Regional Economic Guidance Document for Climate Adaptation and Transportation Resilience Planning

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1 | INTRODUCTION

The changing climate is having substantial impacts on local communities, regional economies, and interconnected ecosystems. Projections of increased temperatures, erratic precipitation, and greater flooding and wildfire risk put people, property, and the environment at even greater risk in future. To deal with, respond and adapt to such risks and potentially dangerous conditions, an understanding of a community's vulnerability to the impacts of future climate events is necessary.

Local jurisdictions in California are required to address climate risk, which is often done through adoption of a Local Hazard Mitigation Plan (LHMP)[1] or the General Plan's Safety Element policies and implementation actions.[2] An alternative approach is to address climate adaptation and resilience through climate adaptation plans, which may be separately developed outside of the General Plan process. Both approaches rely on development of climate vulnerability and risk assessment aspects. While federal[3] and state[4] guidance is available on climate risks, and how adaptation strategies can be developed and integrated into hazard mitigation plans[5] and Safety Elements, local climate adaptation planning has not generally progressed much beyond the vulnerability assessment stage.

In the San Diego region, the San Diego Association of Governments (SANDAG), together with the San Diego Regional Collaborative (SDRCC), prepared a Regional Adaptation Needs Assessment (Regional NA)[6] in 2019 to understand the gaps and challenges in climate adaptation planning. This Regional NA revealed that "local and regional practitioners [still] need consistent and accessible guidance, best practices for adaptation planning, and local and regional case studies that highlight the application of these best practices." Consistent with the Regional NA's findings, a review of the San Diego region's climate change adaptation-focused planning documents reveals limited detail on specific adaptation strategies, scenarios or measures. Most of the region's adaptation planning documents do not currently include economic assessments of climate adaptation strategies (or discussions of equity that may affect economic assessments).

With funding from a Caltrans Senate Bill 1 Adaptation Planning Grant, SANDAG initiated the Holistic Implementation of Adaptation and Transportation Resilience Strategies (HIATRS) project in 2020. The objective of HIATRS was to create climate adaptation guidance documents, tools, and educational outreach material through a holistic approach integrating equity, economic, and environmental considerations. This guidance document focuses on the economic analyses of climate hazard impacts and corresponding adaptation responses. A second guidance document (under separate cover) discusses the integration of equity into climate adaptation and transportation climate resilience planning. A

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[1] Hazard mitigation plans that meet the requirements of Title 44 Code of Federal Regulations (CFR) §201.6 for FEMA approval become eligible to apply for FEMA Hazard Mitigation Assistance grants.

[2] California's SB739 (2015) requires local jurisdictions upon the next revision of their LHMP or the Safety Element to review and update as necessary climate adaptation and resiliency strategies applicable to the city. The purpose of a LHMP is to identify local policies and actions that can be implemented over the long term to reduce risk and future losses from hazards. The goal of the Safety Element is to reduce the potential short and long-term risks from both manmade and natural hazards. To address climate risk, the Safety Element must include a climate change vulnerability assessment. The Safety Element should also contain general hazard and risk reduction strategies complementary with those of the LHMP. Ideally, the LHMP will be incorporated into the Safety Element.

[3] E.g., U.S. Climate Resilience Toolkit

[4] E.g., California Adaptation Planning Guide

[5] Local jurisdictions in San Diego County participate in a consolidated Multi-jurisdictional Hazard Mitigation Plan. At the time of this publication, San Diego County was updating the MHMP with a revision date of 2023.

[6] SANDAG (2020). *Regional Adaptation Needs Assessment*. PDF

prioritization tool has also been developed to assist users in selecting adaptation strategies by ranking strategies along multiple criteria, and the implementation toolkit identifies resources for climate adaptation strategies.

1.1 What Does this Economic Guidance Address?

The intent of this guidance document is to help climate adaptation professionals understand how to direct or engage with those performing economic analyses on climate adaptation impacts and strategies. The guidance document provides a step-by-step approach for:

a. Framing an economic analysis to address climate hazard impacts and adaptation strategies.
b. Understanding and differentiating the economic approaches available.
c. Selecting the most appropriate economic approach or approaches.
d. Identifying and selecting inputs for the economic analysis in the context of climate adaptation planning.

This document is not intended to be a primer on economic analyses or provide extensive direction on a specific methodology. Rather, the purpose is to provide specific direction for tailoring economic approaches to meet the community's objectives for climate adaptation planning. Therefore, this guidance document should be used in combination with existing economic analytical frameworks.

1.2 Intended Audience

The information contained within this economic guidance document is directed toward city and local agency users, and other professionals (e.g., engineers) responsible for climate adaptation planning (collectively referred to as "users"). An assumption made is that these users manage, or provide direction for, climate adaptation planning requiring economic analyses of hazard impacts and corresponding adaptation strategies.

It is assumed users will have a range of expertise and experience with climate adaptation-focused economic analyses. In acknowledgement of this range, the document provides guidance for two levels of user experience:

1) Those with little or no experience performing economic analyses. This experience may include familiarity with reviewing output from models or conclusions in reports (e.g., cost per linear mile of bikeway, fiscal impact to a jurisdiction from implementing a program).
2) Those users with more economic analytical experience and desire more detailed information on approaches, assumptions, and specific considerations to climate-related economic analyses.

To assist these users in navigating this guidance document, select information is organized within color-coded boxes to emphasize content. The following key provides definitions for these informational text boxes:

Key

Definitions	Blue boxes provide definitions for key terms applied throughout this document.
General Information	Green boxes provide information or resources on climate adaptation planning and economic approaches intended to support the user perform their own analyses.
Advanced Information	Gray boxes provide more in-depth information on economic approaches or considerations. It is intended for users with more experience in economics, or those who want to learn more.
Guiding Questions	Yellow boxes contain the guiding questions that provide the organizational framework for this guidance document.

2 | Adaptation Planning for Climate Change

2.1 General Approach

The State of California provides resources to local governments to support local action on climate change. The California Adaptation Planning Guide (APG) provides guidance to communities addressing the vulnerability to, risks associated with, and potential consequences of climate change.[7] **It is highly recommended that users inexperienced in climate adaptation planning familiarize themselves with the APG**.

The APG presents adaptation planning as a step-by-step process that communities (and professionals assisting) can use whether they are at the beginning of the process or already within a planning effort. The APG defines a four-phase process for adaptation planning illustrated in Figure 1. A fifth phase, Phase 0, has been identified in the companion Equity Guidance Document developed as part of this HIATRS grant.

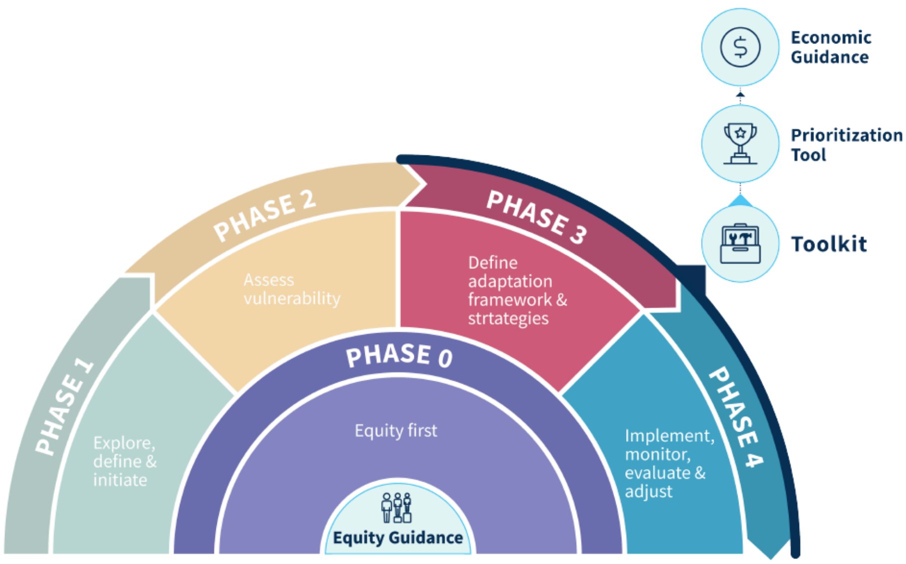


Figure 1. Climate Adaptation Planning Process

Phases of the Adaptation Planning Process

• *Phase 0, Pre-Planning and Capacity Building (not part of the APG process):* Prior to kick-off, perform local and regional agency and stakeholder coordination to prepare all interested parties for future planning activities. The focus should be inclusive engagement to ensure concerns regarding equity are addressed.

• *Phase 1, Explore, Define, and Initiate:* This phase includes scoping the process and project, such as identifying the potential climate change effects and important physical, social, and natural assets in the community.

• *Phase 2, Assess Vulnerability:* This phase includes analysis of potential impacts and adaptive capacity to determine the vulnerability for populations, natural resources, and community assets. The vulnerability assessment identifies how climate change could affect the community.

[7] CalOES (2020). *California Adaptation Planning Guide*. PDF

• *Phase 3, Define Adaptation Framework and Strategies:* This phase focuses on creating an adaptation framework and developing adaptation strategies based on the results of the Vulnerability Assessment. The adaptation strategies are the community's response to the vulnerability assessment—that is, how the community will address the potential for harm identified in the vulnerability assessment, given the community's resources, goals, values, needs, and regional context.

• *Phase 4, Implement, Monitor, Evaluate, and Adjust:* In this phase, the climate adaptation framework is implemented, consistently monitored, evaluated, and adjusted based on continual learning, feedback, and/or triggers.

Definition(s)

Vulnerability Assessment: In the context of climate change, it is an analysis of how a changing climate may harm a community and which elements—people, buildings and structures, resources, and other assets—are most vulnerable to its effects based on an assessment of exposure, sensitivity, the potential impact(s), and the community's adaptive capacity.[1]

Vulnerable Communities: Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical, social, political, and/or economic factor(s), which are exacerbated by climate impacts. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality.[1]

Climate Change Effect[*]: A change in natural processes as a result of climate change, such as changes in precipitation patterns or average temperatures.

Hazard[*]: An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural losses, damage to the environment, interruption of business, or other types of harm or loss.[2]

Impact[*]: In the context of climate adaptation, the effect (especially the negative effects) of a hazard or other conditions associated with climate change. Impact is often considered the combination of exposure and sensitivity.[1]

Direct Impact: Primary effects that are caused by a project [or climate hazard].[3]

Indirect Impact: Secondary effects that are reasonably foreseeable and caused by a project [or climate hazard], but occur at a different time or place, [or as the result of a more complex impact pathway].

Cumulative Impact: Two or more individual [impacts] which, when considered together, are considerable or which compound or increase other environmental impacts

[1] CalOES (2020). *California Adaptation Planning Guide*. PDF
[2] CalOES (2018). *California State Hazard Mitigation Plan*. PDF
[3] Caltrans (2005). *Guidelines for Preparers of Cumulative Impact Assessments: CEQA Guidelines for Cumulative and Indirect Impacts*. PDF
* Terminology may differ depending on the planning resource. Terms used in this document are consistent with those used in the APG and California's Fourth Climate Change Assessment for the San Diego region.

2.2 Where Does Economic Analysis Fit into the Climate Adaptation Planning Process?

An economic analysis, in the context of climate adaptation planning, is intended to reveal the economic impacts of 1) climate hazards and 2) corresponding adaptative response(s) to the climate hazard. The output from these analyses such as benefit-cost ratios can be used to inform and support decision-making related to community resiliency objectives, capital program expenditures, resource allocation, and risk mitigation (and others not identified herein).

