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CHAPTER 26

Adapting to Climate Change

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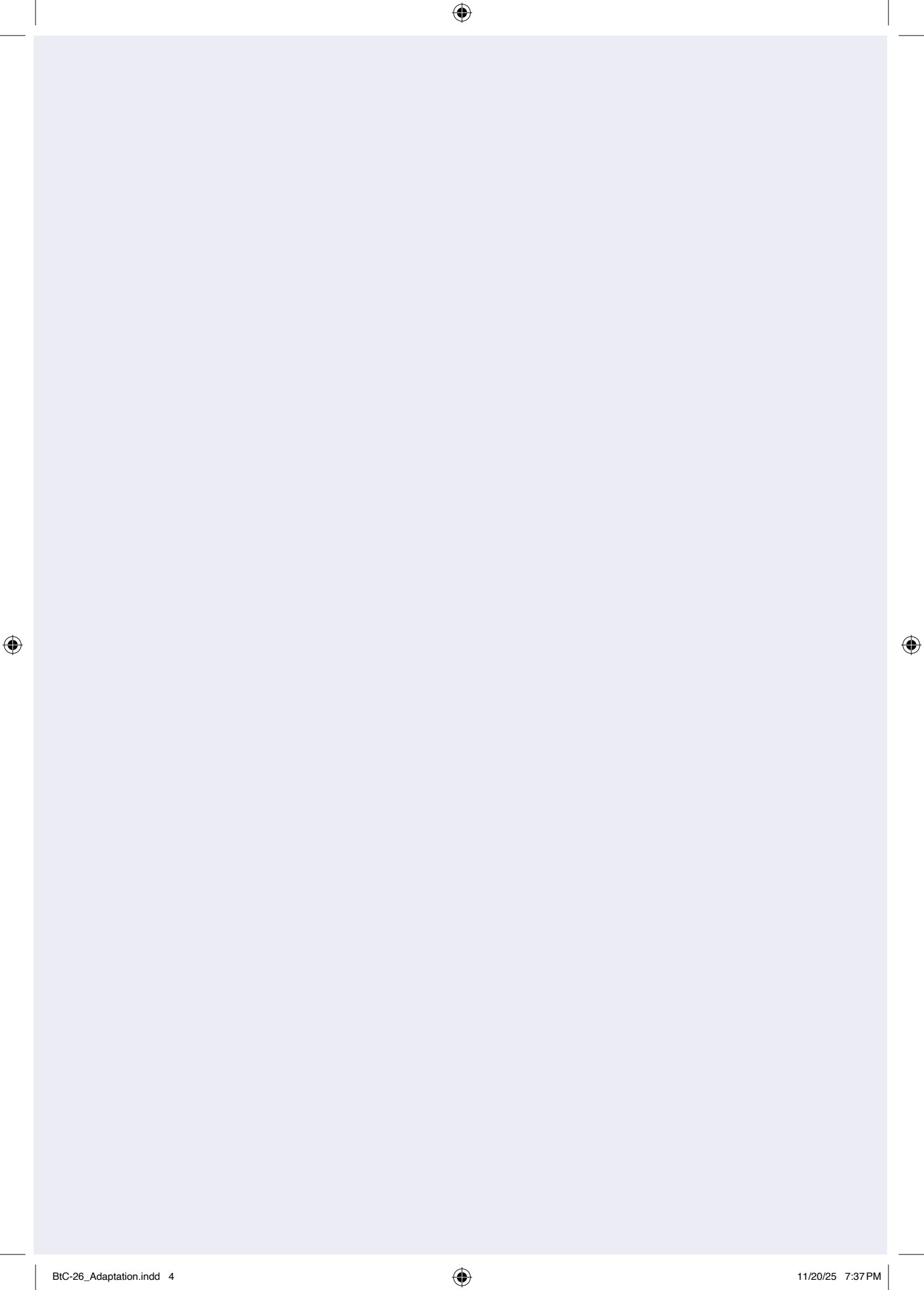


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Learning Objectives

1. Identify climate adaptation activities, and understand why adaptation to climate change is necessary.
2. Categorize different ways people and organizations are adapting to climate change, and describe the contexts where different approaches are best used.
3. Describe different metrics for evaluating what “good” or “effective” adaptation entails, and understand the challenges underlying comprehensive evaluation.
4. Describe the barriers to more widespread, equitable, and effective implementation of adaptation activities.

Overview

Climate change adaptation describes numerous ways that people and organizations can reduce the risks of current and future climate impacts. By altering their behavior, adopting new technologies, developing new institutions, and enhancing ecosystem services, people are finding ways to respond to increased temperatures and the diverse cascading effects they cause, like more regular floods, droughts, and wildfires. This chapter will teach students to identify different types of climate adaptation activities and understand the many roles different organizations play in adaptation. It will also cover the need for more transformative and proactive adaptation, highlight ways that governments and organizations can support more widespread adoption of adaptation, and describe ways to evaluate whether we are adapting enough. Finally, it will describe numerous psychological, institutional, financial, and political barriers to more widespread climate adaptation. Throughout the text, examples of real adaptation activities implemented in California and elsewhere will be used to illustrate the diversity of ways people are already adapting to climate change.

26.1 What Is Climate Adaptation, and Why Do We Need It?

Climate change is here, and it is going to get worse. Under all likely scenarios of greenhouse gas emissions over the next century, the world is extremely likely to face severe impacts to ecosystems and economies worldwide. At 2°C (3.6°F)—the warming target set by international climate policies—extreme weather events are expected to become more frequent and damaging, and unique ecosystems are at risk of becoming extinct. If warming accelerates to 3°C (5.4°F)—our current trajectory—or beyond, aggregate impacts to the economy and ecosystems around the world are high. And at all likely temperature thresholds, the unequal impacts of climate change are likely to get worse at all scales, with poorer, frontline communities and countries in the global South facing more risks than wealthier ones. This is why mitigation is so important: every fraction of a degree that we avoid through reduced greenhouse gas emissions, carbon capture, or other mitigation efforts means less damage, less suffering, and more time to adapt to the changes.

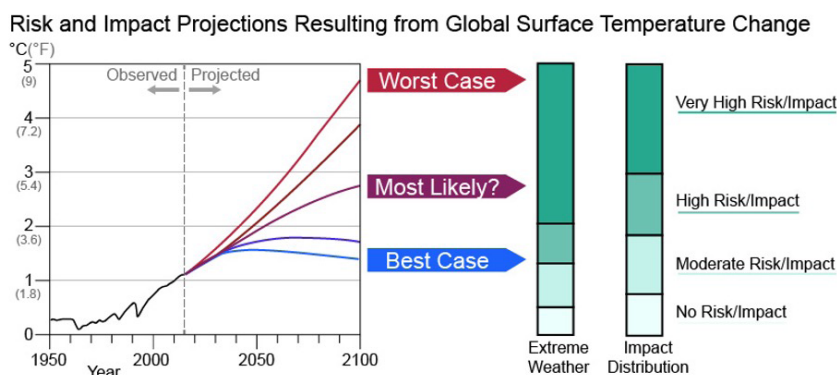


FIGURE 26.1.1. Future societies will face increasing risks from extreme weather and increasingly uneven distribution of impacts across space. Exactly how large the increase in projected risk is (right) depends on how much the global temperature continues to warm (left). Image adapted by Ryan J. McCarty from IPCC 2022.

