climate Mainstreaming in* *the EU Budget: Preparing for the next MFF : Final Report*. LU: Publications Office of the European Union. https://data.europa.eu/doi/10.2834/218038.

European Commission. Joint Research Centre. Institute for Environment and Sustainability. and European Commission. Joint Research Centre. Institute for Prospective Technological Studies. 2009. *Climate Change Impacts in Europe :Final Report of the PESETA Research Project.* LU: Publications Office. https://data.europa.eu/doi/10.2791/32500.

European Parliament and Council. 2020. *Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088 (Text with EEA Relevance)*. *OJ L*. Vol. 198. http://data.europa.eu/eli/reg/2020/852/oj/eng.

European Union. 2018. "Regulation on the Governance of the Energy Union and Climate Action." *Official Journal of the European Union*, L, L (328): 1–77. https://doi.org/10.5040/9781782258674.

———. 2020. "On the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088." *Official Journal of the European Union* L (198): 13–43.

———. 2021. "European Climate Law." *Official Journal of the European Union* L (243): 1–17. https://doi.org/10.5040/9781782258674.

Fankhauser, Samuel. 1997. "The Costs of Adapting to Climate Change." Working Paper, No. 13. Washington, D.C.: Global Environment Facility.

Feyen, L, J.C Ciscar, S Gosling, D Ibarreta, A Soria, European Commission, and Joint Research Centre. 2020. *Climate Change Impacts and Adaptation in Europe: JRC PESETA IV Final Report.* https://op.europa.eu/publication/manifestation_identifier/PUB_KJNA30180ENN.

Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, et al. 2014. "Summary for Policymakers." In *Climate Change 2014: Impacts, Adaptation and Vulnerability*, 1–32. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf.

GIZ. 2013. "Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty. Excel Tools for Cost-Benefit and Multi-Criteria Analysis." Eschborn. https://www.adaptationcommunity.net/download/ms/mainstreaming-guides-manuals-reports/Economic_assessment_of_CC_adaptation_options_-_GIZ_2013.pdf.

Government of Fiji. 2020. "Costing Methodology for Fiji's National Adaptation Plan." Government of Fiji and NAP Global Network/International Institute for Sustainable Development (IISD). https://napglobalnetwork.org/wp-content/uploads/2020/09/napgn-en-2020-costing-methodology-for-Fiji-NAP.pdf.

Hildén, Mikael, Glada Lahn, Timothy R. Carter, Richard J. T. Klein, Ilona M. Otto, Benjamin Pohl, Christopher P. O. Reyer, and Fabien Tondel. 2020. "Cascading Climate Impacts: A New Factor in European Policy-Making." Policy brief from the CASCADES project.

Hoffmann, Christin. 2019. "Estimating the Benefits of Adaptation to Extreme Climate Events, Focusing on Nonmarket Damages." *Ecological Economics* 164 (October): 106250. https://doi.org/10.1016/j.ecolecon.2019.02.014.

Hugenbusch, David, and T. Neumann. 2021. "Enhancing Efficiency in Humanitarian Action through Reducing Risk." https://www.semanticscholar.org/paper/Enhancing-efficiency-in-humanitarian-action-through-Hugenbusch-Neumann/774e45c86ff721177d7aea6d421b252808e6e531.

IPCC. 2014. "Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (Eds.)]." In *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.)]*, 117–30. Geneva, Switzerland: IPCC. https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_Annexes.pdf.

Jahn, Malte. 2014. "A Spatial Computable General Equilibrium Model for the Analysis of Regional Climate Change Impacts and Adaptation Policies." *Hamburg Institute of International Economics (HWWI) Research* 154.

Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47 (2): 263–91. https://doi.org/10.2307/1914185.

Karlsson, Mikael, Eva Alfredsson, and Nils Westling. 2020. "Climate Policy Co-Benefits: A Review." *Climate Policy* 20 (3): 292–316. https://doi.org/10.1080/14693062.2020.1724070.

KfW. 2021. "Climate Risk Analysis – Insuresilience Solutions Fund." Climate Risk Analysis – Insuresilience Solutions Fund. 2021. https://www.insuresilience-solutions-fund.org/our-work/climate-risk-analysis/.

Kikstra, Jarmo S., Paul Waidelich, James Rising, Dmitry Yumashev, Chris Hope, and Chris M. Brierley. 2021. "The Social Cost of Carbon Dioxide under Climate-Economy Feedbacks and Temperature Variability." *Environmental Research Letters* 16 (9): 094037. https://doi.org/10.1088/1748-9326/ac1d0b.