Using the APG adaptation planning process as a guide, the economic analyses of adaptation strategies can, and should, occur during *Phase 3: Define Adaptation Framework & Strategies* and *Phase 4: Implement, Monitor, Evaluate, & Adjust* as further described here:

Phase 3: Define Adaptation Framework & Strategies

Economic analyses begin after defining the adaptation framework in Phase 3. This framework should address the results of any vulnerability assessment with consideration of the community's goals and objectives for adaptation. The adaptation framework then identifies the community's priorities for public health and safety, environmental protection, social equity, and any other community goals. An economic approach, or approaches, can be identified through this guidance document which provides direction for evaluating different climate adaptation strategies to help communities make economically informed decisions.

Phase 4: Implement, Monitor, Evaluate, & Adjust

Economic outputs from analyses performed in Phase 3 are revisited during Phase 4. Through the post-evaluation of implemented climate adaptation strategies, economic analyses may be useful to inform professionals and agency decision-makers about the economic and/or financial success (or failure). In turn, this information can be used, along with other variables identified by the agency, to guide future decisions regarding selection and implementation of new or revised adaptation strategies.

2.3 How to Use this Guidance for Climate Adaptation Planning Economic Analyses

This guidance document is organized around a linear approach to economic analysis using commonly used language to prompt the user. This format is intentionally less formal. Reducing the technical language into a more user-friendly terminology increases accessibility and helps users direct economists or other technical staff. Table 1 shows the guiding questions and the sections where they are addressed. Guiding questions are also provided in Appendix A and can be used as a checklist when initiating the economic analyses.

Table 1. Guiding Questions for Economic Analysis

Guiding Questions	Guidance Document Section
	Section 3. Framing an Economic Analysis
1. What are the community's objectives for climate adaptation?	Section 3. Framing an Economic Analysis
2. Which climate hazard impacts should be included in the economic analysis?	Section 3.1 Evaluating the Economic Impact of Climate Hazards
3. Which adaptation strategies should be included in the economic analysis?	Section 3.2 Evaluating Adaptation Strategies
	Section 4. Implementing the Economic Analysis
4. How will the results of the economic analysis be applied?	Section 4.1 Selecting the Appropriate Economic Approach
5. When will adaptation strategies be implemented and what is their life cycle? 6. For what duration will each adaptation strategy be effective?	Section 4.2 Identifying Timeframe(s)
7. Who will incur costs to implement the adaptation strategies? 8. Who will receive the benefit(s) from the adaptation strategies?	Section 4.3 Identifying Costs and Benefits

Framing the Economic Analysis

As indicated in Table 1, Section 3 frames the broader economic analyses in the context of a community or agency's goals and objectives. Section 3.1 guides development of the framework for the economic analyses so that the output provides the desired information in response to the community's climate adaptation goals and objectives. The guidance assumes the vulnerability assessment (or LHMP, Safety Element, etc.) will provide the community's climate effects, associated climate hazards, potential impacts from the hazards, and potential adaptation strategies. At the completion of Section 3, users should have an understanding of the climate hazard impacts and adaptation strategies they are looking to assess through an economic lens.

Implementing the Economic Analysis

Section 4 guides the user through the four primary economic approaches uses in climate adaption planning including how and when to apply each approach. Other topics addressed are timeline considerations, including the reason for and application of a discount rate; and identifying and collecting cost and benefit data. Technical guidance in this section is further supported by a climate planning case example.

3 | Framing an Economic Analysis

Before performing economic analyses for climate adaptation planning, the problem statement must be developed and solutions identified. This section guides the user through identification of the potential *economic aspects* of climate hazard impacts (Section 3.1) and identification and classification of climate adaptation strategies *in the context of economic analysis* (Section 3.2). Section 4 provides more detail on implementing the analysis.

To frame the economic analysis, the user must understand the community's objectives for climate adaptation planning (Guiding Question 1).

Guiding Questions (1 of 8):

1. What are the community's objectives for the economic analysis?

For example, what are the community priorities? Is human safety more important than infrastructure? Is there a deadline for planning and implementation? Answering these types of questions help the user to frame the economic analysis for two reasons:

1) The community objectives will help rank the potential significance of a climate hazard's impact. For example, assume a community prioritizes a safe and accessible transportation network. And, while the same community may be subject to increased flooding events from projected increased levels of precipitation, the community has a stormwater system capable of addressing future flooding capacity. Therefore, further economic analysis of flooding impacts may not be necessary.

2) The community objectives will help refine a climate hazard's corresponding adaptation strategy to a level of detail so that economic analysis can be performed (for further discussion on this topic see Section 3.2).

Once the user understands the community objectives, they can begin to evaluate the potential economic impacts from climate hazards.

3.1 Evaluating the Economic Impact of Climate Hazards

Guiding Questions (2 of 8):

2. What climate hazard impacts should be included in the economic analysis?

Determine the Climate Hazard Impacts

The recommended first step here is to assess the economic impact of one or more climate hazards affecting the community (refer to the *Climate Change Effects and Hazards in the San Diego Region* box on page 10 for effects and hazards anticipated in the San Diego region). Analyzing the climate hazard's economic impact assumes a business-as-usual approach without implementation of an adaptation strategy. For example, an agency may want to analyze the financial loss of tourism due to extreme heat events. In this example, the increased temperature is the *climate change effect*, the extreme heat event is the corresponding *climate hazard*, loss of tourism is the *climate hazard impact*, and the financial loss is the *economic impact*. As a variable for future comparisons, this output from this analysis becomes the baseline condition (or scenario). Refer to the *Climate Adaptation Scenarios* box on page 11 for more information on baseline and adaptation scenarios.

Table 2 illustrates potential impacts from climate hazards that could be assessed through an economic analysis. The list is not intended to be comprehensive. Rather, it should prompt the user to consider additional impacts that may occur in their own community.

Table 2. Impacts from Climate Hazards

Climate Change Effect	Climate Hazard(s)	Examples of Climate Impacts and Basis of Economic Analysis
Precipitation Increase	Flooding	• Reduced emergency evacuation • Loss of life and property • Loss of recreational opportunities • Ecosystem gain/loss
	Erosion	• Loss of property • Loss of recreational opportunities • Ecosystem loss
Precipitation Decrease	Drought	• Loss of critical ecosystem services • Loss to agriculture • Decrease in water supply
	Wildfire Risk	• Reduced air quality • Loss of life and property • Increased erosion from exposed soils • Ecosystem gain/loss
Sea Level Rise	Coastal Flooding	• Reduced emergency evacuation • Loss of life and property • Loss of recreational opportunities • Ecosystem gain/loss
	Coastal Erosion	• Loss of property • Loss of recreational opportunities • Ecosystem gain/loss
Temperature Increase	Drought	• Loss of critical ecosystem services • Loss to agriculture • Decrease in water supply
	Extreme Heat Events	• Increased hospitalizations. • Loss of life • Loss of agriculture • Ecosystem loss • Increased energy demand
	Wildfire Risk	• Reduced air quality • Loss of life and property • Increased erosion from exposed soils • Ecosystem gain/loss

Once climate impacts have been identified, and based on an agency's resources and climate adaptation goals, they may want to analyze the economic impacts of one or all climate hazards. Some of the considerations when selecting hazard impacts to address are:

- Specifics of hazard impacts should be clearly defined (e.g., a specific geography, time span), leading to more effective and efficient data needs identification. For example, "Loss of Agriculture" can be narrowed down to: Drought impacts to summer employment from loss of avocado crops in Simi Valley. Drought is the *hazard*, summer is the *time span*, loss of avocado refines the agricultural focus to a specific *hazard impact*, and Simi Valley is the *geography*.
- Certain climate hazards cause similar, if not the same, climate impacts to people, property, and the environment. This is beneficial from an economic perspective as the analyses will, at a minimum, share the same data and, at best, may only require a single process to analyze the impact from both hazards.

General Information:
Climate Change Effects and Hazards in the San Diego Region

Multiple climate change effects have been identified for the San Diego region, including projected increases in sea level rise and ambient air temperatures.[1] Specific climate effects of concern for local communities are documented in their climate change vulnerability assessment (sometimes a specific climate effect), LHMP, Safety Element, or similar document. For instance, the County of San Diego analyzed temperature, precipitation, and sea level rise and their associated hazards in their 2017 climate change vulnerability assessment.[2] The City of Imperial Beach's recent efforts focused on sea level rise.[3]

The table below shows how climate change effects and hazards identified in the 4th Climate Assessment for the San Diego region.

San Diego Region Climate Change Effects and Hazards

Climate Change Effect	Corresponding Hazard(s)
Precipitation Increase	Flooding
	Erosion
Precipitation Decrease	Drought
	Wildfire Risk
Sea Level Rise	Coastal Flooding
	Coastal Erosion
Temperature Increase	Drought
	Extreme Heat Events
	Wildfire Risk

[1] CA OPR, CNRA, CEC (2019). *California's 4th Climate Change Assessment – San Diego Region*. PDF
[2] County of San Diego (2017). *Climate Change Vulnerability Assessment: County of San Diego*. PDF

General Information:
Climate Adaptation Scenarios

Two types of scenarios are developed during the adaptation planning process – a baseline scenario (i.e., a no-action reference point) discussed in Section 3.1 and adaptation scenarios (made up of one or more adaptation strategies) in Section 3.2.

The **baseline scenario**, often referred to as a no-adaptation or business-as-usual scenario, represents what might happen to the community if no adaptation strategies are put in place and the impacts of climate change are fully felt. This also provides a reference point. If the agency wants to compare costs or benefits of a proposed adaptation scenario compared to taking no action, then development of a baseline scenario is necessary.

Adaptation scenarios contain one or more adaptation strategies that mitigate, either wholly or partially, the severity of impacts identified in the baseline scenario.

3.2 Evaluating Adaptation Strategies

Guiding Questions (3 of 8):

3. What adaptation strategies should be included in the economic analysis?

The outcome of the previous climate hazard analysis may reveal that current and projected climate hazard impacts are not considered severe enough to require a corresponding adaptation response. While climate change is projected to substantially worsen climate hazards and their impacts, the effects will be different for each community. Therefore, action may not be warranted, and further economic analysis may not be necessary. However, for those communities that decide to plan and implement climate adaptation strategies, it may become necessary to decide which adaptation strategies should be included in an economic analysis.

This guidance assumes that, for an economic analysis, adaptation strategies or scenarios are developed in response to the impacts from a specific climate hazard as identified in Section 3.1. For example, an agency may want to implement a water reduction incentive program or construct a desalinization facility in response to drought caused by reduced precipitation.

Table 4 illustrates potential impacts from climate hazards and examples of potential strategies that could be assessed through an economic analysis. The list is not intended to be comprehensive and its purpose is to illustrate *policy-level* strategies or scenarios. However, policy-level strategies may not be sufficient for an economic analysis or for selection of strategies for the analysis. An *economic analysis* needs greater specificity in the strategy. Without the specificity, it will be difficult to collect economic data and define potential benefits.