While we are mitigating, we need to take action to adapt. Projected increases in climate-associated risks all assume that people will not change anything about where or how we live. But, people can reduce the impacts of climate change on their health, the economy, or the environment by altering their behavior, institutions, and technology in ways that lessen the physical impacts of climate risks and build their capacity to respond to future risks. This is called **adaptation**, which IPCC 2021 more formally defined as “the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.” For example, knowing that wildfires are going to become more frequent and intense, a person might choose to build their home with fire-resistant materials, subscribe to fire-warning media alerts, join a neighborhood network to assist with evacuation and recovery, or move to a new location farther from the wildland-urban interface. Through each of these actions, the individual is lessening the potential for a wildfire to damage their home and/or increasing their capacity to recover if a fire hits.

Adaptation is often considered one approach to help improve the **resilience** of human or environmental systems. IPCC 2021 describes resilience as the “capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.” Importantly, resilience is not always beneficial. If the system that is being maintained isn’t sustainable or equitable, resilience may hinder more effective or transformational adaptation. For instance, continually rebuilding houses that are destroyed in a hurricane is resilient—maintaining the same function, identity, and structure—but perhaps moving those people to a new location would be more beneficial for the residents or society as a whole. Likewise, an ecosystem dominated by invasive species may be resilient, but we may not want it to persist and outcompete native species.

People have been adapting to the climate for as long as we have existed. Many cultural practices arose partly in response to the specific climates of the many places we live around the world. Depending on where you live, you probably have particular clothes in your wardrobe

and live in certain styles of housing, designed to keep you relatively warm or cool or to shed snow or allow breezes to circulate. A house in Alaska probably doesn't have air conditioning (even if they're starting to see more hot days), and a person who lives in Miami probably doesn't need to own a down jacket. You also probably change what you wear and how you warm or cool your house as the seasons progress—but the options available to adjust day-to-day (for example, what clothes are in your closet or whether your house has an air-conditioning system) are shaped by the historical climate that you have lived in. Likewise, if you were a farmer, you would probably grow crops that are well suited to the rainfall patterns and seasonal temperature of your region. Growing up, my parents worked at a ski resort in the Rocky Mountains—a livelihood option that is not available to someone in Irvine, California, where I live now.

However, climate change is now occurring at a more rapid pace than it ever has since humans have existed as a species, which means that we need to adapt much more quickly than we ever have in the past. In this chapter, we will discuss many different ways that people do and can adapt to climate change, how we might evaluate whether that adaptation is successful, and how governments and other organizations can overcome barriers to support more extensive uptake of adaptation activities.

Box 26.1.1 Other Species Adapt Too

Humans are not the only species that alters the way it lives in response to a changing climate. For instance, some plants have changed when they emerge and are reproducing earlier in the year, given warmer springs and summers. Animals have shifted their hunting and grazing patterns to avoid being in the hot midday sun. Both plant and animal species are changing their ranges as locations become relatively warmer, wetter, or drier. Some lizards in the Caribbean have even evolved larger toe pads and longer limbs, enabling them to hold on during gale force winds. However, this chapter focuses on human-led or human-directed adaptation and does not discuss the ways other species can adapt to climate change in the absence of human intervention.

26.2 How Are People and Organizations Adapting to Climate Change?

Adaptation is not a one-size-fits-all concept. Given the diversity of ways climate change is affecting different locations, people, and sectors, there is an equally large number of ways people and organizations can adapt to climate change. This section will introduce different ways of categorizing adaptation approaches, which can help clarify what types of adaptation are occurring and how effective they are.

Impacts from climate change are generally considered to consist of two interrelated components. First is **exposure** to climate change—whether a particular location, piece of infrastructure, or person faces changes in temperature, rainfall patterns, or frequency of lightning strikes that cause wildfire. Second is **vulnerability**—characteristics of

Box 26.2.1 Coping, Disaster Risk Management, and Adaptation

There are many short-term ways people respond to fluctuations in the weather—putting on a sweater on particularly cold days or watering crops extra during a heat wave. However, these are not adaptation activities, but rather short-term **coping** mechanisms. Just as climate is the weather averaged over several decades, adaptation requires a longer-term change: shifting your wardrobe to include more sweaters and fewer shorts, or installing new irrigation equipment in anticipation of future heat waves.

Similarly, we have many policies and institutions in place for **disaster risk management**, designed to protect people and infrastructure against floods, fires, storms, and other events. Disaster risk management can include adaptation if protective infrastructure and policies are designed to accommodate the frequency and size of future events we expect because of climate change. Frequently, however, the infrastructure and policies are based on the most extreme historic event—which does not signal an adaptive action.

the social, natural, or built environment that make the impacts from the exposure better or worse. For instance, a newer home built with sprinklers and fire-resistant materials is likely to be better able to withstand a fire than an older wooden-framed home. Someone whose job relies on the climate (like my parents working at a ski resort) faces more economic risks than someone whose job is less directly related to the environment. And a person who has asthma or other respiratory illnesses is going to face more risks from smoke exposure than someone with healthy lungs. Additionally, some people are better able to respond, learn, and transform effectively, which can reduce their vulnerability. An adaptation can target either exposure or vulnerability: it might move people or infrastructure to reduce exposure, or it might reduce vulnerability by addressing the risks people currently face from climate and/or improving capacity to respond and adapt to this or future events.

Types of adaptation

Understanding different approaches to climate adaptation is challenging because there are almost infinite ways that people can adapt. This is partly because of the very localized nature of adaptation: each individual location faces a unique set of climate risks and is differentially affected by those risks based on its vulnerability. And, each individual person and organization has different preferences and capacities for different adaptation options based on their culture, demographics, knowledge, the resources available to them, etc. This means that for any particular climate impact, there are numerous ways that people might respond.

However, there are several ways we can categorize different types of adaptation activities. The first is by the general approach to adaptation, namely, whether the adaptation entails a behavioral change, adoption of a new technology, development of a new decision-making institution, or working with ecosystem services to enhance resilience.

