CLIMATE ESSENTIALS

WHAT IS CLIMATE RESILIENCE AND WHY DOES IT MATTER?

C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

April 2019

INTRODUCTION

The scientific evidence is overwhelming: The climate is changing, and human activity is the primary factor in the acceleration of climate change over the past century. Regardless of how successful humans are at limiting the root causes of our warming planet, society is facing significant impacts—from more frequent and severe weather, ocean warming and acidification, extended periods of drought and extreme temperatures, and other deleterious effects of climate change. The ability to prepare for, recover from, and adapt to these impacts is called "climate resilience."

Resilience is an increasingly common word in the climate change vernacular. Extreme weather events have shown that resilience is an essential component of any comprehensive climate action program because climate change is both a global and a hyper-local issue. The causes and the broad impacts affect everyone on the planet, but resilience efforts must be executed at the asset, neighborhood, or individual level. It will take a combined and coordinated effort, like none ever seen before, to address this issue. The good news is that addressing these risks can not only protect people and property, but also generate economic activity that will create domestic jobs and drive prosperity.

WHAT IS RESILIENCE?

There are innumerable definitions of the term resilience, starting with its origin and then in the context of climate change. According to the "Oxford English Dictionary,"[1] the first reference to resilience was by Francis Bacon in the 17th Century to describe the physical characteristics of an echo and how it bounces back off a wall. In the beginning, resilience literally meant "to bounce back." Many people have redefined the term from Bacon's day, but one aspect has not changed: there must be something to bounce back *from*. Therefore, resilience is relative term, not an absolute one. One has to be resilient *to* something.

It is important to first understand the threats and vulnerabilities of a particular event or phenomenon, and both the likelihood and consequence of these impacts. When people live in a coastal area or on a low-lying island, sea level rise and tidal flooding may be their biggest concern – it is important to be *resilient to* too much water. But in some places like the western US and very acutely in Cape Town, South Africa, it's the opposite problem – people need to be *resilient to* not enough water. The planning required to bounce back from impacts of climate change – climate resilience – requires that climate risks be more fully understood.

A second issue of resilience relativity is that perspective matters. Individuals and institutions may care more about one risk or impact more than another, depending on how that vulnerability affects them directly. The risk of losing power for a short time, for example, may be less concerning in a temperate climate than if that power is needed to survive a heatwave. Likewise, if electrical medical equipment is routinely needed, the loss of power – even for a short period of time – can be very disruptive. If the power goes out for a few minutes while working on a laptop, the disruption is more an annoyance than really disruptive. If stuck in a hot elevator or on a subway train in a tunnel, the consequence of a short outage may be long-lasting and impactful. If an individual can easily to recover from the event, they are typically considered to be resilient to that event.

The National Academy of Sciences defines resilience as, "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."[2] Likewise, the current U.S. government definition states, "Resilience includes the ability to withstand and recover rapidly from deliberate attacks, accidents, natural disasters, as well as unconventional stresses, shocks, and threats to the economy and democratic system."[3] Many other organizations have defined resilience as specific to their mission and those definitions include things like the developmental resilience of children or of the supply and value chains in the business world, what has not changed from Francis Bacon's day is that bouncing back is at the core of resilience.

The ability to bounce back is different for different people, based on their specific situation. For example, the decades-long financial crisis in Puerto Rico led to a level of infrastructure disrepair and physical and fiscal resource constraints (*chronic stresses*) that made it nearly impossible for the island to absorb or bounce back quickly from the devastating impacts of Hurricanes Irma and Maria (*acute shocks*) in 2017. In contrast, New York City was much better prepared to recover quickly from Hurricane Sandy in 2012 because its infrastructure systems and organizations were better staffed and funded. There are many other issues that affected the difference in recovery between Puerto Rico and New York, but the institutional capacity of the public and private organizations in each location, was a major factor.

Regardless of the specific definition used, understanding the risks and their context enables effective planning for resilience – and this does not change whether looking at climate, terrorist, or other risks.