Knittel, Nina, Birgit Bednar-Friedl, Markus Leitner, and Gabriel Bachner. 2017. "The Costs of Climate Change Adaptation for the Austrian Federal Budget." Graz/Vienna: PACINAS Working Paper #04. http://anpassung.ccca.at/pacinas/wp-content/uploads/sites/3/2017/07/10_Knittel-et-al-WP4-2017.pdf.

Knoke, Irene, and Matthias Duwe. 2012. *Climate Change Financing: The Concept of Additionality in the Light of the Commission Proposal for a Development Cooperation Instrument (DCI) for 2014-2020, Briefing for the European Parliament's Committee on Development*.

Lebègue, Daniel. 2005. "Revision Du Taux d'actualisation Des Investissements Publiques." Commissariat général du plan. http://metroauxrigollots.fr/archives/pdf/SW54/Rapport_Lebegue_Revision_Taux_Actualisation_Investissements_Publics.pdf.

Leitner, Markus, Thomas Dworak, Katie Johnson, Tiago Capela Lourenço, Wolfgang Lexer, Wouter Vanneuville, Angelika Tomasova, and Andrea Prutsch. 2021. "Using Key Type Measures to Report Climate Adaptation Action in the EEA Member Countries." European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA).

https://doi.org/10.25424/CMCC/USING_KEY_TYPE_MEASURES_TO_REPORT_CLIMATE_ADAPTATION_ACTION_IN_THE_EEA_MEMBER_COUNTRIES.

Levina, Ellina, and Dennis Tirpak. 2006. “Adaptation to Climate Change: Key Terms.” OECD/IEA.

Lu, Xianfu, and Rexel Abrigo. 2017. “Understanding Different Approaches to Managing Climate Change Risks.” Development Asia. An Initiative of Asian Development Bank. December 26, 2017. https://development.asia/explainer/understanding-different-approaches-managing-climate-change-risks.

Margulis, Sergio, Burle Carolina, and Jacques Marcovitch. 2011. “The Economics of Climate Change in Brazil: Costs and Opportunities.” http://globaltrends.thedialogue.org/publication/the-economics-of-climate-change-in-brazil-costs-and-opportunities/.

Masson-Delmotte, Valérie, Hans-Otto Pörtner, Jim Skea, Panmao Zhai, Debra Roberts, Priyadarshi R Shukla, Anna Pirani, et al. 2018. “Annex I: Glossary [Matthews, J.B.R. (Ed.)].” In *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, 630. IPCC.

Masson-Delmotte, Valérie, Panmao Zhai, Anna Pirani, Sarah L. Connors, C. Péan, Sophie Berger, Nada Caud, et al., eds. 2021. “Summary for Policymakers.” In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf.

Mendelsohn, Robert. 2000. “Efficient Adaptation to Climate Change.” *Climatic Change* 45 (3): 583–600. https://doi.org/10.1023/A:1005507810350.

Murieta, Elisa Sainz de. 2020. “Ancillary Benefits of Adaptation: An Overview.” In *Ancillary Benefits of Climate Policy: New Theoretical Developments and Empirical Findings*, edited by Wolfgang Buchholz, Anil Markandya, Dirk Rübbelke, and Stefan Vögele, 181–96. Springer Climate. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-30978-7_10.

Murieta, Elisa Sainz de, Ibon Galarraga, Kateřina Kaprová, Jan Melichar, Paolo Scussolini, and Onno Kuik. 2016. “Description of Uncertainties Associated with Planned Investments and Incorporation in Decision Rules.” *ECONADAPT*, Deliverable 6.3, Econadapt FP7 research project, , 77.

Neil Adger, W., Nigel W. Arnell, and Emma L. Tompkins. 2005. “Successful Adaptation to Climate Change across Scales.” *Global Environmental Change*, Adaptation to Climate Change: Perspectives Across Scales, 15 (2): 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005.

Nicklin, Leicher, Dieperink, and Leeuwen. 2019. “Understanding the Costs of Inaction–An Assessment of Pluvial Flood Damages in Two European Cities.” *Water* 11 (4): 801. https://doi.org/10.3390/w11040801.

Nikas, Alexandros, Haris Doukas, and Andreas Papandreou. 2019. “A Detailed Overview and Consistent Classification of Climate-Economy Models.” In *Understanding Risks and Uncertainties in Energy and Climate Policy: Multidisciplinary Methods and Tools for a Low Carbon Society*, edited by Haris Doukas, Alexandros Flamos, and Jenny Lieu, 1–54. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-03152-7_1.