A **behavioral adaptation** enables, implements, or undertakes a lifestyle and/or behavioral change in anticipation of or response to climate change. Anyone who has lived in California during wildfire season has engaged in behavioral adaptation if on smoky days you avoided outdoor activities or wore a face mask if you had to go outside. While these are shorter-term behavior changes, behavioral adaptation can

Four broad categories of adaptations



FIGURE 26.2.1 There are four broad categories of adaptation actions. Top left: An example of a behavioral adaptation is wearing a mask on days with high smoke exposure. Top right: Developing a climate action strategy to guide California's policy priorities is an institutional adaptation. Bottom left: Restoring salt grass marshes to prevent coastal erosion is an ecosystem-based adaptation. Bottom right: Installing air conditioning to combat heat waves is a technological adaptation. Top left and right photos from Ryan J. McCarty, Dry Scientific, Inc. Bottom left photo from CZM. Bottom right photo from Wisc-Online.

entail more long-term lifestyle changes, such as moving away from a high-hazard area or changing jobs to sectors that are less impacted by climate change (for example, from farming to retail). Organizations can also change their behaviors: some national parks in Arizona have started opening at night so people can hike during the cooler hours, and businesses are altering the types of investments they make to avoid sectors that face more substantial climate risks.

A **technological adaptation** enables, implements, or undertakes a technological innovation or infrastructural development in response to climate change. Households installing air conditioning or weatherizing their homes would be engaged in technological adaptation, as would

a farmer switching to drip irrigation or building a canal to access new water sources, or a coastal city building a seawall to protect against storms and sea level rise. The adopted technology could also be digital, such as states investing in early warning systems, which detect hazards like floods or fires and announce to residents, emergency responders, and others that they're coming.

An **institutional adaptation** enhances governance or institutional capabilities through creation of new rules, practices, or decision-making venues. An institution is a set of rules, norms, and structures that dictate how people can interact with one another or with the environment; institutions can be formal (a federal law) or informal (a cultural norm). To enhance institutional capacity, some cities have created new staff positions or even entire offices dedicated to climate resilience. For example, in an effort to embed climate awareness throughout diverse city functions, the City and County of San Francisco created a climate change council called ClimateSF, which is a collection of unified city principles, planning efforts, and capital funding that enhance climate resilience. The US Forest Service has created a framework they call an Adaptation Workbook that provides guidance for natural resource managers to evaluate and plan for the effects of climate change in their areas, helping local decision-makers work through what can be a messy process in a more deliberate fashion. And some governments have enacted laws that require consideration of climate impacts for new infrastructure or programs, such as the State of New York's Community Risk and Resiliency Act (CRRRA), which requires people applying for permits or funding to "demonstrate that future physical climate risk due to sea-level rise, storm surge, and flooding had been considered in project design."

Finally, an **ecosystem-based adaptation** (also called a nature-based adaptation) enhances, protects, or promotes ecosystem services. In many cases, ecosystem adaptations may use what is called **green infrastructure** to provide protection against climate risks in settings where we may have historically used **gray infrastructure** (that is, concrete). At the household or neighborhood level, you might plant a tree to provide shade rather than installing air conditioning. At a larger scale, rather than building a seawall to buffer against coastal flooding and erosion, a city might restore or enhance nearshore wetland ecosystems

or build oyster beds. Likewise, rather than preventing flooding through construction of dams and flood control channels, some land managers are reintroducing beavers to the upper watersheds of rivers, where they build “natural” dams that slow down the water and enhance floodplain habitat. Ecosystem adaptation also includes helping other species and ecosystems to adapt. For instance, the US Fish and Wildlife Service is beginning to engage in conservation introductions, moving species to new locations outside their native range where there is a more favorable future climate.

Globally, most documented adaptation (that is, adaptation that has been studied in the academic, peer-reviewed literature) is behavioral, followed by technological and then ecosystem-based. Behavioral adaptations are prominent on every continent except Europe, which favors technological adaptations.

Proactive versus reactive adaptation

Adaptation can also be classified based on whether it entails a reactive response to a climate impact that has already occurred (**reactive adaptation**) or is done in anticipation of a future climate impact (**proactive adaptation**). Throughout human history, most adaptation to climate shocks has been primarily reactive, in that people change their behaviors or adopt new technologies only once they’ve experienced an extreme weather event. For example, there were numerous adaptations following Hurricane Katrina, from creation of new government agencies like the Louisiana Coastal Protection and Restoration Authority, to updated policy standards for evacuation, to major reorganization of the Federal Emergency Management Agency. While reactive adaptations often improve resilience relative to what existed before the disaster, they may not consider that the big event that just occurred may not reflect future climate risks. To use the example of Katrina, rebuilding seawalls and levees to protect against a Katrina-sized hurricane is great, but a more effective adaptation would look at a Katrina-sized hurricane on top of projected sea level rise and land subsidence (land elevation sinking or eroding).

With improved climate modeling approaches, we now have the opportunity to predict what future climate risks might look like for a

locality well in advance, meaning that we can make choices before a disaster about where and how we want to live in order to avoid negative impacts. Rather than waiting until a highway is flooded by rising sea levels, a city could consider building a seawall to protect the highway, or building a new highway farther inland. Knowing that water is going to be increasingly scarce in the coming decades, Californian cities and water utilities are planning proactively to avoid future water shortages by investing in water recycling and incentivizing drought-tolerant landscaping. In fact, the city of Los Angeles currently uses less water than they did in the 1970s, despite adding over a million new residents.

This proactive adaptation, also referred to as anticipatory adaptation, comes with many potential benefits. It opens up people to be more creative in their potential paths forward. When operating in crisis mode, people tend to resort to predetermined routines and may be less open to unfamiliar approaches. By making decisions when a crisis is not actively befalling people, proactive adaptation gives people the space they need to consider multiple options and select one that meets multiple needs. And, because of the extra space created, anticipatory adaptation can give people the opportunity to be more intentional about equity and the time to acquire needed resources as they iterate through potential solutions.

In reality, most adaptation is a mix of reactive and proactive approaches. For example, someone might choose to sell their house and move after a fire came a little too close to home. In this case, they are reacting to the old fire, but acting *before* the next fire hits. Or, following a moderate-sized flood, a government that had previously ignored warnings about potential catastrophic flooding might choose to look more carefully at existing flood models and retrofit their infrastructure and emergency response systems before a larger flood occurs.

Incremental versus transformative adaptation

As noted in the introduction, people have been adapting to unique climate conditions—and therefore to climate change—for as long as we have existed as a species. However, the pace of climate change in the coming century is going to be more rapid than anything we have lived through. Because of this challenge, many climate adaptation scholars

argue that we need to adapt in a bigger and faster way than we ever have before. This is **transformative adaptation**, which results in fundamental changes in the structure or function of a socio-environmental system. Transformation is distinguished from **incremental adaptation**, in which changes do not depart substantially from the status quo.

There are several dimensions upon which adaptation can be considered transformative. First is the depth of change from prior behaviors and institutions. A relatively shallow adaptation might involve a farmer switching from one variety of legume to another, more drought-resistant one. Here, the day-to-day activity is roughly the same, with a slightly improved resilience to warmer/drier periods. In contrast, a farmer choosing to abandon farming and adopt a new livelihood would be a more in-depth adaptation.