THE RESILIENCE-RISK RELATIONSHIP

Making buildings, systems, and communities more resilient to shocks and stresses requires understanding the concept of risk and how to manage it. Risk is a function of two related concepts: threat and vulnerability. These three terms are frequently used interchangeably but they have precise and very different meanings. *Threats* are the actions that can negatively impact an asset or system and *vulnerability* is the degree of potential damage to the asset. Risk, therefore, is function of threat multiplied by vulnerability as depicted in *Figure 1*. The likelihood of the threat and impact of the vulnerability are part of this equation. As well, the components of vulnerability – sensitivity, exposure, and adaptive capacity – are critical to assessing resilience.

In this model, *sensitivity* is defined as the degree to which a system, population, or resource is or might be affected by hazards. *Exposure* means the presence of people, assets, and ecosystems in places where they could be adversely affected by hazards. And *adaptive capacity* is the ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change.

For example, the "Fourth National Climate Assessment" predicts more frequent and severe weather due to climate change.[4] This is a threat to houses and other structures located in a floodplain. The chance that it will rain is not affected by what is built, but the vulnerability of the house or facilities to flooding is affected by their design and construction. A house may be vulnerable to flood water because it was built at ground level. On the other hand, if the house is elevated and the only elements at ground level are designed to get wet, the house is less vulnerable. The threat of flooding is still there, but the risk is much lower because the impact of flooding is less damaging. The ability to elevate an existing structure is affected by the owner's economic situation, their

FIGURE 1: Calculating risk.

Figure 1: Risk is a function of threat and vulnerability. Vulnerability is determined by sensitivity, exposure, and adaptive capacity of an individual or system.

Source: C2ES

understanding of the risk and ways to mitigate it, and design of the structure itself.

The risk factors are not limited to natural conditions, economic and political power can cause particular populations to be more socially vulnerable. Racial and income inequities can reduce adaptive capacity, increase sensitivity, and also can mean greater exposure to environmental hazards. Lessons learned from major disasters clearly show that the most vulnerable members of society are also the most impacted by disruption. Wealth and social stability are significant predictors of resilience to shocks and stresses. This is a complex issue, and it's not always as simple as just providing money to make things more resilient. One of the lessons learned from the recovery from Hurricanes Katrina and Sandy is that in more affluent communities, providing funding for mitigating risk to homes was effective, but in less affluent communities, issues such as the ability to take off time to deal with contractors, home ownership levels, and other critical demands on time and resources made recovery programs less effective. These types of programs need to be funded, but they also need to be designed to be understandable and actionable by the people who need them.

Risk can also be low, even when the impact is high, if the threat is unlikely. As an example, one aspect of climate change is that coastal glaciers are melting and breaking off icebergs at a higher rate in the arctic.[5] Hitting an iceberg could be catastrophic for a ship, but given that technology has vastly improved since the days of the Titanic, avoiding icebergs is much easier today. So, while the vulnerability from an iceberg collision is very high, the threat (likelihood) is low and thus the risk is also low. According to the "*Fourth National Climate Assessment*," the bigger risk from melting glaciers is the flooding risk from sea level rise and changes in ocean acidity and salinity levels that affect everything from the weather to commercial fishing.[6]

Managing risk requires addressing either the threat or the vulnerability—or both, depending on the situation. In terms of climate risks, it's too late to eliminate the short-term threats by reducing one of the major drivers of climate change, greenhouse gas emissions. The impacts of climate change, such as sea level rise, drought, and more frequent and severe weather, are already here and as such it is important to address climate vulnerabilities and make the nation more resilient. That said, cutting greenhouse gas emissions, such as carbon dioxide (CO_2), can reduce how fast the threat grows and help lower future, long-term risk. Addressing both climate threats and vulnerabilities is the most effective strategy to reduce overall risk.[7]

Significant research is focused on actively removing carbon from the atmosphere (known as carbon capture) and on ways to affect the impacts of atmospheric carbon (known as geoengineering). But until these technologies can be better developed and fully tested, the greatest focus should be on a combination of climate change mitigation (reducing carbon and other greenhouse gas emissions) and climate adaptation (making assets and people less vulnerable to the impacts of climate change). This brief is primarily focused on the adaptation aspects of climate resilience, but without mitigation, the threat will get significantly worse.