Table 3. Potential Adaptation Strategies

Climate Hazard(s)	Examples of Climate Hazard Impacts	Examples of Potential Strategies
Flooding	Reduced emergency evacuation	• Educational Outreach to Vulnerable Communities • Construct New Evacuation Routes
	Damage to critical infrastructure	• Ensure facilities are floodproof • Elevate Stormwater Conveyance Systems • Realign roadways
	Ecosystem gain/loss	• Develop natural systems to prevent flooding
Drought	Loss to agriculture	• Implement water conservation measures • Support transition to more drought resistant crops
	Decreased water supply	• Implement water conservation measures • Provide educational outreach • Construct desalinization facilities
Wildfire Risk	Reduced air quality	• Implement air quality improvement measures • Provide clean air facilities for vulnerable populations
	Loss of life and property	• Implement stricter building regulations • Update evacuation routes and educate public about the routes

As an example, consider the scenario presented in Section 3.1 where drought (*climate hazard*) impacts summer employment from loss of avocado crops in the Simi Valley (*hazard impact*). Policy-level adaptation strategies to address this impact include the implementation of water conservation measures. Further refinement of those adaptation strategies is needed so that they: 1) directly relate and respond to the specific hazard impact, and 2) provide sufficient detail to perform an economic analysis. Such refinement may include:

- Expend 5% of the 2021 – 2022 general fund on developing and implementing an educational and outreach program to reduce residential water use by 20% by 2025. (Assuming that reduction in residential water use would leave more water for avocado farmers.)

Co-Benefits. Adaptation strategies can also provide benefits that go beyond the intended purpose – to respond to a specific climate hazard impact. Using the more focused adaptation strategy provided above for the Simi Valley avocado example, co-benefits may include:

- A substantial transition to drought tolerant plans on rural residential property creating a fire buffer and reducing the risk to property from wildfire;
- A reduction in water use allowing lakes and reservoirs to maintain higher water levels benefiting ecosystems; and
- A reduction in water demand, reducing energy use and potentially greenhouse gas emissions.

Users may need to coordinate with experts to determine the degree of co-benefits achievable (e.g., how much air pollution is reduced) and whether that benefit can be quantified.

4 | Implementing the Economic Analysis

Once a user has identified the climate hazard impacts and adaptation strategies to be included in the economic analysis, they can move on to the implementation stage. This Section details the four primary approaches available to users to assess the economics of climate adaptation strategies and provides guidance for selecting the appropriate approach. In addition, it covers the other inputs that must be identified and defined for an economic analysis including timeframe(s), costs, and benefits.

4.1 Selecting the Appropriate Economic Approach

Guiding Questions (4 of 8):

4. How will the results of the economic analysis be applied?

Selecting the economic analysis approach best suited for any given set of adaptation strategies will be determined by the community's objective(s), the level of data available and how the results are to be applied. Users will likely be relying on economic analyses to provide insights that align with community objectives identified in Section 3. Users may decide that one type of analysis is sufficient or may require multiple analyses to address their needs.

The four general approaches for economic assessment of adaptation strategies described here will assist the user to reconcile the agency and/or community objectives with the approach to be taken. The four general approaches are a fiscal impact analysis (FIA), benefit-cost analysis (BCA), cost-effectiveness analysis (CEA), and multi-criteria analysis (MCA). Table 4 provides a description of each approach followed by more detail on each approach.

Table 4. Economic Approaches for to Assess Adaptation Planning

Economic Approach	Description
Fiscal Impact Analysis (FIA)	Evaluates the monetary changes in governmental expenditures and revenues associated with implementing adaptation strategies. FIAs are concerned with impacts to an agency's general fund and associated community-focused funds.
Benefit-Cost Analysis (BCS)	Weighs the total benefits of strategies against the total costs. BCAs rely on the availability of monetized values for the costs and benefits associated with implementing adaptation strategies.
Cost-Effectiveness Analysis (CEA)	Determines the relative costs of implementing different adaptation strategies in achieving a desired goal to identify the lowest cost option or whether the cost justifies action. CEAs rely on the availability of monetized values for only the costs associated with implementing adaptation strategies.
Multi-Criteria Analysis (MCA)	Evaluates the economic criteria (e.g., costs and benefits) together with other factors. MCAs may incorporate monetary data but are not dependent on it; costs or benefits may also be assessed using non-monetary criteria alongside other societal interests.

The *Broader Economic Guidance for Regional Adaptation Planning* box on pages 14 and 15 discusses similar frameworks and tools that represent current best practices.

General Information:
Broader Economic Guidance for Regional Adaptation Planning (Part 1)

The following economic frameworks, while from international and national sources, are applicable at the local or regional scale to analyze climate adaptation strategies. Two of the frameworks apply a specific economic approach (e.g., benefit-cost analyses) to one or more climate hazard impacts and/or adaptation strategies (see NOAA Framework and ADCCEE below). The remaining provide a broader range of economic approaches to a wider range of strategies (see Hazus, ECONADAPT, and UNFCCC below).

The US National Oceanic and Atmospheric Agency (NOAA) developed an economic guidance framework (NOAA Framework)[1] specifically tailored to help communities evaluate the economics of sea level rise adaptation strategies in their planning and development decisions. The NOAA Framework provides a broad approach to evaluate economic impacts of sea level rise on buildings and infrastructure. It is an example of a guidance document that deals with a specific economic approach applied to adaptation strategies (benefit-cost ratios to compare different sea level rise adaption options.)

The Australian Department of Climate Change and Energy Efficiency (ADCCEE)[2] developed an economic framework where the costs and benefits of adaptation options are assessed against the cost of inaction. Outputs from the model described in the framework suggest preferred timing of if and when to implement adaptation options for the case studies investigated.

However, benefit-cost analyses are not the only economic approach available to evaluate economic impacts of climate hazards or adaptation strategies. In certain circumstances, cost-effectiveness analysis may be sufficient and preferable to benefit-cost analysis, especially when not all benefits are quantifiable or measurable. The Hazus Program[3], managed by the Federal Emergency Management Agency's (FEMA's) Natural Hazards Risk Assessment Program, is a nationally standardized economic framework for evaluating risk that addresses cost effectiveness. Hazus identifies areas with high risk for natural hazards and estimates physical, economic, and social impacts of earthquakes, hurricanes, floods, and tsunamis. While not climate change-specific, it does address onshore and coastal flooding that are projected to worsen with climate change. Hazus can quantify and map risk information for physical damage, economic loss, social impacts, and cost-effectiveness.

[1] NOAA (2013). *What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure*. PDF
[2] ADCCEE (2012). *Economic framework for analysis of climate change adaptation options*. PDF
[3] FEMA (n.d.). *What is Hazus*?. Web

General Information:
Broader Economic Guidance for Regional Adaptation Planning (Part 2)

In other cases, a multi-criteria assessment may be the most appropriate application. The Economics of Adaptation (ECONADAPT)[4] project is a research project funded by the European Union's Seventh Framework Programme (FP7). The objectives are to build the knowledge base on the economics of adaptation to climate change and to convert this into practical information for decision makers, in order to help support adaptation planning. Multi-criteria assessments are evaluated and incorporated into their modeling framework.

The United Nations Framework Convention on Climate Change's (UNFCCC) economic guidance document[5] provides an introduction to a range of different assessment approaches and methodologies and shares best practices and lessons learned. This publication elaborates on the role and purpose of assessing the costs and benefits of adaptation options; introduces a range of key methodological issues; and explains the most commonly used assessment approaches.

[4] EC FP7 (n.d.). *ECONADAPT: The Economics of Adaptation*. Web
[5] UNFCCC (2011). *Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches*. PDF

A **fiscal impact analysis** (FIA; Figure 2a), sometimes referred to as a fiscal analysis or implementation cost analysis[8], compares the anticipated changes in governmental expenditures (e.g., staffing, infrastructure maintenance, operation of public facilities) to the changes in governmental revenues (e.g., sales tax, transient occupancy tax, development fees) as a result of implementing the adaptation strategy or scenario. Results of an FIA are aggregated into a single result, net present value (NPV), which permits a comparison across adaptation strategies or scenarios.

A **benefit-cost analysis** (BCA; Figure 2b), also known as a cost-benefit analysis, may be used when the costs and benefits can be monetized. However, it can often be difficult to monetize the benefits associated with adaptation strategies, especially for non-market goods and services. In some instances, these difficult to quantify benefits may be excluded from the analysis. The output of a BCA compares the aggregated benefits and costs of a strategy using a benefit-cost ratio (BCR). BCRs permit users to compare results across different adaptation strategies or scenarios

A **cost-effectiveness analysis** (CEA; Figure 2c) is used to compare adaptation options to determine the least costly path forward to achieve a desired adaptation objective. CEAs differs from a BCA in that only the costs are monetized and provided in relation to some pre-defined target as defined by the adaptation objective. As such, only those adaptation

Definition(s)

Adaptation Objective: Success target defined for adaptation options and "defined in terms of reducing vulnerability or achieving a certain level of adaptive capacity or resilience." (UN 2010)

[1] CalOES (2010). *California Adaptation Planning Guide*. PDF

[8] Detailed methodology for conducting an implementation cost analysis for mitigation measures included in climate action plans are identified in Technical Appendix IV of SANDAG's Regional Climate Action Planning (ReCAP) framework. However, the implementation cost analysis framework for ReCAP only considers changes in governmental expenditures and excludes changes in revenues.

strategies that reasonably achieve the objective should be included in the analysis. Outputs from a CEA are expressed in a dollar-per-unit value such as cost per homes protected or cost per life saved. These results also allow users to compare across adaptation strategies or scenarios to determine the most cost-effective option(s).

Multi-criteria analyses (MCAs; Figure 2d) are not exclusively an economic approach and are only considered an economic analysis when one or more criteria represent an economic characteristic (e.g., costs or benefits). A MCA can be used when the economic analysis is expected to analyze multiple objectives using both monetary and non-monetary criteria or when the costs and benefits of adaptation strategies cannot be monetized. Economic criteria may be measured qualitatively, such as with a "low-medium-high" ranking, or quantitatively. Quantitative inputs can be actual dollar values or the output of a BCA or CEA. The prioritization tool developed as part of this HIATRS project is an example of a MCA and illustrates how some qualitative economic criteria may be incorporated into a broader analysis.

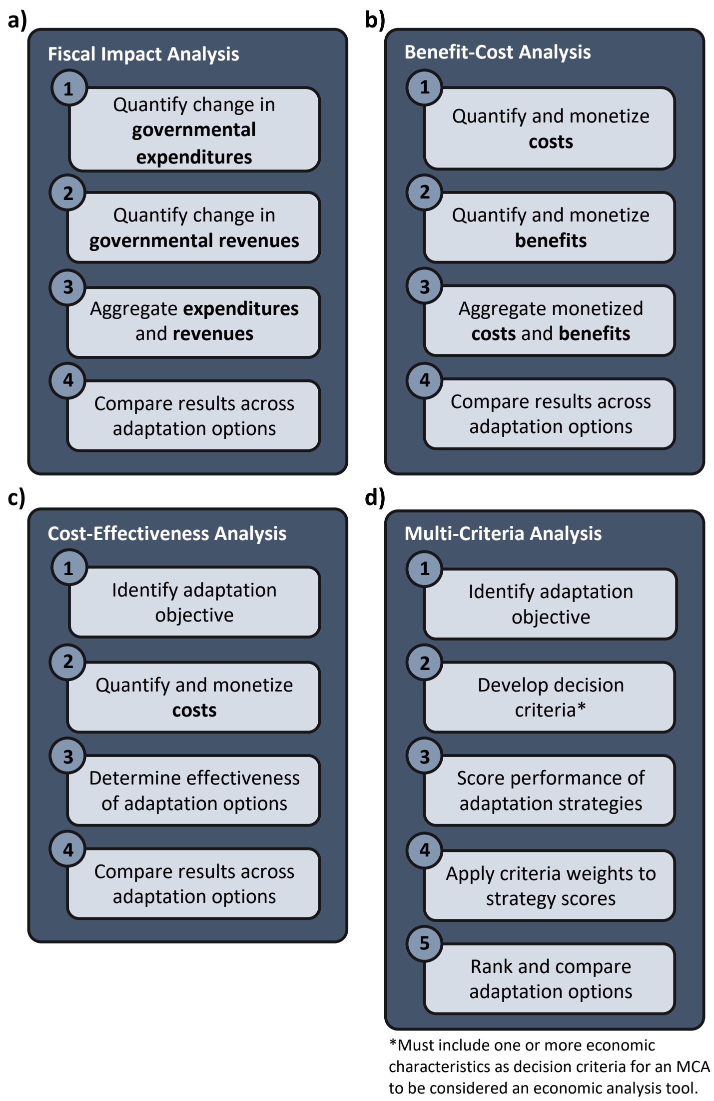


Figure 2. General Methods for Economic Approaches to Assessing Climate Adaptation

Which economic approach is appropriate?