A second dimension is the scope of adaptation, with wider-scope adaptations spanning larger spatial areas or involving multiple sectors. A single farmer switching crops—a relatively low-depth adaptation—could have a transformative impact on systemwide climate risk if all farmers in a region also switched crops. Likewise, an adaptation that is adopted by organizations in multiple sectors—such as adoption of a new air quality monitoring technology by hospitals, labor unions, and schools—can also be transformative through its wider scope.

A final dimension is the extent to which an adaptation challenges or overcomes existing barriers to adaptation. If actors have previously been limited in the extent of their adaptations because of psychological, financial, political, or other challenges (see Section X.5), an adaptation that manages to overcome those barriers can be considered transformational. For example, if a community wants to relocate but is stifled by a lack of funding and laws that will not allow them to purchase sufficient land, managing to acquire funding and/or update the legal regime would signal a transformational change.

While transformative adaptation primarily focuses on climate risk reduction, transformative adaptations can also be an opportunity to create more equitable adaptations that provide numerous **co-benefits**. Because transformation involves fundamentally changing a system, it creates an opportunity to overcome entrenched power dynamics and unsustainable practices and behaviors.

Classifying adaptations

R: Reactive



P: Proactive



I: Incremental



T: Transformative

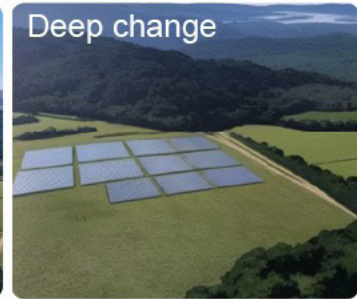


FIGURE 26.2.2 Top: Adaptations can be classified as being reactive (occurring after a hazard occurs) or proactive (preparing for a future climate impact that has not occurred). An example of reactive adaptation is adding a bridge or seawall after a storm surge washes out a highway (left), while using beach nourishment to protect the highway against future sea level would be proactive (right). Bottom: Adaptations can also be incremental or transformative. Left: An example of incremental adaptation is a farmer adopting a new drought-resistant crop variety. Middle: This adaptation could become transformative if it is adopted at a larger scope, that is, if all farmers in a region adopt the drought-resistant variety. Right: A transformative adaptation can also be an in-depth change from the status quo, such as a farmer replacing crops with a solar farm. Images from Ryan J. McCarty, Dry Scientific, Inc.

Globally, most documented adaptation is incremental in nature. While there are numerous examples of people adapting, most adaptation is relatively low in depth and scope and works within the constraints of existing barriers rather than attempting to overcome them.

26.3 Who Is Adapting and How?

Anyone can adapt to climate change. Individuals, households, small and large businesses, civil society organizations like nonprofits and community-based organizations, and governments at all levels (local to international)—collectively termed **actors**—have all engaged to some extent in adaptation activities. However, because of their different needs and capabilities, different types of actors tend to use different types of adaptation. For example, individuals and households often implement behavioral adaptations, small businesses and national governments use many technological adaptations, local and national governments and larger corporations tend to develop institutional adaptations, and individuals, households, and civil society groups implement many ecosystem-based adaptations.

Some adaptations are purely autonomous, meaning that they are undertaken by individuals, households, or other organizations without substantial assistance from or coordination with other actors. All types of actors engage in autonomous adaptation, from households choosing to install air filters for wildfire season, to businesses assessing climate risk when choosing where to locate a new program, to local governments elevating roads to protect against flooding, to federal agencies changing their procurement processes to reflect supply chain climate risk management approaches. Globally, most documented adaptations are autonomous adaptations undertaken by individuals and households. This is especially true in Africa, Asia, and Central and South America, as well as in the food/agriculture and health sectors.

Many adaptations, especially in North America and Europe, involve numerous actors helping to facilitate the development and implementation of the adaptation. Besides directly implementing an adaptation, supporting an adaptation may entail raising awareness about the need to adapt or planning for potential adaptations, financing the adaptation

TABLE 26.3.1 Example adaptations implemented by different types of organizations in California

Each adaptation is labeled according to adaptation type (*Behavioral*, *Institutional*, *Ecosystem based*, or *Technological*), and some are also labeled as *Proactive* versus *Reactive*, and *Incremental* versus *Transformative*.

<i>Organization</i>	<i>Representative Adaptations</i>
Individual	- Across California, farmworkers are starting work earlier in the morning to avoid midday sun. [<i>B,R,I</i>] - Frontline communities are forming networks like the Anthropocene Alliance to advocate for climate and environmental justice. [<i>I,P,T</i>]
Business	- Electrical utilities like Pacific Gas & Electric are implementing rolling blackouts, cutting power from communities on days with high wildfire risk. [<i>B,P,I</i>] - Public-private partnerships are developing desalination plants in Southern California to augment local water supplies. [<i>T,P,T</i>]
Nongovernmental organization	- Nonprofits like Water Drop LA provide water and shelter to unhoused individuals during heat waves. [<i>B,R,I</i>] - NGO Blue Forest developed the Forest Resilience Bond to link forest restoration projects to potential funders in the Sierra Nevada. [<i>I,P,T</i>]
Local government	- Cities across California have drafted climate action plans, detailing strategies to reduce GHG emissions and adapt to local climate change. [<i>I,P,T</i>] - Coastal jurisdictions are investing in diverse coastal protection measures, including seawalls (Foster City), beach nourishment (Huntington Beach), and nature-based solutions like a horizontal levee (Alameda County). [<i>T/E,P,I</i>]
State government	- The California Department of Conservation's Sustainable Agricultural Lands Conservation Program works with farmers to develop climate-adaptive farmland strategies. [<i>I,P,I</i>] - The state launched a California Climate Adaptation Strategy to align adaptation activities throughout the state along six priorities. [<i>I,P,I</i>]
Tribal government	- The Karuk and Yurok tribes have partnered with the US Forest Service to implement traditional wildfire management approaches. [<i>B/I,R,I</i>] - The Twenty-Nine Palms Band of Mission Indians is assessing the potential impacts of climate change on cultural resources, including archaeological sites, spiritual practices, and flora and fauna, to develop an adaptation plan. [<i>I,P,I</i>]
Federal government	- The FEMA BRIC program provides funding for communities to address future risks from hazards and disasters. [<i>I,P,I</i>] - The USDA California Climate Hub develops and provides region-specific information and technologies to support adaptation by natural resource managers. [<i>I,P,I</i>]

or using economic incentives to encourage adaptation, mandating an adaptation, or monitoring an evaluation to see whether it is working.

First, organizations can use information-based approaches to raise awareness about potential climate impacts or adaptation approaches. Advertising campaigns, educational programs, and development of adaptation plans or strategies are all ways to spread the word about adaptation. Extension programs at land grant universities are one key resource in the provision of information about climate change. Extension offices help train farmers, land managers, and other stakeholders to identify and implement possible adaptation approaches and translate best practices emerging from university research into practice.