GETTING TO A RESILIENT OUTCOME

In the aftermath of some of the major extreme weather events in the past ten years (e.g., tropical storms/cyclones, floods), there have been calls to build back "better" or "stronger" than before. Much of this has been done under the flag of resilience and the discussion has often centered around the return on the investment in resilient rebuilding, sometimes called the benefit-cost ratio. The typical argument is that spending more money to build a stronger structure or system will pay back in multiples of the marginal investment (beyond the cost of just building back what was damaged). Research recently published by the National Institute of Building Sciences (NIBS) found that building to the current (2018) common model building code standards as opposed to the model codes from the 1990s returns an average of $11 for every dollar (11:1) invested pre-disaster and presents a range of other benefit-cost ratios by disaster type.[8] This research also considers benefits beyond what Federal Emergency Management Agency (FEMA) funds post disaster and breaks out the benefit-cost ratios by hazard and other factors updating work that NIBS completed more than 10 years ago.

Research like the NIBS work and other studies of the benefits of resilient investment suggest that the value of a resilience investment such as constructing a building out of stronger materials, relocating mechanical and electrical equipment on higher floors, or designing the structure to resist flooding (dry proofing) or even allowing for flooding (wet proofing), depends on the specific threats and vulnerabilities of that specific asset and place. To maximize both the type and the effectiveness of a resilience strategy, public and private organizations should follow a two-step process to plan for resilience investments. The first step is to understand the risk, both the threat and vulnerability aspects. The second step is to use a framework known as *enterprise risk management* to consider the issue holistically.

Enterprise risk management is a structured approach to assessing and managing risk based on three options: risk mitigation, risk transfer, and risk acceptance.

- **Risk Mitigation:** Risks can be mitigated through financial investment and making the structure stronger or more resistant to the threat (lowering the vulnerability) or moving the people or asset out of a higher-risk location. Mitigation may also take the form of redundancy such as additional facilities or even spare parts or extra capacity.
- **Risk Transfer:** The most common form of risk transfer is insurance. Transferring a risk does not actually reduce the risk to society, but it can be an effective way for a city or a company to manage the risk if it gets moved to some other entity that has a better ability manage a group of risks—known as risk pooling.
- **Risk Acceptance:** If a risk cannot be cost-effectively mitigated or transferred, the best course of action is often to accept the risk. In some cases, a risk is accepted if it is so unlikely or globally catastrophic that it is the best alternative. A meteor strike or nuclear explosion are extreme examples of these types of risks, but acceptance is also a strategy for minor risks that are considered part of the "cost of doing business." Restaurants assume that glasses and dishes will get broken in the course of their business and typically do not go to any effort to mitigate or transfer this risk.

In many cases, a comprehensive enterprise risk management strategy will contain aspects of all three options. For example, owning and operating a used car carries some risk. Someone may be injured in an accident and the car can break down and require costly repairs. An effective risk mitigation strategy may be to spend more money to buy a newer, higher quality model that is less likely to break down and may be safer in an accident because of newer safety features. Some of the risk of repairs may be transferred by purchasing a service contract, which is essentially insurance. Most drivers have insurance in case of an accident, but they may reduce their insurance costs by having a higher deductible on that insurance or service contract. The deductible is an acceptance of risk. Effectively balancing these three options is the goal of a risk management strategy. Considering these issues across all the assets and risks brings the enterprise aspect to the strategy.

Looking at assets and systems on an enterprise basis allows comprehensive action on some of the biggest risks from both shocks and stresses—the cascading impacts from an event and interdependencies among systems. If just assessed on an individual or asset basis, significant risks which can affect lifeline systems such as food, water, power, and transportation are often missed.

A *cascading impact* is when one failure leads to the failure of other assets or systems. Cascading impacts can continue to resonate and build. In both Haiti after the earthquake in 2010 and Puerto Rico after Hurricanes Irma and Maria in 2017, failure of the electrical systems degraded the sanitation systems, affecting both sewage and clean water. This led to significant impacts to public health and resulted in the loss of life for some people who survived the initial disaster.

An *interdependency* is when one asset or system depends on another system to operate effectively. Following Hurricane Sandy, wastewater treatment plants in New York and New Jersey were forced to release raw or partially treated sewage into waterways because of the failure of the electrical power grid.[9] While many of these plants sustained little or no physical damage from the hurricane, their dependency on the electrical grid caused them to fail. Many infrastructure systems, especially key lifeline systems such as water, transportation, and healthcare, are dependent on electrical power, so resilience of the power grid is often seen as a primary goal.