The economic approach(es) selected for the economic analysis should reflect the priorities of the agency for which it is being performed. These priorities may differ based on geography, demographics, socioeconomics, and/or environmental and political concerns. At this stage, users should determine what specifically they are trying to accomplish with the economic analysis. How does the user anticipate applying the results of the analysis to meet the needs of the agency?

Table 5 identifies examples of specific needs that may apply to an agency and the economic approach(es) available to the user that would provide useful outputs.

Table 5. Economic Approach(es) to Meet Agency Need(s)

Example Agency Need(s)	FIA	BCA	CEA	MCA
Identifying impacts on local government budget?	X			
Identifying the lowest cost option among multiple strategies			X	X
Comparing costs of strategies to other, non-monetary outcomes			X	X
Comparing costs of strategies or the costs *and* benefits		X		X
Show benefits of a specific project		X		X
Comparing strategies using more than just economic criteria				X

If multiple economic approaches are available to address the same objective and the user is unable to decide which economic analysis approach is appropriate for their situation, a decision tree such as shown in Figure 7, can be used.

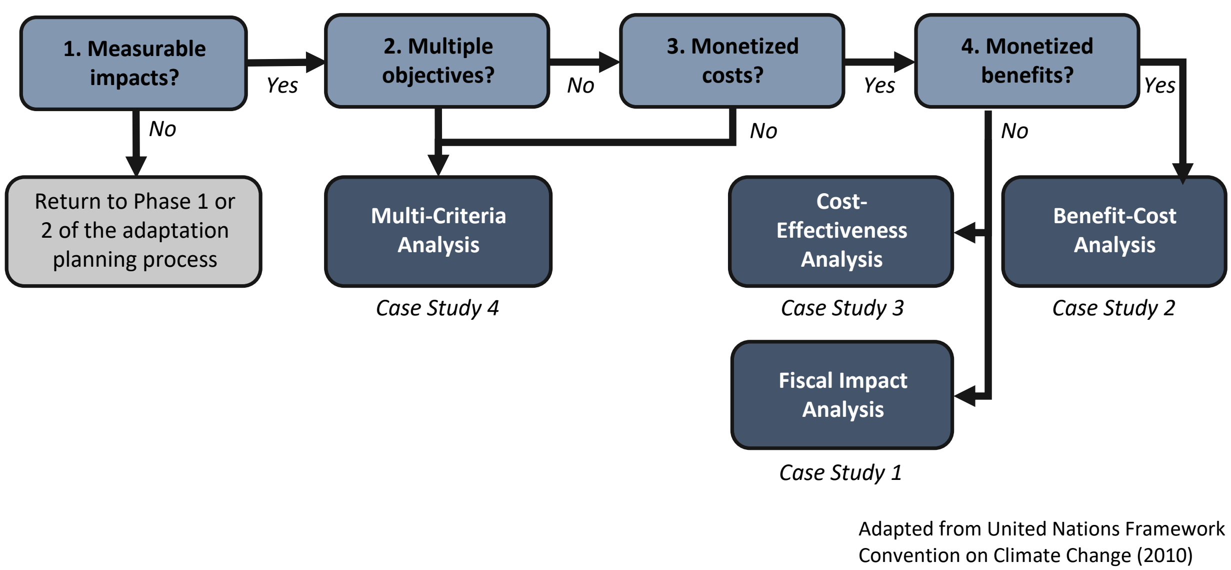


Figure 3. Decision Tree to Select Economic Approach for of Adaptation Planning

This decision tree provides simple questions to help determine which approach is appropriate to use given the objective(s) and parameters the user has identified for the analysis. The following section describes possible responses to the questions in the decision tree followed by an example using a climate hazard impact expected for the San Diego region.

1. ***Are the impacts measurable?***
   Climate hazard impacts must be measurable in order to assess how well a particular adaptation strategy or scenario is expected to reduce those impacts. For example, can the user quantify the number of structures flooded during increased precipitation events? Are there estimates on the increased number of acres expected to burn annually because of increased wildfire risk? Does the user know what municipal assets will be inundated during sea level rise storm surge events? A statement like "0.5 meters of projected sea level rise will reduce public safety" is not considered a measurable impact since it does not indicate how and to what extent public safety is reduced. Identifying the number of critical facilities damaged by sea level rise or the miles of roadway flooded are examples of measurable impacts.

   The information necessary to answer this question should be provided in a vulnerability assessment. Where it is not, it is recommended that users begin or return to earlier stages of the adaptation planning process to identify and measure their jurisdiction's climate hazard impacts before proceeding further with an economic analysis.

2. ***Are there multiple objectives? Or, how many objectives are to be met?*** Is the user interested in analyzing the costs to implement strategies alongside the potential to reduce inequities? Should strategies that address sea level rise *and* temperature increases *and* changes in precipitation be analyzed collectively?

   If the answer to this question is yes, then a multi-criteria analysis is the appropriate economic approach to use.

3. ***Are the costs monetized?*** Can data be obtained for the costs to construct and maintain a cooling center? Can the user estimate the cost to design and adopt a land use policy that restricts development in high wildfire risk areas?

   If the answer to this question is yes, then the costs of adaptation strategies to be included in the analysis have been or can be expressed in dollars; users can proceed to Question 4. If the answer is no, then a multi-criteria analysis should be used, as it can rely on qualitative data only.

4. ***Are the benefits monetized?*** Can the value of homes protected from flooding be estimated? Can the avoided repair costs be estimated for city assets buffered from increased wildfire risk? This is often the most challenging task, especially for those benefits that have non-market values (e.g., ecosystem services) or where assigning a dollar value may be controversial (e.g., the value of a human life).

   If the answer to this question is yes, then the monetary benefits of adaptation strategies to be included in the analysis have been or can be expressed in dollars and a user can proceed with a BCA. If the answer is no, users can conduct a FIA, if only interested in costs to the agency, or CEA, if interested in all costs incurred.[9]

[9] In reality, a MCA can be used if the costs and/or benefits are monetized. To do so, monetary values would need to be converted into a qualitative metric that can be aggregated or compared against other qualitative variables. It is recommended that this only be done when other objectives are included; otherwise, a BCA or CEA is preferred.

There are similarities in how these analyses fit into the broader adaptation planning process, but it is important for users to understand the differences across each approach (Table 6).

Table 6. Strengths and Weaknesses of Economic Approaches

Economic Approach	Strengths	Weaknesses
Fiscal Impact Analysis (FIA)	• Simple design and structure • Minimal inputs to monetize	• Limited scope
Benefit-Cost Analysis (BCA)	• Comprehensive assessment of costs and benefits • Converts all considerations to a common metric (dollars)	• Difficulty in monetizing many benefits • Subjective selection of discount rate may influence results
Cost-Effectiveness Analysis (CEA)	• Not necessary to monetize benefits • Compares all options using a commonly understood metric (dollars/unit)	• Single objective may not apply to all adaptation options • May disproportionally prioritize technical solutions over “soft” solutions
Multi-Criteria Analysis (MCA)	• Allows for non-monetized inputs • Wide range of criteria available, including equity	• Scoring and weighting is subjective • High degree of uncertainty

San Diego Region Example

A planner for the City of XYZ went through the framing process defined in Section 3 and identified that the increase in extreme heat events (*climate hazard*) their community is expected to face is currently the community’s only concern that must be evaluated through an economic analysis. Because of increased extreme heat events, the city is anticipating an increase in adverse public health impacts, reduced economic activity, and adverse impacts to local infrastructure (*climate hazard impacts*). Several adaptation strategies were developed to mitigate these impacts including:

A. Transit Stop Shade Structures: Coordinate with the transit system operator to install 40 new shade structures and transit stops by 2030
B. Expand the Urban Forest: Plant xx trees annually through 2045 in public parks and rights-of-way to shade nearby structures, including transit stops.
C. Residential Building Weatherization: Implement a residential building weatherization incentive program where homeowners can receive up to $3,000 to install energy efficient upgrades such as windows and insulation based on their home’s vintage
D. Public Outreach and Education: Develop and host two spring and summer workshops (annually) to educate local residents and businesses on the dangers of extreme heat events and the precautions they can take to avoid heat-related illnesses.

Using this case example, Table 7 illustrates scenarios based on certain needs a user may have and which economic approach would be most appropriate to address that need.

Table 7. Case Example – Scenarios and Appropriate Economic Approach

Needs Scenario	FIA	BCA	CEA	MCA
Illustrating the impacts on government revenues and expenditures as a result of implementing the strategies to mitigate extreme heat events	X			
Compare strategies to determine which provide the greatest overall benefit to the community relative to the cost to implement		X		
Given limited funding, identify which strategy can be implemented at the lowest cost while still reducing incidences of heat-related illness			X	
Evaluate strategies based on their cost and ability to support those most vulnerable to extreme heat events				X

4.2 Identifying Timeframe(s)

Guiding Questions (5-6 of 8):

5. When will adaptation strategies be implemented and what is their life cycle?

6. For what duration will each adaptation strategy be effective?

As noted in the APG, "*Adaptation planning efforts should look far enough ahead to evaluate the climate change effects that may affect systems and assets over the course of their lifetimes and contain policies that can adequately protect them. The adaptation planning process's horizon should be long enough to ensure that the effort can build meaningful resiliency.*" The economic analyses should be applied in a timeframe consistent with the objectives of planning process.

Climate adaptation planning necessarily involves evaluating potentially uncertain events occurring in the future. To address this, certain vulnerability assessments, such as for sea level rise, will examine scenarios with timeframes determined by regulations (e.g., AB691, Coastal Commission Guidance). For many other vulnerability assessments, there may not be a specific timeframe; therefore, the timeframe for economic analyses should be based on available data. For example:

- Sea level rise: USGS CoSMoS[10] provides coastal flooding data in 0.25 meter increments that can be matched with projected years from Ocean Protection Council sea level rise projections provided in years.
- Extreme precipitation: CalAdapt[11] provides forecasts of extreme heat days, extreme precipitation days, and extended drought scenarios (among others). This data is provided by frequency of events and timing during the month and year.

As revealed by the data sources, the timeframe for analyses can occur across a broad time scale or be discreet. It is recommended that the time period for analysis match the climate hazard impact being

[10] USGS Coastal Storm Modeling System (CoSMoS)
[11] CalAdapt

evaluated (e.g., time horizons included in the vulnerability assessment) and the need to take action (e.g., when should adaptation strategies be implemented).

General Information:
Timeframes in Planning Documents

- Capital improvement plan: 1 to 5 years.
- Local hazard mitigation plan: 5-year minimum, but often includes longer-term strategies.
- Specific plan: Varies depending on the project, but often 15 to 30 years.
- General plan: 20 to 40 years; projections used to inform policies can go out to 2100.
- Climate action/adaptation plan: Varies, but usually at least to 2050, and often to 2100.