Second, they can use economic incentives to make desirable activities cost-effective and undesirable activities cost-prohibitive. Taxes, subsidies, insurance requirements, and direct funding are all forms of economic incentives. Requiring homeowners in a floodplain to purchase flood insurance effectively raises the cost of that house relative to one out of the floodplain, making it less likely that people will buy houses in the floodplain. Likewise, making an electric utility liable for fires started by their transmission lines provides a strong financial incentive for aggressive maintenance to remove trees and, as we have seen recently, more drastic measures in severe weather conditions. Providing tax incentives to businesses who adopt or develop new climate-resilient technologies will speed up the development and adoption of those technologies. Supplying grants for watershed restoration projects or tree planting initiatives in low-income communities makes it feasible for these communities to implement these activities.

Third, they can directly mandate adaptation activities. For instance, if a city wants to avoid construction in a floodplain or area with high wild-fire risk, they can zone the city such that new development is prohibited in those areas. They can also require the use of particular climate-resilient technologies (for example, fire-resistant materials or triple-paned glass in all new buildings) or ecosystem-based approaches (for example, use of bioswales to capture stormwater runoff in all new developments).

Each of these approaches comes with distinct benefits and weaknesses (Table 26.3.2). Because of these characteristics, mixes of support tools tend to be most supportive of successful adaptation.

TABLE 26.3.2 Strengths and weaknesses of policy tools to support adaptation

<i>Adaptation Policy Tool</i>	<i>Strengths</i>	<i>Weaknesses</i>
Information-based instruments	Relatively inexpensive to implement	Large variation in whether targeted actors adopt the intended behavior or technology
Economic incentives	People and organizations are highly responsive to monetary signals	Challenging to determine the appropriate size of the incentive; often benefit larger and wealthier organizations
Direct regulations	Mandate creates relatively high certainty that regulated entities will comply	Requires enforcement, which can be costly; can limit innovation and flexibility

Additionally, different actors tend to favor different support roles. Regarding information-based approaches, civil society organizations play an important role in raising awareness about the need to adapt, while local and state governments often lead efforts to plan and strategize about how to adapt. National governments and international institutions like the UN are key players in financing adaptation efforts. Likewise, governments at all levels (local to national) are key in directly mandating adaptation.

26.4 How Do We Know If Adaptation Is Working?

While more and more people and organizations are starting to adapt to climate change all over the world, a critical question is whether the adaptation that is being or will be implemented is beneficial. This requires an assessment of what we want adaptation to achieve, as well as figuring out how we can measure it—that is, evaluating adaptation.

Evaluating adaptation is incredibly challenging. First, it requires agreement on what the goals of adaptation are. For instance, when implementing a flood-related adaptation, should the goal be to keep flood risk constant despite sea level rise, or to reduce flood risk to a level below the current state? (If a road currently floods once a month, is the goal to make the road flood less often or to keep it flooding only once a month even as sea levels get higher? The first might be much harder to achieve.) Is the goal to protect houses, prevent deaths, protect critical habitat, or save the government or insurance companies money? And who gets to decide what this goal should be?

Second, measuring the impact of the adaptation requires some assumption about what would have happened absent the adaptation. A standard approach is to compare future deaths/damages/expenditures with historic ones. This approach was commonly used to estimate excess deaths from COVID-19. By comparing the number of deaths in 2020 (for instance) relative to the average annual deaths in the decade prior (and assuming that deaths from cancer, car accidents, and other causes were relatively similar), officials could estimate how many extra deaths occurred in 2020 because of the pandemic. However, this approach assumes that historic patterns are representative of the future. With climate change, that assumption does not hold. Comparing the number of homes burned following some adaptation (that is, brush clearing) with the average number of homes burned in years prior does not communicate the full effectiveness of the adaptation if the number, size, and intensity of the fires is also changing.

Finally, it can be challenging to define and agree on what “counts” as an adaptation action. This chapter has introduced many different types of adaptation that can exist, but deciding on the concrete distinction between a coping mechanism and a longer-term adaptation is subjective. For instance, is installing irrigation an “adaptation” or just regular farming? Is a town expanding a stormwater pipe “adaptation” or just regular maintenance to deal with population growth? Likewise, some people consider supporting activities, like development of new regulations or a plan, to be evidence of adaptation, while others look to actual changes in infrastructure or behavior on the ground, as that is what actually reduces risk.

Considerations for evaluating adaptation

Risk Reduction: Are impacts reduced by adaptation actions?



Equity: Adaptation protects some groups more than others



Extent of Implementation: Incomplete adaptations provide no benefit



Co-Benefits: Flood infrastructure adds recreational benefits



Maladaptation: Flood management incentivized building in floodplain



Maladaptation: Levee reduced groundwater and resilience to drought



FIGURE 26.4.1 There are numerous ways to evaluate the potential benefits and impacts of an adaptation action. Images from Ryan J. McCarty, Dry Scientific, Inc.

Despite these challenges, the adaptation field has coalesced on several distinct ways to evaluate adaptations: extent of adaptation, extent of risk reduction, avoided maladaptation, equitable adaptation, and adaptation co-benefits.

Extent of implementation

A frequently used evaluation metric is the status or extent of implementation. An adaptation in the planning and development phase is great—it signals an intent to do something—but provides a lot fewer actual benefits than an adaptation that is fully built out. Looking at the extent of implementation is particularly important for technological and ecosystem-based adaptations, as these efforts can take many years to complete. Even once it's made it past the political commitment that it is a desirable course of action, building a large piece of infrastructure or conducting a restoration activity often requires numerous permits and authorizations, which may take years to obtain. Getting the land and financing the thousands or millions of dollars for implementation can be another hurdle. Because the terms of elected officials are often much shorter than the construction life cycles of large infrastructure projects (or the span of climate change), a politician may commit to a popular project but not be in office to champion its implementation, leaving it to languish in planning. In other words, despite the best of intentions, a planned adaptation activity may actually take decades to implement—and in some cases may never be built!

When we look at the evidence on the extent of implementation, there are far more activities in the early assessment and planning phases than in actual implementation. In other words, there is a lot of planning for adaptation, but not much actual adaptation. Numerous states and local governments have drafted adaptation plans, but many of the activities outlined in these plans have not yet been implemented; the same pattern tracks at the national and international levels.

Climate risk reduction

The gold standard for adaptation evaluation is evidence of climate risk reduction. After all, the reason we are adapting in the first place is to minimize the impacts of climate change on people, the economy, and

the environment. Therefore, understanding whether an adaptation has made people safer from climate impacts than had that adaptation not been implemented is key. Exactly what “safer” or “reduced risk” means in this context depends on what type of climate risk we’re talking about and what impacts or vulnerabilities from the risk we care about. For an adaptation to heat waves, we might want to know whether the adaptation reduced the number of deaths during a heat wave, the number of hospital admissions from heatstroke, or the number of crops lost. For an adaptation to wildfire, we might want to know whether the adaptation reduced the number of buildings burned, the number of acres burned, the dollar value of the properties damaged, the number of lives lost, the number of giant sequoias burned, the landslide potential after the fire, etc. etc.