Understanding how to assess where resilience investments should be made, and the need to balance the direct investment (risk mitigation), risk transfer, and risk acceptance, helps create a decision framework for whether to make a capital investment in a specific asset or system. But there is no perfect model for determining where to best spend limited capital resources. One lesson from rebuilding after hurricanes, floods, fires, and earthquakes is that stronger is not always cost effective, and limited resources should be managed to get the most value. That means that the project with the best benefit-cost ratio may not always be the best selection. Often, that analysis only looks at the cost of the physical asset and not the value of the function. For example, as discussed above, many systems and assets are dependent on electrical power, but making the grid more resilient by relocating all the power lines underground can be prohibitively expensive. It may be more effective to invest in smart grid technology and distribute the sources of power so that when there's a disruption in part of the grid it doesn't affect the entire region. Following Hurricane Sandy, one state agency, New Jersey Transit, used some federal relief funds to build a microgrid system to allow trains to operate even if the power utility's system was damaged.[10] This system won't keep the lights on in the schools or businesses in the region, but if it can allow the critical transportation of workers during and after a disaster, that will help with other systems.

WHAT DOES RESILIENCE COST?

To make an asset more resilient, the simplest and most cost-effective solution is sometimes to move the asset from its current location to a less vulnerable place. It may not cost more to build an asset in a better location than in its current (vulnerable) spot. Of course, if an existing asset has a significant remaining useful life, the cost of replacing it may not seem like a good investment. However, once the likelihood and impact of the threat and vulnerability are factored in, the benefit often exceeds the cost. This is especially the case when assumptions about the remaining useful life consider the current and future risks.

The city of Reedsville, Wisconsin, spent $235,000 to relocate a telephone and electrical substation about 40 feet south from the existing facility. By moving it 40 feet, it was also four feet higher in elevation, moving it out of the 100-year floodplain. Based on the reduction of threat from flooding, the city realized a $2.2 million benefit from the reduced economic and health impacts of losing power and communications in the event of a flood.[11] This is a good example of a significant (>9:1) benefit-cost ratio, and shows the importance of understanding and planning for current and future risks when building new facilities, upgrading older facilities, or rebuilding after a disaster.

A lesson learned from post disaster recovery in places like New Orleans, New York, and Houston, is that retrofitting existing buildings and systems can be expensive and disruptive. Elevating a smaller wood frame house is much more cost effective than trying to retrofit a 19th

Box 1: Mapping Future Risk

With climate change and development in floodplains, the current risks are not predictive of future risk. This is why Federal Emergency Management Agency (FEMA) floodplain maps, even when not out of date, may not be the best planning tool for future risk. The FEMA maps, known officially as Federal Insurance Rate Maps (FIRM) were designed to price flood insurance for the current year risk. In most cases, they do not provide data on future risk due to climate change or additional development in the floodplain. Several planning tools, both from government and private or NGO providers are available to support future risk analysis. Some of those tools are referenced in a list at the end of this brief.

Century brick row house or factory in a dense urban area. In some cases, it makes more sense to transfer some of the financial risk and then plan to rebuild more resiliently if the structure is damaged during its remaining useful life. In nearly all cases, it makes sense to design in resilience when siting and building new facilities.

Having a plan for how to rebuild more resiliently is valuable even if the capital to rebuild or retrofit is not available. In the weeks and months after a disaster, there is immense pressure to get things back to normal quickly, and the easiest thing to do is to rebuild the exact structure that was lost. Often, communities will waive normal planning and approval processes for rebuilding the same structure quickly, but rarely for building back differently, in a manner better prepared for future extreme events. With the adoption of newer and more forward-looking building codes, this is improving, but still, the pressure to get people back in their houses and reopen schools, other public buildings, and private facilities often wins the day. Pre-planning for a resilient rebuild, as some communities and companies are doing, is an effective way to leverage a win from a disaster. Much of the design and planning work can be done ahead of time and requires a much smaller investment, so that if disaster strikes, communities can immediately move into rebuilding mode. One issue that affects rebuilding is that federal funding is more likely available after a disaster than before—even funding to improve the resilience of facilities that were not damaged to future disasters. This is more fully discussed in the section on barriers to resilience.