If a specific timeframe for the economic analysis is not known, users can consider selecting a forecast period in the short, medium, and/or long-range, or one that aligns with similar planning documents (refer to green box at right). Short-range economic analysis for adaptation planning typically cover the immediate future (up to five years) to account for short-term impacts identified in vulnerability assessments, Capital Improvement Projects, and Local Hazard Mitigation Plan implementation actions. A medium-range forecast usually covers a period from five to 30 years. The forecasts may follow General Plan updates or updates in US Census data. A long-range forecast would be more than 25 years to address long-range planning issues where greater uncertainty may exist. These recommendations do not need to be hard and fast rules. For one agency, short-range may be less than one year and long-range may be more than five years. The main point is that timeframes are tied to uncertainty. In general, the shorter the timeframe, the greater the certainty.

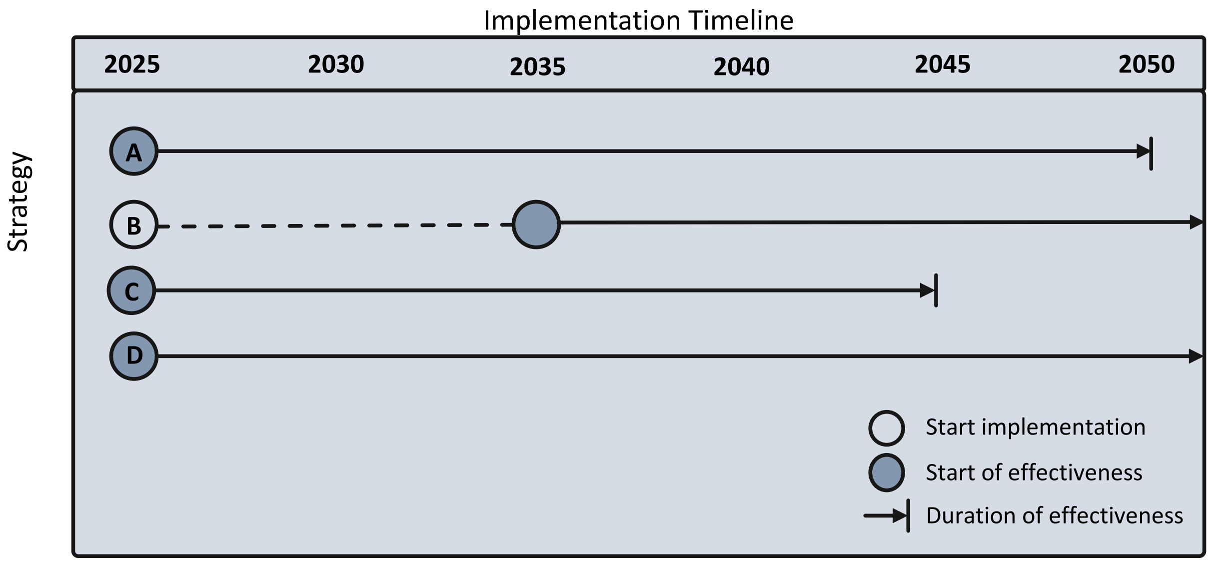
Once a user is aware of the overall timeframe for their analysis, they can begin to ask questions that indicate how adaptation strategies and scenarios align with that timeframe. Economic analyses apply a discount rate to future dollars and ignoring or mischaracterizing when strategies will be implemented can have significant impacts on results (refer to the ***Discount Rates*** box on page 23 for more information).

First, users should consider when adaptation strategies will be implemented and what their life cycle looks like. Will the strategy be implemented in the next year, five years from now, or some other time in the future? Additionally, will the strategy require one time implementation or will it require ongoing effort? Certain strategies (such as infrastructure projects) are one-time events where, aside from any ongoing operations and maintenance, the project is built and the full benefit is received right away. Other strategies may be phased in over time to accommodate changes in climate effects and growth within the community.

Second, users must determine the duration for which adaptation strategy is effective at mitigating climate hazard impacts. Certain strategies may be effective in the short-term, but may become ineffective as climate hazards worsen over time. For example, beach sand nourishment may protect the coastal environment from increasing sea level rise up until sea levels have reached a certain height. At this point, a new strategy, such as a sea wall, may be necessary (refer to Phase 4 of the APG process in section 2.1). Other strategies may take some time to become effective once implemented. For example, planting trees to shade nearby buildings will require a certain amount of years before the trees grow to a size sufficient to shade the structure.

San Diego Region Example

Building on the case example introduced in Section 4.1, a stylized timeframe and life cycle of the adaptation strategies is presented in Figure 4.



A. Transit Stop Shade Structures
B. Expand the Urban Forest
C. Residential Building Weatherization
D. Public Outreach and Education

Figure 4. Case Example – Adaptation Strategy Timeframes and Life Cycles

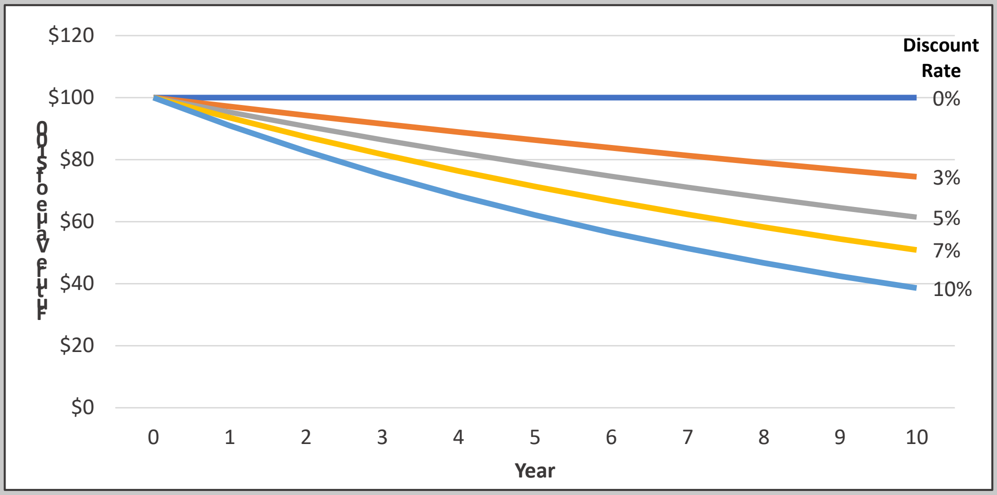
In this example, implementation for each adaptation strategy is expected to being in 2025 and three of the strategies (A, C, and D) will begin to address the hazard impact immediately. Strategy B, however, will not be effective at reducing the impacts of extreme heat events until 2035, ten years after initial implementation. This delay accounts for the time necessary for trees to grow to a certain height and canopy size before they can provide critical shade benefits.[12]

Additionally, the length of time at which each strategy can effectively mitigate the climate hazard impacts differs. Strategies B and D are expected to provide benefits well beyond the 2050 timeframe used here. However, strategies A and C become ineffective at or before 2050. The figure illustrates that transit shelters will become ineffective in 2050 and residential building weatherization upgrades by 2045. Depending on the circumstances, this can be for one of two reasons. First, the project reached the end of its useful and is at a point where it needs to be replaced to remain effective. Second, the external conditions (e.g., outside temperature) have change enough to render the strategy insufficient. For example, transit stop shelters may not cool be able to protect waiting passengers from temperatures that exceed a certain level.

[12] The example provided here is stylized and the actual timeframes and lifecycles for specific measures will differ.

Advanced Information:
Discount Rates

Discount rates are a critical, user-defined parameter for economic analyses and are used to convert future values to present worth. The discount rate selected for an analysis can have a significant effect on the results. Higher discount rates lower the value of future welfare (i.e., lessens the value of future dollars relative to present), while the lowest discount rate (0%) treats future values the same as present values. Additionally, higher discount rates tend to make projects less attractive when costs are paid upfront and benefits are spread out over many years.



Future Value of $100 Dollars

Which discount rate to use can be a fairly complex question to answer. Economists are in disagreement over appropriate rates to use in climate change analyses, especially when dealing with long time horizons. Historically, discount rates have been tied to market-based rates. According to the U.S. Environmental Protection Agency (EPA), projects within a short to medium lifespan (less than 50 years) are assigned a discount rate of approximately 3%, derived from consumer time preferences based on the interest rate of a risk-free asset, such as a government bond.[1] Conversely, the federal Office of Management and Budget (OMB) assigns a standard discount rate of 7%, derived from the opportunity cost of private capital, measured by the before-tax rate of return to investment, for projects with similar lifespans.[2]

However, others have argued that these higher rates reduce intergenerational equity by deemphasizing the welfare of future generations. Using equity considerations as the basis for forming a discount rate, much lower rates have been identified. For instance, the Stern Review on the Economics of Climate Change identified a 1.4% discount rate to be appropriate.

4.3 Identifying Costs and Benefits

Guiding Questions (7-8 of 8):

7. Who will incur costs to implement the adaptation strategies?

8. Who will receive the benefit(s) from the adaptation strategies?

Costs and benefits are the primary inputs for any economic analysis, and this section will help identify who is likely to realize a cost or benefit and examples of what those cost or benefits may be. In many instances, the benefits of an adaptation strategy or scenario will be *avoided costs*. Avoided costs represent those costs that the agency or community would incur if no adaptation strategies were put in place. For example, the damage caused to homes burned during wildfires will be included as costs under the baseline scenario. If the agency adopts a strategy that protects homes from wildfire risk, the benefit of the strategy will be included as the avoided damages homes would have otherwise experienced.

Collecting data on costs and benefits may require the user to work with staff from other departments to estimate the expected costs and/or benefits associated with climate adaptation strategies. Data may also be collected through researching relevant external sources, such as case studies and current literature, or by relying on an experience economist. It is important for users to communicate with those conducting the economic analysis to identify their role in the data collection process and what information they may be able to provide.

Costs

Estimating the costs of adaptation strategies or scenarios is an important step, no matter the economic approach a user chooses for their evaluation. Using the list of strategies identified in Section 3.2, users can begin to identify who is going to be involved in the implementation of the strategy (direct costs) and who may be required or encouraged to undertake some type of activity because of the strategy (indirect costs).

Table 8 categorizes who will likely incur some type of cost based on the five types of adaptation strategies and examples of what those costs might include. To identify specifics for their analysis, users can ask: “what is being asked of each party (e.g., agency, public sector, private sector) in the adaptation strategy to make sure it is successful, what actions are required for them to complete that ask, and what resources do those actions require?”

Table 8. Example Costs by Type of Adaptation Strategy and Who will Pay

Adaptation Strategy Type	Who is likely to incur cost(s)?	Cost Examples
Capital Improvement & Infrastructure Projects	Agency	Project design, permitting, construction, operations, maintenance, and administration
Programmatic	Agency	Program design, incentives paid out, and public engagement
	Public/Private Sector	Project design, permitting, construction, operations, and maintenance
Plans, Regulations, & Policy Development	Agency	Policy design, public engagement, consultant fees, administration, and enforcement
	Public/Private Sector	Project design, permitting, construction, operations, and maintenance
Education, Outreach, & Coordination	Agency	Outreach program design, administration, public engagement, and informational materials
	Private Sector	Project design, permitting, construction, operations, and maintenance
Evaluation	Agency	Administration, consultant fees, and public engagement

Once users know who will be realizing costs, they can begin to explore what data and other information they have available to inform the economic analysis. Users may rely on cost data from past projects or activities, or have access to databases that approximate private project costs within their jurisdiction. For large capital improvement and infrastructure projects, an architecture or engineering firm can provide a more precise estimate on project costs.