Unfortunately, we have very little evidence about whether most adaptations actually reduce risks from climate change. In a systematic review of over 1,600 academic articles on climate adaptation, fewer than 50 articles documented risk reduction, either qualitatively or quantitatively. Each of the challenges for evaluating adaptation highlighted in the introduction to this section—choices about the appropriate counterfactual and goals of adaptation—are particularly prominent for evaluating risk reduction. And these are often compounded by a lack of data on whatever metrics are agreed on as the goals of the adaptation.

Avoided maladaptation

A **maladaptation** is an adaptation that, despite short-term benefits, actually increases climate risks or vulnerability over the long term. There are three broad ways that an adaptation can be maladaptive: (1) it increases greenhouse gas emissions, (2) it creates a false sense of security, thereby disincentivizing other adaptation actions, and (3) it increases risks from a different climate impact.¹

There are many adaptations that reduce the immediate impacts of climate change but exacerbate long-term impacts because they increase

¹ Importantly, some people use the term *maladaptive* in a broader sense—an adaptation that reduces risk from the climate impact but increases risk from other non-climate sources (for example, raising the cost of energy or food, making it harder for people to afford basic necessities). However, a narrower focus on climate risk makes identifying and managing maladaptations more straightforward.

greenhouse gas emissions. A common example is adoption of air conditioning in response to warming temperatures. While air conditioning has saved thousands of lives annually over the last century, if the electricity running the air-conditioning unit is produced from burning fossil fuels, then in the long term, it creates a vicious feedback loop wherein more air conditioning leads to more greenhouse gasses in the atmosphere, leading to warmer temperatures, leading to more need for air conditioning. Likewise, many approaches to using new water sources, such as desalination and groundwater pumping, can be very energy intensive and maladaptive when their energy source is fossil fuel-based.

The second broad class of maladaptive actions tends to occur with technological adaptations designed to reduce the impacts of environmental hazards like flooding. For example, building a levee or dams to protect against flooding can create a false sense of security, as people believe that the levee is invulnerable; in many places there has actually been an increase in building in the floodplain following installation of levees. However, if the levee fails or there is a storm larger than the levee's design capacity, the flood will be worse than had the levee not existed in the first place, both because there are now more houses and infrastructure in the floodplain and because the size of storm required to flood was that much larger.

The final type of maladaptive action occurs when an adaptation designed for one hazard fails when it is subjected to a different hazard. An excellent example of this is planting trees to provide shade (a response to heat waves). While trees are great in general, they pose a significant hazard in hurricanes, windstorms, and ice storms—a lesson learned when atmospheric rivers hit Sacramento in winter 2023.

Equitable adaptation

Just as many impacts from climate change do not affect everyone equally, adaptations are not inherently equitable in who they benefit or burden. There are numerous examples of adaptations that are not equally accessible to all individuals. Much insurance and post-disaster recovery funding is available exclusively to homeowners, leaving renters without financial assistance. Going to cooling centers during a heat wave requires knowledge that the centers exist and the ability to transport oneself to the

cooling center, creating barriers for elderly populations who are most at risk of complications from heatstroke. Accessing federal and state grant funds requires the ability to navigate complex bureaucratic systems, favoring people or organizations who speak English, have reliable computers and internet access, or have the funds or connections to hire consultants or lawyers to navigate these systems for them. Immigrant or undocumented groups may not want to go to “the authorities” for help in adapting, because of fear or mistrust. Installing new technological or ecosystem-based adaptations may require substantial economic and technical capacity, leaving behind smaller or less wealthy cities or organizations.

In addition, adaptations can be both maladaptive and inequitable if they shift risks from one group to another, rather than eliminating them. For example, if a city builds a seawall, that city will be more protected from storm surges, coastal flooding, and erosion. However, the seawall will disrupt natural erosion and deposition patterns along the shoreline, and the same volume of seawater still needs to go somewhere during surge events. This means that cities or environments downshore from the city that built the seawall can actually have a higher vulnerability to flooding after the seawall is built—unless they also build a seawall of their own. This concern is currently playing out in Charleston, South Carolina, where the US Army Corps of Engineers has proposed a seawall that protects historic downtown Charleston but stops short of neighboring communities that are predominantly African American.

Adaptation co-benefits

While evaluating adaptation tends to focus on benefits specifically related to climate risk, activities that lessen climate risk can also benefit other things that we care about, like greenhouse gas mitigation, ecosystem resilience, public health, or economic development. These additional benefits are called **co-benefits**. Ecosystem-based adaptations are particularly likely to provide co-benefits. Using bioswales or other green infrastructure to reduce urban flood risk can also provide habitat for diverse pollinators, improve stormwater quality, and provide areas for recreation—and they are usually considered more pretty to look at than concrete channels. Likewise, agroforestry approaches can sequester

carbon, improve water quality and soil retention, and reduce needed fertilizer and pesticide inputs into the system. However, any adaptation type has the potential for co-benefits—building and operating new infrastructure might create jobs; creating or redesigning institutions might enhance the transparency and democracy of government decision-making processes.

Because proactive adaptations entail making decisions before a crisis is already occurring, they also create more opportunities to provide co-benefits than reactive adaptations do. Making proactive decisions about new behaviors or investments in nature-based solutions or other technologies creates space to be more thoughtful and creative about the decision.

26.5 What Barriers Are Limiting More Widespread Adaptation?

Given everything you've learned about the need for adaptation, you may be wondering why we haven't adapted more, more transformatively, or more equitably. This is because there are numerous **barriers to adaptation**—things that make it harder for people or organizations to develop or implement adaptations.

Cognitive

The first set of barriers are psychological or cognitive in nature, relating to the ability of individual people to perceive climate change, understand climate impacts as risks, and choose to act on them. The majority of American adults know that climate change exists and attribute it to human activity, but fewer understand how they can adapt or feel they have the capacity to. This lack of awareness of adaptation options means that people are unlikely to select or plan for particular options in a systematic way.

People also perceive and interpret risks in nonrational ways. For instance, people are notoriously loss averse, meaning that they disproportionately react to losing things relative to the equivalent gain. A person will overvalue the ability *not* to lose \$100 as opposed to winning \$100. In the context of climate adaptation, this means that people are averse to losing their current way of life (that is, adapting and doing something new)—even if their current way of life is going to get worse or even be unattainable in the future because of climate change. We also tend to discount things that happen in the future, meaning that we place a lower value on things happening in the future relative to those in the present. We value earning \$100 today more than earning \$100 tomorrow or 10 years from now. This means that even if we know our house is most likely going to be underwater in a decade or two, that future harm has much less weight than if it were happening now.

Similarly, people have bad memories and tend to overinflate events

that happened in the recent past relative to older ones. It's hard to convince people that floods might be a concern when we're in the midst of a large drought; when every year is just a little bit hotter, we notice each individual year's difference but don't notice longer-term trends. We also assume that the world should look the way we are familiar with—even if that is a relatively recent occurrence. Today, wide sandy beaches are synonymous with Southern California, yet the beaches we know today only emerged around the 1950s.