MEASURE AND VALUATION OF RESILIENCE

As presented earlier, investments in resilience often have a positive benefit-cost ratio—that is, every dollar spent on mitigating risk before a damaging event occurs, returns multiple dollars of value over the life of the investment. There are several parts to this analysis. The first part requires the calculation of the probability of the threat and the cost to repair the damage or replace the asset. But this approach fails to fully account for some of the benefit of resilience investments. One missing element is the cost due to the loss of function of the asset or system. For example, if a fire station is damaged by flooding and is unusable, there is a cost to the community of added time for firefighters who may need to travel farther to respond to a fire or other emergency. This can result in a loss of life and property and can be calculated using standard econometric tools. The new NIBS study includes some of these calculations and provides a more accurate valuation of the investment.

Just like climate impacts can have cascading physical effects, there are some financial effects that accrue indirectly. One example is wages and tax revenue. If the economic activity in a community is interrupted, this can have an impact on earning for local residents and businesses and the resulting tax revenue of the governments. For example, when the Hawaiian island of Kauai was damaged by Hurricane Iniki in 1992, the impact went far beyond the physical damage to the hotels, roads, schools, and other facilities as well as the tragic loss of life. Iniki, the worst tropical cyclone to hit Hawaii, caused an estimated $8.8 billion (in current dollars) in direct damage to Kauai, but the long-term economic impacts are still being felt several decades later. One study found that it took 7-8 years for the economy of Kauai to recover to pre-storm levels, and when the study was completed 17 years after the storm (2009), the population and labor force had still not fully recovered.[12] The authors of this study note that these costs are "hidden" as they are not typically reported in cost-benefit ratios or in government reporting of the costs of disasters.

These costs may be harder to quantify and may get overlooked in some analyses, but they have very real impacts. Wages for hourly employees, small business income, and wage and sales tax revenue are not typically covered by either insurance or federal disaster relief programs in the way damage to private homes, large businesses, and public infrastructure are protected. If Hurricane Iniki had instead struck Waikiki Beach in Honolulu on the sister Hawaiian island of Oahu, the impact on the state's economy could have been catastrophic. Waikiki is the main resort and retail center of the state and represents nearly 10% of Hawaii's sales tax revenue and employment. The impacts on Kauai were locally devastating and apparently still continue to be felt but move that impact to the state's commercial hub and the impacts would affect everyone in the region. This is one reason that Honolulu joined the 100 Resilient Cities network and is developing an Oahu-wide resilience strategy.[13] In parallel, the state and the city are part of a group focused on protecting the watershed around Waikiki.[14]

WHO PAYS FOR RESILIENCE?

One question often asked in discussions of climate resilience is, who should pay for these investments? And who pays for the cost of inaction? The simple answer to both questions is that everyone does. Resilience investments come in many forms. Some of the costs are for public assets and systems such as roads, schools, and public services. Others are for private infrastructure such as power, communication, and financial systems. Where more resilient building codes are adopted and enforced, a level playing field is established and everyone, including residential, commercial, and public entities, invests in resilience.

In Alabama, the concept of adopting more resilient building standards has been taken a step further by enacting legislation that provides a significant insurance discount for customers who comply with the FORTIFIED Home building standard developed by the Insurance Institute for Home and Business Safety (IBHS). New or existing homes that meet the standard are more resilient to the impacts of severe weather such as hurricanes. While some counties in Alabama made these stronger standards part of their building codes, the legislature enacted SB254 in 2015 which provided the insurance discount to all Alabamans who met the FORTIFIED requirements, regardless of local codes.[15] Research conducted by the University of Alabama found that building homes to the FORTIFIED standard increased resale value by approximately 7 percent.[16]

Across the country, markets are starting to show that investments in resilience are valued and, in some cases, where the investments have not been made, there is a reduction in value. New research by a team at the University of Colorado Boulder and Penn State University show that coastal homes exposed to sea level rise sold on average for 7 percent less than other homes equidistant from the ocean but at higher elevations and less vulnerable to sea level rise.[17] The researchers looked at nearly half a million transactions over a ten-year period and found that the discount is growing over time as well. This research suggests that buyers understand climate risk and are increasingly finding it to be a factor in their purchase decision and pricing.[18]

One area where costs are being hotly debated is in making investor-owned utilities more resilient to wind, flooding, and wildfires. Much of the electrical and natural gas infrastructure in the United States is owned by private utility companies, which are highly regulated by the states in which they operate. Known as investor-owned utilities, they are publicly traded stock companies that typically raise money through bond offerings. Long seen as safe, stable, and highly rated investments, investor-owned utilities set the rates they charge customers through a long and complicated regulatory process with a state utility commission.