As users identify costs, they should consider when they expect to realize those costs as they implement adaptation strategies. To do this, a user should decide if costs are one-time (e.g., project design and construction costs) or ongoing (e.g., operations and maintenance costs). It is equally important to determine when implementation of the strategy is expected to start. Developing a timeline for each strategy or scenario may be a useful way for users to illustrate what costs are incurred and when.

Benefits

Estimating the benefits of climate adaptation is necessary when conducting a BCA and may apply when conducting a MCA, if the benefits are part of the evaluation criteria list. As is with the costs, users can begin by reviewing the adaptation strategies identified in Section 3.2 to evaluate who is expected to receive the benefit(s). Table 9 categorizes who is likely to be the direct beneficiary of adaptation strategies based on the type of strategy and examples of what those benefits might include.

Table 9. Example Benefits of Adaptation Strategies

When Adaptation Strategy Protects or Provides:	Benefit Examples	Who is likely to benefit?
City Assets	Avoided damage to facilities and infrastructure	Agency
Private Assets	Avoided damage to structures such as homes and businesses	Private Sector
Infrastructure	Avoided damage to public infrastructure such as roadways	Agency and Public Sector
Habitat	Avoided damage to and/or increased acreage in quality habitat	Community-wide
Aesthetics	Retention of community character and aesthetic value	Community-wide
Recreational Opportunities	Use value of protected, enhanced, or new recreational sites such as parks and beaches	Community-wide
Critical Ecosystem Services	Inherent value provided by functioning ecosystems such as increased water quality	Community-wide
Public Health	Reduction in public health risks and avoided lives lost such as heat-related deaths	Community-wide

Once the "who" has been identified, follow-up questions can be asked to identify if information is available that can put those benefits into dollar terms. For municipal and other public real estate assets, the user may work with other departments to determine their value. For more complex, community-wide benefits, there are methods available to ascribe a dollar value to these benefits; however, users should consult with an experienced economist to assist in this effort (refer to *Monetization Methodologies* box on pages 28 and 29 for a discussion on methods for monetizing benefits).

If the user identified co-benefits or indirect benefits that should be included in the analysis, it is suggested that they work with an economist or other expert to quantify these benefits. In some instances, assigning dollar values to co-benefits may be too difficult or controversial. If so, these benefits can be assessed qualitatively with other economic inputs in a MCA or discussed alongside economic results to provide additional context.

San Diego Region Example

This case example continues on with the case introduced in Section 4.1 and 4.2. At this stage, the planner is ready to identify who is going to incur a cost or receive a benefit and what those costs/benefits might be.

Costs in this example include both direct costs for adaptation strategies (e.g., the cost to the city to provide incentives) and indirect costs (e.g., the cost to homeowners to weatherize their home after incentives are received. Table 10 provides examples of typical costs that might be identified for adaptation strategies used in this case.

Table 10. Case Example – Example Costs

Adaptation Strategy	Who will pay for implementation?	Example Costs
A. Transit Stop Shade Structures	Agency	• Project design • Permitting • Construction • Ongoing maintenance
B. Expand the Urban Forest	Agency	• Program design • Tree planting • Watering • Annual pruning • Program administration
C. Residential Building Weatherization	Agency	• Incentive program design • Program administration • Incentives paid out • Public engagement
	Private Sector	• Project design • Construction/retrofit cost • Permitting
D. Public Outreach and Education	Agency	• Program design • Program administration • Outreach materials

The benefits in this example are the avoided costs that the city and community will no longer face, because adaptation strategies were adopted. Table 11 provides examples of avoided costs for the mitigated hazard impacts.

Table 11. Case Example –Example Benefits

Mitigated Hazard Impact	Examples of Avoided Costs

Reduced economic activity	• Loss in taxes
	  ○ Transient occupancy tax
	  ○ Sales tax
	• Decreased output from outdoor employment sectors
	  ○ Agriculture
	  ○ Landscaping
	  ○ Construction

Adverse public health impacts	• Urgent care costs • Emergency services (e.g., ambulance) costs • Loss of life

In addition, certain adaptation strategies may provide benefits beyond these avoided costs. In this case example, the residential building weatherization strategy will also provide energy bill reductions for those homeowners who use the incentive program to create a more energy efficient home.

Advanced Information:
Monetization Methodologies (Part 1)

There are four broad methodology categories identified here that can be used to monetize the impacts of climate change hazards, which include: hazard-specific valuation tools, economic or market data, non-market valuation methods, and a benefit transfer method.

Hazard-Specific Valuation Tools. Tools have been developed to assess many impacts associated with certain climate hazards. In some instances, these tools are part of the same resource or toolkit used to assess climate risk within a jurisdiction's vulnerability assessment. It is important that users review corresponding documentation to understand the cost and/or benefit values obtained from these tools and which impacts are and are not captured.

Economic or Market Data. Using economic or market data to value the costs and benefits associated with an impact is likely the most intuitive for individuals to grasp. Using this approach only applies to impacts that affect a market good or service. Market goods and services include things that are currently bought or sold in a marketplace. This includes many primary impacts associated with climate change, including the damage (or avoided damage) to buildings and other physical assets as a result of a wildfire or flooding event. Using this approach, the actual cost or benefit is estimated based on current marketplace data.

When applied to adaptation planning, the objective of non-market valuation methodologies is to capture the value, either cost or benefit, associated with climate change when the impact affects a non-market good or service. Non-market goods and services are not bought or sold in a market and the value is not revealed in market pricing. This includes many environmental impacts, such as ecosystem services provided by natural and working lands (e.g., recreation, flood protection) and some secondary impacts that affect the community (e.g., lost school hours, increased anxiety). There are two general approaches to non-market valuation: stated preference and revealed preference.

Stated Preference. Stated preference methods require surveys to estimate an individuals' willingness to pay (WTP) for a resource or their preferred ranking of individual aspects of a given resource (e.g., ecosystem services). WTP represents the perceived worth as stated by survey respondents. There are two commonly accepted forms of stated preference: contingent valuation and choice experiment.

Under contingent valuation, survey respondents are directly asked how their WTP to prevent the degradation of or to improve a resource. Similarly, they could also be asked how much they would be willing to accept in exchange for the loss of the resource. Survey results are then aggregated to represent a hypothetical market for the resource and determine an overall value or worth. However, with this method, considerable caution and care must be used in the development of the survey questions and methods to limit bias in responses. Contingent valuation surveys are also generally limited to the resource as a whole and typically are not used to evaluate individual ecosystem services.

Advanced Information:
Monetization Methodologies (Part 2)

Choice experiment methods do not directly ask for the WTP of survey respondents, but instead has them rank or rate a set of characteristics relevant to the resource in question alongside a price or cost. The WTP is then inferred from survey results. This approach can be challenging for some survey respondents if little background information or context is known at the time of the survey. However, this method can limit some of the bias, in the form of overstated preferences, found in contingent valuation survey results.

Revealed Preference. Unlike stated preference, revealed preference methods determine the value of a natural resource based on real market data rather than hypothetical markets. The primary downside to this is that non-use values (e.g., existence value) are rarely, if ever, captured. There are two typical revealed preference methods that can be applied to adaptation planning: hedonic pricing and travel cost.

Hedonic pricing generally relies on housing price data to estimate the value of an action. Under this method, a statistical analysis is conducted to determine the relationship between housing values and a defined set of environmental variables. The change in housing price as a function of a change in an individual environmental variable, holding all others variables constant, theoretically represents the value of that resource. However, this method is extremely data heavy and modeled relationships based on the data may not account for some external factors that might influence housing price.

The travel cost method also relies on large datasets, but to determine the amount of money individuals pay to visit or utilize a resource. Data is generally collected that shows the distance at which visitors travelled to get to the site and how often they frequent the site. This typically is only applied for valuing impacts to parks and other recreational areas.

Benefit-Transfer Method. Benefit transfer methodology is separate from the methodologies outlined above, as it relies on information already obtained through other studies conducted for different, but comparable, assets or resources. Values can be from any of the above type of analyses (e.g., non-market valuation or market data) and applied, or transferred, to a study area with similar conditions and characteristics. This method is mostly used in instances where resources (e.g., time and money) are limited. However, caution must be taken to ensure that values are transferred between comparable goods and/or services. If characteristics differ enough, the values may not be accurate and could significantly over or underestimate the costs and/or benefits associated with an impact.

5 | Understanding Results

Once an economic analysis has been completed, users should understand what the results mean in order to make fiscally sound decisions. This section describes typical results for each of the economic approaches and how to interpret them. The San Diego Region example is used to illustrate what the users would expect to see at the end of their economic analysis.

5.1 Fiscal Impact Analysis

A fiscal impact analysis indicates whether adaptation strategies can be expected to have a net positive or negative effect on the City's budget relative to existing conditions. Results of a FIA are presented as NPV, where the NPV is the sum of all future cash flows (discounted to present) in governmental expenditures and revenues associated with the adaptation strategy or scenario. Positive NPVs imply that the net change between expenditures and revenues result in an overall benefit to the agency (e.g., increased revenues exceed increased costs). Conversely, an adaptation strategy or scenario with a negative NPV has a net cost to the agency (e.g., increased costs exceed increased revenues) (Figure 5).

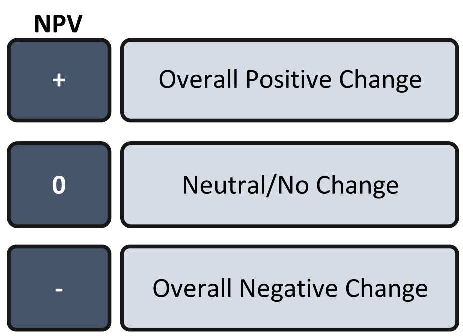


Figure 5. Understanding Net Present Values

San Diego Region Example

Revisiting the extreme heat events case example from Section 4, the planner had an experienced economist conduct a FIA to understand the overall fiscal impacts of each adaptation strategy. Results from the FIA are presented in Table 12.

Table 12. Example – Fiscal Impact Analysis Results

Adaptation Strategy	Net Present Value ($million)
A. Transit Stop Shade Structures	$9.8
B. Expand the Urban Forest	$2.5
C. Residential Building Weatherization	-$4.6
D. Public Outreach and Education	-$1.2
Total	**$6.5**

Results tell the planner that the first two adaptation strategies have an overall positive fiscal impact on the city relative to the baseline, no-adaptation scenario, and that the greatest positive impact comes from strategy A. Using strategy A as an example, the result indicates that increased revenue to the city, which may come from increased transit ridership and local tax collection from associated increases in local tourism and sales outweigh the expenditures the city incurs to implement the strategies, such as the capital cost of building shade structures. Conversely, strategies C and D come at a net cost to the city to implement. However, this does not imply that the city should not implement these strategies, as users may consider other criteria in the decision-making process. The planner can also refer to the total NPV to understand the collective fiscal impact of all adaptation strategies on the city.

5.2 Benefit-Cost Analysis

Results of a BCA for one or more adaptation strategies may be presented as the NPV and/or BCR. The NPV is the total benefits less the total costs, in present value, associated with an adaptation strategy or scenario. Given the uncertainty associated with monetizing benefits and analyzing cash flows over longer time horizons, the NPV is not an expression of the exact economic value to be expected in future years. In addition, the NPV can disguise a disparity in magnitude of costs and benefits across adaptation strategies, making it difficult to compare the relative cost-effectiveness across each.

The BCR is the preferred metric for a BCA when the analysis is being used to compare multiple adaptation options. It can be found by dividing the total present value benefits by total present value costs. A BCR greater than one indicates that the benefits of the strategy or adaptation scenario outweigh its costs (Figure 6). Conversely a BCR less than one indicates that the costs are greater than expected benefits.