The need to adapt can also conflict with one's worldviews, values, and cultural norms. If you have an identity as someone who lives in a particular place, works in a particular field, or likes to ski or surf or play video games, it can be really hard to upend that identity unless it becomes absolutely necessary. And when these identities are cultural and multigenerational—as when a house or farm has been in the family for years—it becomes even harder.

Even when a person doesn't have a strong identity tied to a particular nonadaptive lifestyle, it is hard to change one's behavior and adopt new habits. Indeed, many people who intend to adopt new behaviors or upgrade their homes to be more sustainable don't, simply because they have too many other short-term concerns, like work or raising a family.

Finally, all of these cognitive and psychological barriers are incredibly individual and context specific. This means that there is a huge diversity of risk perceptions and willingness to adapt across actors and organizations, making it harder to develop one-size-fits-all interventions or ways to help people overcome their lack of awareness or built-in biases.

Institutional

The second set of barriers can be broadly classified as institutional, relating to the ability of existing institutions and organizations to respond to climate change. Political and legal systems are designed to be slow to change because we want predictability, not volatility. However, in the context of climate change, we need a better ability to create new institutions and discard those that are no longer beneficial. Unfortunately, once they are created, individual institutions tend to have a lot of inertia, and they can be very hard to change or eliminate. Within institutions, as well, people develop organizational routines, which are specific ways

of doing their work. Implementing a new program might require real-locating resources and people in ways that contradict existing routines, and it is often easier to stick with established habits than develop new routines.

Many laws and regulations also tend to be very inflexible, working against the adaptive nature needed to respond to climate change. For example, we have a variety of permit requirements designed to protect particular resources (for example, air quality, endangered species) from human activities. However, as implementing new ecosystem-based or technological adaptations might harm these resources and are often unfamiliar to the regulators, it can be challenging to get permits for these newer activities—even if they might benefit these resources and numerous other societal goals long term.

A final and substantial institutional barrier to adaptation is the fact that almost all adaptations—and especially more-transformative adaptations—involve many different people and organizations. Deciding how to be more resilient to wildfire involves the individuals who live in high-risk areas, the city and county governments who decide where new housing and infrastructure goes and how that infrastructure is built, the power companies who site and maintain transmission lines, wildland managers (federal, state, tribal, local, private) who make decisions about how to maintain forested areas, and fire agencies (a mix of federal, state, and local organizations) who dictate fire response. Depending on how we frame the problem, we may also include downstream communities who depend on the forested area to provide their water supply or downwind communities who face the health hazards of smoke. Each of these actors has their own views of what the problem is, how large a problem it is, and whether and how it should be solved. They also have varying authority to dictate particular courses of action and varying jurisdictions over which that authority can be exercised—and those authorities and jurisdictions overlap in complex ways. In other words, adapting to wildfire cannot be accomplished by a single organization.

This multi-actor, multilevel nature of adaptation means that to be effective and equitable, any adaptation decision requires collaboration or at least coordination by all these actors. Such coordination requires developing a shared vision (or at least understanding) of what the problem

is and how it should be solved, identifying the specific activities each actor needs to undertake in order to achieve that vision, and then monitoring and coordinating to make sure that everyone does what they said they would. This is an incredibly challenging task, as it means building trust between all of the involved parties such that they are willing to share their true interests, asking governments and more-powerful organizations to cede some power to individuals and community members, and working through a very diverse set of needs and values.

Financial

The third set of barriers are financial, relating to the ability and desire to pay for adaptation. Many adaptations are expensive—building new infrastructure, restoring an adaptation, or reeducating oneself to change jobs all take substantial financial capital. Governments and businesses are not doing a great job providing the finances to support adaptation. At the global scale, the governments in the developed world have committed to support around \$100 billion annually to support adaptation in developing countries; however, actual financial flows fall short of that goal—and that goal covers less than half of estimated needs across developing countries. Within the US, tracking adaptation finance is difficult, but it is generally seen to be insufficient for the magnitude of adaptation needed.

A related financial challenge is choosing to use available funding for adaptation as opposed to any other activity. While some adaptations provide more-immediate co-benefits, many adaptations entail a short-term loss for a potential long-term gain. Often, the short-term loss is easily quantifiable, while the longer-term gain may be subject to more uncertainty and is overall harder to value. And even looking just at economic investments in climate change, far more funding has been allocated to mitigation as opposed to adaptation.

Political

The final set of barriers are political, relating to the incentives elected officials and other people in leadership positions have to implement adaptation activities. We have set up most government and business activities to have relatively short time horizons. Elected officials operate

on the term of their election cycles, which in the US vary from 2 to 6 years at the federal level (and most states and localities follow suit). Politicians therefore value activities that have a visible payoff within that time window. Corporations have an even shorter time horizon, prioritizing activities that will impact the quarterly or annual returns to owners, investors, or shareholders. With few exceptions, none of these time horizons align with the multi-decadal vision necessary for adapting to climate change, meaning that few politicians or businessmen have a built-in incentive to advocate for adaptation.

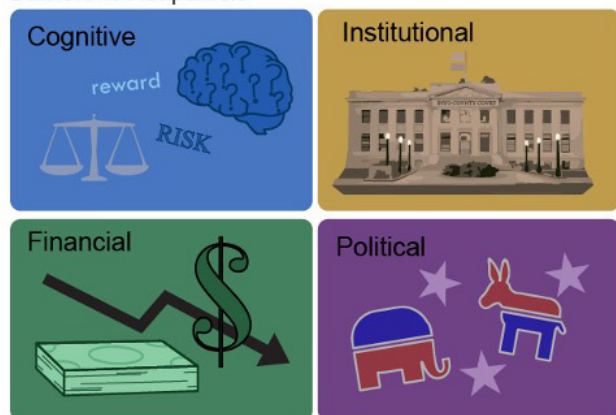
In addition, elected officials often make decisions based on their ability to win reelection, rather than on the broader public good. This means that the political desirability of adaptation projects depends heavily on the opinions of the electorate—many of whom lack knowledge about adaptation, may work in sectors or hold identities that may be threatened by potential adaptations, and have the cognitive biases that make them less likely to support adaptation. Without support from elected officials, many larger institutional and technological adaptations struggle to move toward implementation.

It is important to highlight that all the classes of barriers are highly interdependent and mutually reinforcing. For instance, a lack of awareness or undervaluation of climate risks (cognitive) may lead a government agency not to provide funding for adaptation (financial). This interconnected nature may explain why barriers to adaptation can be so persistent and hard to overcome. Barriers are also highly context specific and dynamic, not static over time. For a particular actor or

Box 26.5.1 Capitalism versus the Climate

Critical scholar Naomi Klein argues that adapting to climate change conflicts with the innate values of capitalism and neoliberalism that have shaped US policy and business investments for decades. Besides encouraging continual growth and consumption, capitalism prioritizes the individual over the community and the economy over the environment or society—neither of which aligns with longer-term transformational or equitable adaptation.