In order for an investor-owned utility to build the cost of resilience investments into its rates, it must convince the utility regulators that the investment is in the best interest of the rate payers in the state. Historically, this has been a hard sell as regulators are often focused on keeping rates down for consumers, but there have been some examples of progress. In New York and New Jersey, following Hurricane Sandy, the major investor owned utilities argued for, and received approval for, several billion dollars in resilience improvements from the regulators in each state. In many cases, the utilities are asking for greater levels of investment than are being approved. Not allowing utilities to invest in resilience may be a short-sighted strategy, as we have seen in recent years major impacts to utilities from ever increasing costs of natural disasters.

Unlike publicly owned utilities, investor-owned utilities are generally not eligible for federal assistance after a major disaster and rely on the rate-setting process to gain approval to invest in more resilient infrastructure and recover those costs from the rate payers. In the case of state or municipally owned utilities, that are eligible for Public Assistance funding under the Stafford Act,[19] the failure to invest in resilience often results in the need for billions in federal recovery funds as seen with the Long Island Power Authority (LIPA) and Puerto Rico's power company PREPA.[20]

BARRIERS TO RESILIENT INVESTMENTS

There are a number of reasons why some organizations and individuals may not invest in climate resilience. Among these are the inability to understand how to assess and value climate risk and the lack of knowledge regarding ways in which it can be managed. Further, not understanding when to mitigate the risk, when to transfer the risk, and when to accept the risk, can be other challenges. Market conditions, cash flow, outstanding debt, contractual obligations, and leadership can also create barriers to investment. Other additional barriers are regulatory and governance policies (beyond those faced by investor-owned utilities). Even political perspectives about climate change in the United States can limit investments in resilience.

As previously mentioned, the federal government spends billions of dollars every year funding recovery from natural disasters, and the scale of those disasters is increasing. Between 2014 and 2018, there were 63 disasters in the United States that cost more than $1 billion each (adjusted for current dollars). The total damage caused by those major disasters was almost $500 billion. In those five years we have seen more than 25% of the 241 disasters of this scale since 1980 and nearly 30% of the total damage from billion-dollar disasters over the 39 years we have been tracking them.[21] In other words, the number of big disasters and the cost of each disaster has more than doubled from what we saw in the previous 35 years.

Federal funding for disaster recovery is appropriated by Congress under a special process that treats it as "emergency" funding, so unlike funds for normal investments in infrastructure or other programs, it does not count against statutory budget caps. This means that funding for resilience investments that are not part of this emergency process, must be considered in the normal budget process. That puts the funding in competition with other funding for national security, veterans' affairs, hospitals, farm loans, and every other discretionary program in the budget. There must be an offset for these funds, meaning that something else needs to go away to find the money for resilience. When post-disaster emergency funding is used to rebuild a fire station or school, there is no need for an offset, as the disaster funding doesn't get counted in the budget scoring. Rebuilding after a disaster may cost ten times more than risk mitigation, but this additional cost is not recognized from a budget perspective. Whether the funding is emergency or normal funding, it costs the American taxpayers the same, and resilience can be the better deal.

THE PATH FORWARD

Breaking the cycle of inefficient federal disaster spending to prioritize spending on pre-disaster resilience is challenging, but there's a solution. The billions it will cost to recover from natural disasters each year justifies counting pre-disaster investments differently and not counting them against the budget cap, as post-disaster funds are currently treated. This will require a political bargain that is currently difficult to achieve but the growing consensus and urgency about climate impacts challenges that inertia.