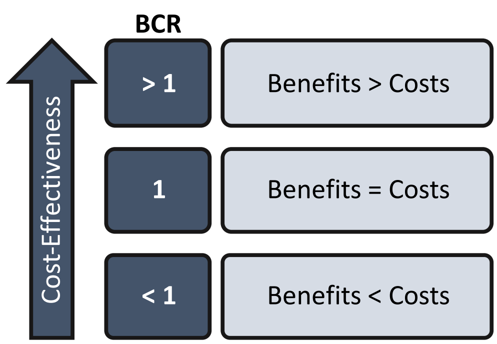


Figure 6. Understanding Benefit-Cost Ratios

San Diego Region Example

Revisiting the extreme heat events case example from Section 4, the planner had an experienced economist conduct a BCA to compare the costs and benefits of each adaptation strategy being considered. Results from the BCA are presented in Table 13.

Table 13. Example – Benefit-Cost Analysis Results

Adaptation Strategy	Benefit-Cost Ratio
A. Transit Stop Shade Structures	8.6
B. Expand the Urban Forest	2.4
C. Residential Building Weatherization	12.1
D. Public Outreach and Education	3.5

Results of the BCA, using the BCR metric, indicate that each of the strategies will provide an overall net benefit to the community, since all BCRs are greater than one. The planner can compare the BCRs across strategies to determine which provide the greatest benefit relative to costs by identifying strategies with larger BCRs, and apply this information into their decision-making process. For instance, strategies A and C provide a higher benefit per cost relative to strategies B and D.

5.3 Cost-Effectiveness Analysis

Results of a CEA are measured in dollars per unit, where the unit is defined by the adaptation objective. For example, an analysis that examines how cost-effective adaptation strategies are at protecting homes from wildfire risk will be measured in cost per home ($/home) or strategies that mitigate the impacts of extreme heat events may be measured in cost per life saved ($/life saved). Results for multiple strategies can then be compared to determine the least costly option to achieve the adaptation objective.

Figure 7 illustrates how to interpret results of a cost-effectiveness analysis. Adaptation strategies or scenarios with lower costs per unit are considered more cost-effective than those strategies or scenarios with higher costs per unit. Users may consider providing additional information alongside CEA results that illustrate the magnitude in impact that each strategy has (e.g., number of homes protected or lives saved) to provide additional context to decision-makers.

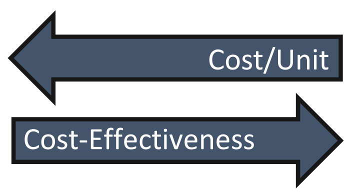


Figure 7. Understanding Cost-Effectiveness Results

San Diego Region Example

Revisiting the extreme heat events case example from Section 4, the planner had an experienced economist conduct a CEA to understand the cost of implementing each adaptation strategy and how that relates to avoiding heat-related illnesses as measured by hospital emergency room (ER) visitation rates. Results from the CEA are presented in Table 14.

Table 14. Example – Benefit-Cost Analysis Results

Adaptation Strategy	Cost-Effectiveness ($thousand per heat-related ER visit avoided)
A. Transit Stop Shade Structures	$250
B. Expand the Urban Forest	$324
C. Residential Building Weatherization	$425
D. Public Outreach and Education	$126

The table illustrates that strategy C has the highest cost per heat-related ER visit avoided. This compares to strategy D, which will prevent ER visits at a lower cost. The planner can pair these results with the estimated total number of heat-related ER visits avoided by each adaptation strategy to determine how many and which strategies are best to adopt given cost constraints.

5.4 Multi-Criteria Analysis

Results of a MCA provide a rank order of adaptation strategies or scenarios. This rank order is determined by both the decision criteria selected for the analysis and the weightings applied to those criteria. This rank comparison of options allows users to identify the strongest path forward (or highest ranked option) to achieve multiple adaptation planning objectives.

Figure 8. Understanding Multi-Criteria Analysis Results

San Diego Region Example

Revisiting the extreme heat events case example from Section 4, the planner had an experienced economist conduct a MCA using economic criteria (costs and benefits) and non-economic criteria (equity impacts, implementation feasibility, and political will) to understand the cost of implementing each adaptation strategy and how that relates to avoiding heat-related illnesses as measured by ER visitation rates. Results from the MCA are presented in Table 15.

Table 15. Example – Multi-Criteria Analysis Results

Adaptation Strategy	Rank
B. Expand the Urban Forest	1
C. Residential Building Weatherization	2
A. Transit Stop Shade Structures	3
D. Public Outreach and Education	4

Results from the MCA rank the adaptation strategies based on how well they met some or all of the criteria incorporated. Results tell the planner that strategy B, which ranked first, best balances the differing priorities integrated into the analysis. Conversely, strategy D ranked the lowest, indicating that, relative to the other strategies, it would not be the best option to meet the many objectives of the community.

6 | CONCLUSION

Economic analyses are an integral component in the adaptation planning process and necessary to make informed, fiscally responsible decisions in both the short- and long-term. Approaches identified here have long been applied in planning and include: fiscal impact analysis, benefit-cost analysis, cost-effectiveness analysis, and multi-criteria analysis. Users can use this guidance document to familiarize themselves with economic analyses within the context of climate change, select the appropriate economic approach or approaches for their situation, and identify the data and other inputs necessary to perform the analysis. Working with an experienced economist, users can leverage this information to tailor their economic analysis(es) to meet the needs of their agency or jurisdiction given their specific adaptation context.

The economics of climate adaptation, however, is only one of many crucial considerations to ensure decisions are also socially responsible. Socially responsible decisions require a holistic approach that integrates other crucial factors including equity, feasibility, and legal requirements. It is recommended that users review this document in partnership with other resources developed as part of this HIATRS project to make robust decisions in their adaptation plans, including the Equity Guidance Document, Prioritization Tool, and Implementation Toolkit.

Appendix A. Guiding Questions

Before Beginning the Analysis

- ☐ Vulnerability assessment completed (Phase 1 and 2 of the APG[13] Planning Process)
- ☐ Adaptation strategies identified (Phase 3 of the APG Planning Process)

Framing the Economic Analysis

1. What climate hazards should be addressed from an economic standpoint?

Evaluating the Economic Impact of Climate Hazards (Section 3.1)

2. What impacts from these climate hazards should be addressed from an economic standpoint?

Evaluating Adaptation Strategies (Section 3.2)

3. Which adaptation strategies should be included in the economic analysis?

Setting Up the Economic Analysis

Selecting the Appropriate Economic Approach (Section 4.1)

4. How will results of the economic analysis be applied?

Timeframe(s) (Section 4.2)

5. When will adaptation strategies be implemented and what is their life cycle?

6. For what duration will each adaptation strategy be effective?

Identifying Costs and Benefits (Section 4.3)

7. Who will incur costs to implement the adaptation strategies?

8. Who will receive the benefit(s) from the adaptation strategies?

[13] CalOES (2020). *California Adaptation Planning Guide*. PDF

Appendix B. DETAILED ECONOMIC METHODOLOGIES

The intent of this appendix is to provide detailed methodologies that, while simplified here, provide more insight into how climate change adaptation economic analyses may be constructed. It is recommended that users consult with economic experts to develop a robust path forward for their economic analysis or defer to tools already developed to support an economic analysis for adaptation strategies where appropriate.

B.1 Fiscal Impact Analysis

B1.1 Quantify Change in Governmental Expenditures

The change in governmental expenditures associated with implementing the adaptation strategies within each scenario must be considered and laid out along the timeframe(s) being considered for the analysis. This includes any administrative, planning, capital, and ongoing maintenance costs incurred by the agency.

Once all changes in expenditures have been identified, they are summed across all adaptation strategies within each scenario for each year and then discounted to a present value using the discount rate(s) selected for the analysis. Present value calculations for the change in expenditures are presented in Equation 4.

Equation 1. Present Value of Change in Expenditures

$$PV_{\Delta expend} = \Delta expend_{TN}/(1 + D)^{(N-Y_0)}$$

Where:

$PV_{\Delta expend}$ = present value of change in expenditures at year *N* for discount rate *D*
$\Delta expend_{TN}$ = total change in expenditures at year *N*
D = discount rate
N = year in which change in expenditures are being assessed
Y_0 = current year

Once present values have been calculated for expenditures in each year, the net present value (NPV) of expenditures for each adaptation scenario can be found by summing all present values. This value represents the total present value in expenditures as a result of implementing all adaptation strategies included in the adaptation scenario.

B1.2 Quantify Change in Governmental Revenues

Similar to expenditures, the change in governmental revenues associated with the adaptation strategies within each scenario must be considered and laid out along the timeframe(s) being considered for the analysis. This includes any changes in tax and fee revenue streams.

Once all changes in revenues have been identified, they are summed across all adaptation strategies in a scenario for each year and then discounted to a present value using the discount rate(s) selected for the analysis. Present value calculations for the change in revenues are presented in Equation 2.

Equation 2. Present Value of Change in Revenue

$$PV_{\Delta revenue} = \Delta revenue_{TN}/(1 + D)^{(N-Y_0)}$$

Where:

$PV_{\Delta revenue}$ = present value of change in revenues at year *N* for discount rate *D*
$\Delta revenue_{TN}$ = total change in revenue at year *N*
D = discount rate
N = year in which change in revenues are being assessed
Y_0 = current year

Once present values have been calculated for revenues in each year, the NPV of revenues for each adaptation scenario can be found by summing all present values. This value represents the total present value in revenues as a result of implementing all adaptation strategies included in the adaptation scenario.

B1.3 Aggregate Changes in Governmental Expenditures and Revenues

Once the change in costs and revenues have been identified for each adaption option in present value, the two pieces are brought together to understand the net fiscal impact. NPV is a metric commonly used to illustrate the relative cost-effectiveness when comparing multiple options (e.g., adaptation scenarios) against one another.

For each adaptation scenario, the NPV is found by summing the present value change in governmental expenditures and revenues using Equation 3.

Equation 3. Net Present Value

$$NPV = PV_{\Delta expend} + PV_{\Delta revenues}$$

Where:

NPV = net present value
$PV_{\Delta expend}$ = present value of change in expenditures
$PV_{\Delta revenue}$ = present value of change in revenues

B1.4 Compare Results Across Adaptation Strategies

Results of the FIA are meant to illustrate the net change in government expenditures and revenues across adaptation scenarios. They seek to answer the question: "Which set of adaptation strategies provides the most positive (or least negative) fiscal impact?" The total change in expenditures and/or revenues reported alongside the NPV may provide a greater sense of magnitude for action scenarios and their impacts.

Adaptation scenarios are compared to one another using calculated NPVs. The scenario with the highest NPV (most positive or least negative) is considered to have the best fiscal impact among the options. Conversely, the option with the lowest NPV (most negative or least positive) is considered to have the poorest fiscal impact among the options. All options that have a positive NPV indicate a net fiscal benefit to the agency, while negative NPVs indicate a net fiscal cost.

B.2 Benefit-Cost Analysis for Adaptation Strategies

B2.1 Quantify and Monetize Costs

The cost to implement the adaptation strategies included within adaptation scenarios must be considered and laid out along the timeframe(s) being considered for the analysis. This includes any administrative, planning, capital, and ongoing maintenance costs associated with each strategy.

Once all costs have been identified, they are summed across all adaptation strategies in an adaptation scenario for each year and then discounted to a present value using the discount rate(s) selected for the analysis. Present value calculations for costs are presented in Equation 4.