Noble, I.R., S. Huq, Y.A. Anokhin, J. Carmin, D. Goudou, F.P. Lansigan, B. Osman-Elasha, and A. Villamizar. 2014. "Adaptation Needs and Options." In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution to Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 833–68. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Noleppa, Steffen. 2013. *Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty Excel Tools for Cost-Benefit and Multi-Criteria Analysis Competence Center for Climate Change*. Deutsche Gesellschaft Für Internationale Zusammenarbeit (GIZ) GmbH.

Nordhaus, William. 2007. "The Challenge of Global Warming: Economic Models and Environmental Policy." *Technical Report*, January.

OECD. 2008a. "Costs of Inaction on Environmental Policy Challenges: Summary Report." https://www.oecd.org/env/40501169.pdf.

———. 2008b. *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*. Edited by Shardul Agrawala and Samuel Fankhauser. OECD. https://doi.org/10.1787/9789264046214-en.

———. 2015a. "Climate Change Risks and Adaptation: Linking Policy and Economics." Paris: OECD Publishing. https://read.oecd-ilibrary.org/environment/climate-change-risks-and-adaptation_9789264234611-en.

———. 2015b. *The Economic Consequences of Climate Change*. Paris: Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/environment/the-economic-consequences-of-climate-change_9789264235410-en.

———. 2016. "OECD DAC Rio Markers for Climate: Handbook." https://www.oecd.org/dac/environment-development/Revised%20climate%20marker%20handbook_FINAL.pdf.

———. 2021. "Understanding the Six Criteria: Definitions, Elements for Analysis and Key Challenges." Paris: OECD. https://doi.org/10.1787/c249f611-en.

Pauw, W. P., L. Kempa, U. Moslener, C. Grüning, and C. Çevik. 2021. "A Focus on Market Imperfections Can Help Governments to Mobilize Private Investments in Adaptation." *Climate and Development* 0 (0): 1–7. https://doi.org/10.1080/17565529.2021.1885337.

Pittel, Karen, and Dirk Rübbelke. 2008. "Climate Policy and Ancillary Benefits: A Survey and Integration into the Modelling of International Negotiations on Climate Change." *Ecological Economics* 68 (1–2): 210–20.

Project Catalyst. 2009. "Adaptation to Climate Change: Potential Costs and Choices for a Global Agreement. Findings of the Adaptation Working Group of Project Catalyst." Climate Works Foundation.

Raworth, Kate. 2007. “Adapting to Climate Change: What’s Needed in Poor Countries, and Who Should Pay.” Oxfam International. https://oxfamilibrary.openrepository.com/bitstream/handle/10546/114075/bp104-adapting-to-climate-change-290507-en.pdf;jsessionid=00F8FBBAB29759C1726114F40A89D10F?sequence=1.

Raymond, Christopher M., Niki Frantzeskaki, Nadja Kabisch, Pam Berry, Margaretha Breil, Mihai Razvan Nita, Davide Geneletti, and Carlo Calfapietra. 2017. “A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas.” *Environmental Science & Policy* 77 (November): 15–24. https://doi.org/10.1016/j.envsci.2017.07.008.

Sanderson, Benjamin M., and Brian C. O’Neill. 2020. “Assessing the Costs of Historical Inaction on Climate Change.” *Scientific Reports* 10 (1): 9173. https://doi.org/10.1038/s41598-020-66275-4.

Stadelmann, Martin, Axel Michaelowa, Sonja Butzengeiger-Geyer, and Michel Köhler. 2015. “Universal Metrics to Compare the Effectiveness of Climate Change Adaptation Projects.” In *Handbook of Climate Change Adaptation*, edited by Walter Leal Filho, 2143–60. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-38670-1_128.

Steininger, Karl W., Birgit Bednar-Friedl, Herbert Formayer, and Martin König. 2016. “Consistent Economic Cross-Sectoral Climate Change Impact Scenario Analysis: Method and Application to Austria.” *Climate Services* 1 (March): 39–52. https://doi.org/10.1016/j.cliser.2016.02.003.

Stern, N. H., and Great Britain, eds. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge, UK ; New York: Cambridge University Press.

Strehl, Clemens, Adriana Bruggerman, Alberto Freitas, Anasha Petersen, Andrea Hein, Ashenafi Seifu Grange, Ayis Iacovides, et al. 2019. “D5.3 Report on Economic and Societal Impacts of the Proposed Measures.” BINGO project report from WP5 Developing risk treatment and adaptation strategies for extreme weather events. Brussels: European Commission. http://www.projectbingo.eu/downloads/BINGO_Deliverable5.3.pdf.