There is practically no debate in the scientific community on either the fact that the climate is changing or that human activity has been a major factor in its acceleration. A new study published in the journal *Science* finds that the oceans are warming at a rate 40 percent faster than predicted by the United Nations in 2013.[22] The National Climate Assessment and other science-based reports clearly show that the costs of climate change to the U.S. and global economy are real and significant. In its 2019 Global Risks Report, the World Economic Forum, an organization primarily supported by major corporations and investors, found that the three most likely and impactful global risks were 1) extreme weather events, 2) failure of climate-change mitigation and adaptation, and 3) natural disasters.[23]

These and many other data points make it clear that the risks of climate change are real, they are increasing, and we will either manage those risks and adapt to their impacts, or the costs of inaction will have to be paid. As discussed throughout this paper, the most cost-effective path forward is to understand and manage those risks across all sectors and organizations. To do this requires a change in the discussions and valuation of climate risk.

There is, however, a silver lining to understanding risk and impact: Resilience investments, especially government-funded investments in technology and research, tend to create economic activity and grow the overall economy. The call to action by business leaders in the United States and across the globe sends a clear message that action on both climate mitigation and adaptation are needed and are the best path to a sustainable, resilient, and prosperous future for the nation and the world.

Additional Resources and Tools

U.S. RESILIENCE TOOLKIT:

As an interactive website, this tool allows users to discover climate hazards and develop solutions that reduce climate-risk. It provides a library of tools for individuals and city officials including case studies of how communities, businesses and individuals are documenting vulnerability and taking action (with several related to extreme heat).
https://toolkit.climate.gov/

CLIMATE CHANGE ADAPTATION RESOURCE CENTER (ARC-X) EPA'S ADAPTATION RESOURCE CENTER:

(ARC-X) is an interactive resource to help local governments effectively deliver services to their communities even as the climate changes. Decision makers can create an integrated package of information tailored specifically to their needs. Once users select areas of interest, they will find information about the risks posed by climate change to the issues of concern; relevant adaptation strategies; case studies illustrating how other communities have successfully adapted to those risks and tools to replicate their successes; and EPA funding opportunities.
https://www.epa.gov/arc-x

CLIMATE RESILIENCE EVALUATION AND AWARENESS TOOL (CREAT) CLIMATE SCENARIOS PROJECTION MAP (EPA):

This mapping tool allows users to look at projections for precipitation (as well as other climate impacts) in hot and dry, central, and warm and wet scenarios in the years 2035 and 2060.
https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e

WORLD WILDLIFE FUND TOOL SCREENING:

The World Wildlife Fund published a report in 2017 that looked at the publicly-available screening tools, polices, and frameworks used by international financial institutions and infrastructure sustainability bodies for assessing sustainability and climate resilience. This report is a desk-level review of the polices and tools but does provide a broad overview of what was in use when the report was written.
https://www.worldwildlife.org/publications/review-of-screening-tools-final-report-sep-2017

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15 Ala. Code §§27-31D-1 *et seq.*, as amended in June 2015

16 https://aciir.culverhouse.ua.edu/wp-content/uploads/sites/26/2018/12/FORTIFIEDReport_V2__2_.pdf

17 Bernstein, Asaf and Gustafson, Matthew and Lewis, Ryan, Disaster on the Horizon: The Price Effect of Sea Level Rise (May 4, 2018). Journal of Financial Economics (JFE), Forthcoming. Available at SSRN: https://ssrn.com/abstract=3073842 or http://dx.doi.org/10.2139/ssrn.3073842

18 https://aciir.culverhouse.ua.edu/wp-content/uploads/sites/26/2018/12/FORTIFIEDReport_V2__2_.pdf

19 Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended, 42 U.S.C. 5121 et seq., section 406

20 $1.4 billion for LIPA and $1.52 billion for PREPA have been obligated by FEMA (as of September 2018). However, Puerto Rico's government says it will need $15 billion in upfront costs and an additional $11 billion in recurring costs to totally rebuild and improve the electrical grid on the island.

21 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

22 http://science.sciencemag.org/content/363/6423/128

23 The Global Risks Report 2019, 14th Edition, World Economic Forum, Figure 1, page 5

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3100 CLARENDON BLVD. SUITE 800 ARLINGTON, VA 22201 703-516-4146 C2ES.ORG