Equation 4. Present Value of Costs

$$Cost_{PVND} = Cost_{TN}/(1+D)^{(N-Y_0)}$$

Where:

$Cost_{PVND}$	= present value of costs at year *N* for discount rate *D*
$Cost_{TN}$	= total costs at year *N*
D	= discount rate
N	= year in which costs are being assessed
Y_0	= current year

Once present values have been calculated for costs in each year, the NPV of costs for each adaptation scenario can be found by summing all present values. This value represents the total present value cost to implement all adaptation strategies included in the adaptation scenario.

B2.2 Quantify and Monetize Benefits

One or more of the methodologies detailed in the *Monetization Methodologies* section (gray boxes on pages 28 and 29) should be used to assign dollar values to the impacts expected under the baseline scenario and each of the adaptation scenarios. How impacts are initially monetized does not differ when using an impact assessment or risk assessment. However, risk assessment values do require additional calculations when being incorporated to a BCA.

Impact Assessment. When using an impact assessment for the BCA, document the damage values for each climate hazard under each scenario. Damage values are then summed across climate hazards and impact type for each climate impact scenario.

The next step is to assess each adaptation scenario against the baseline scenario. This is done using Equation 5.

Equation 5. Benefits of Adaptation Scenario Relative to Baseline Scenario – Impact Assessment

$$Ben_T = IC_{NA} - IC_A + Ben_A$$

Where:

Ben_T	= total benefit
IC_{NA}	= baseline scenario damage
IC_A	= adaptation scenario damage

Ben_A = other benefits of the adaptation scenario

Risk Assessment. When using a risk assessment for the BCA, each climate hazard event included for each climate hazard is identified, along with its probability of occurrence and estimated damage values over the analysis timeframe(s). Expected damage values are then calculated using Equation 6.

Equation 6. Expected Damages of Climate Hazard Events

$$ED_X = AD_X * AP_X$$

Where:

ED_X = expected damage of event *X*
AD_X = annual probability of event *X* occurring
AP_X = average damage of event *X*

Adjustments to these calculations may be required for climate hazards with events that are not mutually exclusive for a given year (e.g., a 1-year and 100-year storm surge event can occur consecutively within the same year).

Expected damage values are then summed across all climate hazard events for each year and scenario and then compared to each adaptation scenario against the baseline scenario. This is done using Equation 7.

Equation 7. Benefits of Adaptation Scenario Relative to Baseline Scenario – Risk Assessment

$$Ben_T = ED_{NA} - ED_A + Ben_A$$

Where:

Ben_T = total benefit
ED_{NA} = baseline scenario expected damage
ED_A = adaptation scenario expected damage
Ben_A = other benefits of the adaptation scenario

Impact and Risk Assessment. The final step is to develop a full timeline of all expected damages and then discount them to present value using the discount rate(s) selected for the analysis. This may require extrapolating values linearly between key years used in the analysis. Discounting is done using Equation 8.

Equation 8. Present Value of Benefits

$$Ben_{PVND} = Ben_{TN}/(1+D)^{(N-Y_0)}$$

Where:

Ben_{PVND} = present value of benefits at year *N* for discount rate *D*
Ben_{TN} = total benefits at year *N*
D = discount rate
N = year in which costs are being assessed
Y_0 = current year

Once present values have been calculated for each year, the NPV for each adaptation scenario can be found by summing all present values. This value represents the total present value benefit (or cost) associated with each scenario.

B2.3 Aggregate Monetized Costs and Benefits

Once all impacts have been monetized and the costs of adaptation strategies have been identified, the two pieces are brought together to calculate BCRs. The BCR is a metric commonly used to illustrate the relative cost-effectiveness when comparing multiple options (e.g., adaptation scenarios) against one another and can provide a more complete picture for analysis.

For each adaptation scenario, the BCR is found by dividing the NPV benefits by the NPV costs using Equation 9.

Equation 9. Benefit-Cost Ratio

$$BCR = NPV_{benefits}/NPV_{costs}$$

Where:

BCR = benefit-cost ratio
$NPV_{benefits}$ = net present value benefits
NPV_{costs} = net present value costs

B2.4 Compare Results Across Adaptation Strategies

Results of the BCA are meant to illustrate the *relative* cost-effectiveness of adaptation scenarios and answer the question: "Which set of adaptation strategies is the most cost-effective in relation to costs and benefits at mitigating the risks of climate change?" Total benefits and costs reported alongside the BCR may provide a sense of magnitude for actions and their impacts; however, they do not indicate *actual* dollars to be incurred, and may be misleading to those unfamiliar with climate adaptation BCA.

For both an impact and risk assessment, adaptation scenarios are compared to one another using calculated BCRs. An adaptation scenario with a higher BCR value is considered to be more cost-effective than an adaptation scenario with a lower BCR value. In addition, BCRs that are greater than one signify that anticipated benefits of the adaptation scenario are greater than the costs; BCRs equal to one signify the adaptation scenario is cost neutral; and BCRs less than one signify the anticipated costs are greater than the benefits.

B.3 Cost-Effectiveness Analysis for Adaptation Strategies

B3.1 Identify Adaptation Objective

The adaptation objective defines how success of an adaptation strategy or scenario is to be measured. It is important that the same objective is used for adaptation scenarios that are to be compared to one another; as such, only those adaptation strategies that reasonably achieve the objective should be included in the analysis.

Data within the vulnerability assessment should be referenced to determine what adaptation objectives are supported. For instance, if a vulnerability assessment only quantifies the number of homes damaged by wildfire, then success of an adaptation scenario should be measured as the number of homes protected as a result of the adaptation strategy(s).

For each adaptation scenario, the level of success at achieving the adaptation objective should be identified. This is done by taking the difference between the number of units impacted under the baseline scenario (e.g., number of homes burned with no adaptation strategy in place) and the number of remaining units impacted under the adaptation scenario (e.g., number of homes still likely to burn even with an adaptation strategy in place). This is done using Equation 10.

Equation 10. Units Protected in Adaptation Scenario Relative to Baseline Scenario

$$US = UI_{NA} - UI_A$$

Where:

US	= units successfully protected
UI_{NA}	= units impacted under baseline scenario
UI_A	= units impacted under adaptation scenario

B3.2 Quantify and Monetize Costs

The cost to implement the adaptation strategies included within adaptation scenarios must be considered and laid out along the timeframe(s) being considered for the analysis. This is the same as the BCA methods identified in Section B2.1 and includes any administrative, planning, capital, and ongoing maintenance costs associated with each strategy.

Once all costs have been identified, they are summed across all adaptation strategies in an adaptation scenario for each year and then discounted to a present value using the discount rate(s) selected for the analysis. Present value calculations for costs are presented in Equation 11.

Equation 11. Present Value of Costs

$$Cost_{PVND} = Cost_{TN}/(1 + D)^{(N-Y_0)}$$

Where:

$Cost_{PVND}$	= present value of costs at year *N* for discount rate *D*
$Cost_{TN}$	= total costs at year *N*
D	= discount rate
N	= year in which costs are being assessed
Y_0	= current year

Once present values have been calculated for costs in each year, the NPV of costs for each adaptation scenario can be found by summing all present values. This value represents the total present value cost to implement all adaptation strategies included in the adaptation scenario.

B3.3 Determine Effectiveness of Adaptation Options

Once all impacts have been assessed to determine the level at which the adaptation objective has been met and the costs of adaptation strategies have been identified, the two pieces are brought together for a more complete picture and dollar per unit values are calculated. Dollar per unit values standardize adaptation scenarios across a common unit, which is a measure of the adaptation objective. This allows for comparison across scenarios to determine which is the most cost-effective at achieving the desired objective.

For each adaptation scenario, the dollar per unit is found by dividing the NPV costs by the measured level at which the adaptation objective is met using Equation 12.

Equation 12. Dollar per Unit

$$DPR = NPV_{costs}/US$$

Where:

DPR	= dollar per unit
NPV_{costs}	= net present value costs
US	= units successfully protected

B3.4 Compare Results Across Adaptation Strategies

Results of the cost-effectiveness analysis are meant to illustrate the *relative* cost-effectiveness of adaptation scenarios to one another and to answer the question: “Which set of adaptation strategies is the most cost-effective at achieving the stated adaptation objective?” It may also be helpful to report total costs and units protected alongside the dollar per unit metric to provide a sense of magnitude for each action scenario.

When comparing adaptation scenarios using a CEA, scenarios with a lower cost per unit ($/unit) are considered to be the most cost-effective at achieving the adaptation objective. However, relying solely on a cost per unit to select strategies may lead to selecting less desirable options. For instance, a set of strategies may be extremely cost-effective but only have the potential to achieve a minimal level of protection (or avoided damages) from the impacts of climate change. Pairing cost-effectiveness results with the total number of units protected can provide a more robust view of adaptation options and assist in identifying options that are both lower in cost and higher in benefit.

B.4 Multi-Criteria Analysis for Adaptation Strategies

B4.1 Identify Adaptation Objective(s)

MCAs use adaptation objectives similar to the objective used in a CEA. The primary differences here are that multiple objectives can be incorporated into the same analysis and objectives may be measured either quantitatively *or* qualitatively. This allows strategies to be integrated into the analysis that have impacts that are difficult to quantify and permits comparison across strategies that do not necessarily work towards achieving the same objective.

While data within the vulnerability assessment should be referenced to determine what adaptation objectives are supported, additional objectives may be considered provided there is sufficient evidence to support, at least qualitatively, how adaptation scenarios will achieve those objectives.

For each adaptation scenario, the level of success at achieving the adaptation objective(s) should be identified. How success is documented in a MCA will depend on whether or not quantitative or qualitative data is being used.

B4.2 Develop Decision Criteria

Decision criteria underscore those characteristics of adaptation strategies that users deem most important in evaluating options. This importance may be for practical reasons (e.g., cost or feasibility) or come through in discussions with community-based organizations (e.g., equity).

Each criterion included in the analysis should be documented for transparency purposes, including: description, units measured, and range in possible scores. There is no limit on the number of criteria included; however, adding additional criteria adds complexity to the analysis.

B4.3 Score Performance of Adaptation Strategies

Once all decision criteria have been identified, each adaption strategy or scenario must be evaluated against each of the criteria. In some instances, this may require a subjective evaluation, requiring subject matter experts to assist in evaluation.

The next step is to standardize across all criteria to account for the different units in which each set of criteria are measured. This process permits scores to be aggregated across criteria in later stages. Scores should be standardized to some numeric scale (e.g., 0-1, 0-100) so that criteria weights may be applied.

B4.4 Apply Criteria Weights to Strategy Scores

Some decision criteria may be more important to one agency than others. Criteria weights adjust the level of impact each criterion has in the final score for an adaptation option based on each criterions level of importance. For instance, users may wish to apply a higher weighting to equity-related criteria relative to cost-related criteria. Weights should be assigned as a percentage (or as a numeric value between 0-1), with the sum of all decision criteria weights equal to 100% (or 1).

A final, single score is calculated for each adaptation strategy or scenario by summing weighted criteria scores using Equation 13.

Equation 13. Weighted Criteria Scoring

$$S_F = (\omega_{C1} * S_{C1}) + (\omega_{C2} * S_{C2}) + \cdots + (\omega_{Cn} * S_{Cn})$$

Where:

S_F = final score
ω_{C1-n} = criteria weight for criteria 1 through n
S_{C1-n} = criteria score for criteria 1 through n

B4.5 Rank and Compare Adaptation Options

Once all adaptation options have been scored, results are ranked and then compared. The option with the highest final score is ranked first and the lowest score is ranked last. This rank order allows users to easily identify the strongest path forward (or highest ranked option) to achieve adaptation objectives based on the decision criteria and weighting applied.