Tanner, Thomas, Swenja Surminski, Emily Wilkinson, Robert Reid, Jun Rentschler, and Sumati Rajput. 2015. “The Triple Dividend of Resilience: Realising Development Goals through the Multiple Benefits of Disaster Risk Management.” Global Facility for Disaster Reduction and Recovery (GFDRR) at the World Bank and Overseas Development Institute (ODI). www.odi.org/tripledividend.

Tröltzsch, Jenny, Benjamin Görlach, Helen Lückge, Martin Peter, and Christian Sartorius. 2011. “Ökonomische Aspekte Der Anpassung an Den Klimawandel Literaturauswertung Zu Kosten Und Nutzen von Anpassungsmaßnahmen an Den Klimawandel.” 19/2011. Climate Change. Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4185.pdf.

Tröltzsch, Jenny, Dr Josselin Rouillard, John Tarpey, Dr Manuel Lago, P. Watkiss, and A. Hunt. 2016. “The Economics of Climate Change Adaptation.” Report. https://www.ecologic.eu/14368.

UNDP. 2007. “Fighitng Climate Change : Human Solidarity in a Divided World.” Human Development Report. https://hdr.undp.org/sites/default/files/hdr_20072008_summary_english.pdf.

UNEP. 2014. “The Adaptation Gap Report 2014.” Nairobi: United Nations Environment Programme (UNEP). https://wedocs.unep.org/bitstream/handle/20.500.11822/9331/-Adaptation_gap_report_a_prel.pdf?sequence=2&isAllowed=y.

———. 2016. “The Adaptation Finance Gap Report 2016.” Nairobi: United Nations Environment Programme. https://climateanalytics.org/media/agr2016.pdf.

———. 2021. “Adaptation Gap Report 2021.” UNEP - UN Environment Programme. October 31, 2021. http://www.unep.org/resources/adaptation-gap-report-2021.

UNFCCC. 2007. “UNFCCC: INVESTMENT AND FINANCIAL FLOWS TO ADDRESS CLIMATE CHANGE.” Bonn: Climate Change Secretariat. https://unfccc.int/resource/docs/publications/financial_flows.pdf.

———. 2009. “Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature.” FCCC/TP/2009/2. UNFCCC. https://unfccc.int/resource/docs/2009/tp/02.pdf.

———. 2011. “Assessing the Costs and Benefits of Adaptation Actions: An Overview of Approaches.” UNFCCC, The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change. https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf.

———. 2012. “Current Knowledge on Relevant Methodologies and Data Requirements as Well as Lessons Learned and Gaps Identified at Different Levels, in Assessing the Risk of Loss and Damage Associated with the Adverse Effects of Climate Change.” UNFCCC. https://unfccc.int/resource/docs/2012/tp/01.pdf.

———. 2021. “National Adaptation Plans | UNFCCC.” United Nations Climate Change. 2021. https://unfccc.int/topics/adaptation-and-resilience/workstreams/national-adaptation-plans.

United Nations Environment Programme. 2021. “Adaptation Gap Report 2021: The Gathering Storm - Adapting to Climate Change in a Post-Pandemic World.” Nairobi: United Nations Environment Programme (UNEP). http://www.unep.org/resources/adaptation-gap-report-2021.

Watkiss, Paul, ed. 2015. “The Costs and Benefits of Adaptation,” July. https://www.ecologic.eu/12427.

Watkiss, Paul, Paul Watkiss Associates, Alistair Hunt, Manuel Lago, Aline Chiabai, Ibon Galarraga, Anil Markandya, et al. 2015. “Results from the ECONADAPT Project,” 54.

Watkiss, Paul, Jenny Troeltzsch, and Katriona McGlade. 2019. “The Economic Cost of Climate Change in Europe: Synthesis Report on Interim Results. Policy Brief by the COACCH Project.”

World Bank. 2006. “Clean Energy and Development: Towards an Investment Framework.” http://web.worldbank.org/archive/website01021/WEB/IMAGES/DC2006-2.PDF.

———. 2010. “Economics of Adaptation to Climate Change : Synthesis Report.” Washington, DC: World Bank. https://doi.org/10/01/16436675/economics-adaptation-climate-change-synthesis-report.

———. 2021. “Investment in Disaster Risk Management in Europe Makes Economic Sense: Background Report. Economics for Disaster Prevention and Preparedness.” Text/HTML. Washington, DC. https://openknowledge.worldbank.org/handle/10986/35686.