Barriers to Adaptation



Adaptation Landscapes

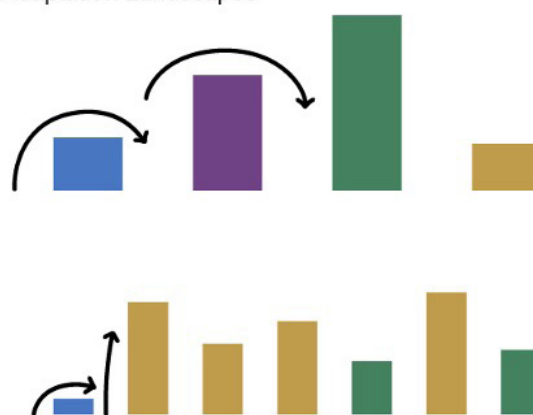


FIGURE 26.5.1 Left: The most common barriers to adaptation are cognitive, institutional, financial, and political. Right: Barriers may arise sequentially or concurrently and, depending on their magnitude, may take more or less effort to overcome. A barrier that is too large to overcome is called a limit. Images from Ryan J. McCarty, Dry Scientific, Inc.

place, the finances they have available, the risks they perceive, etc., are variable.

Barriers versus limits

Finally, while these barriers definitely constrain adaptation activity, they are not insurmountable. However, there are concrete **limits to adaptation**, which are barriers that cannot be overcome. For instance, at certain temperature thresholds, simply being outside is lethal to humans and other species. After 1.5°C warming above 1990 levels, most parts of the Great Barrier Reef will be functionally dead, and no amount of ecosystem-based restoration or other adaptations will help the corals survive. Likewise, the more the globe warms and the more frequent certain extreme events become, the narrower will become the scope of adaptation options we have available. With 1 foot of sea level rise, a seawall or nature-based barrier is a viable option. With 10 feet of sea level rise, a seawall large enough to protect the shore would completely change the character of the coastline and may no longer make sense. In other words, we cannot adapt to everything that climate change may bring—unless we manage to keep warming relatively low with aggressive mitigation efforts.

26.6 Summary: What Have We Learned So Far?

- ▶ Adapting to climate change is necessary to lessen the magnitude of health, economic, social, environmental, and other impacts humans will face from climate change. While humans have been adapting to a changing climate for as long as we have been a species, given the pace of current climate change, we will need to adapt more and faster than we have at any point in our history.
- ▶ Adaptation is distinct from coping mechanisms, which entail short-term changes in response to a specific weather event. Adaptation can entail a variety of behavioral, technological, institutional, and ecosystem-based changes. Adaptation can also react to past or current climate impacts, or it can proactively anticipate future changes.
- ▶ Experts agree that in order to keep up with the pace of climate change, we will need to engage in more transformative adaptation, which entails adaptations that are substantial changes from the status quo, that are adopted across larger geographic and sectoral scales, and/or that overcome existing barriers to adaptation. However, most adaptation to date is relatively incremental.
- ▶ Diverse types of individuals and organizations are engaging in adaptation activities. While anyone—from a household to a federal government agency—can directly implement adaptation activities, many adaptations involve coordination by multiple types of actors or may be supported by planning, financial, and regulatory activities implemented by other actors.
- ▶ Evaluating the extent and effectiveness of adaptation is critical for understanding what gaps exist, how much more we need to adapt, and whether there are any unintended side effects of adaptation activities. Commonly used evaluation metrics include the extent of implementation, amount of risk reduction, avoided maladaptation, adaptation equity, and adaptation co-benefits.

- There are numerous barriers to adaptation. These include psychological, institutional, financial, and political constraints that limit the amount, effectiveness, and equity of implemented adaptation. Most barriers are not hard limits, meaning that they can be overcome. However, we cannot adapt to all climate impacts, and adaptation is more feasible the more we also mitigate greenhouse gas emissions.

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Figure 26.2.1: Top left and right photos from Ryan J. McCarty, Dry Scientific, Inc. Bottom left photo from CZM. <https://www.flickr.com/photos/103100415@N04/48055920227/>. Bottom right photo from Wisc-Online. <https://www.wisc-online.com/assetrepository/viewasset?id=4194>.

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Figure 26.4.1: Image from Ryan J. McCarty, Dry Scientific, Inc.

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Chapter Glossary

Following is a list of terms and acronyms used in the chapter.

Glossary Items

<i>Term</i>	<i>Definition</i>
actors	The collective of individuals and organizations (including government, private, and civil sectors) involved in climate adaptation.
adaptation	The process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.
barrier to adaptation	A challenge or constraint that can slow or halt adaptation progress; barriers can be overcome with concerted effort.
behavioral adaptation	An adaptation that enables, implements, or undertakes a lifestyle and/or behavioral change in anticipation of or response to climate change.
co-benefit	A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment. Co-benefits are also referred to as ancillary benefits.
coping	The use of available skills, resources, and opportunities to address, manage, and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organizations, and systems in the short to medium term.
disaster risk management	Social processes for designing, implementing, and evaluating strategies, policies, and measures that promote and improve disaster preparedness, response, and recovery practices at different organizational and societal levels.
ecosystem-based adaptation	The use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change.
exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
gray infrastructure	Engineered physical components and networks of pipes, wires, roads, and tracks that underpin energy, transport, communications (including digital), built form, water and sanitation, and solid-waste management systems.

Glossary Items

<i>Term</i>	<i>Definition</i>
green infrastructure	The strategically planned interconnected set of natural and constructed ecological systems, green spaces, and other landscape features that can provide functions and services including air and water purification, temperature management, floodwater management, and coastal defense, often with co-benefits for human and ecological well-being. Green infrastructure includes planted and remnant native vegetation, soils, wetlands, parks and green open spaces, as well as building and street-level design interventions that incorporate vegetation.
incremental adaptation	Adaptation that maintains the essence and integrity of a system or process at a given scale. In some cases, incremental adaptation can accrue to result in transformational adaptation. Incremental adaptations to change in climate are understood as extensions of actions and behaviors that already reduce the losses or enhance the benefits of natural variations in extreme weather/climate events.
institutional adaptation	An adaptation that enhances governance or institutional capabilities through creation of new rules, practices, or decision-making forums.
limits to adaptation	The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions.
maladaptation	(1) An adaptation that increases climate risks or vulnerability over the long term; may have short-term benefits to risk reduction. (2) Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.
proactive adaptation	An adaptation implemented in anticipation of future climate change impacts.
reactive adaptation	An adaptation implemented in response to a past or present climate impact.
resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning, and/or transformation.

Continued

Glossary Items

<i>Term</i>	<i>Definition</i>
technological adaptation	An adaptation that enables, implements, or undertakes a technological innovation or infrastructural development in response to climate change.
transformative adaptation	Adaptation that changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts.
vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.